CHAPTER 2
BASIN SETTING

2.1 INTRODUCTION TO BASIN SETTING

Physical Setting and Characteristics

The Oxnard Subbasin (Subbasin) of the Santa Clara River Valley Groundwater Basin is located near the western edge of the Transverse Ranges Geomorphic Province, which extends from the San Bernardino Mountains in the east to the San Miguel, Santa Rosa, and Santa Cruz Islands in the west (Figure 2-1, Oxnard Subbasin Vicinity Map; CGS 2002). The Transverse Ranges Geomorphic Province is characterized by a series of east-to-west-trending mountain ranges and valleys that are formed by north–south compression across a restraining bend in the San Andreas Fault (Hadley and Kanamori 1977; Bohannon and Howell 1982; Eberhart-Philips et al. 1990; Nicholson et al. 1994). Compression across this restraining bend is responsible for rapid, ongoing uplift of the mountain ranges (Yeats 1988; Feigl et al. 1993; Marshall et al. 2008) and extensive folding and faulting of the Pleistocene and older geologic formations in the province (Rockwell et al. 1988; Huftile and Yeats 1995).

The Oxnard Subbasin underlies the Oxnard Plain, an approximately 58,000-acre coastal plain formed by deposition of sediments from the Santa Clara River and Calleguas Creek, in southwestern Ventura County (DWR 1965, 2006). The northern boundary of the Oxnard Subbasin is the Oak Ridge Fault, and the southern boundary is the contact between permeable alluvium and semipermeable rocks of the Santa Monica Mountains (SWRCB 1956; DWR 2006). The eastern boundary of the Oxnard Subbasin lies against the Las Posas Valley Basin (LPVB) and Pleasant Valley Basin (PVB). The western boundary of the Oxnard Subbasin is the Pacific Ocean (SWRCB 1956; DWR 2006).

The stratigraphic sequence underlying the Oxnard Plain comprises an upper unit of younger and older alluvial deposits that unconformably overlies the San Pedro and Santa Barbara Formations (Table 2-1). The San Pedro Formation is a lower to middle Pleistocene shallow marine deposit that grades upward from a white-gray sand and gravel basal layer into an overlying series of interbedded silts, clays, and gravels. The Santa Barbara Formation is a lower Pleistocene marine sand and clay deposit (SWRCB 1956; Weber and Kiessling 1976; Turner 1975). The primary water-bearing units in the Oxnard Subbasin are the alluvial deposits that compose the Oxnard and Mugu Aquifers and the white-gray sand and gravel layer of the San Pedro Formation that composes the Fox Canyon Aquifer (FCA; Table 2-1). In addition, wells in the Oxnard Subbasin also produce water from the Hueneme Aquifer in the Upper San Pedro Formation and the Grimes Canyon Aquifer (GCA) in the Santa Barbara Formation.

The shallowest aquifer in the Oxnard Subbasin is a semi-perched aquifer comprising sands and gravels deposited by the Santa Clara River. This unit is underlain by a clay layer, commonly referred to as the "clay cap," that is nearly continuous throughout the Subbasin, with the notable exception of an approximately 10-square-mile area in the northeastern part of the Subbasin, adjacent to and south of the Santa Clara River, referred to as the "Forebay area" (Figure 2-1; Mukae and Turner 1975). In this region, the Oxnard and underlying Mugu Aquifers are unconfined. In the areas where the clay cap separates the semi-perched aquifer from the underlying Oxnard Aquifer, the Oxnard Aquifer is confined. The area in which the Oxnard Aquifer is confined is referred to as the "pressure plain area" of the Oxnard Subbasin (Figure 2-1; Mukae and Turner 1975).

The majority of the Oxnard Subbasin lies within the jurisdiction of the Fox Canyon Groundwater Management Agency (FCGMA), with two exceptions (Figure 2-1). These exceptions include an area in the northeastern corner of the Oxnard Subbasin, at the western end of South Mountain, and along the southeastern edge of the Oxnard Subbasin adjacent to the foothills of the Santa Monica Mountains. The reason for the discrepancy is that the FCGMA boundary was established based on a vertical projection of the FCA as defined by the Fox Canyon Groundwater Management Agency Act in 1982, whereas the Oxnard Subbasin boundary is based on the surface extent of the alluvium in the Oxnard Plain, and the location of both geologic structures and facies changes that impede flow between the Oxnard Subbasin and neighboring groundwater basins (DWR 2006). The geologic and hydrologic descriptions of the Oxnard Subbasin in this Groundwater Sustainability Plan (GSP) are based on the boundaries of the Oxnard Subbasin, including the areas to the northeast and southeast which are outside of the FCGMA jurisdictional boundaries.

2.2 HYDROGEOLOGIC CONCEPTUAL MODEL

The six commonly recognized water-bearing units in the Oxnard Subbasin are the semi-perched aquifer and the Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon Aquifers (DWR 1965, 2006; Turner 1975). Of the six commonly recognized water-bearing units, five are considered primary aquifers in the Oxnard Subbasin. The semi-perched aquifer is a water-bearing unit, but is not considered a primary aquifer in the Subbasin. The five aquifers are grouped into an Upper Aquifer System (UAS) and Lower Aquifer System (LAS), with the Oxnard and Mugu Aquifers composing the UAS and the Hueneme, Fox Canyon, and Grimes Canyon Aquifers composing the LAS. The UAS primarily comprises recent to upper Pleistocene age alluvial deposits of the Santa Clara River system. The LAS is primarily composed of upper to lower Pleistocene age marine sediments.

The Forebay area is the primary recharge area for the primary aquifers in the Oxnard Subbasin. In this area, the UAS rests directly on the folded and eroded upper surface of the Hueneme Aquifer and FCA. Water that recharges the UAS in the Forebay area is able to migrate throughout the Subbasin. Both the lithologic units and geologic structures present in the Oxnard Subbasin affect the hydrology of the Subbasin. These features are discussed in more detail in Sections 2.2.1 through 2.2.5.

2.2.1 Geology

Geologic Units and Variation

Tertiary Sedimentary and Igneous Formations

Tertiary sedimentary and igneous rocks that underlie the Oxnard Subbasin are generally considered semipermeable or non-water-bearing (Turner and Mukae 1975). These tertiary formations include the Oligocene/Eocene-age Sespe Formation, the lower Miocene Conejo Volcanics, the upper Miocene Modelo and Monterey Formations, and the Pliocene Pico Formation (Table 2-1; Weber and Kiessling 1976; Dibblee 1992a, 1992b). These formations have been sampled in deep wells drilled in the Oxnard Subbasin (Figure 2-2, Geology of the Oxnard Subbasin; Turner 1975; Weber and Kiessling 1976). These formations are not considered an important source of groundwater in the Oxnard Subbasin (Turner 1975).

Quaternary Sedimentary Formations

Santa Barbara Formation (Lower Pleistocene; Marine)

The Santa Barbara Formation typically comprises laminated, poorly indurated blue-gray marine mud- and siltstone with sand and gravel (Table 2-1; Turner and Mukae 1975). The upper clay-rich sediments act as an aquitard between the Santa Barbara Formation and the overlying San Pedro Formation (Weber and Kiessling 1976). The localized basal conglomerate within the upper member of the Santa Barbara Formation hosts the GCA (Weber and Kiessling 1976).

San Pedro Formation (Lower to Middle Pleistocene; Marine and Nonmarine)

The San Pedro Formation is an interbedded, poorly lithified fine marine, silty sandstone, shale, and mudstone with local pebble conglomerate and an extensive basal sand unit that unconformably overlies the Santa Barbara Formation in the Oxnard Subbasin (Mukae and Turner 1975; Weber and Kiessling 1976).

The upper and lower parts of the San Pedro Formation are separated by a laterally extensive clay marker bed (Turner 1975). Overlying the clay marker bed are lenticular layers of sand, gravel, and silt (Mukae and Turner 1975). The lenticular deposits of sand and gravel in the Upper San Pedro Formation are known as the Hueneme Aquifer in the Oxnard Subbasin. The sediments of the Upper San Pedro Formation coarsen to the west, with a larger percentage of sand and gravel in the western part of the Subbasin and a larger percentage of fines in the eastern part of the Subbasin, particularly in the area adjacent to the boundary with the LPVB.

In contrast, the basal unit of the San Pedro Formation fines to the west. This unit comprises a 100- to 600-foot-thick continuous white or gray fine to medium marine sand with stringers of gravel and local silt and clay lenses (Turner 1975).[1] The lower part of the San Pedro Formation is the FCA, which is an important source of groundwater supply in the Oxnard Subbasin (Turner 1975).

Older Alluvium (Upper Pleistocene; Terrestrial)

The older alluvium, which comprises gravel, sand, silt, and clay, unconformably overlies the Upper San Pedro Formation. The older alluvium can be divided into two units: an upper clay zone and a lower sand and gravel zone (Mukae and Turner 1975). The Mugu Aquifer occurs in the sand and gravel zone at the base of the older alluvium (Mukae and Turner 1975).

Recent Alluvium (Holocene; Terrestrial)

The recent alluvium in the Oxnard Subbasin comprises sands and gravels interbedded with silt and clay (DWR 1965). These sediments, which unconformably overlie the older alluvium, reach a thickness of up to 300 feet. The basal unit includes coarse sands and gravels intercalated with clay layers (Mukae and Turner 1975). Overlying the basal unit throughout much of the Subbasin is a laterally continuous clay layer that reaches a thickness of up to 160 feet locally. The Oxnard aquifer occurs in the sand and gravel layer below the clay. Above the clay is the semi-perched aquifer.

Geologic Structure

Wright Road Fault

The Wright Road Fault is an active oblique right reverse fault that generally parallels the eastern jurisdictional boundary of the Oxnard Subbasin, separating the LPVB to the east from the Oxnard Subbasin to the west (Figure 2-2; DeVecchio et al. 2007). The fault trace is characterized by a 20-meter-high (66-foot-high) topographic scarp with up-to-the-east displacement along the north-northwest-trending fault (DeVecchio et al. 2007). There is no evidence that the Wright Road Fault impacts groundwater flow between the Oxnard Subbasin and the LPVB.

Oak Ridge and McGrath Faults

The Oak Ridge Fault is a high-angle, south-dipping, left-lateral reverse fault that juxtaposes water-bearing alluvium and older, semipermeable formations in the subsurface (Figure 2-2; SWRCB 1956). To the east of the Oxnard Subbasin, anticlinal folding in the hanging wall of the Oak Ridge Fault resulted in the Oak Ridge and South Mountain uplift (Yeats 1988). In the Oxnard Subbasin, the western extent of the Oak Ridge Fault is concealed beneath the recent alluvium (Mukae and Turner 1975).

[1] This marine sand has been identified as both the Saugus Formation (Kew 1924; Jakes 1979) and the Las Posas Sand (Pressler 1929, as cited in DeVecchio et al. 2012a.; Dibblee 1992a, 1992b; DeVecchio et al. 2012b). The term "San Pedro Formation" is used here for consistency with California Department of Water Resources nomenclature (DWR 2006).

The McGrath Fault, located approximately 1 mile south of the Oak Ridge Fault along the coast in the Oxnard Subbasin, is a branch of the Oak Ridge Fault system with the same sense of motion (Mukae and Turner 1975). The McGrath Fault defines the northerly limit of the Forebay area (Turner 1975). Together, the McGrath and Oak Ridge Faults limit hydraulic communication between the Oxnard Subbasin to the south and the Mound and Santa Paula Subbasins of the Santa Clara River Valley Groundwater Basin to the north.

Bailey Fault

Along the northern edge of the Santa Monica Mountains, the Bailey Fault Zone trends northeast–southwest through the Oxnard Subbasin (Figure 2-2; Turner 1975). The Bailey Fault is a near-vertical fault with up-to-the-south displacement in the subsurface that offsets quaternary sedimentary formations to the north with older formations to the south (Turner 1975). Groundwater elevation differences and chloride ion concentration differences across the fault suggest that it is a barrier to groundwater movement (Turner 1975). The FCA is absent to the south of the Bailey Fault.

Las Posas Syncline

The Las Posas syncline has resulted in thickening and downwarping of the San Pedro Formation and older formations in the central part of the Oxnard Subbasin (Figure 2-2). The axis of the Las Posas syncline trends northeast from its western mapped extent at the intersection of West 5th Avenue and Harbor Boulevard, through El Rio, and into the Las Posas Valley (Turner 1975). At the deepest part of the Las Posas syncline, the Upper San Pedro Formation reaches a thickness of approximately 1,150 feet (Mukae and Turner 1975).

Montalvo Anticline

Deformation in the hanging wall of the Oak Ridge and McGrath Faults has resulted in anticlinal structures on the northern boundary of the Oxnard Subbasin, including the Montalvo anticline (Figure 2-2). The Upper San Pedro Formation has been eroded away in the Forebay area of the Oxnard Subbasin along the axis of the anticline (Turner 1975). Erosion of the Upper San Pedro Formation results in direct communication between the alluvium and the white and gray marine sands of the Lower San Pedro Formation that compose the FCA.

2.2.2 Basin Bottom

The bottom of the Oxnard Subbasin generally corresponds to the base of the San Pedro Formation and the base of the FCA in the northern and western parts of the Subbasin, where the Santa Barbara Formation is absent (Figure 2-2 and Figure 2-3, Cross Section A–A′; Turner 1975). In the southern and eastern parts of the Subbasin, where the Santa Barbara Formation is present, the bottom of the

Subbasin is defined by the contact between the upper member of the Santa Barbara Formation, the GCA, and the underlying strata that have poor water quality (Figure 2-4, Cross Section B–B′).

In general, the bottom of the Oxnard Subbasin is shallower in the east and deeper in the west. Along the eastern margin of the Subbasin, the Subbasin bottom has been mapped at elevations between 0 feet above mean sea level (msl) and −1,200 feet msl (Turner 1975). Along the western edge of the Subbasin, the Subbasin bottom depth ranges from −400 to more than −1,800 feet msl (Turner 1975). The deepest part of the Subbasin occurs along the axis of the Las Posas syncline in the north-central part of the Subbasin.

2.2.3 Principal Aquifers and Aquitards

Semi-Perched Aquifer

River-deposited sands and gravels interbedded with minor silt and clay compose the semi-perched aquifer in the Oxnard Subbasin (DWR 1965; Turner 1975). The term “semi-perched aquifer” is used in this GSP as the name for the uppermost unit of the Oxnard Subbasin, which overlies the extensive clay cap in the pressure plain area of the Oxnard Subbasin (Figure 2-2 and Table 2-1). This name was used in the State Water Resources Control Board’s Bulletin 12 (SWRCB 1956) to distinguish the water-bearing sedimentary units in the pressure plain area from those in the Forebay area, and this terminology has been adopted by subsequent investigators (Mukae and Turner 1975; Turner 1975; Hanson et al. 2003; DWR 2006). Water-level data indicate that the sediments underlying the semi-perched aquifer are saturated. Therefore, the term “semi-perched aquifer” is used in this GSP to denote the limited migration of water from the uppermost aquifer to the underlying confined aquifer in the pressure plain area. It is not used to denote a discontinuity in saturation. Furthermore, there is limited groundwater production (<50 acre-feet per year [AFY]) from this unit (see Section 2.4, Water Budget). Therefore, although this unit is referred to as the “semi-perched aquifer,” it is not considered to be a principal aquifer in the Subbasin.

The semi-perched aquifer is part of the recent alluvium described in Section 2.2.1, Geology. This aquifer extends from the base of developed soil horizons to a depth of approximately 75 feet throughout most of the Subbasin (Turner 1975). Notably, this aquifer is absent in the Forebay area of the Oxnard Subbasin adjacent to and south of the present course of the Santa Clara River. The permeable sand and gravel deposits of the semi-perched aquifer tend to be continuous in a northeast–southwest orientation, which is similar to the present orientation of the Santa Clara River and lenticular to the northwest and southeast (Turner 1975).

The lenticular shape of the semi-perched aquifer deposits limits flow in the northwest–southeast direction and facilitates flow in the northeast–southwest direction. These deposits have not been affected by faulting or folding in the Subbasin, and there are no structural restrictions to flow through the semi-perched aquifer (UWCD Model Report [2018], provided as Appendix C to this GSP).

Agricultural return flows, saline connate water, and coastal flooding affect both groundwater quality and groundwater elevation in the semi-perched aquifer (Mukae and Turner 1975). The highest water levels in the aquifer, which are typically within a few feet of land surface, are found in heavily irrigated areas (Turner 1975). Tile drains are used throughout the Oxnard Subbasin to alleviate the high groundwater conditions. Agricultural return flows that cause the high water conditions have resulted in high concentrations of total dissolved solids (TDS) and chloride (as high as 23,000 milligrams per liter [mg/L]) in the semi-perched aquifer (Turner 1975; USGS 1996).

Clay Cap

Underlying the semi-perched aquifer is a clay layer that separates the semi-perched aquifer from the Oxnard Aquifer below (Turner 1975). The thickness of the clay cap is approximately 160 feet adjacent to the Pacific Ocean. The clay cap is absent in the Forebay area (DWR 1968; Mukae and Turner 1975). Although the clay cap functions as an aquitard, water can migrate vertically through the clay cap under conditions of differential head (Turner 1975), and in some cases, through casings of wells that have been improperly abandoned.

Oxnard Aquifer

The Oxnard Aquifer is a laterally continuous layer of upper Pleistocene and Holocene nonmarine gravel and cobbles (up to 6 inches in diameter); coarse to fine sand; and interbedded clay, silty clay, and silt lenses (Turner 1975). The deposits that compose this aquifer are part of the recent alluvium and are found beneath the entire Oxnard Subbasin and extend several miles offshore, where they are exposed in the walls of the Hueneme and Mugu submarine canyons (DWR 1965, 1968). The deposits tend to be finer near the coast and coarsen to the east (Turner 1975; DWR 2006). The local silty clay and silt lenses restrict both horizontal and vertical movement of water through the aquifer, and distinct permeable horizons have been identified in logs (DWR 1971).

The top of the Oxnard Aquifer has been shaped by differential erosion and sedimentation of the Santa Clara River (Turner 1975). Throughout much of the Oxnard Subbasin, a clay-rich aquitard that ranges in thickness from 10 to 100 feet separates the Oxnard Aquifer system from the underlying Mugu Aquifer (Mukae and Turner 1975). The basal surface of the clay is more uniform than the upper surface and generally deepens to the west–southwest (DWR 1968). The thickness of the Oxnard Aquifer also generally increases to the west-southwest, with a minimum thickness of less than 50 feet in the vicinity of the Forebay area and reaching a maximum thickness of greater than 150 feet in the vicinity of Point Mugu (DWR 1968; Turner 1975).

Flow of groundwater through the Oxnard Aquifer is controlled by lithologic variability. The only structural feature that restricts flow in this aquifer is the Bailey Fault, in the southern Oxnard Subbasin (Appendix C). The Oxnard Aquifer crops out offshore in the Hueneme and Mugu canyons, making it susceptible to seawater intrusion. The chloride concentration of native water in the Oxnard Aquifer is approximately 40 mg/L (similar to background values in the Mugu and Hueneme Aquifers), although this concentration varies with geographic location in the Subbasin (USGS 1996). In the vicinity of the Hueneme and Mugu submarine canyons, chloride concentrations have been affected by seawater intrusion. In 2016, the chloride concentration in the vicinity of Hueneme Canyon was as high as 4,800 mg/L, and in the vicinity of Mugu Canyon the chloride concentration was as high as 16,600 mg/L (FCGMA 2016).

The specific yield of the gravels of the Oxnard Aquifer is about 16% in the Forebay area where there are few clay deposits and the aquifer is unconfined (SWRCB 1956; DWR 2006). Wells screened in the Oxnard Aquifer are typically screened in multiple aquifers, including the underlying Mugu Aquifer. (For information on well construction requirements intended to prevent degradation of water quality of the aquifers in the LAS—referred to as requirements for "sealing zone"—see DWR 1968). The California Department of Water Resources (DWR) reports that the average well yield in the Oxnard Aquifer is about 900 gallons per minute (gpm; DWR 2006). Aquifer test results for two wells screened solely within the Oxnard Aquifer, however, have a higher average well yield, of approximately 1,500 gpm, with an average specific capacity of 47 gpm per foot (Hopkins, pers. comm. 2016). Storage coefficients of 6.18×10^{-4} and 3×10^{-4} were estimated from pumping test data at these two wells, and the transmissivity was estimated to be approximately 20,400 feet squared per day (Hopkins, pers. comm. 2016). The well yield and specific capacity were measured at three additional wells screened solely in the Oxnard Aquifer, although aquifer tests were not performed at these wells. The average well yield and specific capacity for these wells is 2,450 gpm and 108 gpm per foot. Based on these measurements, the average transmissivity is approximately 32,000 feet squared per day (Hopkins, pers. comm. 2016).

Water quality in the Oxnard Aquifer has been degraded by seawater intrusion and leakage of agricultural return flows through the clay cap separating the Oxnard Aquifer from the overlying semi-perched aquifer (UWCD 2016a). Seawater intrusion has been documented in both the Port Hueneme and Port Mugu areas (Turner 1975; UWCD 2016a). Water produced from this aquifer is used for agricultural and municipal and industrial (M&I) purposes.

Mugu Aquifer

The sediments that compose the Mugu Aquifer are upper Pleistocene age fine to coarse sands and gravels (DWR 1965; Turner 1975). These sand and gravel deposits are laterally extensive throughout the Subbasin and represent the basal deposits of the older alluvium. In general, the sediments of the Mugu Aquifer are finer near the coast and coarsen to the east (Turner 1975). A low-permeability clay deposit that ranges in thickness from 10 to 100 feet separates the Mugu Aquifer from the overlying Oxnard Aquifer throughout much of the Oxnard Subbasin. However, the clay layer is absent in the Forebay area of the Subbasin near the Santa Clara River (DWR 1965; SWRCB 1979; Turner 1975). The Mugu Aquifer ranges in thickness from approximately 30 feet in the Forebay to approximately 270 feet in the vicinity of Point Mugu (DWR 1965; Turner 1975).

The Mugu Aquifer extends several miles offshore and crops out offshore in the Hueneme and Mugu canyons, making it susceptible to seawater intrusion. The chloride concentration of native water in the Mugu Aquifer is approximately 40 mg/L (USGS 1996). In the vicinity of the Hueneme and Mugu submarine canyons, however, chloride concentrations have been affected by seawater intrusion. In 2016, the chloride concentration in the vicinity of Mugu Canyon was as high as 3,200 mg/L (FCGMA 2016).

The base of the Mugu Aquifer was deposited over an irregular surface that has been affected by both folding and erosion (Turner 1975). The extensive folding of the aquifers underlying the Mugu Aquifer, however, has not been documented within the sediments of the Mugu Aquifer. Within the boundaries of the DWR Bulletin 118 basin, the only documented fault that acts as a barrier to flow is the Bailey Fault in the southern part of the Subbasin. Offshore, however, additional faults that act as barriers to flow exist in the vicinity of the Mugu submarine canyon (Hanson et al. 2003; Appendix C).

Wells screened in the Mugu Aquifer are typically screened in multiple aquifers, including the overlying Oxnard Aquifer. DWR does not report aquifer properties specifically for the Mugu Aquifer (DWR 2006). In the Forebay, Well 02N22W36E04S, screened solely within the Mugu Aquifer, has a well yield of 1,500 gpm, a specific capacity of 17.8 gpm per foot, and an estimated transmissivity of 7,900 feet squared per day (Hopkins, pers. comm. 2016). For wells screened in both the Oxnard and Mugu Aquifers, the average yield is 2,300 gpm, the average specific capacity is 110 gpm per foot, and the average estimated transmissivity is 29,000 feet squared per day (Hopkins, pers. comm. 2016). Water produced from this aquifer is used for agricultural and M&I purposes.

Hueneme Aquifer

The Hueneme Aquifer comprises a series of lenticular silts, sands, and gravels in the Upper San Pedro Formation. This aquifer is present in the northern part of the Oxnard Subbasin but is absent to the south of Hueneme Roads (Mukae and Turner 1975). Within the Oxnard Subbasin, the Hueneme Aquifer is up to 1,150 feet thick along the axis of the Las Posas syncline (Turner 1975). The Hueneme Aquifer extends several miles offshore and crops out in the Hueneme and Mugu submarine canyons.

Changes in lithologic composition, with the aquifer generally containing a higher percentage of fine materials adjacent to the LPVB and PVB, affect flow through the aquifer. The change in composition is accompanied by an increase in the lenticular nature of the deposits that compose the Hueneme Aquifer along the eastern boundary of the Oxnard Subbasin. These changes limit subsurface flow between the Oxnard Subbasin and the LPVB and PVB to the east.

In addition to changes in lithology, structural folding of the Hueneme Aquifer also affects subsurface flow (Turner 1975). Folding, subsequent erosion, and recent deposition have resulted in a direct hydraulic connection between the Hueneme Aquifer and the overlying Mugu Aquifer throughout much of the Oxnard Subbasin (Turner 1975). However, in the southwestern portion of the basin, where seawater intrusion has affected the Mugu Aquifer, the Mugu and Hueneme Aquifers are not in direct hydraulic communication. As a result, water quality in the Hueneme Aquifer has not been affected by seawater intrusion in this area (Turner 1975; Hanson et al. 2003). Offshore faulting in the Hueneme Aquifer also limits direct seawater intrusion into the aquifer in the vicinity of Mugu Canyon, and faulting along the northern and southern boundaries of the Oxnard Subbasin limit flow out of the Hueneme Aquifer to the Mound Basin or to the south of the Bailey Fault (Hanson et al. 2003; Appendix C).

The chloride concentration of native water in the Hueneme Aquifer is approximately 40 mg/L (USGS 1996). In the vicinity of Point Hueneme, the chloride concentration of the Hueneme Aquifer was as high as 9,900 mg/L in 2016 (FCGMA 2016).

Wells screened solely within the Hueneme Aquifer have an average yield of approximately 2,500 gpm and an average specific capacity of 38 gpm per foot (Hopkins, pers. comm. 2016). Storage coefficients of 2×10^{-4} and 3×10^{-4} were estimated from pumping test data at two wells and the transmissivity was estimated to be approximately 13,400 feet squared per day (Hopkins, pers. comm. 2016). Water produced from this aquifer is used for agricultural and M&I purposes.

Fox Canyon Aquifer

The FCA is a 100- to 600-foot-thick marine sand and gravel deposit in the Lower San Pedro Formation (Mukae and Turner 1975). The water-bearing deposits of the FCA fine toward the west (Turner 1975). This unit is laterally continuous throughout the Oxnard Subbasin except at the western tip of South Mountain, where the Santa Barbara Formation is in direct contact with the Mugu Aquifer, and in the southwestern part of the Subbasin, where uplift and erosion have removed the FCA (Turner 1975). In the northern and western parts of the Subbasin, the FCA defines the base of the freshwater zone.

In the Oxnard Subbasin, the FCA is thickest along the axis of the Las Posas syncline. In this area, the FCA reaches thickness in excess of 500 feet, and the base of the aquifer is below −2,000 feet msl (Turner and Mukae 1975; Turner 1975). The primary source of freshwater recharge to the FCA is infiltration through the Oxnard and Mugu Aquifer systems in the Forebay area (Turner 1975; FCGMA 2007).

As with the other primary aquifers in the Oxnard Subbasin, the FCA extends several miles offshore and water quality in the FCA has been impacted by seawater intrusion. The native water in the FCA had a chloride concentration of 40 mg/L (USGS 1996). Chloride concentration measured in

2002 from a well in the southeastern part of the Subbasin ranged from 183 to 367 mg/L (Izbicki et al. 2005). However, the concentration of chloride measured in Well 01N21W32Q04, located inland of Mugu Canyon in the southern part of the Subbasin, was 5,070 mg/L in 2015.

Offshore faulting in the vicinity of Mugu Canyon is thought to limit direct seawater intrusion into the FCA (Hanson et al 2003; Appendix C). Instead, increasing concentrations of chloride in the FCA near Mugu Canyon are thought to originate in the aquifers of the UAS and migrate vertically into the FCA.

There are no aquifer-specific hydraulic parameter measurements for the FCA. Several specific capacity aquifer tests have been conducted in the Oxnard Subbasin, but typically these tests occur in wells screened across multiple aquifers (Appendix C). More detail on the limitations of hydraulic parameter measurements is found in the UWCD model documentation report (Appendix C). Well 02N22W20J02S, in the northern Oxnard Subbasin, is screened in both the FCA and overlying Hueneme Aquifer. This well has a yield of 3,030 gpm, a specific capacity of 95.3 gpm per foot, and a transmissivity of 40,100 feet squared per day (Hopkins, pers. comm. 2016). Water produced from this aquifer is used for agricultural and M&I purposes.

Grimes Canyon Aquifer

The GCA comprises lower Pleistocene age sand with minor amounts of gravel. This aquifer corresponds with the basal conglomerate within the upper member of the Santa Barbara Formation and is only found underlying the southern and eastern parts of the Oxnard Subbasin (Turner 1975). In the southern part of the Subbasin, the GCA is found in a band approximately 5 miles wide along the base of the Santa Monica Mountains from the Pacific Ocean to the boundary with the PVB to the east (Turner 1975). Throughout the rest of the Subbasin, the Grimes Canyon member of the Santa Barbara Formation is absent. As with the other aquifers in the Subbasin, the GCA extends several miles offshore.

The GCA, where present in the Oxnard Subbasin, is in hydraulic communication with the overlying FCA, and there are no production wells perforated solely in the GCA (Turner 1975; VCWPD 2013). As a result, there is little information on the water quality or aquifer properties of the GCA. Water quality has been sampled in some basal portions of the aquifer, and has been found to have brackish water that is likely a result of limited flushing since deposition and upward migration of brines from underlying formations (Mukae and Turner 1975; Turner 1975; Hanson et al. 2003).[2, 3] In addition, seawater intrusion may have impacted some wells screened in the GCA (see Section 2.3.3, Seawater Intrusion). Direct seawater flow into the GCA in the vicinity of Mugu Canyon is thought to be limited

2 Brackish water is typically defined as water with a concentration of total dissolved solids (TDS) between 3,000 and 10,000 mg/L.

3 Brines typically have concentrations of TDS greater than 35,000 mg/L.

by offshore faulting (Hanson et al 2003; Appendix C). Concentrations of chloride have been increasing in this area since the 1990s. In 2016 the groundwater concentration measured in a sample collected from Well 01S21W08L03S was 6,428 mg/L (FCGMA 2016). Measured aquifer properties specific to the GCA are not currently available.

2.2.4 Data Gaps and Uncertainty in the Hydrogeologic Conceptual Model

The primary data gaps in the hydrogeologic conceptual model are as follows:

- Distributed measurements of aquifer properties from wells screened solely in a single aquifer
- Distributed measurements of groundwater quality from wells screened solely in a single aquifer
- Measurements of groundwater quality that distinguish the sources of high TDS concentrations in the FCA and the GCA
- Temporal limitations on groundwater elevation data
- Spatial limitations on groundwater elevation data
- The relative impacts of production from areas within the Subbasin on seawater intrusion
- Connection between the semi-perched aquifer and potential groundwater-dependent ecosystems (GDEs)
- Potential impacts of increased production in the semi-perched aquifer

The data gaps listed above create uncertainty in the understanding of the impacts of water level changes on change in storage in the aquifer and on the inland extent of seawater intrusion in the aquifers. Additional aquifer tests, groundwater elevations, and groundwater quality sampling in the future would help reduce the uncertainty associated with these data gaps. Closing the data gaps is discussed further in Chapter 4, Monitoring Networks, of this GSP.

2.3 GROUNDWATER CONDITIONS

2.3.1 Groundwater Elevation Data

Groundwater elevations in the Oxnard Subbasin were first measured in agricultural wells in the 1930s, and multiple entities, including the United Water Conservation District (UWCD), DWR, and the County of Ventura (the County), have recorded water elevations in the Oxnard Subbasin over the intervening decades. In the early 1990s, after the U.S. Geological Survey (USGS) installed a series of nested monitoring wells during the Regional Aquifer System Analysis (Densmore 1996), an annual groundwater monitoring program was initiated in the Subbasin by the County, UWCD, and USGS (FCGMA 2007). The groundwater monitoring programs conducted by the

Ventura County Watershed Protection District and other agencies, including UWCD, include production wells and multiple-completion nested monitoring wells. Many of the production wells included in the monitoring program are screened across multiple aquifers. Historically, the FCGMA annual reports have included potentiometric surface maps for wells screened in the UAS and wells screened in the LAS since 2013 (FCGMA 2015).

To conform with the DWR GSP Regulations, Section 354.16, the following discussion of groundwater elevation is limited to production and monitoring wells screened in a single aquifer. Water level measurements collected between March 2 and March 29, 2015, are used to represent groundwater elevations in spring 2015. Water level measurements collected between October 2 and 29, 2015, are used to represent groundwater elevations in fall 2015.

Because many production wells within the Subbasin are screened across multiple aquifers and there are a limited number of dedicated monitoring wells, the depiction of representative regional potentiometric surfaces in each aquifer is limited. Similarly, the depiction of groundwater trends is also limited by spatial and temporal constraints that are imposed when only using wells screened in a single aquifer. Groundwater pumping data for the year 2015 were mapped to provide context for interpreting the potentiometric surfaces presented in this section (see Figure 2-5, Upper Aquifer System 2015 Extraction [acre-feet] in Oxnard and Pleasant Valley and Figure 2-6, Lower Aquifer System 2015 Extraction [acre-feet] in Oxnard and Pleasant Valley). Self-reported groundwater extraction data for 2015 are shown in Figures 2-5 and 2-6 for wells screened in the UAS and LAS, respectively. In the UAS, the location of the greatest amount of extraction is within the Forebay, with additional extraction areas both west and southeast of the City of Oxnard (Figure 2-5). The majority of the production from the LAS is in the southeastern portion of the Subbasin (Figure 2-6). The volume of groundwater extracted from the LAS is greater than that extracted from the UAS.

Current and historical groundwater elevations are discussed below by aquifer. Full hydrographs for all Oxnard Subbasin wells in which five or more water level measurements have been recorded are included in Appendix D, Water Elevation Hydrographs. In general, climate cycles, management actions, and the construction of water conservation facilities have impacted water elevations in the Oxnard Subbasin. The Freeman Diversion, completed in 1991, allows UWCD to divert surface water from the Santa Clara River to spreading basins, where it can infiltrate into the aquifers of the UAS and be transported via pipelines to other areas. This additional recharge enhanced aquifer recovery in the 1990s after a period of drought (FCGMA 2007). Additionally, UWCD’s Pumping Trough Pipeline (PTP), constructed in 1986, which delivers diverted Santa Clara River water to agricultural parcels on the Oxnard Plain in lieu of groundwater production from that area, resulted in rising groundwater elevations during the late 1980s. In 1991, Ventura County adopted Ordinance 3991, which provided a temporary prohibition on drilling of new wells in the UAS, which also contributed to water elevation recovery in the UAS in the 1990s.

2.3.1.1 Oxnard Aquifer

Spring and Fall 2015 Groundwater Elevations

In the spring of 2015, recorded groundwater elevations in the Oxnard Aquifer wells ranged from −27.2 to 46.3 feet msl (Figure 2-7, Groundwater Elevation Contours in the Oxnard Aquifer, March 2–29, 2015). In the fall of 2015, recorded groundwater elevations ranged from −30.7 to 37.9 feet msl (Figure 2-8, Groundwater Elevation Contours in the Oxnard Aquifer, October 2–29, 2015).

Groundwater flows from areas of high groundwater elevation to areas of low groundwater elevation. The highest groundwater elevations in the Oxnard Aquifer are found in the Forebay in both the fall and spring of 2015 (Figures 2-5 and 2-7). The hydraulic gradient in the Forebay in the spring of 2015 was approximately 0.005 feet/feet with groundwater flowing to the south and southwest, toward the pumping centers west and southeast of the City of Oxnard. In the fall of 2015, the hydraulic gradient was approximately 0.005 feet/feet with groundwater flowing to the southwest and southeast.

Elsewhere in the Subbasin, groundwater elevations in the Oxnard Aquifer are higher on the western and eastern boundaries of the Subbasin than they are in the center of the Subbasin. In this central area, groundwater elevations are more than −20 feet msl in both the spring and fall of 2015, though the areal extent of lower elevations is much greater in fall than in spring (Figures 2-7 and 2-8). In general, elevations in the UAS in the central Oxnard Subbasin are above sea level during wet climatic periods and fall below sea level during droughts (UWCD 2016a). Artesian conditions can occur in the western Oxnard Subbasin during wet climatic cycles (UWCD 1999).

The central area of low elevations reflects the groundwater production from wells southeast of the City of Oxnard in the central Oxnard Subbasin (Figure 2-5). The hydraulic gradient, directed toward the production wells, was less than approximately 0.001 feet/feet in both the spring and fall of 2015. Coastal elevations were measured below or near sea level in both spring and fall of 2015, and consequently, the hydraulic gradient was generally landward at the coast (Figures 2-7 and 2-8).

There is uncertainty associated with the groundwater elevation contours, hydraulic gradient, and groundwater flow direction in the Oxnard Aquifer in the spring and fall of 2015. Fewer wells are screened solely within the Oxnard Aquifer than are producing groundwater from the Oxnard Aquifer. The majority of the wells that produce groundwater in the Oxnard Aquifer are screened across multiple aquifers. These wells were not used to create the contour maps in order to conform with the DWR GSP Regulations, Section 354.14. The uncertainty in hydraulic gradient, flow direction, and groundwater elevation within the Oxnard Aquifer is particularly pronounced in the southern Oxnard Subbasin, where there are few wells screened solely within the Oxnard Aquifer but several production wells screened in multiple aquifers (Figures 2-7 and 2-8).

Vertical Gradients

Groundwater elevations in the Oxnard Aquifer are higher than those in the underlying Mugu Aquifer, resulting in a downward vertical gradient from the Oxnard Aquifer to the Mugu Aquifer in all areas of the Oxnard Subbasin for which Mugu-specific elevation data are available (Table 2-2). The magnitude of the vertical gradient varies with distance from the coast. The downward vertical gradient between the Oxnard and Mugu Aquifers was calculated for five wells in the fall of 2015 (Table 2-2). The wells in Table 2-2 were selected from a larger group of nested groundwater monitoring wells to represent the vertical gradient at different geographic locations in the Subbasin.

In the spring of 2015, the vertical gradient from the Oxnard Aquifer to the underlying Mugu Aquifer ranged from 0.004 feet/feet at the coast near Port Hueneme to 0.278 feet/feet inland of Point Mugu (Table 2-2). In the fall of 2015, the vertical gradient from the Oxnard Aquifer to the underlying Mugu Aquifer ranged from 0.002 feet/feet at the coast near Port Hueneme to 0.468 feet/feet inland of Point Mugu (Table 2-2). The vertical gradients along the coast are lower than they are inland, possibly reflecting the influence of seawater in the aquifer, moderating water levels at the coast. Alternatively, the vertical gradients may be lower at the coast because there is less pumping near the coast (Figures 2-5 and 2-6), and gradients may be higher in some inland areas that are closer to the Forebay area, as recharge in the Forebay affects water pressure in the Oxnard Aquifer more than the other aquifers.

The vertical gradient between the Oxnard and Mugu Aquifers was higher in the fall than in the spring, except at the coast where it was the same in the spring and fall (Wells 01N22W20M02S and 01N22W20M03S), and in the Forebay where the gradient was higher in the spring than in the fall (Wells 02N22W23B07S and 02N22W23B08S). The vertical gradient in the Forebay was higher in the spring because of surface water spreading grounds in the Forebay that are primarily used during periods of higher flow in the Santa Clara River.

Vertical gradients within the Oxnard Aquifer were determined from monitoring well clusters 01N21W19L, 02N22W23B, and 01N22W28G, which have two screen intervals within the Oxnard Aquifer (Table 2-2). For each of these locations, the vertical hydraulic gradient within the Oxnard Aquifer was directed downward. The downward vertical hydraulic gradient ranged from 0.009 to 0.278 feet/feet in the spring of 2015. In the fall of 2015, the downward vertical gradient ranged from 0.016 to 0.643 feet/feet. The downward vertical hydraulic gradient was larger in the fall than in the spring, and the largest downward vertical hydraulic gradient was in the Oxnard Forebay (Forebay). The smallest downward vertical hydraulic gradient within the Oxnard Aquifer was adjacent to the coast (Table 2-2; Figure 2-8).

Historical Groundwater Elevation Trends

Groundwater elevations in the Oxnard Aquifer have declined and recovered over climatic cycles since the 1930s (Figure 2-9a, Groundwater Well Hydrographs in the Oxnard Aquifer – Oxnard Plain). Management policies and the construction and operation of water conservation facilities have also impacted historical groundwater elevations (see Section 2.3.1, Groundwater Elevation Data). Full hydrographs for Oxnard Subbasin wells with five or more groundwater elevation measurements are included in Appendix D.

Groundwater elevation trends in Well 01N21W07H01S, the well with the longest historical groundwater elevation record in the Oxnard Subbasin, track with the trends observed in the record of cumulative departure from the mean precipitation on the Oxnard Plain (Figure 2-9a). Declines in groundwater elevation occurred between 1941 and 1966, 1970 and 1977, 1984 and 1990, and 2011 and 2016, coincident with periods of drought shown in the declining limb of the cumulative departure from the mean precipitation curve (Figure 2-9a). Groundwater elevations recovered after each historical drought period, but have not yet recovered from the drought beginning in 2011. The amount of historical recovery depended on the length of time between droughts and the amount of precipitation received in each of the water years between the droughts, as well as management measures, including surface water spreading and deliveries, operative during the various periods. By 1980, the groundwater elevation recovered to within 10 feet of the previous maximum measured in 1941, and by 1999, water levels exceeded the 1941 maximum (Figure 2-9a), likely due to several wet years during the 1990s and the influence of management actions taken, and water conservation facilities constructed, in the 1980s and 1990s (see Section 2.3.1). In the late 1990s, artesian conditions were documented in the western Oxnard Subbasin (UWCD 1999). Since 2011, groundwater elevations in this well have declined approximately 40 feet.

The patterns of water level decline and recovery observed in Well 01N21W07H01S are observed in Oxnard Aquifer wells throughout the Oxnard Subbasin, although absolute changes in water level vary geographically within the Oxnard Subbasin (Figure 2-9a and Figure 2-9b, Groundwater Well Hydrographs in the Oxnard Aquifer – Forebay Area). Wells in the Forebay area and northeastern Oxnard Subbasin have experienced water level declines of approximately 90 feet since 2011 (Figure 2-9b), while water levels in wells adjacent to the coast and in wells farther south have declined between 18 and 40 feet over the same period (Figure 2-9a). The larger water level changes observed in the northeastern Oxnard Subbasin reflect the influence of UWCD’s managed aquifer recharge activities in the Forebay area; additionally, water level changes at the coast may be smaller due to the fact that seawater may be intruding and occupying volume within the aquifer as freshwater recedes.

Although groundwater elevations in the Oxnard Subbasin recover to some degree after each drought period, elevations in coastal wells do not always recover to mean sea level. Historical elevations of coastal wells over time in relation to sea level are discussed in Section 2.3.3.

2.3.1.2 Mugu Aquifer

Spring and Fall 2015 Groundwater Elevations

In the spring of 2015, recorded groundwater elevations in the Mugu Aquifer in the Oxnard Subbasin ranged from −60.7 to 8.2 feet msl (Figure 2-10 Groundwater Elevation Contours in the Mugu Aquifer, March 2–29, 2015). In the fall of 2015, groundwater elevations ranged from −97.7 to −12.1 feet msl (Figure 2-11, Groundwater Elevation Contours in the Mugu Aquifer, October 2–29, 2015).

The highest groundwater elevations in the Mugu Aquifer are found in the Forebay in both the fall and spring of 2015 (Figures 2-10 and 2-11). The hydraulic gradient in the Forebay in the spring of 2015 was approximately 0.003 feet/feet with groundwater flowing to the south and southwest. In the fall of 2015, the hydraulic gradient was approximately 0.002 feet/feet with groundwater flowing to the south and southwest. These gradients are based on the wells that are screened solely within the Mugu Aquifer, which are primarily located in the eastern part of the Subbasin. Groundwater elevations in the Mugu Aquifer are lowest in the southeastern area of the Subbasin. In general, elevations in the UAS in the southernmost corner of the Subbasin tend to be lower than in the central Subbasin (by as much as 40 to 80 feet), regardless of climatic cycles (FCGMA 2013).

In the southeastern area of the Subbasin, groundwater elevations were −30 to −100 feet msl in 2015 (Figures 2-10 and 2-11). The hydraulic gradient, directed toward the area of low groundwater elevations, was approximately 0.002 feet/feet to the southeast in the spring of 2015. In the fall of 2015, the hydraulic gradient directed toward the area of low groundwater elevations ranged from approximately 0.004 to 0.009 feet/feet to the east-southeast. Coastal groundwater elevations were measured below or near sea level in both spring and fall of 2015, creating a presumably landward hydraulic gradient at the coast (Figures 2-10 and 2-11).

There is uncertainty associated with the groundwater elevation contours, hydraulic gradient, and groundwater flow direction in the Mugu Aquifer in the spring and fall of 2015. The gradient is unknown in the northwestern area of the Subbasin, where there are no wells screened solely within the Mugu Aquifer. Additionally, fewer wells are screened solely within the Mugu Aquifer than are producing groundwater from the Mugu Aquifer. The majority of the wells that produce groundwater in the Mugu Aquifer are screened across multiple aquifers. These wells were not used to create the contour maps, in order to conform with the DWR GSP Regulations, Section 354.14. For the central and eastern areas of the Subbasin in which there are well data in the Mugu Aquifer, the uncertainty in hydraulic gradient, flow direction, and groundwater elevation within the aquifer is particularly pronounced. In this area, groundwater appears to flow to the south-southeast from the Oxnard Subbasin to the PVB (Figures 2-10 and 2-11).

Vertical Gradients

Groundwater elevations in the Mugu Aquifer are lower than those in the overlying Oxnard Aquifer, resulting in a downward vertical gradient from the Oxnard Aquifer to the Mugu Aquifer throughout the Oxnard Subbasin (Table 2-2; Section 2.3.1.1, Oxnard Aquifer). Groundwater elevations in the Mugu Aquifer are higher than those in the underlying Hueneme Aquifer, resulting in a downward vertical gradient from the Mugu Aquifer to the Hueneme Aquifer in the Forebay and adjacent to Port Hueneme (Table 2-2). At monitoring well cluster 01N22W20M, adjacent to Port Hueneme, the downward vertical hydraulic gradient was 0.033 feet/feet in the spring of 2015 and 0.039 feet/feet in the fall of 2015. At monitoring well cluster 02N22W23B, in the Forebay, the downward vertical hydraulic gradient was 0.012 feet/feet in the spring of 2015 and 0.028 feet/feet in the fall of 2015.

Within the Mugu Aquifer, a downward vertical gradient of 0.365 feet/feet was calculated in the spring of 2015 between Wells 01N21W32Q07S and 01N21W32Q05S (Figure 2-10). In the fall of 2015, the downward vertical gradient was 0.560 feet/feet (Table 2-2; Figure 2-11).

Historical Groundwater Elevation Trends

Groundwater elevations in the Mugu Aquifer have declined and recovered over climatic cycles since the 1970s (Figure 2-12, Groundwater Well Hydrographs in the Mugu Aquifer). Management policies and the construction and operation of water conservation facilities have also impacted historical groundwater elevations (see Section 2.3.1). Full hydrographs for Oxnard Subbasin wells with five or more groundwater elevation measurements are included in Appendix D.

Groundwater elevation trends in Well 02N22W24P01S, the well with the longest historical groundwater elevation record in the Mugu Aquifer, track with the trends observed in the record of cumulative departure from the mean precipitation on the Oxnard Plain (Figure 2-12). Declines in groundwater elevation occurred between 1974 and 1977, 1984 and 1990, and 2011 and 2016, coincident with periods of drought shown in the declining limb of the cumulative departure from the mean precipitation curve (Figure 2-12). Groundwater elevations recovered after each historical drought period, but have not yet recovered from the drought beginning in 2011. The amount of historical recovery depends on the length of time between droughts and the amount of precipitation received in each of the water years between the droughts, as well as management measures, including artificial recharge and surface water deliveries, operative during the various periods. In 1996, water levels exceeded the previous maximum in 1980 (Figure 2-12), likely due to several wet years during the 1990s and the influence of management actions taken, and water conservation facilities constructed in the 1980s and 1990s (see Section 2.3.1). In the late 1990s, artesian conditions were documented in the western Oxnard Subbasin (UWCD 1999). Since 2011, groundwater elevations in this well have declined approximately 100 feet.

The patterns of water level decline and recovery observed in Well 02N22W24P01S are observed in Mugu Aquifer wells throughout the Oxnard Subbasin, although absolute changes in water level vary geographically within the Subbasin (Figure 2-12). Well 02N22W24P01S is located near the Forebay area. Other wells in the Forebay area experienced similar water level declines and recoveries to those observed in Well 02N22W24P01S (Figure 2-12). Water levels in wells adjacent to the coast and in wells farther south, however, tend to have larger intra-annual variation (variation that occurs within a single year) in groundwater level, but a smaller drought response (e.g., Wells 01N21W32Q05S and 01N21W19L11S; see Figure 2-12). The groundwater elevation in these wells declined between 20 and 80 feet between 2011 and 2015, whereas the groundwater elevation in wells in the Forebay area declined approximately 100 feet over the same period. The larger groundwater level changes observed in the northeastern Oxnard Subbasin likely reflect the influence of groundwater recharge from spreading basins in the Forebay area; additionally, groundwater level changes at the coast may be smaller due to the fact that seawater may be intruding and occupying volume within the aquifer as freshwater recedes.

Although groundwater elevations in the Oxnard Subbasin recover after each drought period, groundwater elevations in coastal Mugu-specific wells in the southern Subbasin typically remain below mean sea level. Historical elevations of coastal wells over time in relation to sea level are discussed in Section 2.3.3.

2.3.1.3 Hueneme Aquifer

Spring and Fall 2015 Groundwater Elevations

In the spring of 2015, recorded groundwater elevations in the Hueneme Aquifer in the Oxnard Subbasin ranged from −89.4 to 10.2 feet msl (Figure 2-13, Groundwater Elevation Contours in the Hueneme Aquifer, March 2–29, 2015). In the fall of 2015, groundwater elevations ranged from −115.5 to 2.1 feet msl (Figure 2-14, Groundwater Elevation Contours in the Hueneme Aquifer, October 2–29, 2015). There are fewer wells screened solely in the Hueneme Aquifer than are screened in the Oxnard Aquifer, Mugu Aquifer, or FCA in the Oxnard Subbasin. The small number of wells screened solely within the Hueneme Aquifer creates uncertainty in the groundwater elevation contours, hydraulic gradient, and groundwater flow direction (Figures 2-13 and 2-14). This aquifer is present in the northern part of the Oxnard Subbasin but is absent to the south of Etting and Hueneme Roads (Mukae and Turner 1975).

The highest groundwater elevations in the Hueneme Aquifer are found in the Forebay in both the fall and spring of 2015 (Figures 2-13 and 2-14). The hydraulic gradient in the Forebay in the spring of 2015 was approximately 0.008 feet/feet, with groundwater flowing to the southwest. In the fall of 2015 the hydraulic gradient was approximately 0.007 feet/feet, with groundwater flowing to the south-southwest.

Groundwater elevations in the Hueneme Aquifer are lowest south of the Forebay and west of Central Avenue (Figures 2-13 and 2-14). In this area, groundwater elevations were −80 to −100 feet msl in 2015 (Figures 2-13 and 2-14). This area of lower groundwater elevations coincides with the location of several production wells that are screened solely within the Hueneme Aquifer (Figure 2-6). The hydraulic gradient, directed toward the area of low groundwater elevations, ranged from approximately 0.003 feet/feet to the southeast in the spring of 2015 to approximately 0.008 feet/feet to the east-southeast in the fall of 2015. Coastal groundwater elevations were below or near sea level in both spring and fall of 2015, resulting in a landward hydraulic gradient at the coast (Figures 2-13 and 2-14).

Vertical Gradients

Groundwater elevations in the Hueneme Aquifer are lower than those in the overlying Mugu Aquifer, resulting in a downward vertical gradient from the Mugu Aquifer to the Hueneme Aquifer (Table 2-2; Section 2.3.1.2, Mugu Aquifer). Groundwater elevations in the Hueneme Aquifer were higher than those in the underlying FCA in both the spring and fall of 2015, except in the Forebay at Wells 02N22W23B03 and 02N22W23B04. In these wells, the groundwater elevation in the Hueneme Aquifer was higher than it was in the FCA in the spring of 2015, and lower than that in the FCA in the fall of 2015 (Table 2-2). In the spring of 2015, the downward vertical hydraulic gradient between the Hueneme Aquifer and FCA ranged from 0.014 feet/feet to 0.040 feet/feet. In the fall of 2015, the vertical hydraulic gradient between the Hueneme Aquifer and FCA ranged from 0.050 feet/feet downward adjacent to the coast, to 0.032 upward in the Forebay (Table 2-2).

Within the Hueneme Aquifer, a downward vertical gradient of 0.017 feet/feet was calculated for Wells 01N22W20M03S and 01N22W20M02S in the spring of 2015 (Figure 2-13). In the fall of 2015, the gradient in these wells was 0.019 feet, which is the same as it was in the spring. Farther north, in Wells 01N23W01C03S and 01N23W01C04S, the vertical gradient within the Hueneme Aquifer was similar to that calculated for Wells 01N22W20M03S and 01N22W20M02S. In the spring of 2015, the downward vertical hydraulic gradient was 0.009 feet/feet in Wells 01N23W01C03S and 01N23W01C04S. In the fall, the downward vertical hydraulic gradient was 0.010 feet/feet between Wells 01N23W01C03S and 01N23W01C04S (Table 2-2).

In Wells 02N22W23B07S and 02N22W23B08S, in the Forebay, the downward vertical gradient is greater in the upper Hueneme Aquifer than in the lower Hueneme Aquifer (Table 2-2). The gradients within the Hueneme Aquifer in the Forebay are similar to those within the Hueneme Aquifer along the coast.

Historical Groundwater Elevation Trends

Groundwater elevations in the Hueneme Aquifer have declined and recovered over climatic cycles (Figure 2-15, Groundwater Well Hydrographs in the Hueneme Aquifer). Management policies and the construction and operation of water conservation facilities have also impacted historical groundwater elevations (see Section 2.3.1). Full hydrographs for Oxnard Subbasin wells with five or more groundwater elevation measurements are included in Appendix D.

Groundwater elevation trends in Well 02N21W31P03S, the well with the longest historical groundwater elevation record in the Hueneme Aquifer, track with the trends observed in the record of cumulative departure from the mean precipitation on the Oxnard Plain (Figure 2-15). Declines in groundwater elevation occurred between 1974 and 1977, 1984 and 1990, and 2011 and 2016, coincident with periods of drought shown in the declining limb of the cumulative departure from the mean precipitation curve (Figure 2-15). Groundwater elevations largely recovered after each historical drought period, but have not yet recovered from the drought beginning in 2011. The amount of historical recovery depends on the length of time between droughts and the amount of precipitation received in each of the water years between the droughts, as well as the management measures, including artificial recharge and surface water deliveries, operative during the various periods. Since 2011, groundwater elevations in this well have declined approximately 60 feet (Figure 2-15).

The patterns of water level decline and recovery observed in Well 02N21W31P03S are also observed in Hueneme Aquifer Wells 01N22W03F05S and 01N22W26M03S, although the magnitude of the change in groundwater levels varies between the wells (Figure 2-15). Ignoring seasonal variations reflecting pumping, the spring high elevations between 1996 and 2010 were relatively stable in Well 01N22W26M03S and declined by approximately 32 feet in Well 01N22W03F05S. Between 2011 and 2015, during a period of drought, groundwater elevations declined approximately 47 feet in Well 01N22W26M03S and approximately 55 feet in Well 01N22W03F05S (Figure 2-15).

Although groundwater elevations in the Oxnard Subbasin recover after each drought period, groundwater elevations in coastal wells can remain below mean sea level, resulting in a landward gradient near the coast.

2.3.1.4 Fox Canyon Aquifer

Spring and Fall 2015 Groundwater Elevations

In the spring of 2015, recorded groundwater elevations in the FCA in the Oxnard Subbasin ranged from −107.3 to 3.9 feet msl (Figure 2-16, Groundwater Elevation Contours in the Fox Canyon Aquifer, March 2–29, 2015). In the fall of 2015, groundwater elevations ranged from −156.3 to −24.6 feet msl (Figure 2-17, Groundwater Elevation Contours in the Fox Canyon Aquifer, October 2–29, 2015).

The highest groundwater elevations in the FCA are found in the Forebay in both the fall and spring of 2015 (Figures 2-16 and 2-17). The lowest recorded groundwater elevations are found at Well 01N21W06J05S, south of 5th Street, west of Pleasant Valley Road (Figures 2-16 and

2-17). The low groundwater elevations in this well reflects the production from the FCA at this location (Figure 2-6). However, there are several wells in the surrounding areas that produced more groundwater in 2015, but are screened across multiple aquifers in the LAS. The hydraulic gradient in the FCA was directed toward Well 01N21W06J05S in both the spring and fall of 2015. In the spring of 2015, the hydraulic gradient was approximately 0.001 to 0.002 feet/feet. In the fall of 2015, the hydraulic gradient ranged from approximately 0.002 to approximately 0.005 feet/feet. These gradients may not fully depict the direction and magnitude of flow within the FCA because more production wells are screened across multiple aquifers in the LAS than are screened solely within the FCA, and consequently production is occurring in areas of the aquifer that lack aquifer-specific groundwater elevation data. Coastal groundwater elevations were measured below or near sea level in both spring and fall of 2015, resulting in a landward hydraulic gradient (Figures 2-16 and 2-17).

Vertical Gradients

Groundwater elevations in the FCA are generally lower than those in the overlying aquifers (Figures 2-16 and 2-17; Table 2-2). In the spring of 2015, the downward vertical gradient from the Mugu Aquifer to the FCA ranged from 0.012 feet/feet in the Forebay to 0.390 feet/feet adjacent to Highway 1 (Figure 2-16; Table 2-2). In the fall of 2015, the downward vertical gradient from the Mugu Aquifer to the FCA ranged from 0.620 feet/feet in the Forebay to 0.028 feet/feet south of Hueneme Road.

In the spring of 2015, the downward vertical gradient from the Hueneme Aquifer to the FCA was similar geographically, ranging from 0.014 feet/feet in the Forebay and along the coast north of Port Hueneme to 0.040 feet/feet adjacent to the coast at Port Hueneme (Table 2-2). In the fall of 2015, the vertical hydraulic gradient between the Hueneme Aquifer and FCA ranged from 0.050 feet/feet downward along the coast near Port Hueneme to 0.032 feet/feet upward in the Forebay (Table 2-2).

Within the FCA, a downward vertical gradient of 0.005 feet/feet was calculated for Wells 01N22W36K06S and 01N22W36K07S in the spring of 2015. The vertical hydraulic gradient in these wells, near Point Mugu, was 0.019 feet/feet downward in the fall of 2015. In the Mugu area the vertical flow to the FCA is a major mechanism for seawater intrusion. In the Forebay area, the vertical hydraulic gradient within the FCA was 0.014 feet/feet downward in the spring of 2015 and 0.022 feet/feet upward in the fall of 2015 (Table 2-2; Wells 02N21W07L04S and 02N21W07L06S).

Groundwater elevations in the FCA are higher than those in the underlying GCA, except adjacent to Port Hueneme in Wells 01N22W28G04S and 01N22W28G05S (Table 2-2).

Historical Groundwater Elevation Trends

Groundwater elevations in the FCA have declined and recovered over climatic cycles (Figure 2-18, Groundwater Well Hydrographs in the Fox Canyon Aquifer). Management policies and the construction and operation of water conservation facilities have also impacted historical groundwater elevations (see Section 2.3.1). Full hydrographs for Oxnard Subbasin wells with five or more groundwater elevation measurements are included in Appendix D.

Groundwater elevation trends in Well 01N22W26K04S, the well with the longest historical groundwater elevation record in the FCA, track with the trends observed in the record of cumulative departure from the mean precipitation on the Oxnard Plain (Figure 2-18). Declines in groundwater elevation occurred between 1974 and 1977, 1984 and 1990, and 2011 and 2016, coincident with periods of drought shown in the declining limb of the cumulative departure from the mean precipitation curve (Figure 2-18). Groundwater elevations recovered after each drought period prior to the most recent drought. Groundwater elevations have not yet recovered to pre-2011 levels.

The amount of historical recovery depends on the length of time between droughts and the amount of precipitation received in each of the water years between the droughts, as well as management measures, including artificial recharge and surface water deliveries, operative during the various periods. In 1999, water levels exceeded the previous maximum in 1983 (Figure 2-18), likely due to several wet years during the 1990s and the influence of management actions taken, and water conservation facilities constructed, in the 1980s and 1990s (see Section 2.3.1). In the late 1990s, artesian conditions were documented in the western Oxnard Subbasin (UWCD 1999).

The patterns of groundwater level decline and recovery observed in Well 01N22W26K04S are observed in FCA wells throughout the Oxnard Subbasin, although absolute changes in groundwater level vary geographically within the Oxnard Subbasin (Figure 2-18). Well 01N22W26K04S is located south of Hueneme Road. Other wells in this area experienced similar groundwater level declines and recoveries to those observed in Well 01N22W26K04S (Figure 2-18). Wells farther inland tend to have larger intra-annual variations in groundwater level (e.g., Wells 01N21W06J05S and 01N21W09C04S; see Figure 2-18). The groundwater elevation in these wells declines by 40 to 50 feet each year between the spring high and fall low groundwater levels. In contrast, Well 01N23W01C02S, adjacent to the coast, declines approximately 5 feet between the spring high and fall low groundwater level (Figures 2-16, 2-17, and 2-18). Groundwater level changes at the coast may be smaller due to the fact that seawater may be intruding and occupying volume within the aquifer as freshwater recedes.

Although groundwater elevations in the Oxnard Subbasin recover after each drought period, groundwater elevations in coastal FCA-specific wells in the southern Subbasin typically remain below mean sea level.

2.3.1.5 Grimes Canyon Aquifer

Spring and Fall 2015 Groundwater Elevations

The GCA is only found underlying the southern and eastern parts of the Oxnard Subbasin (Turner 1975). Only six wells in the Oxnard Subbasin are screened solely within the GCA. These wells are located in the southern part of the Subbasin, all located west of Revolon Slough (Figure 2-19, Groundwater Elevation Contours in the Grimes Canyon Aquifer, March 2–29, 2015). In the spring of 2015, recorded groundwater elevations in the GCA ranged from −31.3 to −75.6 feet msl (Figure 2-19). In the fall of 2015, groundwater elevations ranged from −38.6 feet msl to −114.2 feet msl (Figure 2-20, Groundwater Elevation Contours in the Grimes Canyon Aquifer, October 2–29, 2015).

Where measured, groundwater in the GCA flows to the east-northeast from the coast toward the Revolon Slough (Figures 2-19 and 2-20). In the spring of 2015, the hydraulic gradient in the vicinity of Point Mugu was approximately 0.003 feet/feet (Figure 2-19). In the fall of 2015, the hydraulic gradient was approximately 0.008 feet/feet (Figure 2-20).

There is a large degree of uncertainty associated with the groundwater elevation contours, hydraulic gradient, and groundwater flow direction in the GCA in the spring and fall of 2015 because so few wells are screened solely within the GCA. The direction of flow, as contoured by the wells that are screened within the GCA, likely reflects the LAS groundwater production south of Hueneme Road (Figure 2-6). However, no wells are screened solely within the GCA north of Hueneme Road; therefore, the groundwater elevation, hydraulic gradient, and direction of flow in the GCA is unknown for much of the Oxnard Subbasin. Coastal groundwater elevations were measured below or near sea level in both spring and fall of 2015, and consequently the hydraulic gradient was landward at the coast (Figures 2-19 and 2-20).

Vertical Gradients

Groundwater elevations in the GCA are generally lower than those in the overlying FCA, except adjacent to Port Hueneme in Wells 01N22W28G04S and 01N22W28G05S (Table 2-2). The downward vertical hydraulic gradient in the spring of 2015 ranged from 0.047 feet/feet downward at Wells 01N21W32Q04S and 01N21W32Q05S to 0.01 feet/feet upward Wells 01N22W28G04S and 01N22W28G05S (Table 2-2). Vertical hydraulic gradients were similar in the fall of 2015, ranging from 0.044 feet/feet downward to 0.019 feet/feet upward, in the same wells.

Only well cluster 01N21W32Q has two wells screened within the GCA (Wells 01N21W32Q02 and 01N21W32Q03; Figure 2-19). Within the GCA, the vertical hydraulic gradient was 0.084 feet/feet upward in both the spring and fall of 2015 (Table 2-2).

Historical Groundwater Elevation Trends

Groundwater elevations in the GCA have been measured since 1989. Similar to the water levels in the overlying FCA, the groundwater levels in the GCA recovered between 1990 and 1996 (Figure 2-21, Groundwater Well Hydrographs in the Grimes Canyon Aquifer). Between 1996 and 2010, groundwater elevations were relatively stable, with intra-annual variation of up to 80 feet per year, but with inter-annual variation (variation that occurs over a series of years) of 10 feet or less. Between 2011 and 2015 groundwater elevations in the GCA declined, coincident with a period of drought. Groundwater elevations in Wells 01N22W28G01S and 01N22W35E01S vary less than groundwater elevations in other GCA wells, potentially because they are relatively far from major centers of groundwater extraction or because they are adjacent to the coast, and the intrusion of seawater may moderate freshwater elevation changes (Figures 2-19 and 2-21).

Although groundwater elevations in the Oxnard Subbasin recover to some degree after each drought period, elevations in coastal GCA-specific wells in the southern Subbasin remain below mean sea level.

2.3.2 Estimated Change in Storage

Estimated monthly change in storage values for the Oxnard Subbasin were generated by the numerical groundwater flow model prepared by UWCD (Appendix C). Monthly data reported from the model was summed to get the annual change in storage for the period from water year 1986 to water year 2015. There are inherent uncertainties in using any numerical groundwater flow model. The uncertainty associated with the UWCD model estimates is explored in more detail in Appendix E, UWCD Model Peer Review. Model estimated change in storage for the aquifer, the UAS, and the LAS is presented below.

The annual change in storage in the semi-perched aquifer ranged from an increase of approximately 16,300 AF in water year 1995 to a decrease of approximately 11,000 AF in water year 2014. The average annual change in storage in the semi-perched aquifer was a loss of storage of approximately 410 AFY.

In the UAS, the annual change in storage ranged from an increase of approximately 63,000 AF in water year 2005 to a decrease of approximately 34,200 AF in water year 1987. The average annual change in storage in the UAS was a loss of approximately 2,800 AFY.

The LAS had a maximum annual increase in storage of approximately 7,300 AF in water year 2005 and a maximum annual decrease in storage of approximately 8,000 AF in water year 1987. The average annual change in the LAS was a loss of approximately 220 AFY.

Total average annual change in storage in the Oxnard Subbasin was a decrease in storage of approximately 3,400 AFY. For the entire Oxnard Subbasin, the annual change in storage ranged from an increase of approximately 81,000 AF in water year 2005 to a decrease of approximately 48,700 AF in water year 1987 (Figure 2-22, Oxnard Subbasin Annual Change in Storage).

The cumulative change in storage calculated by the model over the period of record, water years 1986 through 2015, is presented on Figure 2-23, Oxnard Subbasin Cumulative Change in Storage. For the semi-perched aquifer, the UAS, and the LAS, the cumulative change in storage was a loss of approximately 12,300 AF, 82,500 AF, and 6,600 AF, respectively. The total cumulative loss for the entire Oxnard Subbasin was approximately 101,400 AF (Figure 2-23). Groundwater extraction (pumping) in the FCGMA is reported on a calendar year basis, so pumping and artificial recharge in figures is per calendar year, while change in storage is per water year. Annual change in storage is not strongly correlated to groundwater pumping in the Oxnard Plain ($R^2 < 0.5$). In contrast, artificial groundwater recharge at the UWCD spreading grounds is correlated with change in storage ($R^2 > 0.8$; see Figures 2-22 and 2-23). Therefore, maintaining the ability to recharge groundwater via the UWCD spreading grounds is critical to maintaining groundwater production in the Subbasin.

The model results illustrated in Figures 2-22 and 2-23 represent the net change in groundwater storage in each of the aquifer systems in the Subbasin. These results, however, include flux of seawater into the coastal areas of the aquifer systems from offshore. The volume of seawater that intruded between 1986 and 2015 was calculated for the UAS and LAS. The volume of seawater calculated does not include coastal flux into or out of the semi-perched aquifer, as few production wells are screened solely in the semi-perched aquifer. In order to assess the change in freshwater storage in the Subbasin, the annual volume of seawater that intruded was subtracted from the annual total storage change discussed above.

In the UAS, the average annual change in freshwater storage is a loss of approximately 6,600 AFY, which is more than two times greater than the total average annual change in storage for the UAS (2,800 AFY), including seawater intrusion (Figure 2-24, Oxnard Subbasin Annual Change in Storage Without Coastal Flux). In other words, approximately 3,800 AFY of seawater intrusion occurred in the UAS between water years 1986 and 2015. The maximum annual increase in freshwater storage was approximately 61,500 AF in water year 2005 and the maximum annual decrease in freshwater storage was approximately 48,500 AF in water year 1990.

The average annual change in freshwater storage in the LAS is a loss of approximately 5,700 AFY, which is 26 times greater than the total average annual change in storage for the LAS (220 AFY), including seawater intrusion (Figure 2-24). Therefore, there was approximately 5,500 AFY of seawater intrusion into the LAS between water years 1986 and 2015. The maximum increase of freshwater in storage in the LAS was approximately 2,820 AF in water year 1998 and the maximum decrease of freshwater in storage was approximately 15,150 AF in water year 1990.

For the entire Oxnard Subbasin, there was an average decrease in freshwater storage of approximately 12,700 AFY, when coastal flux is removed, with a maximum increase in storage of approximately 74,700 AF in water year 2005 and a maximum decrease in storage of approximately 73,500 AF in water year 1990 (Figure 2-24). Cumulatively between 1986 and 2015, the loss of freshwater in storage in the UAS was approximately 197,200 AF and the loss of freshwater in storage in the LAS was approximately 170,200 AF. The cumulative change in freshwater storage for both the UAS and LAS was a loss of approximately 367,400 AF. The cumulative change in storage for the entire Oxnard Subbasin, including the semi-perched aquifer, calculated by the model over the period of record, was a loss of approximately 380,200 AF of freshwater in storage, excluding coastal flux (Figure 2-25, Oxnard Subbasin Cumulative Change in Storage Without Coastal Flux).

Estimates of model changes in storage have a level of uncertainty and are dependent on model input parameters. These parameters include groundwater pumping, artificial aquifer recharge, interbasin flows, recharge from precipitation and irrigation returns, stream leakage and groundwater discharge to streams, and inflows from the ocean. Numbers may also initially be biased due to assumptions about the initial groundwater levels used in the model, which are based on available well locations and measurements that may bias starting groundwater elevations modeled in the aquifers. These inputs were estimated using the best available data and calibrated to groundwater levels in the model to a reasonable extent (Appendix C). Changes in these input values from additional monitoring wells, the filling of data gaps, and model calibration and validation may result in changes in the modeled estimates of change in storage in the future.

2.3.3 Seawater Intrusion

Evidence of seawater intrusion in the Oxnard Subbasin was first documented in the 1930s in the vicinity of Port Hueneme and Point Mugu (DWR 1965). Since that time, the landward extent of the saline water impact front has been monitored and the causes and sources of increasing chloride concentrations have been studied. Table 2-3 lists historical seawater intrusion reports and studies on the Oxnard Subbasin.

An elevated risk of seawater intrusion has been found to exist near Port Hueneme and Point Mugu due to the near shore presence of the groundwater–seawater contact in deeply incised submarine canyons (UWCD 2016a).

Seawater intrusion has been documented in both aquifer systems, and in each primary aquifer, in the Oxnard Subbasin. Seawater preferentially intrudes the aquifers in permeable sand and gravel beds (UWCD 2016a). As a result, the eastward extent of the saline water impact front varies from north to south along the coastline and within each aquifer (UWCD 2016a). In the Oxnard Subbasin, seawater that has intruded the aquifers in the vicinity of Port Hueneme tends to flow southward toward Point Mugu even after groundwater elevations rise and the landward hydraulic gradient is reversed (UWCD 2016a). As a result, higher groundwater elevations in the aquifer do not tend to flush the seawater back out of the aquifer via the original intrusion pathway (UWCD 2016a). Consequently, impacts associated with seawater intrusion have not been eliminated during wetter-than-average climatic periods.

2.3.3.1 Causes of Saline Impacts in the Oxnard Subbasin

Under seaward groundwater gradients, groundwater in the Oxnard Subbasin generally flows south and west from the Oxnard Forebay area toward the Pacific Ocean and out to sea. When groundwater heads near the coast fall below sea level or, in confined aquifers, the sea-level-equivalent elevation according to the depth of the aquifer outcrop, the gradient reverses.[4]

In addition to seawater intrusion, low groundwater heads in confined zones in the Oxnard Subbasin can create conditions under which high-salinity waters from non-marine sources impact freshwater aquifers. These sources include connate (groundwater trapped in sedimentary rocks due their deposition) brines released during compaction of aquitards and older, higher-salinity groundwater upwelling from geologic formations deeper than the lower extent of the freshwater aquifers (Izbicki 1991, 1996; UWCD 2016a; Izbicki et al. 2005).

Thirdly, although the major aquifer units in the Oxnard Subbasin are commonly separated by low-permeability units, vertical gradients, long-screened wells, and areas of mergence between aquifers can result in vertical groundwater movement between major aquifers (UWCD 2016a). In particular, because water elevations are typically higher in the semi-perched aquifer than in the deeper confined aquifers, higher-salinity water from the semi-perched aquifer may reach confined aquifers via one or more of these mechanisms. Seawater intrusion also enters the FCA from vertical flow from the Mugu aquifer in the Mugu area.

Because zones of low groundwater head cause seawater intrusion and release of connate water from aquitards, and potentially influence non-marine brine migration into freshwater aquifers, distinguishing the source of salts in any given well is not always possible, particularly at chloride concentrations less than 500 mg/L (Izbicki 1996). In the southeastern Subbasin, near the Mugu

4 Because seawater is approximately 1.025 times denser than freshwater (using the Ghyben-Herzberg theory [De Wiest 1998]), the elevation of confined freshwater necessary to counterbalance the pressure of the water in the sea can be several feet above sea level, and depends on the depth at which an aquifer crops out in the ocean (i.e., the deeper the outcrop, the higher the freshwater elevation necessary to counterbalance the pressure of seawater).

submarine canyon, upward migration of brines can cause chloride concentrations to increase before the saline water impact front reaches a well (Izbicki 1996). Because the chloride concentration measured in wells near the Mugu submarine canyon reflect the combined effects of brine migration and seawater intrusion, it is difficult to define the leading edge of the saline water impact front using chloride concentrations in this area (Izbicki 1996). The USGS and UWCD models included faults in the Mugu Lagoon area that limit the hydraulic connection of the LAS in the Oxnard Basin to the Pacific Ocean (Hanson et al. 2003; Appendix C).

2.3.3.2 Current Extent of Seawater Intrusion

The known extent of saline water intrusion in the UAS and LAS in 2015 generally occurred near and southeast of Port Hueneme and in the area surrounding Mugu Lagoon. As of 2015, although seawater intrusion had been reduced in the Oxnard Subbasin due to management actions and wet climatic conditions in the 1990s and 2000s, TDS and chloride concentrations as high as 49,600 and 20,700 mg/L, respectively, were found in wells inland of the southern Oxnard coast (both measured in Well 01N22W07R05S; see Appendix F, Coastal Seawater Intrusion WL vs. CL Plots, and recent water quality data in Section 2.3.4, Groundwater Quality). The extent of saline water intrusion in the Oxnard Subbasin in 2015 is shown in cross section on Figure 2-26 (Approximate 2015 North–South Saline Water Intrusion Extent) and in plan view on Figures 2-27 through 2-32 (Coastal Chloride Concentrations, Fall 2015).[5] As discussed, chloride concentrations above 500 mg/L in the area of the Mugu Lagoon can be caused by both seawater intrusion and brine migration. Although this section focuses on areas that are known to be susceptible to seawater intrusion, the precise extent of current seawater intrusion impacts is difficult to separate from the areas that are impacted by release of saline water from connate brines. Therefore, the current area of seawater intrusion is smaller than the area of high chloride concentrations shown in Figures 2-27 through 2-32.

Additionally, the inland extent of seawater intrusion varies by aquifer (see Figure 2-26). Between 1985 and 2015, UWCD groundwater model estimates suggest that approximately 1,800 AFY of groundwater flowed from the semi-perched aquifer to the Pacific Ocean. In the UAS (Oxnard and Mugu Aquifers), in years characterized by relatively high rainfall, groundwater flowed from the aquifers to the ocean in the spring, and the flow reversed in the fall; conversely, in dry years ocean water flowed into the aquifers in all seasons. On average, over the entire model period, there was approximately 3,900 AFY of seawater intrusion into the UAS in the Oxnard Subbasin. In the LAS, the direction of flow varied by aquifer. The direction of flow in the Hueneme Aquifer was primarily from the ocean to the aquifer, though there are some months in which the flow direction was seaward. In the FCA and the GCA, ocean water flowed into the aquifers in every month in the period of record. The average seawater intrusion in the LAS was approximately 5,500 AFY during the model period.

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5 Saline water is typically defined as groundwater with a TDS concentration between 10,000 and 35,000 mg/L.

2.3.3.3 Historical Progression of Seawater Intrusion

Chloride concentrations were first measured in the Oxnard Subbasin in the 1920s. Between 1920 and 1929, the chloride concentration in three wells in the UAS ranged from 40 to 81 mg/L, with the lowest chloride concentration detected at the coast near Port Hueneme (FCGMA 2007). Groundwater elevations at this time ranged from 2 to 22 feet msl (FCGMA 2007). By 1934, when groundwater elevations in the UAS declined to −2 to 9 feet msl, the chloride concentration at a coastal well near Port Hueneme was 1,346 mg/L (FCGMA 2007). This was the first evidence of a potential saline water impact front in the vicinity of Port Hueneme. Between 1935 and 1940, chloride concentrations at the coast declined again and remained below 50 mg/L from 1934 to 1949 (FCGMA 2007). By 1954, however, as groundwater elevations in the UAS had declined to as much as −35 feet msl, seawater intrusion is interpreted to have affected an approximately 1-square-mile area near Port Hueneme, where two UAS wells had chloride concentrations of 1,070 and 1,925 mg/L.

This area of seawater intrusion expanded to the north and east between 1954 and 1959, and by 1959 an additional area of seawater intrusion was identified in the UAS north and east of Point Mugu (FCGMA 2007). Chloride concentrations near Port Hueneme reached 27,350 mg/L and those near Point Mugu reached 11,475 mg/L (FCGMA 2007). As groundwater elevations remained below sea level, the two areas of seawater intrusion continued to expand through the 1960s and 1970s, with the saline water impact front eventually reaching as much as 3 miles inland near Port Hueneme by the early 1980s (Izbicki 1996; FCGMA 2007).

The implementation of management strategies and pumping allocations by the FCGMA, along with increased rainfall in the late 1970s and early 1980s, reduced the area of the UAS affected by seawater intrusion, even as groundwater elevations remained below sea level throughout much of the Subbasin (FCGMA 2007). With the completion of the Freeman Diversion, which allowed for increased aquifer recharge at the spreading basins operated by UWCD, and additional above-average rainfall years, groundwater elevations in much of the UAS rose above sea level and the area of the UAS affected by seawater intrusion decreased in the 1990s (FCGMA 2007).

At the same time that seawater intrusion in the UAS was being managed and mitigated in the 1980s and 1990s, seawater intrusion began to affect the LAS (FCGMA 2007). By 1989, chloride was detected at a concentration of 6,700 mg/L at a well near Port Hueneme (FCGMA 2007). By 1994, chloride concentrations between 1,000 and 7,000 mg/L were detected near both Port Hueneme and Point Mugu (FCGMA 2007). The area impacted by seawater intrusion remained smaller in the LAS than in the UAS throughout the 1980s and 1990s.

Between 2000 and 2013, groundwater elevations in the UAS remained above sea level and there was little change in the extent of seawater intrusion near Port Hueneme (UWCD 2016a). As groundwater elevations dropped below sea level during the recent drought, however, chloride concentrations in UAS monitoring wells near the coast began to increase and the saline water impact front expanded eastward again (UWCD 2016a). Near the Mugu submarine canyon, the groundwater elevations in the UAS have remained below sea level and chloride concentrations in wells near the coast are close to those of seawater (UWCD 2016a). The current extent of saline water intrusion in both the UAS and the LAS is shown in Figures 2-27 through 2-32.

2.3.3.4 Relationships between Groundwater Elevation and Seawater Intrusion

The relationship between groundwater elevations and seawater intrusion, as measured by changes in chloride concentration, is complex. Since the 1950s, water levels in the Oxnard and Mugu Aquifers in coastal areas have historically fallen below sea level in response to increased production and drought cycles (Figures 2-9a and 2-12). Unlike areas farther inland, the water levels below sea level resulted in seasonal seawater intrusion during the fall irrigation season and during droughts in coastal wells in the vicinity of Point Hueneme and Point Mugu (Figure 2-33, Groundwater Flux along the Coast in the Upper Aquifer System). In contrast, as groundwater production increased in the LAS, water levels in the FCA and the GCA near the coast quickly fell below sea level and have remained there since the 1980s, even after periods of above-average precipitation (Figures 2-18 and 2-21). The UWCD model indicates continuous flux from the ocean into these aquifers since 1985 (Figure 2-34, Groundwater Flux along the Coast in the Lower Aquifer System).

Some wells located near Port Hueneme and screened in the Oxnard Aquifer and the Hueneme Aquifer have chloride concentrations that rise as groundwater elevations decline and that decline as groundwater elevations rise. This relationship is shown in Wells 01N22W20M05S and 01N22W29D03S on Figure 2-35 (Selected Historical Records of Water Elevation and Chloride Concentration). All the wells with chloride and groundwater measurements are shown on Figure 2-36 (Locations of Selected Coastal Wells with Historical Measurements of Chloride Concentration and Water Elevation). It should be noted, however, that changes in chloride concentration in groundwater lag behind changes in groundwater elevation by up to 2 years in these wells. This response suggests that by the time the chloride response to declining groundwater elevations is measured, seawater intrusion has already begun.

The relationship between chloride concentration and groundwater elevation observed in Wells 01N22W20M05S and 01N22W29D03S is not universal throughout the Subbasin. In Well 01N22W29D02S, which is located in the same well cluster as Well 01N22W29D03S and is screened deeper in the Hueneme Aquifer, the concentration of chloride increased from 1995 through 2015, independent of groundwater elevation (Figures 2-35[C] and 2-36). The long-term increase in chloride concentration observed in this well suggests that groundwater elevations, even when above sea level, are not limiting the increasing chloride concentrations. A similar trend is observed in Well 01S21W08L03S, which is screened in the GCA and is located near Point Mugu; however, in this well groundwater elevations have remained below sea level since 1990 (Figures 2-35[D] and 2-36). One explanation is that the southern flow of groundwater along the coast from Port Hueneme discussed above may limit the ability to flush some areas of saltwater back out of Grimes Canyon.

A complete set of hydrographs for all wells from which both chloride and groundwater elevation data have been collected, showing the relationship between chloride concentration and groundwater elevation, is provided in Appendix F. A summary of the relationship between chloride concentration and groundwater elevation by region within the Oxnard Subbasin is provided below.

North Coast

In the north coastal Oxnard Plains, groundwater elevations in one nested well cluster (01N23W01C02S-05S) screened in the Oxnard Aquifer, the Hueneme Aquifer, and the FCA, were below sea level in the early 1990s, generally remained above or near sea level between the mid-1990s and early 2010s, and dropped below sea level between 2013 and 2015 (Appendix F). In spite of the low groundwater elevations in the historical record, the chloride concentration in the four nested wells 01N23W01C02S–01N23W01C05S (Figure 2-36) has not exceeded 55 mg/L since the wells were completed in 1990 (Appendix F). Additionally, recent chloride concentrations in both the UAS and the LAS are typically below 100 mg/L (see Section 2.3.4). The aquifers of the Oxnard Subbasin are believed to crop out on the ocean floor where direct documentation of seawater intrusion cannot be measured.

Port Hueneme

In the vicinity of Port Hueneme, groundwater elevations in confined aquifers were below sea level in the early 1990s, recovered to elevations above sea level, remained there for two decades, and dropped below sea level between 2011 and 2014 after the onset of the recent drought. Records from nested wells 01N22W20M01 through 01N22W20M06 (which are screened in the semi-perched aquifer, the Oxnard Aquifer, the Mugu Aquifer, two zones in the Hueneme Aquifer, and the FCA; see Figure 2-36 and Appendix F) underscore the variability in the relationships between groundwater elevation and seawater intrusion in different water-bearing units. Despite the similarity in the five profiles of groundwater elevation over time, seawater preferentially intruded the Oxnard Aquifer in the past, and rising concentrations of chloride are observed in the Oxnard Aquifer, the Hueneme Aquifer, and the FCA in response to the recent decline in groundwater elevations. In this area, offshore outcrops of the older alluvium and the San Pedro Formation occur in the Hueneme submarine canyon. These outcrops provide a direct link between the Pacific Ocean and the freshwater aquifers of the Oxnard Subbasin. This region is susceptible to seawater intrusion, as demonstrated by chloride concentrations and groundwater elevations since the 1950s.

South Coast

In general, groundwater elevations in the Mugu Aquifer, FCA, and GCA in the South Coast Region have remained near or below sea level since the early 1990s (Figure 2-36 and Appendix F). Elevations in the Hueneme and Oxnard Aquifers largely remained above sea level between the mid-1990s and early 2010s. Within the upper Oxnard Aquifer, chloride concentrations have been decreasing, while rising chloride concentrations have been measured in the lower Oxnard Aquifer. In this area, elevated chloride concentrations in the Oxnard Aquifer likely result from southward migration of seawater that intruded the aquifer in the vicinity of Port Hueneme during earlier periods of low groundwater elevations (UWCD 2016a). This region does not typically experience direct seawater intrusion via offshore outcrops, but rather rising chloride concentrations indicate previous episodes of seawater intrusion via the Hueneme Canyon to the north.

Point Mugu

In all but one case, groundwater elevations in the vicinity of Mugu Lagoon have remained below sea level since the 1990s. Chloride concentrations exceeding 1,000 mg/L are measured in the majority of monitoring wells in this region (Figure 2-36; Appendix F). However, as noted above, some of the elevated chloride concentrations in this area are from the upwelling of connate water and the migration of groundwater to the LAS from the UAS.

2.3.4 Groundwater Quality

FCGMA adopted Basin Management Objectives (BMOs) for nitrate, chloride, and TDS in the Oxnard Subbasin for its 2007 Groundwater Management Plan Update (FCGMA 2007; Table 2-4). Additionally, the Water Quality Control Plan: Los Angeles Region (Basin Plan) specifies Water Quality Objectives (WQOs) for TDS, chloride, nitrate, sulfate (SO_4), boron, and nitrogen (mg/L nitrate) (LARWQCB 2013; Table 2-4). The current and historical distribution of these five constituents are discussed below. There are too few measurements of water quality in wells screened solely within a single aquifer to allow for meaningful discussion of water quality by aquifer. Additionally, as discussed in Section 2.3.1, the majority of the groundwater production in the Oxnard Subbasin occurs in wells that are screened across multiple aquifers. This production has the potential to impact water quality in multiple aquifers simultaneously. Therefore, impacts to groundwater quality in the Oxnard Subbasin are considered based on aquifer system.

Groundwater quality monitoring within the Oxnard Subbasin occurs on different schedules for different wells. In order to assess the current groundwater quality conditions within the Oxnard Subbasin, the most recent concentration of each of the five constituents listed above was mapped for samples collected between 2011 and 2015. Historical groundwater quality hydrographs are presented in Appendix G, Water Quality Hydrographs. Statistics on the most recent sample date, the maximum and minimum concentrations measured, the number of times sampled, and the number of samples whose concentration exceeded the relevant water quality threshold are presented in Appendix H, FCGMA Water Quality Statistics.

2.3.4.1 Total Dissolved Solids

Sources of high TDS water in the Oxnard Subbasin include seawater and brines migrating via faults or upwelling from older geologic formations (see Section 2.3.3). Additionally, in the UAS, improperly abandoned wells in the semi-perched aquifer and high chloride brines in fine-grained lagoonal deposits in the Oxnard and Mugu Aquifers, can contribute to high concentrations of TDS in the groundwater (Izbicki 1996). The water quality objective for TDS is 1,200 mg/L in the Forebay and confined aquifers, and 3,000 mg/L in the unconfined aquifers (LARWQCB 2013). The 2007 FCGMA BMO for TDS is 1,200 mg/L for the Forebay (FCGMA 2007). UAS wells with concentrations of TDS greater than 1,200 mg/L are found throughout the Oxnard Subbasin.

Upper Aquifer System

Concentration of TDS in groundwater in the UAS ranged from 652 mg/L to 49,600 mg/L between 2011 and 2015 (Figure 2-37a, Upper Aquifer System – Most Recent Total Dissolved Solids [mg/L] Measured 2011–2015, and Figure 2-37b, Upper Aquifer System, Forebay Area – Most Recent Total Dissolved Solids [mg/L] Measured 2011–2015). Water with TDS concentrations greater than 35,000 mg/L is considered brine. Both the highest and lowest concentrations of TDS were measured adjacent to the coast in Wells 01N22W27R05S and 01N22W27C02S, respectively (Figure 2-37a). The highest concentrations of TDS are found in coastal wells in areas known to be impacted by seawater intrusion (e.g., Well 01S21W08L04S) and release of connate brines from clay layers (e.g., Well 01N22W27R05S). The concentration of TDS in Well 01N22W27R05S has been increasing since 2013, while the concentration of TDS in Well 01S21W08L04S has remained stable over the last 5 years.

In the Forebay, Wells 02N22W23B02S and 02N22W23C05S have been used as BMO wells for TDS. In 2015, the concentration of TDS measured in a sample collected from Well 02N22W23B02S was 1,230 mg/L, and the concentration of TDS measured in a sample collected from Well 02N22W23C05S was 1,070 mg/L. The concentration of TDS in each of these wells has been increasing over the past 5 years (FCGMA 2016).

Lower Aquifer System

In general, TDS concentrations in the LAS are higher in the southern Oxnard Subbasin than in the northern part of the Subbasin (Figure 2-38, Lower Aquifer System – Most Recent Total Dissolved Solids [mg/L] Measured 2011–2015). Concentration of TDS in groundwater in the LAS ranged from 392 mg/L to 37,200 mg/L between 2011 and 2015 (Figure 2-38). The highest concentration was measured in Well 01N21W32Q03S, which is in the southern Oxnard Subbasin, inland from the coast, and is screened within the GCA (Figure 2-38). The higher concentration of TDS in this area likely resulted from upward migration of brines in deeper formations. This migration may have been induced or exacerbated by lowered groundwater elevations from groundwater production in the LAS, although the concentration of TDS in this well has increased steadily since 1995, even during periods when groundwater elevations were 40 to 100 feet higher than they were in 2015 (Izbicki 1991; Izbicki et al. 2005; UWCD 2016a).

The lowest concentration of TDS was measured in Well 01N22W35E03S, screened in the FCA south of Port Hueneme (Figure 2-38). The concentration of TDS in this well was 392 mg/L in 2015. TDS concentrations in this well have remained relatively stable over the last 5 years, neither increasing nor decreasing with the onset of the 2011 drought.

2.3.4.2 Chloride

Sources of water high in chloride in the Oxnard Subbasin include modern seawater, groundwater from the semi-perched aquifer, connate water from fine-grained lagoonal deposits in the Oxnard and Mugu formations, and brines migrating via faults or upwelling from older geologic formations (see Section 2.3.3). The UAS has a long history of seawater intrusion, with groundwater elevations below sea level measured as early as the 1930s (see Section 2.3.3; UWCD 2016a). Seawater intrusion affects a smaller area of the LAS than the UAS, and is more pronounced near Point Mugu than near Port Hueneme (UWCD 2016a). Brine migration along faults and from deeper geologic formations also affects the chloride concentration in the LAS (Izbicki 1991).

The water quality objective for chloride is 150 mg/L in the Forebay and confined aquifers, and 500 mg/L in the unconfined aquifers (LARWQCB 2013). The BMO for chloride is 150 mg/L for the UAS and LAS.

Upper Aquifer System

Concentration of chloride in groundwater in the UAS ranged from 23 mg/L to 20,700 mg/L between 2011 and 2015 (Figure 2-39a, Upper Aquifer System – Most Recent Chloride [mg/L] Measured 2011–2015, and Figure 2-39b, Upper Aquifer System, Forebay Area – Most Recent Chloride [mg/L] Measured 2011–2015). Chloride concentrations in the UAS are higher near the coast, from Point Hueneme south to Point Mugu, than inland or north of Port Hueneme (Figure 2-39a). The lowest concentration of chloride was measured in Well 01N22W11C02S in the central Oxnard Subbasin (Figure 2-39a). This well was only sampled one other time, in 1952, and the concentration of chloride measured at that time was 83 mg/L. Between 2011 and 2015, the concentration of chloride was less than 150 mg/L in the Forebay (Figure 2-39b).

The highest concentration of chloride (20,700 mg/L) was measured in Well 01N22W27R05S, adjacent to the coast south of Port Hueneme (Figure 2-39a). Groundwater from this well also had the highest concentration of TDS. The concentration of chloride in this well has been increasing since 2013. The concentration of chloride in Well 01S21W08L04S, a BMO well near Point Mugu, was 17,500 mg/L in 2015. The concentration of chloride in this well has been stable over the last 5 years (FCGMA 2016). Of the nine BMO wells with chloride concentration objectives in the UAS, three have had increasing chloride concentrations over the past 5 years (Wells 01N22W20J07S, 01N22W20J08S, and 01S22W01H03S), although all of the BMO wells have had water levels below their targets as a result of the drought.

Lower Aquifer System

In general, chloride concentrations in the LAS are higher in the southern Oxnard Subbasin than they are elsewhere in the Oxnard Subbasin (Figure 2-40, Lower Aquifer System – Most Recent Chloride [mg/L] Measured 2011–2015). In the Forebay, the concentration of chloride in groundwater is less than 100 mg/L, while concentrations of chloride south of Port Hueneme exceed 500 mg/L (Figure 2-40).

Concentration of chloride in groundwater in the LAS ranged from 33 mg/L to 14,300 mg/L between 2011 and 2015 (Figure 2-40). The lowest concentration of chloride was measured in Well 01N23W01C02S on the coast, north of Port Hueneme (Figure 2-40). The concentration of chloride in this well has remained stable since it was first measured in 1990.

The highest concentration of chloride was measured in Well 01N21W32Q03S, in the southern Oxnard Subbasin (Figure 2-40). In this well, the concentration of chloride has increased since it was first measured in 1991. At that time the concentration of chloride in the well was 340 mg/L. BMO Well 01S21W08L03S is also located in the southern Oxnard Subbasin, in the vicinity of Point Mugu. This is the only BMO well in the LAS that has had increasing concentrations of chloride over the past 5 years despite all of the BMO wells having water levels below their targets (FCGMA 2016).

2.3.4.3 Nitrate

Nitrate concentrations above WQOs and BMOs are present in the Forebay of the Oxnard Subbasin (UWCD 2008). These concentrations are likely a legacy of historical septic discharges and agricultural fertilizer application practices.[6] Historical discharges have resulted in concentrations that impact beneficial uses and users of the Oxnard Subbasin. In particular, not all municipal users of groundwater in this area have the ability to blend groundwater with nitrate exceeding the federal maximum contaminant level for nitrate as NO_3 of 45 mg/L.

[6] Ventura County extended sewer lines into this area in the years between 2000 and 2011 to address additional discharges of nitrate.

Historical nitrate concentrations in the Forebay are most impacted by the quantity of surface water available for spreading from the Santa Clara River. The river water has lower concentrations of nitrate than the groundwater. Therefore, during periods when Santa Clara River water is used to recharge the Subbasin, groundwater concentrations of nitrate decrease. Conversely, during periods of drought, groundwater concentrations of nitrate in the Forebay tend to increase.

The BMO for nitrate is 22.5 mg/L in the Forebay (FCGMA 2007). The WQO for nitrate as NO_3 is 45 mg/L for the entire Oxnard Subbasin (LARWQCB 2013).

Upper Aquifer System

Between 2011 and 2015, concentrations of nitrate as NO_3 in groundwater in the UAS ranged from below the detection limit to 240 mg/L (Figure 2-41a, Upper Aquifer System – Most Recent Nitrate [mg/L as Nitrate] Measured 2011–2015, and Figure 2-37B). The highest concentration was measured in Well 02N22W26C01S in the Forebay (Figure 2-41b, Upper Aquifer System, Forebay Area – Most Recent Nitrate [mg/L as Nitrate] Measured 2011–2015). However, the concentration of nitrate measured in a sample collected from the same well in 2011 was only 4.9 mg/L. Similarly, nitrate concentrations in Wells 02N22W23B02 and 02N33W23C05S, which are both BMO wells, increased between 2011 and 2016. The concentration of nitrate in Well 02N22W23B02 was 4.1 mg/L in 2011 and was as high as 127 mg/L in 2015. The concentration of nitrate in Well 02N22W23C05 was 2.8 mg/L in 2011 and was as high as 31.9 mg/L in 2015.

Outside of the Forebay, the concentration of nitrate in the groundwater decreases rapidly and is not correlated with recharge from the spreading basins. In general, nitrate as NO_3 concentrations are highest in the southern Forebay and northeastern Oxnard Subbasin. The lowest concentrations are found in the southern Oxnard Subbasin, with the concentration of nitrate below the detection limit in the majority of the wells in the southern Subbasin (Figure 2-41a).

Lower Aquifer System

Concentrations of nitrate as NO_3 in groundwater in the LAS are lower than they are in the UAS. Between 2011 and 2015, the concentration of nitrate as NO_3 in wells screened in the LAS ranged from below the detection limit to 57 mg/L. The highest concentration was measured in Well 02N21W19A03S, in the northeastern Oxnard Subbasin. The concentration of nitrate in this well may be influenced by downward migration of water and is not representative of general nitrate concentrations within the LAS. The next-highest concentration of nitrate was measured in Well 01N22W23R02. The concentration of nitrate in the well was 22.1 mg/L (Figure 2-42, Lower Aquifer System – Most Recent Nitrate [mg/L as Nitrate] Measured 2011–2015). The majority of the wells in the LAS have nitrate as NO_3 concentrations below the detection limit. In the Forebay, the concentration of nitrate as NO_3 is lower in the LAS than it is in the UAS (Figures 2-41b and 2-42).

2.3.4.4 Sulfate

Sources of sulfate in the Oxnard Subbasin include mineral dissolution in groundwater and seawater intrusion. The majority of the wells in the Oxnard Subbasin have sulfate concentrations below 600 mg/L. Similar to nitrate, wells in the Forebay tend to have higher concentrations of sulfate than wells farther south, with the notable exception of Wells 01N22W27R05S and 01S21W08L04S (Figure 2-43a, Upper Aquifer System – Most Recent Sulfate [mg/L] Measured 2011–2015). The water quality objective for sulfate is 600 mg/L in the Forebay and confined aquifers, and 1,000 mg/L in the unconfined aquifers (LARWQCB 2013).

Upper Aquifer System

Concentrations of sulfate in the UAS ranged from 100 mg/L to 5,740 mg/L between 2011 and 2015 (Figure 2-43a and Figure 2-43b, Upper Aquifer System, Forebay Area – Most Recent Sulfate [mg/L] Measured 2011–2015). High concentrations of sulfate near the coast are generally indicative of seawater intrusion. The highest concentration was measured in Well 01N22W27R05S, which also had the highest concentration of chloride and TDS. The concentrations of each of these constituents has increased since 2013. The lowest concentration was measured in Well 01N22W36K09S in the southern Oxnard Subbasin.

Lower Aquifer System

Concentrations of sulfate in the LAS ranged from below the detection limit to 2,030 mg/L between 2011 and 2015 (Figure 2-44, Lower Aquifer System – Most Recent Sulfate [mg/L] Measured 2011–2015). High concentrations of sulfate near the coast are generally indicative of seawater intrusion. The highest concentration was measured in Well 01N21W32Q03S, which also had the highest concentration of chloride and TDS. Only four wells in the LAS had concentrations of sulfate that exceeded 600 mg/L. These wells are distributed throughout the Oxnard Subbasin and do not follow a clear geographic pattern. Similar to nitrate, LAS wells in the Forebay have lower concentrations of sulfate than UAS wells in the Forebay (Figure 2-44).

2.3.4.5 Boron

Sources of boron in the Oxnard Subbasin include seawater intrusion in coastal areas and release of anthropogenic (introduced by human activities) boron from past septic tank uses. The WQO for boron in the Oxnard Subbasin is 1 mg/L (LARWQCB 2013).

Upper Aquifer System

Concentrations of boron in the UAS ranged from 0.05 mg/L to 5.9 mg/L between 2011 and 2015 (Figure 2-45a, Upper Aquifer System – Most Recent Boron [mg/L] Measured 2011–2015, and

Figure 2-45b, Upper Aquifer System, Forebay Area – Most Recent Boron [mg/L] Measured 2011–2015). The highest concentration was measured in Well 01N22W27R05S, which also had the highest concentrations of sulfate, chloride, and TDS. The lowest concentration was measured in Well 02N22W24A01S, in the northeastern Oxnard Subbasin (Figure 2-45a). Only seven wells in the UAS had boron concentrations greater than 1 mg/L between 2011 and 2015.

Lower Aquifer System

Concentrations of boron in the LAS ranged from 0.3 mg/L to 2.2 mg/L between 2011 and 2015 (Figure 2-46, Lower Aquifer System – Most Recent Boron [mg/L] Measured 2011–2015). The highest concentration was measured in Well 01N21W32Q03S, which also had the highest concentrations of sulfate, chloride, and TDS. Only five wells in the LAS had boron concentrations greater than 1 mg/L between 2011 and 2015.

2.3.4.6 Map of Oil and Gas Deposits

In the database maintained by the County of Ventura (2016), five oil fields entirely or partially fall within the Oxnard Subbasin: Montalvo, W.; Oxnard; El Rio; Santa Clara Avenue; and Saticoy (Figure 2-47, Oil Fields in the Vicinity of FCGMA Groundwater Basins). Petroleum extraction in the FCGMA basins occurs below the deepest freshwater aquifer (Hopkins 2013). While no evidence of impacts of petroleum extraction on beneficial use of groundwater in the FCGMA basins has been identified, there are limited available data. Few wells exist in deep aquifers near oil fields that could be monitored for potential impact. However, trace amounts of organic compounds have been found in deeper wells in southeastern Pleasant Valley (Izbicki et al. 2005), and there have been anecdotal reports of trace petroleum hydrocarbons observed in irrigation wells near some oil fields.

2.3.4.7 Maps of Locations of Impacted Surface Water, Soil, and Groundwater

Impacted surface water, soil, and groundwater have been documented in the Oxnard Subbasin, although these impairments tend to be limited to the semi-perched aquifer. This uppermost unit in the Oxnard Subbasin is underlain by a clay cap layer that limits the vertical migration of impaired water to the underlying UAS.

Impaired surface waters (i.e., 303(d) Listed Reaches) that overlie the Oxnard Subbasin include approximately 3 miles of the Santa Clara River, the Revolon Slough, Calleguas Creek, and a number of lined drains serving agricultural areas south of the City of Oxnard (Figure 2-48, Impaired Surface Waters in the Vicinity of FCGMA Groundwater Basins; SWRCB 2004). The names of the reaches used by the State Water Resources Control Board, and the impairments listed for each, are included in tabulated form in Appendix I, Oxnard 303(d) List Reaches.

Locations of impacted soil and groundwater were assessed on a basin-wide scale by reviewing information available on the SWRCB GeoTracker website and the California Department of Toxic Substances Control EnviroStor website. Cases that were closed by the supervisory agency were not considered.

Of the 290 open cases located within the boundaries of the Oxnard Subbasin and Pleasant Valley, groundwater was impacted in 77. Dudek reviewed and catalogued the constituents of concern (COCs) present on site in these 77 cases (Figure 2-49, Constituents of Concern at Open GeoTracker Cases with Impacted Groundwater within FCGMA Groundwater Basin Boundaries). Case details are included in Appendix J, GeoTracker Open Sites.

Of the 71 open cases in the Oxnard Plain in which groundwater is, or is potentially, impacted, the following COCs were identified as present at the following number of sites (Figure 2-49; Appendix J):

- Chlorinated volatile organic compounds (VOCs), including COCs marked as *solvents*, *VOCs*, and *chlorinated hydrocarbons*, were present at 34 sites.
- Gasoline and diesel, including COCs marked *TPH* and *petroleum*, were present at 32 sites.
- Metals were present at 27 sites.
- Polychlorinated biphenyls (PCBs) were present at 23 sites.
- Benzene, toluene, ethylbenzene, and/or xylenes (BTEX) were present at 18 sites.
- Pesticides were present at 12 sites.
- Methyl tert-butyl ethylene (MTBE) and/or tert-butyl alcohol (TBA) were present at seven sites.
- Two sites listed other COCs.

Many of these sites are located on land administered by the U.S. military (Figure 2-49). Outside of military bases, these sites tend to occur within the city limits of the Cities of Oxnard, Port Hueneme, and Camarillo.

The risk that contamination in the shallow groundwater of the Oxnard Subbasin would reach the UAS is somewhat mitigated by the presence of a confining layer that separates the semi-perched aquifer from the water-bearing units of the UAS throughout much of the Oxnard Plain (Turner and Mukae 1975). However, the vertical gradient is directed downward from the semi-perched aquifer to the underlying Oxnard Aquifer, indicating the potential for groundwater movement from the semi-perched aquifer to the Oxnard Aquifer.

Based on a review of open GeoTracker and EnviroStor cases with impacted groundwater, it does not appear that existing groundwater contamination in the semi-perched aquifer poses a substantial threat to beneficial use of groundwater in the UAS and the LAS. Based on a review of the files available on GeoTracker for each of the cases in the Oxnard Subbasin that fell outside the bounds of a military base, it appears that in none of the cases were any liable parties required to investigate deeper than 50 feet below ground surface (bgs), indicating that impacts to groundwater in the UAS were not a concern for regulatory agencies.

2.3.5 Subsidence

Inelastic, or irrecoverable, land subsidence (subsidence) can be a concern in areas of active groundwater extraction, including the Oxnard Subbasin. Active causes of land subsidence in the Oxnard Subbasin include tectonic forces, petroleum reservoir compaction, and clay compaction (Hanson et al. 2003). Significant water level declines in the FCGMA groundwater basins since the early 1900s suggest that fluid extraction, rather than tectonic activity, is the major cause of land subsidence (Hanson et al. 2003). Subsidence resulting from any of these sources can cause increased flood risk, well casing collapse, and a permanent reduction in the specific storage of the aquifer (Hanson et al. 2003).

Direct measurement of subsidence within the Oxnard Subbasin is limited. Elevation data from USGS benchmark (BM) E548 in the southern part of the Oxnard Plain indicate subsidence of about 1.6 feet (0.49 meters) during the period from 1939 to 1960, and an additional 1 foot (0.31 meters) of subsidence from 1960 to 1978 (Hanson et al. 2003). The average rate of subsidence for these two periods was similar, averaging approximately 0.07 feet (0.02 meters) per year from 1939 to 1960, and approximately 0.06 feet (0.02 meters) per year from 1960 to 1978 (Hanson et al. 2003). In contrast, elevation data from USGS BM Z901, located approximately 2.6 miles southeast of BM E548, indicate subsidence of approximately 0.3 feet (0.10 meters) between 1960 and 1978. The average rate of subsidence at BM E548 was 0.02 feet (0.01 meters) per year for this period. The rate of subsidence at BM Z901 decreased to approximately 0.01 feet per year from 1978 to 1992. Data are not available for BM E548 after 1978. The amount of subsidence measured at both BM E548 and BM Z901is the cumulative subsidence from all possible sources, including groundwater pumping, tectonic activity, and petroleum reservoir compaction.

In addition to direct measurement of subsidence in the southern part of the Oxnard Plain, potential subsidence was modeled for the entire Oxnard Plain for different future water production scenarios (Hanson et al. 2003). The scenarios included consideration of proposed water projects and ordinances for the FCGMA Basins. The model results suggest that areas within the Oxnard Plain may experience an additional 0.1 to 1 feet of subsidence by 2040 (Hanson et al. 2003). DWR classified the Subbasin as an area that has a medium to high potential for future subsidence. The amount of future subsidence will depend on whether future water levels decline below previous low levels and remain there for a considerable amount of time (Hanson et al. 2003). Maintaining water levels above the previous low water levels will limit the risk of future subsidence.

From March 2015 to June 2016, the Jet Propulsion Laboratory (JPL) analyzed interferometric synthetic aperture radar (InSAR) data from the European Space Agency's satellite-borne Sentinel-1A and NASA's airborne UAVSAR, along with similar previous studies from 2006 to 2015, to examine subsidence in areas of California. The study included the south-central coast of California in Ventura and Oxnard (Farr et al. 2017). The map generated from this study for this area of the south-central coast of California (Farr et al. 2017, Figure 23) showed less than 1 foot of subsidence for the Oxnard Subbasin.

2.3.6 Groundwater–Surface Water Connections

The Santa Clara River, Calleguas Creek, Revolon Slough, Mugu Lagoon, Ormond Beach, and McGrath Lake have all been identified as surface water bodies that may have a connection to the semi-perched aquifer in the Oxnard Subbasin (see Section 2.3.7, Groundwater-Dependent Ecosystems). However, groundwater elevation data for the semi-perched aquifer in the Oxnard Subbasin are extremely limited, with no monitoring sites near enough to surface water bodies to establish the extent of the connection between these surface water bodies and underlying groundwater (Figure 2-50, Groundwater Elevation Contours in the Semi-Perched Aquifer, March 2–29, 2015, and Figure 2-51, Groundwater Elevation Contours in the Semi-Perched Aquifer, October 2–29, 2015).The spatial extents of gaining, losing, and dry reaches in the Santa Clara River are seasonally variable (UWCD 2014, 2018).

The best available estimates for groundwater–surface water connections comes from the UWCD numerical model, which simulates the leakage from major surface water bodies in the Oxnard Subbasin using data from stream gauges and estimated aquifer properties (Appendix C). The UWCD model reports stream leakage from the Santa Clara River and Calleguas Creek into the underlying semi-perched aquifer. Numbers from the model represent net stream leakage and do not necessarily indicate direct connection between surface water bodies and groundwater in the semi-perched aquifer.

The UWCD model calculated stream percolation for water years from 1986 to 2015 (Table 2-5). The Santa Clara River had net recharge to groundwater in 26 of 30 water years, with an average net recharge to groundwater of approximately 5,700 AFY. The recharge to groundwater primarily occurs in the vicinity of the Forebay, where Santa Clara River water percolates into the UAS. Downstream of the Forebay, some reaches of the Santa Clara River are typically gaining in most years, generally from the semi-perched aquifer. Net groundwater discharge to the Santa Clara River was identified as occurring during 1999, 2002, 2006, and 2013. Calleguas Creek exhibited net recharge to groundwater in all years modeled, with an average net recharge to groundwater of approximately 3,450 AFY.

2.3.7 Groundwater-Dependent Ecosystems

Six potential GDE units, defined by dominant surface hydrologic features, were identified in the Oxnard Subbasin (Appendix C, UWCD Model Report; TNC 2017 [see Appendix K of this GSP]; Figure 2-52, Groundwater-Dependent Ecosystems for the Oxnard Subbasin). The potential GDE units were identified using the statewide potential GDE map (Appendix K). Of the six potential GDE units identified, the Lower Santa Clara River, McGrath Lake, Ormond Beach, and Mugu Lagoon units were validated using groundwater elevations measured in wells within or adjacent to the unit to confirm the potential hydrologic connection to groundwater in the semi-perched aquifer, as described in The Nature Conservancy's GDE Guidance Framework (Appendix K). Insufficient well data are available to confirm the depth to groundwater in the Revolon Slough unit or the Lower Calleguas Creek unit. Therefore, in the discussion below, these units remain as potential GDEs. Groundwater elevation in the vicinity of these units will be required in order to confirm whether or not the habitat is supported by groundwater (see Section 4.6.5, Shallow Groundwater Monitoring near Surface Water Bodies and GDEs).

Lower Santa Clara River GDE

The lower Santa Clara River GDE (located downstream of Highway 101 and upstream of the estuary) comprises approximately 750 acres of aquatic habitat, in-channel wetland, and a range of willow–cottonwood riparian forest (Figure 2-53, Lower Santa Clara River Groundwater-Dependent Ecosystems; Appendix K, The Nature Conservancy GDE Tech Memo). The GDE is located in the floodplain of the lower Santa Clara River, which undergoes substantial transformations in vegetation composition and distribution due to the dynamic nature of the river flows during winter. The lower Santa Clara River GDE supports habitat for several state- and federally listed species (Table 2-6).

Flow in the lower Santa Clara River downstream of Highway 101 has historically been perennial (SFEI 2011; City of Ventura 2016). The source of the perennial flow in this region is groundwater from the semi-perched aquifer, which is separated from the underlying UAS by a clay cap that limits groundwater migration and allows differences in groundwater elevation between the semi-perched aquifer and the Oxnard Aquifer. In the spring of 2015, groundwater elevations in the Oxnard Aquifer were below sea level (Figure 2-7).

Groundwater from the semi-perched aquifer provides the dry summer baseflow, if it exists, and a quarter of the winter flow (City of Ventura 2011). Groundwater flow direction between the semi-perched aquifer and the lower Santa Clara River, its estuary, and nearby McGrath Lake, depends on tidal conditions, river stage, and recharge rates due to agricultural irrigation (City of Ventura 2016). Groundwater levels from wells in the vicinity of the lower Santa Clara River GDE generally range between 7 and 11 feet bgs (Figure 2-53). The groundwater depths are within the range considered necessary for juvenile establishment (<10 feet) and mature vegetation growth (<20 feet) (City of Ventura 2016).

McGrath Lake GDE

The McGrath Lake GDE includes a coastal freshwater back-dune lake, arroyo willow riparian forest, freshwater emergent marsh, and saline emergent marsh (Figure 2-54, McGrath Lake Groundwater-Dependent Ecosystems). The McGrath Lake GDE supports critical habitat for several state- and federally listed endangered species as well as many special-status bird species (Table 2-6).

McGrath Lake is formed by shallow groundwater that remains perched above a clay layer in the semi-perched aquifer (ESA 2003). McGrath Lake operational water surface elevations are maintained between 2.7 and 3.6 feet msl (City of Ventura 2011). Groundwater flows toward the Santa Clara River during open-mouth conditions and towards McGrath Lake when the Santa Clara River Estuary fills following mouth closure (City of Ventura 2011). As measured since 2009, depths to groundwater around the McGrath Lake GDE range from ground surface to 10 feet bgs, depending on the well (Appendix K).

Ormond Beach GDE

The Ormond Beach GDE, which includes isolated patches of southern coastal salt marsh and coastal freshwater/brackish marsh that have been drained, filled, and degraded by past industrial and agricultural use, is part of a larger 1,500-acre coastal dune–marsh system of dunes, lakes, lagoons, and saltwater and freshwater marshes (WRA 2007; CCC 2017; Figure 2-55, Ormond Beach Groundwater-Dependent Ecosystems). The Ormond Beach GDE supports habitat for state- and federally listed species as well as 27 special-status plant species and 42 special-status wildlife species (Table 2-6).

The Ormond Beach GDE is hydrologically connected to the semi-perched aquifer. Shallow groundwater elevations are influenced by rainfall, tidal events, and the surface water elevations of the agricultural drains and flood control channels. Depth to groundwater ranges from ground surface to 15 feet bgs (Appendix K).

Mugu Lagoon GDE

Mugu Lagoon GDE is the largest salt marsh estuary in Southern California (USFWS 2016a). The GDE provides habitat for several state- and federally listed species (Table 2-6; Figure 2-56, Mugu Lagoon Groundwater-Dependent Ecosystems).

The estimated groundwater depth in the Mugu Lagoon GDE varies between ground surface and 6 feet bgs (Appendix K). Estimated depths to groundwater in the GDE, are based on interpolation of water elevation data from representative wells at Naval Base Ventura County Point Mugu to reference point locations within the Mugu Lagoon GDE. Mugu Lagoon receives groundwater discharge from the semi-perched aquifer along with freshwater from Calleguas Creek, the drainage ditches, primarily Oxnard Drainage Ditch No. 2, and salt water from tidal fluctuations.

Lower Calleguas Creek Potential GDE

The lower Calleguas Creek potential GDE includes aquatic habitat and mulefat and willow riparian forest. This potential GDE may support native special-status species (Table 2-6).

The Lower Calleguas Creek potential GDE overlies the semi-perched aquifer. The channel has been separated from the adjacent floodplain since the 1960s by a riprap and earthen levee countersunk about 3 feet below the surrounding grade. Thus, Calleguas Creek is a losing reach in the Oxnard Plain. Lower Calleguas Creek maintains a perennial streamflow due to a combination of wastewater effluent and pumped tile drain discharge from adjacent agricultural fields, with the addition of natural precipitation and stormwater runoff during winter months. The degree of groundwater recharge and/or discharge has not been studied and groundwater elevation data are not available for this area. Groundwater elevations at semi-perched aquifer monitoring wells (located approximately 1 mile to the southwest at Naval Base Ventura County Point Mugu) indicate typical groundwater elevations range from −1 to 6 feet msl. Extrapolated depths to groundwater at the downstream end of the Calleguas Creek GDE, at approximately 12 feet msl, are between 6 to 13 feet bgs. The extrapolated groundwater depths indicate the potential for the riparian vegetation to access shallow groundwater. Additional data need to be collected within the boundaries of the Calleguas Creek potential GDE in order to determine whether or not the riparian vegetation is accessing shallow groundwater.

Revolon Slough Potential GDE

The Revolon Slough potential GDE comprises aquatic habitat and willow riparian forest. This potential GDE may support native special-status species (Table 2-6). The riparian habitat within this potential GDE is considered “de minimis” because of its poor quality and limited extent adjacent to the waterway. Streamflow in lower Revolon Slough is considered to be a combination of agricultural return flow and precipitation and stormwater runoff. The degree of groundwater recharge and/or discharge has not been studied and groundwater elevation data are not available for this area. Groundwater elevations at semi-perched aquifer monitoring wells located approximately 1 mile to the southwest at Naval Base Ventura County Point Mugu indicate typical groundwater elevations range from −1 to 6 feet msl. Extrapolated depths to groundwater at the downstream end of the Revolon Slough potential GDE would be between 9 and 16 feet bgs. The extrapolated groundwater depths indicate the potential for the riparian vegetation to access shallow groundwater. Additional data need to be collected within the boundaries of the Revolon Slough potential GDE in order to determine whether or not the riparian vegetation is accessing shallow groundwater.

2.3.8 Potential Recharge Areas

To evaluate potential future recharge areas within the Oxnard Subbasin, soil types were obtained from the Web Soil Survey, available online at https://websoilsurvey.nrcs.usda.gov/ (USDA 2019). Soil Ksat rates (saturated hydraulic conductivity rates) for soils of 92 micrometers per second or greater were plotted. Figure 2-57, Oxnard Potential Recharge Areas, shows the results of this evaluation and areas with the most favorable soil recharge rates. The most favorable areas are near the current UWCD spreading grounds, along the Santa Clara River, in sands along the northern coastal areas, and in loamy sands, which may represent old Santa Clara River drainages.

2.4 WATER BUDGET

This section presents the current, historical, and simulated future water budget analysis for the Oxnard Subbasin. This water budget analysis has been completed in accordance with the DWR GSP Regulations. The historical water budget has been prepared for the 31-year period from the beginning of calendar year 1985 through 2015 (the current year for the Sustainable Groundwater Management Act [SGMA]) and is described in units of AF or AFY. The five commonly recognized aquifer units in the Oxnard Subbasin are the Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon Aquifers (DWR 1965, 2006; Turner 1975). As described in Section 2.2, Hydrogeologic Conceptual Model, these aquifers are grouped into a UAS and an LAS, with the Oxnard and Mugu Aquifers composing the UAS and the Hueneme, Fox Canyon, and Grimes Canyon Aquifers composing the LAS. The UAS primarily comprises recent to upper Pleistocene age alluvial deposits of the Santa Clara River system.

UWCD (2018; Appendix C) developed the “Ventura Regional Groundwater Flow Model (VRGWFM),” a MODFLOW numerical groundwater flow model, for the Oxnard Subbasin, the Mound Basin, the western part of the LPVB, and the PVB. Details of the UWCD modeling effort are included in Appendix C. The groundwater budget analysis for the Oxnard Subbasin is based on the DWR Bulletin 118 basin boundary for the Oxnard Subbasin, and does not incorporate the remainder of the model domain. As with all groundwater flow models, the UWCD model has undergone several revisions and will continue to be revised as additional data are collected and the understanding of the hydrogeologic interactions in the model domain improves. This GSP uses the version of the model finalized in June 2018, which was developed to support the GSP process. This version of the model was used for the current and historical water budget analysis as well as for the future projected groundwater scenarios discussed in Section 2.4.5, Projected Future Water Budget and Sustainable Yield.

2.4.1 Sources of Water

Aquifer systems in the Oxnard Subbasin receive water from several sources. Native sources consist predominantly of rainfall infiltration within the Oxnard Subbasin and along its margins (mountain-front recharge), and subsurface inflows from the adjacent basins.

Water sources consist predominantly of streambed seepage from Calleguas Creek where it enters the Oxnard Subbasin from the adjoining PVB; streambed seepage from the Santa Clara River; artificial recharge by the UWCD; deep percolation of a portion of the irrigation water that is applied to agricultural, residential, and commercial lands, and to public open spaces; leakage from water distribution systems; septic system return flows; and wastewater treatment plant (WWTP) percolation ponds. Two small community WWTPs are located adjacent to the Santa Clara River in the Oxnard Subbasin. The Saticoy and the Montalvo WWTPs discharge treated effluent to percolation ponds.

Water supplies for the Oxnard Subbasin consist of locally pumped potable and nonpotable groundwater; imported water provided by UWCD (nonpotable) and Calleguas Municipal Water District (CMWD) (potable); nonpotable surface water provided by UWCD from its Freeman Diversion on the Santa Clara River and delivered to agricultural users in the Oxnard Subbasin via the PTP and to agricultural users in the Oxnard Subbasin and PVB via the Pleasant Valley Pipeline (PVP); the Oxnard Subbasin portion of a nonpotable water supplied provided by the Camrosa Water District (CWD) to the Pleasant Valley County Water District (PVCWD) from a diversion on Conejo Creek; and fully advanced treated recycled water produced by the City of Oxnard (the Groundwater Recovery Enhancement and Treatment (GREAT) Program) that began to be delivered to PVCWD and a few other agricultural users in early 2016.

The predominant municipal water suppliers in the Oxnard Subbasin are the City of Oxnard, the Port Hueneme Water Agency, the City of Ventura, and the Naval Base Ventura County. Water supplies for these municipal users include deliveries by UWCD via the Oxnard–Hueneme Pipeline, which obtains its water exclusively from wells located at the El Rio Spreading Grounds and along Rose Avenue. These municipal users may also receive imported water supplied by the CMWD. The City of Oxnard has wells within the Oxnard Subbasin. The City of Ventura also has wells in the Oxnard Subbasin, but uses water in their service areas inside and outside of the Oxnard Subbasin. Figure 1-8 shows a map of water purveyors with service areas within the Oxnard Subbasin.

In addition to groundwater pumping, agricultural water supplies are provided by UWCD via its PTP and PVP. The PTP services users in the Oxnard Subbasin, and the PVP services users in both the Oxnard Subbasin and the PVB. UWCD’s water source for the PTP and PVP consists primarily of surface water obtained at the Freeman Diversion, which may include State Water Project water from Lake Piru. Groundwater is also extracted at five LAS wells located along the PTP pipeline in many years and is included in the water supplied by the PTP. Occasionally, temporarily stored recharge water is pumped from shallow wells at UWCD's Saticoy Spreading Grounds and included in water supplied by the PVP.[7]

2.4.1.1 Surface Water

Figure 2-58, Oxnard Subbasin Stream Gauges and Water Infrastructure, shows the locations of streams and primary drainage systems in and around the Oxnard Subbasin, as well as water infrastructure locations including WWTP ponds, stream gauge stations, and the two diversion structures (Freeman and Conejo Creek Diversions) that provide a portion of the water supply for the Oxnard Subbasin.

Santa Clara River

The Santa Clara River interacts with the groundwater system in the Oxnard Subbasin. Reaches of the Santa Clara River in the Oxnard Subbasin range from perennial to intermittent to ephemeral (Appendix C). The river flows through the adjoining Santa Paula Basin into the Oxnard Subbasin in the Forebay area, and then out of the Oxnard Subbasin to the Mound Basin. Climatic and geologic characteristics of the Santa Clara River watershed result in an intermittent flow regime; however, flows can increase rapidly in response to high-intensity rainfall with the potential for severe flooding. During winter months, storm events may cause periods of continuous surface flow to the Pacific Ocean in the Santa Clara River.

Santa Clara River Recharge

The UWCD groundwater model used the MODFLOW STR stream package to simulate stream flow recharge. The stream flow discharge and percolation for the Santa Clara River were estimated using this stream package and the results are provided in Table 2-7a (for the semi-perched aquifer) Table 2-7b (for the UAS), and Table 2-7c (for the LAS). Except for 1998, 1999, and 2006, following the high rains in 1998 and 2005, the net effect of surface-water/groundwater interaction along the Santa Clara River was recharge to the UAS and the semi-perched aquifer in the Oxnard Subbasin (Appendix C). During these years, the net effect of surface-water/groundwater interaction was discharge from the UAS to the Santa Clara River. From 1985 to 2015, the average estimated recharge from the Santa Clara River to the semi-perched aquifer was 661 AFY, and the average estimated recharge to the UAS was 4,848 AFY (Tables 2-7a and 2-7b). These numbers do not include diversions from the Santa Clara River by the UWCD for artificial recharge at their spreading grounds or for direct use, which are discussed below.

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[7] UWCD extracts limited amounts of temporarily stored water from shallow wells at its Saticoy Spreading Grounds to the PVP during periods of mounding, as authorized by FCGMA Resolution 2011-02.

Santa Clara River Diversions and Recharge

Table 2-8 summarizes the historical diversions of Santa Clara River water by UWCD and deliveries to both the Oxnard Subbasin and the PVB. On average, UWCD diverted 62,467 AFY from the Santa Clara River between 1985 and 2015, although diversion volumes, which depend on local climatic conditions, are highly variable (Table 2-8). These diversions may include State Water Project water held at Lake Piru and then delivered to the UWCD via the Santa Clara River. UWCD diverts surface water from the Santa Clara River in the Santa Paula Basin, just upstream of the Oxnard Forebay. The majority of this water, on average, is used for groundwater recharge in its spreading basins within the Oxnard Forebay (Table 2-8). Additionally, the water is used as supply for the PTP that services agricultural water users on the Oxnard Plain and as supply for the PVP agricultural water supply line that services agricultural water users in both the PVB and the Oxnard Subbasin. During drought periods, the relative percentage of diverted water used to recharge groundwater in the spreading basins declines, and the relative percentage of groundwater delivered through the PTP increases.

Table 2-9 provides the amounts of diverted water recharged by the UWCD in the three UWCD recharge grounds. Approximately 93% of the diverted water is recharged in the El Rio and Saticoy Spreading Grounds, on average, and the remaining 7% is recharged in the Noble Spreading Grounds (Table 2-9). Figure 2-59, Freeman Diversion and Uses in the Oxnard Subbasin, shows the amounts of diverted water by UWCD, and Figure 2-60, UWCD Groundwater Recharge, shows the annual recharge by UWCD. As shown in Table 2-10, the UWCD supply delivered in the PTP supply line is a mixture of surface water, and groundwater pumped by UWCD from their PTP wellfield, which pumps from the LAS, and less frequently, from their Saticoy wellfield.

Recharge from the UWCD groundwater recharge spreading grounds is included with recharge in Table 2-7a and Table 2-7b, but identified individually in Table 2-11. Of the total average annual recharge shown in Table 2-11 (73,669 AFY), UWCD groundwater recharge accounts for 48,306 AFY, or 65.6%. Recharge related to the PTP/PV system averaged 3,319 AFY from 1985 to 2015 as shown in Table 2-11, this is 4.5% of the total recharge. Of the average 62,467 AFY diverted from the Santa Clara River (Table 2-8), the average of 48,306 AFY (Table 2-11) recharged to the UWCD spreading grounds constitutes 77%.

The water delivered in the Oxnard–Hueneme Pipeline consists of groundwater pumped from the UAS and LAS near the El Rio Spreading Grounds. As shown in Table 2-10, deliveries from the Oxnard–Hueneme Pipeline are primarily used for municipal purposes, but small volumes are occasionally used for agricultural water supply along Hueneme Road on the southern part of the Oxnard Subbasin.

Calleguas Creek

Calleguas Creek enters the Oxnard Subbasin almost 2 miles upstream of its confluence with Revolon Slough and discharges to the Pacific Ocean at Mugu Lagoon. This reach of Calleguas Creek is perennial, with flow occurring primarily as maintenance flows provided by CWD (6 cubic feet per second required bypass flow at its diversion on Conejo Creek), inflows from agricultural field tile drains, inflows from Revolon Slough, and treated wastewater discharges into the lower reaches of Conejo Creek from the Camarillo Water Reclamation Plant (in the PVB) and the Hill Canyon WWTP in the City of Thousand Oaks. Table 2-12 summarizes the estimated flows in Arroyo Las Posas and Conejo Creek that enter Calleguas Creek, which then flows into the Oxnard Subbasin.

Table 2-12 summarizes the historical diversions of water from Conejo Creek by CWD at the Conejo Creek Diversion near Highway 101 that are supplied to the Oxnard Subbasin via PVCWD (Figure 2-58). The estimated diversions by CWD that are used in the Oxnard Subbasin are shown on Table 2-10. The source of water to Conejo Creek is mostly wastewater discharge from the Hill Canyon WWTP upstream of the Arroyo Santa Rosa Valley Basin. Table 2-10 shows only that portion of this water that is supplied to PVCWD and used in the Oxnard Subbasin.

Calleguas Creek Recharge

The UWCD (2018; Appendix C) groundwater model used the MODFLOW STR stream package to simulate recharge for Calleguas Creek in the Oxnard Subbasin. Calleguas Creek in the Oxnard Subbasin does not have hydraulic communication with the underlying UAS, but modeling indicates recharge to the semi-perched aquifer from 1985 to 2015 averaged 3,394 AFY (Table 2-7a).

Beardsley Wash/Revolon Slough

Beardsley Wash/Revolon Slough is a shallow drainage that captures shallow groundwater and stormwater from agricultural field tile drains and is lying at a similar elevation as the surrounding fields in its lower reaches where it is perennial. Consequently, it is not thought to be a recharge source.

2.4.1.2 Imported Water Supplies

Table 2-13 and Figure 2-61, Water Deliveries to the PVCWD and UWCD, show the historical volumes of water sold to the two water retailers (City of Oxnard and Port Hueneme Water Agency) that have historically purchased imported water from the CMWD. As shown in the table, sales to Port Hueneme Water Agency and to the City of Oxnard have occurred since 1996 and 1964, respectively. Sales have averaged approximately 1,564 AFY (from 1996 to 2015) and 13,500 AFY (from 1985 to 2015) to the Port Hueneme Water Agency and to the City of Oxnard, respectively.

As discussed in Section 2.4.1.1, Surface Water, the UWCD-diverted surface water from the Santa Clara River may include State Water Project water used for groundwater recharge in UWCD spreading basins or water directly delivered to water users by either the PVP or the PTP.

Percolation of Outdoor Irrigation (Urban Return Flows)

In the UWCD (2018; Appendix C) model, an assumed amount of M&I delivered water (5%) is estimated as groundwater recharge. This water is included as recharged water in Tables 2-7a and 2-7b and the total is provided in Table 2-11 by sources. Of the total annual recharge shown in Table 2-11 (73,669 AFY), percolation of applied water accounts for 928 AFY, or 1.3%.

2.4.1.3 Recycled Water Supplies

Two small community WWTPs are located adjacent to the Santa Clara River in the Oxnard Subbasin (Figure 2-58). The Saticoy WWTP and the Montalvo WWTP discharge treated effluent to percolation ponds. According the UWCD (Appendix C, p. 47), the average annual volumes of effluent discharged to the percolation ponds are approximately 80 and 200 AF, respectively, based on reports provided by California’s State Water Resources Control Board online database, GeoTracker (http://geotracker.waterboards.ca.gov/). The Saticoy WWTP is within the Oxnard Forebay, where percolating water can directly recharge the UAS. The Montalvo WWTP is farther downstream, in an area of the Oxnard Subbasin where percolating water recharges the semi-perched aquifer, which is not used for water supply. According to UWCD (Appendix C), the Montalvo WWTP ceased operating in 2016, subsequent to the model calibration period.

Recycled water by the City of Oxnard began to be provided to PVCWD and other agricultural users in early 2016. Wastewater effluent generated by the City of Oxnard historically has been treated at the Oxnard WWTP and discharged directly to the Pacific Ocean. However, the first phase of the GREAT Program’s Advanced Water Purification Facility (AWPF) was completed in 2015, which provides this supply to PVCWD and other growers on the southern part of the Oxnard Subbasin.

Recycled Water Recharge

Recharge from the Saticoy and Montalvo WWTPs is simulated in the UWCD model using the recharge package. The monthly percolation volumes reported in the state’s GeoTracker system were added to other areal recharge rates specified for the model grid cells corresponding to the WWTP percolation-pond sites (Appendix C, p. 83).

2.4.1.4 Percolation of Precipitation

Much of the rain that falls in the Oxnard Subbasin quickly returns to the atmosphere via evaporation, or runs off to creeks, storm drains, and ultimately the ocean; the remainder percolates into the soil where it is subject to evapotranspiration (ET), soil absorption, or for plant use.

However, some precipitation can percolate into the soil and downward past the plant root zone and reach an underlying aquifer. This recharge process is referred to as deep infiltration (or percolation) of precipitation.

Deep percolation of precipitation depends on many factors, including: precipitation rate and duration, evaporation rate, ambient temperature, texture and slope of land surface, soil type and texture, antecedent soil moisture, vegetation cover, seasonal plant activity, and others is highly variable over time and location (Appendix C). Thus estimates of the percolation of precipitation is subject to substantial uncertainty.

UWCD downloaded monthly precipitation data for 180 rainfall gauge stations across the model domain from the Ventura County Watershed Protection District (http://www.vcwatershed.net/hydrodata/) (Appendix C, p. 80). UWCD used the Kriging method of geostatistical analysis to generate monthly precipitation distributions across model area, and the areal recharge from deep infiltration of precipitation was input to the model using the recharge package and was calculated as follows:

- If monthly precipitation is less than 0.75 inches, the precipitation is lost to evapotranspiration.
- If monthly precipitation is 0.75 to 1 inch, then recharge is assigned from 0% to 10% of precipitation (on a sliding scale).
- If monthly precipitation is 1 to 3 inches, then recharge is assigned from 10% to 30% of precipitation.
- If monthly precipitation is greater than 3 inches, then recharge is assigned as 30% of precipitation.
- Urban (non-agricultural) land use, including residential, commercial, and industrial areas: 5% of the total water precipitation.
- Undeveloped land: 10% of the total water precipitation.

Precipitation Recharge

Recharge from the percolation of precipitation is include with recharge in Tables 2-7a and 2-7b, but identified individually in Table 2-11. Of the total annual recharge shown in Table 2-11 (73,669 AFY), percolation of precipitation accounts for 8,947 AFY, or 12.1%.

2.4.1.5 Basin Groundwater Subsurface Inflow and Outflow

UWCD (Appendix C) provided model monthly groundwater inflows and outflows between the Oxnard Subbasin and the Pleasant Valley, Mound, west Las Posas Valley, and Santa Paula Basins, and unincorporated areas, as well as for three coastal segments adjacent to the Pacific Ocean. These inflows and outflows were combined to generate the annual estimates used for the groundwater budget. Additionally Table 2-7b shows the subsurface flows between the UAS and the semi-perched aquifer as well as the UAS and the LAS.

2.4.1.6 Mountain-Front Recharge

UWCD (Appendix C) used the MODFLOW WEL package to input mountain-front recharge specified flux amounts into model grid cells adjacent to each small drainage system (sub-watershed) along the margins of the model area, and to the base of elevated bedrock or mountains areas. In the Oxnard Subbasin, mountain-front recharge was applied at the base of the volcanic outcrops adjacent to the southwest side of the CWD Water Reclamation Plant shown on Figure 2-58, and along the Santa Monica Mountains. Recharge rates were calculated from monthly precipitation rates for the area receiving the precipitation. The monthly mountain-front-recharge rate inputs to the model followed the precipitation/recharge-percentage relationship used for agricultural return flows (Section 2.4.1.9, Percolation of Agricultural Irrigation Water [Agricultural Return Flows]). For the Oxnard Subbasin, mountain-front recharge from and to the volcanic outcrops and the Santa Monica Mountains (Unincorporated Areas) are shown in Tables 2-7a and 2-7b.

2.4.1.7 Septic Systems Recharge

The number and location of septic systems in the Oxnard Subbasin were estimated by DBS&A (2017) based on the Ventura County septic database. If septic systems were present within any parcel within a tract, it was assumed that all parcels in the tract contained septic systems. The number of septic systems in the Forebay decreased beginning in 2011 due to a County of Ventura program to phase out septic systems in the area. It was estimated that the number of systems in the Forebay decreased from 1,823 in 1985 to 485 in 2015 (DBS&A 2017).

Household water use and annual disposal was estimated to decrease from 0.21 AFY per household for 1985 to 1997, 0.20 AFY per household for 1988 to 2010, and 0.16 AFY per household from 1998 to 2015 based on DeOreo and Meyer (2012, as cited in DBS&A 2017). The resulting estimated percolation from all septic systems was estimated to decrease from 382 AFY in 1985 to 75 AFY in 2015 (DBS&A 2017). These values are small compared to known recharge values (UWCD spreading) and other estimated recharge values (Santa Clara River recharge; agricultural and municipal return flows).

The UWCD groundwater model assumed that septic system recharge was widespread and small relative to other recharge sources and incorporated septic system return flows implicitly as a component of agricultural and municipal return flows.

2.4.1.8 Distribution Systems Leakage

Distribution system losses from leakage of water-supply pipelines, sewer lines, and storm drains are included with M&I return flows in the UWCD model.

2.4.1.9 Percolation of Agricultural Irrigation Water (Agricultural Return Flows)

Groundwater pumping is discussed in Section 2.4.2.1; only recharge from agricultural return flow is discussed in this section. The UWCD groundwater model used the following water sources that were applied to irrigated land and assumed an agricultural return flow of 14%:

- Extracted groundwater from wells for agricultural use
- Groundwater and surface water delivered by the PVCWD pipeline
- Surface water diverted from Conejo Creek to PVCWD

If the precipitation is more than 1 inch per month, the agricultural return flow ratio is compared with precipitation recharge ratio. If the precipitation recharge ratio is larger than 14%, the agricultural return flow is replaced by the precipitation recharge ratio.

Agricultural Recharge

Recharge from the agricultural return flow is included with recharge in Tables 2-7a and 2-7b, and identified individually in Table 2-11. Of the total annual recharge shown in Table 2-11 (73,669 AFY), agricultural return flow accounts for 12,169 AFY, or 16.5%.

2.4.2 Sources of Water Discharge

Sources of groundwater discharge predominantly include groundwater pumping, tile drain discharges, and evapotranspiration. However, depending on groundwater levels (as noted in Section 2.4.1.1), groundwater/surface interactions can also discharge groundwater to surface water, which can then either be lost from the Subbasin or recharge elsewhere in the Subbasin. Likewise, groundwater pumped and used for agricultural, M&I, and domestic purposes can produce return flows (Section 2.4.1.2, Imported Water Supplies; Section 2.4.1.7, Septic Systems Recharge; Section 2.4.1.8, Distribution Systems Leakage; and Section 2.4.1.9). Subsurface groundwater flows (interbasin flows) can discharge groundwater from the Oxnard Subbasin to the adjacent groundwater basins, unincorporated areas, and the Pacific Ocean (Section 2.4.1.5, Basin Groundwater Subsurface Inflow and Outflow).

2.4.2.1 Groundwater Pumping

Table 2-14 shows the amount of groundwater pumped for agricultural, M&I, and domestic uses by aquifer systems from the UWCD model results. UWCD modeled groundwater withdrawals using the multi-node well (MNW2) package. The extraction amounts in Table 2-14 were combined with well types from the FCGMA well database to distinguish the amounts extracted by type. Figure 2-62, Groundwater Pumping, shows the amounts of agricultural, M&I, domestic, and total groundwater pumped from the Oxnard Subbasin. Groundwater pumping is also shown in the Oxnard Subbasin groundwater budget in Tables 2-7a through 2-7c.

Available data indicate that during the calendar year 2015, a total of 80,814 AF (Table 2-14) of groundwater was extracted from the Oxnard Subbasin, of which, about 69% was for agricultural use (55,973 AF), 30% was for M&I use (24,648 AF), and about 0.2% was for domestic use (193 AF). For the Oxnard Subbasin, the FCGMA groundwater pumping database contains 732 known wells, of which 403 are currently listed as active use, 217 have been destroyed, 106 are inactive, and 6 could not be located. An additional 13 agricultural wells are in the UWCD database outside the FCGMA boundary.

Not all the groundwater produced in the Oxnard Subbasin remains in the Subbasin. Four agricultural users (PVCWD, Coastal Berry Co., Montalvo Water Co., Alta Mutual Water Co., and Guadalasca Mutual Water Co.) may export a portion of the groundwater that they pump from the Oxnard Subbasin to areas inside the PVB. The PVCWD uses a combination of pumped groundwater from the Oxnard Subbasin and the PVB, delivered UWCD water from the PVP, CWD-delivered water from Conejo Creek, and other sources. FCGMA groundwater pumping records indicate that from 1985 to 2015, approximately 41% and 59% of PVCWD’s pumped groundwater has come from the PVB and the Oxnard Subbasin, respectively. A geographic information system (GIS) calculation of the area of the PVCWD in Figure 1-8 indicates that approximately 56% of the PVCWD service area is in the Oxnard Subbasin, and the remaining 44% is in the PVB. For purposes of estimating PVCWD water deliveries, a ratio of 44% PVB and 56% Oxnard Subbasin area was assumed to be a reasonable basis for PVCWD water supplies between the two basins. As shown in Table 2-10, during some years, groundwater pumping by PVCWD in the Oxnard Subbasin is less than this ratio resulting in a net import from the PVB. Conversely, in some years, groundwater pumping in the Oxnard Subbasin is more than this ratio, resulting in a negative import (an export) to the adjacent PVB.

2.4.2.2 Tile Drain Recharge Losses

Tile drains are used beneath many agricultural lands in the Oxnard Subbasin to maintain a sufficiently deep groundwater table where poorly drained soils create shallow groundwater conditions that can negatively affect plant health and crop yields. These conditions prompted the installation of tile drains across most of the Oxnard Plain in the 1900s. Tile drains are present beneath many agricultural land parcels in the PVB as well. These drains discharge to local drainage ditches and then to surface water bodies Revolon Slough and Calleguas Creek. The flows in the tile drains are not metered.

Tile drains were implemented in the UWCD groundwater model using MODFLOW’s drain package (DRN). Model grid cells with simulated tile drains in the uppermost active layer correspond with agricultural areas where tile drains are known or suspected to exist. The UWCD model has calculated losses to tile drains based on groundwater model simulated water levels and the results are provided in Tables 2-7a and 2-7b. Average annual loss to tile drains in the UWCD model is 10,752 AFY.

2.4.2.3 Evapotranspiration (ET)

The UWCD model used the U.S. Fish and Wildlife Service online "Wetlands Mapper" (https://www.fws.gov/wetlands/data/mapper.html) to indicate areas of riparian vegetation along stream channels. These areas, together with parts of the Santa Clara River (including its estuary), Revolon Slough/Beardsley Wash, McGrath Lake, Ormond Beach wetlands, and Mugu Lagoon wetlands were used to estimate evapotranspiration (ET) (Appendix C). ET is the discharge of groundwater from the saturated zone where the water table is present at very shallow depths. Such conditions mostly occur in the Oxnard Subbasin where the semi-perched aquifer interacts with surface water bodies, which is also where riparian vegetation is typically found in the Oxnard Subbasin. These areas are hydraulically connected to, and exchange fresh- to brackish-water with, the semi-perched aquifer near the coast. It should be noted that nearly all of the riparian vegetation that takes up groundwater in the Oxnard Subbasin occurs in land overlying the semi-perched aquifer, which is rarely, if ever, pumped as a source of agricultural or M&I water supply. Additional discussions about these areas are in Sections 2.3.6 and 2.3.7.

UWCD (Appendix C) applied USGS estimates for ET rates from 1.1 to 5.2 feet per year to calculated long-term annual average groundwater discharge as ET. UWCD implemented ET using MODFLOW's ET package, EVT. Model grid cells corresponding to areas of mapped wetlands with shallow groundwater were simulated. The maximum ET flux was 0.010 feet per day (3.65 feet per year) for model grid cells subject to ET over their entire area. The maximum ET flux is scaled down proportionally for grid cells that are only partially occupied by wetlands. The ET surface elevation was set at 3 feet bgs, and the ET extinction depth was set at 5 feet bgs (Appendix C, p. 84).

According to UWCD model results, the estimated annual loss from ET is 8,328 AFY, with most coming from the semi-perched aquifer (8,291 AFY, a shown in Table 2-7a) and a small amount from the UAS (37 AFY, as shown in Table 2-7b).

2.4.3 Current and Historical Water Budget Analysis

2.4.3.1 Water Year Types

Water year type is based on the percentage of the water year precipitation compared to the 30-year precipitation average. Types are defined in this GSP as wet (≥ 150% of average), above normal (≥ 100% to <150% of average), below normal (> 75% to <100% of average), dry (> 50% to <75% of average), and critical (<50% of average). Figures 2-22 through 2-25 show the water year type from 1986 to 2015. The water type year for 2015 is dry.

2.4.3.2 Historical Water Budget Analysis

DWR has designated the Oxnard Subbasin as a high-priority basin. The DWR GSP Regulations, Section 354.18, Water Budget, states that, "If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions." According to the DWR Bulletin 118, "A basin is subject to critical overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts" (DWR 2006). Bulletin 118 Interim Update 2016 (October 18, 2016) lists the Oxnard Subbasin (Basin 4-004.02) as being in critical overdraft (DWR 2016).

Because of Bulletin 118's listing of the Oxnard Subbasin as being in critical overdraft, the DWR GSP Regulations, Section 354.18 (b)(5), requires a quantification of the overdraft over a period of years during which water years and water supply conditions approximated average conditions. Using the water year types discussed in Section 2.4.3.1, and the above normal (> 100% to <150% of average) and the below normal (> 75% to <100% of average) water year types to bracket water supply conditions approximating average conditions, the following years have near average conditions: 1988, 1991, 1992, 1994, 1996, 1997, 2000, 2001, 2003, 2006, 2008, 2010, and 2011.

The change in storage during these years was an increase of 6,045 AFY in the UAS and an increase of 1,029 AFY in the LAS (Tables 2-7b and 2-7c). However, the net seawater intrusion during these years was 4,189 AFY in the UAS, and 5,225 AFY in the LAS (Table 2-7c). Thus, the net change in groundwater storage for the UAS without seawater intrusion was an increase in 1,856 AFY in the UAS and the net change in storage without seawater intrusion in the LAS was a decrease of 4,196 AFY. Total groundwater pumping during these years averaged 47,080 AFY in the UAS and 28,893 AFY in the LAS for a total of 65,973 AFY (Tables 2-7b and 2-7c). This quantification of the overdraft over a period of years during which water years and water supply conditions approximated average conditions would indicate that the Oxnard Subbasin was in overdraft of about 2,340 AFY (4,196 AFY [LAS] − 1,856 AFY [UAS]). It should be noted that except for 2011, Tables 2-7b and 2-7c show net seawater intrusion for the UAS and LAS for each of the years that approximated average conditions. This seawater intrusion analysis suggests that based on the historical pumping patterns and pumping amounts, the Oxnard Subbasin was in overdraft by about 2,340 AFY during average water supply conditions.

GSP regulation Section 354.18 (c)(2) requires that the historical water budget information be used to evaluate availability or reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year type. Historically, the Oxnard Subbasin has received surface water supply deliveries directly from one main source: the Santa Clara River. Additionally, but to a lesser degree, Calleguas Creek, imported water delivered by the CMWD, and Conejo Creek water diversions have contributed surface water supplies to the Oxnard

Subbasin. Table 2-8 shows that the diversion of Santa Clara River from 1985 to 2015 have averaged 62,467 AFY, and leakage from the Santa Clara River has averaged about 5,650 AFY (770 AFY [see Tables 2-7a and 2-7b] + 4,989 AFY [see Table 2-7b] – 109 AFY [see Table 2-7b]). This indicates a total Santa Clara River supply of approximately 68,117 AFY. In comparison, Calleguas Creek has supplied approximately 3,394 AFY (see Table 2-7a) to the semi-perched aquifer, CMWD has delivered 14,543 AFY of imported water (see Table 2-13), and Conejo Creek diverted flows have averaged 1,159 AFY (see Table 2-10). These last three sources total 19,096 AFY, or 22% of the total surface water deliveries (87,213 AFY) or only 28% of the total Santa Clara River. Tables 2-7a, 2-13, and 2-10 for Calleguas Creek, CMWD imported water, and Conejo Creek (starting in 2002), respectively, suggest that these sources are reliable and not significantly affected by the water year type. However, diversions from the Santa Clara River as shown in Table 2-8 and on Figure 2-59 vary widely depending on climate conditions. The high diversion years of 1993, 1998, and 2005 were wet years (Figures 2-22 and 2-59). The low diversion years of 1990, 2013 and 2014 were critical dry years, and 2015 was a dry year (Figures 2-22 and 2-59). Diversions of surface water by the UWCD from the Santa Clara River are critical to the surface water supplies of the Oxnard Subbasin.

2.4.3.3 Current (2015) Groundwater Conditions

Groundwater level data presented in Section 2.3, Groundwater Conditions, and the change in storage estimates for the calendar year 2015 from Tables 2-7a through 2-7c indicate that the Oxnard Subbasin had greater groundwater outflows than inflows in 2015. The estimated 2015 groundwater change in storage is a loss of about 38,703 AF (Tables 2-7a through 2-7c). This change in groundwater storage would be larger and groundwater storage declines greater if seawater intrusion had not replaced groundwater in the Oxnard Subbasin. Model results in Tables 2-7a through 2-7c indicate a net seawater intrusion in 2015 of approximately 19,200 AF. There was a net outflow of water to the Pacific Ocean in the semi-perched aquifer of approximately 504 AF (Table 2-7a), but a positive inflow (seawater intrusion) in the UAS of approximately 11,633 AF (Table 2-7b) and a positive inflow in the LAS of approximately 8,081 AF (Table 2-7c).

Tables 2-7a through 2-7c show that from 1985 to 2015, seawater intrusion has replaced freshwater in storage in the Oxnard Subbasin in the LAS every year, and 23 of 31 years in the UAS. Tables 2-7a and 2-7b indicate that seawater flows both in and out of the Oxnard Subbasin in the semi-perched aquifer and the UAS. However, groundwater generally flows out of the Subbasin from the semi-perched aquifer (which is not currently a usable aquifer), and seawater usually inflows to the UAS and LAS, which affects usable groundwater aquifers.

2.4.3.4 Estimates of Historical Sustainable Yield

Historical estimates for the Oxnard Subbasin sustainable yield[8] have also included the PVB. These historical sustainable yield estimates include the following:

- FCGMA, 1985, Groundwater Management Plan
- FCGMA, 2007, 2007 Update to the Fox Canyon Groundwater Management Agency Groundwater Management Plan
- UWCD and CMWD, 2012, Preliminary Draft Yield Analysis (UWCD 2016c)
- UWCD, 2016, Proposed Method for Estimating Sustainable Yield (UWCD 2016c)

All of these historical estimates for the combined Oxnard Subbasin and PVB sustainable yield are about 65,000 AFY, but do not demonstrate that this groundwater pumping rate prevents seawater intrusion. The UWCD Open-File Report 2017-02 (UWCD 2017a) Scenario D estimated that seawater intrusion would be halted if: (1) there were no groundwater pumping in what the report refers to as an assumed future "seawater intrusion management area," (2) groundwater pumping were reduced by about 70% in LAS in the Oxnard Plain (excluding the Forebay) and in the PVB, and (3) there were no reduction in UAS pumping. However, this scenario assumed that groundwater for irrigation in the assumed future "seawater intrusion management area" would be supplied by a project to be implemented in the future. The combined estimated sustainable yield under Scenario D was 59,900 AFY for the Oxnard Subbasin (excluding the seawater intrusion management area) and the PVB.

To estimate the sustainable yield under historical conditions where no future project is implemented, the UWCD conducted Scenario F in Addendum Open-File Report 2017-02a (UWCD 2017b). In Scenario F, the assumed seawater intrusion management area was eliminated, and a uniform reduction in groundwater pumping was simulated to achieve sustainable yield. The scenario defined a sustainable yield as maintaining groundwater elevations along the coast at levels sufficiently high to prevent seawater intrusion and other forms of saline water intrusion. In the Port Hueneme area, where the UAS and LAS are believed to have direct hydraulic connection with the Pacific Ocean, UWCD assumed minimum thresholds[9] as defined in Open File Report 2017-02. However, under Scenario F, UWCD assumes a minimum threshold for the LAS near Mugu Lagoon to be −20 feet msl instead of 18.5 feet msl, as assumed in Open File Report 2017-02. This is because the most recent UWCD Saline Intrusion Update report (UWCD 2016b) interpreted the source of elevated

[8] SGMA requires that an estimate of the "sustainable yield" be made for the Oxnard Subbasin based on historical data. However, as used in this section the sustainable yield does not address undesirable results, which are discussed in Chapter 3, Sustainable Management Criteria.

[9] "Minimum threshold" used here is in reference to the Open File Report 2017-02 usage and not to the minimum threshold discussed in Chapter 3 of this GSP.

chloride concentrations in the LAS near Mugu Lagoon to be saline water yielded from marine clays and/or from adjacent Tertiary-age sedimentary rocks, as a result of large declines in potentiometric head in the LAS over the past several decades, and not a direct result of current seawater intrusion. Additional discussion of saline water and seawater intrusion can be found in Section 2.3.3.

Based on the results from UWCD Scenario F (UWCD 2017b, Table 2-2), the sustainable yield under historical conditions with no changes from the current pumping locations (i.e., without water supply or infrastructure projects) for the Oxnard Subbasin would be a total of 39,000 AFY (27,000 AFY from the Oxnard Plain and 12,000 AFY from the Oxnard Forebay area). The results from UWCD Scenario F (2017b, Table 2-2) would indicate a total of 10,000 AFY for the PVB. Evaluation of the volume of water entering and leaving the model along the Pacific coastline under Scenario F indicated that there is a net outflow of water from the model to the Pacific Ocean over the 31-year simulation period. Groundwater left the model to the ocean in the UAS, while a smaller amount of seawater intruded the LAS. This suggests that additional production may be possible from the Oxnard Subbasin by reducing groundwater pumping in the LAS and increasing it in the UAS. This shift in pumping may also better protect against seawater intrusion.

2.4.4 General Uncertainties in the Water Budget

There are several limitations and uncertainties associated with other water budget terms used for both the historical and future conditions due to necessary simplifying of assumptions and data gaps. Uncertainties about the groundwater models used are discussed in Section 2.4.5.8. Some of the general water budget limitations and/or uncertainties include the following:

1. The reporting of groundwater pumping outside the boundaries of the FCGMA is limited and there is a possibility of underreporting of pumping within the FCGMA boundaries due to non-reporting, inaccurate reporting, and equipment problems. Additional future data collection is needed to verify the existence and extent of and to eliminate this data gap. However, the amount of pumping outside the FCGMA boundary is expected to be minor given the limited number of wells (estimated at fewer than 12).
2. The hydrologic base period (calendar years 1985–2015, DWR's 31-year base period) may not necessarily be representative of long-term average conditions. As shown on Figure 1-6, Long-Term Precipitation Trends in the Oxnard Plain, this was a generally wetter-than-average period. However, the future water budget analysis in Section 2.4.5, which used a model 50-year period with an average precipitation period (1939 to 1979), does not suggest that the historical sustainable yield estimate based on this wetter-than-average period is too high. The combined UAS and LAS sustainable yield for the future water budget ranged from 30,000 AFY to 48,000 AFY (Section 2.4.5.9). The estimated historical sustainable yield using UWCD Scenario F (Section 2.4.3.4) of 39,000 AFY is within this range. The uncertainty associated with the future water budget sustainable yield is discussed in Section 2.4.5.8.

3. Conclusions regarding uncertainties in the UWCD model are discussed in Section 2.4.5.8, Uncertainty Analysis, and in the Dudek peer review of the UWCD model (Appendix E).
4. Subsurface inflows and outflows across basin boundaries are not measurable. The groundwater level data in these areas by themselves do not provide a clear indication of groundwater flow directions because of the limited water level measurements and the variation in time between measurements. The UWCD model provides a significantly improved understanding of these boundary fluxes and their variability under different pumping and recharge conditions in the region, but checking model values with observations and calculating the gradient with three-point groundwater flow problems should be considered to verify model estimates. Attempts to estimate inflows and outflows across basin boundaries using well groundwater level data was attempted for this GSP, but data gaps and limited well locations screened in one aquifer made the results unreliable.
5. Some semi-perched groundwater in the Oxnard Subbasin is potentially captured by tile drains, rather than recharging the UAS. This uncertainty could be reduced through installation of instrumentation and measurement of discharges from the tile drains.
6. Currently, aquifer-specific water level maps are not reliable to estimate aquifer change in groundwater storage due to the limited number and distribution of aquifer-specific water wells. Dedicated monitoring wells could installed and equipped with water-level measuring data loggers in all of the aquifers. This would help decrease uncertainty in estimates of future changes in groundwater storage by enabling use of aquifer-specific water-level maps to check groundwater model change in storage calculations.

2.4.5 Projected Future Water Budget and Sustainable Yield

Several model scenarios were developed in accordance with SGMA guidelines to assess the future sustainable yield of the Oxnard Subbasin. Each future scenario covered a 50-year time frame, from 2020 to 2069. In this GSP, the period from 2020 to 2039 is referred to as the implementation period, and the period from 2040 to 2069 is referred to as the sustaining period. The sustainable yield was determined from the model scenarios that did not result in a net flux of seawater into either the UAS or the LAS in Oxnard Subbasin, within the level of the model uncertainty, during the 30-year sustaining period (Figure 2-63, Coastal Flux from the UWCD Model Scenarios).

Because the Oxnard Subbasin is hydraulically connected to the PVB and the WLPMA, the sustainable yield of the Oxnard Subbasin is influenced by groundwater production and projects in these adjacent basins. The UWCD model used to assess the sustainable yield of the Oxnard Subbasin includes both the PVB and the WLPMA in the model domain, and the modeling assumptions associated with each scenario discussed below include the assumptions made for these adjacent basins.

The model scenarios developed for Oxnard Subbasin, the PVB, and the WLPMA all included existing projects and the 2070 DWR climate-change factor applied to the 1930–1970 historical precipitation and hydrology base period. The model scenarios are the following:

- Future Baseline Simulation (2015–2017 average production rates adjusted by surface water deliveries)
- Future Baseline Simulation With Projects (2015–2017 average production rates adjusted by surface water deliveries; potential future projects that met the DWR conditions for incorporation in the GSP)
- Reduction With Projects (35% reduction of 2015–2017 average production rates adjusted by surface water deliveries for the UAS and LAS in the Oxnard Subbasin, 20% reduction for the UAS and LAS in PVB; and 20% in the LAS in the WLPMA; potential future projects that met the DWR conditions for incorporation in the GSP)
- Reduction Without Projects 1 (reduction of 2015–2017 average production rates adjusted by surface water deliveries by 25% in the UAS, 60% in the LAS, and 45% for wells screened in both aquifer systems in the Oxnard Subbasin; 25% reduction for the UAS and the LAS in the PVB; and 25% in the LAS in the WLPMA)
- Reduction Without Projects 2 (reduction of 2015–2017 average production rates adjusted by surface water deliveries by 55% in the UAS and the LAS in the Oxnard Subbasin; 20% reduction for the UAS and the LAS in the PVB; and 20% in the LAS in the WLPMA)
- Reduction Without Projects 3 (reduction of 2015–2017 average production rates adjusted by surface water deliveries by 55% in the UAS and the LAS in the Oxnard Subbasin; 0% reduction for the UAS and the LAS in the PVB; and 0% in the LAS in the WLPMA)

Two of the model scenarios listed above, the Future Baseline Simulation With Projects Scenario and the Reduction With Projects Scenario, incorporated projects that were approved for inclusion in the GSP model scenarios by the FCGMA Board. The Board’s approval of these projects only indicates that they were sufficiently defined by the project proponent to be analyzed as part of the GSP. It does not indicate that these specific projects will necessarily be constructed or, conversely, that other projects will not be developed in the future. The projects included are discussed in more detail with the description of each scenario below.

An initial set of four modeling simulations were conducted using the future baseline conditions with two 50-year average climate cycles (1930–1979 and 1940–1989), and two DWR climate-change factors (2030 and 2070) applied to each of the 50-year periods. The 1930 to 1979 50-year period with the 2070 DWR climate-change factor was found to be the most conservative and was used for the comparison with the other modeling simulations conducted. Additional details about the selection of the two 50-year average climate cycles is provided in Section 2.4.5.7.

In addition to the initial set of four modeling simulations and the six model scenarios listed above, the Reduction Without Projects Scenario 1 was simulated with the DWR 2030 climate-change factor and with a historical precipitation and hydrology base period from 1940 to 1989. These simulations were conducted to better understand the potential impact of precipitation patterns and climate-change factors on the model results. While the results of these simulations were primarily used as a check on the minimum threshold groundwater elevations discussed in Chapter 3, the predicted impact on seawater intrusion is discussed in Section 2.4.5.7.

Over the next 5 years, as additional projects are developed the model assumptions discussed below will need to be altered and incorporated into the 5-year GSP evaluation.

2.4.5.1 Future Baseline Model Simulation

SGMA requires that the GSP include an assessment of the "future baseline" conditions. In the Future Baseline Scenario, in order to assess whether or not groundwater extractions from the Oxnard Subbasin, PVB, and WLPMA were sustainable at their current rates, the average annual 2015–2017 production rates, adjusted by surface water deliveries, were simulated. Future surface water deliveries were estimated by UWCD using Santa Clara River flows for historical periods, the 1930–1979 climate period adjusted for future DWR climate-change factors, and estimated diversions based on similar historical Santa Clara River flows. UWCD also considered current allowable diversions, which accounts for current environmental restraints and diversion operating conditions, and optimization of water deliveries for the PVP and spreading basins. Additional details about the UWCD future model scenarios are included in Appendix L, UWCD GSP Model Documentation. For the Oxnard Subbasin, this rate is approximately 68,000 AFY without surface diversions, for the combined UAS and LAS (Table 2-15).

Future Baseline Scenario Model Assumptions

The Future Baseline model simulation included the following:

- Constant pumping at the 2015–2017 average rate of approximately 68,000 AFY adjusted for surface water deliveries in the Oxnard Subbasin (39,000 AFY in the UAS; 29,000 AFY in the LAS), 13,000 AFY in the WLPMA, and approximately 14,000 AFY in the PVB
- Starting water levels equal to the final 2015 water levels from the historical simulations
- Precipitation and streamflow for two 50-year periods (1930–1979 and 1940–1989), with an average precipitation that equaled the average precipitation for the entire historical record
- Estimates of Santa Clara River surface water available for diversion prepared by UWCD staff using climate-change factors provided by DWR and historical measured flow in the river for the 50-year periods

- East Las Posas Management Area outflows to Arroyo Las Posas to the PVB from the CMWD model
- Projects that are currently operating in the Subbasin or currently under development

The historical measurements of precipitation for the two 50-year periods were modified using the DWR 2030 and 2070 climate-change factors. Stream flows were estimated using the adjusted rainfall. UWCD estimated Santa Clara River flow and the volume of water diverted to direct delivery and spreading. Pumping was decreased where the water is delivered to account for the surface water delivered. Future streamflow in Conejo and Calleguas Creeks in Pleasant Valley was estimated by regression.

No projects currently under development were identified in the Oxnard Subbasin, but two projects under development in the PVB were incorporated into the future baseline simulation because these projects affect inflows to the Oxnard Subbasin. The two projects in PVB are the City of Camarillo’s North Pleasant Valley Desalter (desalination) Project and Conejo Creek Diversion deliveries to Pleasant Valley County Water District. The North Pleasant Valley Desalter Project was simulated by dividing the total project pumping of 4,500 AFY between project extraction wells 02N20W19L05 and 02N20W19F04. Additionally, pumping from Well 02N21W34C01 increased by 1,300 AFY to reflect a shift in areas of production.

In this scenario, Conejo Creek diversions will increase deliveries to agriculture by an additional 2,200 AFY to make the total deliveries in the PVB 4,500 AFY starting in 2020. The Conejo Creek Project allows CWD to increase pumping by up to 4,500 AFY based on credits for surface water delivered to PVCWD. However, in running the future simulations, it became apparent that the model area identified for production from the CWD wells was not able to extract the full amount. The amount of simulated CWD pumping that was achievable in the future baseline simulation was therefore limited to 2,816 AFY.

It is important to remember that groundwater extractions are not the only source of water to the Oxnard Subbasin. Surface water deliveries vary between the model scenarios because the model adjusts the deliveries of Santa Clara River water based on simulated groundwater elevations in the Oxnard Subbasin Forebay. Therefore, the total water available to the Oxnard Subbasin in the Future Baseline Scenario is approximately 72,000 AFY. Additionally, although the model calculates the groundwater extractions and surface water deliveries with precision, the values reported in Table 2-15 have been rounded to the nearest 1,000 AFY to reflect the uncertainty in the model calculations.

Future Baseline Scenario Model Results

Both the modeled flux of seawater and the particle tracks from the Future Baseline Scenario indicate that continuing the 2015–2017 extraction rate for the next 50 years would cause net seawater intrusion in both the UAS and LAS as well as ongoing inland migration of the saline water impact front (Figure 2-63 and Figure 2-64a through 2-64e, UWCD Model Particle Tracks, Future Baseline). The average annual flux of seawater into the UAS during the sustaining period was 4,400 AFY and the average annual flux of seawater into the LAS during the sustaining period was 5,300 AFY. The saline water impact front continued to migrate landward throughout the sustaining period, even during wetter than average climate periods. Based on these factors, the current areal and aquifer-system distribution of groundwater production at the extraction rates modeled in the Future Baseline Scenario was determined not to be sustainable.

2.4.5.2 Future Baseline With Projects Model Simulation

Future Baseline With Projects Scenario Model Assumptions

Modeling of future conditions included all of the assumptions incorporated into the Future Baseline simulation, and also incorporated potential future projects approved for inclusion by the FCGMA Board. Incorporation of the potential future projects in the Future Baseline With Projects Scenario neither represents a commitment by FCGMA to impose pumping reductions in the amounts specified at the wells identified below nor a commitment to move forward with each project included in the future model scenarios. Assumptions about projects and project implementation may have changed since the modeling was conducted and will continue to change over the next 5 years. These changes should be incorporated into the modeling for the 5-year GSP evaluation.

In the Oxnard Subbasin simulated future projects included delivery of 4,600 AFY of recycled water to farmers in the vicinity of Hueneme Road, expansion of the GREAT Program to increase groundwater recharge by 4,500 AFY in the Saticoy Spreading Grounds, and a 504 AFY reduction of pumping through temporary fallowing. These projects are discussed in detail in Chapter 5 of this GSP.

To simulate the delivery of 4,600 AFY of recycled water to farmers in the vicinity of Hueneme Road, pumping from wells near the coast in the pumping depression area (UWCD model parameter zone 4; Figure 2-65, UWCD Model Zones) was reduced uniformly and proportionally by 4,600 AFY. Additionally, pumping from Wells 02N22W23C05S and 02N22W23C07S in the Forebay was adjusted to allow the City of Oxnard to pump up to 8,000 AFY of accumulated credits for 2,600 AF recycled agricultural water delivered annually from the GREAT Program (FCGMA 2018).

To simulate the expansion of the GREAT Program, spreading recharge was increased by 4,500 AFY starting in 2025. To simulate the 504 AFY reduction of pumping through fallowing, pumping from Wells 01N22W26K04S, 01N22W27H02S, 01N22W26M03S, 01N22W26K03S, 01N22W26P02S, 01N22W26Q03S, and 01N22W26D05S was reduced uniformly and proportionally by 504 AFY. It should be noted that these wells were selected for modeling purposes only and use of these wells in the model simulations was not intended to represent any planned pumping restrictions or limitations on these wells.

In the PVB, a proposed temporary fallowing project was simulated near the pumping depression (in model parameter zone 11; Figure 2-65). This project would generate a 2,407 AFY reduction in pumping, however, actual simulated fallowing totaled 2,234 AFY due to considerations of existing contracts for the delivery of surface water from the Santa Clara River. Pumping was preferentially reduced in wells in the LAS within the PVB to the extent possible.

In the WLPMA, future projects included the purchase of 1,762 AFY of water to be delivered to the eastern portion of the WLPMA in lieu of groundwater extraction. Simulated pumping was reduced in Zone Mutual Water Company Wells 02N20W07R03, 02N20W07R02, 02N20W08M01, 02N20W08E01, and 02N20W08F01, as well as Ventura County Waterworks District No. 19 Wells 02N20W06R01 and 02N20W08B01. The pumping reductions of 1,762 AFY were applied uniformly and proportionally across the wells.

After incorporating the potential future projects, the average groundwater production rate for the UAS in the Oxnard Subbasin was 41,000 AFY and the average groundwater production rate for the LAS in the Oxnard Subbasin was 24,000 AFY for the Future Baseline With Projects Scenario. In the PVB, the average groundwater production rate was 4,300 AFY in the UAS and 7,600 AFY in the LAS. In the WLPMA, the average production rate in the LAS was 11,200 AFY.

Because the projects that were incorporated into the Future Baseline With Projects Scenario included reduction of approximately 500 AFY from temporary fallowing in Oxnard, and deliveries of recycled water from the GREAT Program, the groundwater extractions in the LAS decreased by approximately 4,000 AFY, relative to the Future Baseline Scenario. At the same time, the groundwater extractions from the UAS increased by approximately 2,000 AFY, relative to the Future Baseline Scenario, in the Future Baseline With Projects Scenario (Table 2-15). Consequently, the effect of incorporating the projects was to shift groundwater extraction from the LAS to the UAS, and reduce overall groundwater extraction by approximately 2,000 AFY. The total water available to the Oxnard Subbasin in the Future Baseline With Projects Scenario was approximately 73,000 AFY, with the reduction in groundwater production being offset by the addition of approximately 3,000 AFY of project water.

Future Baseline With Projects Scenario Model Results

Although the shift in groundwater extractions from the LAS to the UAS and reduction in the total extractions helped reduce the flux of seawater into the Oxnard Subbasin, overall the Future Baseline With Projects Scenario resulted in approximately 3,000 AFY of seawater flux into the UAS and 2,700 AFY into the LAS during the sustaining period (Figures 2-66a through 2-66e, UWCD Model Particle Tracks, Base Case with Projects). Particle tracks for the Future Baseline With Projects Scenario also showed net landward migration of the saline water impact front during the sustaining period (Figures 2-66a through 2-66e). Based on these factors, the current areal and aquifer-system distribution of groundwater production at the extraction rates modeled in the Future Baseline With Projects Scenario was determined not to be sustainable.

2.4.5.3 Reduction With Projects Scenario

Reduction With Projects Scenario Model Assumptions

The Reduction With Projects Scenario included all of the assumptions incorporated into both the Future Baseline simulation and the Future Baseline With Projects Scenario. The Reduction With Projects Scenario also included a 35% reduction of 2015–2017 average production rates for the UAS and LAS in the Oxnard Subbasin, 20% reduction for the UAS and LAS in the PVB, and 20% in the LAS in the WLPMA. Groundwater production rates were reduced linearly over the implementation period and held constant during the sustaining period. In the Oxnard Subbasin UAS, the simulated groundwater production rate in model year 2020 was 40,000 AFY. The production rate in model year 2040 at the beginning of the sustaining period was 24,300 AFY.[10] The average production from the UAS for the sustaining period was 26,500 AFY. In the LAS, the simulated groundwater production rate in model year 2020 was 28,500 AFY and the simulated groundwater production rate in model year 2040 was 14,000 AFY. The average production rate from the LAS for the sustaining period was 12,800 AFY.

Reduction With Projects Model Scenario Results

Reducing groundwater production in the UAS and LAS, and shifting some groundwater extractions from the LAS to the UAS via the potential future projects in the Reduction With Projects Scenario, resulted in an average flux of groundwater out of the UAS into the Pacific Ocean of approximately 3,300 AFY during the sustaining period. In the LAS, the Reduction With Projects Scenario resulted in an average flux of approximately 1,200 AFY of seawater into the LAS during the sustaining period (Figures 2-67a through 2-67e, UWCD Particle Tracks, Reduction With

10 Modeled extraction rates depend on climate, surface water availability, and simulated groundwater elevations for each model year. The reductions implemented reflect a reduction in overall water demand for the Oxnard Subbasin and are not the exact percentage specified for any given year. Therefore, the extraction rate from the UAS in 2040 is 39% of the extraction rate in 2020 rather than the 35% specified in the model scenario description.

Projects Simulation). Particle tracks for the Reduction With Projects Scenario indicate that the location of the 2015 saline water impact front would likely migrate toward the Pacific Ocean in the UAS as freshwater diluted saline concentrations, while it would experience some landward migration in the LAS (Figures 2-67a through 2-67e). The continued landward migration of the saline water impact front in the LAS suggests that groundwater production in the LAS may need to be reduced further than it was in this model scenario, while at the same time the groundwater production rate in the UAS was likely lower than it needed to be, as groundwater left the aquifers of the UAS and entered the Pacific Ocean.

2.4.5.4 Reduction Without Projects Scenario 1

Reduction Without Projects Scenario 1 Model Assumptions

The Reduction Without Projects Scenario 1 included all of the assumptions incorporated into the Future Baseline simulation but did not include the projects that were incorporated into the Future Baseline With Projects and Reduction With Projects Scenarios. In the Oxnard Subbasin, the Reduction Without Projects Scenario 1 also included a 25% reduction of 2015–2017 average production rates for wells screened solely in the UAS, a 60% reduction of the 2015–2017 average production rates for wells screened solely in the LAS, and a 45% reduction of the 2015–2017 average production rates for wells screened in both aquifer systems. The 2015–2017 average pumping rate was reduced by 25% in the UAS and LAS in the PVB, and 25% in the LAS in the WLPMA. Groundwater production rates were reduced linearly over the implementation period and held constant during the sustaining period.

In the Oxnard Subbasin UAS, the simulated groundwater production rate in model year 2020 was 40,300 AFY. The production rate in model year 2040 at the beginning of the sustaining period was 27,300 AFY.[11] The average production from the UAS for the sustaining period was 27,200 AFY. In the LAS, the simulated groundwater production rate in model year 2020 was 33,100 AFY and the simulated groundwater production rate in model year 2040 was 13,000 AFY. The average production rate from the LAS for the sustaining period was 11,600 AFY. The resulting average combined extraction rate from the two aquifer systems was approximately 39,000 AFY for the 30-year sustaining period (Table 2-15).

Reduction Without Projects Scenario 1 Model Results

The fluxes in the UAS and LAS in the Reduction Without Projects Scenario 1 were similar to those simulated in the Reduction With Projects Scenario (Figures 2-68a through 2-68e, UWCD Model

[11] Modeled extraction rates depend on climate, surface water availability, and simulated groundwater elevations for each model year. The reductions implemented reflect a reduction in overall water demand for the Oxnard Subbasin and are not the exact percentage specified for any given year. Therefore, the extraction rate from the UAS in 2040 is 32% of the extraction rate in 2020 rather than the 25% specified in the model scenario description.

Particle Tracks, Reduction Without Projects Scenario (1) Simulation). There was an average flux of groundwater out of the UAS into the Pacific Ocean of approximately 2,800 AFY during the sustaining period in the Reduction Without Projects Scenario 1. In the LAS, the Reduction Without Projects Scenario 1 resulted in an average flux of approximately 1,300 AFY of seawater into the LAS during the sustaining period. Particle tracks for this scenario indicate that the 2015 saline water impact front would likely migrate toward the Pacific Ocean in the UAS as freshwater diluted saline concentrations in the UAS, while it would migrate farther landward in the LAS than in the Reduction With Projects Scenario (Figures 2-68a through 2-68e). As in the Reduction With Projects Scenario, the continued landward migration of the saline water impact front in the LAS suggests that groundwater production in the LAS may need to be reduced further than it was in the Reduction Without Projects Scenario 1, while at the same time the groundwater production rate in the UAS was likely lower than it needed to be, as groundwater left the aquifers of the UAS and entered the Pacific Ocean.

2.4.5.5 Reduction Without Projects Scenario 2

Reduction Without Projects Scenario 2 Model Assumptions

The Reduction Without Projects Scenario 2 included all of the assumptions incorporated into the Future Baseline simulation but did not include the projects that were incorporated into the Future Baseline With Projects and Reduction With Projects Scenarios. In the Oxnard Subbasin, the Reduction Without Projects Scenario 2 also included a 55% reduction of 2015–2017 average production rates for the UAS and LAS. The 2015–2017 average pumping rate was reduced by 20% in the UAS and LAS in the PVB, and 20% in the LAS in the WLPMA. Groundwater production rates were reduced linearly over the implementation period and held constant during the sustaining period.

In the Oxnard Subbasin UAS, the simulated groundwater production rate in model year 2020 was 40,000 AFY. The production rate in model year 2040 at the beginning of the sustaining period was 17,600 AFY.[12] The average production from the UAS for the sustaining period was 17,600 AFY. In the LAS, the simulated groundwater production rate in model year 2020 was 33,100 AFY and the simulated groundwater production rate in model year 2040 was 12,800 AFY. The average production rate from the LAS for the sustaining period was 11,500 AFY. The resulting average combined extraction rate from the two aquifer systems was approximately 29,000 AFY for the 30-year sustaining period (Table 2-15).

12 Modeled extraction rates depend on climate, surface water availability, and simulated groundwater elevations for each model year. The reductions implemented reflect a reduction in overall water demand for the Oxnard Subbasin and are not the exact percentage specified for any given year. Therefore, the extraction rate from the UAS in 2040 is 56% of the extraction rate in 2020 rather than the 55% specified in the model scenario description.

Model results indicate that under this scenario the groundwater flux in the LAS between the PVB and the Oxnard Subbasin is mostly reversed from the above scenarios from model year 2027 to 2055. The groundwater flow during this period (2027 to 2055) in the LAS is from the Oxnard Subbasin to the PVB. This increased the seawater intrusion in the LAS in the Oxnard Subbasin, exacerbating Oxnard Subbasin's seawater intrusion problem.

Reduction Without Projects Scenario 2 Model Results

There was an average flux of groundwater out of the UAS into the Pacific Ocean of approximately 4,700 AFY during the sustaining period in the Reduction Without Projects Scenario 2 and an average flux of approximately 900 AFY of seawater into the LAS. As in the Reduction Without Projects Scenario 1, the continued inflow of seawater into the LAS suggests that groundwater production in the LAS may need to be reduced further than it was in the Reduction Without Projects Scenario 2, while at the same time the groundwater production rate in the UAS was likely lower than it needed to be, as groundwater left the aquifers of the UAS and entered the Pacific Ocean.

2.4.5.6 Reduction Without Projects Scenario 3

Reduction Without Projects Scenario 3 Model Assumptions

The Reduction Without Projects Scenario 3 included all of the assumptions incorporated into the Future Baseline simulation but did not include the projects that were incorporated into the Future Baseline With Projects and Reduction With Projects Scenarios. In the Oxnard Subbasin, the Reduction Without Projects Scenario 3 also included a 55% reduction of 2015–2017 average production rates for the UAS and LAS. The 2015–2017 average pumping rate was not reduced in the UAS and LAS in the PVB or in the LAS in the WLPMA. Groundwater production rates were reduced in the Oxnard Subbasin linearly over the implementation period and held constant during the sustaining period.

In the Oxnard Subbasin UAS, the simulated groundwater production rate in model year 2020, at the beginning of the implementation period, was 40,000 AFY. The production rate in model year 2040 at the beginning of the sustaining period was 18,100 AFY. The average production from the UAS for the sustaining period was 18,100 AFY. In the LAS, the simulated groundwater production rate in model year 2020 was 33,200 AFY and the simulated groundwater production rate in model year 2040 was 13,700 AFY. The average production rate from the LAS for the sustaining period was 12,300 AFY. The resulting average combined extraction rate from the two aquifer systems was approximately 30,000 AFY for the 30-year sustaining period (Table 2-15).

Reduction Without Projects Scenario 3 Model Results

There was an average flux of groundwater out of the UAS into the Pacific Ocean of approximately 3,700 AFY during the sustaining period in the Reduction Without Projects Scenario 3 and an average flux of approximately 1,400 AFY of seawater into the LAS. As in the Reduction Without Projects Scenarios 1 and 2, the continued inflow of seawater into the LAS suggests that groundwater production in the LAS may need to be reduced further than it was in the Reduction Without Projects Scenario 3, while at the same time the groundwater production rate in the UAS was likely lower than it needed to be, as groundwater left the aquifers of the UAS and entered the Pacific Ocean.

Model results indicate that under this scenario the groundwater flux in the LAS between the PVB and the Oxnard Subbasin is reversed from model year 2027 to the end of the model period (2070). The groundwater flow during this period (after 2027) in the LAS is from the Oxnard Subbasin to the PVB. This significantly increases the seawater intrusion in the LAS in the Oxnard Subbasin exacerbating Oxnard Subbasin's seawater intrusion problem.

2.4.5.7 Alternative Climate and Rainfall Patterns

To assess the potential impacts on model predictions from alternate climate-change assumptions and precipitation patterns, two additional simulations were conducted using the Reduction Without Projects Scenario 1. These additional simulations changed the scenario assumptions in two ways. First, the Reduction Without Projects Scenario 1 was simulated using the DWR 2030 climate-change factor, rather than the more conservative 2070 climate-change factor. This revised scenario is referred to as the Reduction Without Projects Scenario 1a. Second, the Reduction Without Projects Scenario 1a was simulated with the DWR 2030 climate-change factor applied to the historical precipitation and hydrology period from 1940 to 1989, rather than the original period from 1930 to 1979. This revised scenario is referred to as the Reduction Without Projects Scenario 1b.

The 50-year periods from 1930 to 1979 and 1940 to 1989 were selected because they were the two periods from the entire historical record with the closest mean, or average, precipitation to the mean precipitation for the entire historical record of 14.4 inches. The mean precipitation for the historical period from 1930 to 1979 is also 14.4 inches and the mean precipitation from the historical period from 1940 to 1989 is 14.6 inches. These periods also have a similar distribution of precipitation years to the historical record and a similar average drought length to the average drought length in the historical record. The primary difference between the two periods is the timing of the dry periods in the records. The period from 1930 to 1979 begins with a 7-year dry period from 1930 to 1936 (model years 2020–2026), while the period from 1940-1989 begins with a 5-year wetter than average period (model years 2020–2024). The differences between these scenarios are discussed below.

Reduction Without Projects Scenario 1a

The Reduction Without Projects Scenario 1a had approximately 2,200 AFY of freshwater flowing out of the UAS to the Pacific Ocean and 1,500 AFY of seawater intrusion into the LAS during the sustaining period. Compared to the Reduction Without Projects Scenario 1, there was approximately 600 AFY less flow out of the UAS and approximately 200 AFY more flow into the LAS from the Pacific Ocean (Figure 2-63). This is the result of lower water levels in the UAS and LAS under this scenario than the Reduction Without Projects Scenario 1. The 2030 climate-change factor showed lower potential water levels and more seawater intrusion than the 2070 climate-change factor; however, the difference between the simulated fluxes in the two scenarios is within the uncertainty of the model predictions and is not significant compared to other uncertainties in the future simulations, including the actual precipitation pattern that will prevail over the period from 2020 to 2069.

Reduction Without Projects Scenario 1b

The Reduction Without Projects Scenario 1b had approximately 4,300 AFY of freshwater flowing out of the UAS to the Pacific Ocean and 760 AFY of seawater intrusion into the LAS during the sustaining period. Compared to the Reduction Without Projects Scenario 1a, the Reduction Without Projects Scenario 1b had 2,100 AFY more freshwater leaving the UAS and 800 AFY less seawater intrusion in the LAS during the sustaining period (Figure 2-63). The reduced seawater intrusion and increased freshwater outflow are the result of higher simulated groundwater levels during the sustaining period than in the Reduction Without Projects Scenario 1a. The groundwater elevations in the Reduction Without Projects Scenario 1b rise faster in response to the wetter than average precipitation pattern that occurs at the beginning of the model period (model years 2020–2024) and remain higher during the sustaining period (model years 2040–2069) than they do in the Reduction Without Projects Scenario 1a. The differences in seawater intrusion and water levels between the Reduction Without Projects Scenarios 1a and 1b show that the model is more sensitive to actual precipitation patterns than it is to the predicted relative changes in climate between 2030 and 2070. The actual climate and precipitation patterns over the next 5 years should be used to revise the model simulations and refine the estimated potential for net seawater intrusion during the sustaining period.

2.4.5.8 Uncertainty Analysis

A review of the UWCD model was conducted to provide an independent evaluation of the model for use in the context of developing a GSP and to quantify the uncertainty associated with the modeling estimates of the sustainable yield for the basins in the model domain (Appendix E). UWCD conducted a *local* sensitivity analysis of its model prior to this review, in order to evaluate how the model input parameters obtained via the model calibration affect the model outputs. The peer review conducted an additional *global* sensitivity analysis that keys off of their local sensitivity analysis, and allows for a quantitative assessment of uncertainty in seawater flux and sustainable yield.

General Results

Results of the model scenarios discussed above indicate that changes to groundwater production rates or to extraction locations for the Oxnard Subbasin are needed to avoid seawater intrusion in the LAS during the sustaining period. Understanding the uncertainties in the model predictions underscores the desirability of making gradual changes in production rates while additional monitoring and studies help to reduce these uncertainties.

The largest potential sources of uncertainty in the model were found to be hydraulic properties, for a given precipitation pattern. As discussed in Section 2.4.5.7, Alternative Climate and Rainfall Patterns, precipitation and surface water availability are a critical input parameter for predictive simulations. Critical areas of hydraulic properties were constrained in the historical simulations by aquifer testing. In particular, the model parameters that accounted for the most variance (approximately 37% of total variance) in minimizing error between observed groundwater levels and model simulated heads throughout the model were the horizontal hydraulic conductivities assigned to the Oxnard and Mugu Aquifers in the Forebay. The values assigned in the model were consistent with horizontal hydraulic conductivities determined from aquifer testing in that area. The fact that the most sensitive parameter assignments were well constrained by observations reduces uncertainty and provides good confidence in model predictions of groundwater levels overall.

Additionally and importantly, these same zones of horizontal hydraulic conductivity accounted for approximately 24% of total variance in model calculations of seawater flux across the ocean boundary. In contrast, the conductance of the ocean general head boundaries only accounted for approximately 3% of the variance in seawater flux. This indicates that the movement of artificially recharged groundwater from the Forebay to the coast is key in seawater flux. Additionally, the amount of Forebay recharge that enters the WLPMA rather than moving toward the coast was found to affect the seawater flux more than the conductance of the general head boundaries representing the ocean outcrops at the model boundary.

Stream infiltration, a parameter that was estimated based on the correlation between predicted and observed water levels accounted for approximately 5% of the variance in seawater flux and horizontal and vertical hydraulic conductivity of the aquitard separating Layer 5 (Mugu Aquifer) from Layer 7 (the Hueneme Aquifer) in the PVB accounted for approximately 3% of the variance in seawater flux. This sensitivity is associated with the flux across the basin boundary and flow between the UAS and the LAS. Again, these parameters in the PVB accounted for more seawater flux than that accounted for by the conductance of the aquifer outcrops beneath the ocean.

Quantifying Uncertainty

The uncertainty associated with model simulations of seawater flux was calculated by determining the relationship between simulated groundwater levels in wells near the coast and simulated seawater flux at the ocean boundary for the six model scenarios described in Section 2.4.5. This relationship was established by calculating the mean errors between observed and simulated groundwater levels at the coastal wells and applying the relationship between simulated groundwater levels and seawater flux to determine what the flux would have been had the model exactly reproduced observed groundwater levels. This analysis was conducted for both the entire model period from 2020 to 2069 and the sustaining period from 2040 to 2060. In general the analysis indicated that there is approximately 2,000 AFY uncertainty due to model error in simulated total seawater flux, though this varies depending on which time frame is analyzed. Alternatively, using calculated seawater flux from 121 realizations in a global sensitivity analysis yielded a comparable result of approximately 3,000 AFY uncertainty in seawater flux. The global sensitivity analysis is discussed in Appendix E. For the sustaining period, the relationship between seawater flux and pumping gives a confidence interval for the sustainable yield of approximately ± 6,000 AFY for the UAS and ± 3,600 AFY for the LAS. For the entire model period from 2020 to 2069, the relationship between seawater flux and pumping gives a confidence interval for the sustainable yield of approximately ± 4,100 AFY for the UAS and ± 2,300 AFY for the LAS. The relationship between seawater flux and water levels will continue to be refined through data collection and analysis over successive 5-year periods for the GSP evaluations, and these uncertainty estimates are anticipated to contract accordingly.

2.4.5.9 Estimates of Future Sustainable Yield

The sustainable yield for Oxnard Subbasin was assessed by examining the modeled flux of seawater into the Subbasin over the 50-year model period and 30-year sustaining period predicted by the UWCD model for the Subbasin, the PVB, and the WLPMA. The sustaining period was assessed because SGMA recognizes that undesirable results may occur during the 20-year implementation period, as basins move toward sustainable groundwater management. In addition to the flux of seawater, particle tracks from the model runs were analyzed to evaluate the potential migration of the current extent of saline water impact in the UAS and the LAS. The particles were placed along the approximate inland extent of the zone of saline water impact in 2015. Scenarios that minimize the net flux of seawater into the Oxnard Subbasin and the landward migration of the saline water impact front over the 30-year sustaining period are sustainable for Oxnard, while those that allow for net seawater intrusion and landward migration of the saline water impact front are not.

None of the model scenarios described in Section 2.4.5 successfully eliminated seawater intrusion in the LAS during the 50-year model period or the 30-year sustaining period, while the majority of the model scenarios resulted in net freshwater loss from the UAS to the Pacific Ocean. Therefore, none of the direct model scenarios was used to estimate the sustainable yield of the Oxnard Subbasin. Instead, the relationship between seawater flux and groundwater production from the model scenarios for both the 50-year period and the 30-year period were plotted graphically and the linear relationship between the seawater flux and groundwater production was used to predict the quantity of groundwater production that would result in no net seawater intrusion over the periods in either the UAS or the LAS. This method is also discussed in Appendix E, Section 2.3.2.2, and the seawater flux and groundwater production plots are provided in Appendix E as Figures 4 and 5. In order to provide separate estimates for the two aquifer systems, independent relationships between groundwater production and seawater intrusion were developed for the UAS and LAS. It was possible to develop relationships for each aquifer within the UAS and LAS, but in general wells in the Oxnard Subbasin are screened in multiple aquifers in each aquifer system. Therefore, for management purposes, the sustainable yield estimates were developed for the aquifer systems rather than for independent aquifers.

The sustainable yield of the UAS was calculated to be approximately 32,000 AFY for both the entire 50-year model period and the 30-year sustaining period. The uncertainty in the estimated sustainable yield for the UAS is lower if only the sustaining period is used. For the entire model period, the uncertainty in the sustainable yield is approximately ± 6,000 AFY, whereas for the sustainable period the uncertainty in the sustainable yield is approximately ± 4,100 AFY. Consequently, this analysis suggests that the sustainable yield of the UAS may be as high as 38,000 AFY or as low as 26,000 AFY.

The sustainable yield of the LAS was calculated to be approximately 7,000 AFY for both the entire 50-year model period and the 30- year sustaining period. The uncertainty in the estimated sustainable yield for the LAS is lower if the entire model period is used. For the entire model period, the uncertainty in the sustainable yield of the LAS is approximately ± 2,300 AFY, whereas for the sustainable period the uncertainty in the sustainable yield is approximately ± 3,600 AFY. Consequently, this analysis suggests that the sustainable yield of the LAS may be as high as 10,600 AFY or as low as 3,400 AFY.

It is anticipated that the analysis for the 5-year update to the GSP will focus on differential extractions on the coast and inland, particularly in the LAS. Additional modeling is recommended for the 5-year update process to understand how changes in pumping patterns can increase the overall sustainable yield of the Oxnard Subbasin. As this understanding improves, projects to support increases in the overall sustainable yield can be developed.

2.5 MANAGEMENT AREAS

In order to sustainably manage the groundwater resources of the Oxnard Subbasin, the Subbasin has been divided into five management areas (Figure 2-69, Oxnard Subbasin Management Areas). These areas are the Forebay Management Area, the West Oxnard Plain Management Area, the Oxnard Pumping Depression Management Area, the Saline Intrusion Management Area, and the East Oxnard Plain Management Area (EOPMA). These areas are separated by hydrogeologic and water quality characteristics.

The Forebay Management Area is in the northeastern Oxnard Subbasin. In this area of the Subbasin, the semi-perched aquifer and clay cap are absent, resulting in direct communication between the alluvium and the underlying aquifer systems. The majority of surface water recharge to the Oxnard Subbasin occurs within the UWCD spreading grounds located in the Forebay Management Area.

The West Oxnard Plain Management Area lies within the Oxnard Subbasin jurisdictional boundaries. The West Oxnard Plain Management Area, which includes the City of Oxnard, is south and west of the Forebay Management Area.

The Oxnard Pumping Depression Management Area is south and east of the West Oxnard Plain Management Area. The boundaries of the Oxnard Pumping Depression Management Area include are Highway 101 to the north, North Rice Avenue and North Rose Avenue to the west, East Hueneme Road and Highway 1 to the south, and the Bailey Fault and the PVB to the east. This management area was established based on the low groundwater elevations historically recorded in both the UAS and the LAS in the area.

The Saline Intrusion Management Area lies to the west of the Oxnard Pumping Depression Management Area, and south of the West Oxnard Plain Management Area. The Saline Intrusion Management Area includes both Port Hueneme and Point Mugu, where saline intrusion has occurred historically and has impacted wells in both the UAS and LAS.

The EOPMA lies to the east of the Bailey Fault and is predominantly within the jurisdiction of the County of Ventura. A small area on the northern boundary between the EOPMA and the PVB is covered by the Camrosa Water District–Oxnard Subbasin GSA (see Figure 1-2).The FCGMA jurisdictional boundary extends into the EOPMA along the boundary with the Oxnard Pumping Depression Management Area (Figure 2-69). This management area was established based on groundwater elevation and chloride concentration differences across the Bailey Fault, which acts as a barrier to groundwater flow (Turner 1975; Section 2.2.1).

This GSP has been prepared for the entire Oxnard Subbasin and management areas defined in this GSP will be managed by the FCGMA. The minimum thresholds and measurable objectives developed in Chapter 3 are based on the data available in the Forebay Management Area, the West Oxnard Plain Management Area, the Oxnard Pumping Depression Management Area, and the Saline Water Intrusion Management Area. Comparable historical data on groundwater elevation, storage, production, and quality are not available for the EOPMA. Therefore, the minimum thresholds and measurable objectives for the West Oxnard Plain and Oxnard Pumping Depression Management Areas, which are adjacent to the EOPMA, will be applied to age and/or depth equivalent hydrostratigraphic units in the EOPMA. As additional data are collected in the EOPMA, separate minimum thresholds and management objectives may be developed. If changes to the minimum thresholds and management objectives are warranted, justification will be provided in the 5-year GSP updates.

2.6 REFERENCES CITED

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Table 2-1
Oxnard Subbasin Stratigraphic and Hydrostratigraphic Nomenclature

Geologic Period	Geologic Epoch	Mukae and Turner (1975)	Kew (1924); Bailey (1951)[a]	Weber and Kiessling (1976)	Dibblee (1992a, 1992b)	Mukae and Turner (1975); DWR (2006)		
		Lithologic Units and Formations				*Hydrostratigraphy*		
Quaternary	**Holocene**	**Alluvium**: Active stream deposits, sand, and gravel; stream, swamp, and lagunal deposits of clay, sand, and gravel	**Recent Alluvium**: Active lagoonal, beach, river, and floodplain and alluvial deposits			**Oxnard**	**Semi-Perched**	**Upper Aquifer System**
	Upper Pleistocene		**Terrace deposits**: Deformed river deposits	**Older Alluvium**: Deformed beach, river, floodplain, and terrace deposits			**Oxnard**	
		Older Alluvium: Clays silts, sands, and gravels from the Santa Clara River				**Mugu**		
			Saugus Formation: Terrestrial and marine sand and gravel	**Saugus Formation**: Terrestrial fluvial	**Saugus Formation**: Terrestrial			
				San Pedro Formation: Marine clays and sand and terrestrial sediment		**Hueneme**		**Lower Aquifer System**
	Lower Pleistocene	**San Pedro Formation**: Marine and nonmarine clay, sand, and gravel			**Las Posas Sand**: Shallow marine sand			
						Fox Canyon		
		Santa Barbara Formation: Marine clay, sand, and gravel		**Santa Barbara Formation**: Shallow marine sand		**Grimes Canyon (upper member)**		
Tertiary	**Pliocene**	**Pico Formation**: Shale, sandstone, and conglomerate	**Fernando Group**			**Non-Freshwater Bearing**		
	Miocene	**Santa Margarita and Modelo Formations**	**Modelo Formation**: Marine mudstones		**Monterey Formation**			
		Topanga Formation and Volcanics	**Conejo Volcanics**: Terrestrial and marine extrusive and intrusive igneous rocks					
	Oligocene/ Eocene	**Older Rocks**	**Sespe Formation**: Sandstone and cobble conglomerate					

Note:

[a] As cited in DeVecchio et al. 2012a.

Table 2-2
Vertical Gradient

Location	Nested Group (First 9 Digits of SWN)	Well (Penultimate 2 Digits of SWN)	Screen Interval		Spring 2015 Elevation (ft msl)	Spring 2015 Gradient (ft/ft)[a]	Fall 2015 Elevation (ft msl)	Fall 2015 Gradient (ft/ft)[a]	Aquifer[b]
			Top	*Bottom*					
Forebay	02N22W23B	09	75	95	NA	—	10.41	−0.643	Oxnard
		08	135	155	−13.06	−0.057	−28.19	−0.019	Oxnard
		07	260	300	−20.72	−0.012	−30.81	−0.028	Mugu
		06	460	500	−23.2	−0.114	−36.43	−0.107	Hueneme
		05	830	870	−65.53	−0.036	−75.84	−0.039	Hueneme
		04	1,110	1,150	−75.59	−0.014	−86.77	0.032	Hueneme
		03	1,210	1,250	−77	—	−83.55	—	Fox
Forebay	02N21W07L	06	135	155	8.2	−0.012	−12.07	−0.042	Mugu
		04	500	540	3.88	−0.014	−27.9	0.022	Fox
		03	640	700	1.84	—	−24.59	—	Fox
North - Coastal	01N23W01C	05	120	145	1.18	−0.040	−0.92	−0.048	Oxnard
		04	630	695	−20.03	−0.009	−26.52	−0.010	Hueneme
		03	965	1,065	−23.24	−0.014	−29.95	−0.010	Hueneme
		02	1,390	1,490	−29.31	—	−34.34	—	Fox
Port Hueneme	01N22W20M	06	50	70	1.27	−0.071	1.8	−0.131	Semi-Perched
		05	150	170	−5.78	−0.004	−11.27	−0.002	Oxnard
		04	280	300	−6.26	−0.033	−11.55	−0.039	Mugu
		03	520	560	−14.6	−0.017	−21.3	−0.019	Hueneme
		02	700	740	−17.57	−0.040	−24.8	−0.048	Hueneme
		01	900	940	−25.65		−34.47		Fox
Port Hueneme	01N22W28G	5	180	200	−7.4	−0.009	−12.4	−0.016	Oxnard
		4	255	275	−8.1	−0.030	−13.6	−0.032	Oxnard
		3	720	760	−22.3	−0.039	−28.8	−0.051	Hueneme
		2	995	1,095	−34.2	0.010	−44.2	0.019	Fox
		1	1,295	1,395	−31.3	—	−38.6	—	GCA

Table 2-2
Vertical Gradient

Location	Nested Group (First 9 Digits of SWN)	Well (Penultimate 2 Digits of SWN)	Screen Interval		Spring 2015 Elevation (ft msl)	Spring 2015 Gradient (ft/ft)[a]	Fall 2015 Elevation (ft msl)	Fall 2015 Gradient (ft/ft)[a]	Aquifer[b]
			Top	*Bottom*					
Point Mugu	01N22W36K	09	175	195	−13.07	−0.110	−24.14	−0.156	Oxnard
		08	310	330	−27.89	−0.220	−45.17	−0.561	Mugu
		07	410	450	−52.06	−0.005	−106.82	−0.019	FCA
		06	540	580	−52.71	−0.025	−109.32	−0.014	FCA
		05	680	720	−56.26	—	−111.34	—	GCA
South/ Central	01N21W19L	14	18	38	11.97	−0.278	10.1	−0.331	Semi-Perched
		13	110	130	−13.63	−0.048	−20.33	−0.096	Oxnard
		12	200	220	−17.93	−0.109	−28.96	−0.119	Oxnard
		11	300	320	−28.85	−0.390	−40.87	−0.620	Mugu
		10	394	414	−65.55	—	−99.19	—	FCA
South	01N21W32Q	06	275	285	−41.21	−0.278	−65	−0.468	Oxnard
		07	180	220	−12.7	−0.356	−20.24	−0.560	Mugu
		05	330	370	−60.7	−0.021	−97.74	−0.028	Mugu
		04	600	640	−66.3	−0.047	−105.38	−0.044	FCA
		03	800	840	−75.6	0.084	−114.17	0.084	GCA
		02	930	970	−64.7	—	−103.2	—	GCA

Notes: FCA = Fox Canyon Aquifer; ft/ft = feet per feet; ft msl = feet above mean sea level; GCA = Grimes Canyon Aquifer; SWN = State Well Number.

[a] Negative gradients are directed downward.

[b] The Oxnard and Mugu Aquifers compose the UAS, and the Hueneme, Fox, and Grimes Aquifers compose the LAS. Aquifer designations were provided by UWCD.

Table 2-3
Seawater/Saline Water Historical Reports and Studies

Title	Author/Agency	Date
Sea Water Intrusion, Oxnard Plain Ventura County	California Department of Water Resources	October 1965
Sea-Water Intrusion: Aquitards in the Coastal Ground Water Basin of Oxnard Plain, Ventura County	California Department of Water Resources, Bulletin No. 63-4	September 1971
Oxnard Plain Groundwater Study	State Water Resources Control Board	March 1979
Chloride Sources in a California Aquifer	John A. Izbicki, U.S. Geological Survey	July 1991
A Study of Seawater Intrusion Using Direct-Current Soundings in the Southeastern Part of the Oxnard Plain, California	U.S. Geological Survey, Open File Report 93-524	1993
Use of δ18O and δD to Define Seawater Intrusion	John A. Izbicki, U.S. Geological Survey	1996
Simulation of Ground-Water/Surface-Water Flow in the Santa Clara–Calleguas Ground-Water Basin, Ventura County, California	Hanson et al., U.S. Geological Survey; Water Resources Investigation Report 02-4136	2003
Mugu Seawater/Saline Water Intrusion Monitoring Program: AB303 Grant, Agreement No. 4600004100	United Water Conservation District	April 2007
2007 Update to the Fox Canyon Groundwater Management Agency Management Plan	Fox Canyon Groundwater Management Agency	2007
Oxnard Plain Time Domain Electromagnetic Study for Saline Intrusion	United Water Conservation District, Open-File Report 2010-003	2010
Saline Intrusion Update, Oxnard Plain and Pleasant Valley Basins	United Water Conservation District	October 2016

Table 2-4
Basin Plan and FCGMA Water Quality Thresholds for Groundwater in the Oxnard Subbasin

Threshold Source	Sub-Area/Zone Description	Threshold Concentration (mg/L)				
		TDS	*Chloride*	*Nitrate*	*Sulfate*	*Boron*
LARWQCB Basin Plan WQO	Oxnard Forebay and Confined Aquifers	1,200	150	45	600	1
	Unconfined and Perched Aquifers	3,000	500	45	1,000	—
FCGMA 2007 BMO	Oxnard Forebay	1,200	—	22.5	—	—
	Oxnard Plain	—	150	—	—	—

Sources: LARWQCB 2013; FCGMA 2007.
Notes: BMO = Basin Management Objective; FCGMA = Fox Canyon Groundwater Management Agency; LARWQCB = Los Angeles Regional Water Quality Control Board; mg/L = milligrams per liter; TDS = total dissolved solids; WQO = Water Quality Objective.

Table 2-5
Modeled Surface Water Percolation from Streams in the Oxnard Subbasin

Water Year[a]	Santa Clara River Percolation (acre-feet)[b]	Calleguas Creek Percolation (acre-feet)
1986	8,466	4,423
1987	115	2,586
1988	10,402	3,572
1989	780	3,308
1990	943	2,140
1991	11,306	2,357
1992	18,255	5,290
1993	19,821	6,274
1994	3,303	3,468
1995	9,085	5,846
1996	560	3,687
1997	3,386	3,953
1998	3,922	6,760
1999	−4,404	3,699
2000	2,973	3,707
2001	4,225	4,770
2002	−521	3,341
2003	10,382	3,571
2004	3,913	1,873
2005	17,975	6,536
2006	−890	3,184
2007	47	1,802
2008	7,073	3,159
2009	4,281	2,617
2010	14,173	2,732
2011	10,803	3,763
2012	3,023	1,890
2013	−268	968
2014	5,821	819
2015	1,520	1,476
Average	**5,682**	**3,452**

Notes:

[a] Results presented are in water years, and will not match values presented in Section 2.4 text and Tables 2-7a through 2-7c, which are presented in calendar years.

[b] Negative numbers represent discharge of groundwater to the stream.

Table 2-6
Ecological Assets

Ecological Assets	Lower Santa Clara River	McGrath Lake	Ormond Beach Wetlands	Mugu Lagoon and Wetlands	Lower Calleguas Creek	Revolon Slough
Locally important, special-status, rare, threatened, or endangered plants or animals supported by the GDE	• Santa Ana sucker • western pond turtle • tidewater goby • coast horned lizard • white rabbit-tobacco • southern riparian scrub • least Bell's vireo *(CDFW 2016)* • steelhead	• Belding's savannah sparrow • burrowing owl • California least tern • least Bell's vireo • salt marsh bird's-beak • sandy beach tiger beetle • silvery legless lizard • Ventura Marsh milk-vetch *(CDFW 2016)* • sandy beach tiger beetle • brown pelican • western least bittern • white-faced ibis • osprey • white-tailed kite • northern harrier • sharp-shinned hawk • Cooper's hawk • light-footed clapper rail • western snowy plover • long-billed curlew • California least tern • western yellow-billed cuckoo • burrowing owl • southwestern willow flycatcher • loggerhead shrike • least Bell's vireo • yellow warbler • yellow-breasted chat • Belding's savannah sparrow • California red-legged frog • southwestern pond turtle • silvery legless lizard • San Diego horned lizard • two-striped garter snake • south coast garter snake • Townsend's big-eared bat *(ESA 2003, Table 3-2)*	• Belding's savannah sparrow • California least tern • Coulter's goldfields • California brackish water snail • salt marsh bird's-beak • tidewater goby • western snowy plover *(CDFW 2016)* • western snowy plover • California least tern • California brown pelican • light-footed clapper rail • least Bell's vireo • Southern California saltmarsh shrew • San Diego black-tailed jackrabbit • double-crested cormorant • American bittern • great blue heron • great egret • snowy egret • black-crowned night heron • white-faced ibis • white-tailed kite • northern harrier • Cooper's hawk • sharp-shinned hawk • merlin • mountain plover • long-billed curlew • western burrowing owl • loggerhead shrike • yellow warbler • California horned lark • tricolored blackbird • south coast garter snake • tiger beetle • sandy beach tiger beetle • wandering skipper • globose dune beetle • red sand-verbena • spiny rush • woolly seablite *(WRA 2007)*	• arroyo chub • Belding's savannah sparrow • burrowing owl • California brown pelican • California least tern • Coulter's goldfields • estuary seablite • ferruginous hawk • globose dune beetle • least Bell's vireo • light-footed clapper rail • salt marsh bird's-beak • sandy beach tiger beetle • senile tiger beetle • southern coastal salt marsh • tidewater goby • wandering (=saltmarsh) skipper • western snowy plover *(CDFW 2016)* • peregrine falcon	• arroyo chub • two-striped gartersnake • least Bell's vireo *(CDFW 2016)*	• arroyo chub *(CDFW 2016)* • least Bell's vireo *(Appendix K)*

Table 2-6
Ecological Assets

Ecological Assets	Lower Santa Clara River	McGrath Lake	Ormond Beach Wetlands	Mugu Lagoon and Wetlands	Lower Calleguas Creek	Revolon Slough
Important or critical habitat provided for native species (USFWS 2016b)	• southwestern willow flycatcher critical habitat (569 acres) • tidewater goby critical habitat (22 acres) • western snowy plover critical habitat (35 acres) • steelhead critical habitat • Audubon California Important Bird Area	• southwestern willow flycatcher critical habitat (32 acres) • tidewater goby critical habitat (18 acres) • Ventura Marsh milk-vetch critical habitat (78 acres) • Audubon California Important Bird Area	• tidewater goby critical habitat (88 acres) • western snowy plover critical habitat (26 acres) • Audubon California Important Bird Area	• western snowy plover critical habitat (51 acres) • Wetland of Regional Importance in the Western Hemisphere Shorebird Reserve Network • Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) are designated for Pacific Coast groundfish and coastal pelagic species in the nearshore marine and estuarine habitats • Laguna Point to Latigo Point Area of Special Biological Significance • Audubon California Important Bird Area	None	None
Portion of GDE that is a recognized wetland (USFWS 2016a; Appendix K)	1,180 acres (93%)	197 acres (71%)	207 acres (96%)	5,943 acres (93%)	6 acres (4%)	2 acres (8%)
Protected area, locally important conservation or wildlife corridor plan areas within the GDE	• The Nature Conservancy (160 acres) • City of Ventura (1.2 acres)	• McGrath State Beach (56 acres) • Mandalay State Beach (29 acres) • Mandalay County Park (0.7 acres)	• The Nature Conservancy (129 acres) • Port Hueneme Beach Park (1.3 acres)	• Point Mugu State Park (0.1 acres)	None	None
List any environmental beneficial uses designated in the RWQCB Basin Plan for the surface water found in the groundwater basin.	• Wildlife Habitat (WILD) • Rare, Threatened, or Endangered Species (RARE) • Migration of Aquatic Organisms (MIGR) • Spawning, Reproduction, and/or Early Development (SPWN) • Wetlands (WET) Also REC1, REC2	• Estuarine Habitat (EST) • Wildlife Habitat (WILD) • Rare, Threatened, or Endangered Species (RARE) • Wetlands (WET) Also REC1, REC2	• Estuarine Habitat (EST) • Wildlife Habitat (WILD) • Rare, Threatened, or Endangered Species (RARE) • Wetlands (WET) Also, REC1, REC2	• Estuarine Habitat (EST) • Marine Habitat (MAR) • Wildlife Habitat (WILD) • Preservation of Biological Habitats of Special Significance (BIOL) • Rare, Threatened, or Endangered Species (RARE) • Migration of Aquatic Organisms (MIGR) • Spawning, Reproduction, and/or Early Development (SPWN) • Shellfish Harvesting (SHELL) • Wetlands (WET) Also REC1 (potential), REC2	**Reach 2:** • WARM • COLD • Wildlife Habitat (WILD) • Rare, Threatened, or Endangered Species (RARE) • Wetlands (WET) Also REC1, REC2	**Reach 4 (Revolon Slough):** • WARM • Wildlife Habitat (WILD) • Wetlands (WET) Also REC1, REC2
Is the GDE area composed of >30% native vegetation? (Appendix K)	Yes	Yes	Yes	Yes	Yes	Yes

Sources: CDFW 2016; GreenInfo Network 2016; USFWS 2016a, 2016b; Appendix K; WRA 2007; ESA 2003.

Table 2-7a
Groundwater Recharge and Discharge in the Semi-Perched Aquifer

Calendar Year[a]	Groundwater Recharge (AF)										Groundwater Discharge (AF)											Storage Change (AF)
	Stream Leakage (Santa Clara River in Oxnard Forebay)	*Recharge*	*Subsurface Inflow from PVB*	*Unincorporated Areas*	*Subsurface Inflow from West LPVB*	*Subsurface Inflow from the UAS*	*Sum of Coastal Flux from Arnold Road to Point Mugu*	*Coastal flux from Channel Islands Harbor to Arnold Road*	*Stream Leakage Calleguas Creek*	*Total Inflow*	*Pumping*	*Tile Drains*	*Subsurface Outflow to UAS*	*Groundwater Discharge to Streams (Santa Clara River in Oxnard Forebay)*	*Evapotranspiration*	*Unincorporated Areas*	*Subsurface Outflow to West LPVB*	*Coastal Flux North to Channel Islands Harbor*	*Coastal flux from Channel Islands Harbor to Arnold Rd*	*Subsurface Outflow to Mound Basin*	*Total Outflow*	*Change in Groundwater Storage[b]*
1985	0	23,081	1,525	152	0	0	843	0	2,592	28,192	−44	−2,983	−15,889	−404	−5,765	0	−374	−2,076	−266	−1,247	−29,050	857
1986	1,133	28,960	1,720	59	0	0	632	0	4,243	36,748	−65	−6,579	−13,989	0	−8,312	0	−66	−1,789	−235	−844	−31,879	−4,869
1987	0	24,587	1,780	16	0	0	672	0	3,097	30,153	−65	−5,886	−18,182	−407	−7,100	0	−335	−1,628	−243	−626	−34,472	4,319
1988	1,021	23,162	1,758	0	0	0	658	0	3,236	29,836	−61	−5,715	−17,824	0	−7,138	−25	−72	−1,442	−206	−622	−33,105	3,269
1989	0	20,613	1,641	0	0	0	667	0	3,146	26,068	−73	−4,848	−19,673	−245	−6,582	−57	−10	−1,315	−188	−451	−33,441	7,373
1990	0	18,731	1,312	0	0	0	701	0	1,901	22,645	−141	−3,032	−22,805	−136	−5,008	−89	0	−1,076	−176	−362	−32,825	10,180
1991	1,857	26,208	1,074	0	0	0	652	0	2,526	32,316	−128	−2,856	−23,955	0	−5,207	−107	−2	−854	−119	−470	−33,698	1,382
1992	4,382	28,816	1,448	0	0	0	567	0	5,661	40,875	−92	−5,605	−19,636	0	−7,684	−84	−47	−773	−25	−645	−34,589	−6,285
1993	3,165	29,069	2,161	0	8	0	552	21	6,209	41,186	−70	−8,637	−8,873	0	−9,404	−25	0	−950	0	−594	−28,553	−12,633
1994	42	21,586	2,249	0	0	0	668	0	3,240	27,784	−89	−7,101	−6,674	0	−7,680	−5	−349	−1,219	−12	−607	−23,735	−4,048
1995	1,563	31,175	3,070	53	105	2,351	558	0	6,037	44,912	−55	−13,095	0	0	−10,618	0	0	−1,449	−85	−609	−25,912	−19,001
1996	521	25,153	3,281	58	0	0	650	0	4,168	33,831	−27	−12,061	−1,148	0	−9,283	0	−223	−1,592	−105	−892	−25,332	−8,498
1997	0	26,109	3,628	69	0	0	652	0	4,050	34,508	−20	−14,177	−6,733	−187	−9,647	0	−266	−1,821	−200	−855	−33,905	−602
1998	598	32,461	4,336	134	811	5,986	542	0	6,184	51,052	−6	−20,912	0	0	−12,445	0	0	−2,006	−257	−575	−36,199	−14,852
1999	0	19,869	4,254	94	0	0	680	0	3,506	28,404	−10	−15,444	−3,958	−585	−9,755	0	−392	−2,008	−244	−975	−33,371	4,967
2000	0	22,718	4,259	69	0	0	660	0	3,706	31,412	−11	−15,051	−8,528	−360	−9,840	0	−342	−2,128	−321	−836	−37,418	6,006
2001	0	27,888	4,414	87	0	0	611	0	4,974	37,974	−8	−17,135	−3,472	−18	−10,797	0	−41	−2,073	−324	−720	−34,589	−3,385
2002	0	19,479	4,219	60	0	0	686	0	3,562	28,007	0	−12,918	−10,775	−199	−8,925	0	−455	−1,944	−299	−779	−36,294	8,287
2003	624	20,846	4,207	62	0	0	664	0	2,610	29,012	0	−13,054	−9,433	0	−9,096	0	−125	−1,897	−290	−755	−34,649	5,637
2004	1,268	23,658	4,131	50	0	0	683	0	3,262	33,052	0	−11,527	−13,653	0	−8,265	0	−59	−1,791	−293	−646	−36,234	3,182
2005	2,113	26,133	4,668	91	430	0	581	0	5,453	39,468	0	−16,632	−625	0	−10,950	0	0	−1,681	−232	−548	−30,668	−8,800
2006	406	22,032	4,622	75	56	2,744	681	0	2,975	33,590	0	−14,711	0	0	−9,156	0	0	−1,697	−189	−794	−26,547	−7,043
2007	0	17,401	4,673	40	0	0	726	0	1,982	24,822	0	−12,812	−9,238	−533	−7,984	0	−626	−1,809	−222	−812	−34,036	9,213
2008	595	21,781	4,791	45	0	0	680	0	3,613	31,505	0	−13,449	−9,365	0	−8,859	0	−156	−1,812	−254	−689	−34,584	3,079
2009	789	19,847	4,711	46	0	0	696	0	2,370	28,458	0	−12,256	−10,893	0	−8,129	0	−157	−1,685	−235	−622	−33,978	5,521
2010	1,851	27,065	4,706	72	0	0	652	0	2,737	37,083	0	−13,439	−10,338	0	−8,689	0	−59	−1,613	−229	−655	−35,022	−2,060
2011	1,022	20,056	4,774	85	0	0	644	0	3,648	30,229	0	−14,172	−3,689	0	−9,306	0	−10	−1,513	−177	−638	−29,506	−723
2012	115	17,308	4,651	59	0	0	720	0	1,813	24,665	0	−11,317	−7,982	0	−7,644	0	−203	−1,498	−166	−622	−29,431	4,766
2013	0	14,694	4,237	23	0	0	745	0	437	20,136	0	−8,415	−13,937	−234	−6,478	0	−17	−1,483	−212	−539	−31,316	11,180
2014	809	18,636	3,467	−9	0	0	720	0	1,489	25,112	0	−6,185	−19,272	0	−5,952	−9	0	−1,358	−257	−534	−33,567	8,446

Table 2-7a
Groundwater Recharge and Discharge in the Semi-Perched Aquifer

Calendar Year[a]	Groundwater Recharge (AF)										Groundwater Discharge (AF)											Storage Change (AF)
	Stream Leakage (Santa Clara River in Oxnard Forebay)	*Recharge*	*Subsurface Inflow from PVB*	*Unincorporated Areas*	*Subsurface Inflow from West LPVB*	*Subsurface Inflow from the UAS*	*Sum of Coastal Flux from Arnold Road to Point Mugu*	*Coastal flux from Channel Islands Harbor to Arnold Road*	*Stream Leakage Calleguas Creek*	*Total Inflow*	*Pumping*	*Tile Drains*	*Subsurface Outflow to UAS*	*Groundwater Discharge to Streams (Santa Clara River in Oxnard Forebay)*	*Evapotranspiration*	*Unincorporated Areas*	*Subsurface Outflow to West LPVB*	*Coastal Flux North to Channel Islands Harbor*	*Coastal flux from Channel Islands Harbor to Arnold Rd*	*Subsurface Outflow to Mound Basin*	*Total Outflow*	*Change in Groundwater Storage[b]*
2015	0	13,543	2,760	−36	0	0	721	0	801	17,790	−2	−4,451	−18,043	−80	−5,322	0	0	−1,048	−177	−401	−29,524	11,734
Maximum	**4,382**	**32,461**	**4,791**	**152**	**811**	**5,986**	**843**	**21**	**6,209**	**51,052**	**0**	**−2,856**	**0**	**0**	**−5,008**	**0**	**0**	**−773**	**0**	**−362**	**−23,735**	**11,734**
Minimum	**0**	**13,543**	**1,074**	**−36**	**0**	**0**	**542**	**0**	**437**	**17,790**	**−141**	**−20,912**	**−23,955**	**−585**	**−12,445**	**−107**	**−626**	**−2,128**	**−324**	**−1,247**	**−37,418**	**−19,001**
Average	**770**	**22,989**	**3,372**	**47**	**45**	**357**	**663**	**1**	**3,394**	**31,639**	**−31**	**−10,531**	**−10,600**	**−109**	**−8,291**	**−13**	**−141**	**−1,582**	**−201**	**−676**	**−32,175**	**535**

Notes: AF = acre-feet; LPVB = Las Posas Valley Basin; PVB = Pleasant Valley Basin; UAS = Upper Aquifer System.

[a] Results from these tables are in calendar years, and will not exactly match data in Table 2−5 and Sections 2.3.2 and 2.3.6, which are presented in water years.

[b] A negative number indicates that water entered storage.

Table 2-7b
Groundwater Recharge and Discharge in the Upper Aquifer System

Calendar Year[a]	Groundwater Recharge (AF)													Groundwater Discharge (AF)														Storage Change (AF)
	Stream Leakage (Santa Clara River in Oxnard Forebay)	*Volcanic Outcrops*	*Recharge*	*Subsurface Inflow from PVB*	*Unincorporated Areas*	*Subsurface Inflow from the Semi-Perched Aquifer*	*Subsurface Inflow from Santa Paula Basin*	*Subsurface Inflow from West LPVB*	*Coastal Flux north to Channel Islands Horbor*	*Coastal flux from Channel Islands Harbor to Arnold Rd*	*Sum of Coastal Flux from Arnold Rd to Point Mugu*	*Subsurface Inflow from the Mound Basin*	*Total Inflow*	*Pumping*	*Tile Drains*	*Subsurface Outflow to the Semi-Perched Aquifer*	*Subsurface Outflow to LAS*	*Subsurface Outflow to West LPVB*	*Groundwater Discharge to Streams (Santa Clara River in Oxnard Forebay)*	*Evapotranspiration*	*Unincorporated Areas*	*Subsurface Outflow to the Santa Paula Basin*	*Subsurface Outflow to PVB*	*Coastal Flux north to Channel Islands Harbor*	*Coastal flux from Channel Islands Harbor to Arnold Rd*	*Subsurface Outflow to Mound Basin*	*Total Outflow*	*Change in Groundwater Storage[b]*
1985	737	5	36,262	0	430	15,889	0	963	742	1,415	2,408	3,014	61,865	−71,157	−356	0	−21,581	0	0	0	0	−1,020	−1,551	0	0	0	−95,665	33,800
1986	6,880	17	63,061	0	0	13,989	0	0	1,254	1,454	2,316	2,227	91,198	−64,234	0	0	−20,735	−2,629	0	0	−52	−968	−613	0	0	0	−89,230	−1,968
1987	1,271	8	35,362	0	431	18,182	0	0	3,076	2,312	3,128	4,181	67,951	−67,347	0	0	−23,240	−137	0	0	0	−744	−15	0	0	0	−91,483	23,532
1988	9,147	8	42,938	142	136	17,824	2,145	0	3,434	2,458	3,150	1,233	82,614	−63,663	0	0	−24,847	−2,053	0	0	0	0	0	0	0	0	−90,563	7,949
1989	530	2	19,007	588	412	19,673	0	0	5,376	2,977	3,402	3,046	55,012	−61,443	0	0	−26,103	−778	0	0	0	−524	0	0	0	0	−88,848	33,835
1990	1,095	2	11,112	1,153	397	22,805	544	0	7,476	3,914	4,095	2,259	54,853	−57,820	0	0	−30,731	−109	0	0	0	0	0	0	0	0	−88,661	33,807
1991	10,696	15	42,247	956	0	23,955	2,244	0	7,221	3,974	4,092	463	95,863	−49,646	0	0	−27,671	−2,705	0	0	−9	0	0	0	0	0	−80,031	−15,832
1992	16,092	22	104,442	0	0	19,636	3,089	0	4,412	2,769	3,084	0	153,544	−45,853	0	0	−24,091	−7,151	0	0	−592	0	−73	0	0	−4,193	−81,953	−71,591
1993	13,448	19	97,426	0	0	8,873	2,372	0	287	1,145	2,051	0	125,620	−47,504	0	0	−25,390	−8,460	0	0	−194	0	−2,107	0	0	−5,603	−89,259	−36,360
1994	2,931	6	52,967	0	394	6,674	837	0	221	857	1,768	0	66,656	−49,868	0	0	−24,598	−4,155	0	0	0	0	−1,808	0	0	−422	−80,853	14,197
1995	8,600	25	102,350	0	0	0	1,039	0	0	133	1,212	0	113,359	−39,520	−292	−2,351	−24,364	−7,649	0	−127	−384	0	−1,346	−1,750	0	−4,568	−82,352	−31,008

Table 2-7b
Groundwater Recharge and Discharge in the Upper Aquifer System

Calendar Year[a]	Groundwater Recharge (AF)													Groundwater Discharge (AF)														Storage Change (AF)
	Stream Leakage (Santa Clara River in Oxnard Forebay)	Volcanic Outcrops	Recharge	Subsurface Inflow from PVB	Unincorporated Areas	Subsurface Inflow from the Semi-Perched Aquifer	Subsurface Inflow from Santa Paula Basin	Subsurface Inflow from West LPVB	Coastal Flux north to Channel Islands Horbor	Coastal flux from Channel Islands Harbor to Arnold Rd	Sum of Coastal Flux from Arnold Rd to Point Mugu	Subsurface Inflow from the Mound Basin	Total Inflow	Pumping	Tile Drains	Subsurface Outflow to the Semi-Perched Aquifer	Subsurface Outflow to LAS	Subsurface Outflow to West LPVB	Groundwater Discharge to Streams (Santa Clara River in Oxnard Forebay)	Evapotranspiration	Unincorporated Areas	Subsurface Outflow to the Santa Paula Basin	Subsurface Outflow to PVB	Coastal Flux north to Channel Islands Harbor	Coastal flux from Channel Islands Harbor to Arnold Rd	Subsurface Outflow to Mound Basin	Total Outflow	Change in Groundwater Storage[b]
1996	2,598	15	56,775	0	128	1,148	310	0	0	0	960	0	61,935	−35,068	−734	0	−22,583	−4,454	0	−119	0	0	−1,375	−2,233	−202	−401	−67,168	5,233
1997	2,300	14	54,861	0	221	6,733	0	0	0	181	1,231	1,123	66,666	−52,122	−532	0	−23,393	−3,560	0	−30	0	−387	−407	−1,139	0	0	−81,568	14,902
1998	0	26	122,199	0	0	0	0	0	0	0	509	0	122,734	−43,078	−967	−5,986	−21,766	−8,501	−663	−420	−625	−4,282	−67	−2,733	−589	−1,247	−90,925	−31,809
1999	0	5	37,762	0	529	3,958	0	0	0	0	639	1,413	44,305	−48,269	−1,180	0	−18,830	−1,847	−2,309	−131	0	−1,162	−106	−2,688	−590	0	−77,113	32,807
2000	3,677	9	54,044	1,084	0	8,528	0	0	0	90	1,047	749	69,228	−45,561	−454	0	−20,784	−2,743	0	0	−38	−500	0	−852	0	0	−70,931	1,704
2001	3,944	19	77,935	1,233	0	3,472	0	0	0	9	949	0	87,561	−42,551	−457	0	−20,746	−4,589	0	0	−69	−1,091	0	−1,447	0	−2,070	−73,019	−14,543
2002	3,129	7	22,151	1,150	432	10,775	1,237	0	0	427	1,191	861	41,360	−44,571	−191	0	−21,202	−1,420	0	0	0	0	0	−319	0	0	−67,703	26,344
2003	7,334	10	36,230	1,803	120	9,433	3,016	0	156	476	1,098	0	59,677	−47,327	0	0	−18,335	−2,591	0	0	0	0	0	0	0	−342	−68,596	8,919
2004	9,742	15	25,471	2,485	149	13,653	3,421	0	1,766	1,170	1,513	86	59,471	−46,670	0	0	−19,410	−2,397	0	0	0	0	0	0	0	0	−68,477	9,006
2005	8,009	18	121,368	1,757	0	625	0	0	0	219	937	0	132,932	−41,034	−222	0	−23,873	−10,233	0	−86	−615	−1,174	0	−1,101	0	−5,909	−84,247	−48,685
2006	0	10	82,755	1,283	72	0	0	0	0	0	665	0	84,785	−42,858	−1,041	−2,744	−22,640	−6,474	−1,416	−244	0	−3,135	0	−2,273	−301	−3,285	−86,411	1,626
2007	1,031	3	31,445	2,419	404	9,238	0	0	0	107	901	828	46,376	−54,564	−430	0	−18,531	−1,122	0	0	0	−683	0	−786	0	0	−76,116	29,740
2008	6,446	11	58,687	3,135	0	9,365	0	0	71	537	1,138	0	79,389	−51,775	−5	0	−21,473	−4,242	0	0	−52	−25	0	0	0	−405	−77,978	−1,412
2009	7,141	7	24,406	3,515	283	10,893	2,661	0	960	815	1,174	259	52,114	−51,431	0	0	−18,696	−1,734	0	0	0	0	0	0	0	0	−71,861	19,748
2010	12,155	20	48,796	3,938	32	10,338	3,016	0	834	785	1,134	0	81,048	−44,145	0	0	−17,864	−3,033	0	0	0	0	0	0	0	−1,365	−66,407	−14,641
2011	5,847	8	73,711	3,049	0	3,689	0	0	0	301	930	0	87,535	−41,608	0	0	−20,530	−6,136	0	0	−216	−244	0	−758	0	−2,941	−72,434	−15,101
2012	2,878	4	22,461	3,162	348	7,982	1,122	0	0	401	1,067	905	40,330	−43,460	0	0	−19,728	−2,338	0	0	0	0	0	−278	0	0	−65,803	25,472
2013	0	0	4,132	3,767	342	13,937	0	0	2,121	1,383	1,803	2,546	30,032	−44,900	0	0	−20,628	−1,388	0	0	0	−27	0	0	0	0	−66,943	36,911
2014	6,504	6	4,860	4,552	229	19,272	2,448	0	4,573	2,641	2,793	2,205	50,084	−43,012	0	0	−24,557	−1,603	0	0	0	0	0	0	0	0	−69,172	19,089
2015	506	1	3,843	4,639	186	18,043	357	0	5,641	3,037	2,955	2,145	41,354	−42,177	0	0	−21,886	−1,304	0	0	0	0	0	0	0	0	−65,367	24,013
Maximum	**16,092**	**26**	**122,199**	**4,639**	**529**	**23,955**	**3,421**	**963**	**7,476**	**3,974**	**4,095**	**4,181**	**153,544**	**−35,068**	**0**	**0**	**−17,864**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**−65,367**	**36,911**
Minimum	**0**	**0**	**3,843**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**509**	**0**	**30,032**	**−71,157**	**−1,180**	**−5,986**	**−30,731**	**−10,233**	**−2,309**	**−420**	**−625**	**−4,282**	**−2,107**	**−2,733**	**−590**	**−5,909**	**−95,665**	**−71,591**
Average	**4,989**	**11**	**50,680**	**1,478**	**183**	**10,600**	**963**	**31**	**1,601**	**1,161**	**1,785**	**953**	**74,434**	**−49,169**	**−221**	**−357**	**−22,284**	**−3,469**	**−142**	**−37**	**−92**	**−515**	**−305**	**−592**	**−54**	**−1,056**	**−78,295**	**3,861**

Notes: AF = acre-feet; LAS = Lower Aquifer System; LPVB = Las Posas Valley Basin; PVB = Pleasant Valley Basin.

[a] Results from these tables are in calendar years, and will not exactly match data in Table 2-5 and Sections 2.3.2 and 2.3.6, which are presented in water years.

[b] A negative number indicates that water entered storage.

Table 2-7c
Groundwater Recharge and Discharge in the Lower Aquifer System

Calendar Year[a]	Groundwater Recharge (AF)										Groundwater Discharge (AF)					Storage Change (AF)
	Subsurface Inflow from PVB	*Subsurface Inflow from the UAS*	*Unincorporated Areas*	*Subsurface Inflow from Santa Paula Basin*	*Subsurface Inflow from West LPVB*	*Coastal Flux north to Channel Islands Harbor*	*Coastal flux from Channel Islands Harbor to Arnold Road*	*Sum of Coastal Flux from Arnold Road to Point Mugu*	*Subsurface Inflow from the Mound Basin*	*Total Inflow*	*Pumping*	*Subsurface Outflow to West LPVB*	*Subsurface Outflow to Santa Paula Basin*	*Subsurface Outflow to PVB*	*Total Outflow*	*Change in Groundwater Storage* [b]
1985	0	21,581	81	0	292	2,954	1,763	1,016	2,014	29,702	−34,579	0	−123	−100	−34,802	5,100
1986	285	20,735	162	0	0	2,900	1,689	899	2,482	29,151	−28,475	−292	−162	0	−28,929	−223
1987	1,146	23,240	71	0	1,091	4,005	2,176	1,185	2,687	35,601	−38,471	0	−1	0	−38,473	2,872
1988	710	24,847	109	0	470	4,187	2,203	1,183	2,272	35,981	−37,023	0	−53	0	−37,076	1,094
1989	43	26,103	77	6	1,569	4,989	2,386	1,210	3,279	39,663	−44,754	0	0	0	−44,754	5,091
1990	1,027	30,731	93	130	1,838	6,233	2,890	1,450	3,174	47,566	−51,926	0	0	0	−51,926	4,359
1991	0	27,671	132	133	911	5,865	2,811	1,392	2,356	41,272	−37,084	0	0	−491	−37,575	−3,698
1992	0	24,091	223	120	0	4,288	2,198	1,070	1,033	33,023	−23,641	−1,474	0	−1,073	−26,188	−6,835
1993	0	25,390	217	63	0	2,764	1,733	964	1,829	32,960	−25,392	−2,170	0	−1,205	−28,767	−4,192
1994	0	24,598	121	48	0	2,964	1,763	952	1,937	32,383	−32,806	−719	0	−263	−33,789	1,406
1995	0	24,364	161	57	0	2,126	1,476	848	2,150	31,184	−24,584	−1,393	0	−235	−26,212	−4,972
1996	0	22,583	125	16	0	1,763	1,351	772	2,031	28,642	−27,440	−866	0	−117	−28,423	−220
1997	167	23,393	118	0	0	2,273	1,604	885	2,679	31,120	−32,248	−557	−28	0	−32,832	1,712
1998	109	21,766	194	0	0	1,114	1,130	656	3,186	28,156	−21,883	−2,093	−13	0	−23,989	−4,167
1999	116	18,830	89	0	0	977	1,132	742	1,285	23,171	−26,844	−834	−77	0	−27,755	4,584
2000	546	20,784	90	0	0	1,814	1,392	886	1,856	27,368	−27,819	−450	−27	0	−28,295	927
2001	1,030	20,746	118	0	0	1,784	1,388	882	1,361	27,310	−23,661	−620	−2	0	−24,282	−3,028
2002	913	21,202	63	14	470	2,483	1,631	875	1,961	29,612	−33,324	0	0	0	−33,324	3,712
2003	210	18,335	61	59	36	2,124	1,444	814	1,906	24,989	−24,017	0	0	0	−24,017	−972
2004	353	19,410	59	39	529	3,060	1,796	888	1,917	28,052	−30,513	0	0	0	−30,513	2,461
2005	819	23,873	211	0	0	1,959	1,426	733	2,961	31,983	−25,225	−1,799	−9	0	−27,033	−4,950
2006	1,430	22,640	120	0	0	1,436	1,284	696	2,672	30,278	−28,316	−999	−83	0	−29,398	−880
2007	1,266	18,531	57	0	0	1,565	1,299	705	2,349	25,772	−27,854	−55	−108	0	−28,016	2,244
2008	1,608	21,473	133	0	195	2,139	1,482	751	2,862	30,643	−30,891	0	−41	0	−30,933	290
2009	1,657	18,696	67	8	772	2,338	1,538	715	2,727	28,519	−30,458	0	0	0	−30,458	1,940
2010	1,162	17,864	103	126	0	2,171	1,402	660	2,719	26,208	−23,680	−136	0	0	−23,816	−2,393
2011	1,618	20,530	143	21	0	1,785	1,359	699	2,725	28,881	−26,984	−1,115	0	0	−28,099	−782
2012	1,431	19,728	71	9	463	2,032	1,405	666	2,864	28,670	−31,169	0	0	0	−31,169	2,500
2013	1,499	20,628	56	0	1,061	3,111	1,853	857	2,921	31,986	−39,159	0	−1	0	−39,160	7,175
2014	1,346	24,557	63	109	1,681	4,593	2,441	1,060	3,150	39,000	−39,905	0	0	0	−39,905	905
2015	1,420	21,886	86	113	1,264	4,690	2,343	1,038	2,838	35,679	−38,635	0	0	0	−38,635	2,956
Maximum	**1,657**	**30,731**	**223**	**133**	**1,838**	**6,233**	**2,890**	**1,450**	**3,279**	**47,566**	**−21,883**	**0**	**0**	**0**	**−23,816**	**7,175**
Minimum	**0**	**17,864**	**56**	**0**	**0**	**977**	**1,130**	**656**	**1,033**	**23,171**	**−51,926**	**−2,170**	**−162**	**−1,205**	**−51,926**	**−6,835**
Average	**707**	**22,284**	**112**	**35**	**408**	**2,854**	**1,735**	**908**	**2,393**	**31,436**	**−31,250**	**−502**	**−24**	**−112**	**−31,888**	**452**

Notes: AF = acre-feet; LPVB = Las Posas Valley Basin; PVB = Pleasant Valley Basin; UAS = Upper Aquifer System.

[a] Results from these tables are in calendar years, and will not exactly match data in Table 2-5 and Sections 2.3.2 and 2.3.6, which are presented in water years.

[b] A negative number indicates that water entered storage.

Table 2-8
UWCD Diversions and Usage of Santa Clara River Water (AF)

Calendar Year	Freeman Diversion	Recharge in Oxnard Forebay Spreading Grounds	PTP Supply Line Deliveries (To Oxnard Subbasin Only)	PVP Supply Line Deliveries to Oxnard Subbasin and Pleasant Valley Basin[a]
1985	42,802	33,837	0	8,738
1986	69,805	59,810	35	9,851
1987	37,638	32,825	2,492	4,560
1988	49,128	40,571	3,709	6,922
1989	24,123	16,920	6,653	5,702
1990	9,553	8,892	9,762	319
1991	44,646	39,289	7,827	1,674
1992	118,151	101,421	7,622	9,320
1993	117,937	94,241	8,462	15,294
1994	71,238	50,588	9,005	12,336
1995	121,235	98,952	8,616	14,014
1996	70,280	54,047	9,513	9,356
1997	71,115	52,006	9,631	11,375
1998	142,279	118,672	7,681	16,064
1999	56,401	35,816	9,017	12,856
2000	71,868	51,793	9,155	11,682
2001	97,061	75,176	6,223	15,635
2002	31,144	20,209	8,632	6,055
2003	47,630	34,111	7,464	6,311
2004	34,160	23,166	8,389	5,245
2005	138,246	118,629	6,470	13,047
2006	101,592	80,554	8,125	12,495
2007	46,430	29,703	8,806	9,908
2008	71,933	56,433	9,639	11,333
2009	40,872	22,438	9,180	14,589
2010	64,005	46,228	7,177	11,555
2011	92,119	71,959	8,700	12,672
2012	37,036	20,816	8,129	10,182
2013	8,941	2,686	8,691	3,230
2014	4,501	2,900	6,644	199
2015	2,607	2,516	5,476	0
Maximum	**142,279**	**118,672**	**9,762**	**16,064**
Minimum	**2,607**	**2,516**	**0**	**0**
Average	**62,467**	**48,297**	**7,320**	**9,114**

Note:

[a] For water supplied by the UWCD PVP to PVCWD, 56% is used in the Oxnard Subbasin and 44% in the Pleasant Valley Basin; only the 56% used in the Oxnard Subbasin is shown in this table.

Table 2-9
United Water Conservation District Water (AF)

Calendar Year	Recharge to Saticoy	Recharge to Noble	Recharge to El Rio	Total Recharge
1985	19,909	0	13,928	33,837
1986	43,407	0	16,403	59,810
1987	16,152	0	16,673	32,825
1988	21,496	0	19,075	40,571
1989	9,729	0	7,192	16,920
1990	3,308	0	5,584	8,892
1991	23,306	0	15,982	39,289
1992	55,606	0	45,815	101,421
1993	45,064	0	49,177	94,241
1994	17,982	0	32,606	50,588
1995	35,419	10,657	52,876	98,952
1996	25,608	3,806	24,633	54,047
1997	22,323	4,412	25,271	52,006
1998	56,935	18,710	43,027	118,672
1999	16,539	1,285	17,992	35,816
2000	28,620	0	23,173	51,793
2001	26,918	8,824	39,434	75,176
2002	5,291	32	14,886	20,209
2003	7,158	44	26,909	34,111
2004	8,105	0	15,061	23,166
2005	46,872	19,490	52,267	118,629
2006	29,005	10,709	40,840	80,554
2007	11,404	99	18,200	29,703
2008	28,631	8,562	19,240	56,433
2009	9,215	0	13,223	22,438
2010	15,108	995	30,125	46,228
2011	23,435	10,679	37,845	71,959
2012	3,985	538	16,293	20,816
2013	34	263	2,389	2,686
2014	387	578	1,935	2,900
2015	1,231	0	1,285	2,516
Maximum	**56,935**	**19,490**	**52,876**	**118,672**
Minimum	**34**	**0**	**1,285**	**2,516**
Average	**21,232**	**3,216**	**23,850**	**48,297**

Table 2-10
Summary of Water Deliveries

Calendar Year	PVCWD (AF)[a]			United Water Conservation District (AF)											Total UWCD and PVCWD Water Deliveries in Oxnard Subbasin (AF)
				PTP (Oxnard Subbasin Only)					O-H Supply Line (Oxnard Subbasin Only)			PVP (Oxnard Subbasin and Pleasant Valley Basin)[c]			
	Conejo Creek Flows Delivered by CWD for Agriculture[b]	*Pumped Groundwater from Oxnard Subbasin Basin*	*Total PVCWD Water Delivered*	*PTP Wells 1–5 (LAS)*	*Saticoy Wells (UAS)*	*Total PTP Groundwater Pumpage*	*Total PTP Surface Water*	*Total PTP Water*	*Municipal Deliveries*	*Agriculture Deliveries*	*Total O-H Water*	*Diversions of Santa Clara River Water Used in the Oxnard Subbasin for Agriculture*	*Recharged Spreading Water Pumped and Used in the Oxnard Subbasin for Agriculture (Saticoy Wells)*[d]	*Total PVP Water*	
1985	0	−170	−170	0	0	0	0	0	13,901	0	13,901	4,893	0	4,893	18,624
1986	0	−282	−282	0	0	0	35	35	14,096	0	14,096	5,517	0	5,517	19,366
1987	0	−231	−231	2,321	0	2,321	171	2,492	15,364	0	15,364	2,554	0	2,554	20,179
1988	0	387	387	2,184	0	2,184	1,525	3,709	15,513	0	15,513	3,876	0	3,876	23,486
1989	0	121	121	5,301	0	5,301	1,352	6,653	14,494	0	14,494	3,193	0	3,193	24,462
1990	0	273	273	9,506	0	9,506	256	9,762	14,757	0	14,757	179	0	179	24,971
1991	0	708	708	5,042	0	5,042	2,785	7,827	12,644	0	12,644	938	0	938	22,117
1992	0	−604	−604	989	0	989	6,633	7,622	12,669	0	12,669	5,219	0	5,219	24,906
1993	0	−197	−197	825	0	825	7,637	8,462	14,977	0	14,977	8,565	0	8,565	31,807
1994	0	−369	−369	1,564	0	1,564	7,441	9,005	13,092	0	13,092	6,908	0	6,908	28,635
1995	0	−308	−308	1,128	0	1,128	7,488	8,616	8,664	0	8,664	7,848	0	7,848	24,820
1996	0	−1,007	−1,007	3,264	0	3,264	6,249	9,513	6,881	0	6,881	5,239	0	5,239	20,627
1997	0	−425	−425	2,389	0	2,389	7,242	9,631	17,776	0	17,776	6,370	0	6,370	33,351
1998	0	107	107	511	0	511	7,170	7,681	16,784	0	16,784	8,996	0	8,996	33,567
1999	0	−119	−119	2,142	0	2,142	6,875	9,017	17,671	0	17,671	7,200	0	7,200	33,769
2000	0	−376	−376	1,341	0	1,341	7,814	9,155	14,043	79	14,122	6,542	0	6,542	29,442
2001	0	−484	−484	423	0	423	5,800	6,223	13,337	0	13,337	8,756	0	8,756	27,832
2002	1,468	−145	1,323	4,120	0	4,120	4,512	8,632	14,132	786	14,918	3,391	0	3,391	28,264
2003	3,364	−298	3,066	758	0	758	6,706	7,464	16,759	0	16,759	3,534	0	3,534	30,823
2004	2,995	−767	2,228	2,682	0	2,682	5,276	7,958	11,644	431	12,075	2,937	0	2,937	25,197
2005	3,115	−1,051	2,064	59	0	59	6,411	6,470	9,796	0	9,796	7,307	0	7,307	25,636
2006	3,607	2	3,609	105	0	105	8,020	8,125	9,906	0	9,906	6,997	0	6,997	28,637
2007	3,382	−41	3,342	898	696	1,594	7,211	8,806	22,763	0	22,763	5,245	303	5,548	40,459
2008	2,718	−213	2,505	2,936	1,452	4,388	5,251	9,639	17,304	51	17,356	5,534	813	6,347	35,846
2009	2,239	−218	2,021	2,995	685	3,680	5,500	9,180	18,160	68	18,228	7,179	990	8,170	37,598
2010	2,733	77	2,810	512	382	894	6,283	7,177	15,709	19	15,727	6,260	211	6,471	32,185
2011	3,598	164	3,762	817	254	1,071	7,629	8,700	10,747	0	10,747	6,826	271	7,096	30,305
2012	2,415	−5	2,410	929	1,031	1,960	6,169	8,129	14,210	0	14,210	5,389	313	5,702	30,451
2013	1,822	101	1,923	4,647	349	4,996	2,696	7,692	12,854	998	13,852	1,737	72	1,809	25,276

Table 2-10
Summary of Water Deliveries

	PVCWD (AF)[a]			United Water Conservation District (AF)											Total UWCD and PVCWD Water Deliveries in Oxnard Subbasin (AF)
				PTP (Oxnard Subbasin Only)					*O-H Supply Line (Oxnard Subbasin Only)*			*PVP (Oxnard Subbasin and Pleasant Valley Basin)[c]*			
Calendar Year	*Conejo Creek Flows Delivered by CWD for Agriculture[b]*	*Pumped Groundwater from Oxnard Subbasin Basin*	*Total PVCWD Water Delivered*	*PTP Wells 1–5 (LAS)*	*Saticoy Wells (UAS)*	*Total PTP Groundwater Pumpage*	*Total PTP Surface Water*	*Total PTP Water*	*Municipal Deliveries*	*Agriculture Deliveries*	*Total O-H Water*	*Diversions of Santa Clara River Water Used in the Oxnard Subbasin for Agriculture*	*Recharged Spreading Water Pumped and Used in the Oxnard Subbasin for Agriculture (Saticoy Wells)[d]*	*Total PVP Water*	
2014	1,151	−287	864	7,027	0	7,027	22	7,049	10,773	0	10,773	112	0	112	18,798
2015	1,319	−876	443	5,476	0	5,476	0	5,476	10,920	0	10,920	0	0	0	16,839
Maximum	**3,607**	**708**	**3,762**	**9,506**	**1,452**	**9,506**	**8,020**	**9,762**	**22,763**	**998**	**22,763**	**16,064**	**990**	**8,996**	**40,459**
Minimum	**0**	**−1,051**	**−1,007**	**0**	**0**	**0**	**0**	**0**	**6,881**	**0**	**6,881**	**0**	**0**	**0**	**16,839**
Average	**1,159**	**−211**	**948**	**2,351**	**156**	**2,508**	**4,779**	**7,287**	**13,947**	**78**	**14,025**	**9,113**	**96**	**5,104**	**27,364**

Notes: AF = acre-feet; CWD = Camrosa Water District; LAS = Lower Aquifer System; O-H = Oxnard–Hueneme; PTP = Pumping Trough Pipeline; PVCWD = Pleasant Valley County Water District; PVP = Pleasant Valley Pipeline; UAS = Upper Aquifer System; UWCD = United Water Conservation District.

[a] Negative value indicates groundwater pumped in the Oxnard Subbasin and used in Pleasant Valley.

[b] For water supplied by Camrosa Water District to PVCWD, 56% is used in the Oxnard Subbasin and 44% in the Pleasant Valley Basin; only the 56% used in the Oxnard Subbasin is shown in this table.

[c] For water supplied via the UWCD PVP to PVCWD, 56% is used in the Oxnard Subbasin and 44% in the PVB; only the 56% used in the Oxnard Subbasin is shown in this table.

[d] UWCD extracts limited amounts of temporarily stored water from shallow wells at its Saticoy Spreading Grounds to the PVP during periods of mounding, as authorized by FCGMA Resolution 2011-02.

Table 2-11
Recharge by Type (AF)

Calendar Year	UWCD Spreading	Precipitation	Pumped Groundwater	Applied Water (M&I and Domestic)	PTP/PVP System	Total Recharge
1985	33,837	4,937	18,562	753	1,254	59,343
1986	59,810	14,048	16,017	747	1,399	92,021
1987	32,825	7,149	17,878	744	1,353	59,949
1988	40,579	6,096	16,719	771	1,934	66,100
1989	16,920	2,130	17,158	869	2,542	39,620
1990	8,904	1,502	16,449	939	2,051	29,844
1991	39,289	11,869	14,044	745	2,510	68,455
1992	101,421	15,752	11,886	863	3,336	133,258
1993	94,241	15,461	11,778	784	4,230	126,494
1994	50,588	6,173	12,936	853	4,003	74,553
1995	98,952	19,121	10,501	874	4,075	133,525
1996	54,047	12,566	10,908	635	3,771	81,928
1997	52,261	10,592	13,396	725	3,995	80,970
1998	118,672	21,656	9,555	755	4,022	154,660
1999	35,816	4,927	11,928	846	4,114	57,631
2000	51,793	8,733	11,216	1,113	3,906	76,762
2001	75,176	15,715	10,105	1,079	3,748	105,823
2002	20,209	5,728	11,440	1,116	3,137	41,630
2003	34,111	8,670	9,949	1,003	3,343	57,076
2004	23,166	10,322	10,642	1,342	3,658	49,129
2005	118,629	14,794	8,733	1,292	4,053	147,501
2006	80,554	8,575	9,855	1,239	4,564	104,786
2007	29,703	2,704	11,588	779	4,072	48,846
2008	56,433	7,548	10,761	1,036	4,689	80,468
2009	22,438	6,057	10,135	932	4,690	44,252
2010	46,228	16,086	8,695	954	3,899	75,861
2011	71,959	6,759	9,425	1,079	4,544	93,767
2012	20,816	3,695	10,640	975	3,643	39,768
2013	2,686	735	11,663	1,044	2,698	18,825
2014	2,900	6,182	11,404	1,011	1,999	23,496
2015	2,516	1,064	11,278	857	1,671	17,386
Maximum	**118,672**	**21,656**	**18,562**	**1,342**	**4,690**	**154,660**

Table 2-11
Recharge by Type (AF)

Calendar Year	UWCD Spreading	Precipitation	Pumped Groundwater	Applied Water (M&I and Domestic)	PTP/PVP System	Total Recharge
Minimum	**2,516**	**735**	**8,695**	**635**	**1,254**	**17,386**
Average	**48,306[a]**	**8,947**	**12,169**	**928**	**3,319**	**73,669**

Notes: AF = acre-feet; M&I = municipal and industrial; PTP = Pumping Trough Pipeline; PVP = Pleasant Valley Pipeline; UWCD = United Water Conservation District.

[a] The difference between 48,306 AFY in this table and 48,279 AFY in Table 2-9 is caused by how UWCD tracks monthly spreading. The UWCD hydrologist entered a negative number in some of the monthly records to reconcile their percolation total. So for the following 3 months, Table 2-7 has:

- August 1988 recharge to Saticoy is −8 acre-feet.
- April 1990 recharge to Saticoy is −11.34 acre-feet.
- September 1997 recharge to Saticoy is −255.06 acre-feet.

Table 2-12
Stream Flows in Arroyo Las Posas and Conejo Creek, and Conejo Creek Diversion and Deliveries to the Pleasant Valley County Water District (AF)

Calendar Year	Arroyo Las Posas Flows Measured at Stream Gauge 806 until 1997 and 806A to 2005	Conejo Creek Flows Measured at Stream Gauge 800 until 2011 and 800A to 2012	Conejo Creek Water Delivered by CWD for Agriculture (AF)[a]	Conejo Creek Flows Delivered by CWD for Agriculture In PVCWD[b]	Conejo Creek Flows Delivered by CWD for M&I	Total CWD Conejo Creek Flows Diversions
1985	1,174	14,265	2,450	0	0	2,450
1986	11,707	25,621	2,450	0	0	2,450
1987	3,487	16,851	2,450	0	0	2,450
1988	3,256	16,922	2,450	0	0	2,450
1989	840	14,785	2,450	0	0	2,450
1990	1,068	12,608	2,450	0	0	2,450
1991	9,715	20,227	2,450	0	0	2,450
1992	26,792	44,305	2,450	0	0	2,450
1993	27,749	52,306	2,450	0	0	2,450
1994	2,956	16,195	2,450	0	0	2,450
1995	26,984	45,909	2,450	0	0	2,450
1996	9,919	22,862	2,450	0	0	2,450
1997	10,742	22,905	2,450	0	0	2,450
1998	47,361	49,704	2,450	0	0	2,450
1999	923	16,479	2,450	0	0	2,450
2000	4,884	18,000	2,450	0	0	2,450
2001	18,819	28,092	2,450	0	0	2,450
2002	3,003	16,744	2,450	2,621	0	5,071
2003	12,973	21,592	1,249	6,008	256	7,513
2004	13,757	23,522	1,345	5,348	276	6,969
2005	54,549	46,396	1,639	5,562	336	7,537
2006	NA	23,175	1,457	6,441	298	8,196

Table 2-12
Stream Flows in Arroyo Las Posas and Conejo Creek, and Conejo Creek Diversion and Deliveries to the Pleasant Valley County Water District (AF)

Calendar Year	Arroyo Las Posas Flows Measured at Stream Gauge 806 until 1997 and 806A to 2005	Conejo Creek Flows Measured at Stream Gauge 800 until 2011 and 800A to 2012	Conejo Creek Water Delivered by CWD for Agriculture (AF)[a]	Conejo Creek Flows Delivered by CWD for Agriculture In PVCWD[b]	Conejo Creek Flows Delivered by CWD for M&I	Total CWD Conejo Creek Flows Diversions
2007	NA	17,048	3,288	6,040	674	10,002
2008	NA	25,254	2,895	4,854	358	8,107
2009	NA	19,099	3,225	3,998	673	7,896
2010	NA	20,293	2,554	4,880	594	8,028
2011	NA	17,518	2,359	6,425	533	9,317
2012	NA	7,612	2,603	4,312	653	7,568
2013	NA	NA	2,999	3,253	754	7,006
2014	NA	NA	2,858	2,055	854	5,767
2015	NA	NA	2,555	2,355	794	5,704
Maximum	**54,549**	**52,306**	**3,288**	**6,441**	**854**	**10,002**
Minimum	**840**	**7,612**	**1,249**	**0**	**0**	**2,450**
Average	**13,936**	**24,153**	**2,423**	**2,069**	**227**	**4,720**

Notes: AF = acre-feet; CWD = Camrosa Water District; M&I = municipal and industrial; NA = not applicable; PVCWD = Pleasant Valley County Water District.

[a] 2,450 AFY between 1985 and 2002 accounts for riparian water rights holders' use of Conejo Creek water prior to development of CWD's Diversion Facility and non-potable surface water system. Between 2003 and 2006, deliveries are less than previous assumptions as not all riparian customers had connected to the CWD non-potable system. It is fair to assume the difference between those volumes and 2,450 were still applied to land.

[b] For water supplied by CWD to PVCWD, 56% is used in the Oxnard Subbasin and 44% in the PVB.

Table 2-13
Sales and Usage of Imported Water Supplied by the Calleguas Municipal Water District (AF)

Calendar Year	Delivered and Used by the City of Oxnard for M&I	Delivered and Used by Port Hueneme Water Agency for M&I	Total Imported Water Supplied
1985	14,094	0	14,094
1986	14,023	0	14,023
1987	14,422	0	14,422
1988	14,565	0	14,565
1989	15,026	0	15,026
1990	16,853	0	16,853
1991	12,705	0	12,705
1992	15,576	0	15,576
1993	14,799	0	14,799
1994	11,441	0	11,441
1995	14,513	0	14,513
1996	12,392	64	12,456
1997	13,615	641	14,256
1998	12,675	2,234	14,909
1999	14,721	2,615	17,336
2000	14,487	2,935	17,422
2001	13,201	1,731	14,932
2002	13,591	3,054	16,645
2003	12,858	1,072	13,930
2004	13,742	1,595	15,337
2005	12,447	1,590	14,037
2006	11,994	2,067	14,061
2007	14,008	2,221	16,229
2008	15,150	1,197	16,347
2009	10,431	1,278	11,709
2010	11,238	838	12,076
2011	11,506	1,072	12,578
2012	13,474	1,047	14,521
2013	15,331	2,011	17,342
2014	13,550	1,483	15,033
2015	11,116	556	11,672
Maximum[a]	**16,853**	**3,054**	**17,422**
Minimum[a]	**10,431**	**64**	**11,441**
Average[a]	**13,534**	**1,565**	**14,543**

Notes: AF = acre-feet; M&I = municipal and industrial.
[a] Maximum, minimum, and average values are calculated for the period over which water deliveries occurred.

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Table 2-14
Oxnard Subbasin Groundwater Used

Calendar Year	Agricultural Pumpage (AF)				M&I Pumpage (AF)				Domestic Pumpage (AF)				Totals (AF)			
	Pumpage (UAS)	*Pumpage (LAS)*	*Pumpage (Semi-Perched)*	*Total Agricultural*	*Pumpage (UAS)*	*Pumpage (LAS)*	*Pumpage (Semi-Perched)*	*Total M&I*	*Pumpage (UAS)*	*Pumpage (LAS)*	*Pumpage (Semi-Perched)*	*Total Domestic*	*Pumpage (UAS)*	*Pumpage (LAS)*	*Pumpage (Semi-Perched)*	*Total Pumpage*
1985	42,652	27,990	26	70,669	23,578	5,996	15	29,589	4,926	593	3	5,522	71,157	34,579	44	105,780
1986	36,285	23,167	37	59,489	24,196	5,038	24	29,258	3,752	270	4	4,026	64,234	28,475	65	92,773
1987	39,028	33,285	38	72,350	25,198	5,004	24	30,226	3,122	182	3	3,307	67,347	38,471	65	105,883
1988	34,505	31,938	33	66,476	26,475	4,574	25	31,074	2,683	511	3	3,196	63,663	37,023	61	100,746
1989	34,238	35,435	41	69,713	24,548	8,521	29	33,098	2,657	798	3	3,458	61,443	44,754	73	106,269
1990	34,082	42,137	83	76,302	23,000	9,780	56	32,837	738	8	2	748	57,820	51,926	141	109,887
1991	25,830	30,008	67	55,905	19,682	7,068	51	26,801	4,134	7	11	4,152	49,646	37,084	128	86,858
1992	24,076	20,070	48	44,194	21,286	3,562	43	24,892	491	9	1	501	45,853	23,641	92	69,587
1993	23,621	19,757	35	43,413	23,294	5,626	34	28,954	589	8	1	598	47,504	25,392	70	72,966
1994	26,820	23,981	48	50,849	22,505	8,818	40	31,363	544	7	1	552	49,868	32,806	89	82,764
1995	21,580	17,759	30	39,369	17,335	6,818	24	24,177	605	7	1	613	39,520	24,584	55	64,159
1996	21,642	22,211	17	43,870	12,866	5,221	10	18,096	560	8	0	568	35,068	27,440	27	62,535
1997	25,190	25,725	10	50,925	26,612	6,515	10	33,138	320	8	0	327	52,122	32,248	20	84,390
1998	20,263	15,279	3	35,545	22,611	6,597	3	29,211	204	7	0	211	43,078	21,883	6	64,966
1999	23,082	23,765	5	46,852	24,871	3,073	5	27,949	316	5	0	322	48,269	26,844	10	75,123
2000	21,982	21,027	5	43,014	23,380	6,788	6	30,174	199	4	0	203	45,561	27,819	11	73,390
2001	19,046	17,194	4	36,244	23,292	6,460	5	29,757	212	6	0	219	42,551	23,661	8	66,220
2002	20,837	24,502	0	45,338	23,555	8,819	0	32,374	179	3	0	182	44,571	33,324	0	77,895
2003	17,772	17,645	0	35,417	29,374	6,368	0	35,742	182	4	0	186	47,327	24,017	0	71,345
2004	19,299	21,732	0	41,031	27,091	8,775	0	35,866	280	6	0	286	46,670	30,513	0	77,183
2005	16,464	15,140	0	31,604	24,213	10,080	0	34,292	357	5	0	362	41,034	25,225	0	66,258
2006	18,290	16,268	0	34,558	24,405	12,044	0	36,449	163	4	0	168	42,858	28,316	0	71,174
2007	24,110	20,802	0	44,912	30,289	7,047	0	37,336	165	5	0	170	54,564	27,854	0	82,418
2008	23,618	22,853	0	46,471	27,999	8,034	0	36,033	159	5	0	163	51,775	30,891	0	82,667
2009	20,027	22,784	0	42,811	31,272	7,670	0	38,942	132	5	0	137	51,431	30,458	0	81,890
2010	17,056	16,767	0	33,822	26,963	6,890	0	33,853	126	23	0	150	44,145	23,680	0	67,825
2011	18,648	18,253	0	36,901	22,832	8,725	0	31,558	128	6	0	134	41,608	26,984	0	68,592
2012	20,914	22,376	0	43,290	22,415	8,790	0	31,205	131	3	0	134	43,460	31,169	0	74,629
2013	22,514	29,341	0	51,855	22,202	9,816	0	32,018	184	2	0	186	44,900	39,159	0	84,059
2014	22,536	32,236	0	54,772	20,224	7,667	0	27,891	252	2	0	254	43,012	39,905	0	82,917
2015	23,102	32,870	1	55,973	18,884	5,762	1	24,648	191	3	0	193	42,177	38,635	2	80,814
Maximum	**42,652**	**42,137**	**83**	**76,302**	**31,272**	**12,044**	**56**	**38,942**	**4,926**	**798**	**11**	**5,522**	**71,157**	**51,926**	**141**	**109,887**
Minimum	**16,464**	**15,140**	**0**	**31,604**	**12,866**	**3,073**	**0**	**18,096**	**126**	**2**	**0**	**134**	**35,068**	**21,883**	**0**	**62,535**
Average	**24,487**	**24,010**	**17**	**48,514**	**23,756**	**7,160**	**13**	**30,929**	**925**	**81**	**1**	**1,007**	**49,169**	**31,250**	**31**	**80,450**

Notes: AF = acre-feet; LAS = Lower Aquifer System; M&I = municipal and industrial; UAS = Upper Aquifer System.
Pumping amounts are from the UWCD model and usage type is from the FCGMA well database.

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Table 2-15
Modeled 2040–2069 Groundwater Extraction Rates and Surface Water Deliveries for the Oxnard Subbasin

Model Scenario	Upper Aquifer System Groundwater Extractions (AFY)	Lower Aquifer System Groundwater Extractions (AFY)	Total Groundwater Extractions (AFY)
Future Baseline	39,000	29,000	68,000
Future Baseline With Projects	41,000	25,000	66,000
Reduction With Projects	27,000	13,000	40,000
Reduction Without Projects Scenario 1	27,000	12,000	39,000
Reduction Without Projects Scenario 2	18,000	12,000	30,000
Reduction Without Projects Scenario 3	18,000	12,000	30,000

Notes: AFY = acre-feet per year.

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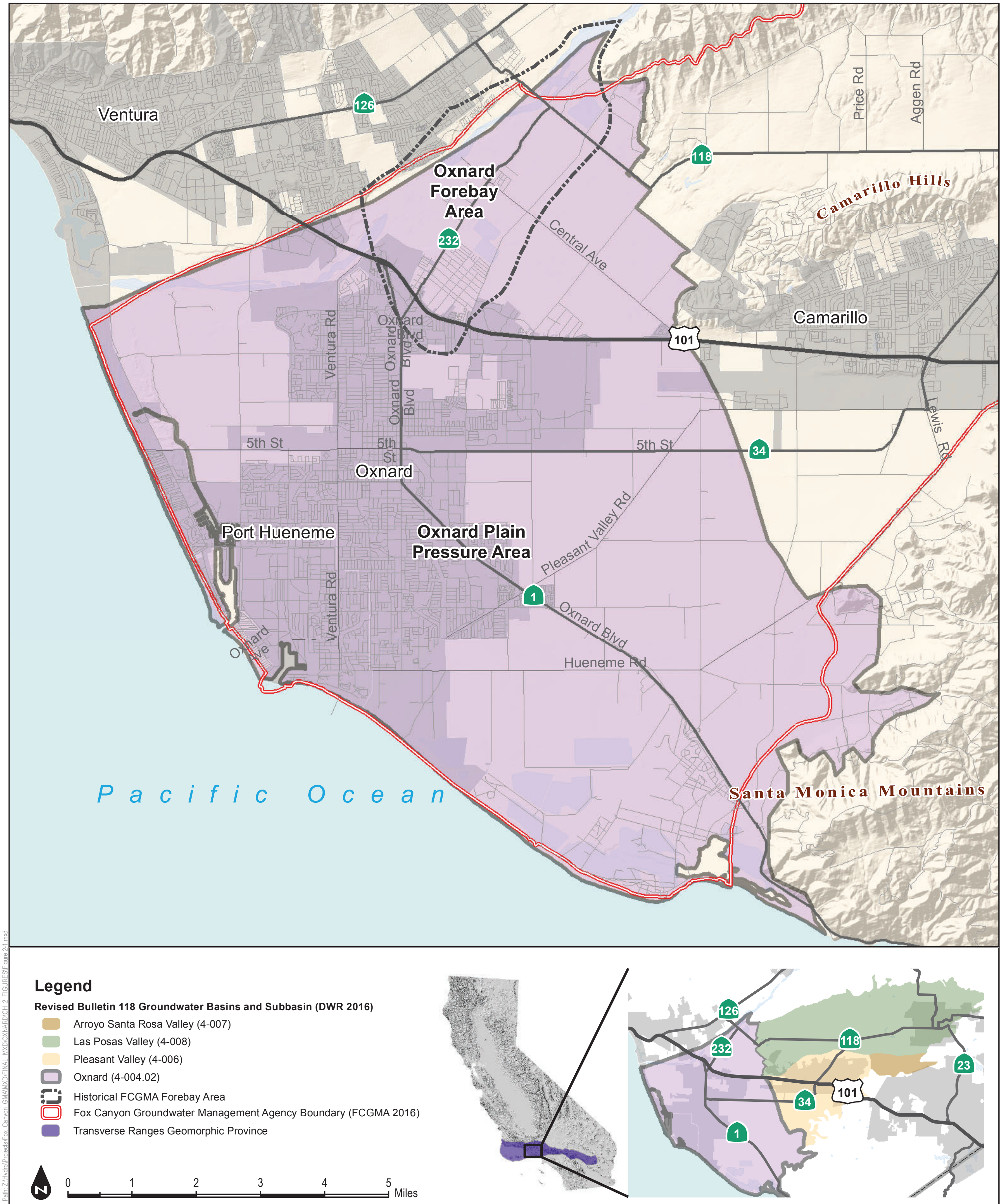

DUDEK

SOURCE: CGS 2002; DWR 2016; Cal-Atlas 2016; FCGMA 2016

FIGURE 2-1

Oxnard Subbasin Vicinity Map

Groundwater Sustainability Plan for the Oxnard Subbasin

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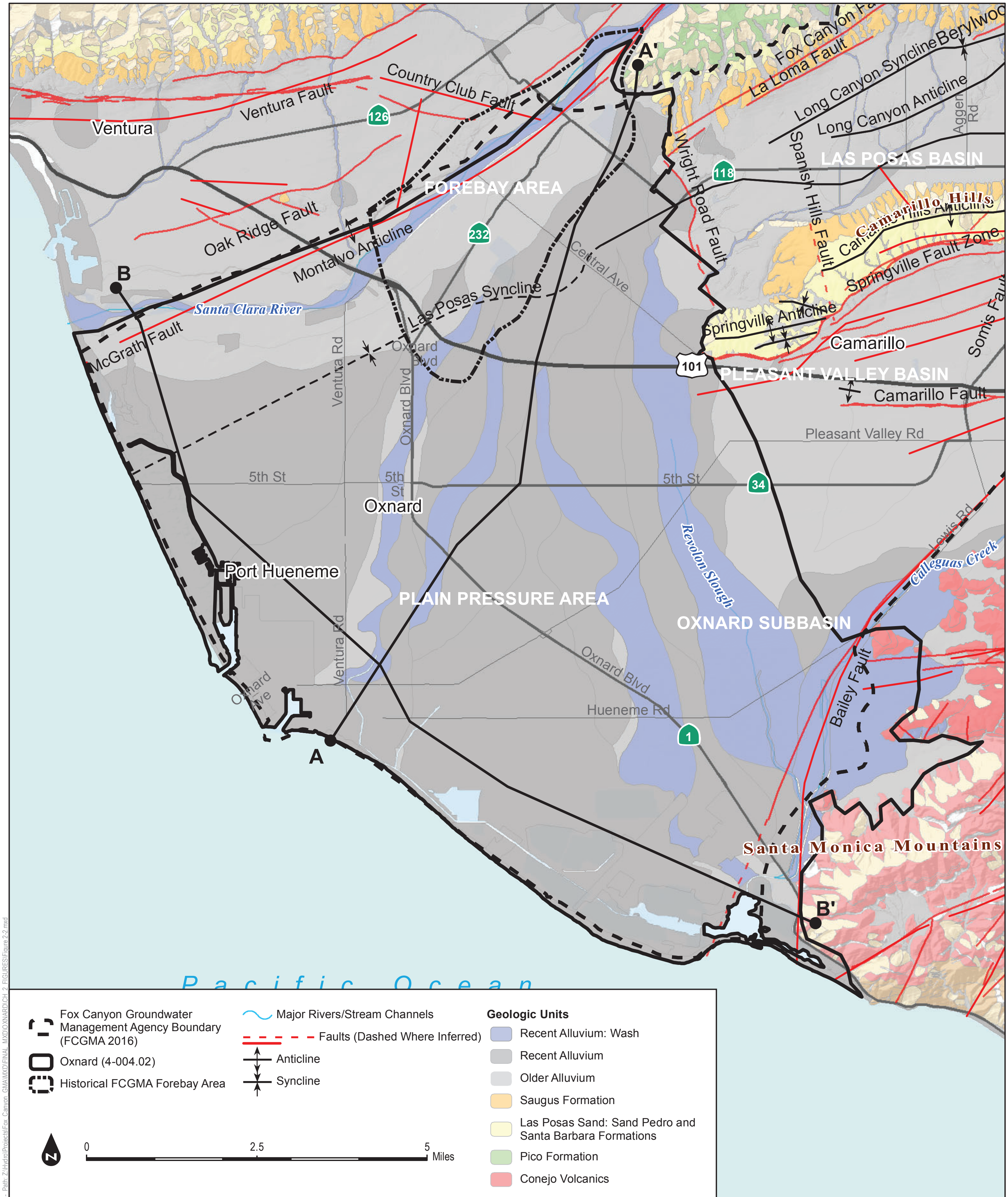

DUDEK

SOURCE: DWR; FCGMA; surficial geology after California Geological Survey; folds after Dibblee 1992a and 1992b, Devecchio 2012a, Turner 1975; faults after DeVecchio et al. 2012a

FIGURE 2-2

Geology of the Oxnard Subbbasin

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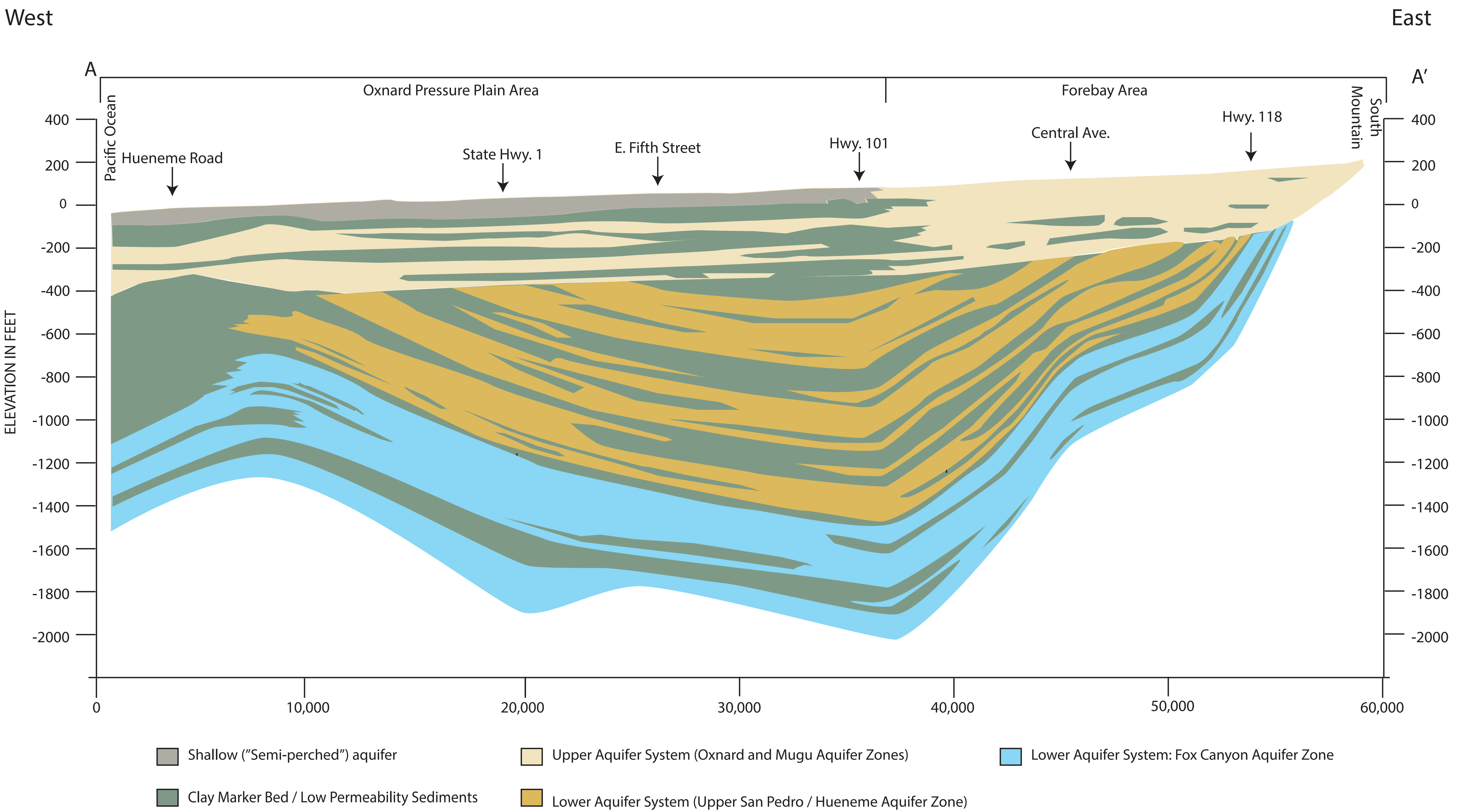

SOURCE: Turner 1975; Based on Plates 9A and 9B (Cross Section C-C').

DUDEK

FIGURE 2-3
Cross Section A-A'

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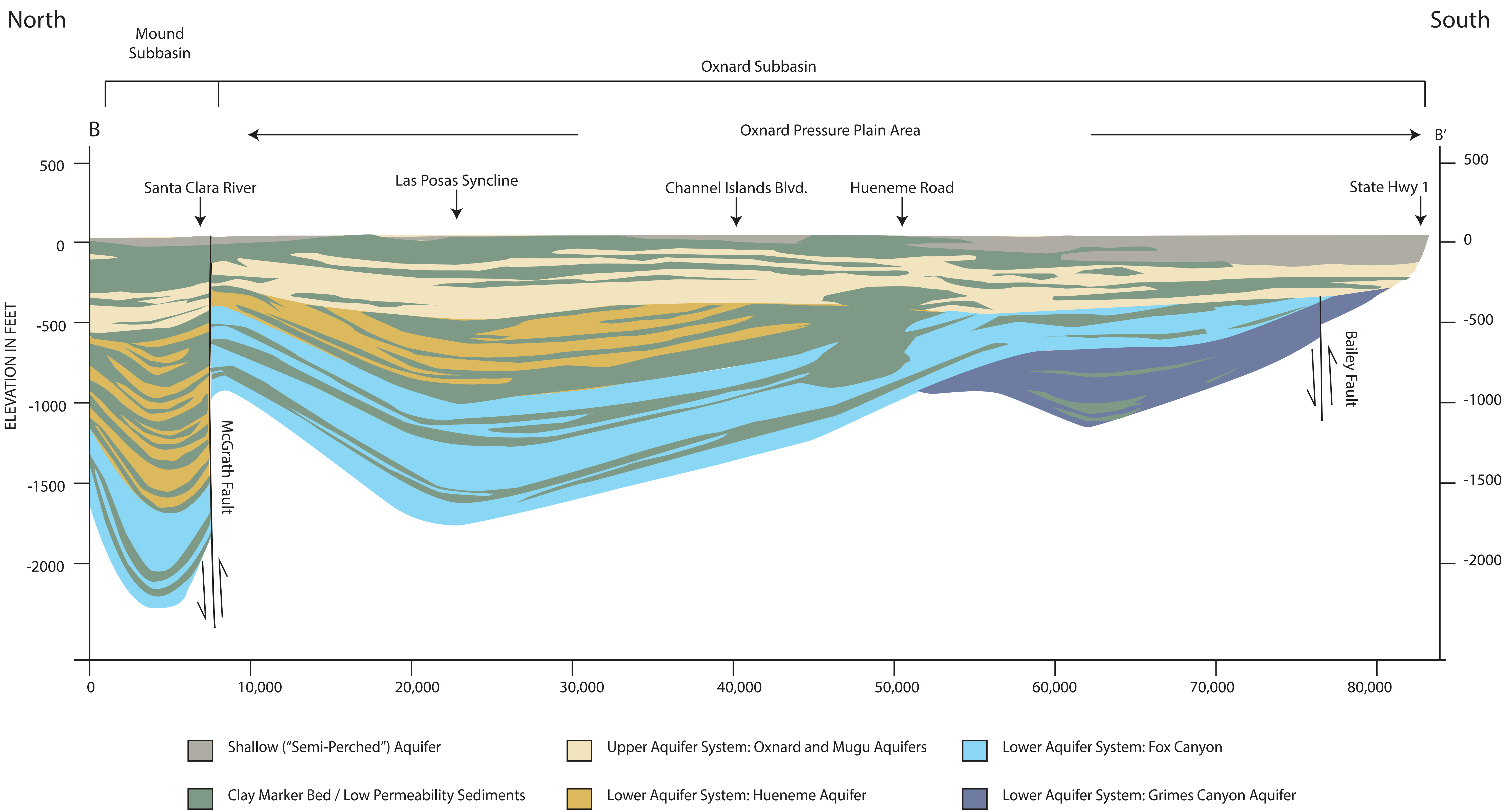

SOURCE: Turner 1975; Based on Plates 7A and 7B (Cross Section A-A').

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FIGURE 2-4
Cross Section B-B'

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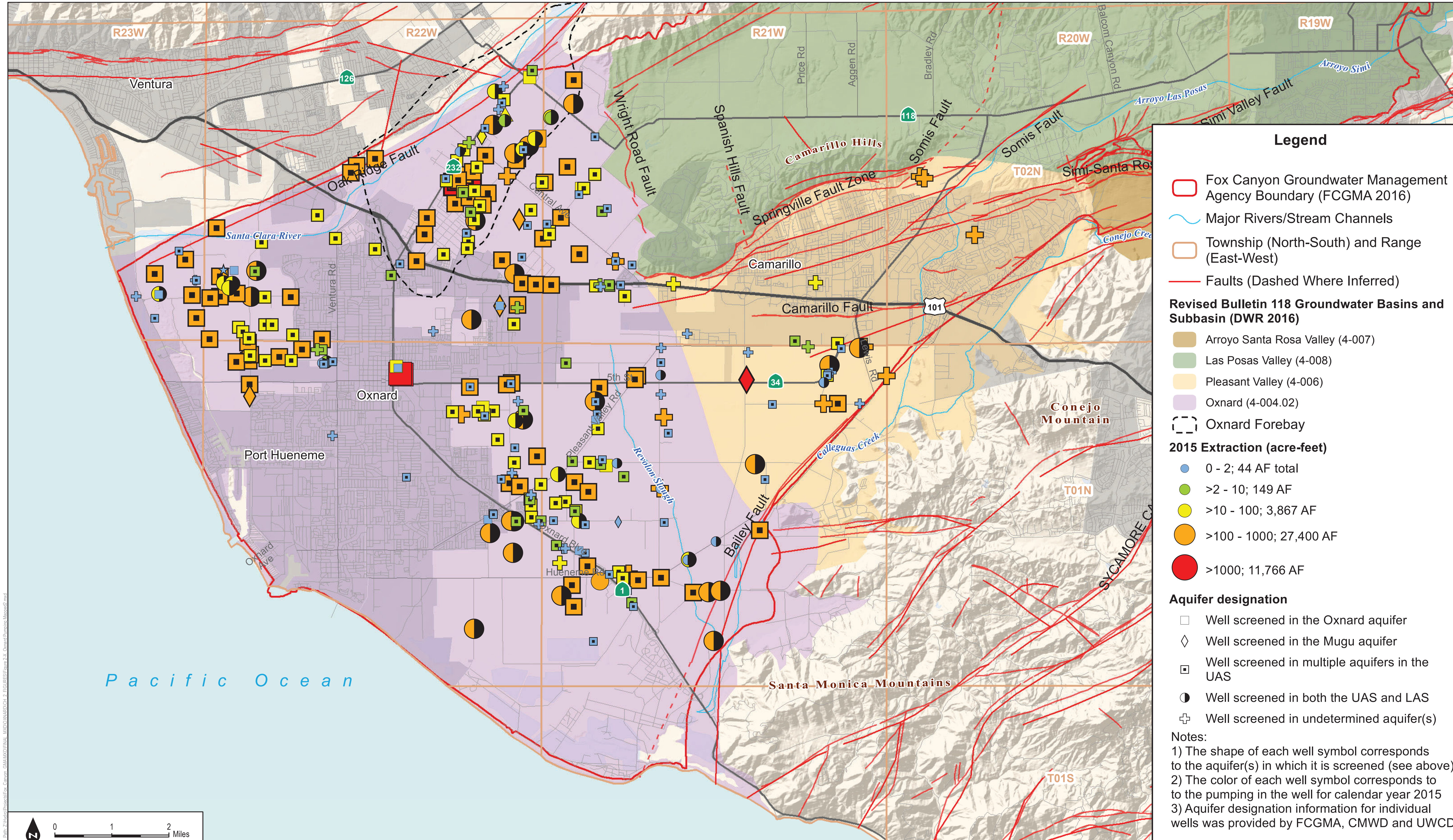

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-5

Upper Aquifer System 2015 Extraction (acre-feet) in Oxnard and Pleasant Valley

Groundwater Sustainability Plan for the Oxnard Subbasin

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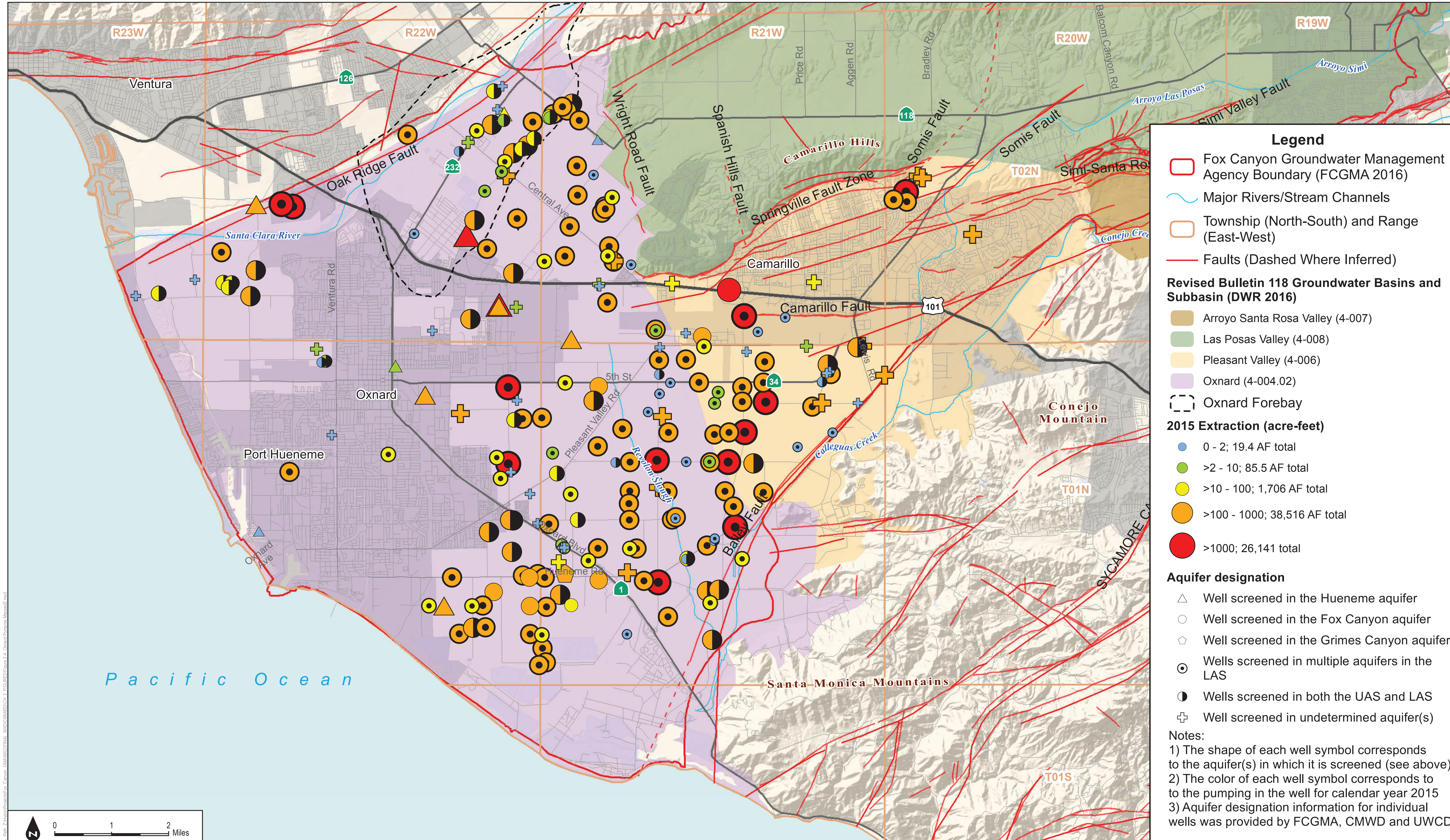

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

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FIGURE 2-6

Lower Aquifer System 2015 Extraction (acre-feet) in Oxnard and Pleasant Valley

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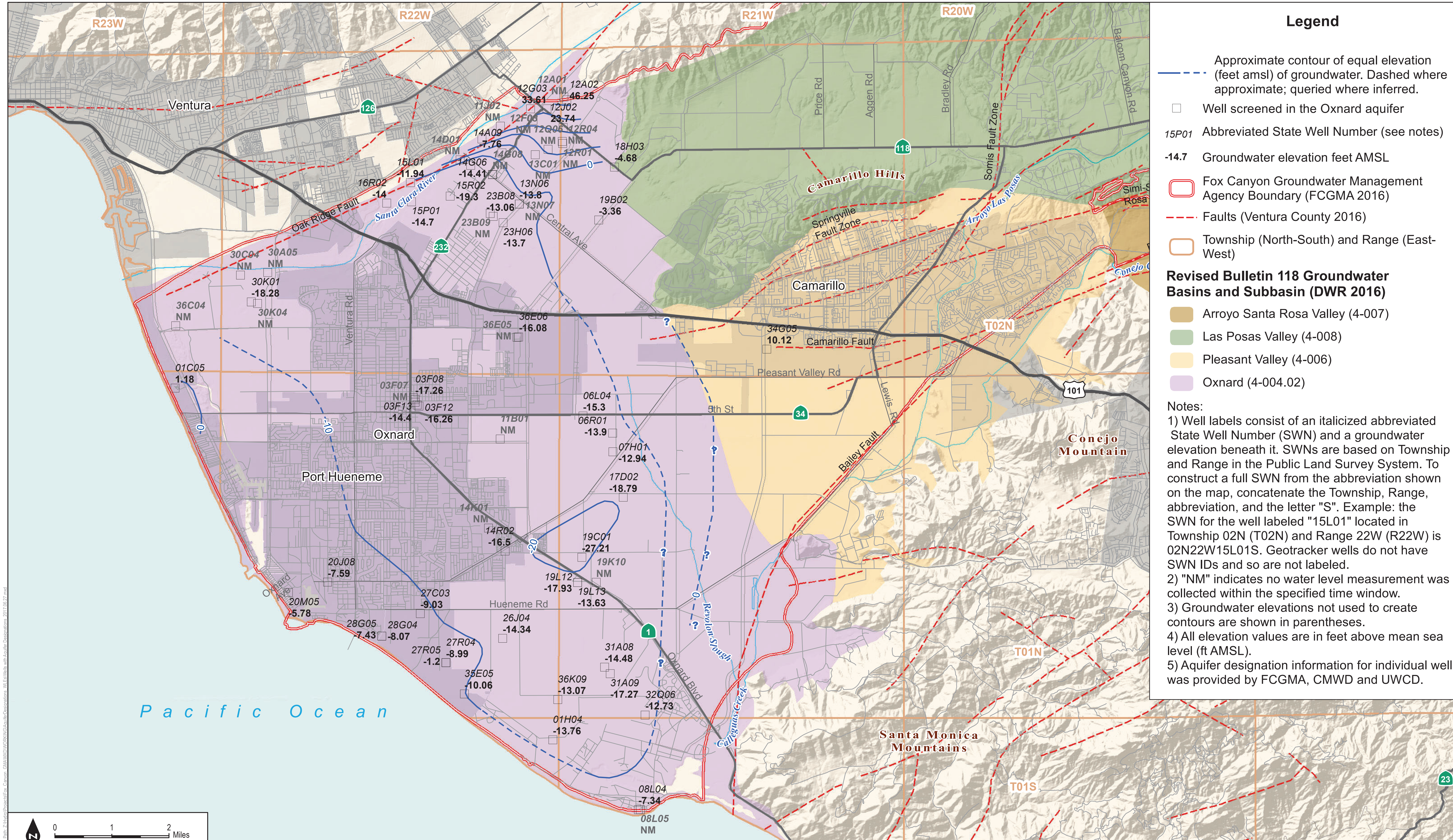

SOURCE: DWR; Ventura County; UWCD; CMWD

DUDEK

FIGURE 2-7

Groundwater Elevation Contours in the Oxnard Aquifer, March 2-29, 2015

Groundwater Sustainability Plan for the Oxnard Subbasin

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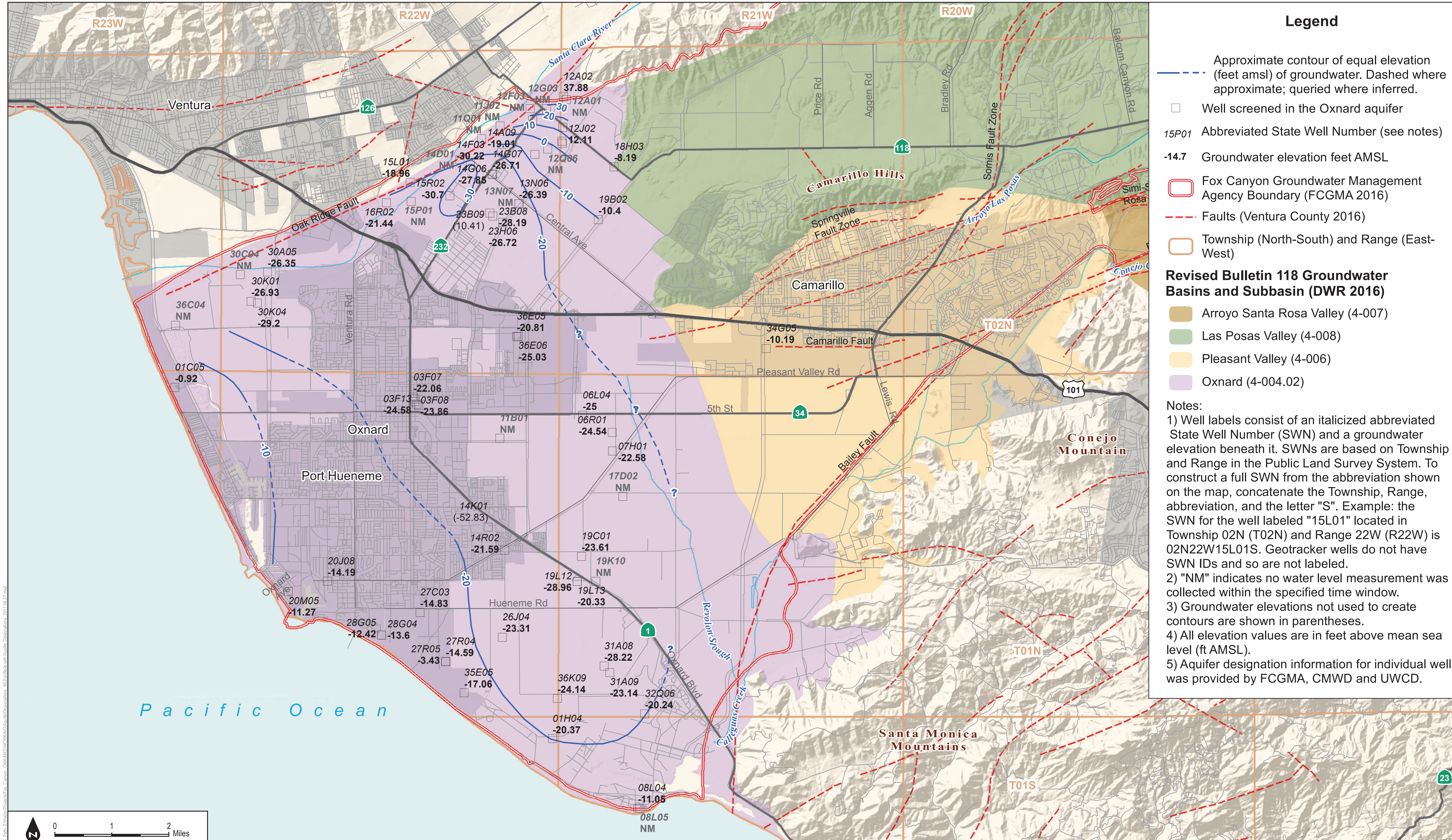

SOURCE: DWR; Ventura County; UWCD; CMWD

DUDEK

FIGURE 2-8

Groundwater Elevation Contours in the Oxnard Aquifer, October 2-29, 2015

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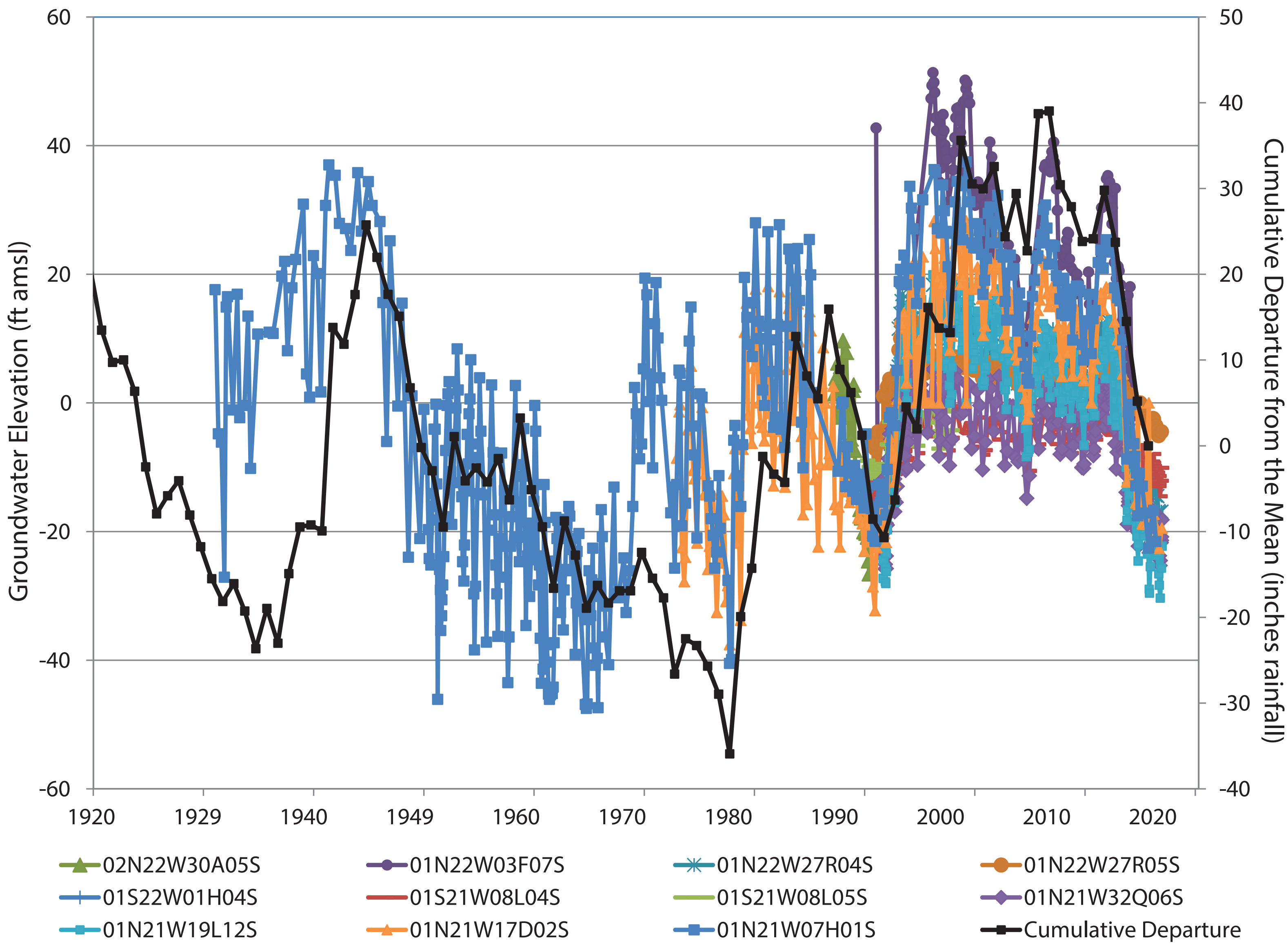

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FIGURE 2-9A

Groundwater Well Hydrographs in the Oxnard Aquifer - Oxnard Plain

Groundwater Sustainability Plan for the Oxnard Subbasin

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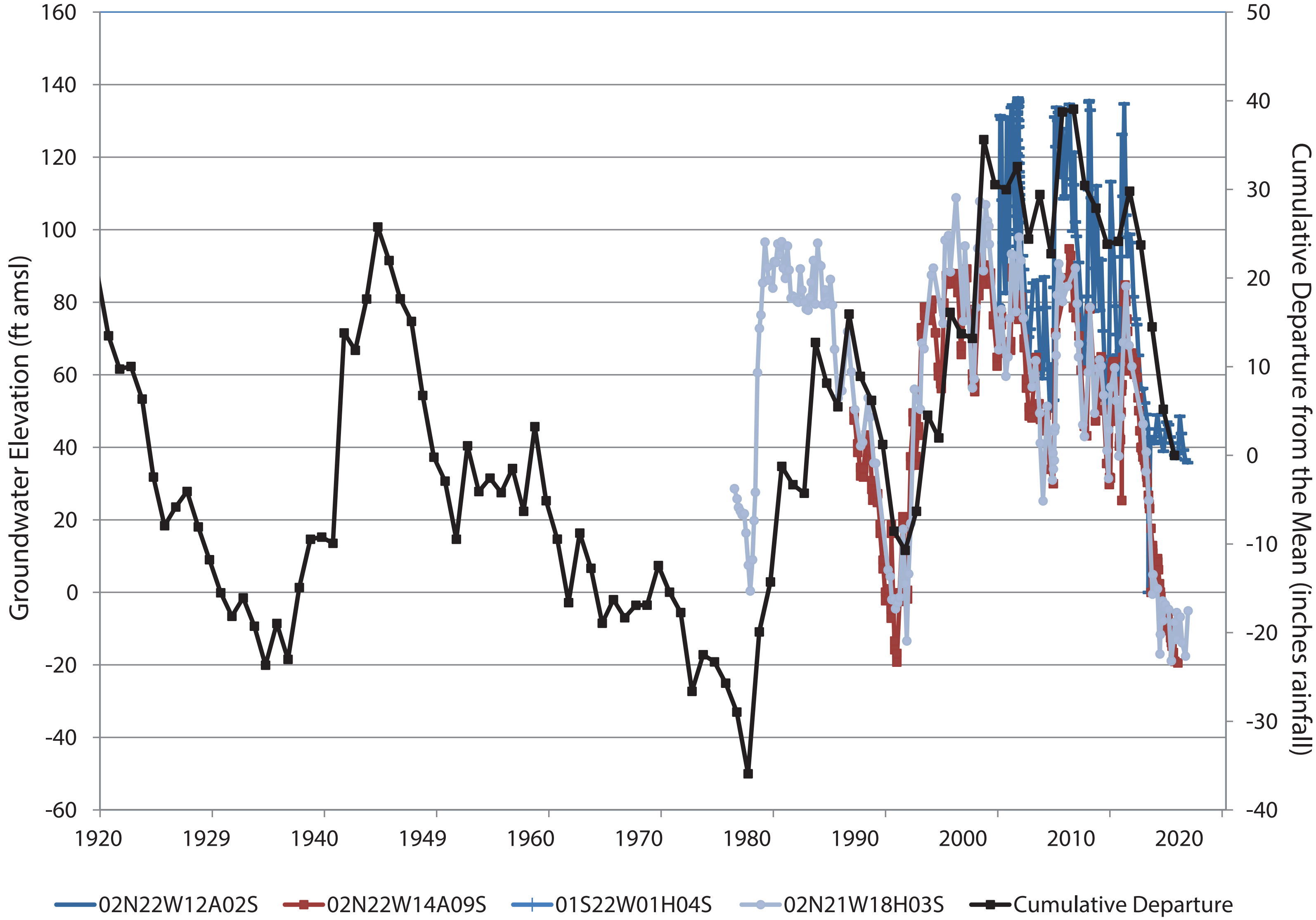

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FIGURE 2-9B

Groundwater Well Hydrographs in the Oxnard Aquifer - Forebay Area

Groundwater Sustainability Plan for the Oxnard Subbasin

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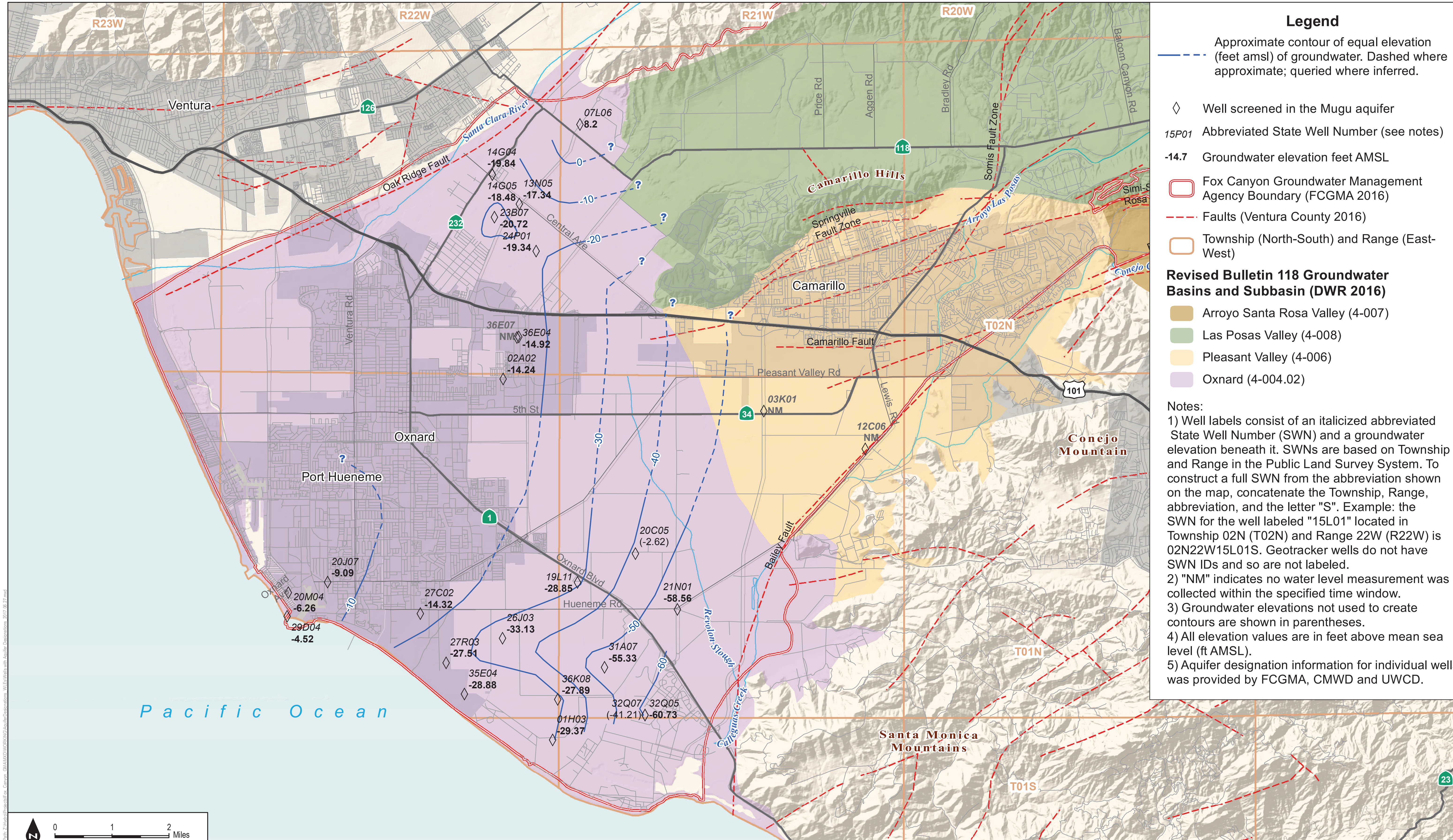

SOURCE: DWR; Ventura County; UWCD; CMWD

DUDEK

FIGURE 2-10

Groundwater Elevation Contours in the Mugu Aquifer, March 2-29, 2015

Groundwater Sustainability Plan for the Oxnard Subbasin

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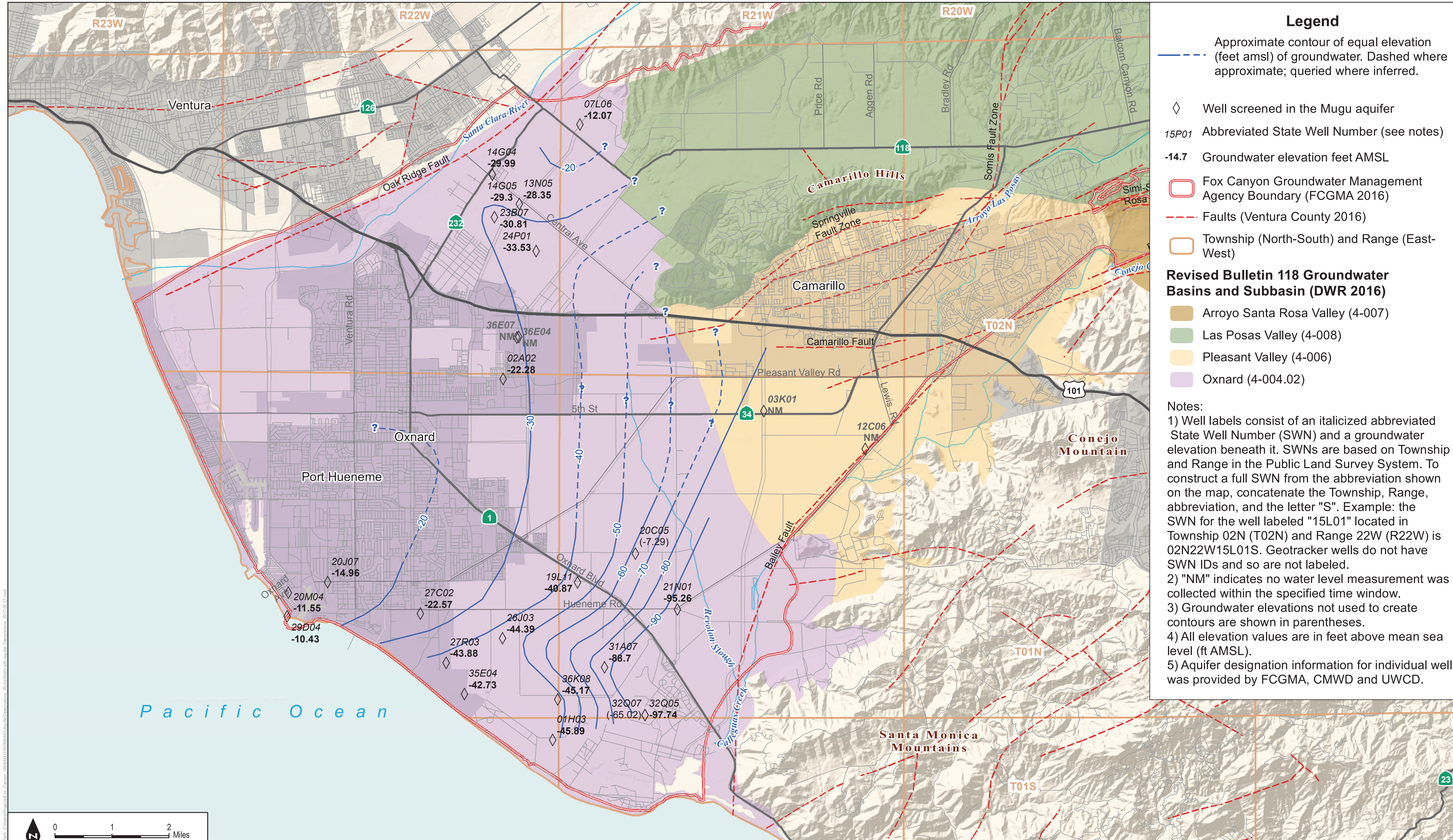

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-11

Groundwater Elevation Contours in the Mugu Aquifer, October 2-29, 2015

Groundwater Sustainability Plan for the Oxnard Subbasin

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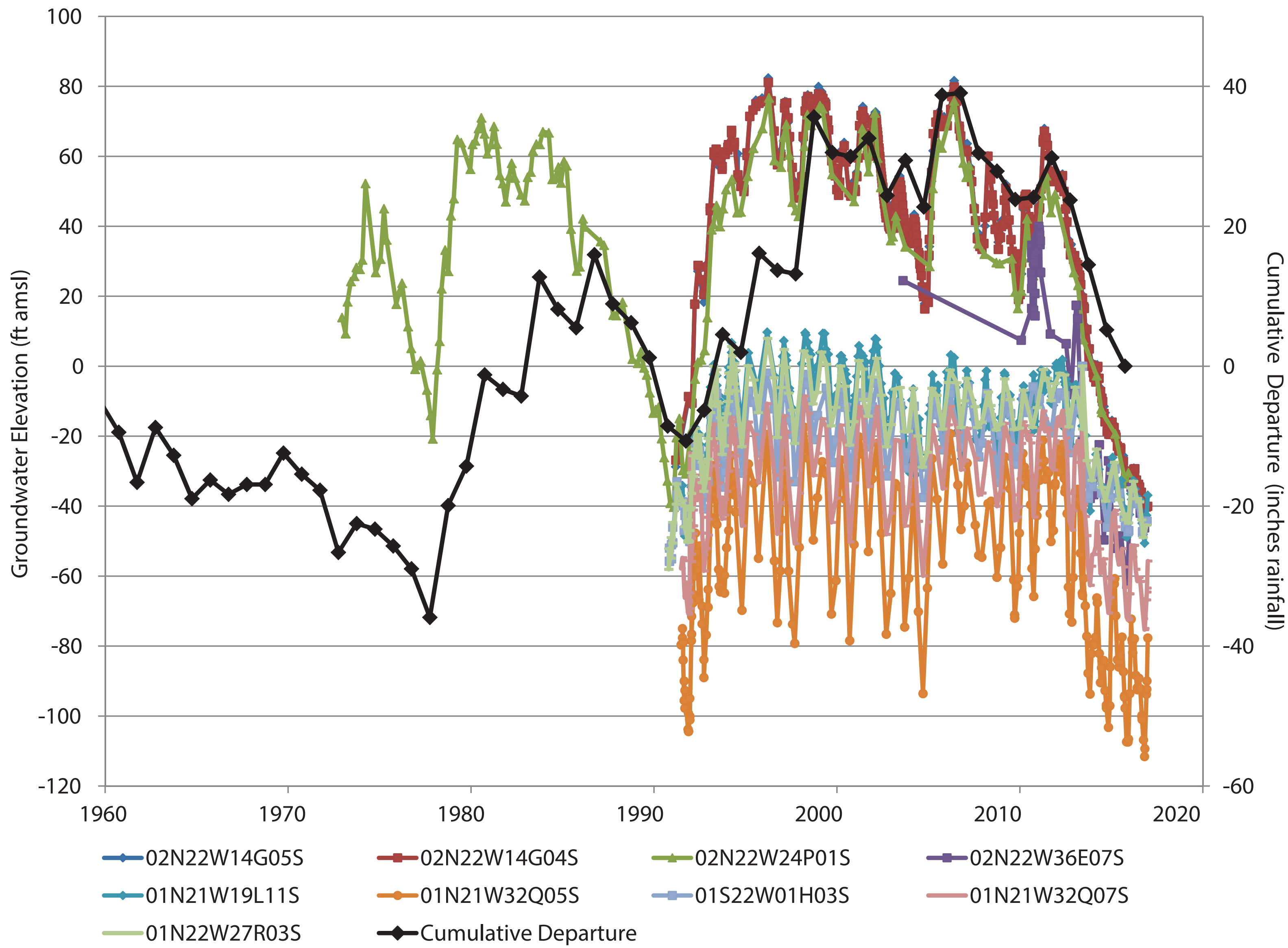

DUDEK

FIGURE 2-12

Groundwater Well Hydrographs in the Mugu Aquifer

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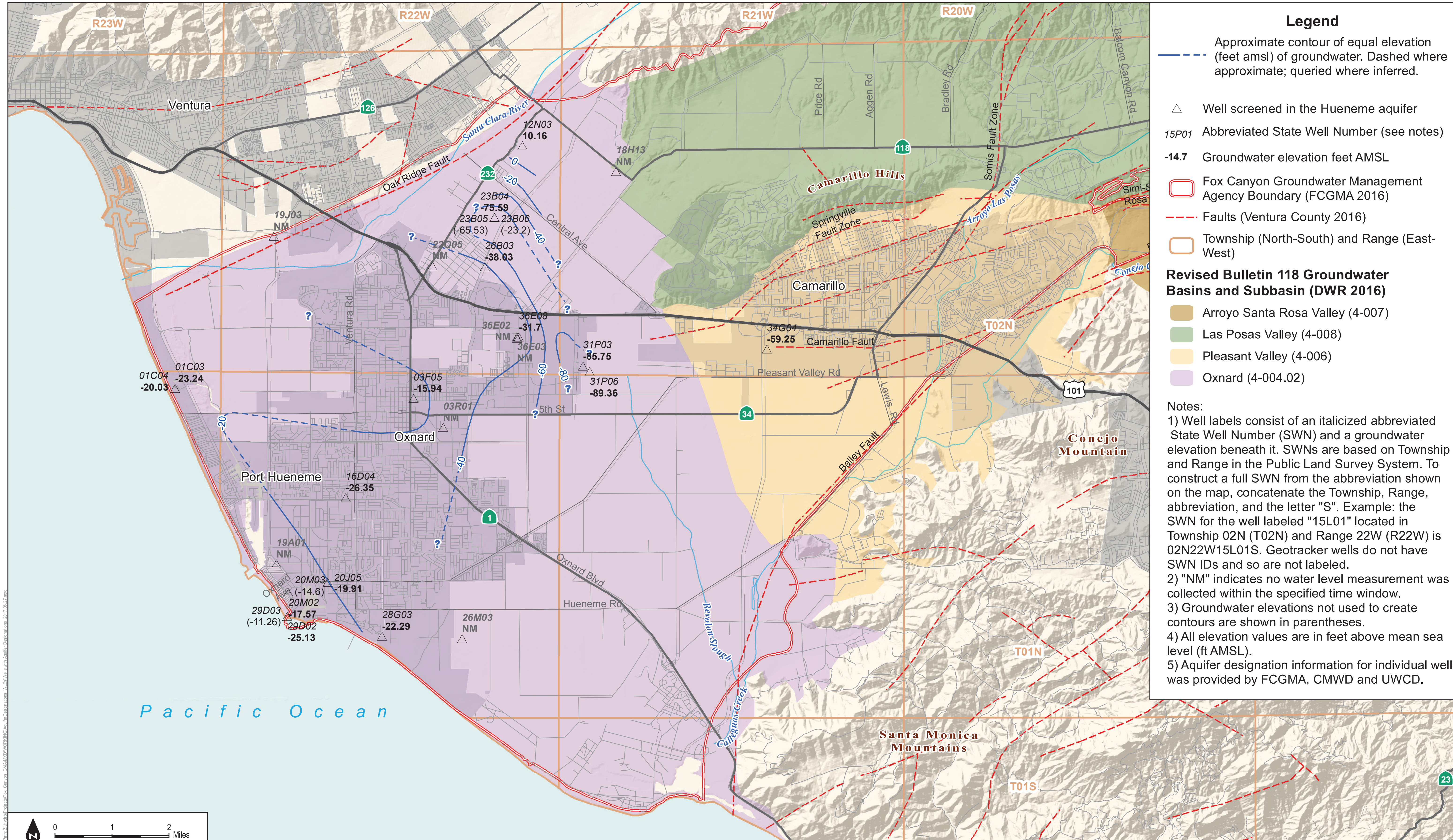

SOURCE: DWR; Ventura County; UWCD; CMWD

DUDEK

FIGURE 2-13

Groundwater Elevation Contours in the Hueneme Aquifer, March 2-29, 2015

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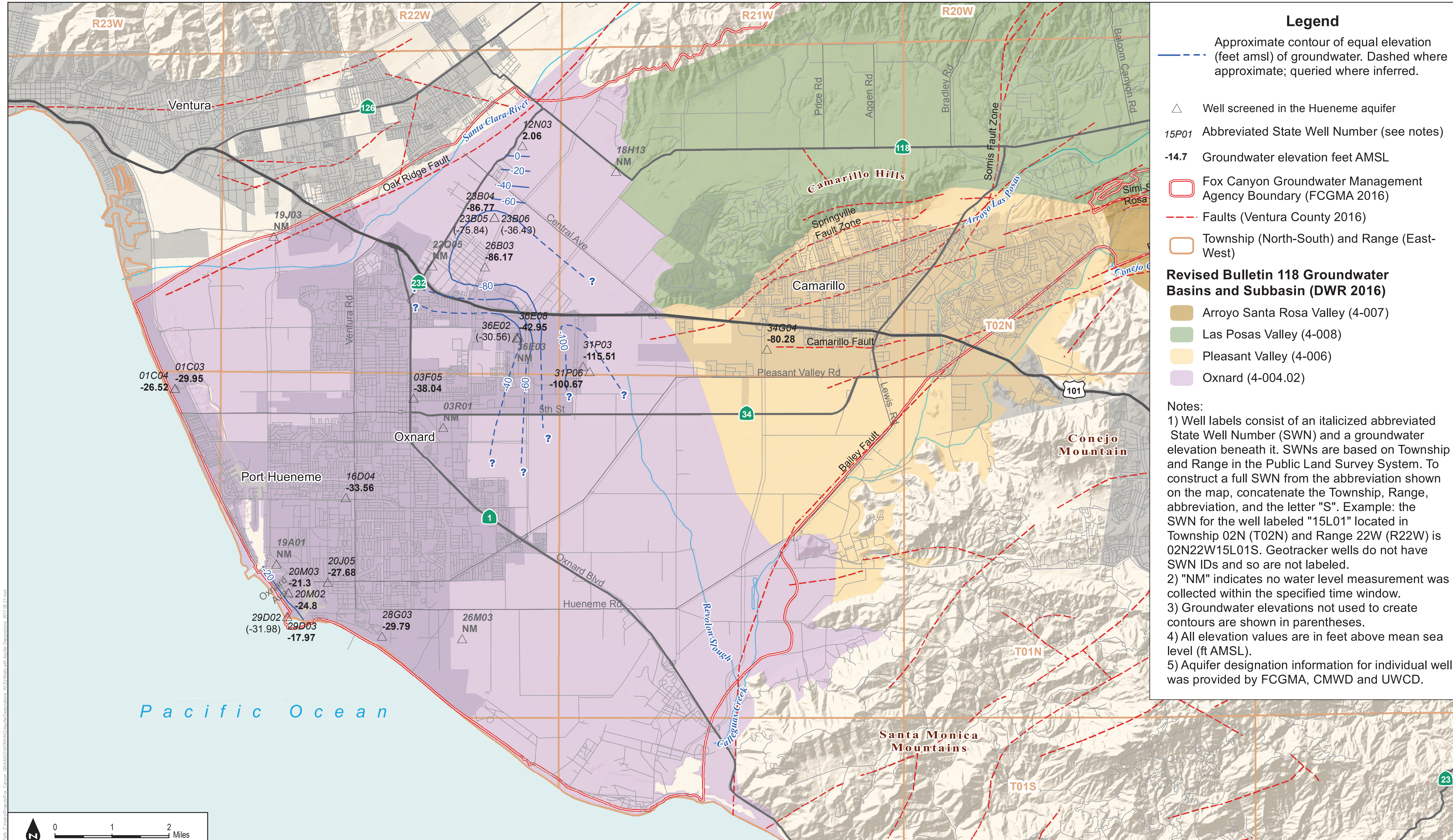

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-14

Groundwater Elevation Contours in the Hueneme Aquifer, October 2-29, 2015

DUDEK

Groundwater Sustainability Plan for the Oxnard Subbasin

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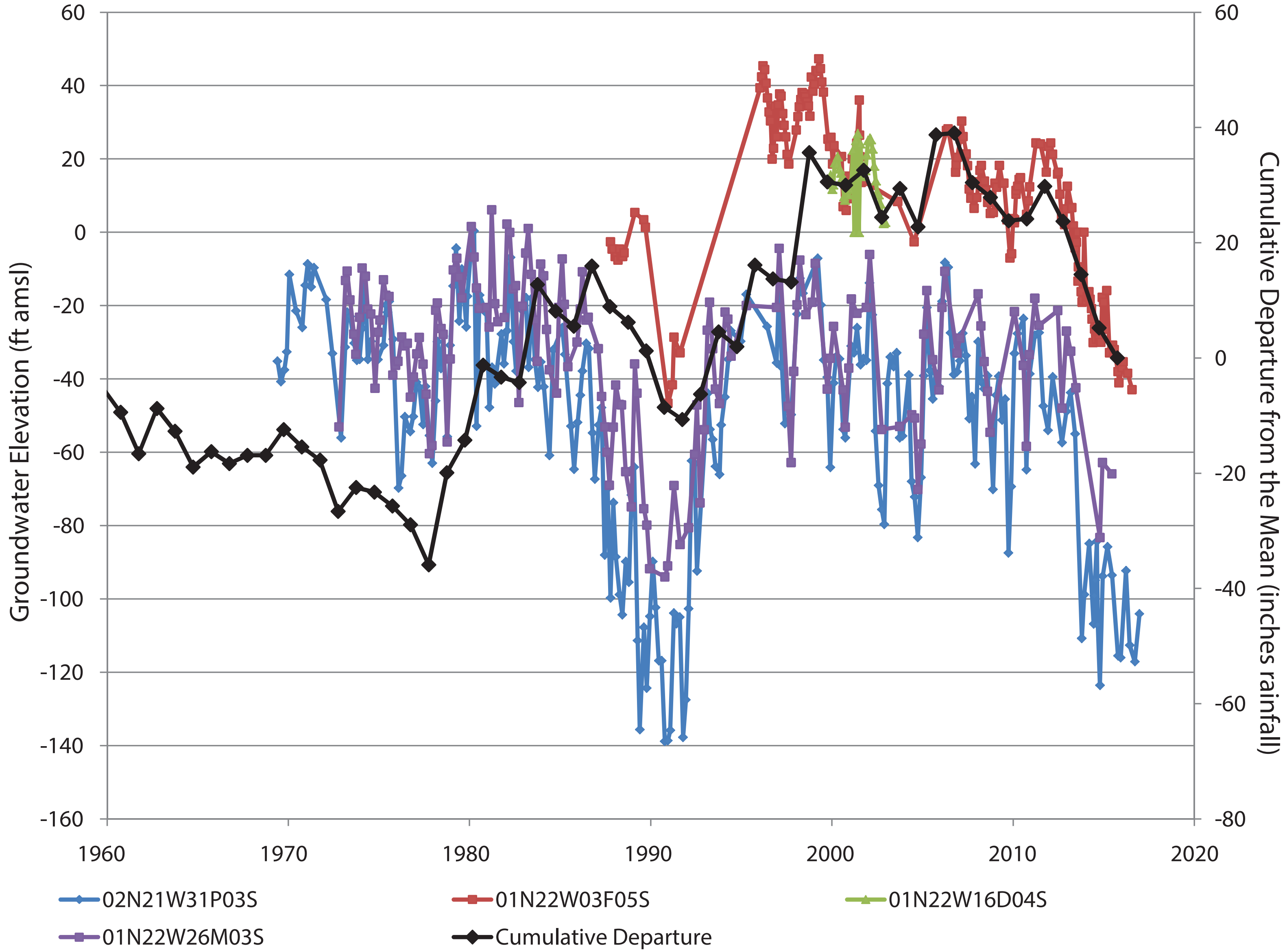

DUDEK

FIGURE 2-15

Groundwater Well Hydrographs in the Hueneme Aquifer

Groundwater Sustainability Plan for the Oxnard Subbasin

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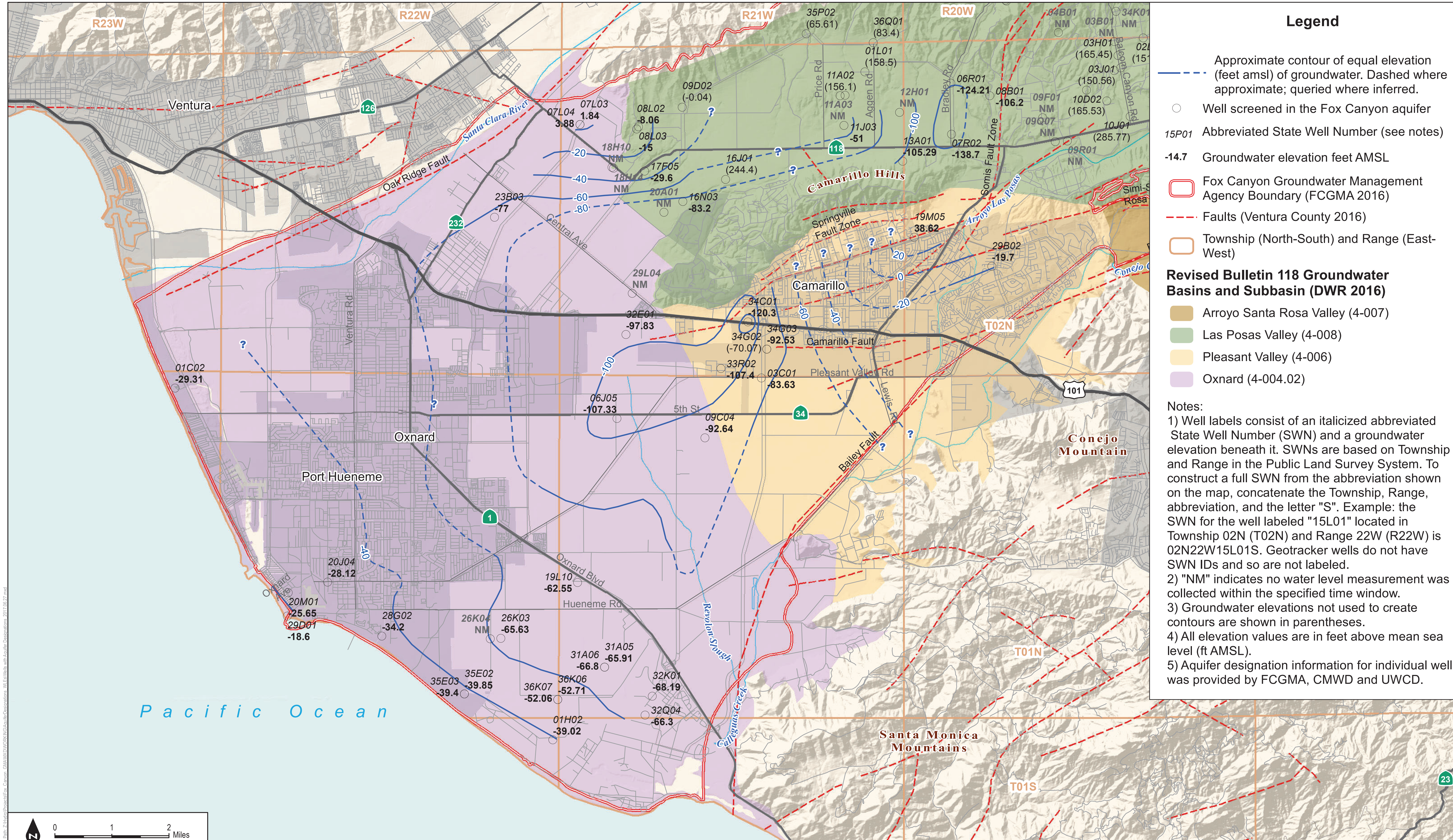

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-16

Groundwater Elevation Contours in the Fox Canyon Aquifer, March 2-29, 2015

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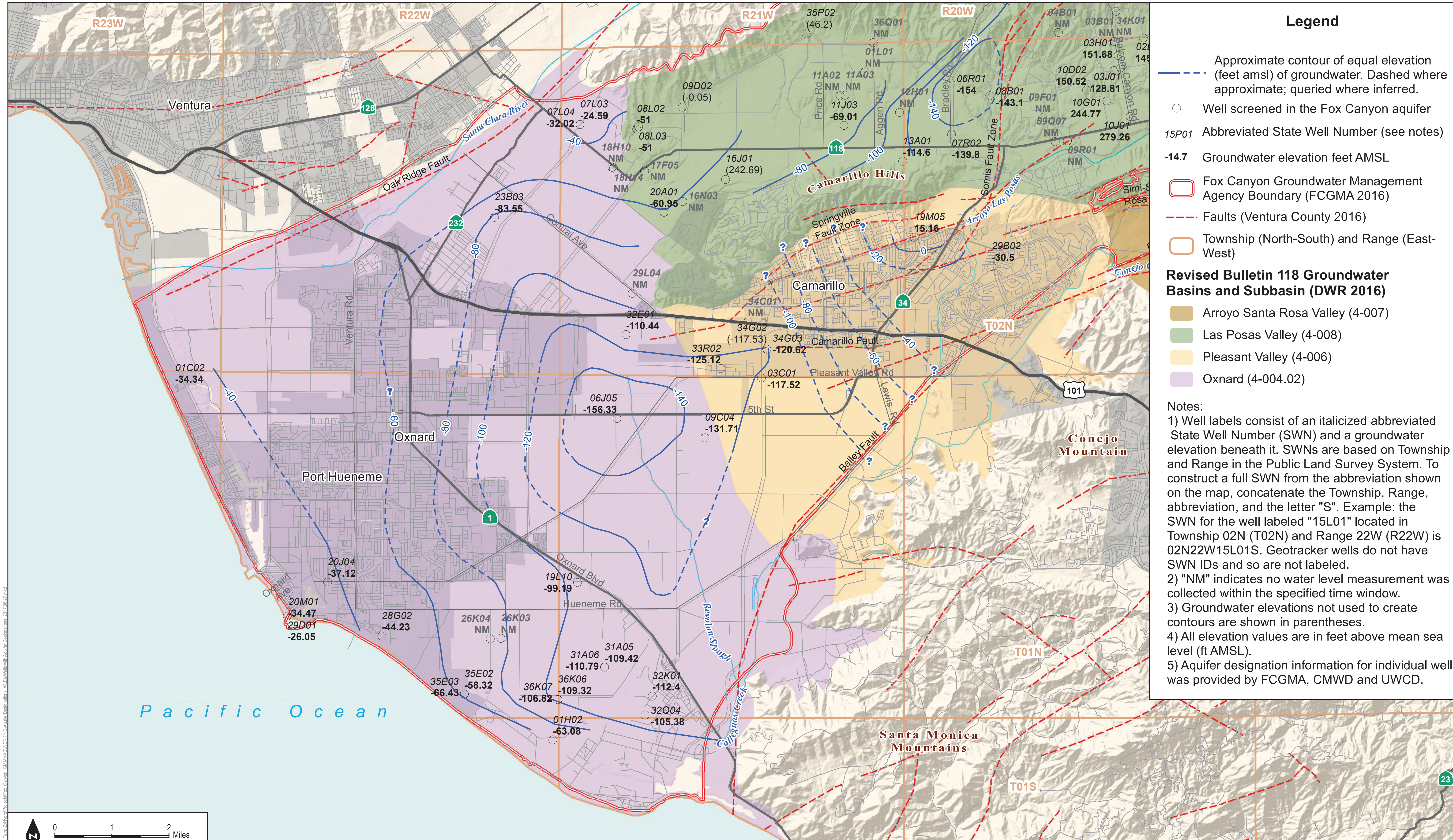

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-17

Groundwater Elevation Contours in the Fox Canyon Aquifer, October 2-29, 2015

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Groundwater Sustainability Plan for the Oxnard Subbasin

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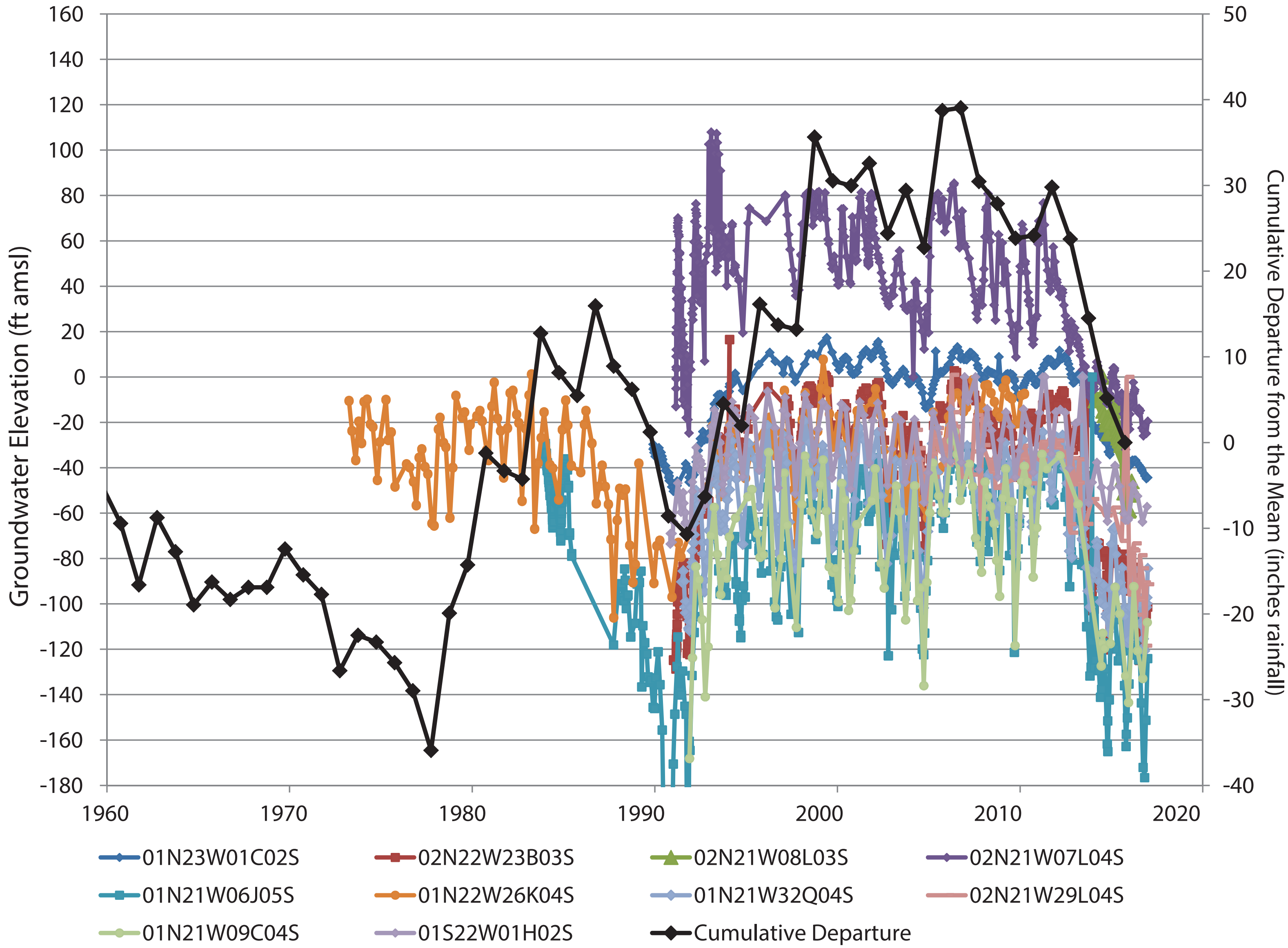

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FIGURE 2-18

Groundwater Well Hydrographs in the Fox Canyon Aquifer

Groundwater Sustainability Plan for the Oxnard Subbasin

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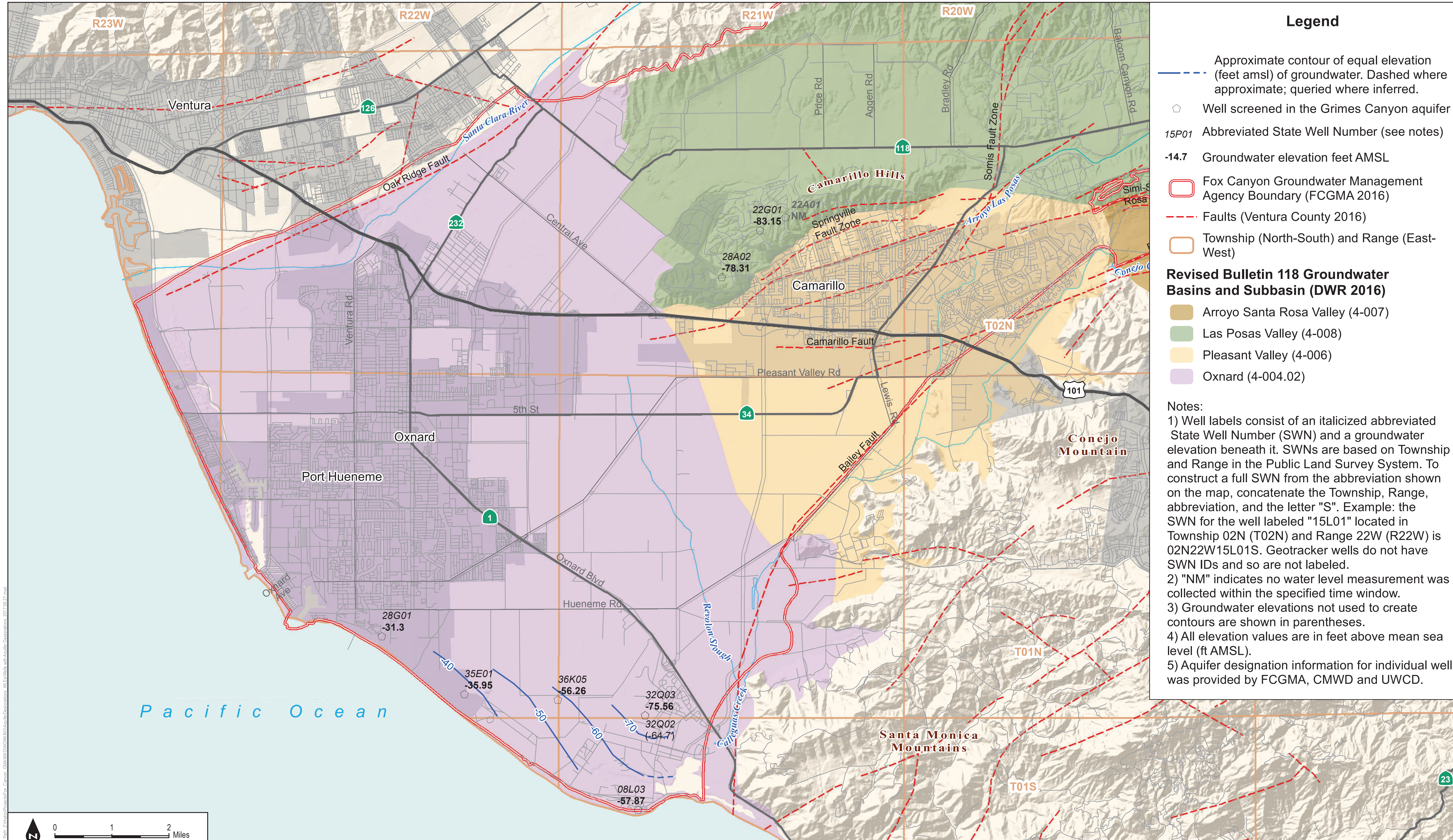

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-19

Groundwater Elevation Contours in the Grimes Canyon Aquifer, March 2-29, 2015

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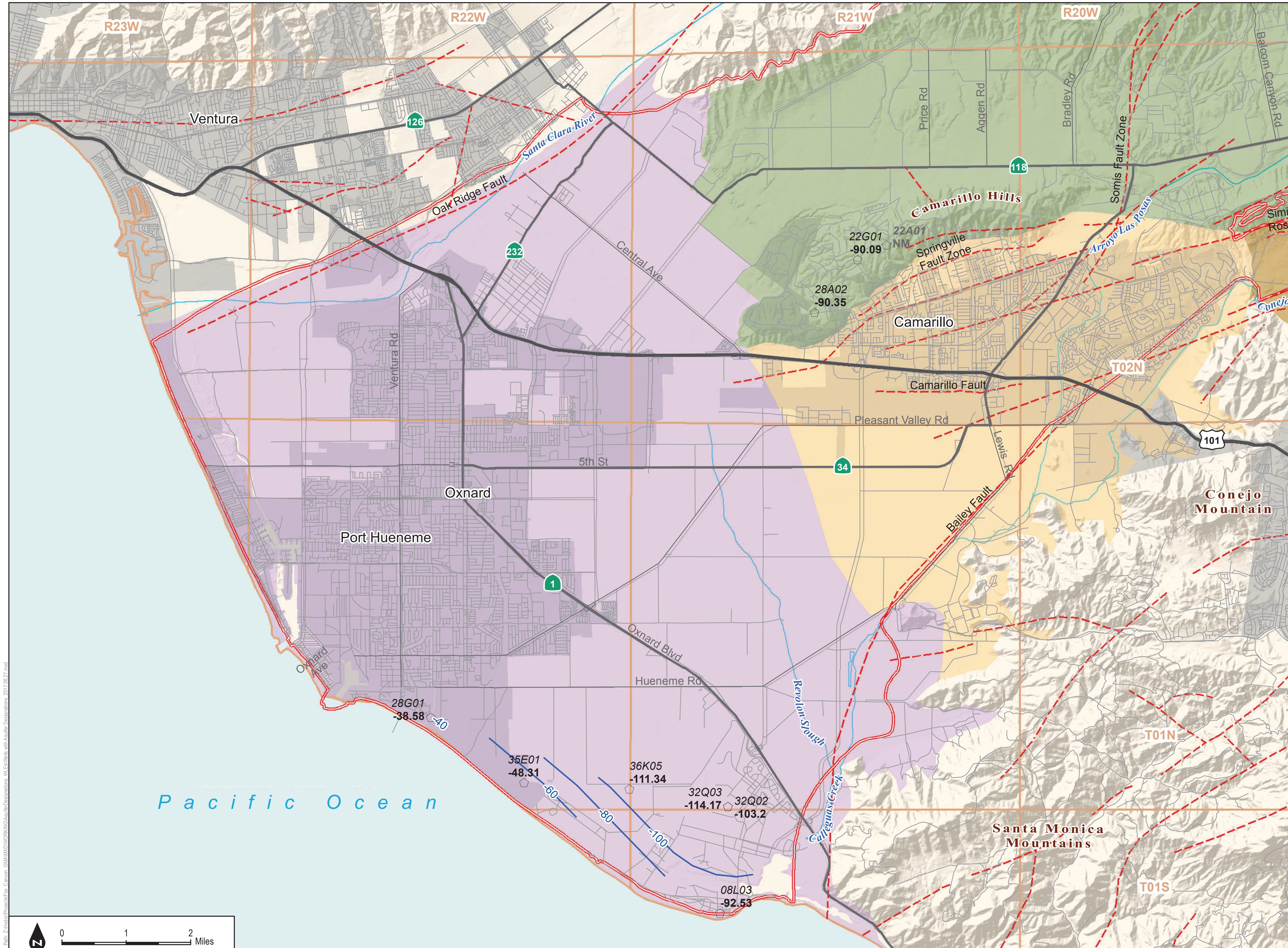

Legend

Approximate contour of equal elevation (feet amsl) of groundwater. Dashed where approximate; queried where inferred.

Well screened in the Grimes Canyon aquifer

15P01 Abbreviated State Well Number (see notes)

-14.7 Groundwater elevation feet AMSL

Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)

Faults (Ventura County 2016)

Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

Arroyo Santa Rosa Valley (4-007)

Las Posas Valley (4-008)

Pleasant Valley (4-006)

Oxnard (4-004.02)

Notes:

1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a groundwater elevation beneath it. SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map, concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S. Geotracker wells do not have SWN IDs and so are not labeled.

2) "NM" indicates no water level measurement was collected within the specified time window.

3) Groundwater elevations not used to create contours are shown in parentheses.

4) All elevation values are in feet above mean sea level (ft AMSL).

5) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-20

Groundwater Elevation Contours in the Grimes Canyon Aquifer, October 2-29, 2015

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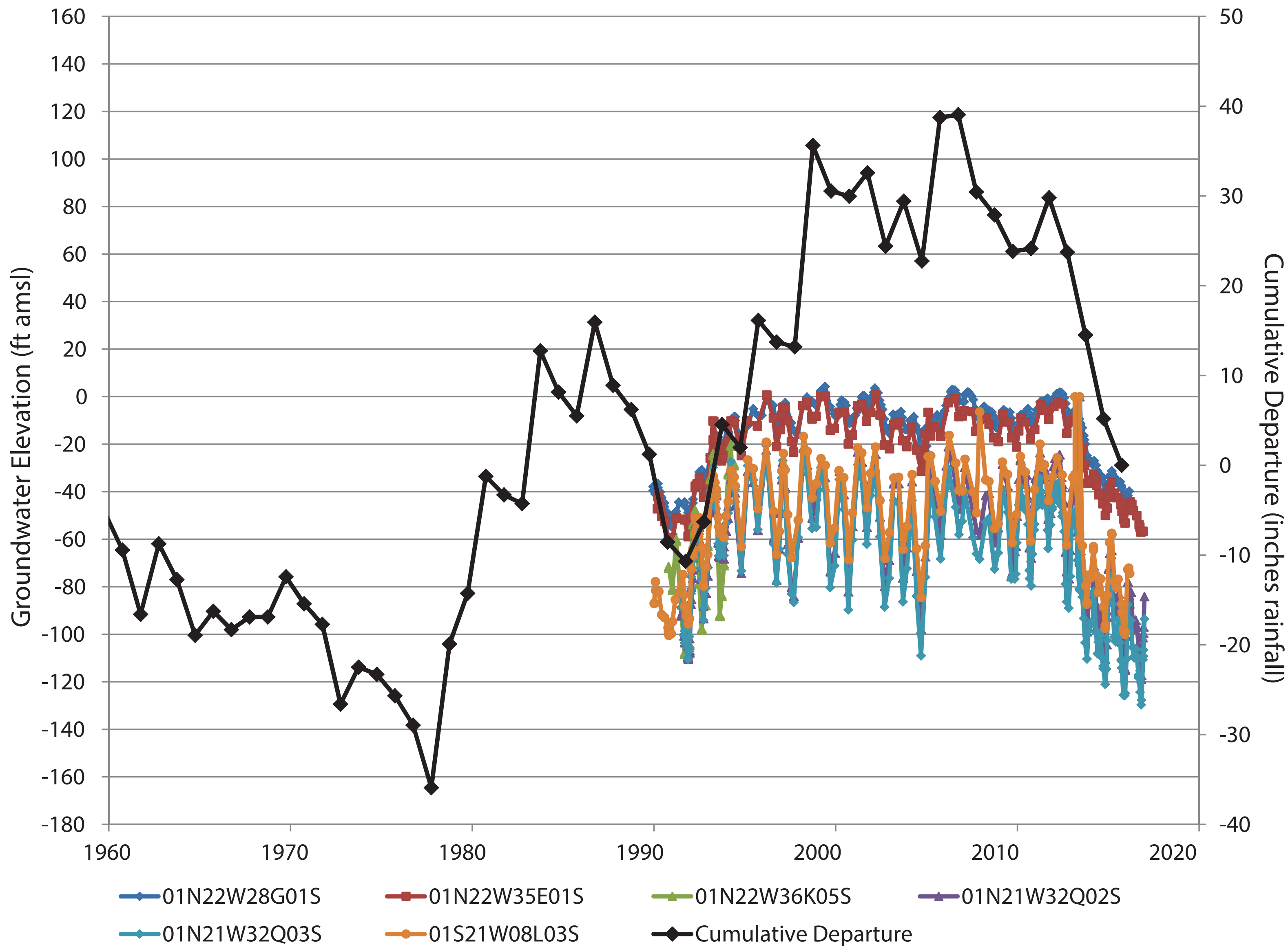

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FIGURE 2-21

Groundwater Well Hydrographs in the Grimes Canyon Aquifer

Groundwater Sustainability Plan for the Oxnard Subbasin

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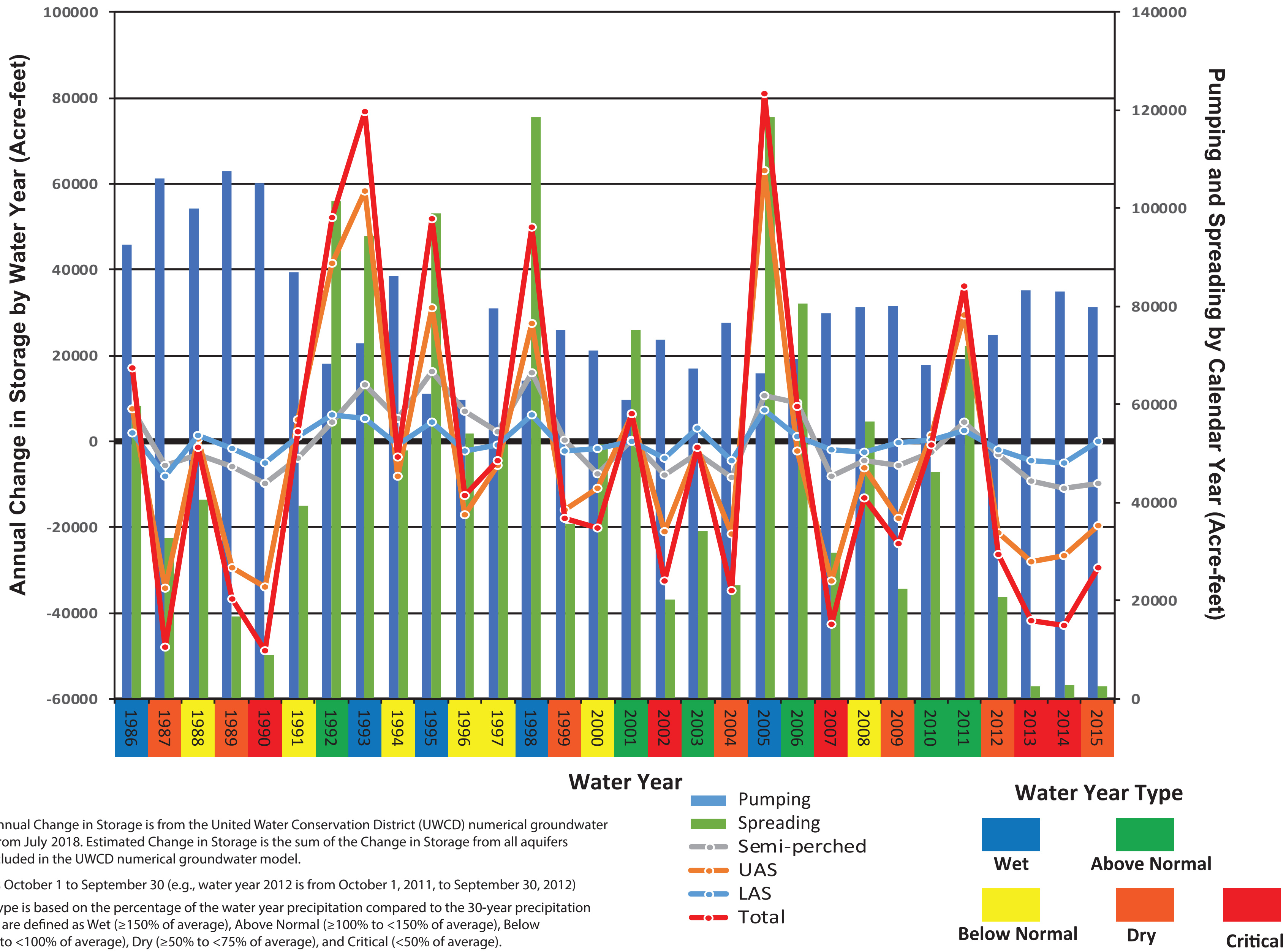

Notes:

1) Estimated Annual Change in Storage is from the United Water Conservation District (UWCD) numerical groundwater model report from July 2018. Estimated Change in Storage is the sum of the Change in Storage from all aquifers in the basin included in the UWCD numerical groundwater model.

2) Water year is October 1 to September 30 (e.g., water year 2012 is from October 1, 2011, to September 30, 2012)

3) Water year type is based on the percentage of the water year precipitation compared to the 30-year precipitation average. Types are defined as Wet (≥150% of average), Above Normal (≥100% to <150% of average), Below Normal (≥75% to <100% of average), Dry (≥50% to <75% of average), and Critical (<50% of average).

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FIGURE 2-22

Oxnard Subbasin Annual Change in Storage

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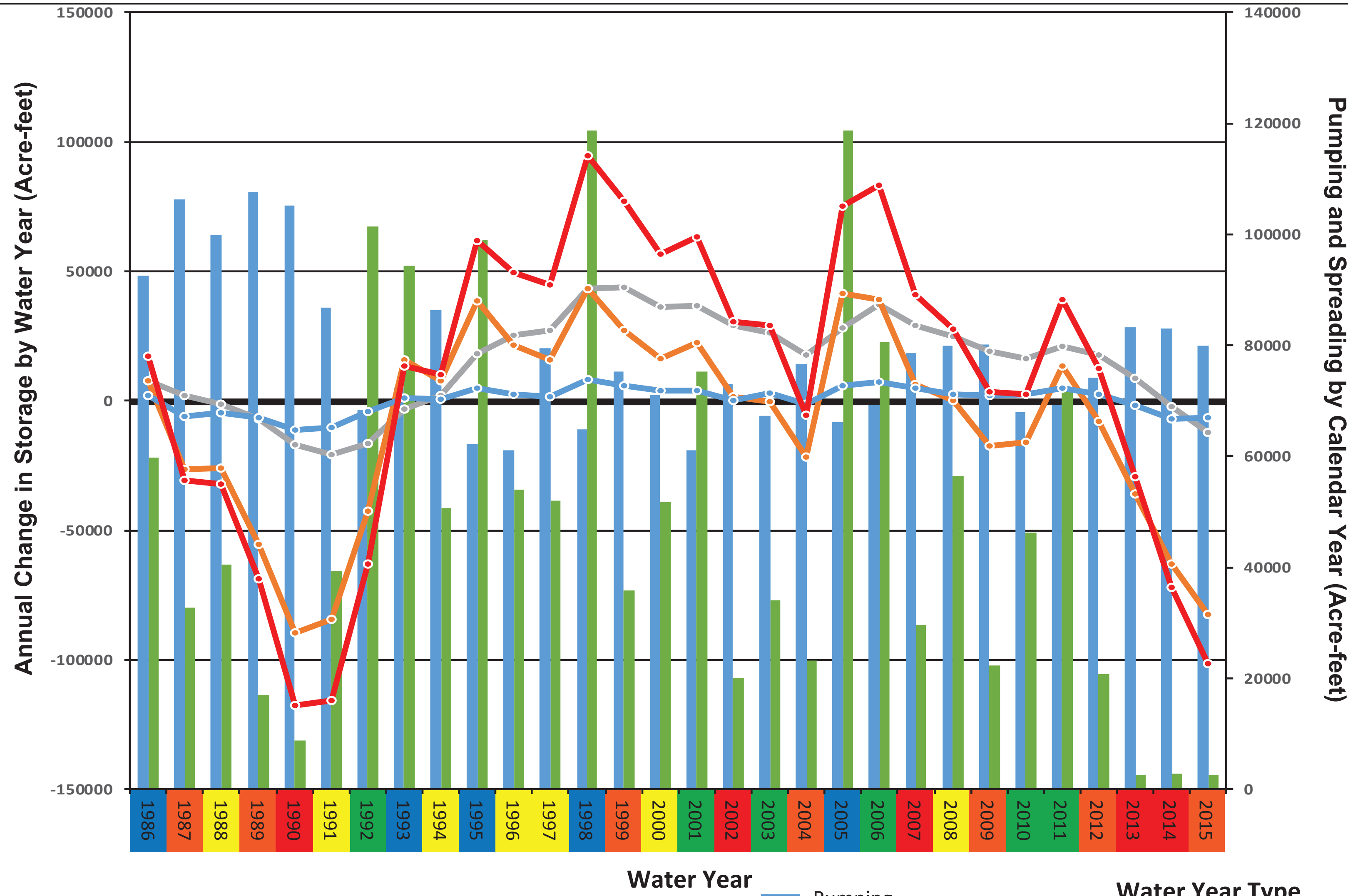

Notes:

1) Estimated Annual Change in Storage is from the United Water Conservation District (UWCD) numerical groundwater model report from July 2018. Estimated Change in Storage is the sum of the Change in Storage from all aquifers in the basin included in the UWCD numerical groundwater model.

2) Water year is October 1 to September 30 (e.g., water year 2012 is from October 1, 2011, to September 30, 2012)

3) Water year type is based on the percentage of the water year precipitation compared to the 30-year precipitation average. Types are defined as Wet (≥150% of average), Above Normal (≥100% to <150% of average), Below Normal (≥75% to <100% of average), Dry (≥50% to <75% of average), and Critical (<50% of average).

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FIGURE 2-23

Oxnard Subbasin Cumulative Change in Storage

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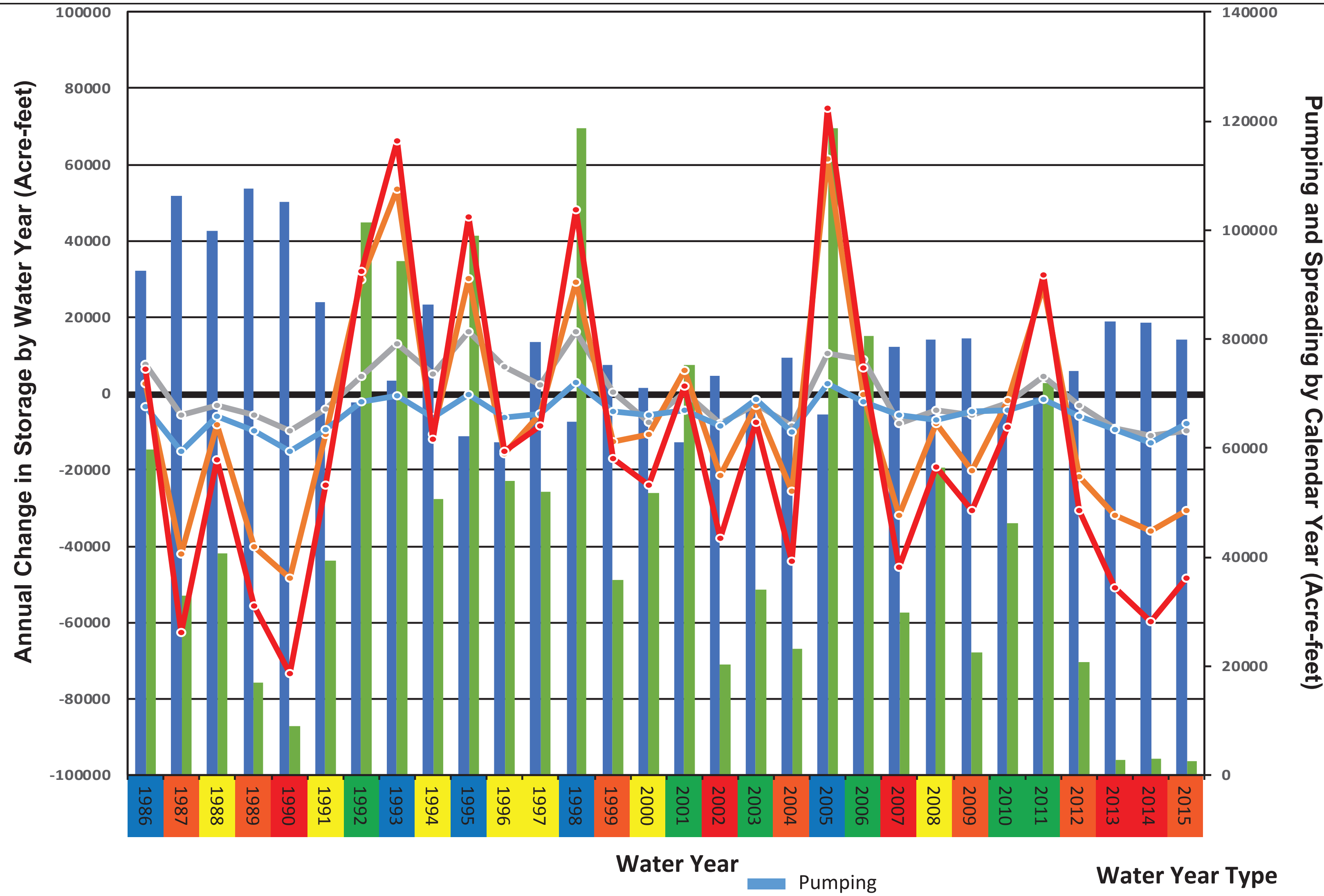

Notes:

1) Estimated Annual Change in Storage is from the United Water Conservation District (UWCD) numerical groundwater model report from July 2018. Estimated Change in Storage is the sum of the Change in Storage from all aquifers in the basin included in the UWCD numerical groundwater model.

2) Water year is October 1 to September 30 (e.g., water year 2012 is from October 1, 2011, to September 30, 2012)

3) Water year type is based on the percentage of the water year precipitation compared to the 30-year precipitation average. Types are defined as Wet (≥150% of average), Above Normal (≥100% to <150% of average), Below Normal (≥75% to <100% of average), Dry (≥50% to <75% of average), and Critical (<50% of average).

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FIGURE 2-24

Oxnard Subbasin Annual Change in Storage Without Coastal Flux

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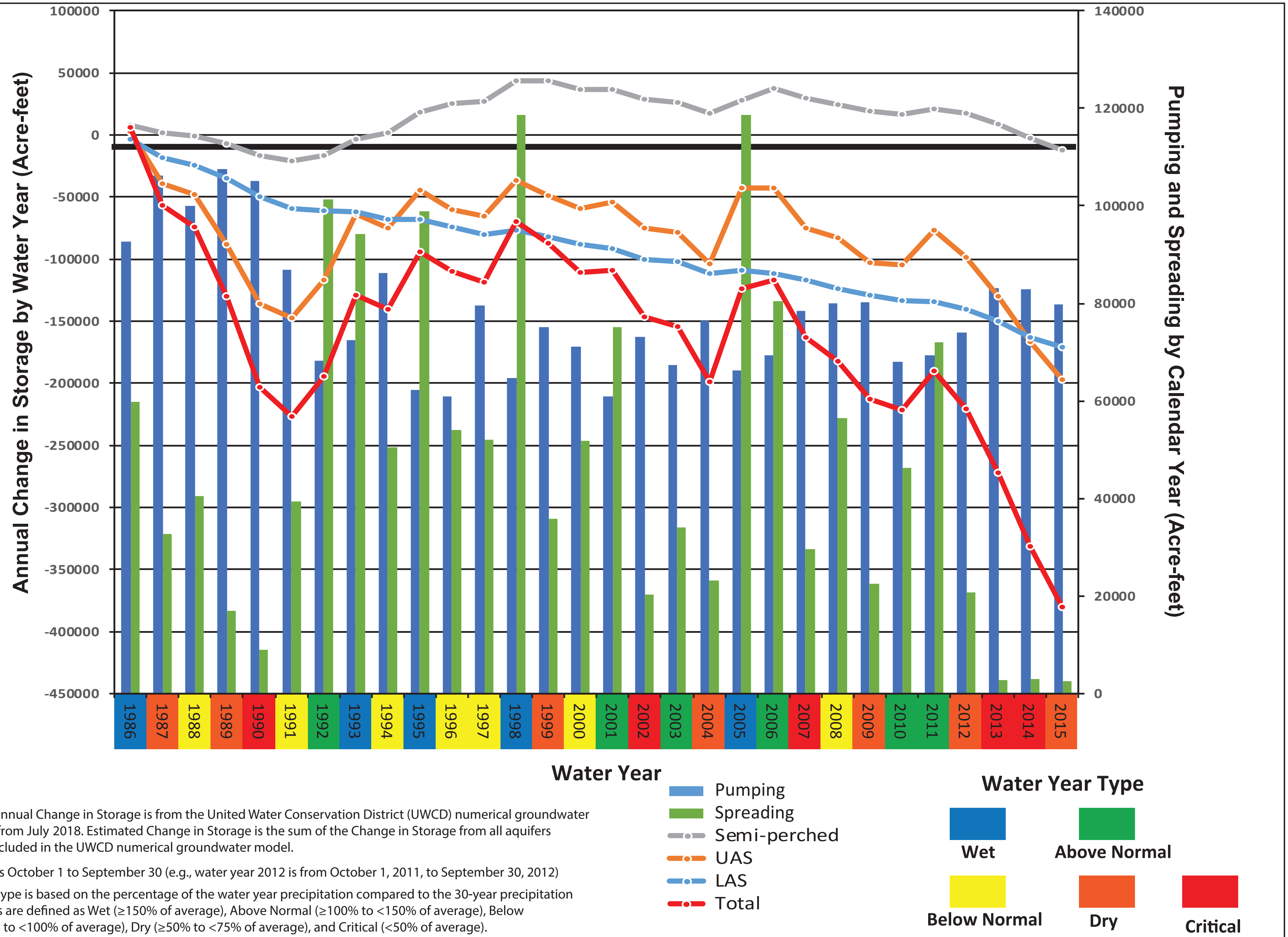

Notes:

1) Estimated Annual Change in Storage is from the United Water Conservation District (UWCD) numerical groundwater model report from July 2018. Estimated Change in Storage is the sum of the Change in Storage from all aquifers in the basin included in the UWCD numerical groundwater model.

2) Water year is October 1 to September 30 (e.g., water year 2012 is from October 1, 2011, to September 30, 2012)

3) Water year type is based on the percentage of the water year precipitation compared to the 30-year precipitation average. Types are defined as Wet (≥150% of average), Above Normal (≥100% to <150% of average), Below Normal (≥75% to <100% of average), Dry (≥50% to <75% of average), and Critical (<50% of average).

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FIGURE 2-25

Oxnard Subbasin Cumulative Change in Storage Without Coastal Flux

Groundwater Sustainability Plan for the Oxnard Subbasin

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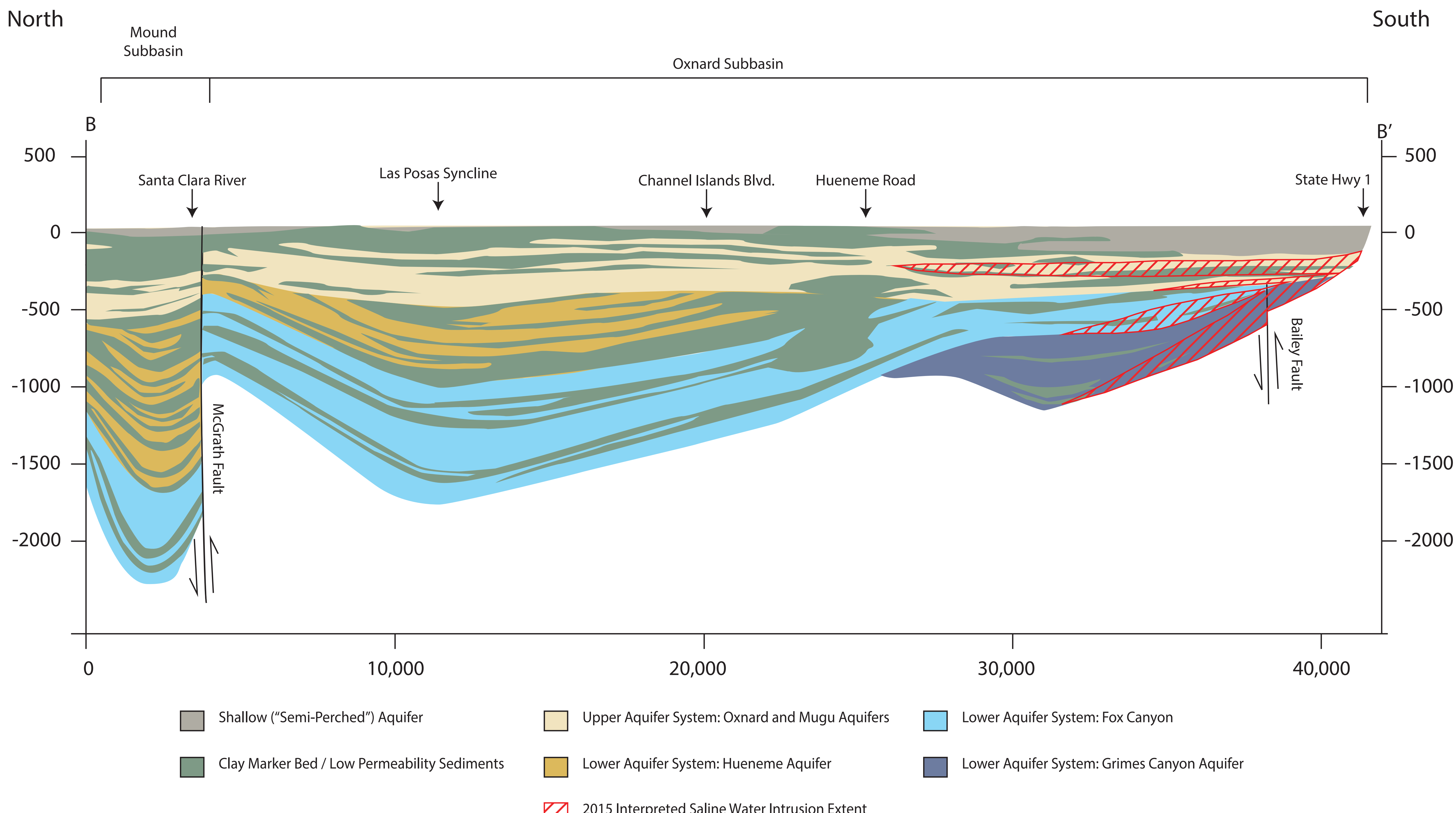

SOURCE: Cross Section: Turner 1975; Based on Plates 7A and 7B (Cross Section A-A')
Interpreted Seawater Inrusion Extent: United Water Conservation District Open File Report, October 2016

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FIGURE 2-26
Approximate 2015 North-South Saline Water Intrusion Extent

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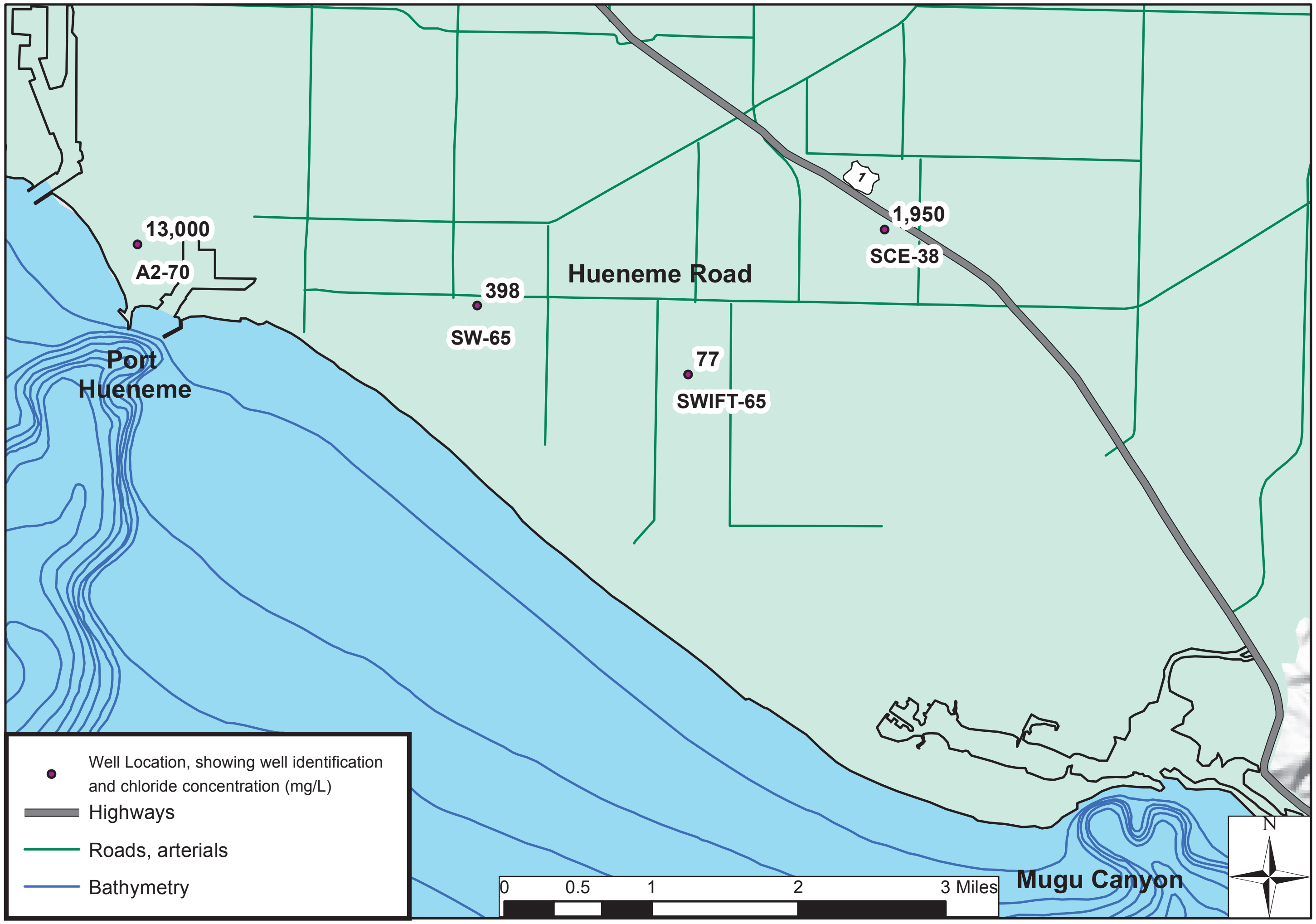

Source: UWCD 2016

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FIGURE 2-27

Semi-Perched Aquifer Coastal Chloride Concentrations, Fall 2015

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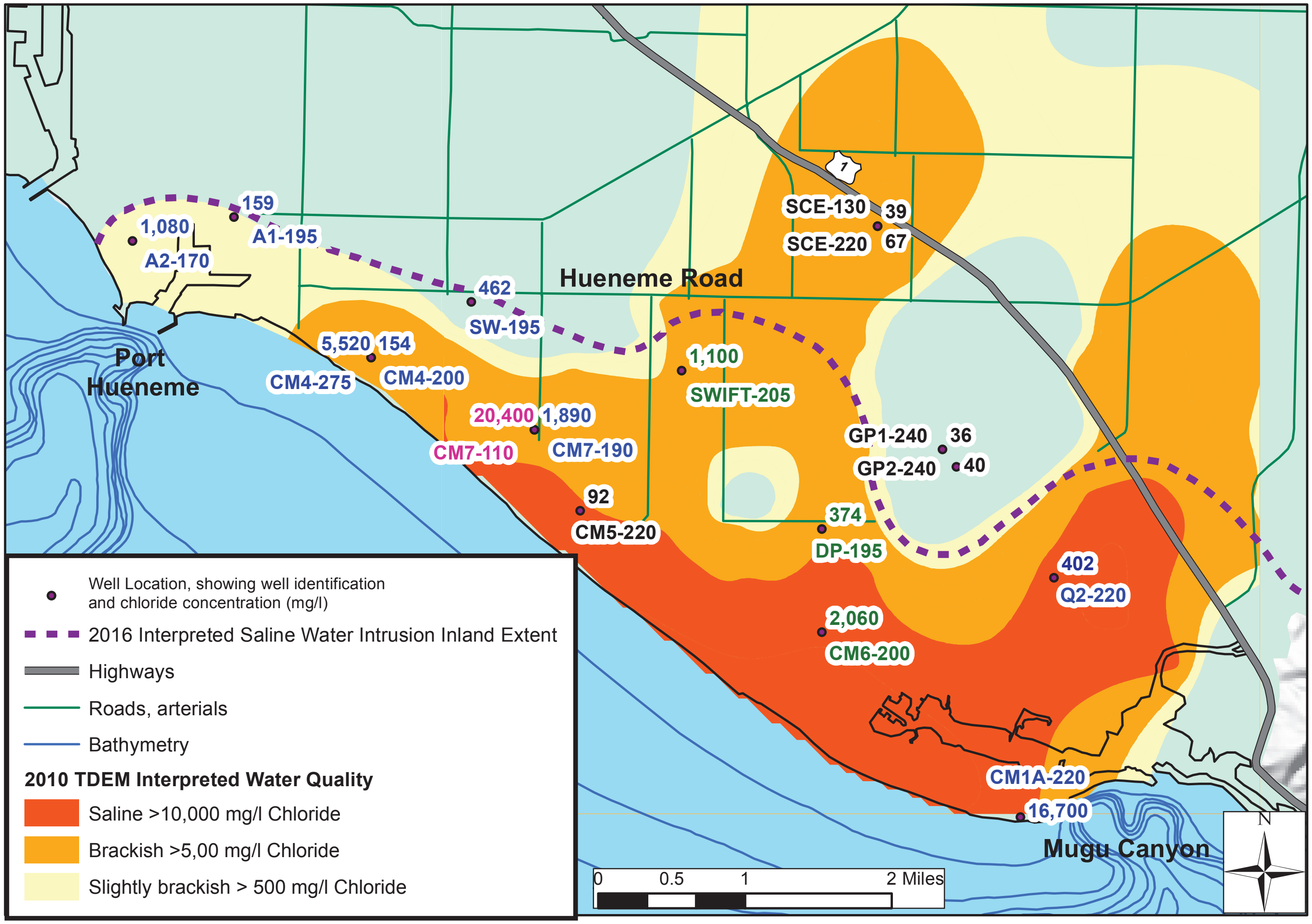

Source: UWCD 2016

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FIGURE 2-28

Oxnard Aquifer Coastal Chloride Concentrations, Fall 2015

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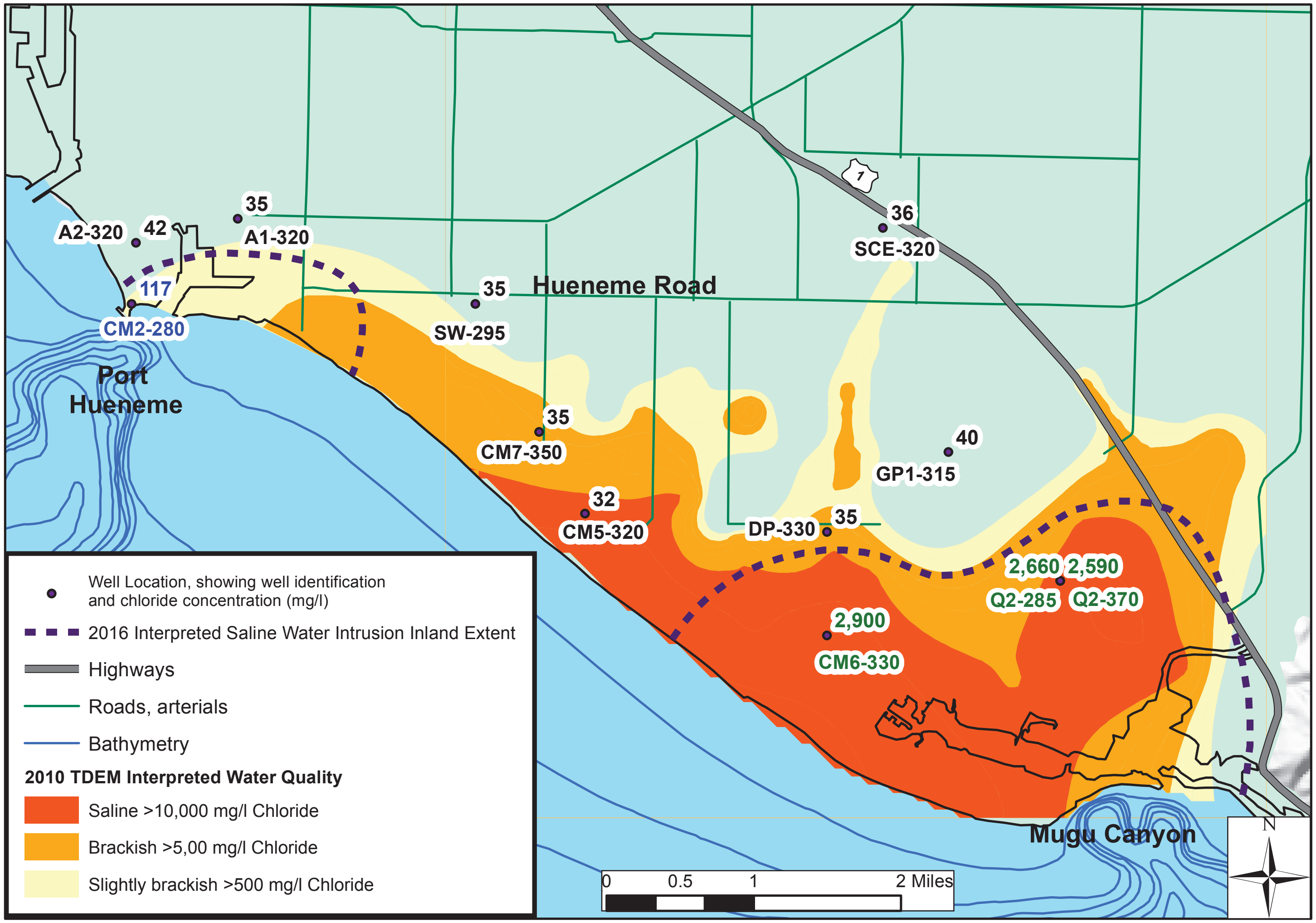

Source: UWCD 2016

FIGURE 2-29

Mugu Aquifer Coastal Chloride Concentrations, Fall 2015

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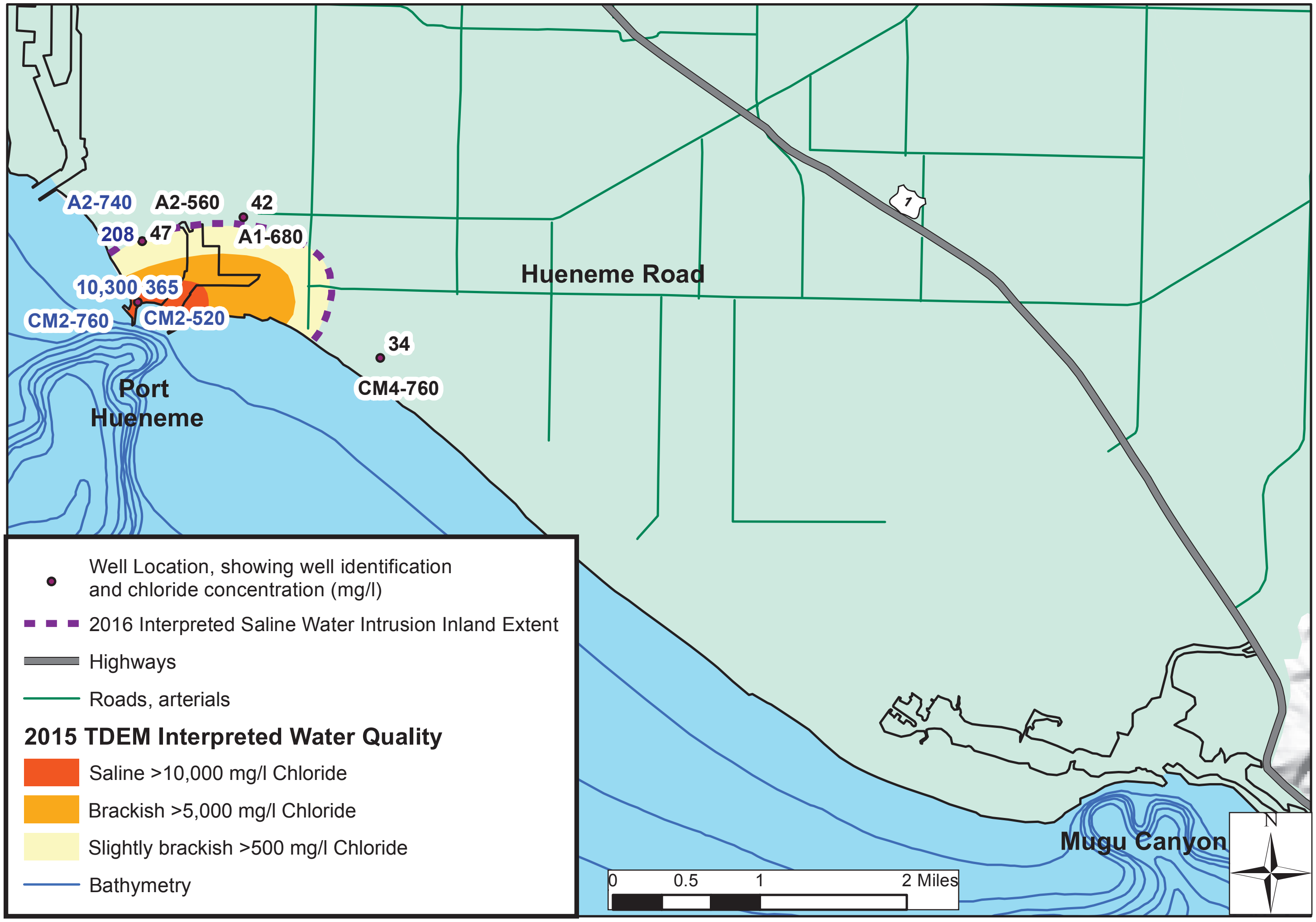

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Source: UWCD 2016

FIGURE 2-30

Hueneme Aquifer Coastal Chloride Concentrations, Fall 2015

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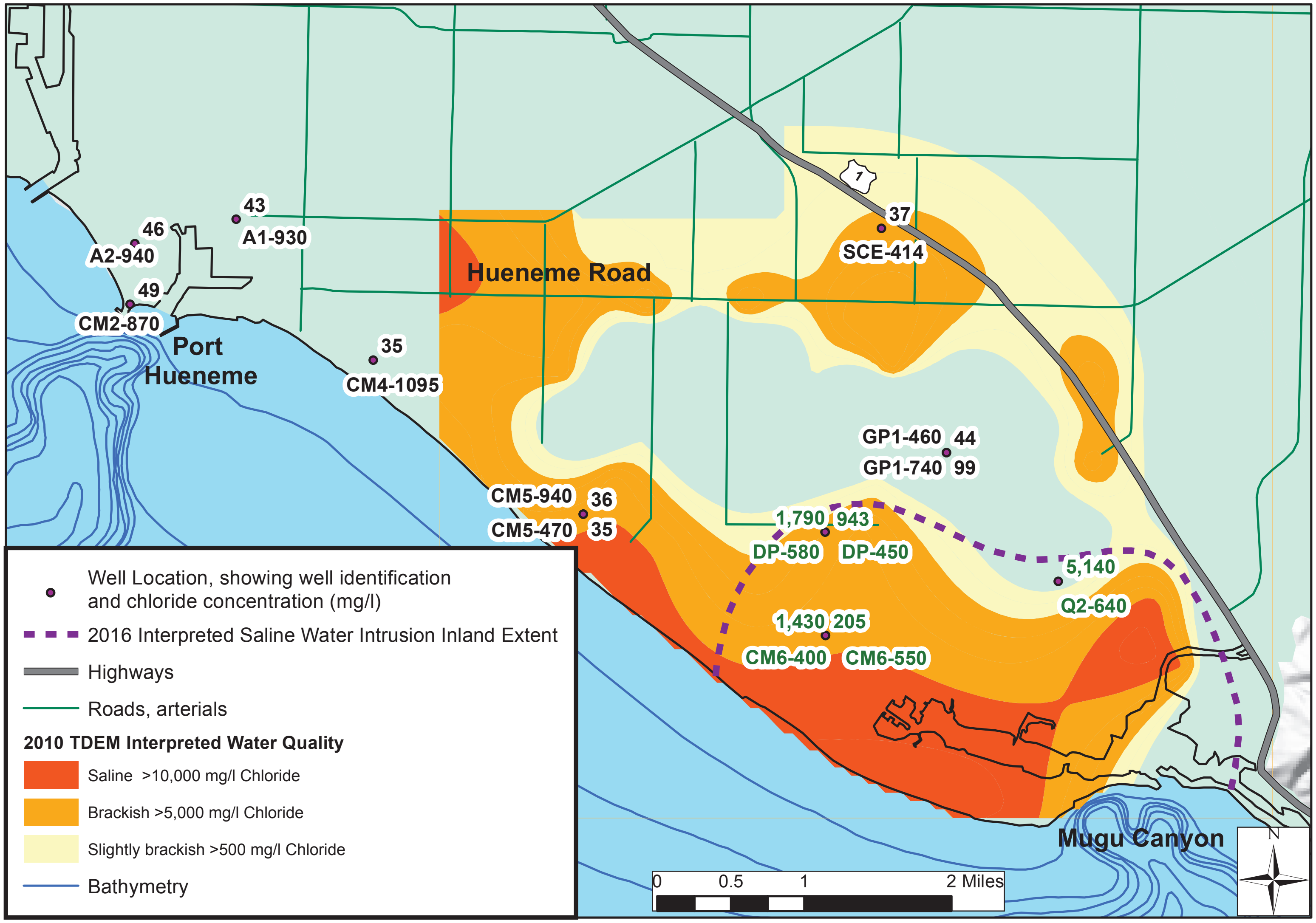

Source: UWCD 2016

DUDEK

FIGURE 2-31

Fox Canyon Aquifer Coastal Chloride Concentrations, Fall 2015

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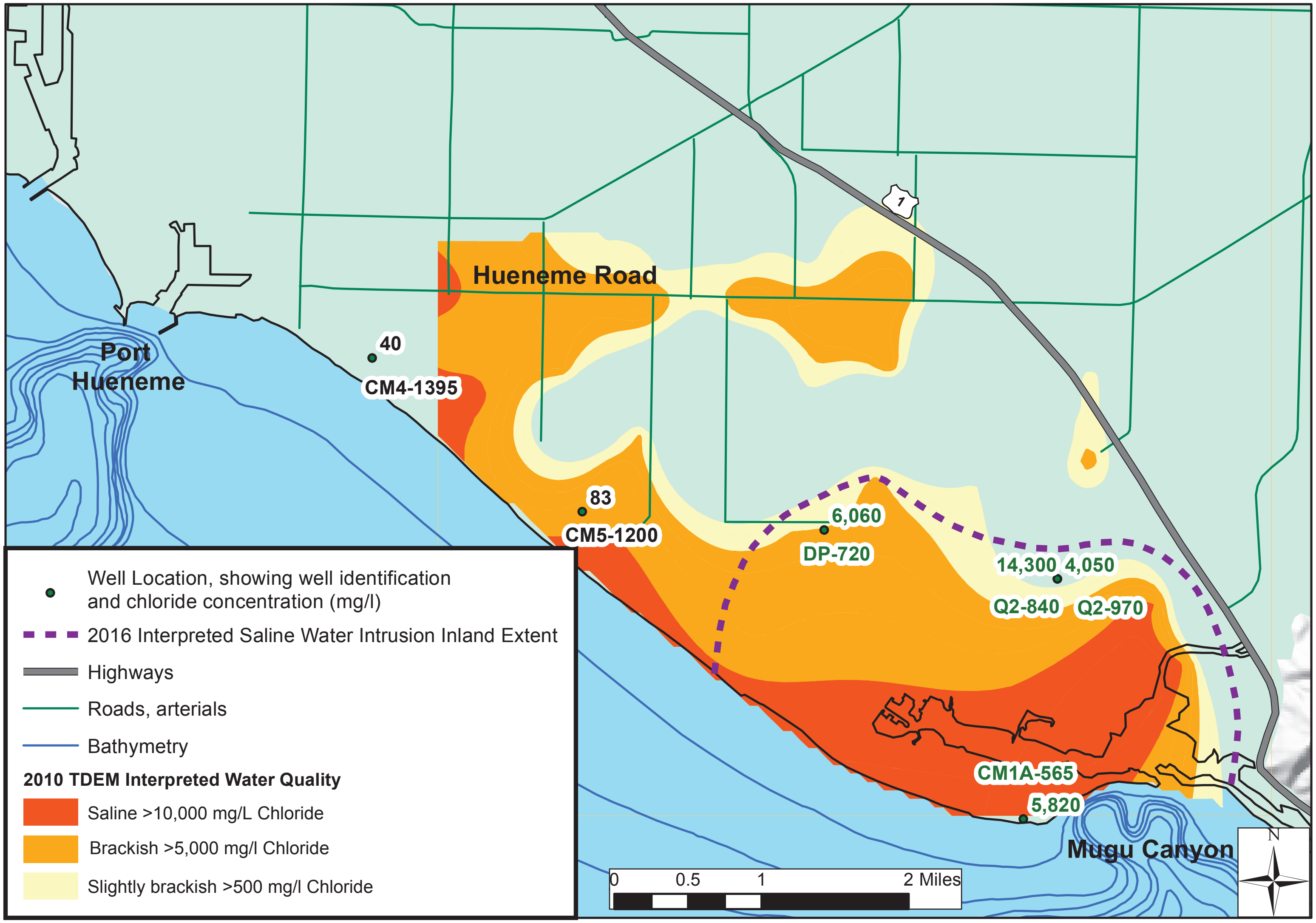

DUDEK

Source: UWCD 2016

FIGURE 2-32

Grimes Canyon Aquifer Coastal Chloride Concentrations, Fall 2015

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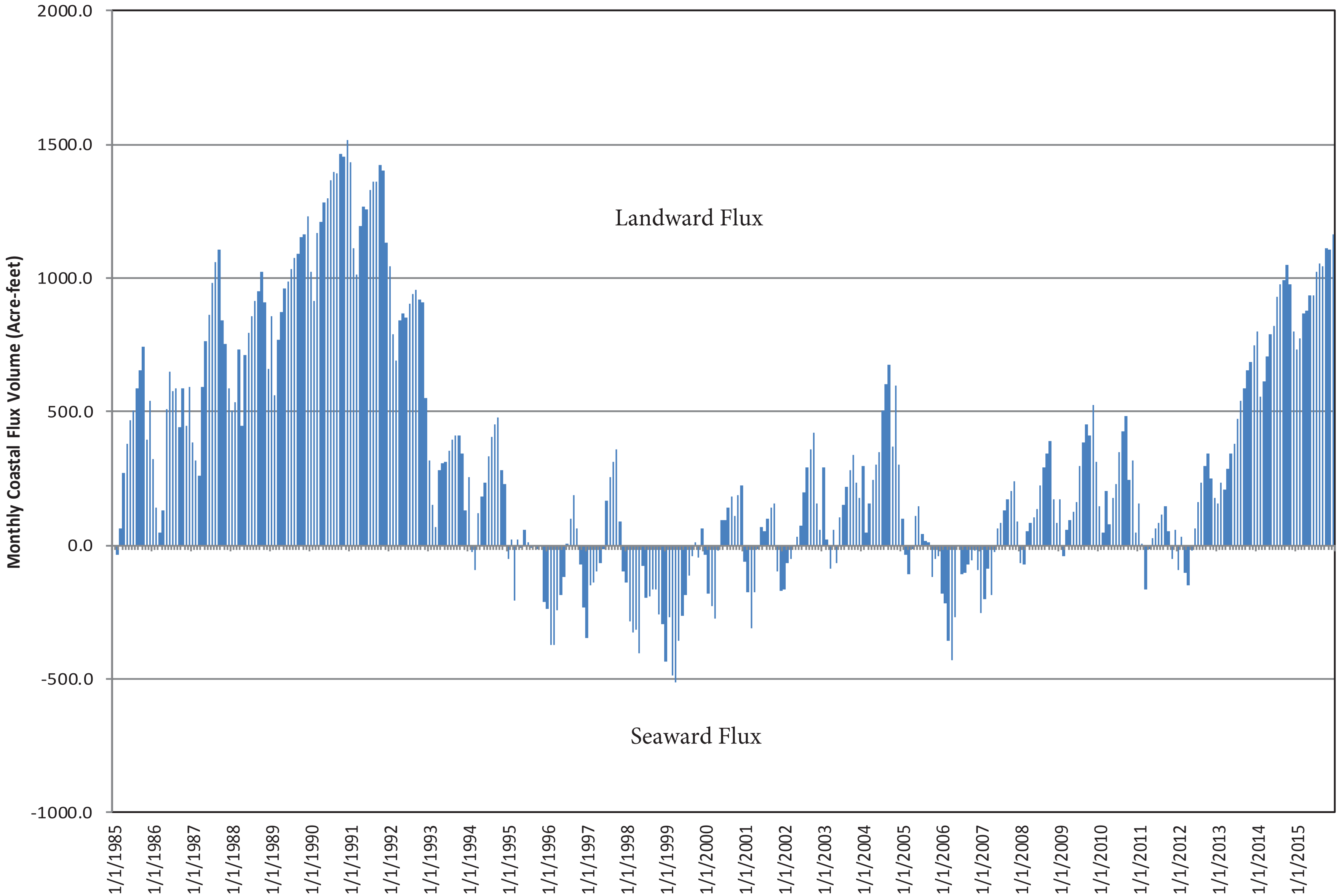

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FIGURE 2-33

Groundwater Flux along the Coast in the Upper Aquifer System

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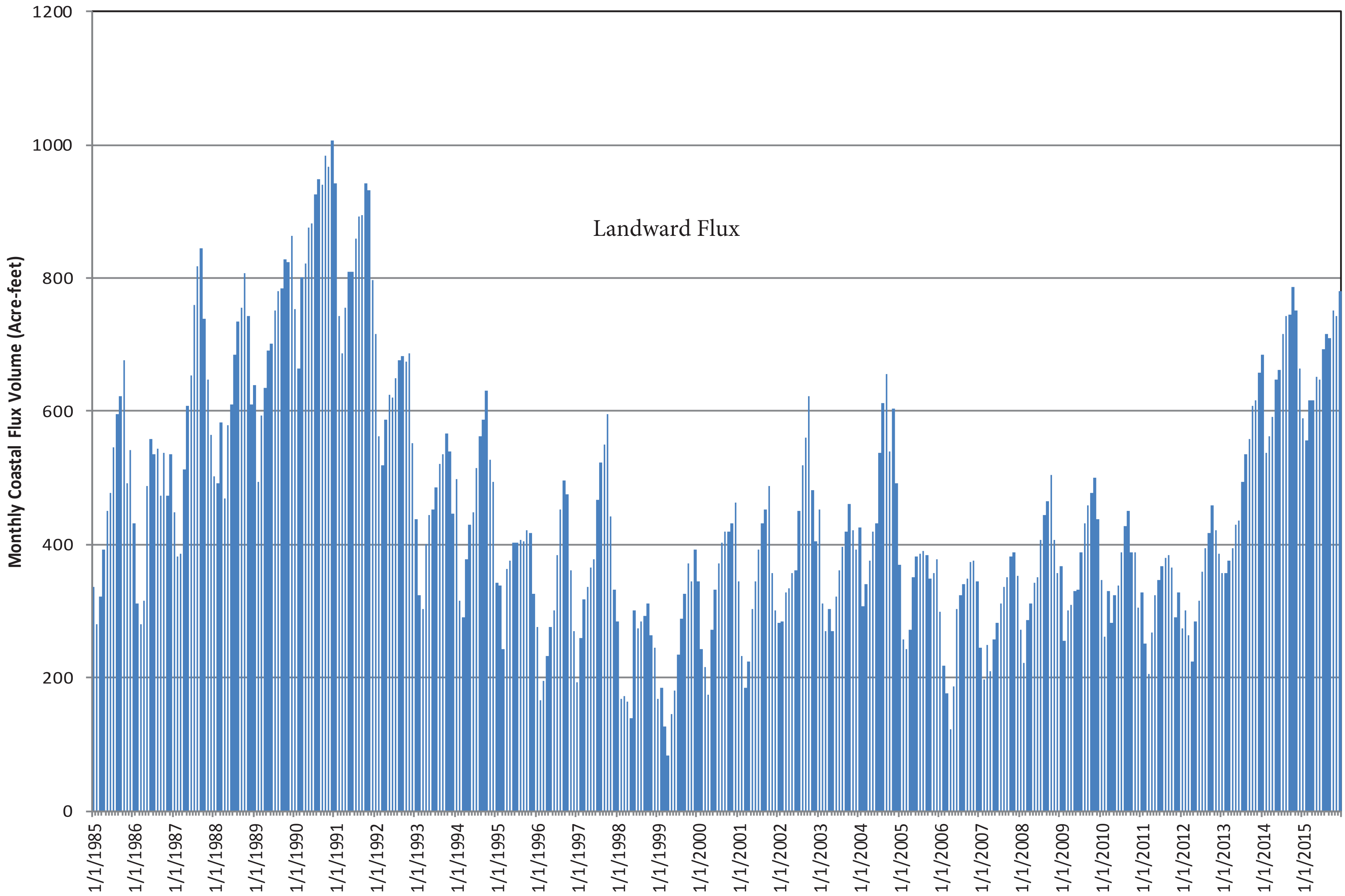

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FIGURE 2-34

Groundwater Flux along the Coast in the Lower Aquifer System

Groundwater Sustainability Plan for the Oxnard Subbasin

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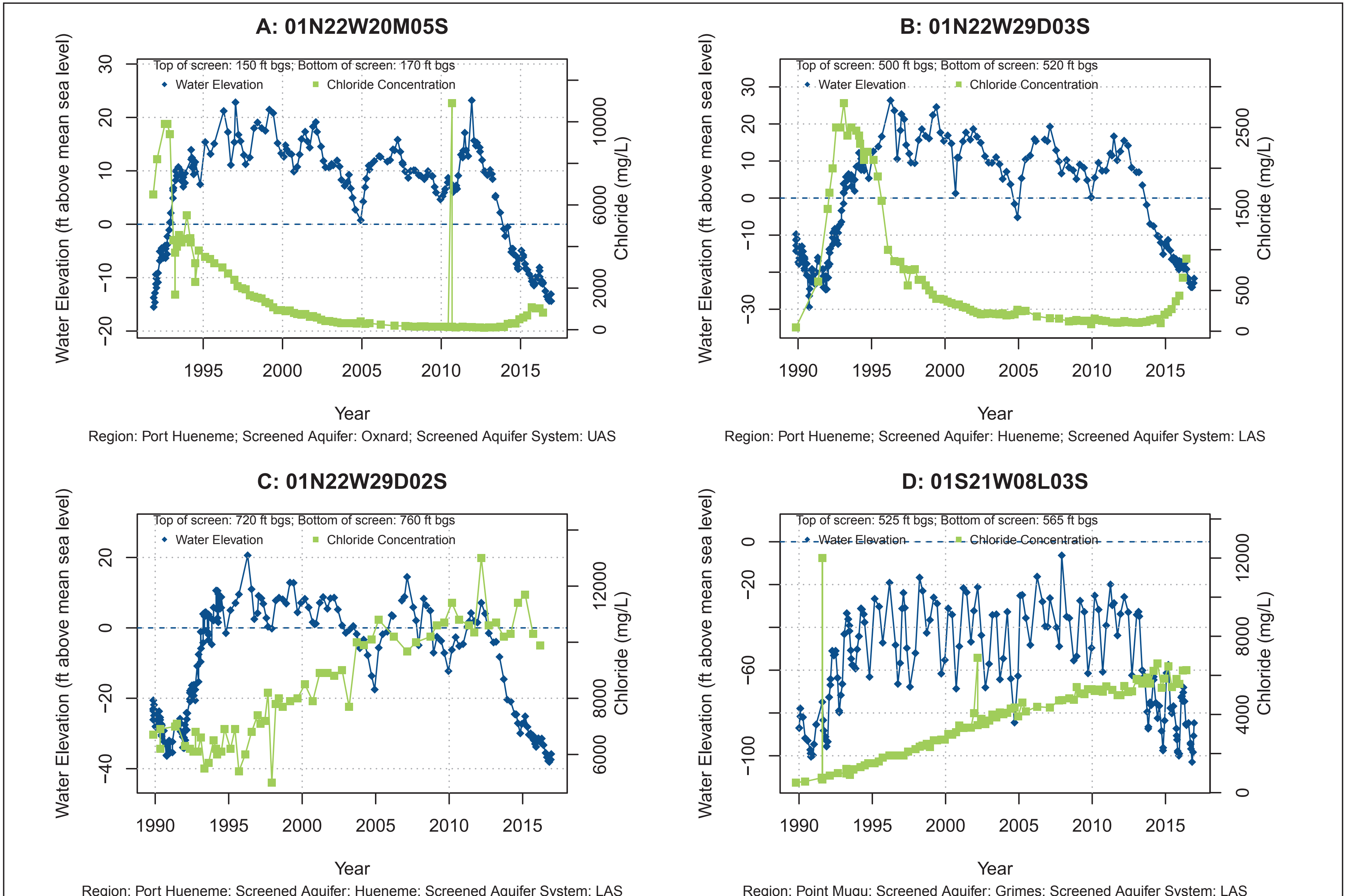

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FIGURE 2-35

Selected Historical Records of Water Elevation and Chloride Concentration

Groundwater Sustainability Plan for the Oxnard Subbasin

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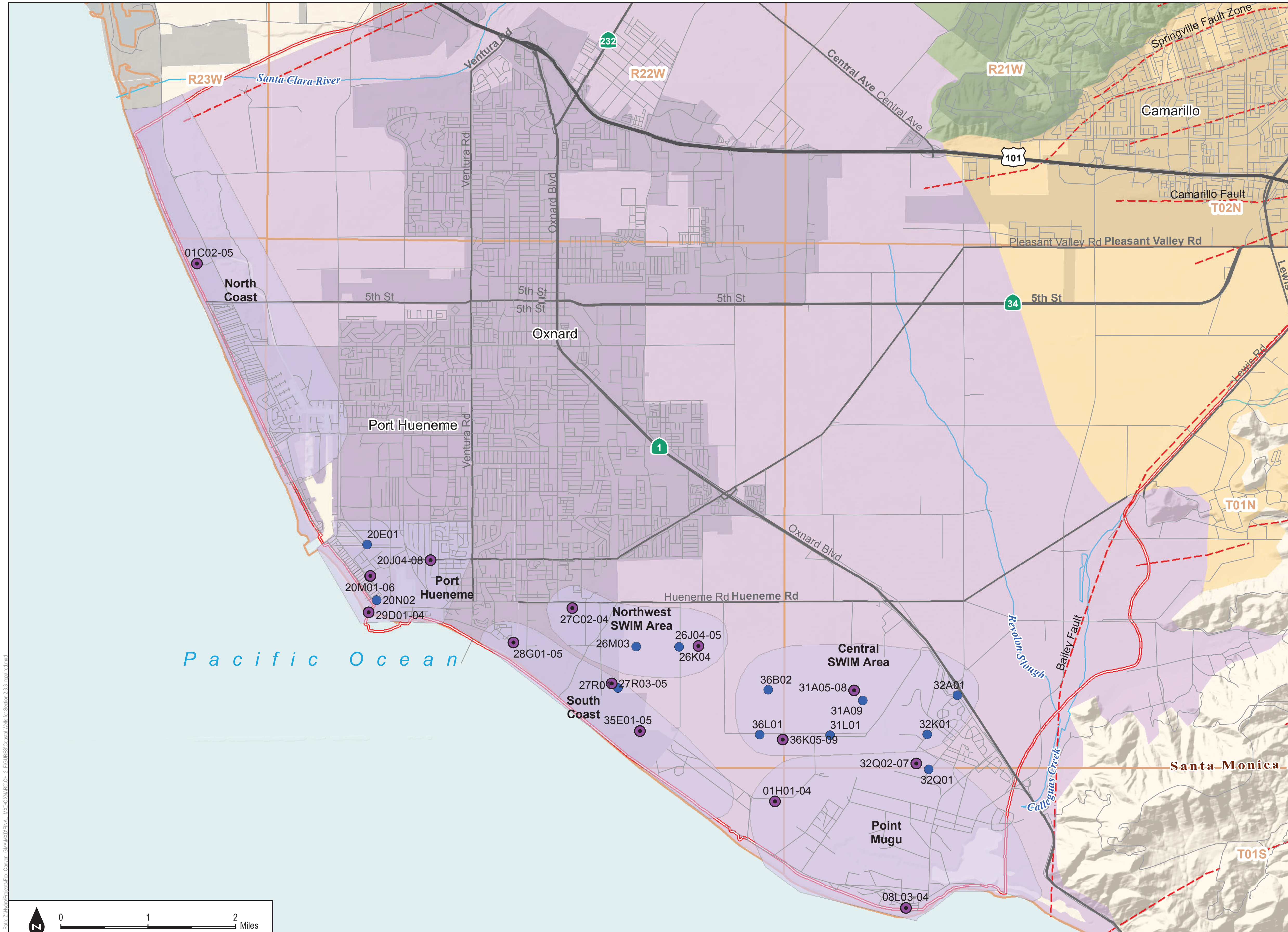

Legend

- Nested Well Set
- Single Well
- Regions for SWI Characterization
- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Township (North-South) and Range (East-West)
- Faults (Ventura County 2016)
- Major Rivers/Stream Channels

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)

15P01 Abbreviated State Well Number (see notes)

Notes:
1) Single well labels consist of an italicized abbreviated State Well Number (SWN). SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map, concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "20E01" located in Township 01N (T01N) and Range 22W (R22W) is 01N22W20E01S.
2) Labels for nested well sets indicate the range of the last two digits in the SWNs completed in each set. Example: The SWNs completed in the nested set labeled "01H01-04," located in Township 01S (T01S) and Range 22W (R22W) are 01S22W01H01S, 01S22W01H02S, 01S22W01H03S, and 01S22W01H04S.
3) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-36

Locations of Selected Coastal Wells with Historical Measurements of Chloride Concentration and Water Elevation

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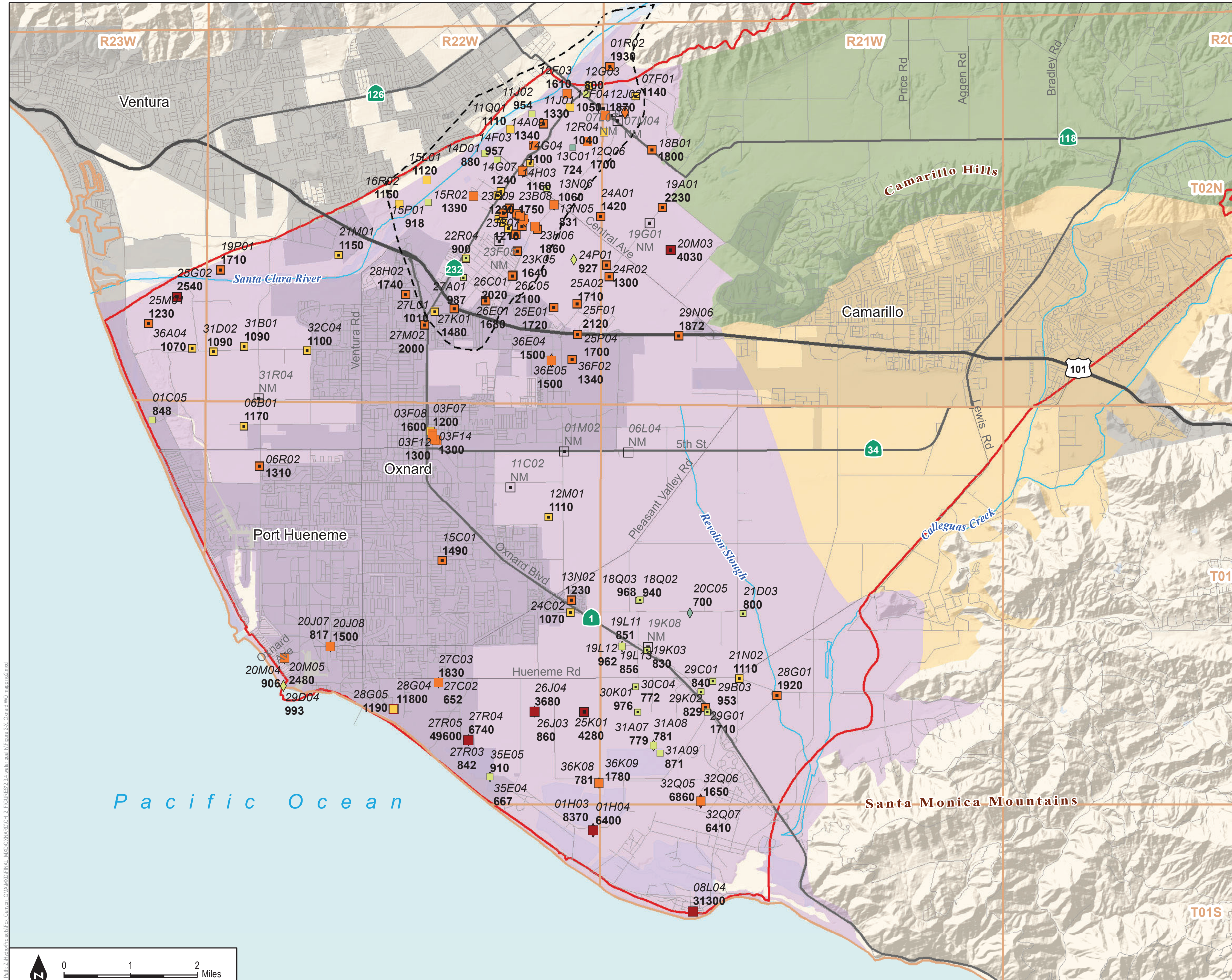

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

TDS concentration (mg/L), 2011-2015

- 290 - 500
- >500 - 750
- >750 - 1000
- >1000 - 1200
- >1200 - 2500
- >2500 - 49,800

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

Groundwater Sustainability Plan for the Oxnard Subbasin

FIGURE 2-37A

Upper Aquifer System - Most Recent Total Dissolved Solids (mg/L) Measured 2011-2015

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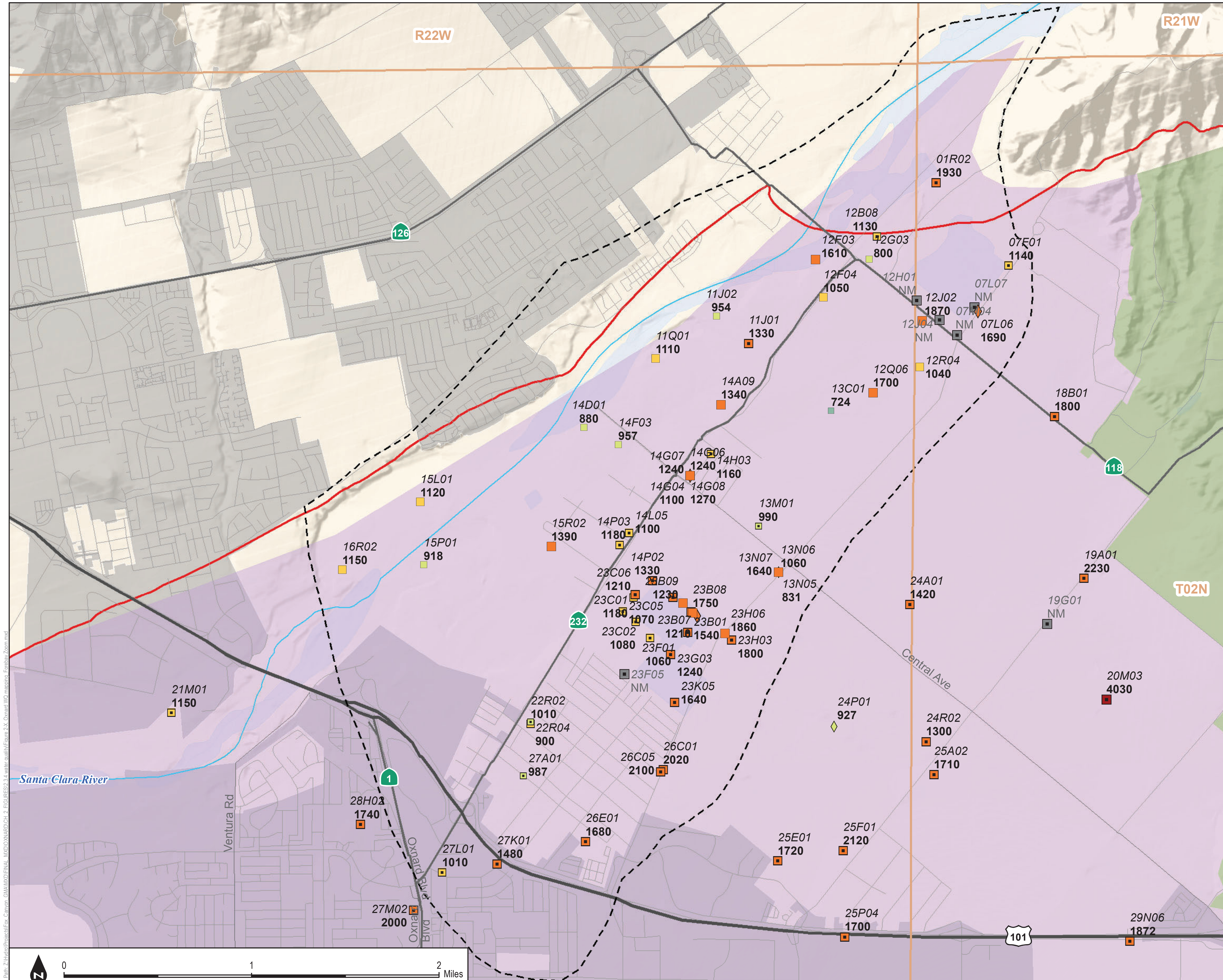

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

TDS concentration (mg/L), 2011-2015

- 290 - 500
- >500 - 750
- >750 - 1000
- >1000 - 1200
- >1200 - 2500
- >2500 - 49,800
- Not Measured (NM)

15P01 Abbreviated State Well Number (see notes)

10.5 Concentration (mg/L)

Notes:

1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix C.
2) "ND" signifies non-detect. "NM" signifies not measured.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well. A solid gray well symbol has no data between 2011 and 2015.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-37B

Upper Aquifer System, Forebay Area - Most Recent Total Dissolved Solids (mg/L) Measured 2011-2015

Groundwater Sustainability Plan for the Oxnard Subbasin

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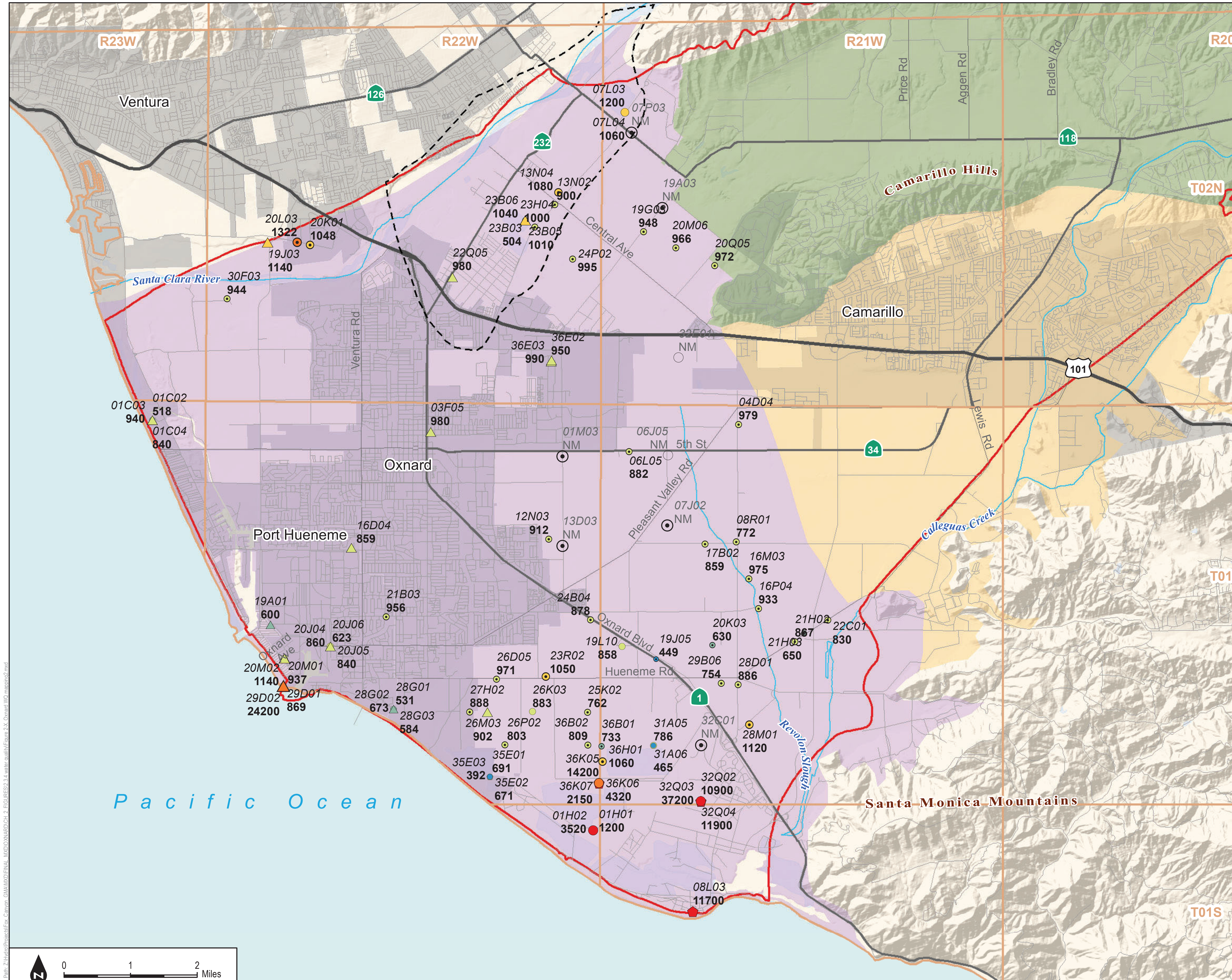

Legend

Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)

Major Rivers/Stream Channels

Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

Arroyo Santa Rosa Valley (4-007)

Las Posas Valley (4-008)

Pleasant Valley (4-006)

Oxnard (4-004.02)

Oxnard Forebay

TDS concentration (mg/L), 2011-2015

- 290 - 500
- >500 - 750
- >750 - 1000
- >1000 - 1200
- >1200 - 2500
- >2500 - 49,800

Aquifer designation

- Well screened in the Hueneme aquifer
- Well screened in the Fox Canyon aquifer
- Well screened in the Grimes Canyon aquifer
- Wells screened in multiple aquifers in the LAS

15P01 Abbreviated State Well Number (see notes)

10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-38

Lower Aquifer System - Most Recent Total Dissolved Solids (mg/L) Measured 2011-2015

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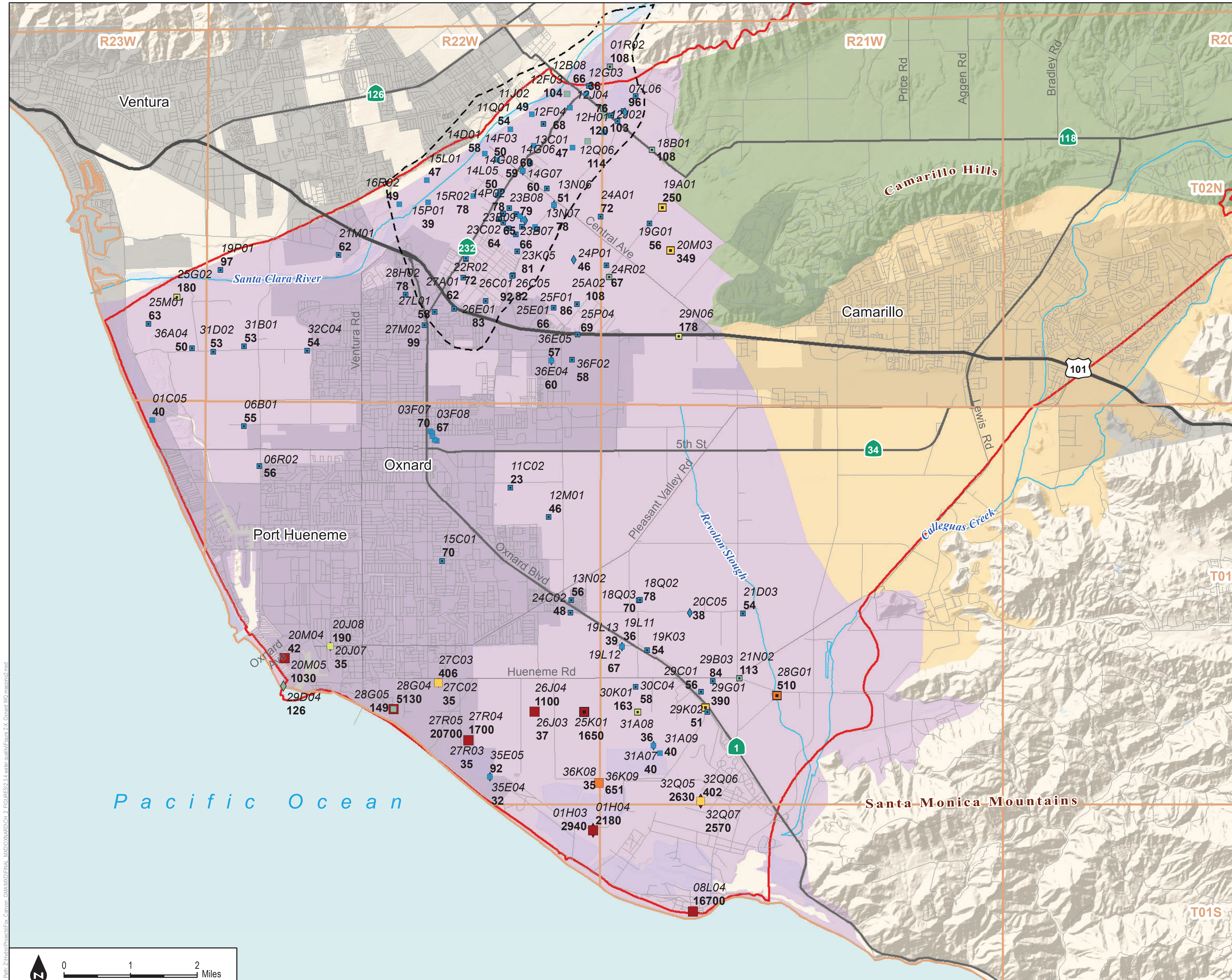

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Chloride concentration (mg/L), 2011-2015

- 23 - 100
- 101 - 150
- 151 - 200
- 201 - 500
- 501 - 1000
- 1001 - 22500

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-39A

Upper Aquifer System - Most Recent Chloride (mg/L) Measured 2011-2015

Groundwater Sustainability Plan for the Oxnard Subbasin

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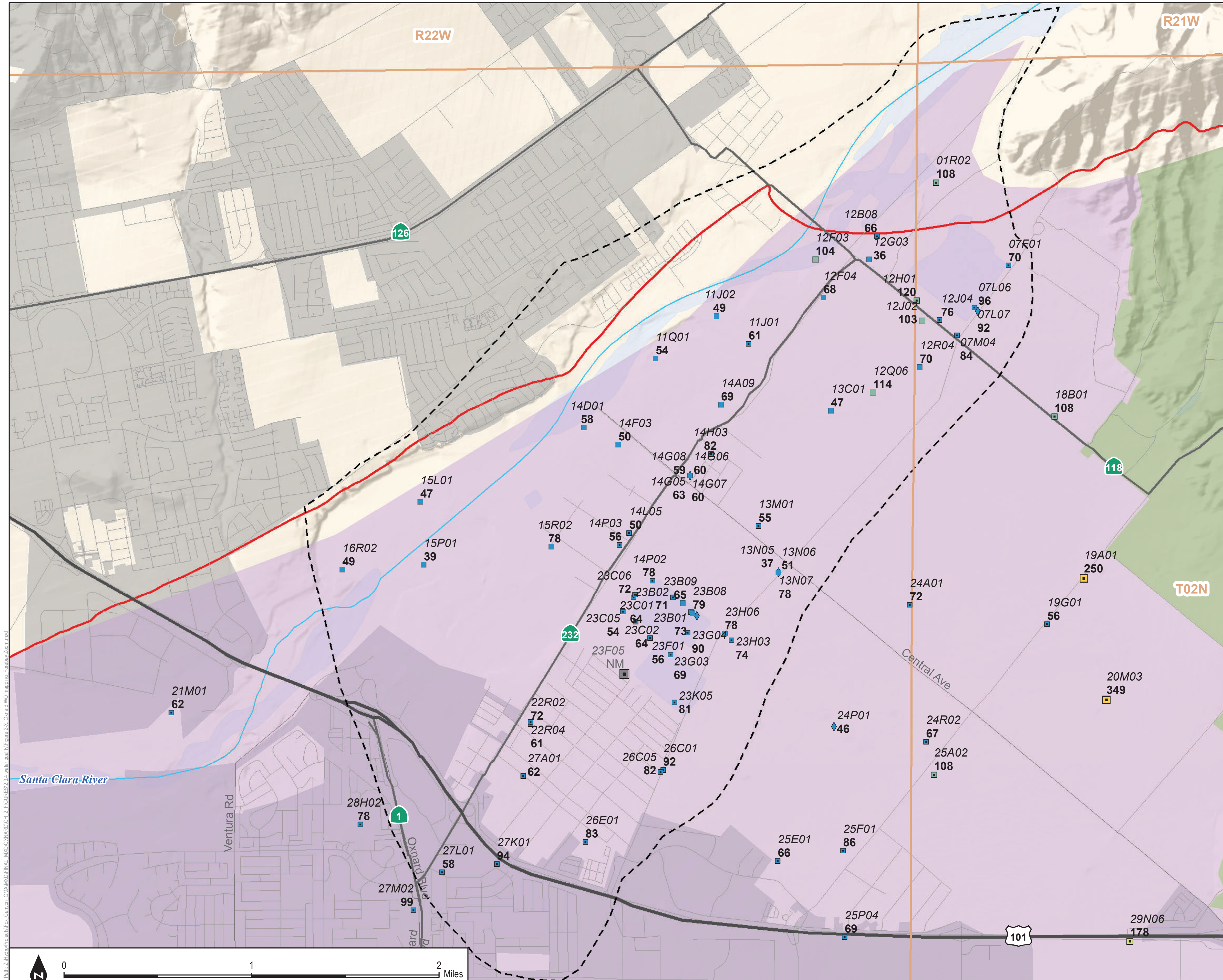

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

Chloride concentration (mg/L), 2011-2015

- 23 - 100
- 101 - 150
- 151 - 200
- 201 - 500
- 501 - 1000
- 1001 - 22500
- Not Measured (NM)

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix C.
2) "ND" signifies non-detect. "NM" signifies not measured.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well. A solid gray well symbol has no data between 2011 and 2015.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-39B

Upper Aquifer System, Forebay Area - Most Recent Chloride (mg/L) Measured 2011-2015

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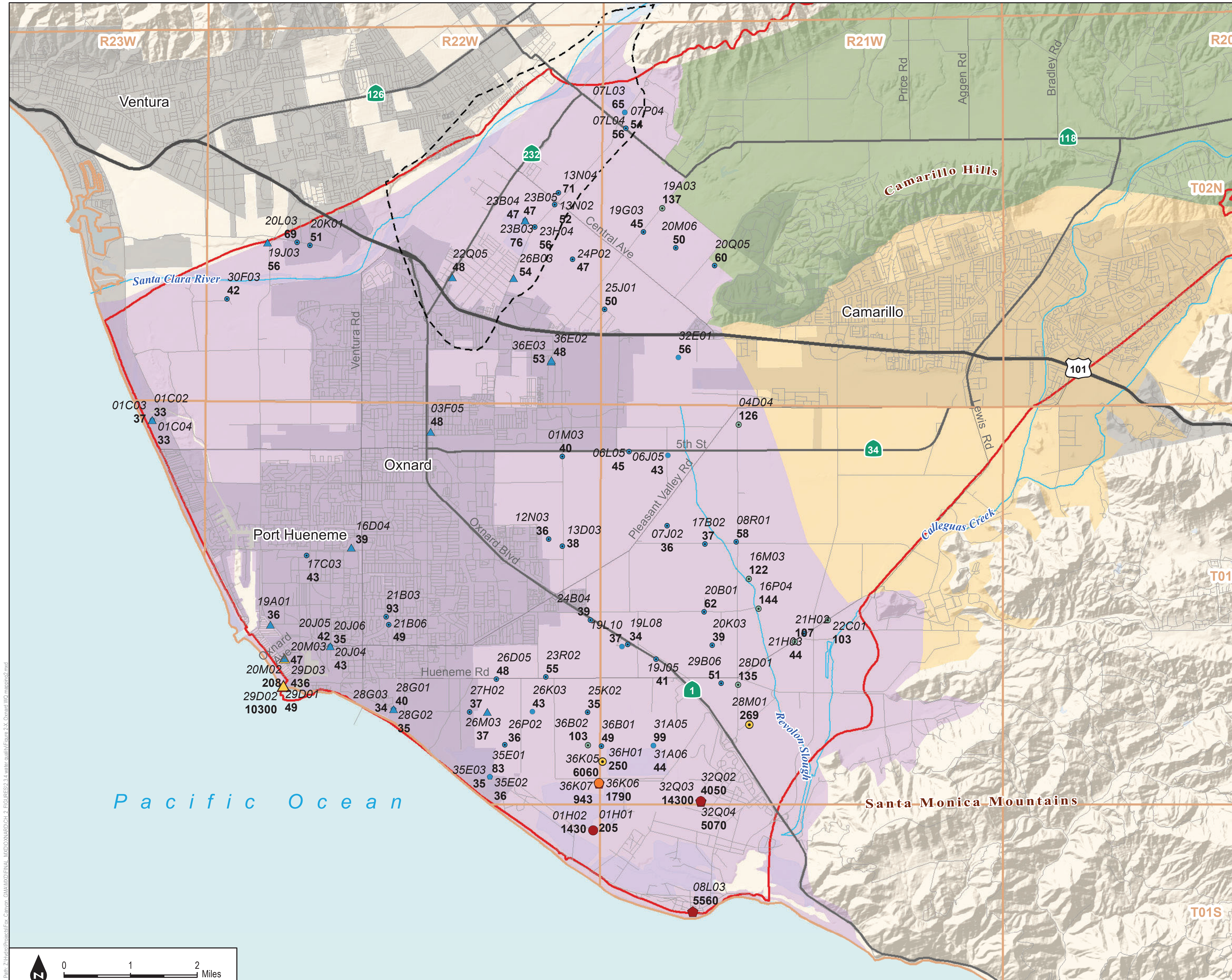

Legend

Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)

Major Rivers/Stream Channels

Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

Arroyo Santa Rosa Valley (4-007)

Las Posas Valley (4-008)

Pleasant Valley (4-006)

Oxnard (4-004.02)

Oxnard Forebay

Chloride concentration (mg/L), 2011-2015

- 23 - 100
- 101 - 150
- 151 - 200
- 201 - 500
- 501 - 1000
- 1001 - 22500

Aquifer designation

- Well screened in the Hueneme aquifer
- Well screened in the Fox Canyon aquifer
- Well screened in the Grimes Canyon aquifer
- Wells screened in multiple aquifers in the LAS

15P01 Abbreviated State Well Number (see notes)

10.5 Concentration (mg/L)

Notes:

1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.

2) "ND" signifies non-detect.

3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.

4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).

5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.

6) All concentrations are in mg/L.

7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-40

Lower Aquifer System - Most Recent Chloride (mg/L) Measured 2011-2015

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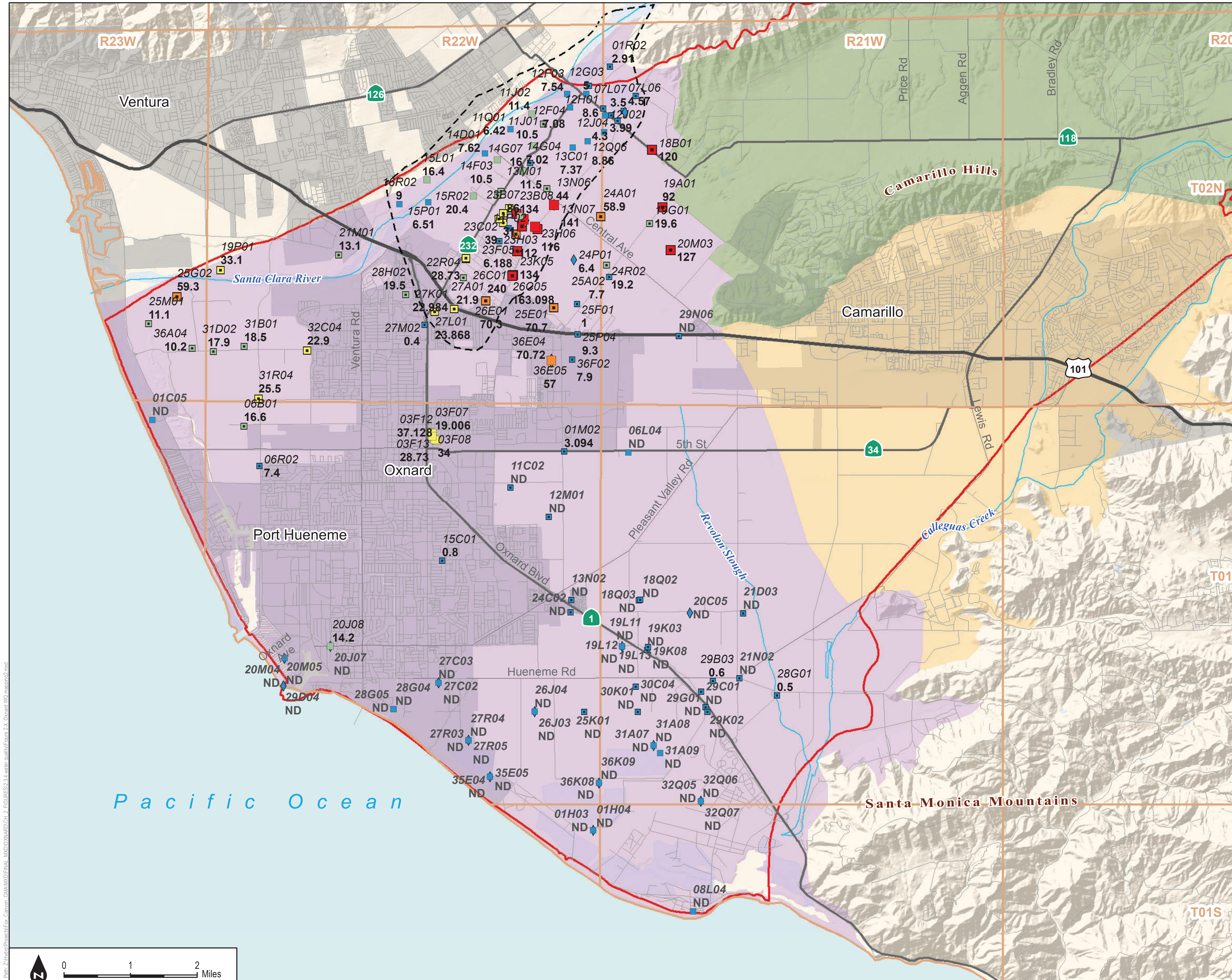

Legend

Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)

Major Rivers/Stream Channels

Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

Arroyo Santa Rosa Valley (4-007)

Las Posas Valley (4-008)

Pleasant Valley (4-006)

Oxnard (4-004.02)

Oxnard Forebay

Nitrate concentration (mg/L as Nitrate), 2011-2015

0 - 10

>10 - 22.5

>22.5 - 45

>45 - 90

>90 - 528

Aquifer designation

Well screened in the Oxnard aquifer

Well screened in the Mugu aquifer

Wells screened in multiple aquifers in the UAS

15P01 Abbreviated State Well Number (see notes)

10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
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5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-41A

Upper Aquifer System - Most Recent Nitrate (mg/L as Nitrate) Measured 2011-2015

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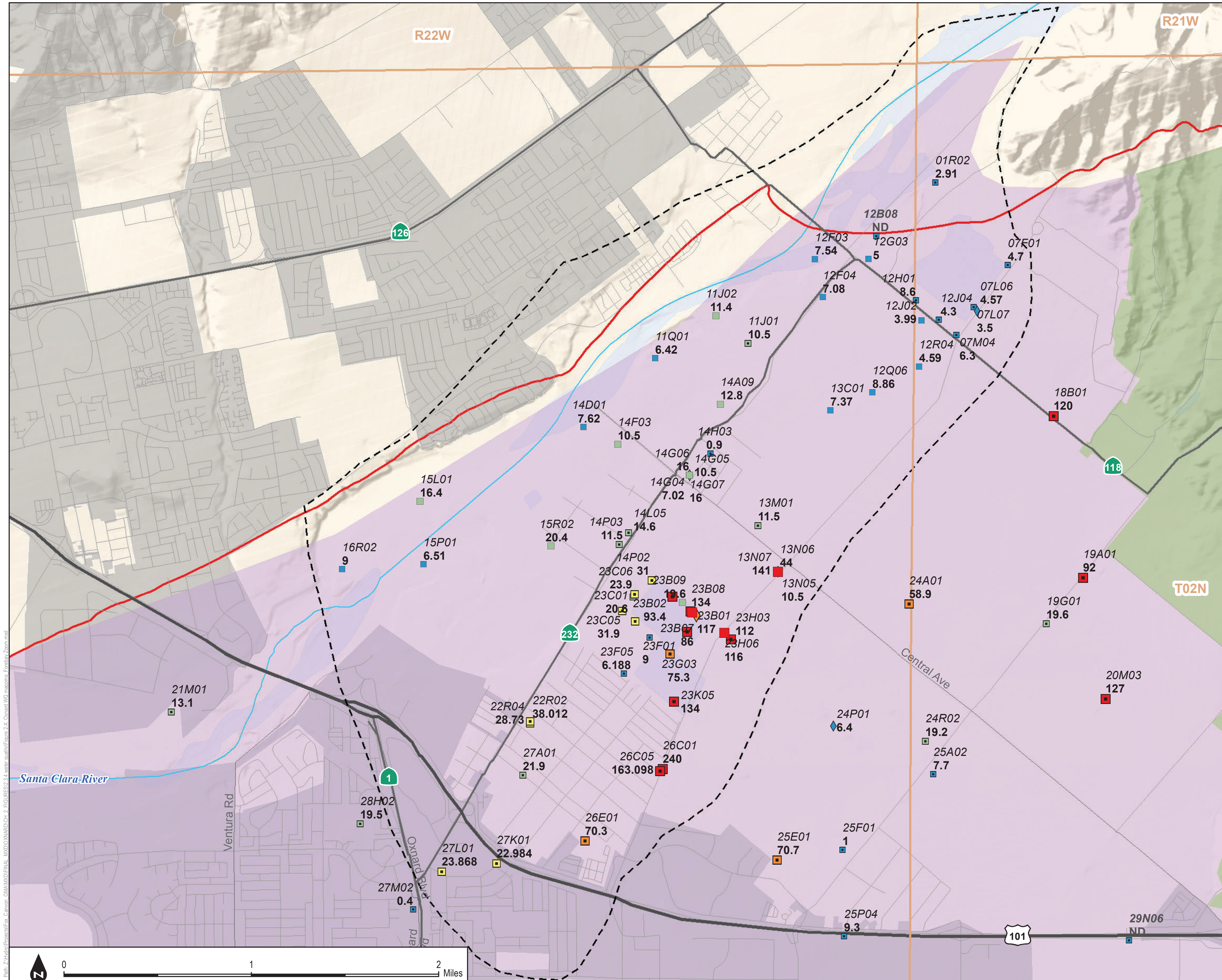

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

Nitrate concentration (mg/L), 2011-2015

- 0 - 10
- >10 - 22.5
- >22.5 - 45
- >45 - 90
- >90 - 528
- Not Measured (NM)

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix C.
2) "ND" signifies non-detect. "NM" signifies not measured.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
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5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well. A solid gray well symbol has no data between 2011 and 2015.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-41B

Upper Aquifer System, Forebay Area - Most Recent Nitrate (mg/L as Nitrate) Measured 2011-2015

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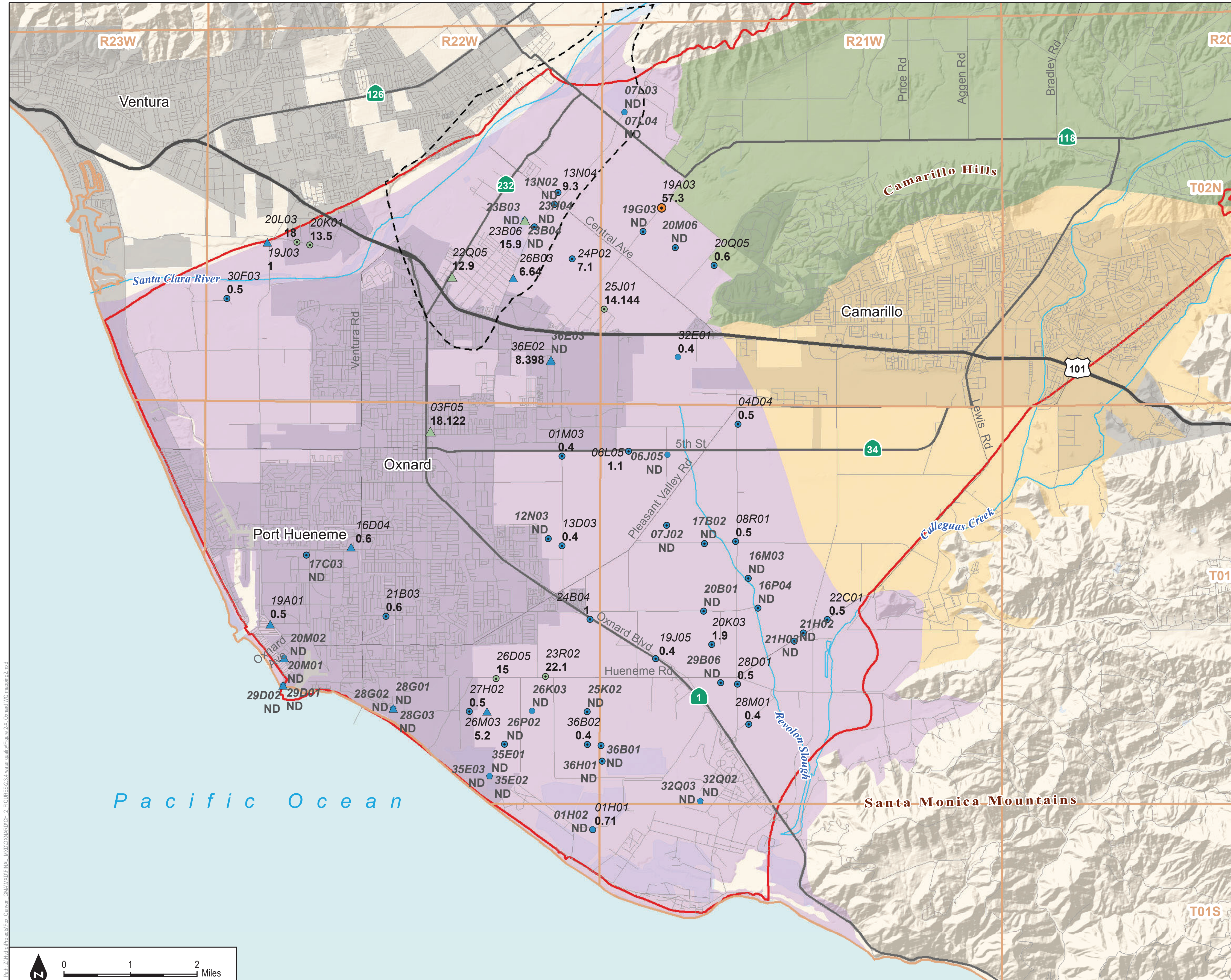

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Nitrate concentration (mg/L), 2011-2015

- 0 - 10
- >10 - 22.5
- >22.5 - 45
- >45 - 90
- >90 - 528

Aquifer designation

- Well screened in the Hueneme aquifer
- Well screened in the Fox Canyon aquifer
- Well screened in the Grimes Canyon aquifer
- Wells screened in multiple aquifers in the LAS

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
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5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-42

Lower Aquifer System - Most Recent Nitrate (mg/L as Nitrate) Measured 2011-2015

Groundwater Sustainability Plan for the Oxnard Subbasin

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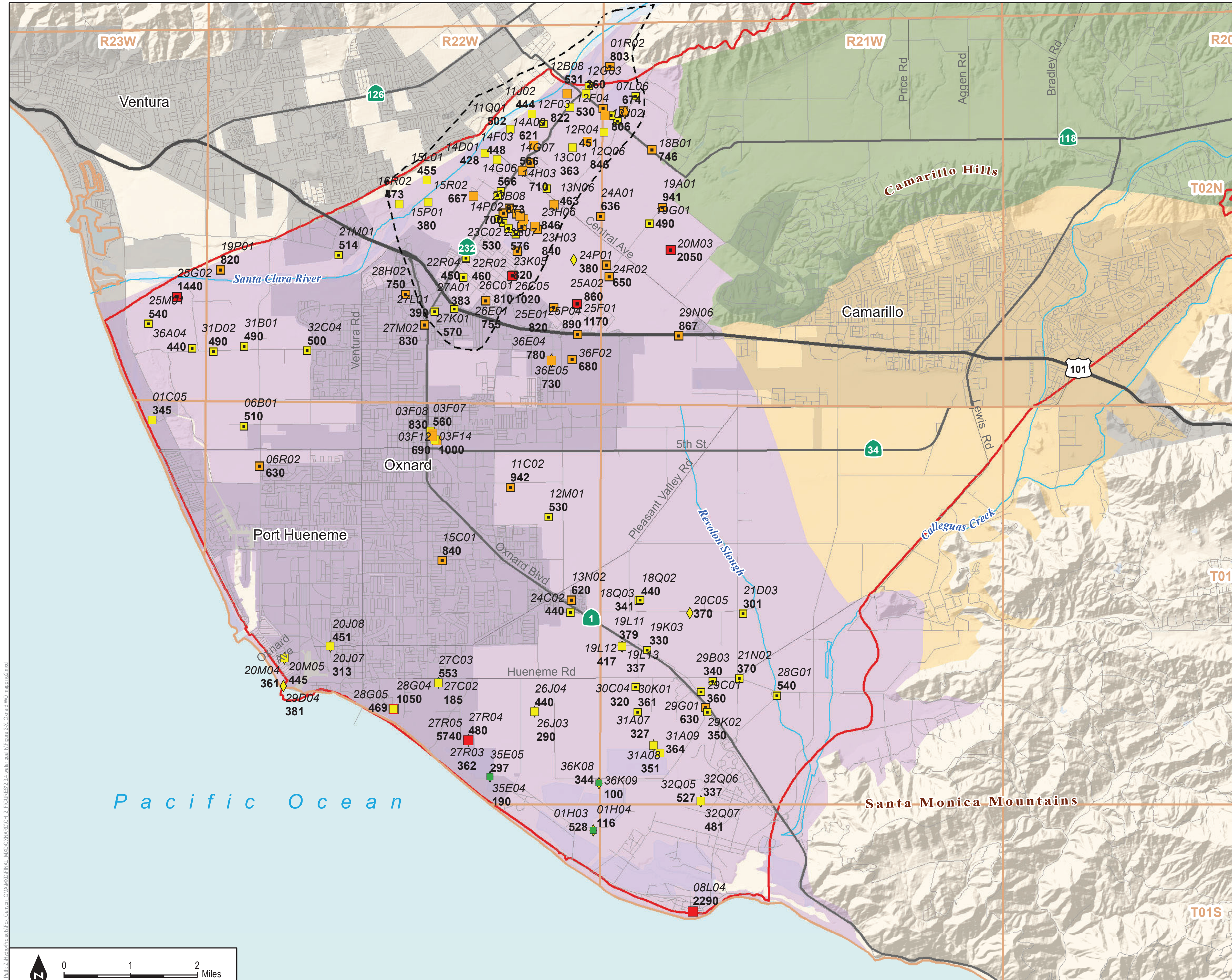

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Sulfate concentration (mg/L), 2011-2015

- 29 - 300
- 301 - 600
- 601 - 1000
- 1001 - 5740

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-43A

Upper Aquifer System - Most Recent Sulfate (mg/L) Measured 2011-2015

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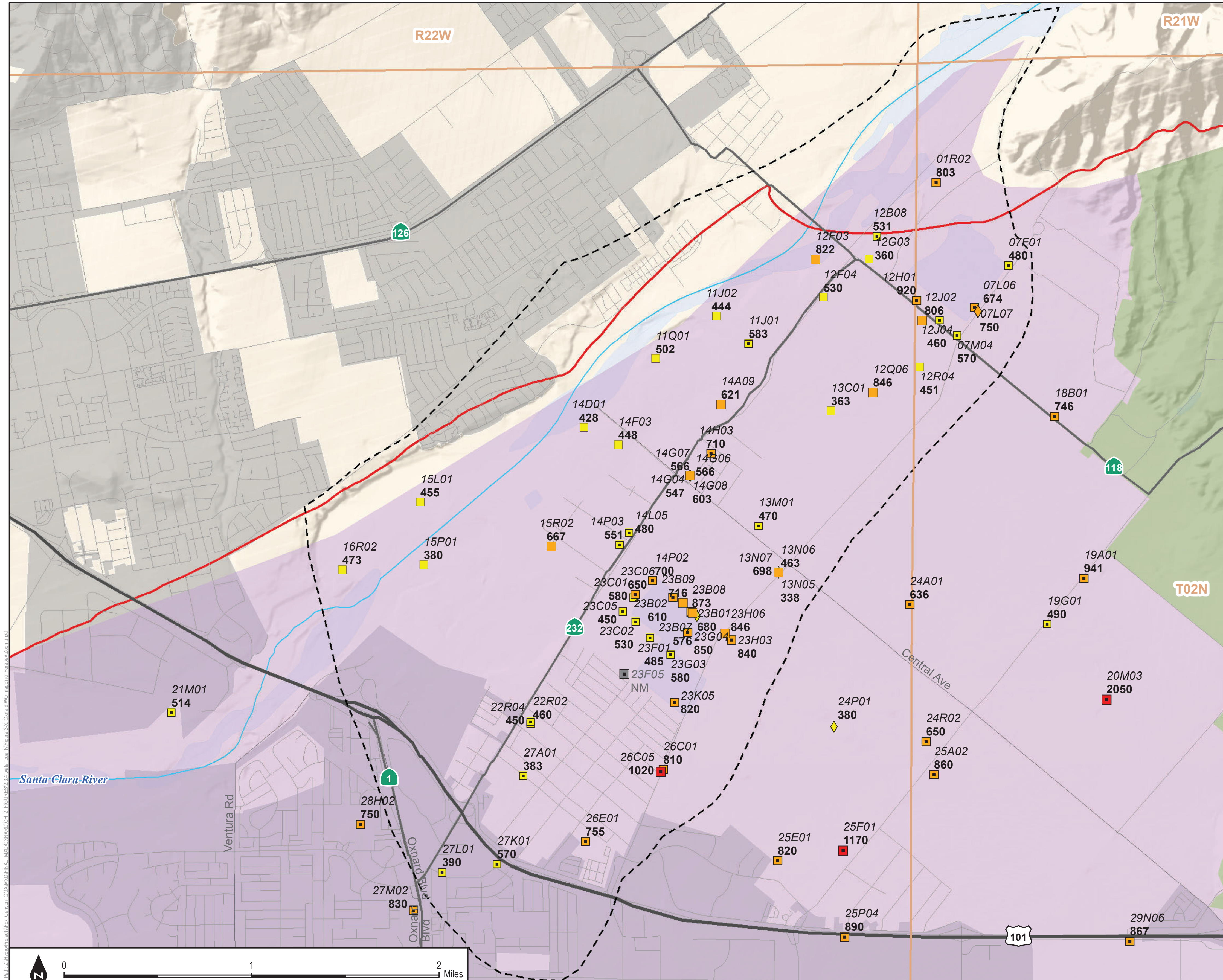

Legend

Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)

Major Rivers/Stream Channels

Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

Las Posas Valley (4-008)

Pleasant Valley (4-006)

Oxnard (4-004.02)

Oxnard Forebay

Aquifer designation

Well screened in the Oxnard aquifer

Well screened in the Mugu aquifer

Wells screened in multiple aquifers in the UAS

Sulfate concentration (mg/L), 2011-2015

29 - 300

301 - 600

601 - 1000

1001 - 5740

Not Measured (NM)

15P01 Abbreviated State Well Number (see notes)

10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix C.
2) "ND" signifies non-detect. "NM" signifies not measured.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well. A solid gray well symbol has no data between 2011 and 2015.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-43B

Upper Aquifer System, Forebay Area - Most Recent Sulfate (mg/L) Measured 2011-2015

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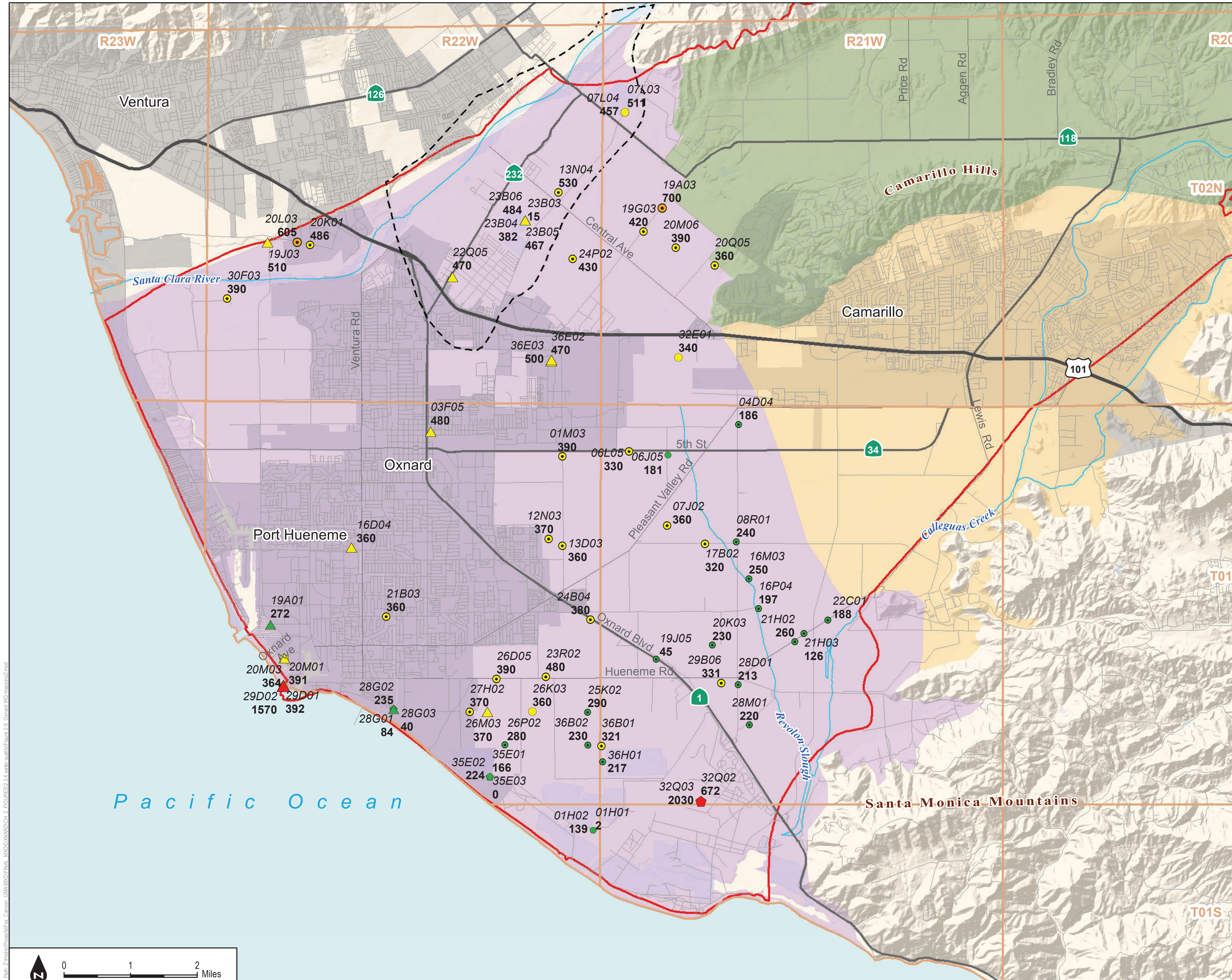

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Sulfate concentration (mg/L), 2011-2015

- 29 - 300
- 301 - 600
- 601 - 1000
- 1001 - 5740

Aquifer designation

- Well screened in the Hueneme aquifer
- Well screened in the Fox Canyon aquifer
- Well screened in the Grimes Canyon aquifer
- Wells screened in multiple aquifers in the LAS

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
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5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-44

Lower Aquifer System - Most Recent Sulfate (mg/L) Measured 2011-2015

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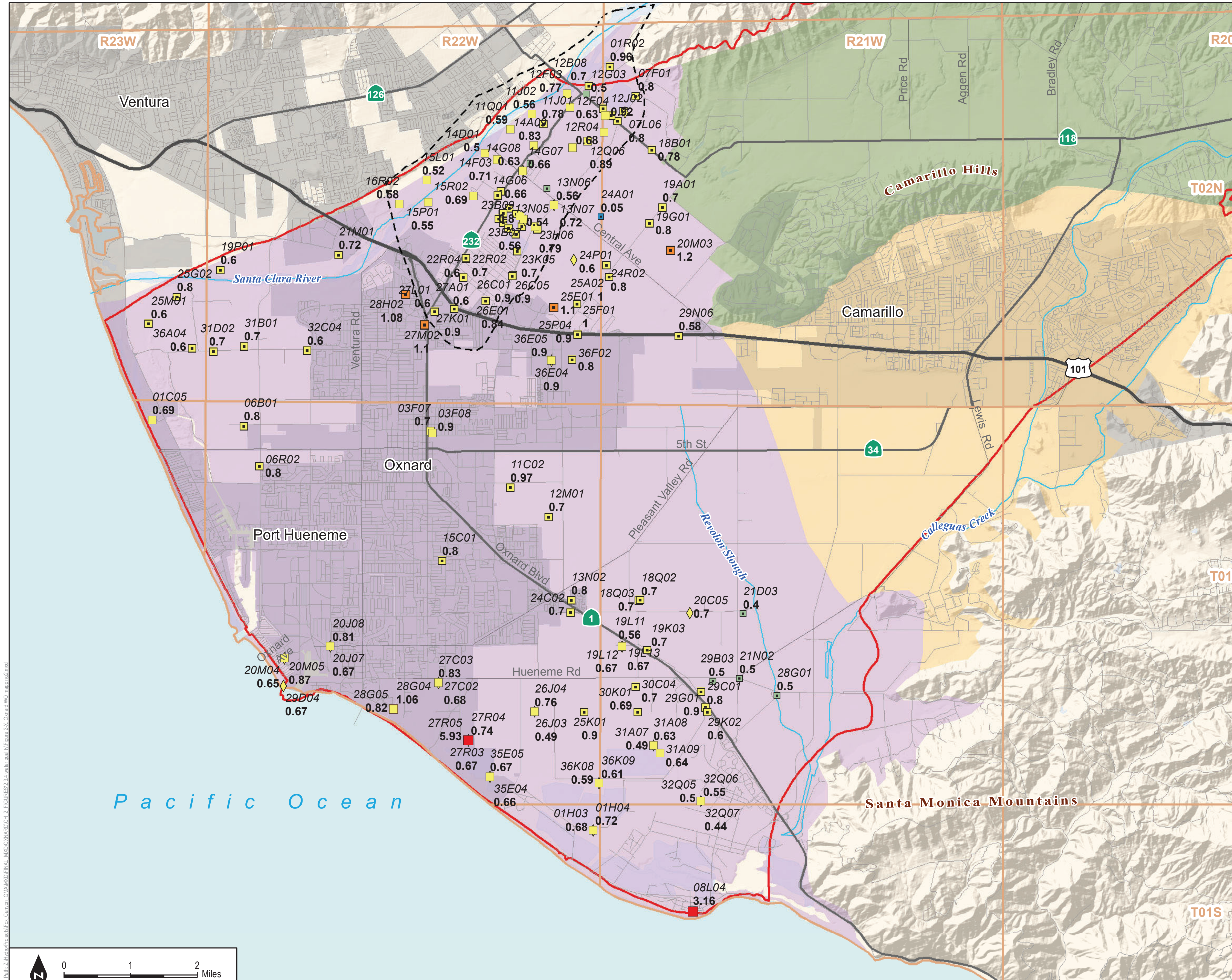

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Arroyo Santa Rosa Valley (4-007)
- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Boron concentration (mg/L), 2011-2015

- 0 - 0.2
- >0.2 - 0.5
- >0.5 - 1.0
- >1.0 - 2.0
- >2.0 - 6.0

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix X.
2) "ND" signifies non-detect.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-45A

Upper Aquifer System - Most Recent Boron (mg/L) Measured 2011-2015

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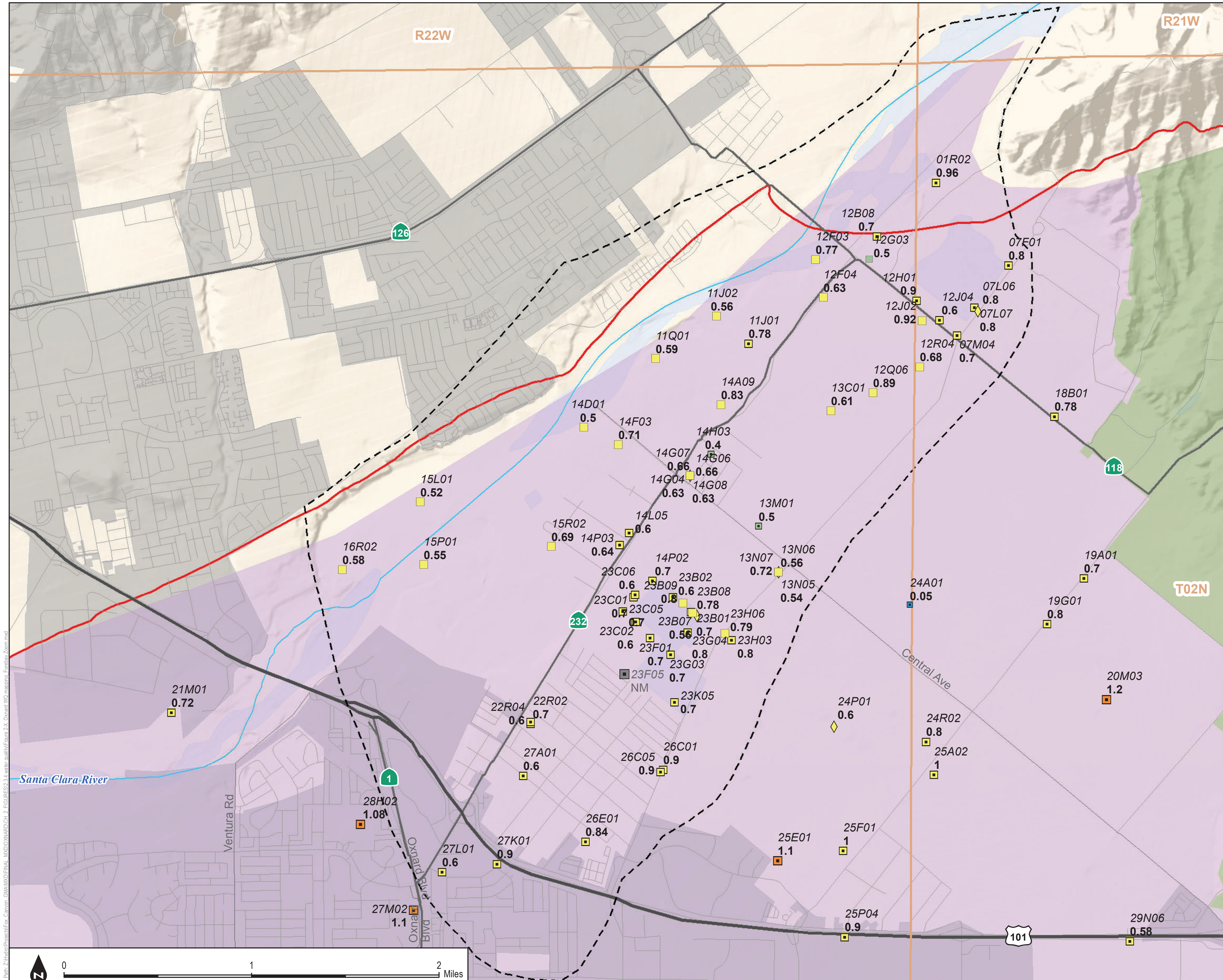

Legend

- Fox Canyon Groundwater Management Agency Boundary (FCGMA 2016)
- Major Rivers/Stream Channels
- Township (North-South) and Range (East-West)

Revised Bulletin 118 Groundwater Basins and Subbasin (DWR 2016)

- Las Posas Valley (4-008)
- Pleasant Valley (4-006)
- Oxnard (4-004.02)
- Oxnard Forebay

Aquifer designation

- Well screened in the Oxnard aquifer
- Well screened in the Mugu aquifer
- Wells screened in multiple aquifers in the UAS

Boron concentration (mg/L), 2011-2015

- 0 - 0.2
- >0.2 - 0.5
- >0.5 - 1.0
- >1.0 - 2.0
- >2.0 - 6.0
- Not Measured (NM)

15P01 Abbreviated State Well Number (see notes)
10.5 Concentration (mg/L)

Notes:
1) Well labels consist of an italicized abbreviated State Well Number (SWN) and a concentration value beneath it.The concentration is the most recent concentration measured in water quality samples collected at that well in the five years from 2011-2015. For a complete water quality record for each well, see Appendix C.
2) "ND" signifies non-detect. "NM" signifies not measured.
3) SWNs are based on Township and Range in the Public Land Survey System. To construct a full SWN from the abbreviation shown on the map,concatenate the Township, Range, abbreviation, and the letter "S". Example: the SWN for the well labeled "15L01" located in Township 02N (T02N) and Range 22W (R22W) is 02N22W15L01S.
4) The shape of each well symbol correspondsto the aquifer(s) in which it is screened (see above).
5) The color of each well symbol corresponds to the most recent concentration measured in a water quality sample from that well. A solid gray well symbol has no data between 2011 and 2015.
6) All concentrations are in mg/L.
7) Aquifer designation information for individual wells was provided by FCGMA, CMWD and UWCD.

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-45B

Upper Aquifer System, Forebay Area - Most Recent Boron (mg/L) Measured 2011-2015

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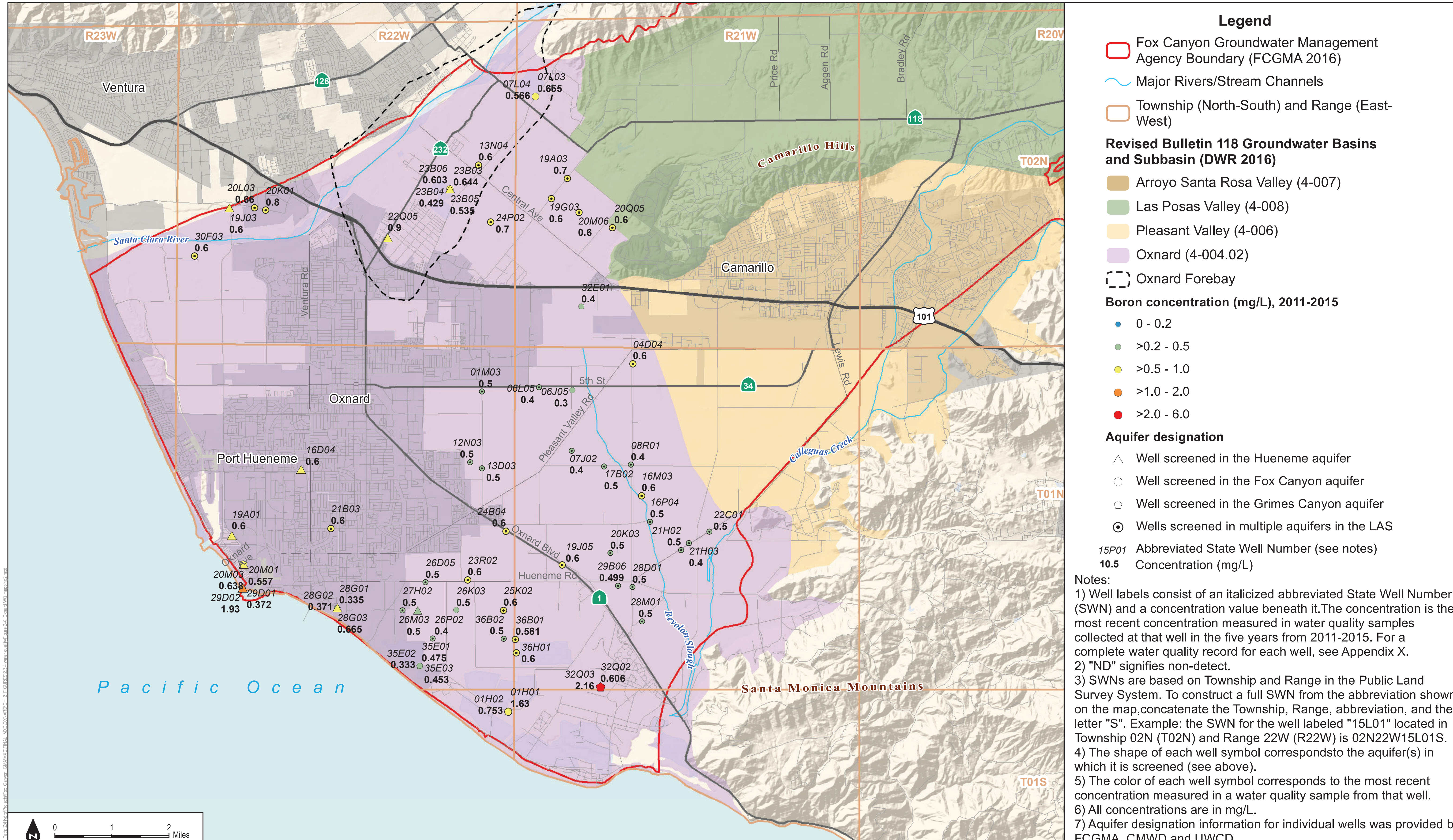

DUDEK

SOURCE: DWR, FCGMA, VCWPD, CMWD, UWCD

FIGURE 2-46

Lower Aquifer System - Most Recent Boron (mg/L) Measured 2011-2015

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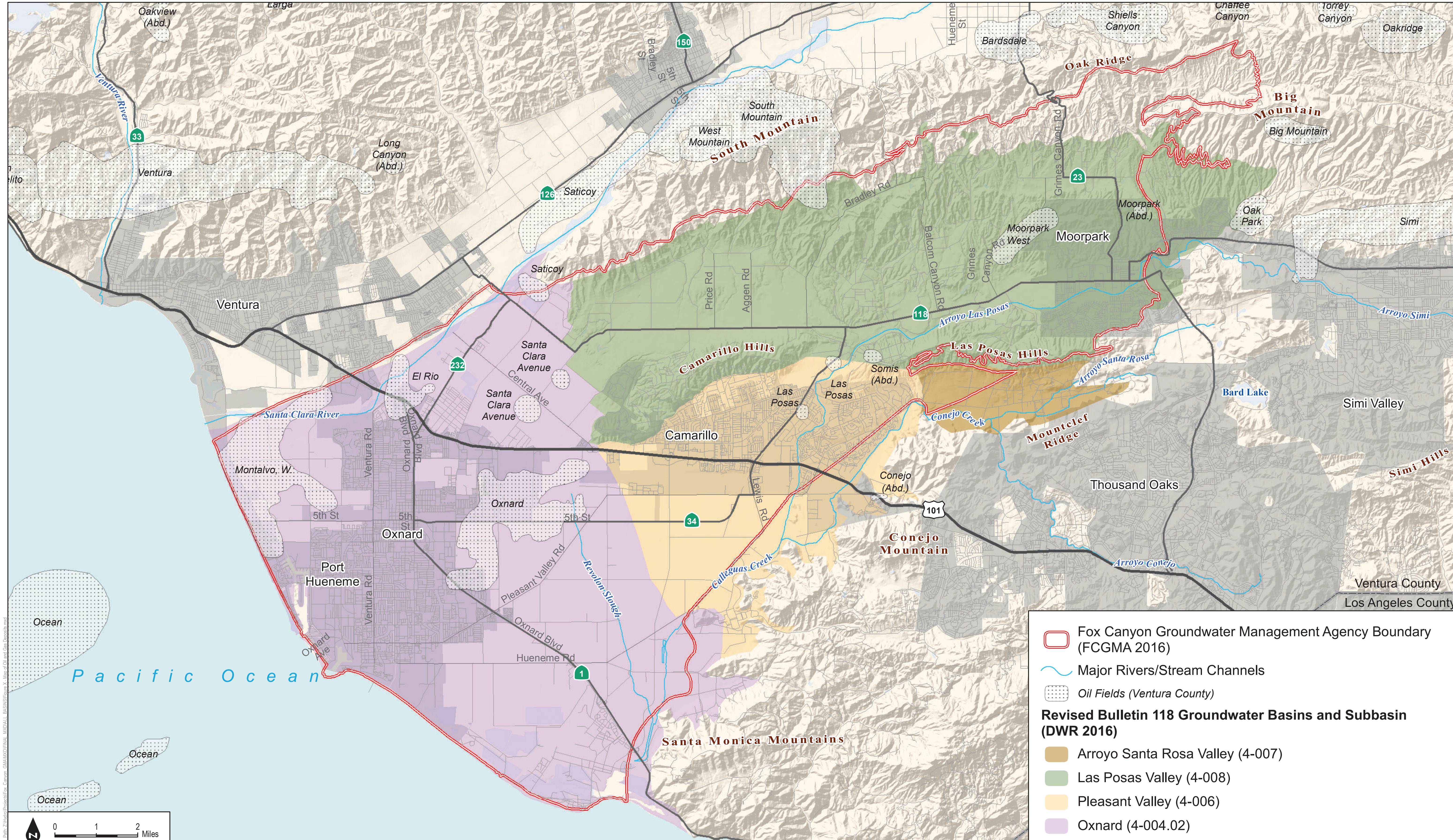

DUDEK

SOURCE: DWR; Ventura County

FIGURE 2-47

Oil Fields in the Vicinity of FCGMA Groundwater Basins

Groundwater Sustainability Plan for the Oxnard Subbasin

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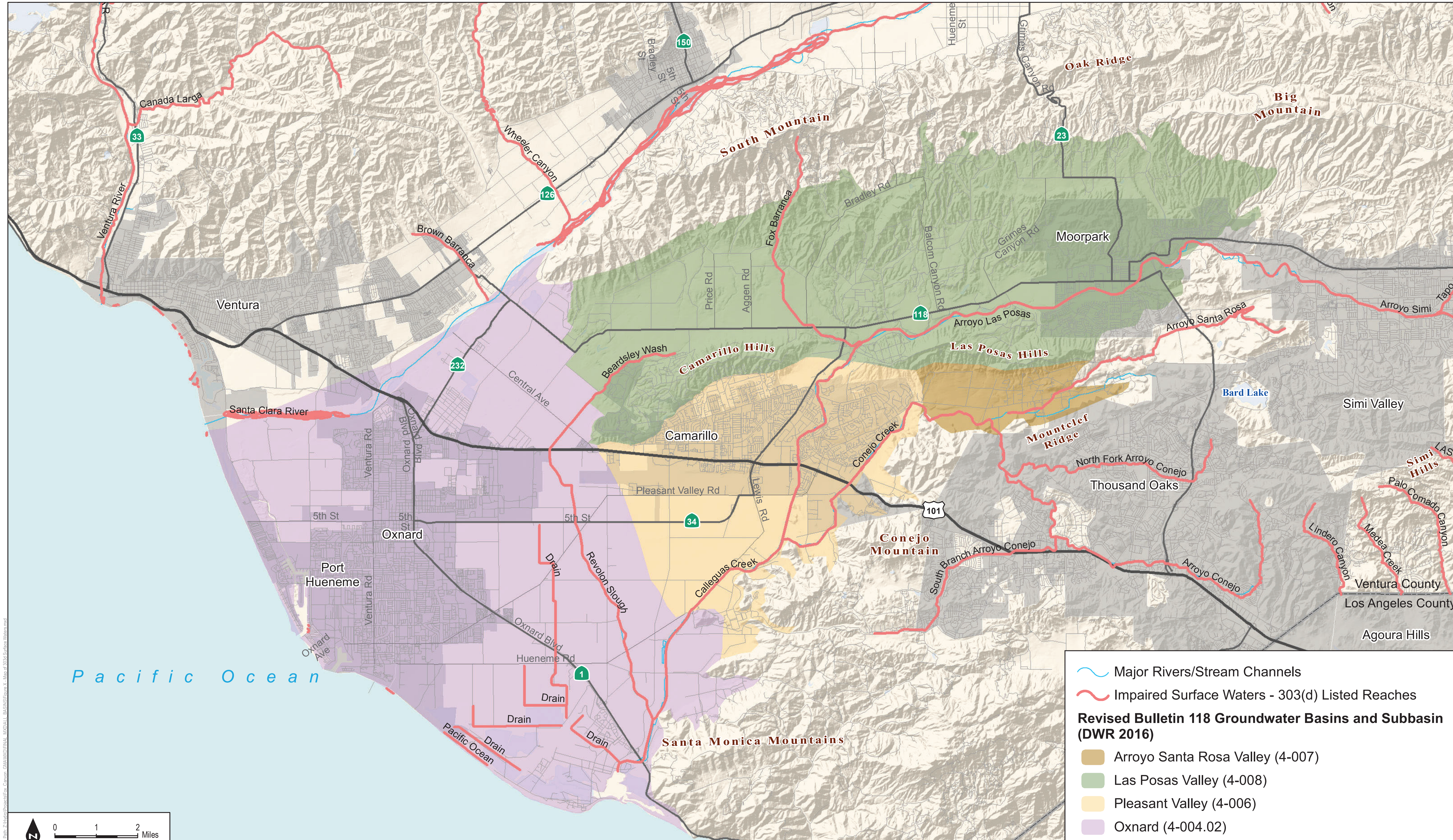

SOURCE: DWR; Ventura County

FIGURE 2-48

Impaired Surface Waters in the Vicinity of FCGMA Groundwater Basins

DUDEK

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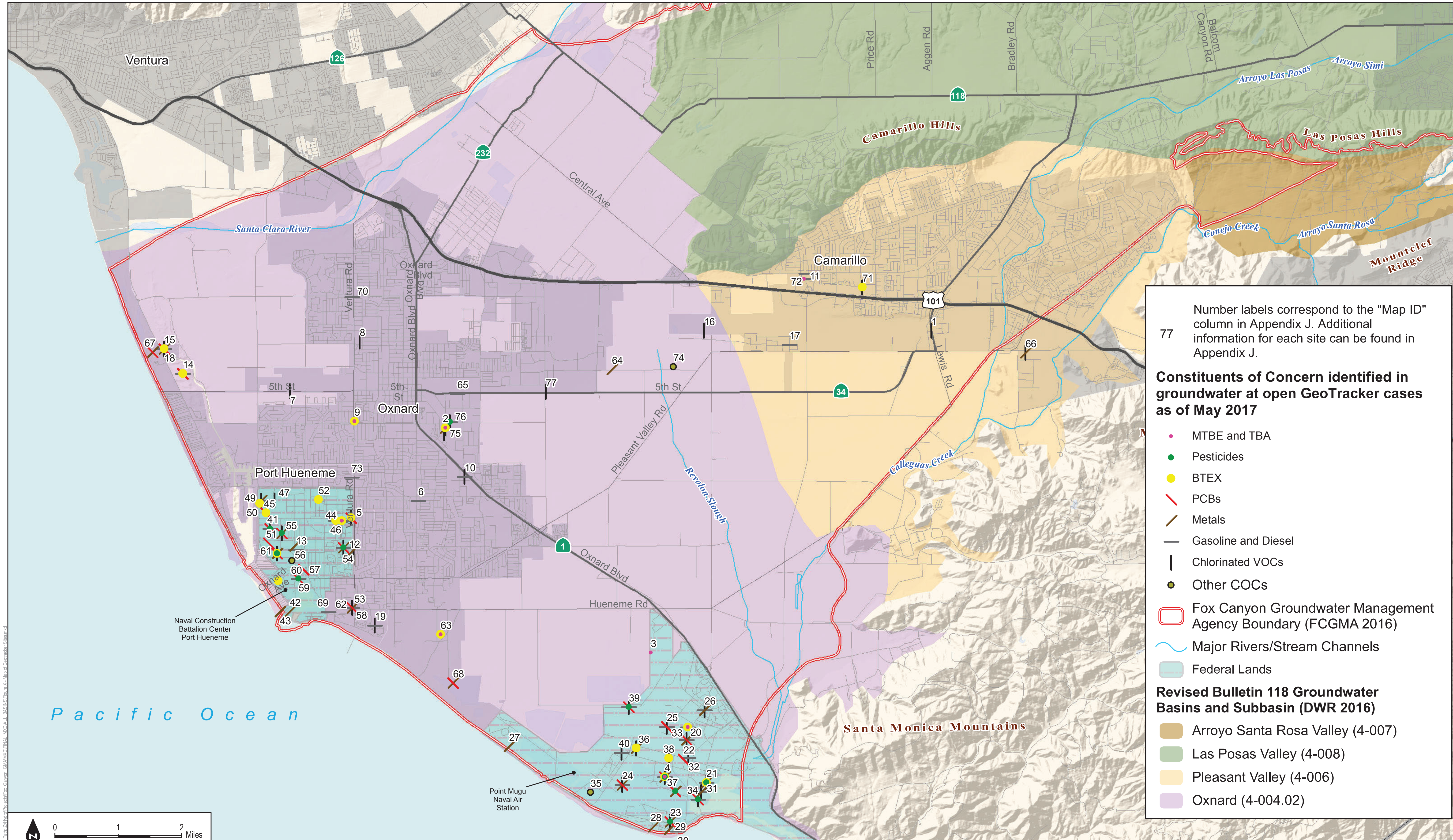

SOURCE: DWR; Ventura County; Geotracker

DUDEK

FIGURE 2-49

Constituents of Concern at Open GeoTracker Cases with Impacted Groundwater within FCGMA Groundwater Basin Boundaries

Groundwater Sustainability Plan for the Oxnard Subbasin

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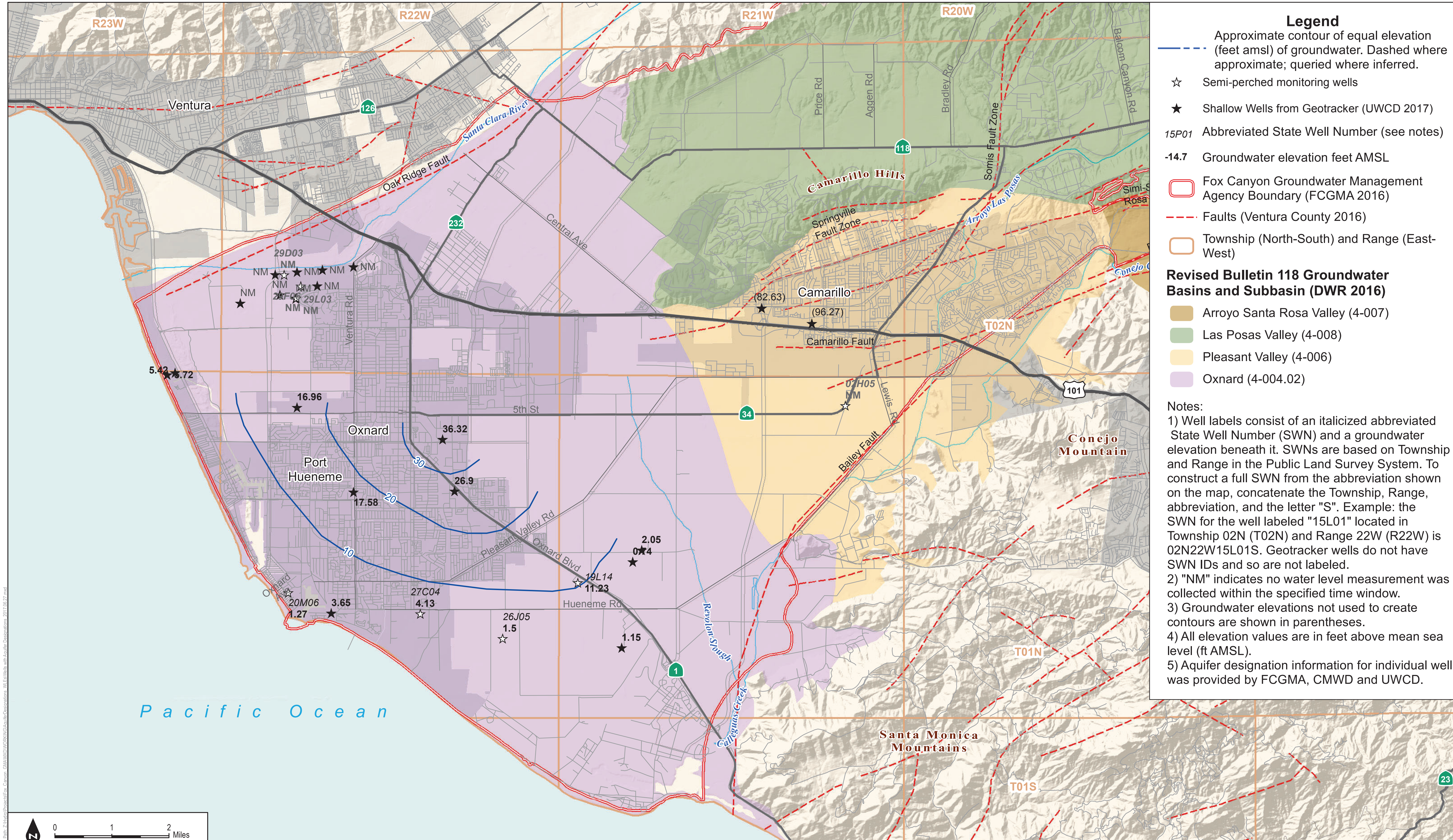

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-50

Groundwater Elevation Contours in the Semi-Perched Aquifer, March 2-29, 2015

DUDEK

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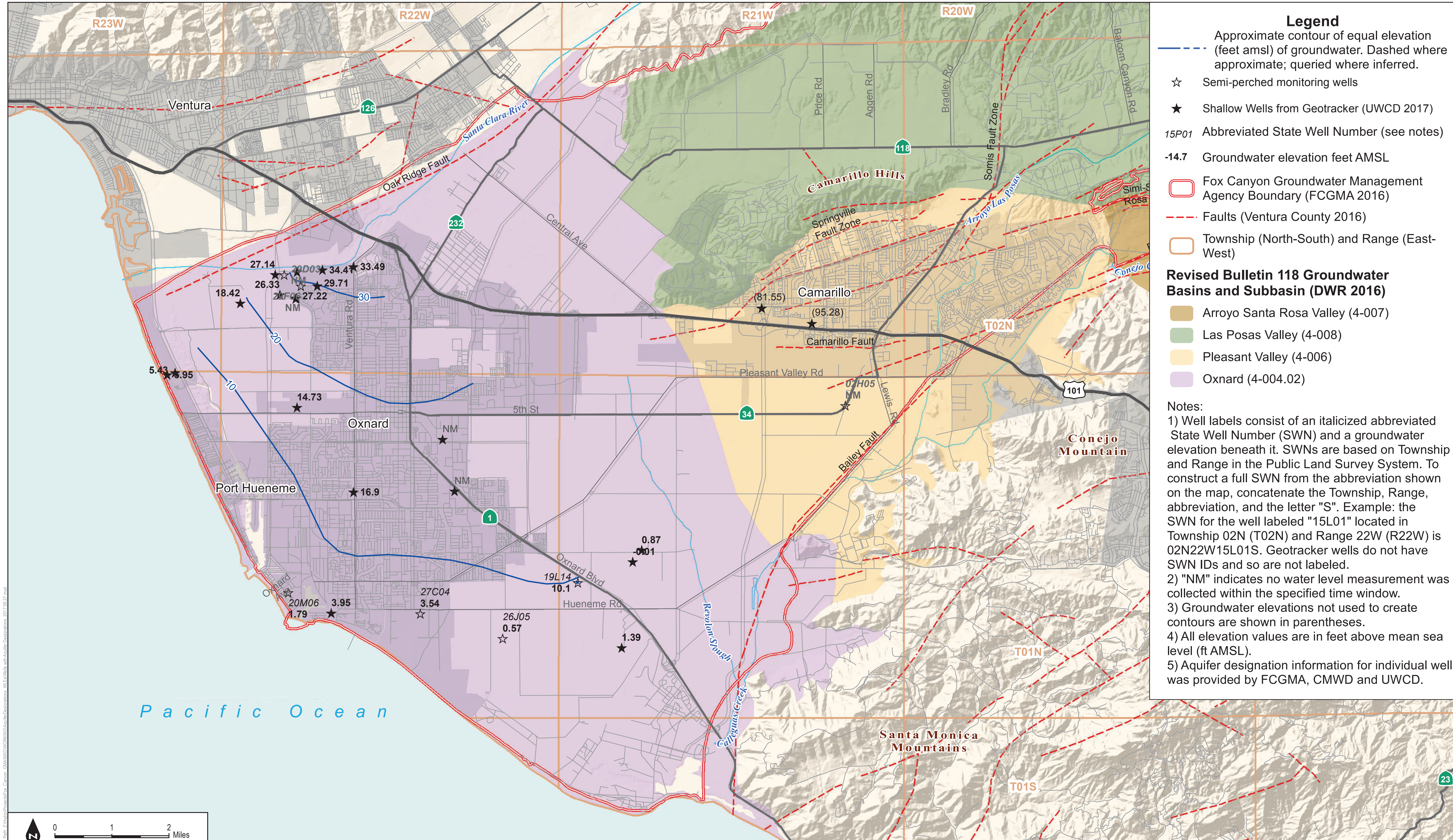

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD

FIGURE 2-51

Groundwater Elevation Contours in the Semi-Perched Aquifer, October 2-29, 2015

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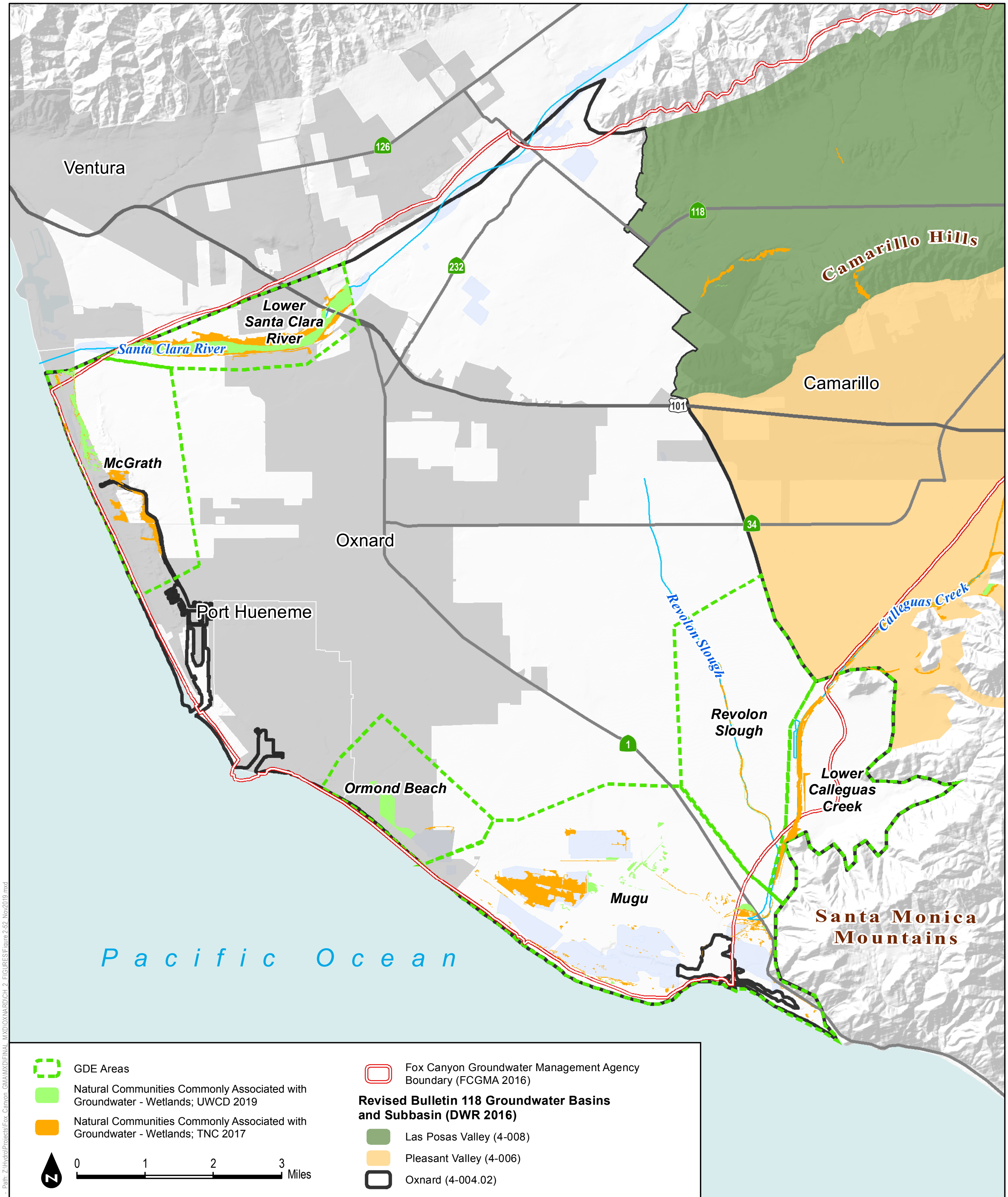

DUDEK

SOURCE: DWR; Santa Barbara County; FCGMA

FIGURE 2-52

Groundwater-Dependent Ecosystems for the Oxnard Subbasin

Groundwater Sustainability Plan for the Oxnard Subbasin

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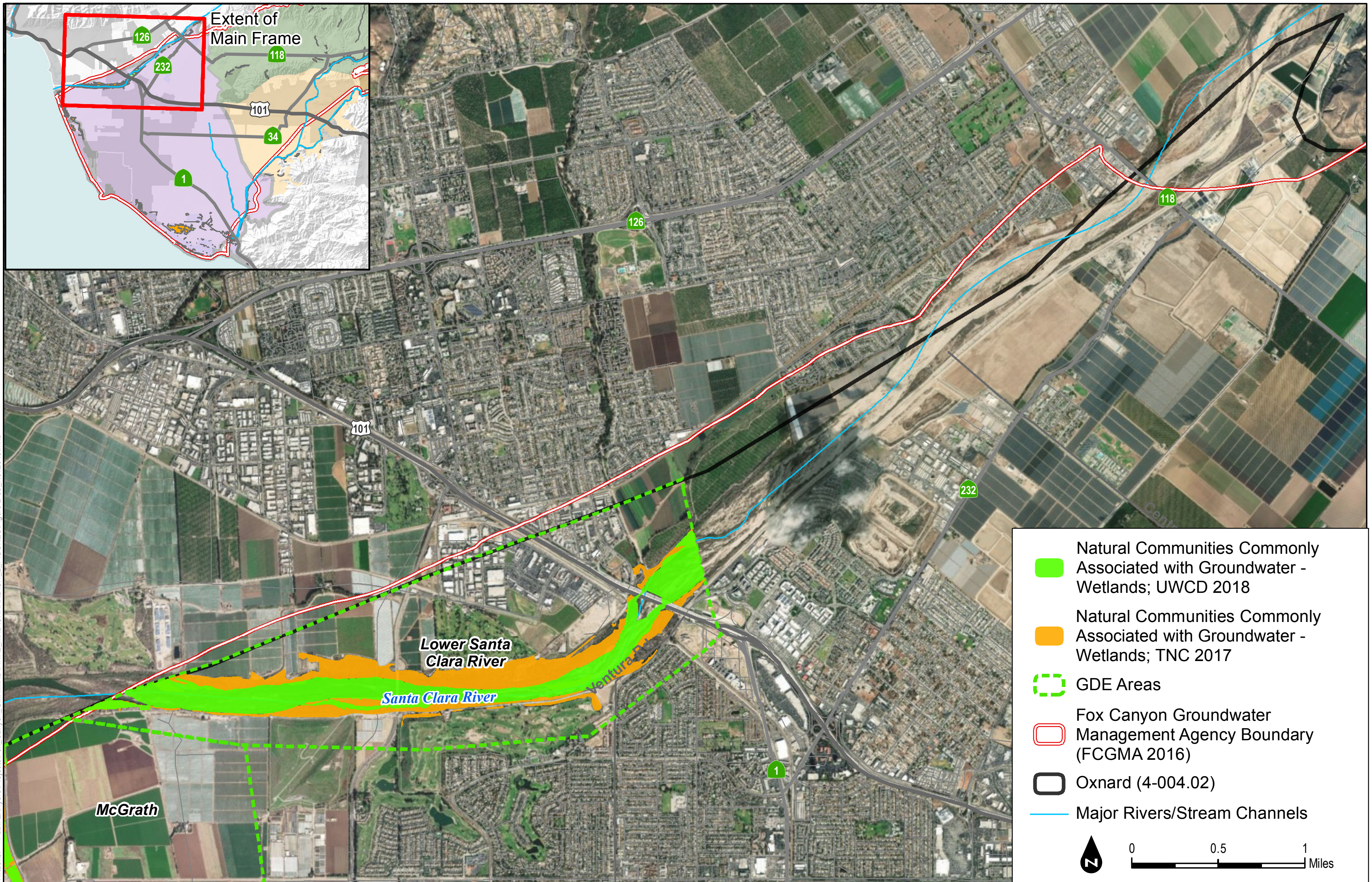

DUDEK

SOURCE: DWR; Santa Barbara County; FCGMA; Esri

FIGURE 2-53

Lower Santa Clara River Groundwater-Dependent Ecosystems

Groundwater Sustainability Plan for the Oxnard Subbasin

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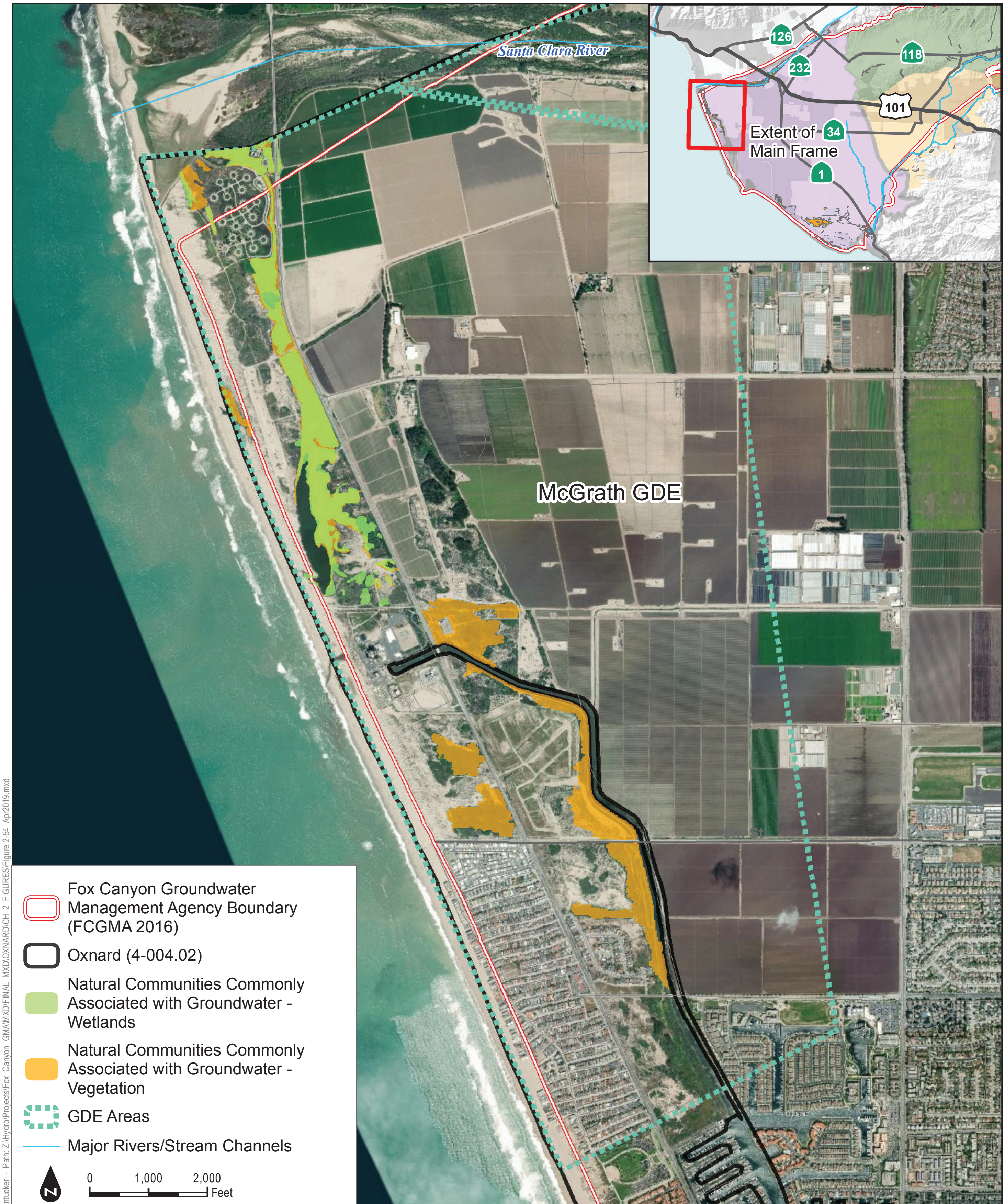

DUDEK

SOURCE: DWR; Santa Barbara County; FCGMA; Esri

FIGURE 2-54

McGrath Lake Groundwater Dependent Ecosystems

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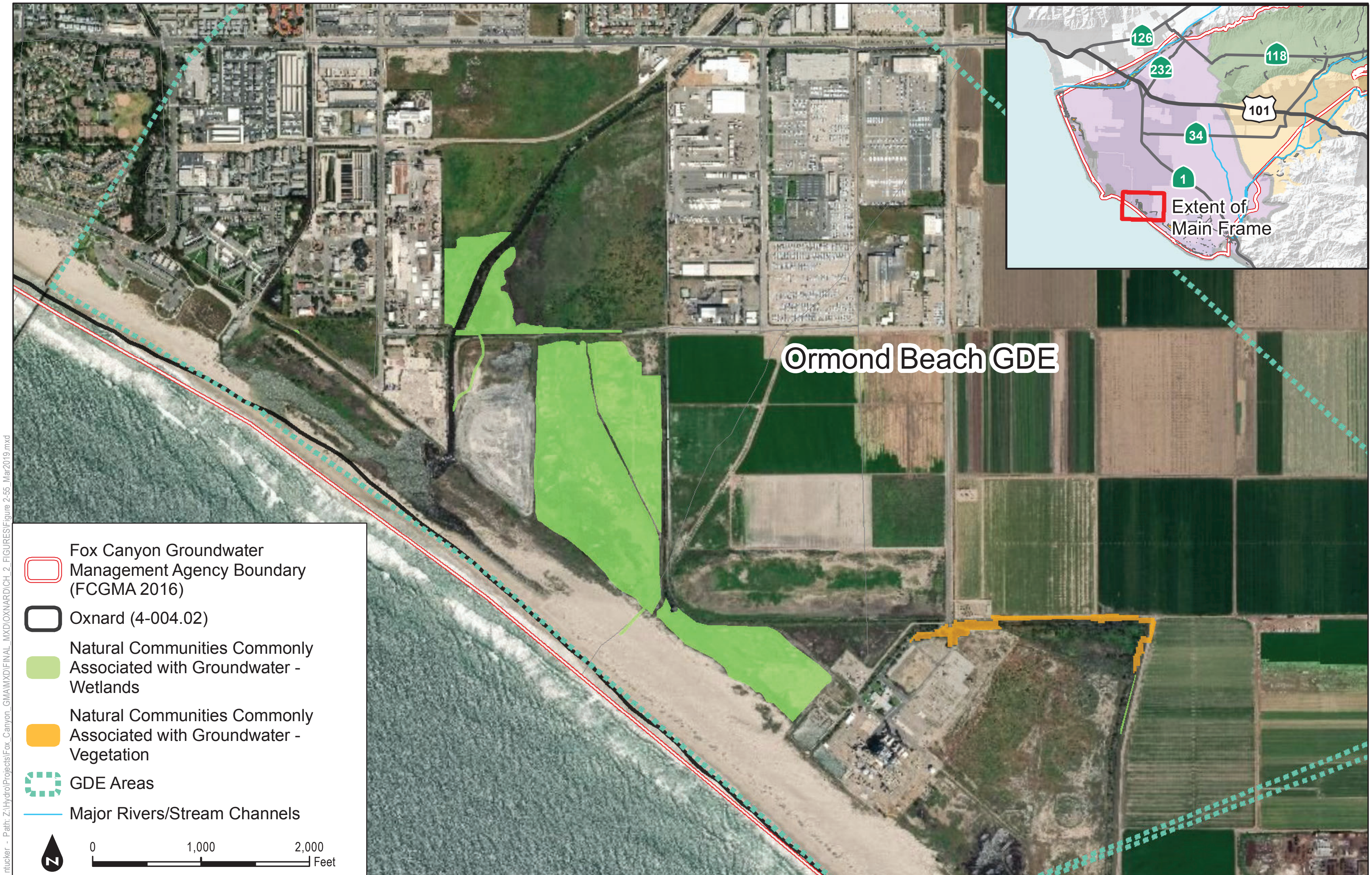

DUDEK

SOURCE: DWR; Santa Barbara County; FCGMA; Esri

FIGURE 2-55

Ormond Beach Groundwater Dependent Ecosystems

Groundwater Sustainability Plan for the Oxnard Subbasin

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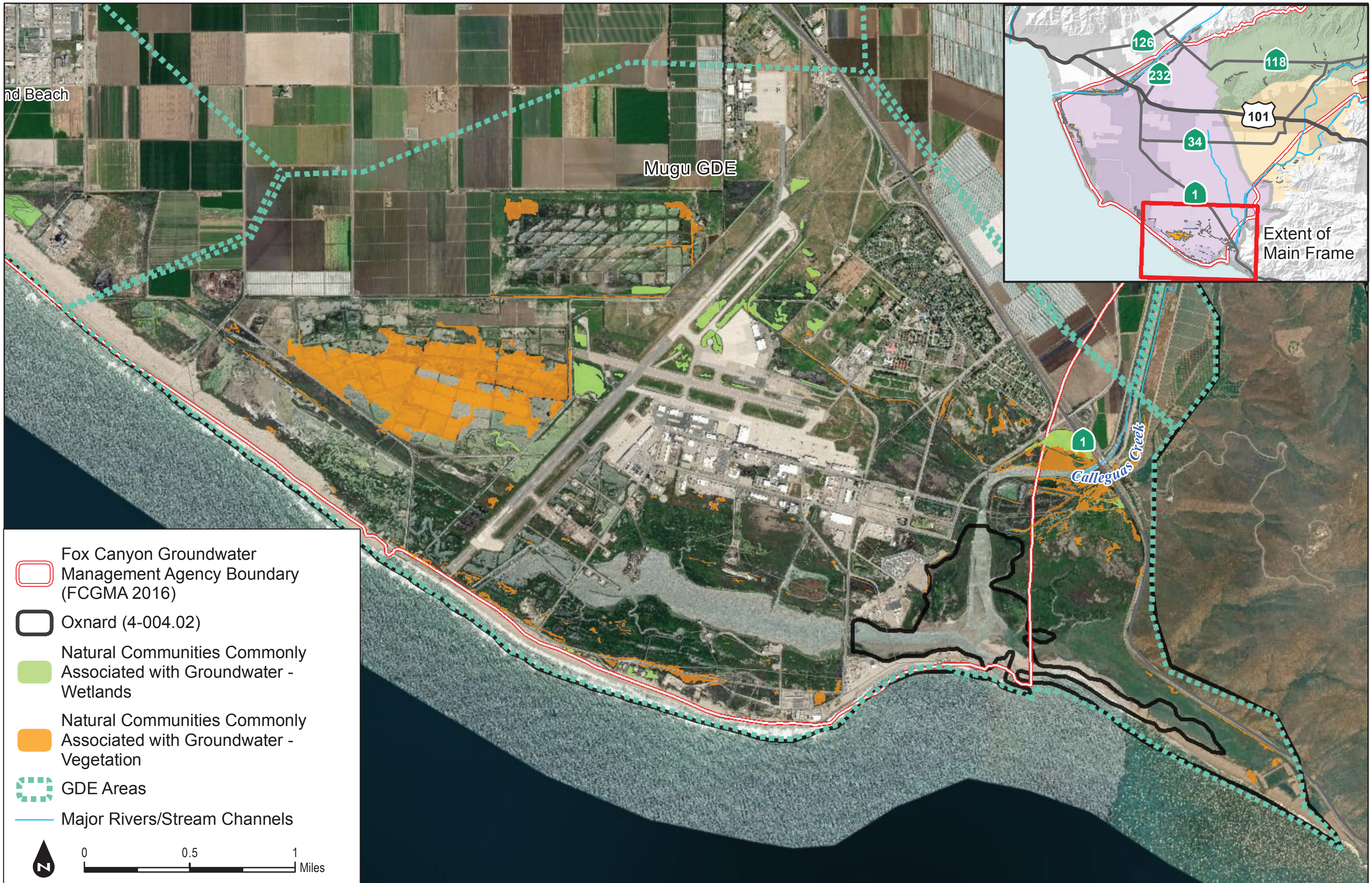

DUDEK

SOURCE: DWR; Santa Barbara County; FCGMA; Esri

FIGURE 2-56

Mugu Lagoon Groundwater Dependent Ecosystems

Groundwater Sustainability Plan for the Oxnard Subbasin

File String

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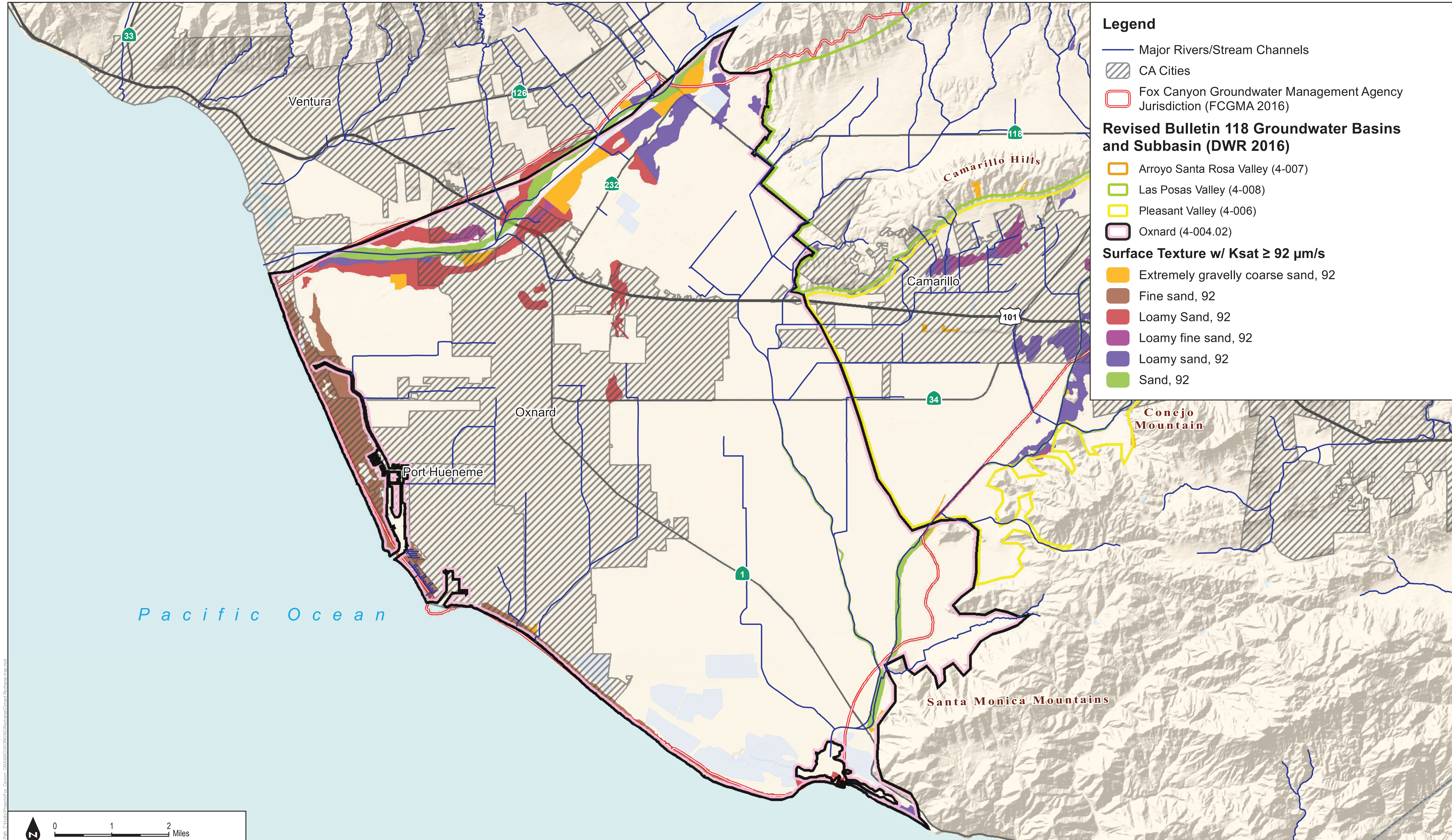

SOURCE: DWR, USGS, NRCS

DUDEK

FIGURE 2-57
Oxnard Potential Recharge Areas

Groundwater Sustainability Plan for the Oxnard Subbasin

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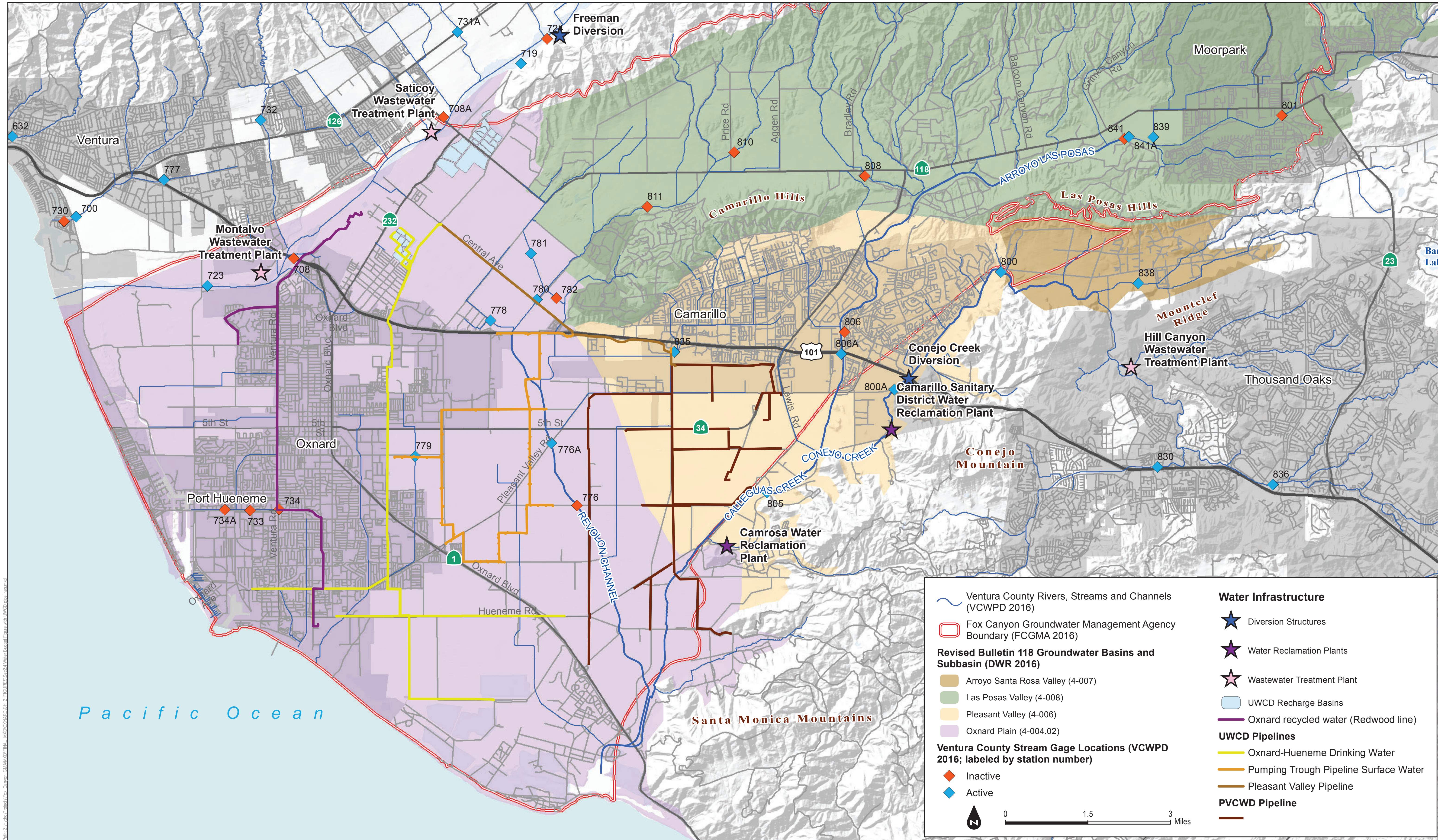

SOURCE: DWR; Ventura County; VCWPD

FIGURE 2-58

Oxnard Subbasin Stream Gauges and Water Infrastructure

DUDEK

Groundwater Sustainability Plan for the Oxnard Subbasin

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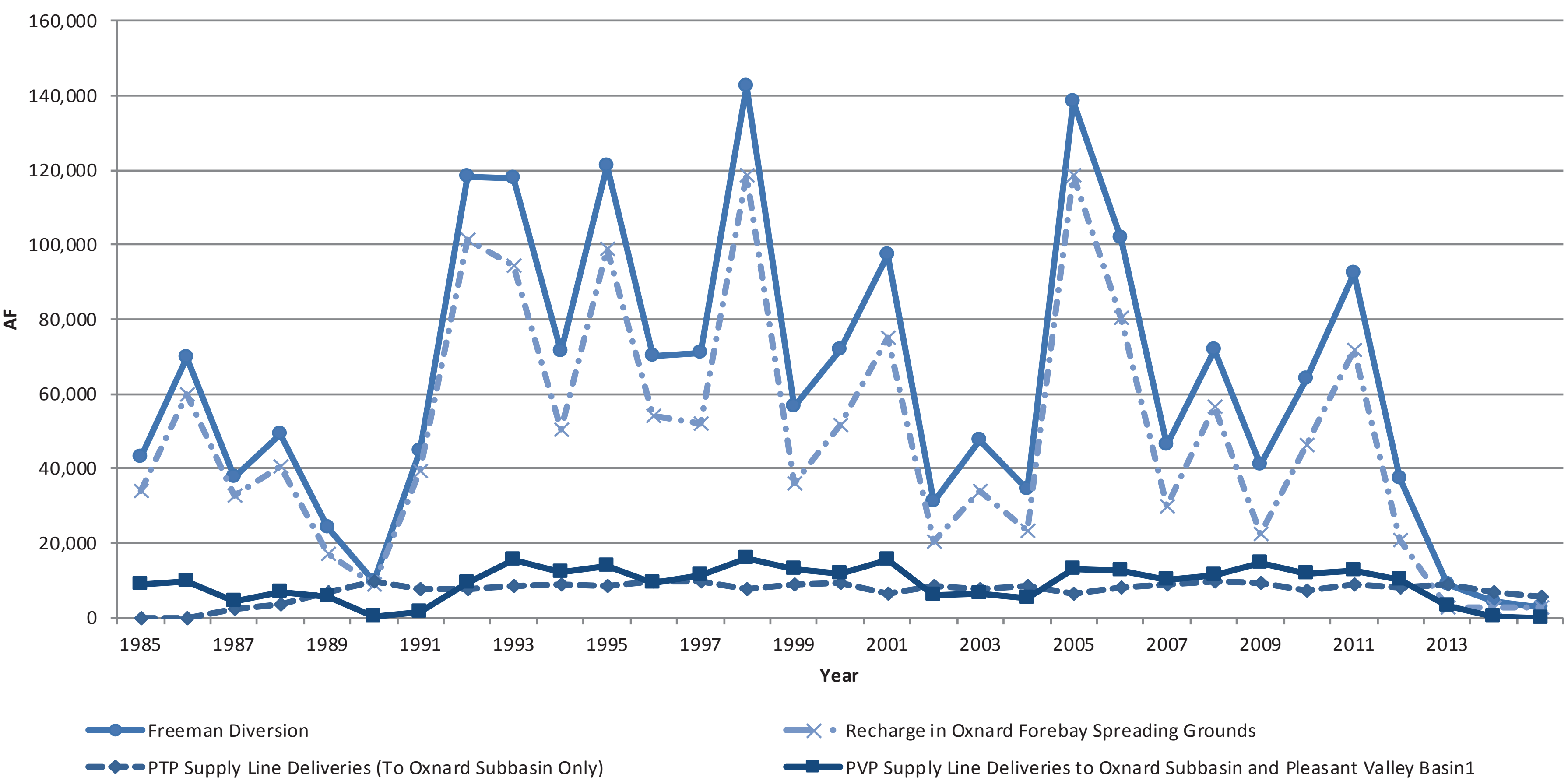

DUDEK

FIGURE 2-59
Freeman Diversion and Uses in the Oxnard Subbasin

Groundwater Sustainability Plan for the Oxnard Subbasin

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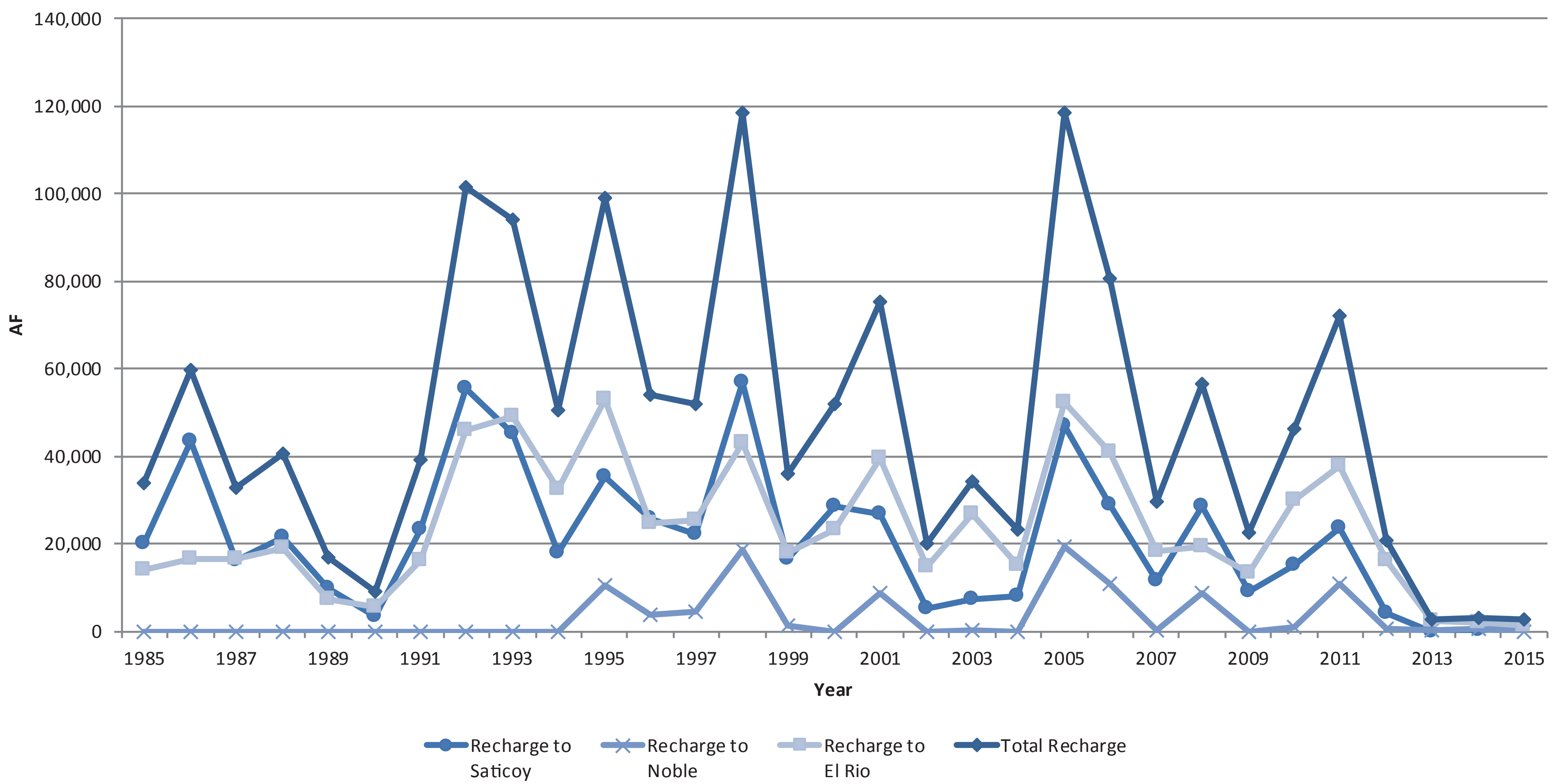

DUDEK

FIGURE 2-60
UWCD Groundwater Recharge

Groundwater Sustainability Plan for the Oxnard Subbasin

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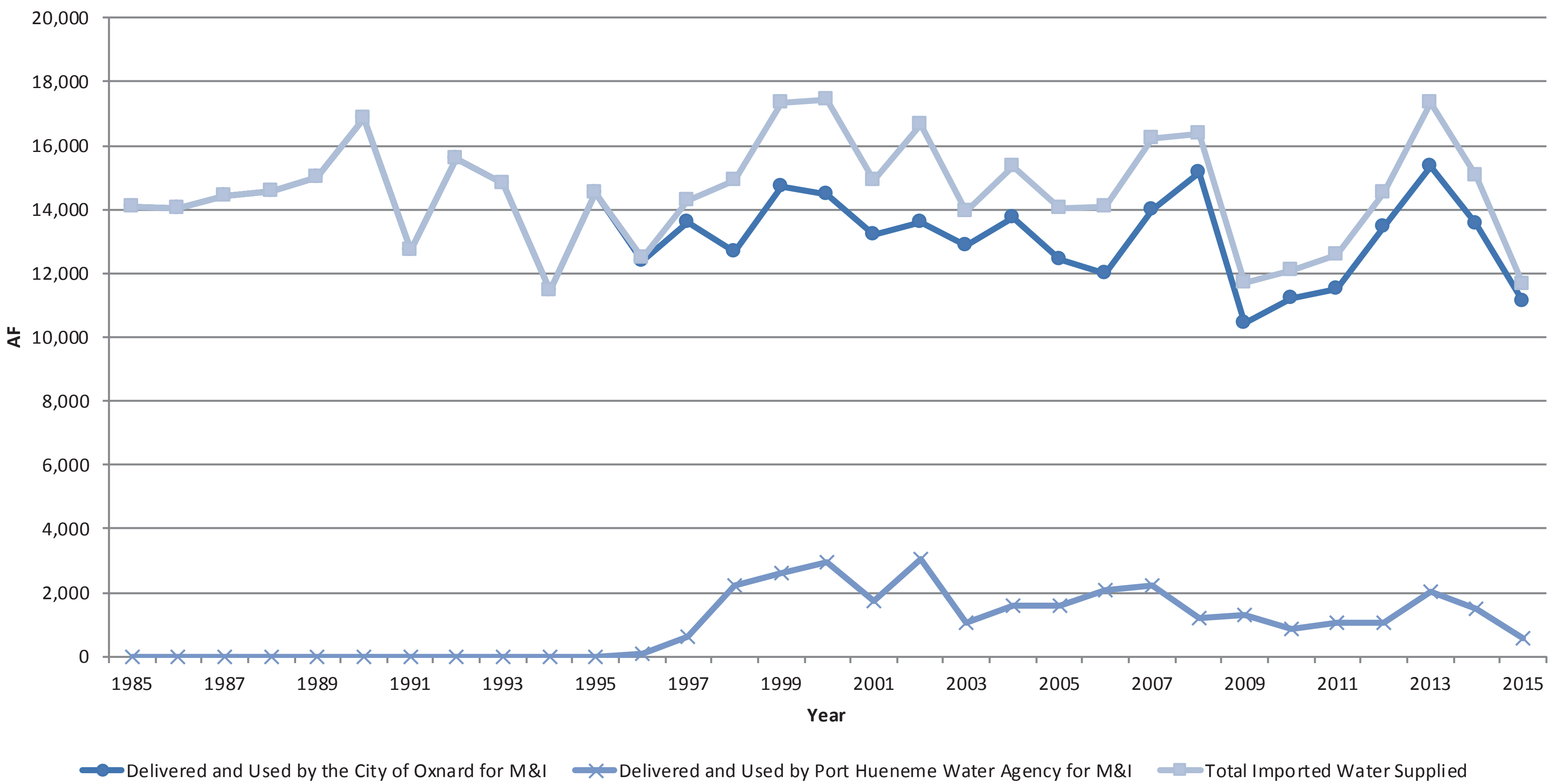

DUDEK

FIGURE 2-61

Water Deliveries to the PVCWD and UWCD

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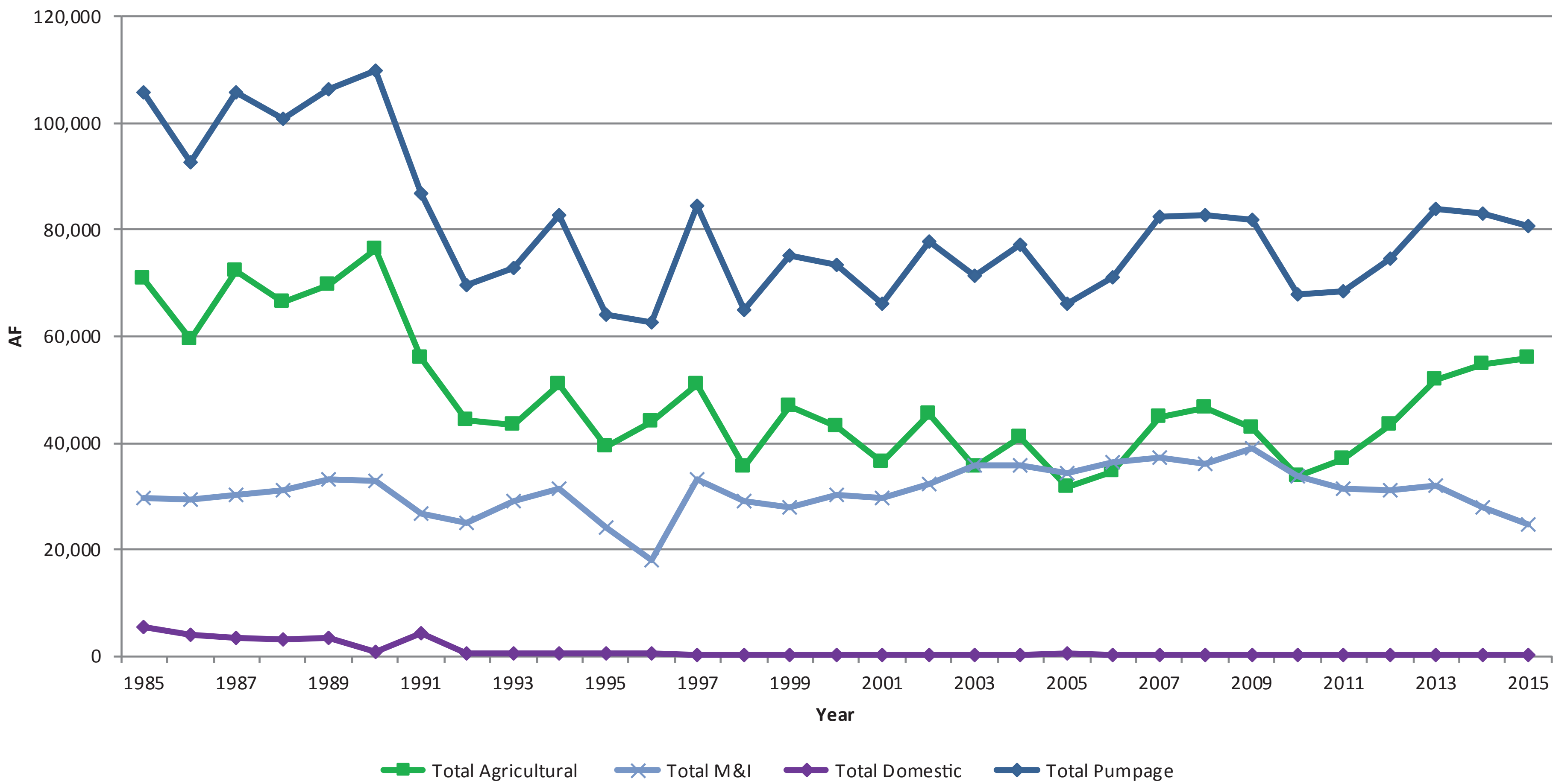

DUDEK

FIGURE 2-62
Groundwater Pumping

Groundwater Sustainability Plan for the Oxnard Subbasin

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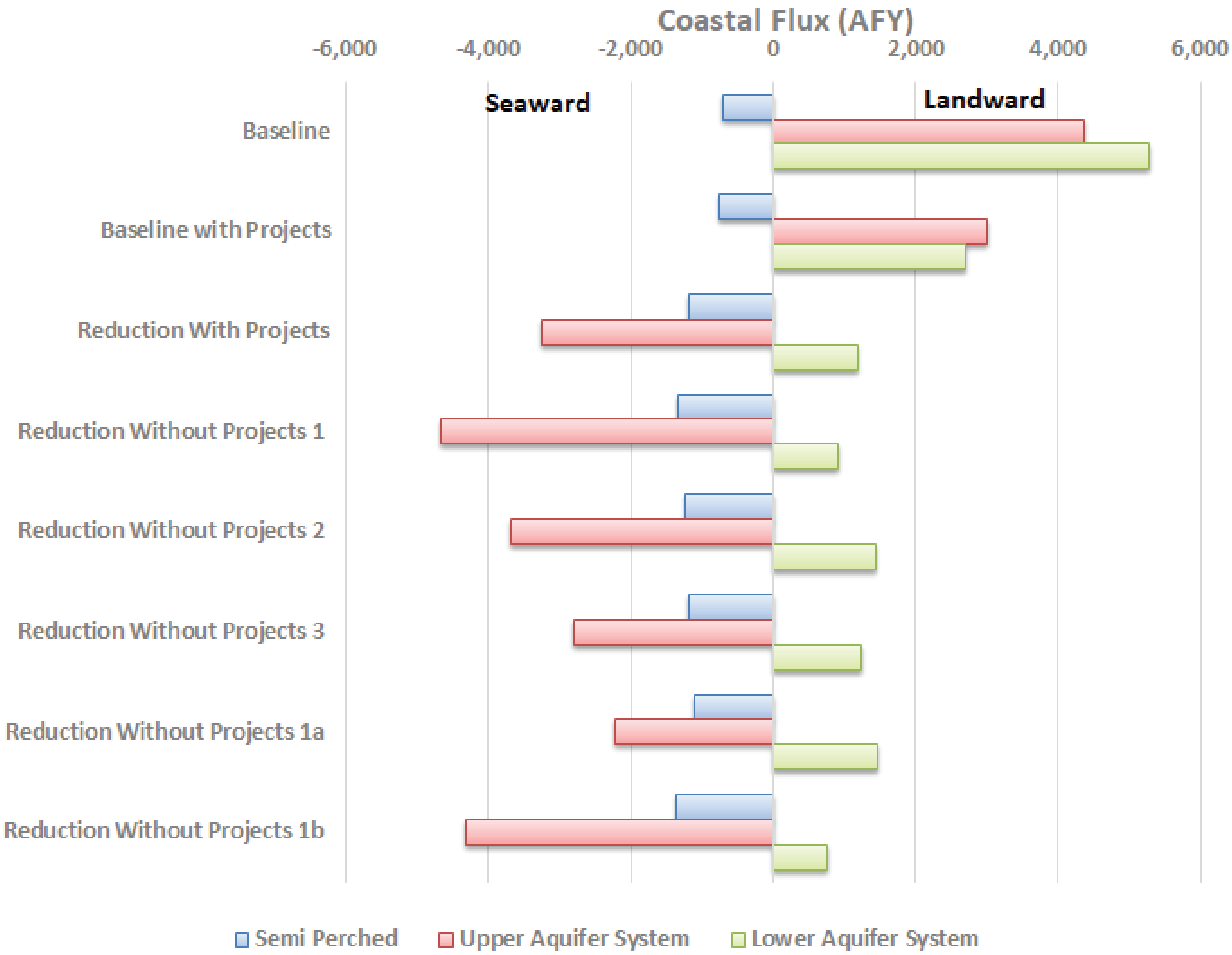

DUDEK

FIGURE 2-63

Coastal Flux From the UWCD Model Scenarios

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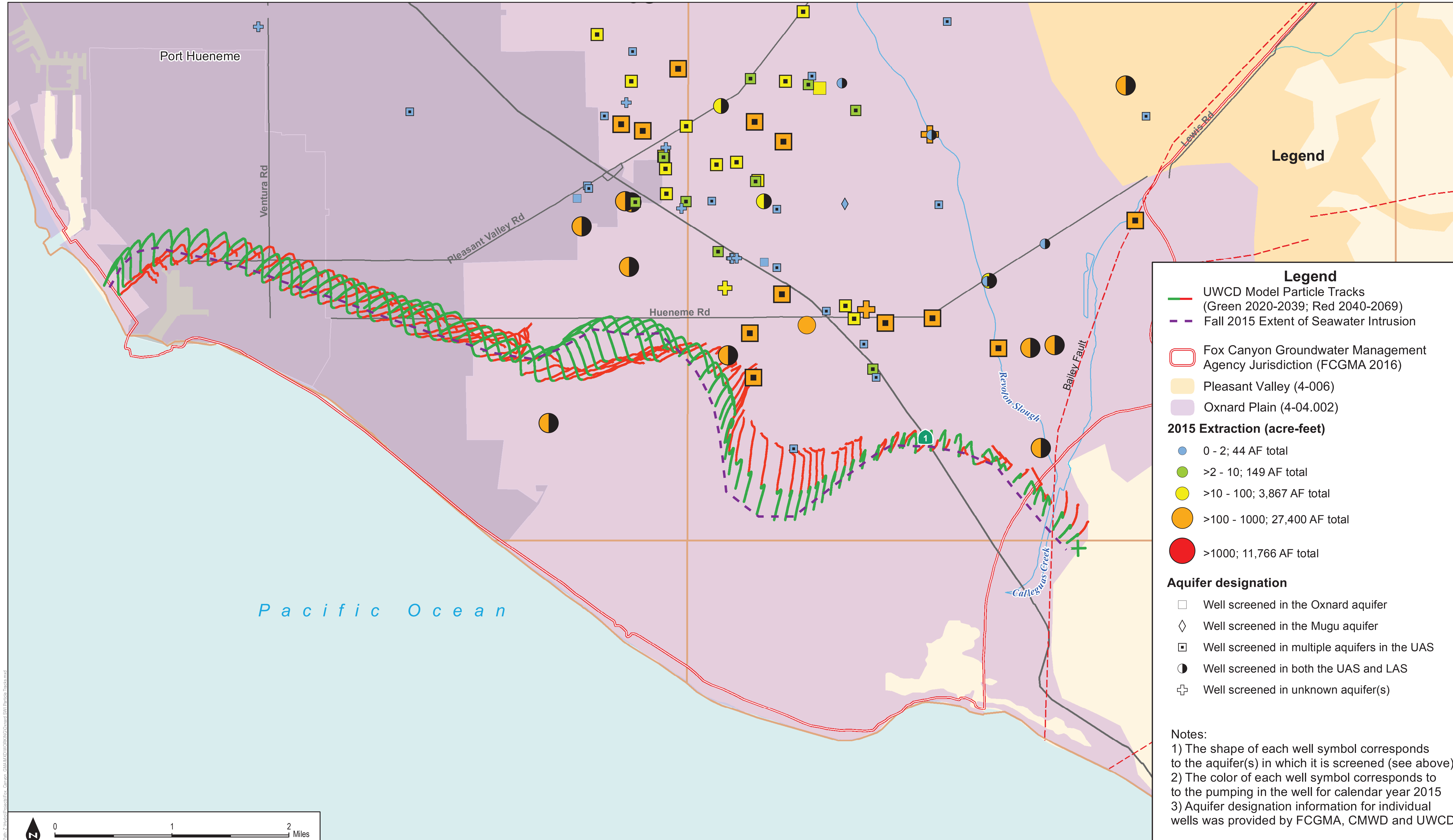

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-64a
UWCD Model Particle Tracks, Oxnard Aquifer, Future Baseline

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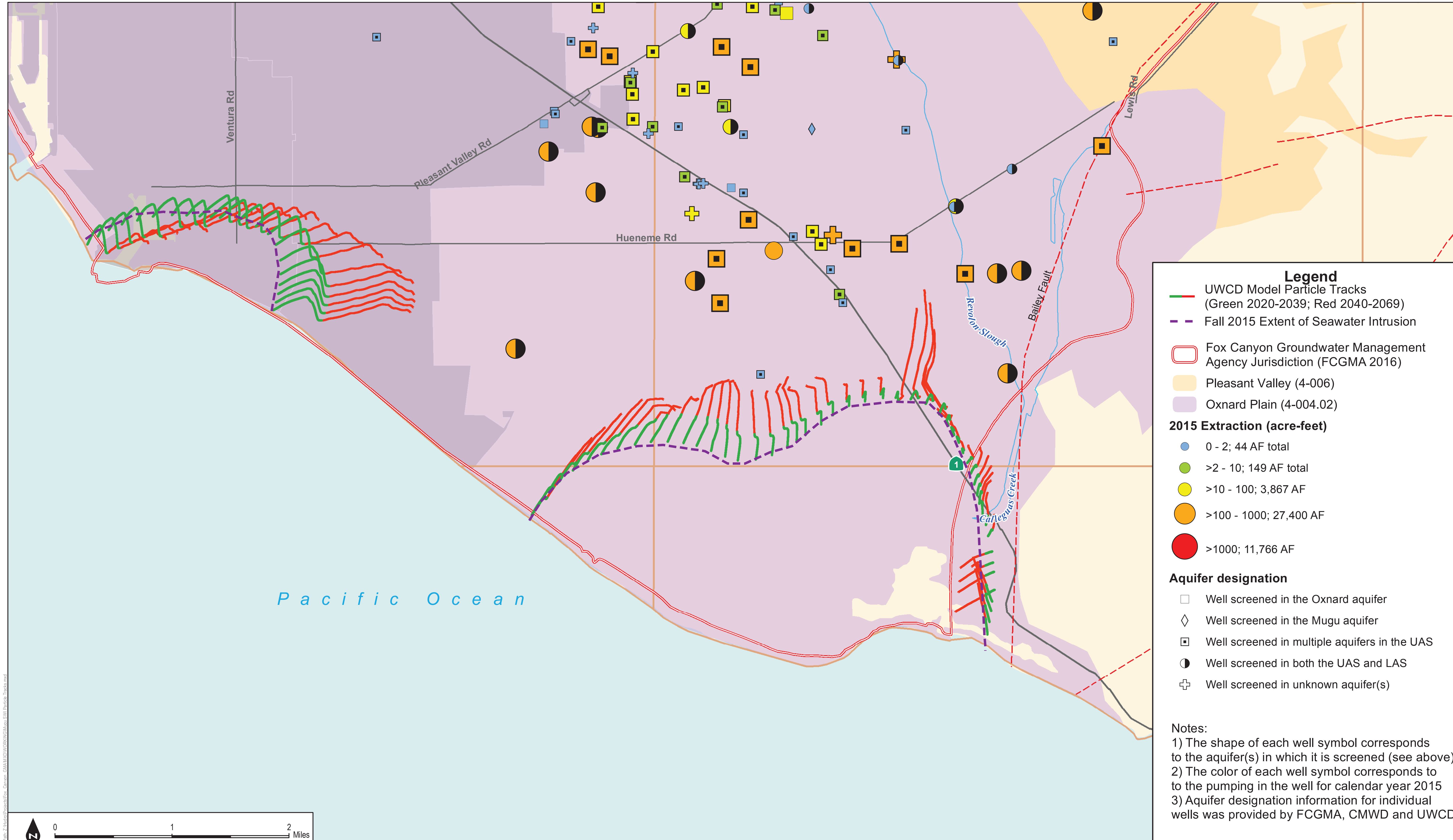

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-64b
UWCD Model Particle Tracks, Mugu Aquifer, Future Baseline

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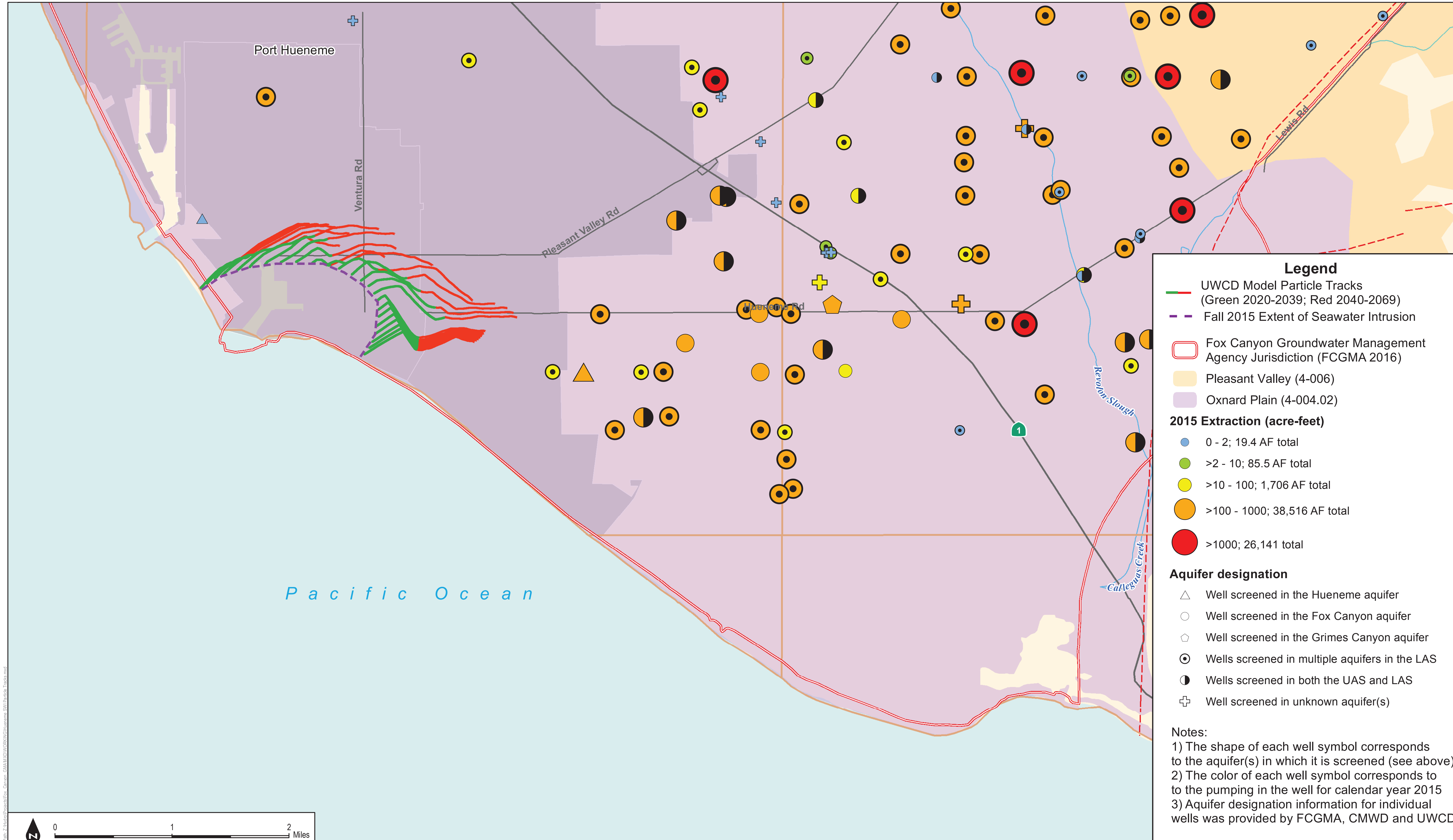

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-64c
UWCD Model Particle Tracks, Hueneme Aquifer, Future Baseline

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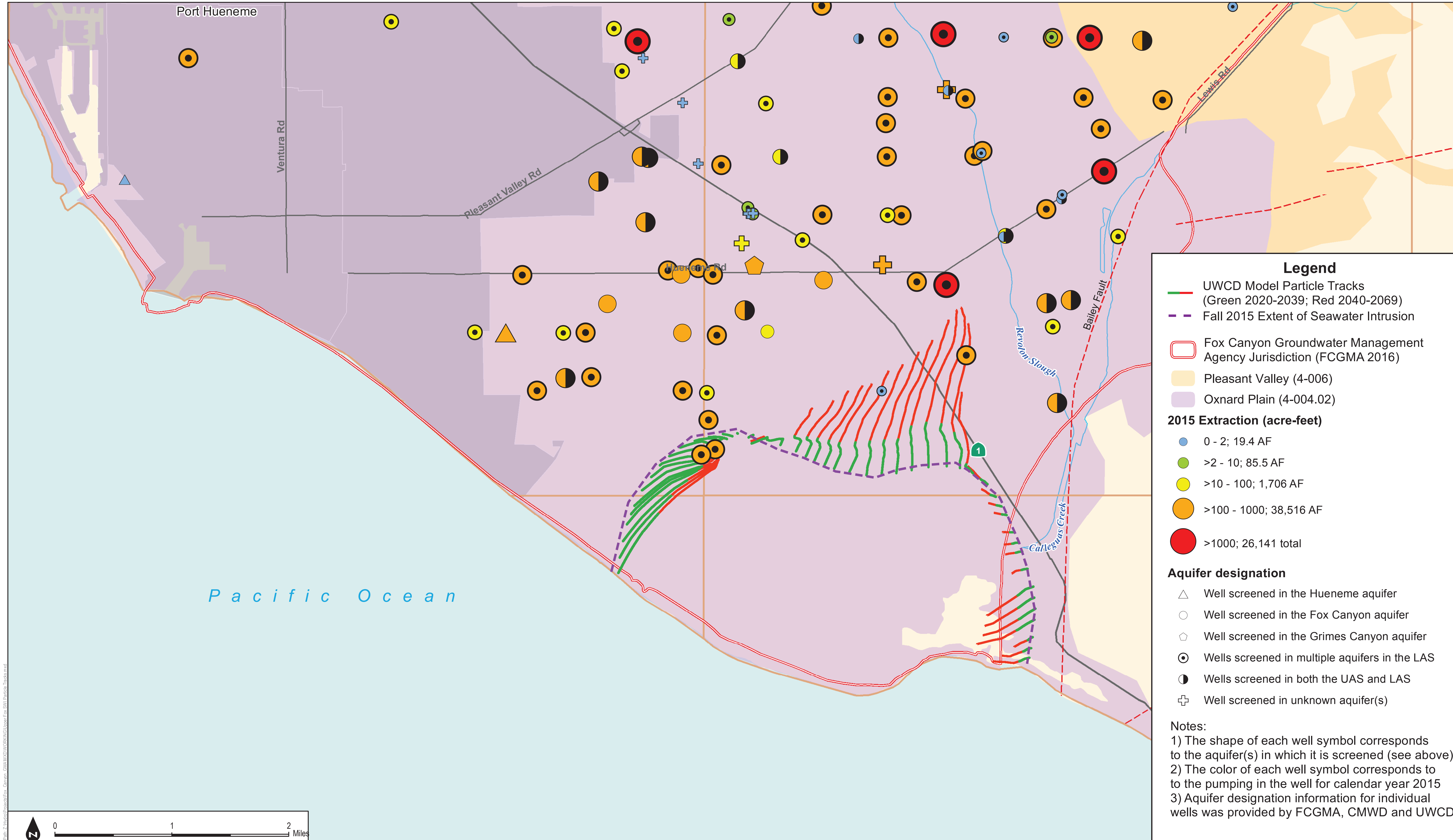

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

DRAFT

Figure 2-64d
UWCD Model Particle Tracks, Upper Fox Canyon Aquifer, Future Baseline

Groundwater Sustainability Plan for the Oxnard Subbasin

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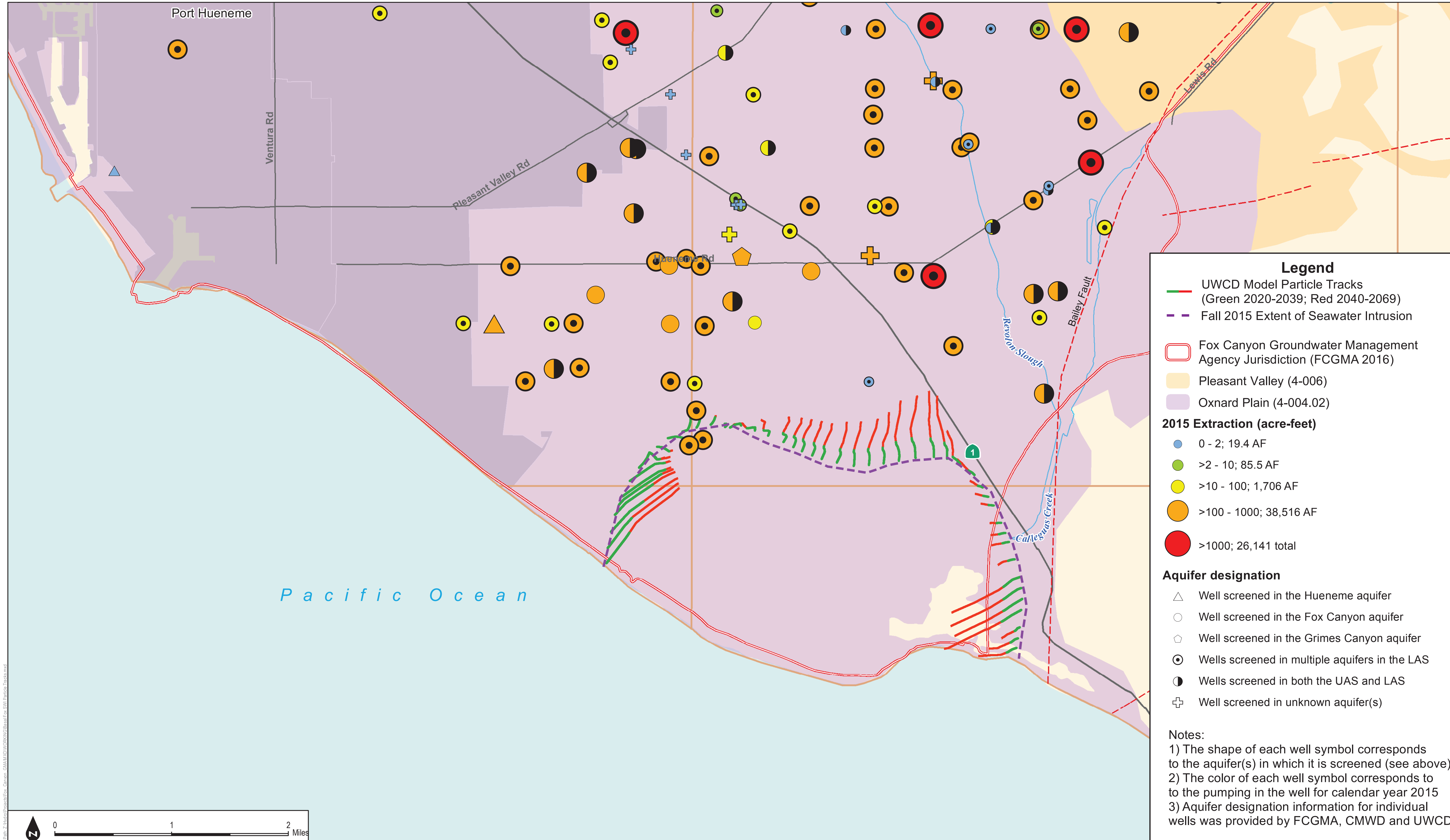

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

DUDEK

Figure 2-64e
UWCD Model Particle Tracks, Basal Fox Canyon Aquifer, Future Baseline

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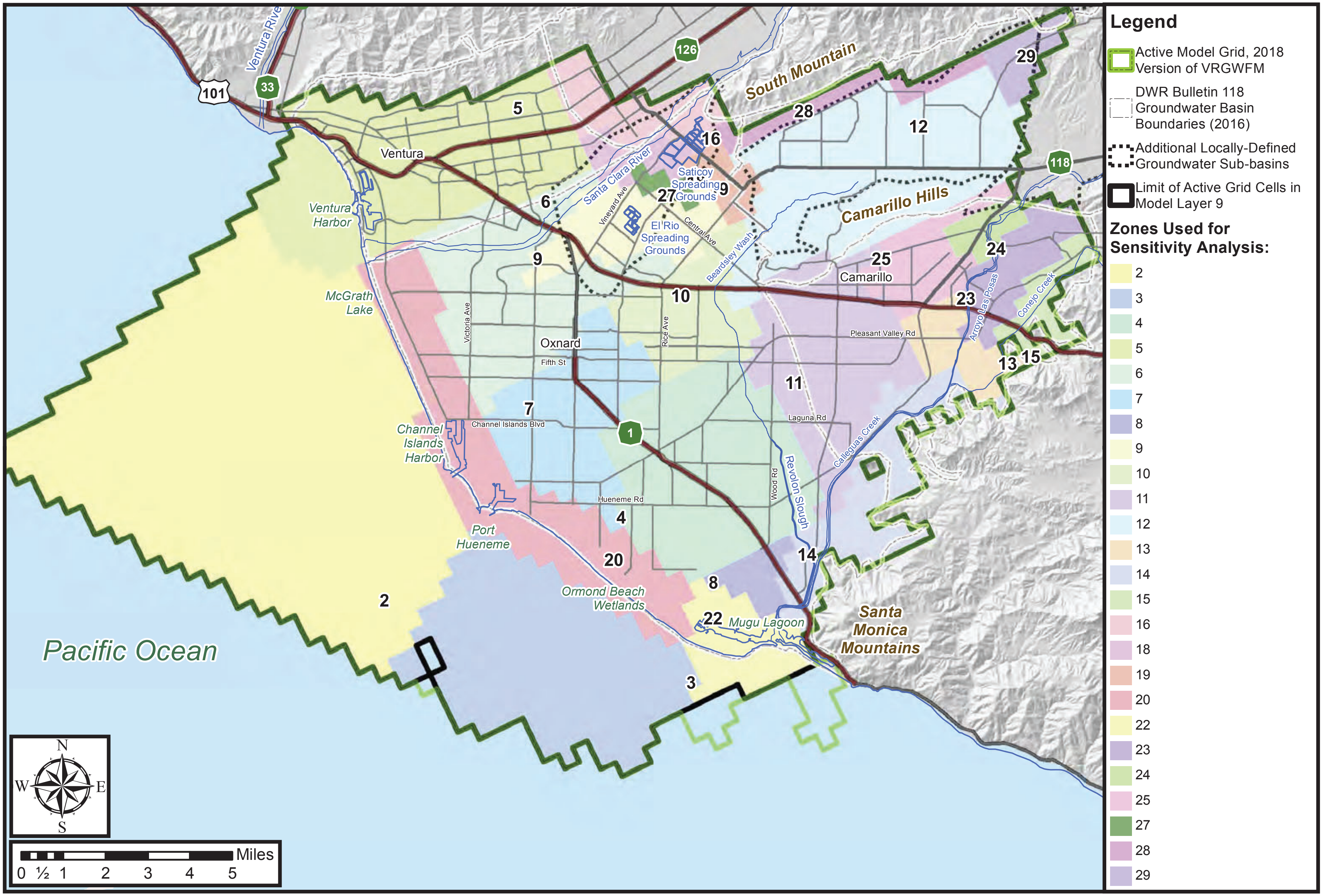

SOURCE: Figure 4-53; UWCD, 2018

FIGURE 2-65

UWCD Model Zones

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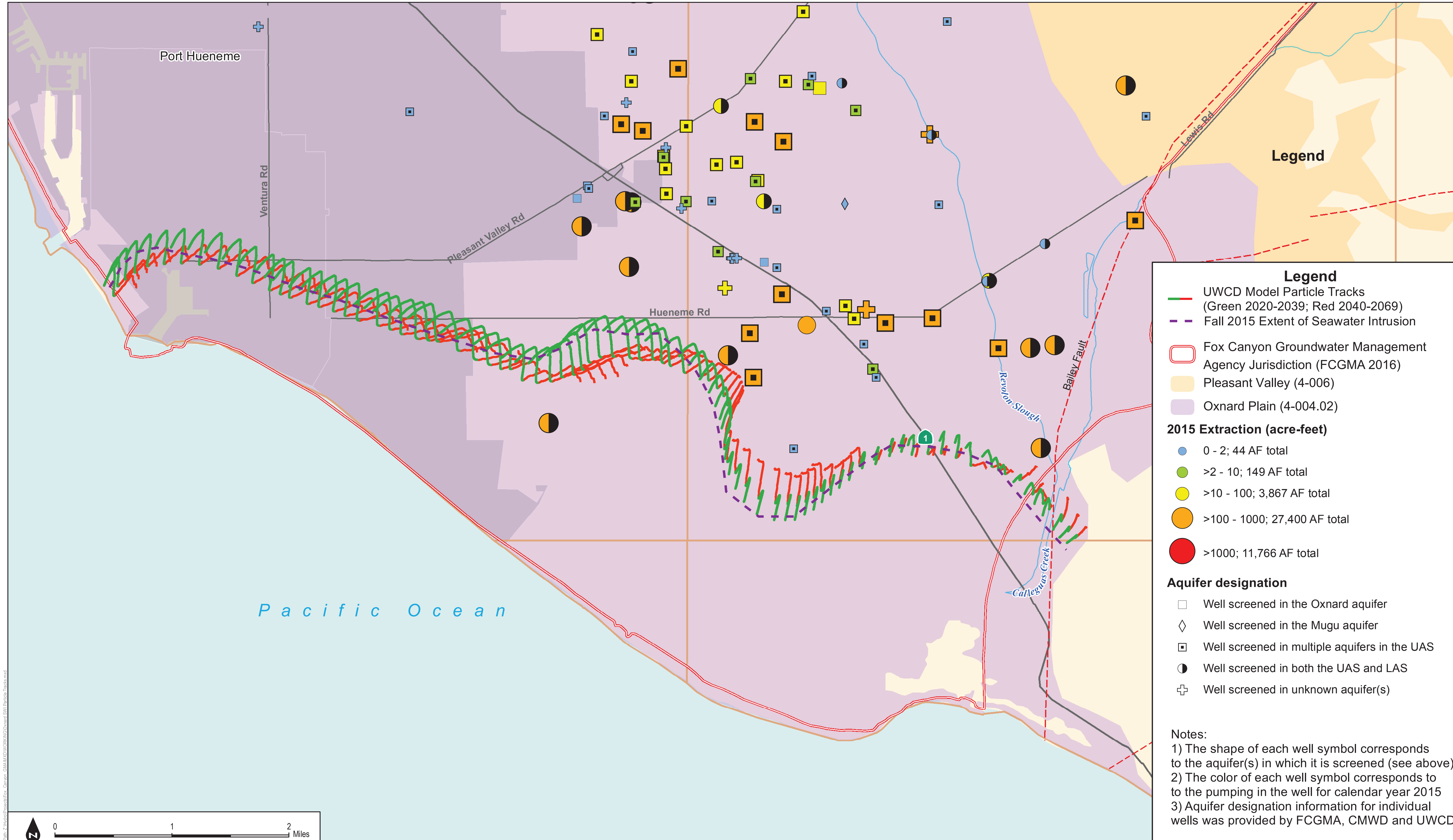

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-66a
UWCD Model Particle Tracks, Oxnard Aquifer, Future Baseline With Projects

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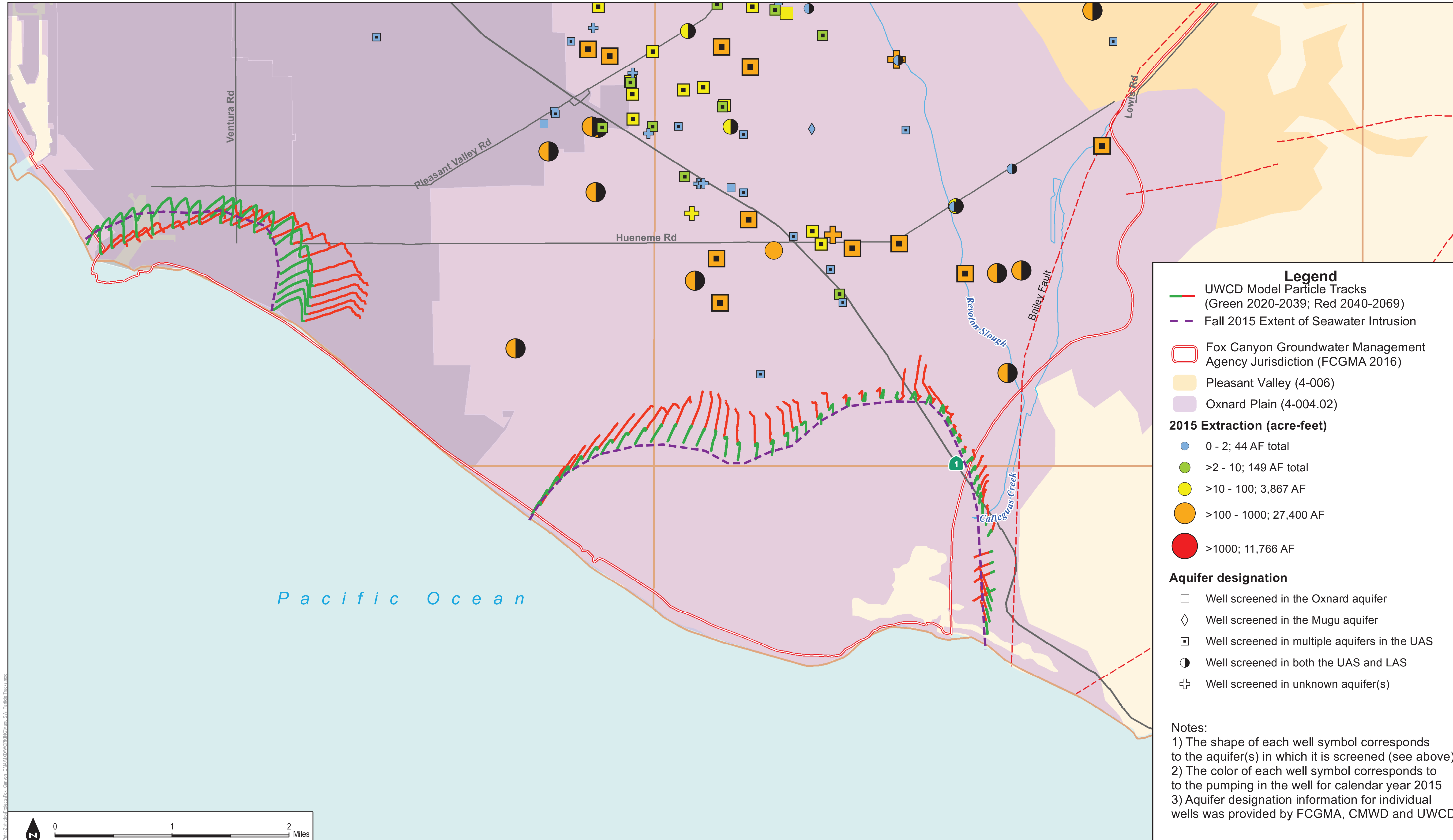

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-66b
UWCD Model Particle Tracks, Mugu Aquifer, Future Baseline With Projects

Groundwater Sustainability Plan for the Oxnard Subbasin

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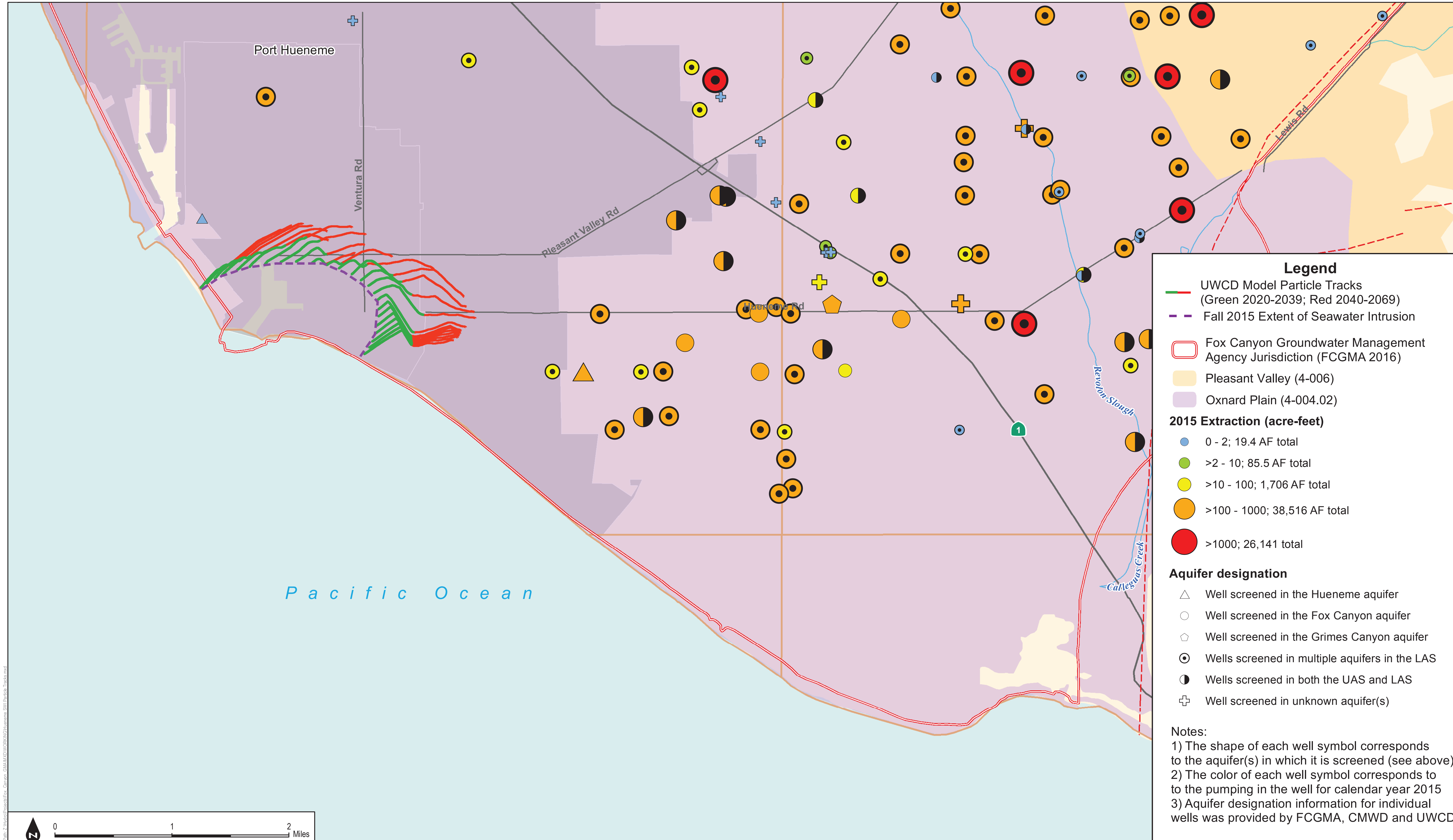

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-66c
UWCD Model Particle Tracks, Hueneme Aquifer, Future Baseline With Projects

Groundwater Sustainability Plan for the Oxnard Subbasin

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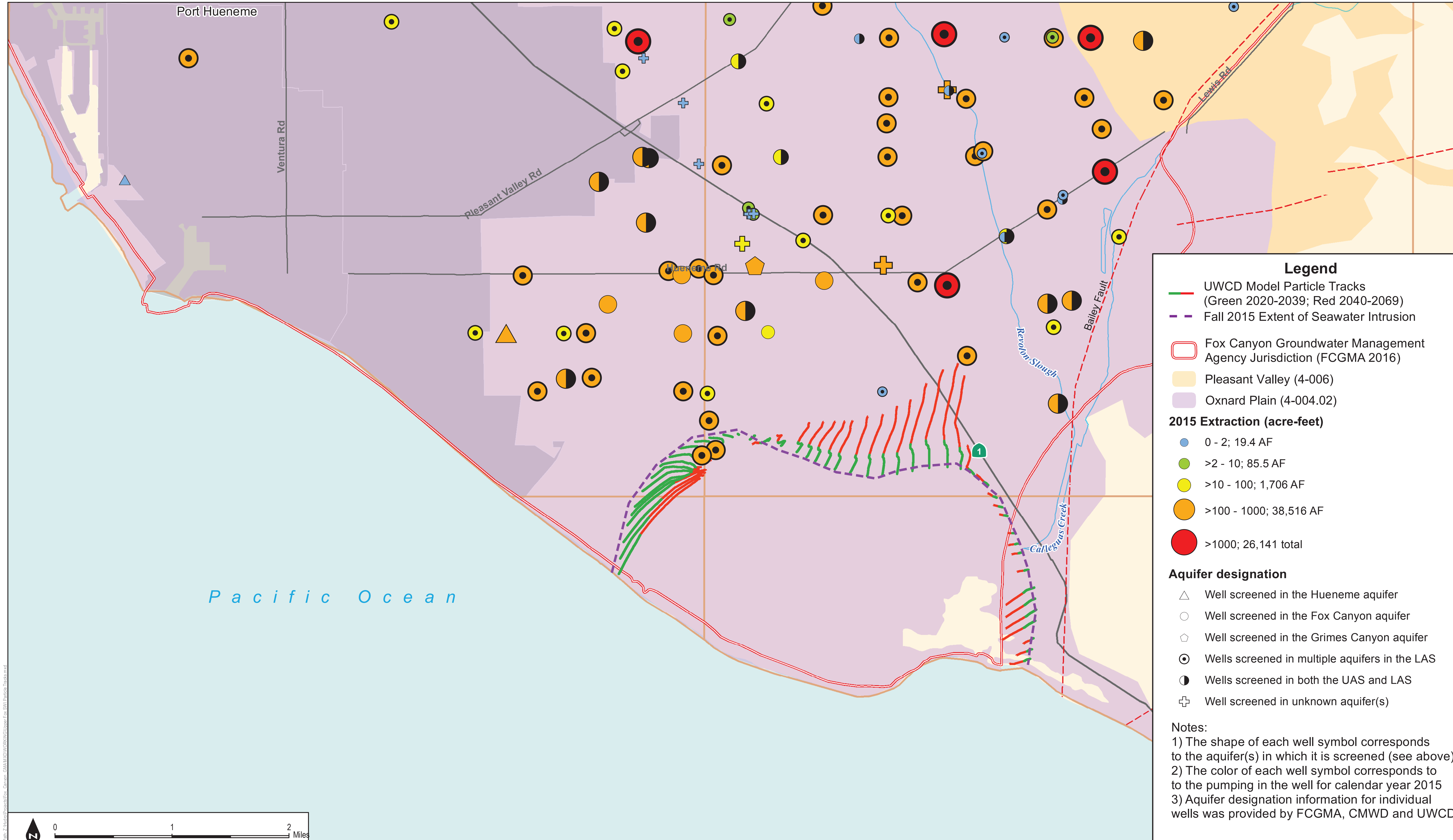

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

DRAFT

FIGURE 2-66d
UWCD Model Particle Tracks, Upper Fox Canyon Aquifer, Future Baseline with Projects

Groundwater Sustainability Plan for the Oxnard Subbasin

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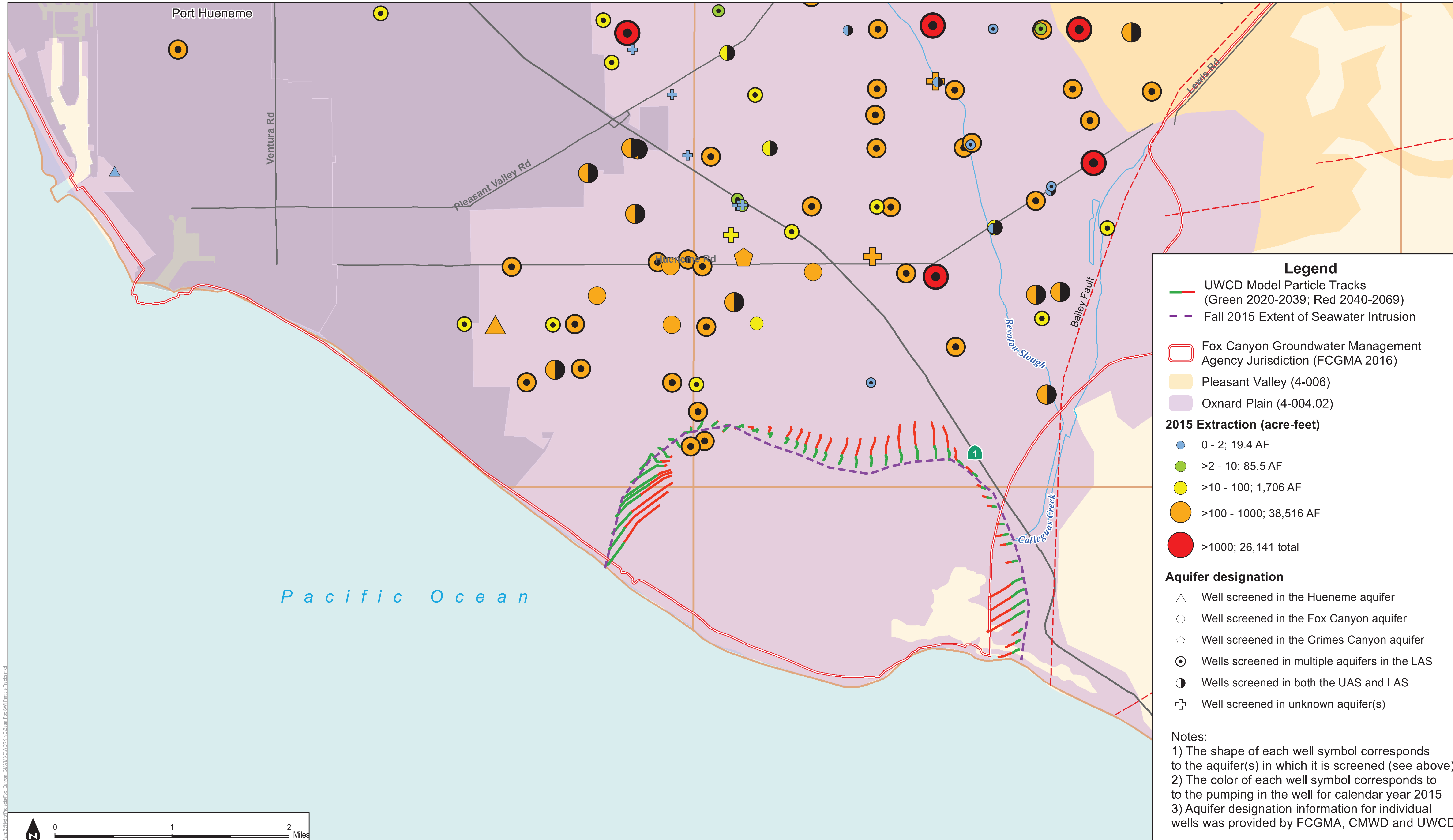

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-66e
UWCD Model Particle Tracks, Basal Fox Canyon Aquifer, Future Baseline with Projects

Groundwater Sustainability Plan for the Oxnard Subbasin

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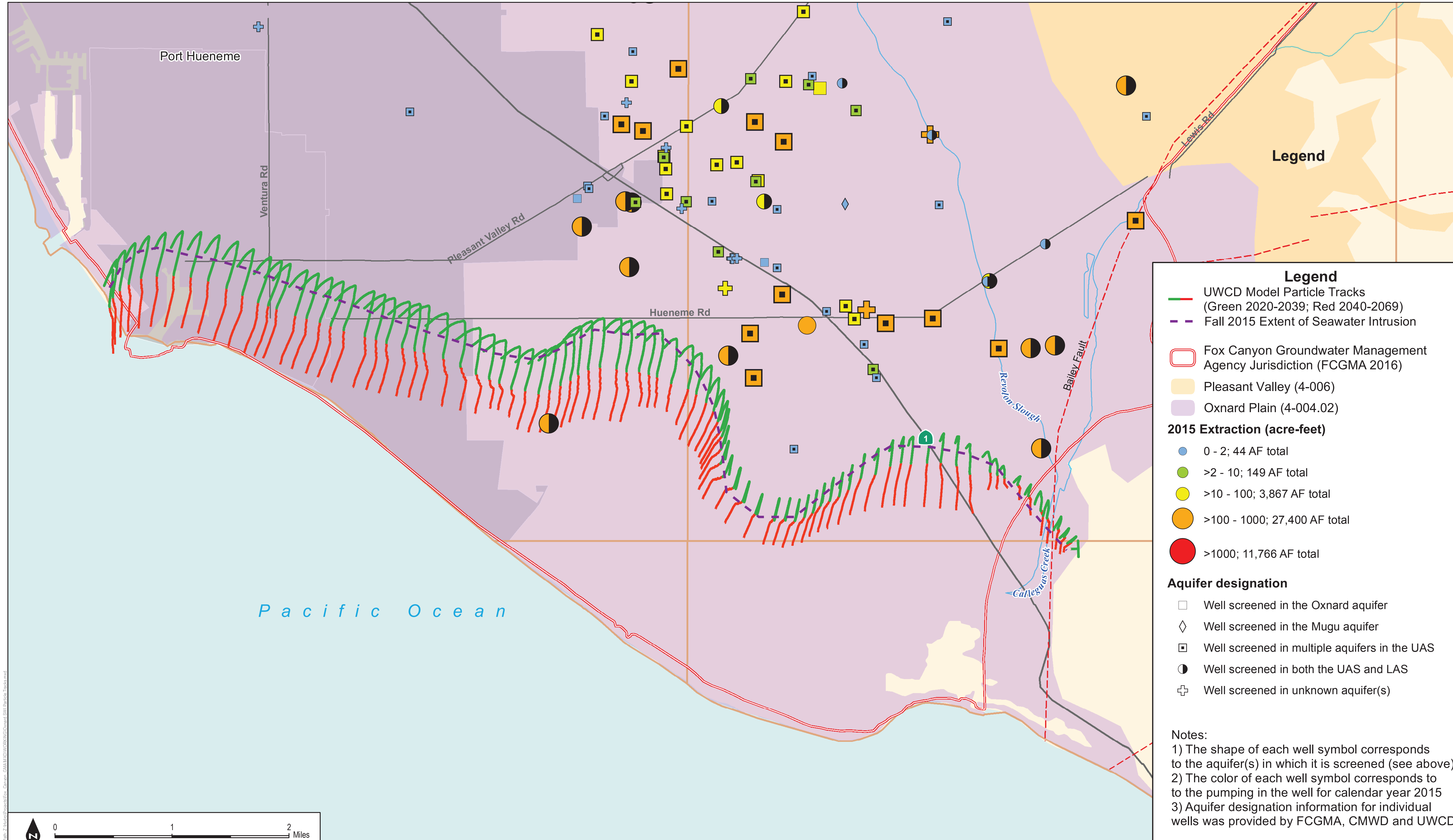

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

DUDEK

Figure 2-67a
UWCD Model Particle Tracks, Oxnard Aquifer, Reduction with Projects Simulation - 26,500 AFY Groundwater Production in the UAS

Groundwater Sustainability Plan for the Oxnard Subbasin

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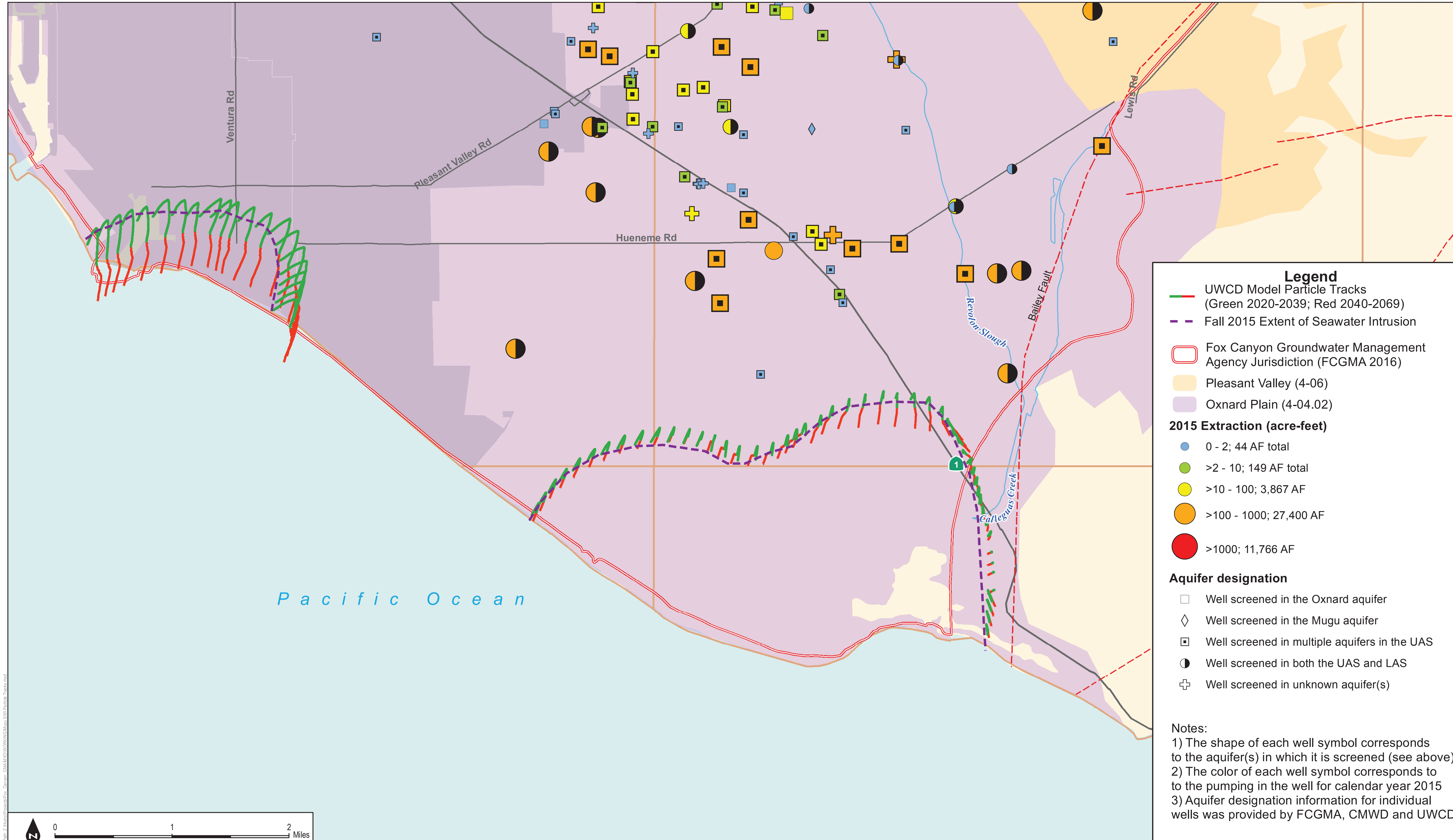

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-67b
UWCD Model Particle Tracks, Mugu Aquifer, Reduction with Projects Simulation - 26,500 AFY Groundwater Production in the UAS

Groundwater Sustainability Plan for the Oxnard Subbasin

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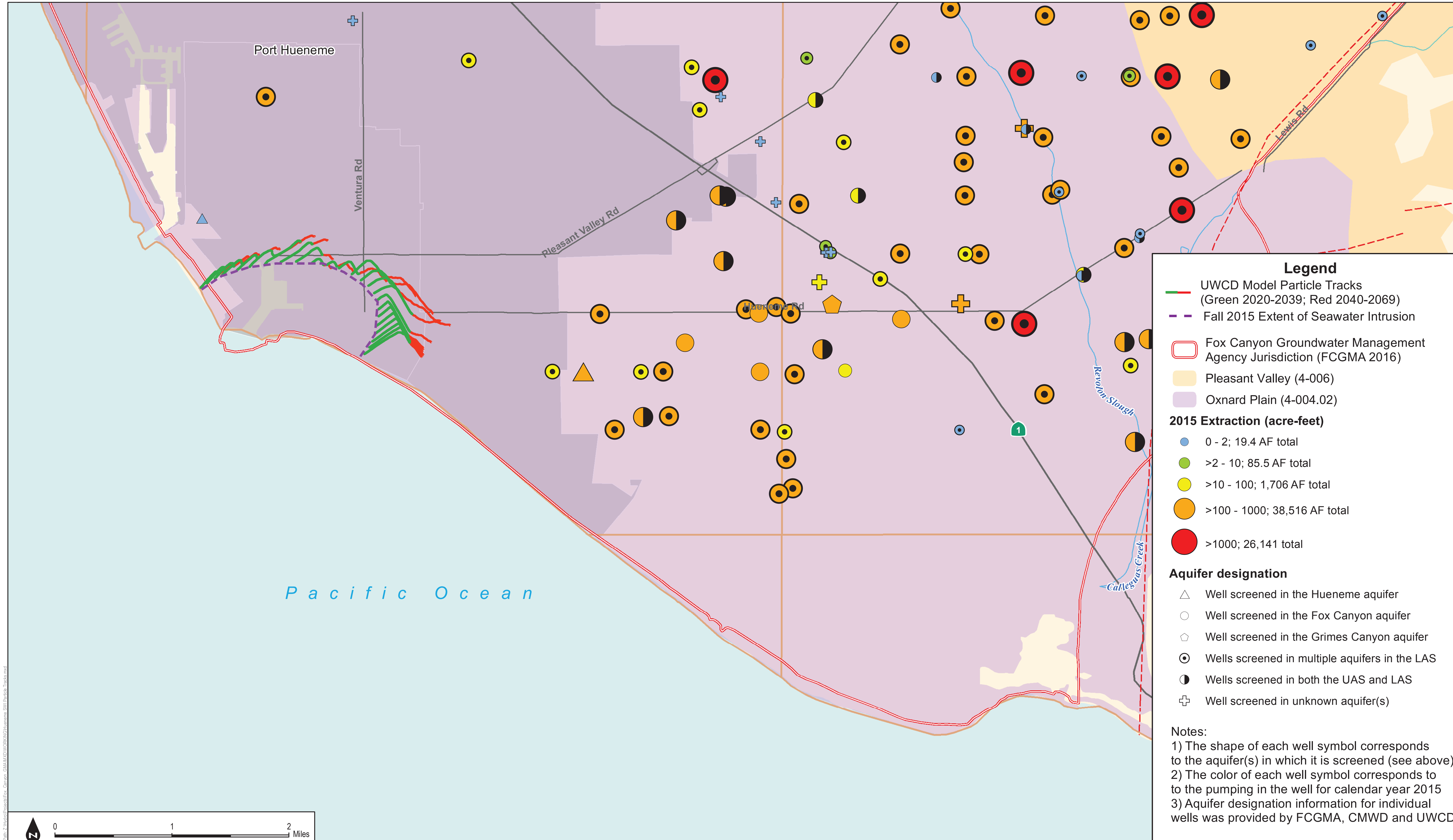

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-67c
UWCD Model Particle Tracks, Hueneme Aquifer, Reduction with Projects Simulation - 12,800 AFY Groundwater Production in the LAS

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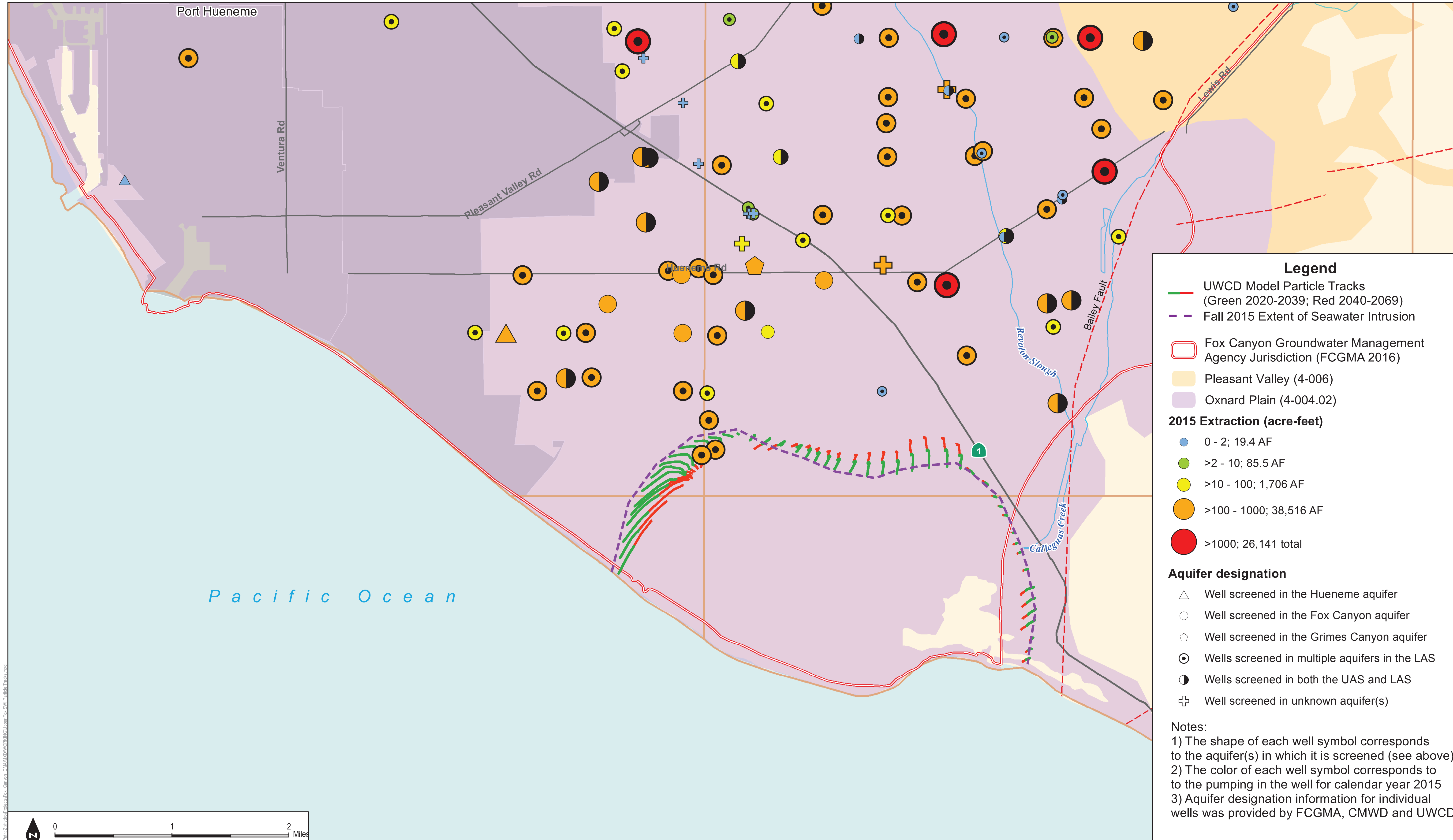

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-67d
UWCD Model Particle Tracks, Upper Fox Canyon Aquifer, Reduction with Projects Simulation - 12,800 AFY Groundwater Production in the LAS

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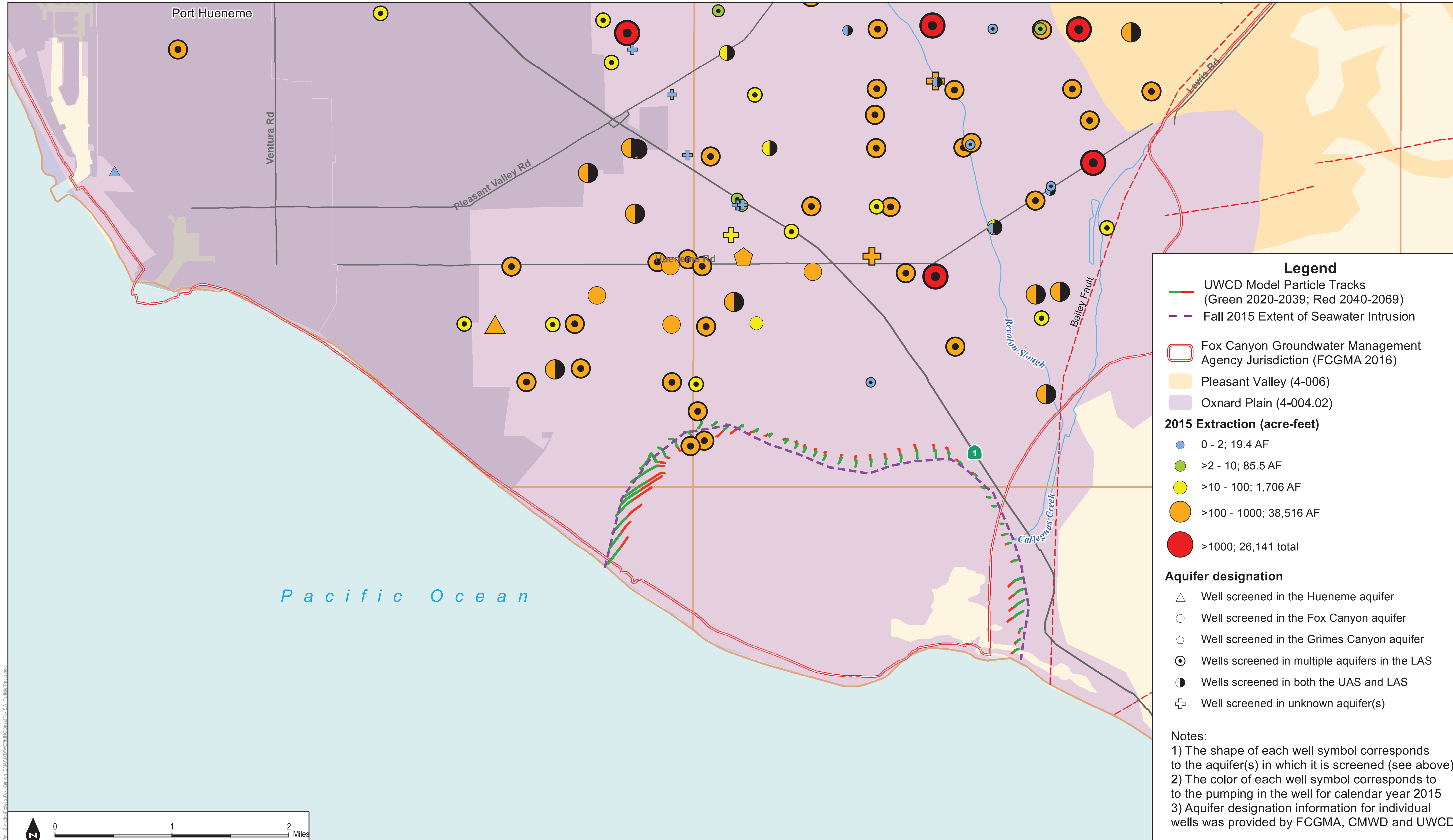

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

DUDEK

Figure 2-67e
UWCD Model Particle Tracks, Basal Fox Canyon Aquifer, Reduction with Projects Simulation - 12,800 AFY Groundwater Production in the LAS

Groundwater Sustainability Plan for the Oxnard Subbasin

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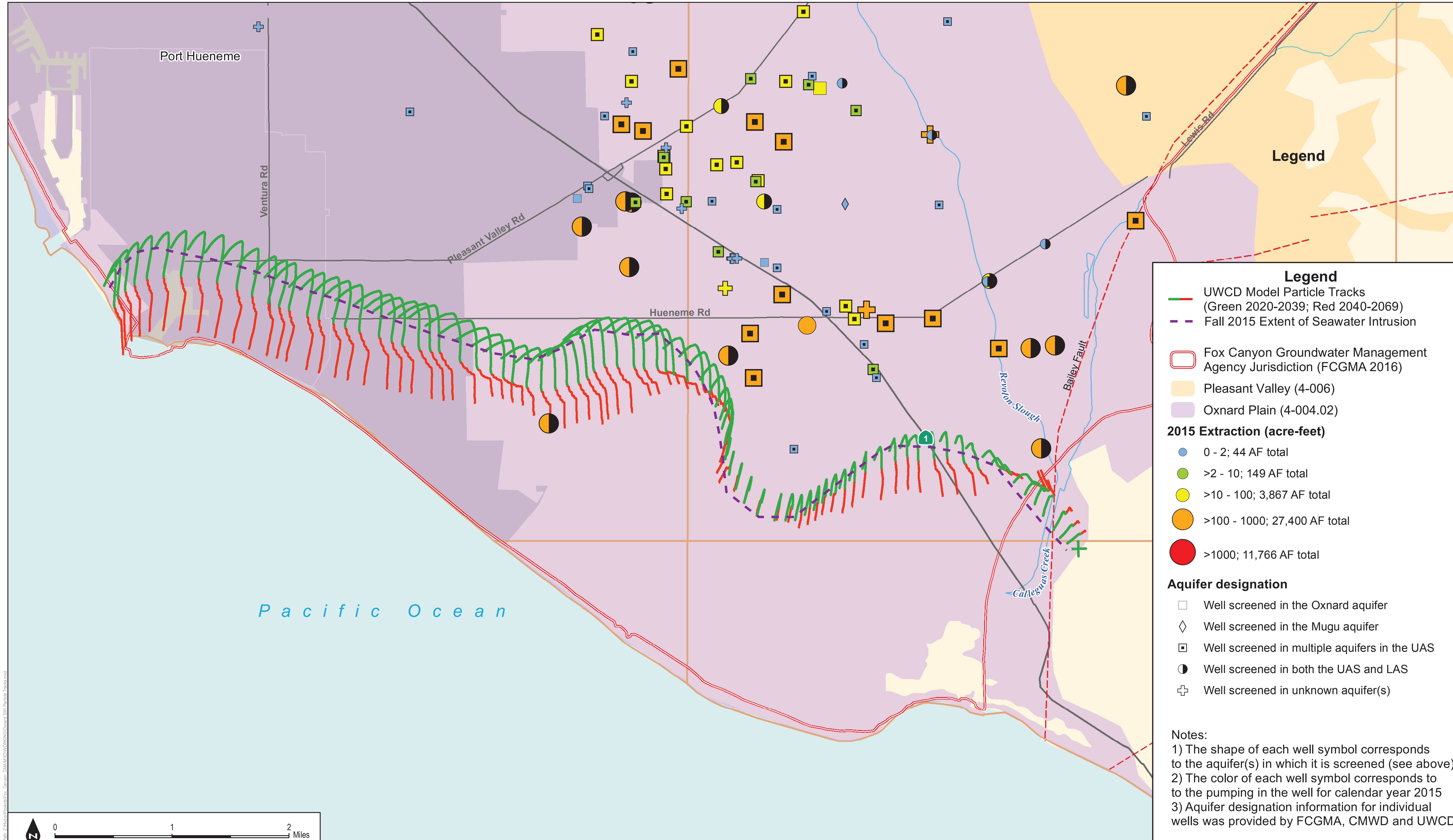

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-68a
UWCD Model Particle Tracks, Oxnard Aquifer, Reduction Without Projects Simulation 1 - 27,200 AFY Groundwater Production in the UAS

Groundwater Sustainability Plan for the Oxnard Subbasin

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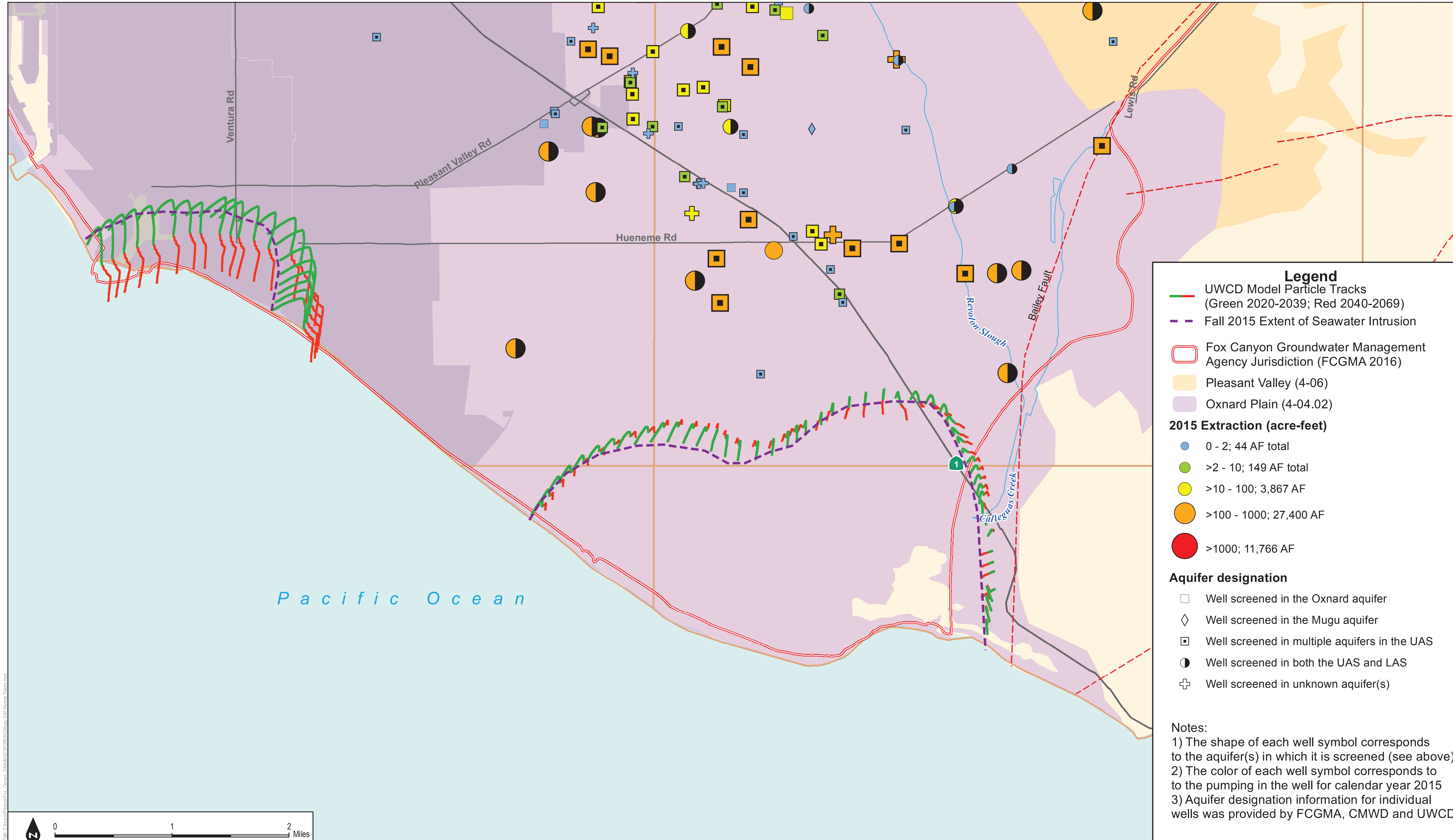

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

DUDEK

Figure 2-68b
UWCD Model Particle Tracks, Mugu Aquifer, Reduction Without Projects Simulation 1 - 27,200 AFY Groundwater Production in the UAS

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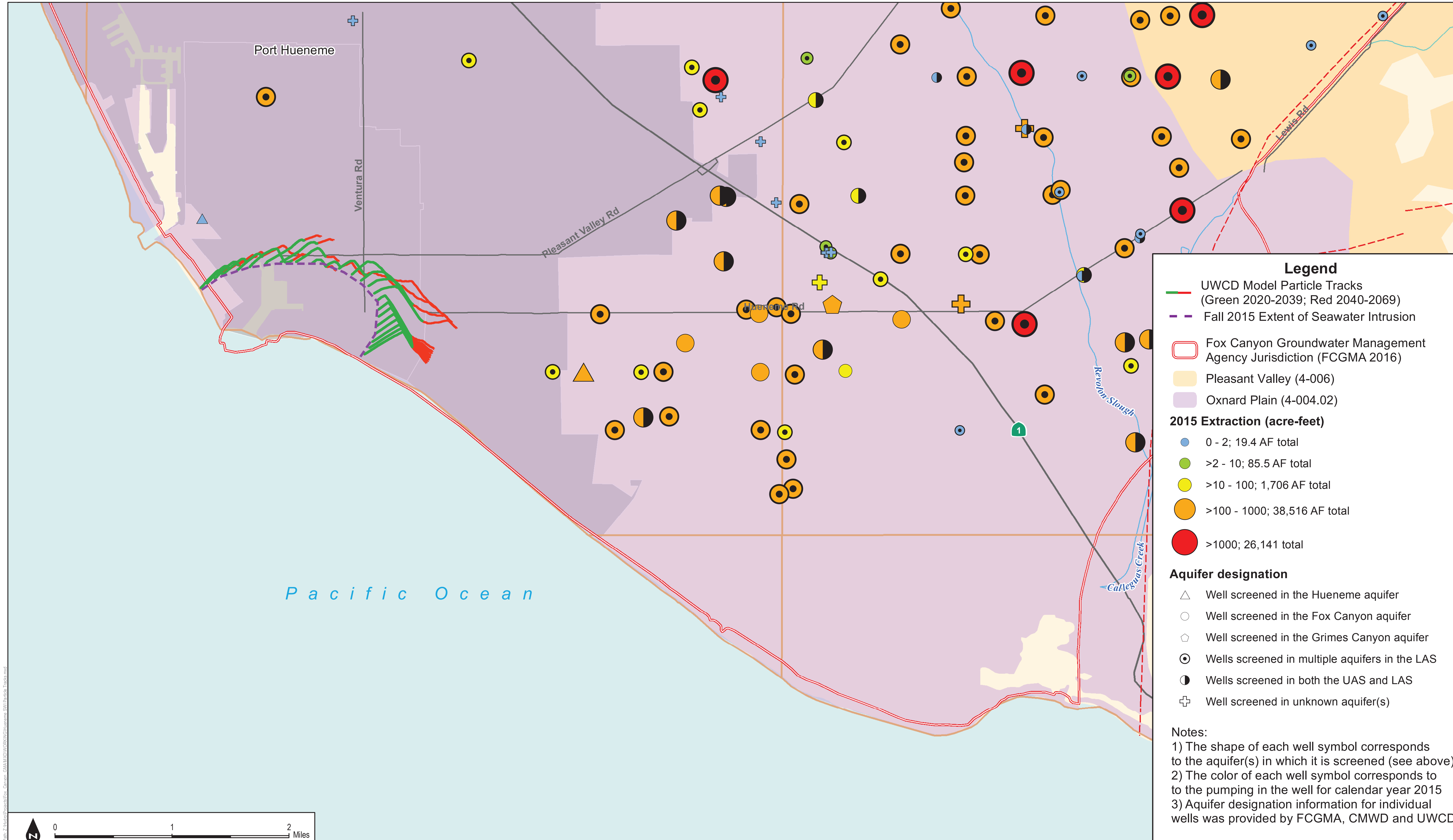

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
Climate Period 1930-1979; Climate Change Factor 2070

Figure 2-68c
UWCD Model Particle Tracks, Hueneme Aquifer, Reduction Without Projects Simulation 1 - 11,600 AFY Groundwater Production in the LAS

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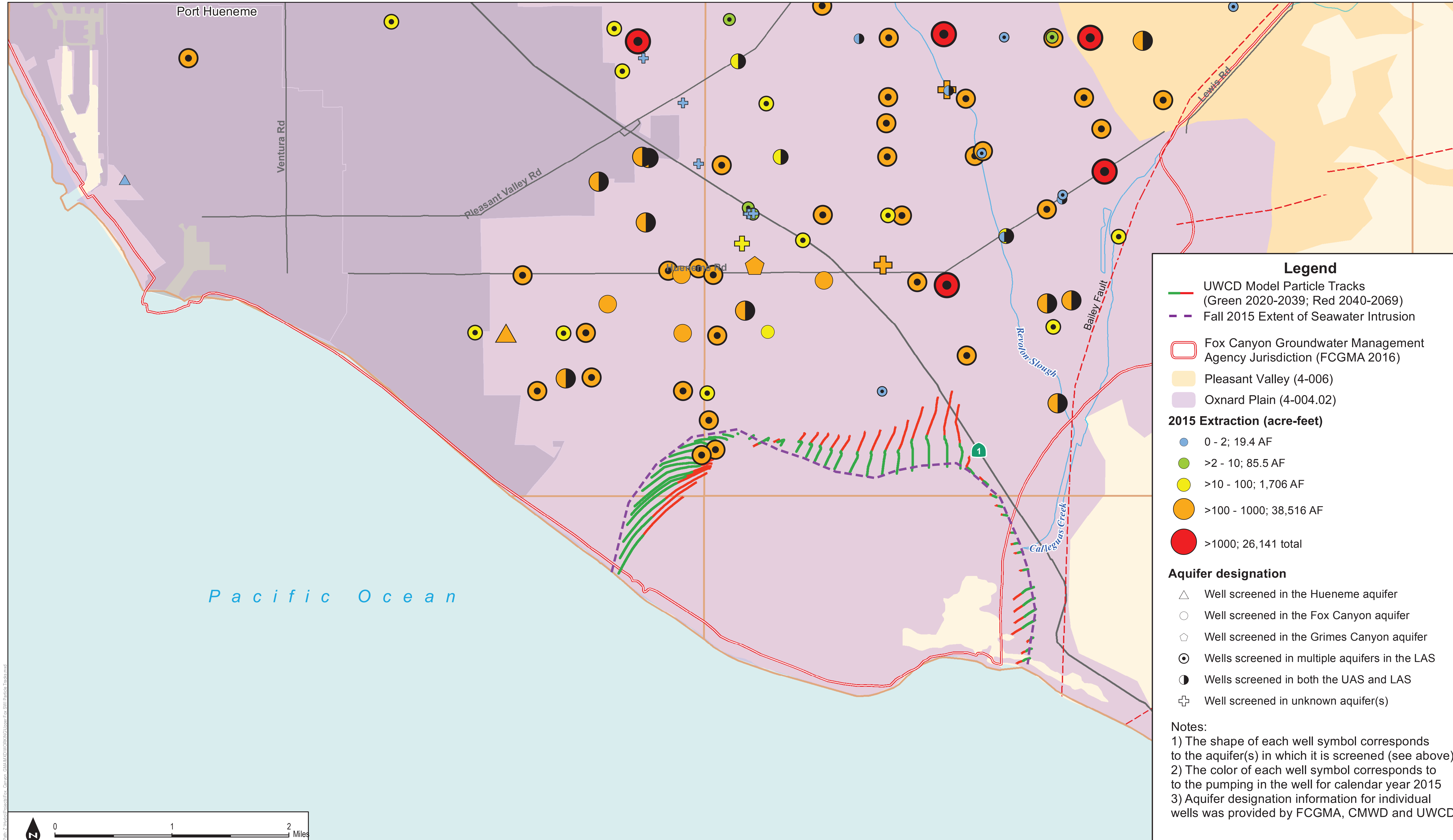

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-68d

UWCD Model Particle Tracks, Upper Fox Canyon Aquifer, Reduction Without Projects Simulation 1 - 11,600 AFY Groundwater Production in the LAS

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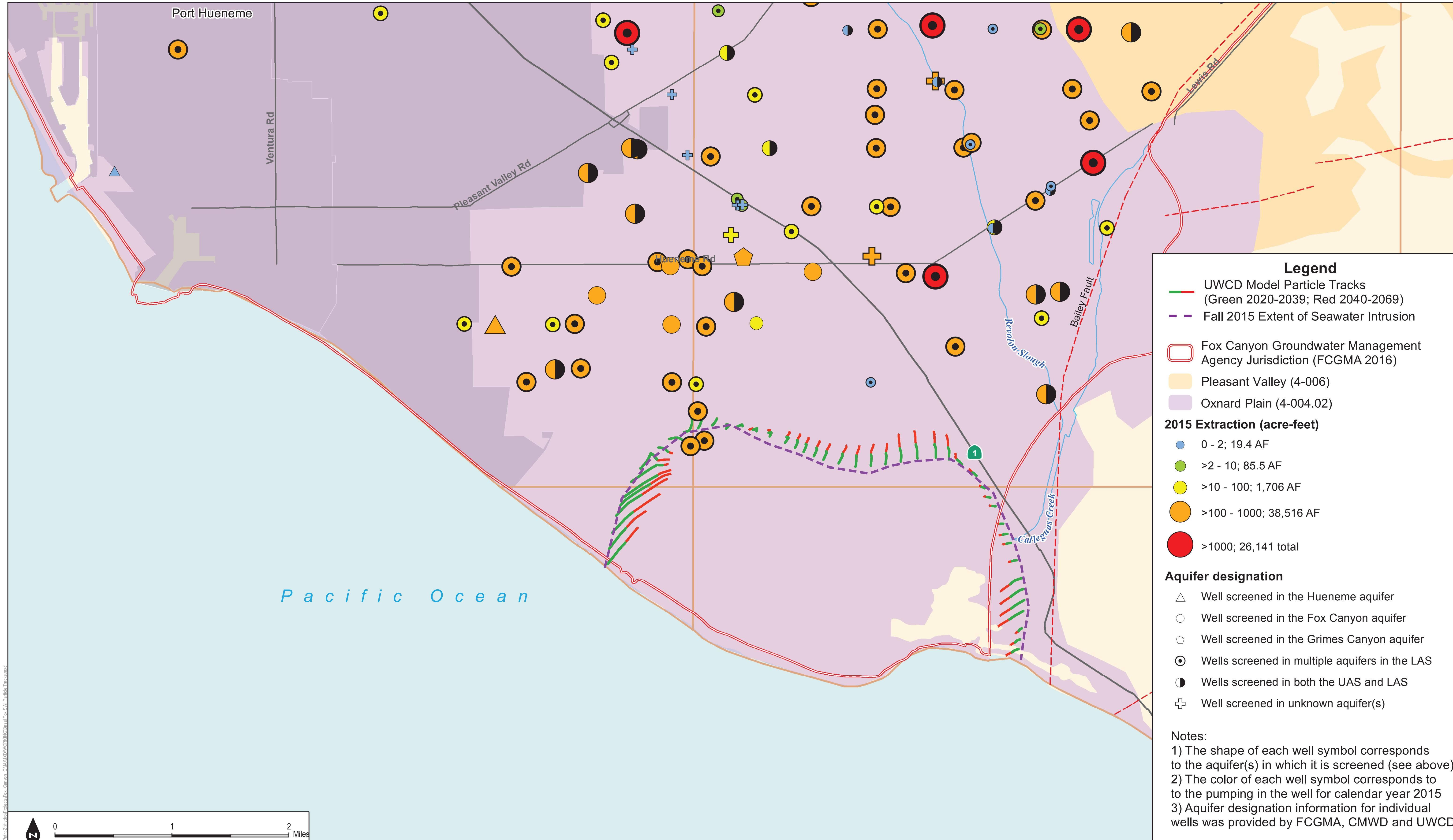

DUDEK

SOURCE: DWR; Ventura County; UWCD; CMWD
1930-1979 Climate Period; 2070 Climate Change Factor

Figure 2-68e

UWCD Model Particle Tracks, Basal Fox Canyon Aquifer, Reduction Without Projects Simulation 1 - 11,600 AFY Groundwater Production in the LAS

Groundwater Sustainability Plan for the Oxnard Subbasin

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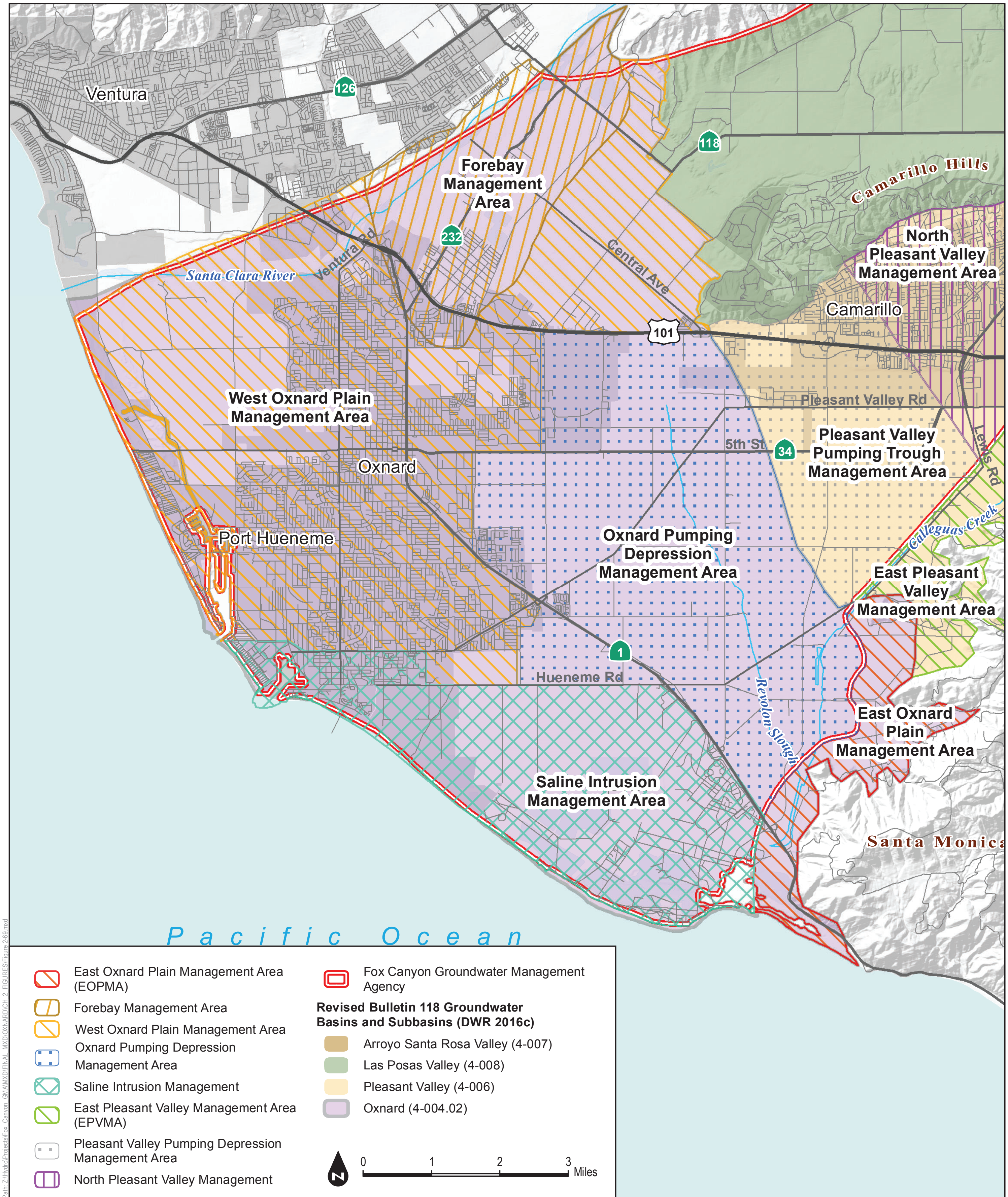

DUDEK

SOURCE: DWR; County of Ventura; FCGMA

FIGURE 2-69

Oxnard Subbasin Management Areas

Groundwater Sustainability Plan for the Oxnard Subbasin

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