SUMMARY OF HISTORICAL EFFORTS TO DEFINE AND ACHIEVE “SAFE” OR “SUSTAINABLE” YIELD IN THE OXNARD AND PLEASANT VALLEY BASINS

United Water Conservation District
Open-File Report 2022-01
November 2022

WATER RESOURCES DEPARTMENT
UNITED WATER CONSERVATION DISTRICT

THIS REPORT IS PRELIMINARY AND SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATIONS

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1 INTRODUCTION

United Water Conservation District (United or UWCD) is a California Special District with a service area of approximately 335 square miles (214,000 acres) in southern Ventura County. United's service area includes the Ventura County portion of the Santa Clara River Valley and much of the Oxnard coastal plain, including the lower part of the Calleguas Creek watershed, as shown on Figure 1. United serves as a steward for surface water and groundwater resources within all or part of seven groundwater basins (Figure 1). United is governed by a seven-person board of directors elected by region, and receives revenue from property taxes, pump charges, recreation fees, and water delivery charges. United is authorized under the California Water Code to conduct water resource investigations, acquire water rights, build facilities to store and recharge water, construct wells and pipelines for water deliveries, commence actions involving water rights and water use, prevent interference with or diminution of stream/river flows and their associated natural subterranean supply of water, and to acquire and operate recreational facilities (California Water Code, section 74500 et al).

This report summarizes efforts made by investigators, agencies, and stakeholders to define and achieve "safe" or "sustainable" yield in the Oxnard Subbasin of the Santa Clara River Basin (abbreviated herein as "Oxnard basin") and the Pleasant Valley basin (together referred to as the "OPV basins"). This report also summarizes historical estimates of "safe yield," "basin yield," and "sustainable yield" in the OPV basins, together with efforts (projects and pumping reductions) in the OPV basins that were planned or implemented to aid in improving what is now referred to as groundwater sustainability. Finally, this report describes past seawater intrusion in the aquifers underlying the Oxnard coastal plain, and includes a description of United's process for developing updated, model-based estimates of the location of the seawater intrusion "fronts" in each aquifer of the OPV basins as of 2019. Seawater intrusion is the main driver for the sustainable yield estimates provided in the GSPs for the OPV basins and west part of the Las Posas Valley basin (Dudek, 2019a, 2019b, and 2019c). The objective of compiling this information in an open-file report is to provide readers with the basic level of background and context necessary to understand the complexities, challenges, and opportunities faced by groundwater users and management agencies working toward achieving a sustainable, resilient water-supply in the OPV basins.

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2 EFFORTS TO ESTIMATE AND ACHIEVE "SAFE YIELD" IN OPV BASINS PRIOR TO THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA) OF 2014

Since the formation of the Santa Clara Valley Water Conservation District in 1927, water users on the Oxnard coastal plain (including the area overlying the OPV basins as currently defined) have attempted to mitigate, with varying degrees of success, local groundwater supply and quality challenges related to discharge (dominated by groundwater extractions) frequently exceeding recharge. Past approaches have included artificial recharge of groundwater, conjunctive-use projects, and demand-reduction measures, including conservation. All of these approaches have been proven to be partially effective, but seawater intrusion has continued to be a persistent challenge, as described in Section 5

2.1 EFFORTS PRECEDING FORMATION OF THE FCGMA

Groundwater has been a key source of water supply in the OPV basins since the early 1900s (Hanson and others, 2003). In the 1920s, water users in the Santa Clara River Valley and Oxnard coastal plain became concerned that increasing agricultural groundwater withdrawals would exceed replenishment (recharge), resulting in wells going dry. In 1927, the Santa Clara Water Conservation District (United's predecessor agency) was established and began diverting and recharging surface water from the Santa Clara River, (and later from Piru Creek and Santa Paula Creek) to increase the stored volume of groundwater available for withdrawal during dry periods—this is one type of conjunctive use of surface water and groundwater that has proven effective in Ventura County and elsewhere.

In the 1930s, the potential for seawater intrusion in the Oxnard Basin became a concern, as declining groundwater levels were measured throughout the area and geologists recognized that the aquifers extended beyond the coastline to crop out on the seafloor (Edmonston, 1956). Subsequently, during a drought that began in the mid-1940s, seawater intrusion was detected in the Oxnard Aquifer below Port Hueneme and Point Mugu Naval Air Station (currently named Naval Base Ventura County Point Mugu [NBVC Point Mugu]). In these two areas, submarine canyons have exposed some of the confined aquifers of the Oxnard basin to seawater within approximately 1/4 mile of the coastline, as shown on Figures 1 and 2. In other stretches of the coastline offshore of Oxnard basin, there are no known areas where the aquifers are in contact with seawater so close to the coast. Therefore, the Hueneme and Mugu submarine canyons (Figures 1 and 2) are preferential pathways for seawater intrusion, and are currently the only known locations where seawater has intruded directly into the confined aquifers of the Oxnard basin.

By 1950, it was recognized that the area of seawater intrusion near Port Hueneme and Point Mugu was growing. This development motivated the reorganization of the Santa Clara Water Conservation District into United Water Conservation District, increasing its population base and its capacity to issue bonds. Several important water-infrastructure improvements were constructed by United during the 1950s, including Santa Felicia Dam (on Piru Creek), additional spreading grounds at El Rio, a potable water treatment and conveyance system to deliver water to coastal communities threatened by seawater intrusion (the Oxnard-Hueneme [OH] System), and a pipeline to deliver surface water and groundwater

to the Pleasant Valley County Water District (PVCWD) for distribution to farms (in this report, United's pipeline to PVCWD and the PVCWD's distribution network is informally referred to as the "Pleasant Valley Pipeline," or PVP), as shown on Figure 2. The OH Pipeline and PVP, which reduce groundwater extractions near the coast and in the Pleasant Valley basin, are the second type of conjunctive use projects implemented in the OPV basins, and have been recognized as one of the most effective measures taken to date to mitigate seawater intrusion (FCGMA and others, 2007).

Also in the 1950s, John F. Mann, Jr. & Associates (Mann, 1959) was contracted by United to synthesize available information from previous investigations and data collected by United staff, with the following objectives:

- "A refinement of the ground water geology of the District (United), in order to analyze the influence of the geologic complexities on ground water management;
- A recalculation of the District's ground water inventories on the basis of the refined geologic framework;
- A detailed study of ground water quality to spell out the influence of poor quality waters on continued ground water development;
- A description of the current status of sea-water intrusion, and the development of a general plan for combating it."

Mann's (1959) final report estimated potential "safe yields" from the groundwater basins, delineated hydrostratigraphic units (aquifers and confining layers, or aquitards), and reported on groundwater quality problems specific to certain aquifers and locations. Mann (1959) defined safe yield as follows:

> *"Safe yield of a ground water basin may be defined as the maximum perennial rate of extraction which will not produce certain undesirable conditions. These conditions might be:*
>
> > *(1) Lowering the water levels so far as to make pumping uneconomical;*
> >
> > *(2) Causing a serious deterioration of water quality;*

(3) Interfering unreasonably with existing water rights."

As will be described further in Section 3, this definition of safe yield has some notable differences from—as well as some similarities with—the California Department of Water Resources (DWR) definition of "sustainable yield" under the SGMA. It should be noted that groundwater basin boundaries as defined in 1959 did not coincide exactly with current basin boundaries as defined by DWR. Further complicating comparisons of safe-yield estimates made by Mann (1959) to recent sustainable yield estimates is that instead of estimating safe yield specifically for the OPV basins, available data and technology at the time required Mann to estimate safe-yield as follows:

- The Montalvo basin (now referred to as the Forebay area of the Oxnard basin), was estimated to have a safe yield of 8,380 acre-feet per year (AFY) during the 1936-57 base period of Mann's study;
- The Upper Aquifer System (UAS) underlying the combined area of the Mound, Oxnard, and Pleasant Valley basins, was estimated to have a safe yield of approximately 50,800 AFY during the base period; and
- The Fox Canyon Aquifer underlying the OPV basins was estimated to have a safe yield of approximately 6,000 AFY during the base period. The Hueneme Aquifer was not recognized as distinct from the Fox Canyon Aquifer at the time of Mann's (1959) report. Mann did note that there were some sandy lenses that produced water in the "upper San Pedro Formation" between the base of the "upper Pleistocene and recent deposits" (UAS, including the Oxnard and Mugu Aquifers) and the Fox Canyon Aquifer. Today those deposits are defined as the Hueneme Aquifer. Mann (1959) did not provide a safe-yield estimate for the Hueneme Aquifer.

Adding the safe-yield values for these three areas/aquifer systems, the total safe yield estimated by Mann (1959) for the OPV and Mound basins, combined, was approximately 65,000 AFY during the 1936-57 timeframe (excluding the Hueneme Aquifer, which was not recognized at that time). As will be discussed subsequently in this section, this safe-yield estimate is within the range of variability and uncertainty of more recent estimates of the combined safe or sustainable yield of these basins.

Beginning in the summer of 1964, surface water from the Colorado River was imported to the OPV basins primarily for municipal and industrial (M&I) use via conveyance and treatment infrastructure operated by the Metropolitan Water District (MWD) and Calleguas Municipal Water District (CMWD). Cities in the OPV basins—particularly Oxnard—were growing rapidly at that time, and recognized that neither the quantity nor quality of local groundwater would be adequate to meet the forecasted demands associated with their anticipated growth (Perliter & Soring, 1960). Therefore, the cities of Oxnard, Port Hueneme, and Camarillo annexed to CMWD—as did Camrosa Water District and some smaller water districts in the region—in order to supplement their local groundwater production with imported surface water. Demand for this new supply grew rapidly—as did population—in the OPV basins from approximately 800 AFY in 1965 to 15,000 AFY in 1975, when the source of imported surface water shifted from the Colorado River to the SWP (derived from the Feather and Sacramento River systems in northern California). SWP imports (through CMWD's pipelines) to the OPV basins reached 27,000 AFY by 1985, and have remained at approximately that level since, with modest annual variability. Estimates of groundwater use by the USGS (Hanson and others, 2003) from the 1960s through the 1980s do not indicate that imports of SWP water resulted in a significant reduction in groundwater use for M&I purposes in the OPV basins. Instead, estimated M&I groundwater withdrawals in the OPV basins continued to increase between 1965 and 1985. This trend is reflected in United's water delivery data for OH Pipeline, which is used to deliver groundwater pumped by United from its El Rio well field chiefly to M&I users. United's data show a gradual increase in OH Pipeline deliveries from 8,400 AF to 13,900 AF over that same (1965-85) period.

By the early 1970s, the use of digital computers and numerical groundwater flow models for groundwater resource studies had become "state of the art" (Prickett and Lonnquist, 1971). Numerical models allowed more accurate estimates of safe or sustainable yield than were possible using older methods. The earliest use of a numerical groundwater flow model for the basins underlying the Santa Clara River Valley and Oxnard coastal plain was reported by DWR in 1974 (Hasan and others, 1974). That flow model was coupled with a solute-transport model for the purpose of forecasting total-dissolved-solids (TDS) concentrations that would result from groundwater management plans under consideration for the OPV basins at that time. The model was calibrated using groundwater-level measurements from 1957 through 1967. The hydrogeologic information input to Hasan's model was subsequently released by the Ventura County Department of Public Works, Flood Control District (Mukae and Turner, 1975). Mukae and Turner (1975) refined delineation of the aquifers and base of fresh groundwater in "the Oxnard-Calleguas Area" of Ventura County (including the Oxnard, Pleasant Valley, East, West, and South Las Posas, and Santa Rosa basins).

Synthesizing the information compiled by Hasan and others (1974), Mukae and Turner (1975), and other investigators, the State Water Resources Control Board (SWRCB) released a document simply titled "Staff Report—Oxnard Plain Groundwater Study" focusing on groundwater overdraft in the OPV basins and resultant seawater intrusion (SWRCB, 1979). The SWRCB threatened adjudication (under Water Code Section 2100) if actions were not taken to correct overdraft and seawater intrusion in the OPV and Las Posas Valley basins. In response to the SWRCB's threat of adjudication, the FCGMA was created in 1982 to fill an oversight and planning role in preventing further deterioration of groundwater conditions in most of the Oxnard, Pleasant Valley, and Las Posas Valley basins, together with the western approximately one-half of the Arroyo Santa Rosa basin. The FCGMA's enabling legislation (Section 601 of Assembly Bill 2995) provided the agency with an authority that United did not have—to impose pumping restrictions. However, the FCGMA was not given the authority to fund and build new water-supply projects at that time.

2.2 EFFORTS SUBSEQUENT TO FORMATION OF THE FCGMA

From formation of the FCGMA in 1982 to the promulgation of SGMA in 2014, efforts continued to achieve safe yield in the OPV Basins and add to the region's water-supply reliability, as described below.

2.2.1 GROUNDWATER MANAGEMENT PLAN OF 1985

The FCGMA's enabling legislation (Section 601 of Assembly Bill 2995) stated that:

> *"The Agency shall develop, adopt, and implement a plan to control extractions from the Oxnard and Mugu aquifers with the objective of balancing water supply and demand in the Oxnard Plain of Ventura County by the year 2000."*

Additionally, the FCGMA's enabling legislation required that a management plan for the Lower Aquifer System (LAS; including the Hueneme, Fox Canyon, and Grimes Canyon Aquifers) be developed and adopted. In 1985, the FCGMA's first Groundwater Management Plan (GMP) was prepared by the Flood Control and Water Resources Department of the Ventura County Public Works Agency (VCPWA) for the OPV and Las Posas Valley basins and part of Santa Rosa basin (VCPWA, 1985). The primary approaches to "balance supply and demand" proposed for the OPV basins included:

- Limiting future groundwater extractions to specified amounts, which were to increase from 108,800 AFY in 1985 to 110,600 AFY in 2010;
- "Encouraging" wastewater reclamation and water conservation programs, which were anticipated to yield 12,920 AFY of reclaimed (recycled) water that would reduce demand by 11,060 AFY by 2010;
- Implementing the "Oxnard Plain Seawater Intrusion Control Project," which consisted of United's PTP system (already nearing completion by 1985) and the Freeman Diversion (designed by United and VCPWA in the 1980s and supported by State funding).

The term "safe yield" was only used twice in the 1985 GMP, and a specific definition was not provided in the document.

The projected groundwater extraction volumes listed in the 1985 GMP were much larger than previous or subsequent estimates of safe or sustainable yield of the OPV basins. The 1985 GMP estimated that groundwater in storage would decrease approximately 750,000 AF by 2010 (30,000 AF each year on average during the 25-year period from 1985 to 2010) if the 1985 GMP were followed. Therefore, the 1985 GMP included contingency planning to respond to potential problems caused by excessive drawdown or continued seawater intrusion, particularly in the LAS. If reduction of groundwater storage had been excluded from the 1985 GMPs estimates of projected annual pumping from the OPV basins—resulting in a more traditional definition of safe yield—it appears that the combined safe yield of the OPV basins would have been estimated to be approximately 80,600 AFY (30,000 AFY less than the planned 2010 pumping rate of 110,600 AFY).

In 1990, during a severe drought, the FCGMA adopted Ordinance No. 5, which required a 25 percent reduction in pumping throughout the FCGMA's boundaries, "with the objective of reducing extractions to a 'safe yield' level of 120,000 AF per year within the Agency's boundaries (including the Las Posas Valley Basin and western portion of Santa Rosa Basin, in addition to the OPV basins) by the year 2010." During the 1990s, Ordinance No. 5 was amended several times, and new ordinances (i.e., Ordinance Nos. 7 and 8) were adopted to accommodate historical use, conservation credits, and irrigation efficiency in establishing pumping allocations for the OPV basins and the other basins within the FCGMA's boundaries. In 2008, the FCGMA adopted Resolution 2008-03, requiring an additional 5 percent reduction in groundwater pumping allocations effective January 1, 2009.

2.2.2 USE OF RECYCLED WATER AND EXPANSION OF CONJUNCTIVE-USE PROJECTS DURING THE 1980S AND 1990S

During the 1980s and early 1990s, supported by the VCPWA and FCGMA, United expanded its conjunctive-use projects (both those that store surface-water flows in the aquifer via artificial recharge and those that deliver surface water *in lieu* of pumping groundwater) in the OPV basins by constructing the PTP system and the Freeman Diversion (Figure 2). United's records indicate that artificial recharge rates on the Oxnard coastal plain increased from an average of 23,000 AFY during the 1950s to over 50,000 AFY by the 2000s, with an additional 16,000 AFY of surface water delivered in lieu of pumping since the 1990s. It should also be noted that the 1990s had the highest 10-year-average rainfall in the history of southern Ventura County (dating back to 1892). The combination of increased rainfall in the 1990s and expansion of United's conjunctive-use projects raised groundwater levels in the aquifers of the UAS in the OPV basins for much of the next two decades, temporarily limiting, and even partly reversing (in some areas and aquifers), the seawater intrusion that had occurred over the previous decades (United, 2017).

Starting in the 1980s, Camrosa Water District and Camarillo Sanitation District delivered recycled water from their wastewater reclamation facilities to PVCWD and others for agricultural use in the OPV basins at a combined rate of approximately 2,500 AFY, on average (Dudek, 2019a). Use of this recycled water likely reduced pumping in the Pleasant Valley basin, in particular, but also in the eastern portion of the Oxnard basin, which is within PVCWD's service area. Camrosa Water District also delivered approximately 2,500 AFY of surface water diverted from Conejo Creek to agricultural users in the OPV basins during the 1980s and 1990s (Dudek, 2019a). A significant fraction of the base flow in Conejo Creek consists of reclaimed water discharged from the Hill Canyon Wastewater Treatment Plant in Thousand Oaks, east and upstream from Pleasant Valley basin.

In the 1990s, United, FCGMA, and CMWD, contracted the US Geological Survey (USGS) to further study the basins and subbasins of the Santa Clara River Valley, focusing on the interaction between surface water and groundwater. The USGS prepared a report that summarized "…the groundwater system and stream-aquifer interactions along the Santa Clara River," and included additional technical discussions of the hydrologic conditions in the Santa Clara River Valley (Reichard and others, 1998). The USGS followed this study with development of a numerical groundwater flow model (Hanson and others, 2003) for the Santa Clara River and Calleguas Creek watersheds, including the OPV basins. Neither of these USGS reports included estimates of safe yield of the OPV basins. However, the USGS model report (Hanson and others, 2003) concluded that a net decline in groundwater storage and a net influx of "coastal flow" of groundwater (including seawater intrusion) likely occurred over the 10-year period from 1984-93, when USGS-estimated groundwater withdrawals from the OPV basins averaged 119,000 AFY. The decline in storage and influx of seawater suggest this pumping rate exceeded safe or sustainable yield under both current and previous definitions of the terms. A severe drought from 1987-1990 was likely a factor in the high pumping rates occurring during that period. The USGS model of the Santa Clara River and Calleguas Creek watersheds included just two layers to represent seven distinct aquifers and six distinct aquitards of the OPV basins, specifically excluding the shallow, unconfined, Semi-perched aquifer. Furthermore, the USGS model's relatively coarse discretization (uniform 1/2-mile grid spacing) limited the level of detail at which it could be calibrated; therefore, it was not well-suited to evaluating impacts of future pumping/recharge scenarios on specific aquifers, particularly those impacted by seawater intrusion in the OPV basins.

The period from 1992 through 2005 included record-setting rainfall in southern Ventura County. Rainfall in Santa Paula (the meteorological station with the longest continuous record in the Santa Clara River watershed in Ventura County) exceeded 30 inches in 1992, 1995, 1998, and 2005. The 1998 and 2005 water-year rainfall totals exceeded 40 inches, for the first two times in recorded history (continuous records began in 1892). This wet period resulted in high flows in the Santa Clara River, with corresponding high diversion totals at Freeman Diversion and artificial recharge rates in Oxnard basin. During this period, United focused on expanding and optimizing its artificial recharge and conjunctive-use operations to take advantage of the extraordinary rainfall and surface-water availability. During and soon after this period, United obtained the Noble, Ferro, and Rose recharge basins (former gravel-mining pits) and constructed new extraction wells in the Saticoy area (Figure 2). Use of the new Saticoy extraction wells was intended to create additional water-storage capacity in the OPV basins and deliver surface water, temporarily stored in the aquifers, to users along the PVP, PTP, and OH Pipeline systems, while reducing pumping near the coast. This conjunctive-use program was named the Saticoy Well Field Storage Program, and was developed in coordination with the FCGMA (details are provided in their Resolution 11-2).

2.2.3 GROUNDWATER MANAGEMENT PLAN UPDATE OF 2007

In 2007, the FCGMA's GMP was updated (FCGMA and others, 2007) to include new interpretations of hydrogeologic conditions in the FCGMA's area of responsibility, including the OPV basins, based on data collected by the USGS and others subsequent to preparation of the 1985 GMP. The 2007 GMP Update also included estimates of "basin yield" (sometimes referred to as "perennial yield" in the 2007 GMP Update) for all basins within the FCGMA's boundaries combined (i.e., sum of basin yields for Oxnard, Pleasant Valley, and Las Posas Valley basins, as well as the western portion of Santa Rosa Basin). Basin yield is defined in the 2007 GMP Update as follows:

> *"The yield of a basin is the average quantity of water that can be extracted from an aquifer or groundwater basin over a period of time without causing undesirable results. Undesirable results include permanently lowered groundwater levels, subsidence, or degradation of water quality in the aquifer."*

This definition is similar to DWR's current definition of sustainable yield (described in Section 3). However, the 2007 GMP Update did not provide a basin yield estimate for each basin; instead a single combined estimate of basin yield was provided for the entire area within the FCGMA's boundaries. The estimated basin yield was 100,000 AFY, assuming that all pumping reductions required to achieve that yield occurred in the southern half of the OPV basins; the average pumping rate within the FCGMA's boundaries prior to 2007 was approximately 120,000 AFY. The reductions contemplated in the southern OPV basins (presumably 20,000 AFY) represented 85 percent of pumping in that area (FCGMA and others, 2007). The 2007 GMP Update noted that if pumping was reduced equally in all wells within FCGMA's boundaries, the basin yield would be significantly less, at 65,000 AFY. This difference in basin yield estimates may have been the first explicit recognition that safe or sustainable yield is partly dependent on location of groundwater wells, in addition to the volume of water extracted.

The 2007 GMP Update also noted that basin yield:

> *"…depends upon the projects in the basin – increasing the amount of recharge in the basins also increases the yield of the basins. Therefore, the yield of the basins must be recalculated periodically as new projects become operational and conjunctive use is increased."*

In 2007, total pumping in the OPV basins was approximately 98,000 AFY (suggesting that 22,000 AFY were pumped from the other basins within FCGMA boundaries in 2007, the sum being the 120,000 AFY total pumping rate reported in the 2007 GMP update). Modeled pumping scenarios in the 2007 GMP Update indicated that "Overall pumping in the south Oxnard Plain and Pleasant Valley areas" would have to be "reduced by about 25,000 AFY" (FCGMA and others, 2007) from the 98,000 AFY actually being pumped at that time in order to reach the estimated basin yield. This suggests that the combined basin yield specific to the OPV basins would have been estimated to be approximately 73,000 AFY at that time. However, this yield estimate is not explicitly quantified in the 2007 GMP Update, and can only be inferred from the narrative text provided in the document (FCGMA and others, 2007).

The 2007 GMP Update (FCGMA and others, 2007) also included descriptions of “management strategies” that were under development at that time or being considered for the future, to “eliminate overdraft in both Upper Aquifer and Lower Aquifer System aquifers and to prevent further seawater intrusion along the coastline and saline intrusion in more inland areas.” The management strategies are listed in the 2007 GMP Update in order of proposed implementation timing. Some (but not all) of the numerous strategies proposed in the 2007 GMP Update are listed in Table 1 of this report because they remain relevant today, as will be discussed later in this report. One of the proposed strategies to eliminate overdraft and prevent seawater intrusion was reduced pumping. But the 2007 GMP Update also noted that:

> *“The modeling does suggest that further reductions in FCGMA extractions would not be warranted until the effect of the other management strategies can be observed or unless many of the strategies are not implemented because of financial or other reasons. However, implementation of a significant number of the strategies recommended in this Plan would be necessary to avoid further pumping reductions.”*

2.2.4 FURTHER EXPANSION OF CONJUNCTIVE-USE AND RECYCLED WATER PROJECTS DURING THE 2000S AND 2010S

During the 1990s and 2000s, United occasionally made transfer or exchange arrangements with Casitas Municipal Water District (Casitas MWD) to take a portion of their SWP “Table A” allocation for temporary storage in Lake Piru and subsequent release into the Santa Clara River. Some of that SWP water was diverted (at Freeman Diversion) for artificial recharge or conjunctive use in the OPV basins. Adding United’s SWP Table A allocation and the additional SWP water transferred or exchanged with Casitas MWD, an average of 1,500 AFY of SWP water was imported by United from 1991 through 2016. Starting in 2017—during an exceptional dry period that began in 2012 and continues today—United began importing additional SWP water through “Article 21” purchases, as well as exchanges and transfers with other SWP contractors, including the City of Ventura and Santa Clara Valley Water Agency. In 2019, with financial support from the FCGMA, United was able to purchase 15,000 AF of SWP Article 21 water at a cost of approximately $200 per AF and convey it to Freeman Diversion for artificial recharge, with a resultant measurable benefit to groundwater elevations and quality in the Forebay area. In total, including Article 21 purchases, United’s Table A allocation, and exchanges and transfers with other agencies, United was able to import an annual average of 8,800 AFY to its service area between 2017 and 2021 (total of 44,100 AF), much of which was ultimately diverted at Freeman Diversion to improve groundwater conditions in the OPV basins. This was a substantial increase in SWP imports compared to the 1,500 AFY annual average for the previous 26 years. Increasing the volume of SWP imports was consistent with the FCGMA 2007 GMP Update’s 10-year strategic objective to “import additional SWP water.”

In 2008, after repayment of the Federal loan for construction of Freeman Diversion was complete, United began preparing a Multiple Species Habitat Conservation Plan (MSHCP) as part of its application for incidental take permits under Section 10(a)(1)(B) of the federal Endangered Species Act (ESA). Incidental take permits are necessary for United to continue operating Freeman Diversion and to expand the facility to accommodate higher diversion rates in the future. Some of the key covered activities under the MSHCP include:

- Water diversion operations
- Expansion of the Freeman Diversion off-channel water conveyance infrastructure
- Conservation program activities
- Restoring and enhancing habitat
- Renovation of the fish passage facility and the Freeman Diversion headworks.

The MSHCP notes that "These covered activities will aid United in sustaining the long-term and reliable management of water resources based on known and foreseeable demand for agricultural, municipal, and industrial water supplies." Development of the MSHCP is consistent with the 2007 GMP Update's 5-year strategic objective to "protect current sources of recharge, specifically the Santa Clara River…"

Design of the Freeman Diversion Expansion Project was updated by United during the 2010s, focusing on diverting surface water at higher flow rates and with higher sediment loads than were possible historically. Diversion of flows with higher sediment loads, which are less conducive to fish migration, has been encouraged by both regulatory agencies and non-governmental organizations (Dudek, 2019b) for both environmental and water-supply benefits. This project includes expansion of the existing intake, conveyance, and recharge facilities associated with Freeman Diversion and, in a subsequent phase, an associated increase in United's permitted instantaneous diversion rate from 375 cubic feet per second (cfs) to 750 cfs (during periods of peak flow in the river). When completed, this project will result in additional recharge of storm or flood flows to benefit both Oxnard and Pleasant Valley basins. United will improve fish passage and implement the MSHCP concurrently with this project. Some components of this project have been completed or are currently in advanced stages of design, as follows:

- Grand Canal headworks—construction completed in 2021
- Inverted Siphon—100% design completed in 2022
- 3-Barrel Culvert—60% design completed in 2022

Design and implementation of the Freeman Diversion Expansion Project is consistent with the 2007 GMP Update's 15-year strategic objective to "increase diversions from the Santa Clara River at Freeman Diversion" (FCGMA and others, 2007).

Camrosa Water District has also been expanding conjunctive use of surface water in the OPV basins, with construction of a new diversion structure on Conejo Creek (at Highway 101) in 2002. Construction of this structure increased Camrosa Water District's surface-water diversions by 2,500 AFY, on average (Dudek, 2019a). The diverted surface water, which contains a significant fraction of recycled water from the Hill Canyon Treatment Plant (located upstream of the OPV basins in Thousand Oaks), is delivered for non-potable irrigation use by agricultural and municipal customers. Camrosa Water District also provides some of the surface water diverted from Conejo Creek to PVCWD, in exchange for groundwater pumping allocation "credits" in Pleasant Valley basin (https://www.camrosa.com/about/water-systems/).

After decades of planning, recycled water from the City of Oxnard began to be delivered to farms in 2016. Since at least the 1950s (Mann, 1959), water managers in the OPV basins have anticipated the day that the City of Oxnard's wastewater could be used to reduce demand for groundwater. The FCGMA's original GMP (1985) and their 2007 GMP Update both envisioned recycled water from the City of Oxnard providing an important new source of water supply in the OPV basins, whether used for agricultural purposes, recharge, or as a potable source for the M&I sector. Since 2016, an average of approximately 800 AFY of recycled water from the City's Advanced Water Purification Facility (AWPF) has been delivered to farm operators and to PVCWD for agricultural use in the OPV basins. The City also reportedly has used a smaller amount of recycled water for M&I landscaping and irrigating the municipal golf course at River Ridge, and has plans to conduct aquifer storage and recovery (ASR) of recycled water for future potable M&I use. The City completed their Hueneme Road recycled-water pipeline in 2022, providing a permanent connection to the PVCWD and potentially allowing delivery of larger volumes of recycled water for agricultural irrigation in the OPV basins in the future.

2.2.5 EMERGENCY ORDINANCE E

In January 2014, following the Governor of California's proclamation of a state of emergency in response to the exceptional drought that began in 2012, the FCGMA adopted Emergency Ordinance E. This ordinance intended to reduce groundwater extractions in the OPV and other basins within the FCGMA's boundaries. Emergency Ordinance E replaced groundwater allocations for municipal and industrial (M&I) pumpers with "Temporary Extraction Allocations," which required 20 percent pumping reductions by July 2015 (in steps of 5 to 10 percent per half-year period). Emergency Ordinance E also required that agricultural pumping be limited to 75 percent of volumes previously established under Irrigation Allowance Indices (established in FCGMA Resolution No. 2011-04), with the caveat that the FCGMA could further adjust the irrigation allowances as needed to achieve a cumulative 20 percent reduction in agricultural pumping by August 2015. Emergency Ordinance E also prohibited accrual or use of conservation credits, and further prohibited construction of new groundwater extraction facilities other than replacement, backup, or standby facilities. In December 2019, following board adoption of GSPs for Oxnard, Pleasant Valley, and Las Posas Valley basins (described in Section 3), Emergency

Ordinance E was amended to repeal the Temporary Extraction Allocations for M&I pumping, effective January 1, 2020. Pumping data presented in the GSPs (Dudek, 2019a and 2019b) and the 2021 annual GSP update reports for the OPV basins (Dudek, 2022a and 2022b) show that total agricultural pumping in the OPV basins declined from approximately 73,000 AFY in 2014 to 52,000 AFY in 2021, a 29 percent decline. Total M&I and domestic pumping declined from approximately 30,000 AFY in 2014 to 26,000 AFY in 2016 (a 10 percent decline), but M&I and domestic pumping rebounded to nearly 33,000 AFY by 2021, after repeal of the Temporary Extraction Allocations.

3 GROUNDWATER SUSTAINABILITY PLANS FOR THE OPV BASINS

In September 2014, California's Sustainable Groundwater Management Act (SGMA) was signed into law, requiring formation of local Groundwater Sustainability Agencies (GSAs) and preparation of Groundwater Sustainability Plans (GSPs) for groundwater basins designated as "medium" or "high" priority by DWR. In addition, some basins were considered to be "critically overdrafted" by DWR. Both the Oxnard and Pleasant Valley basins were designated as high priority and critically overdrafted. SGMA required that GSPs for critically overdrafted basins be completed and submitted to DWR by January 30, 2020. In January 2015, the FCGMA Board adopted Resolution No. 2015-01, which elected the FCGMA to be the GSA for the OPV basins (as well as the Las Posas Valley basin). Other agencies elected to be the GSAs for four small "outlying areas" along the margins of the OPV basins outside of the FCGMA's boundaries. In 2016 and 2018, some minor changes were proposed to the boundaries of the OPV and adjacent basins by the FCGMA and Mound Basin GSA based on administrative and scientific grounds (https://sgma.water.ca.gov/basinmod/modrequest/submitted). These changes resulted in the current DWR-defined basin boundaries, as shown on Figures 1 and 2. The FCGMA's consultant, Dudek, completed GSPs for the OPV basins that were adopted by the FCGMA's Board of Directors in December 2019 and submitted to DWR in January 2020 (Dudek, 2019a and 2019b). DWR approved the GSPs for the OPV basins—with some recommended corrective actions—in November 2021 (DWR, 2021a and 2021b).

3.1 SUSTAINABILITY YIELD ESTIMATES

Under SGMA, sustainable yield is defined as follows (California AB 1739):

> *"'Sustainable yield' means the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result."*

SGMA defines "undesirable result" as follows:

> *"'Undesirable result' means one or more of the following effects caused by groundwater conditions occurring throughout the basin:*
>
> *(1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.*

(2) Significant and unreasonable reduction of groundwater storage.

(3) Significant and unreasonable seawater intrusion.

(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.

(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.

(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water."

There are notable differences between this definition and the definitions of "safe yield" or "basin yield" used previously in the OPV basins (Section 2). Most significantly, the definition of sustainable yield does not rely directly on water budget estimates or maintaining a balance between recharge and discharge of an aquifer or basin. Rather, sustainable yield is defined by each GSA's definition of "significant and unreasonable" undesirable results. However, operating a basin with a substantial excess of groundwater withdrawals relative to discharge would likely cause undesirable results that most GSAs would consider significant and unreasonable. Therefore, historical concepts of "safe yield" are still relevant to sustainable yield, albeit indirectly. It's important to note that undesirable results are possible at a local scale even if groundwater inflow and outflow in a basin are in overall "balance."

The GSP for the Oxnard Basin (Dudek, 2019b) estimated that the combined sustainable yield of the UAS and LAS in that basin is 39,000 AFY, with an uncertainty of +/-8,300 AFY, for the 50-year planning and implementation period (2020 through 2069). The GSP for the Pleasant Valley Basin (Dudek, 2019a) estimated that the combined sustainable yield of the Shallow Alluvial Aquifer and the LAS in that basin is 11,600 AFY, with an uncertainty of +/-1,200 AFY, for the same 50-year planning and implementation period. These sustainable yield estimates were based primarily on modeled estimates of seawater intrusion in the Oxnard Basin, and assumed that pumping reductions in the Oxnard basin, Pleasant Valley basin, and Western Management Area of the Las Posas Valley basin would be the primary method of mitigating seawater intrusion. In addition, several projects were incorporated in the GSPs to provide alternative sources of supply to replace a small portion of the water supply lost to the pumping reductions that were contemplated in the GSPs (Dudek, 2019a, 2019b, and 2019c). The simulated pumping reductions were forecasted to result in groundwater elevations rising above mean sea level across much of the area of the OPV basins, mitigating most concerns about chronic lowering of groundwater levels, reduction of groundwater storage, degraded groundwater quality, land subsidence, and depletions of interconnected surface water. The projected rise in groundwater levels would also result in a net seaward flow of groundwater, thereby reversing the flow of intruded seawater back toward the ocean. The seaward gradient was also forecasted to result in significant volumes of fresh groundwater discharging from aquifers, primarily in the UAS, to offshore outcrops in the Pacific Ocean.

The combined sustainable yield estimated in the GSPs for the OPV basins of 50,600 AFY (39,000 AFY for the Oxnard Basin plus 11,600 AFY for the Pleasant Valley Basin), is significantly less than prior estimates (i.e., Mann's [1959] estimate of 65,000 AFY [including Mound Basin], interpretation of the FCGMA's 1985 GMP [80,600 AFY], or interpretation of the 2007 GMP Update [73,000 AFY]). However, it should be noted that:

- The 1959 estimate by Mann and the 1985 estimate in the FCGMA's original GMP were based on basin-wide water-balance calculations rather than mitigation of specific undesirable results (e.g., seawater intrusion).
- The estimate in the FCGMA's 2007 GMP Update was developed using the USGS two-layer model, which had insufficient vertical discretization to simulate details of seawater intrusion.

Solely considering the water balances in the OPV basins, the groundwater budget summaries provided in the GSPs for the Oxnard and Pleasant Valley basins suggest that the "overdraft" (groundwater outflow exceeding inflow, or decline in groundwater in storage) in the UAS and LAS of the Oxnard Basin during the modeled historical period (1986 through 2015) was 4,400 AFY, and in Pleasant Valley Basin there was a net *increase* in groundwater in storage of 1,500 AFY over the same period. If seawater intrusion was not counted as an "inflow," then the overdraft in the Oxnard Basin would have been 13,800 AFY. DWR (2022a), in their review of the Oxnard Basin GSP, noted that the average decrease in "freshwater storage" from 1986 through 2015 in the Oxnard Basin was 12,700 AFY, which is slightly less than the 13,800 AFY value reported in the groundwater budget tables in the GSP (Dudek, 2019b).

The average groundwater extraction rate from the OPV basins during the modeled historical period (1985 through 2015) was 90,600 AFY, suggesting that total "safe yield" of the basins (considering only the groundwater balance, and not including undesirable results) would be approximately 76,800 to 78,300 AFY, depending on whether or not the net increase in storage in Pleasant Valley Basin was included. These "safe yield" values are within the range of uncertainty of the safe yield estimate of Mann (1959) and the basin yield estimate of the FCGMA and others (2007).

In conclusion, the sustainable yield estimates provided in the 2019 GSPs for the OPV basins appear to be reasonable when compared to previous estimates of "safe yield" or "basin yield", considering the changes in basin boundaries, changing definitions of "basin yield," "safe yield," and "sustainable yield," and the differences in the hydrologic conditions during the timeframes represented by each estimate.

3.2 PROJECTS INCLUDED IN THE OPV GROUNDWATER SUSTAINABILITY PLANS

The GSPs for the OPV basins identified several new or expanded water-supply projects that "were suggested by stakeholders and were reviewed by the Operations Committee of the FCGMA Board" (Dudek, 2019b and 2019a) to increase sustainable yield or provide alternative sources of water. The projects were intended "to address potential impacts to beneficial uses and users of groundwater in the (Oxnard) Subbasin resulting from groundwater production in excess of the current sustainable yield" (Dudek, 2019b).

In the Oxnard Basin, the following projects were included:

- "GREAT Program Advanced Water Purification Facility (AWPF)"—This project assumed that some or all of the 2019 capacity of the City of Oxnard's recycled water discharged from their AWPF (4,600 AFY) could be put to beneficial use and would reduce groundwater extractions an equivalent amount. This recycled water was assumed to be delivered to agricultural users in the OPV basins.
- "GREAT Program AWPF Expansion"—This project assumed a 4,500 AFY expansion of the AWPF that would result in an equivalent reduction in groundwater extractions.
- "Riverpark-Saticoy Groundwater Replenishment and Reuse Project (GRRP) Recycled Water Project"—This project assumed that the 4,500 AFY of recycled water from Oxnard's AWPF expansion (above) would be recharged at United's recharge basins in the Saticoy area of the Forebay. The City of Oxnard submitted a comment letter that objected to including this project in the Oxnard basin GSP; therefore, it is highly unlikely that this project would advance as described in the GSP.
- "Freeman Expansion Project"—This project assumed that United would expand its Freeman Diversion on the Santa Clara River to allow United to take approximately 7,400 AFY additional "peak flows" of high-silt, high-turbidity surface water than was historically possible. This additional surface water would be recharged in the Forebay area of the Oxnard basin.
- "Temporary Agricultural Land Fallowing"—This project assumed that the FCGMA would lease agricultural land for temporary fallowing, to reduce groundwater demand in the Oxnard Basin by 500 AFY. Land in areas susceptible to seawater intrusion would be targeted.

In the Pleasant Valley Basin, one new project was included:

- "Temporary Agricultural Land Fallowing"—This project assumed that the FCGMA would lease agricultural land in the Pleasant Valley Basin for temporary fallowing, to reduce groundwater demand by 2,400 AFY. Land "in areas susceptible to contributing to seawater intrusion in the adjacent Oxnard Basin" would be targeted.

The GSPs for the OPV basins also included a "Management Action" that could be implemented if new or expanded water-supply projects were not capable of achieving sustainable yield. Specifically, "Management Action No. 1" in both the Oxnard and Pleasant Valley Basin GSPs consisted of mandatory reductions in groundwater pumping. Results of the "Reduction with Projects" scenarios presented in the Oxnard and Pleasant Valley Basin GSPs (Dudek, 2019b and 2019a) indicated that if the projects described above were implemented, pumping reductions of 35 percent (relative to 2015-17 average production rates) in Oxnard Basin, 20 percent in Pleasant Valley Basin, and 20 percent in the west part of the Las Posas Valley Basin would come close to achieving sustainable yield (eliminate most, but not all, seawater intrusion in the Oxnard Basin). However, the FCGMA reiterated in February 2021 that "The GSP estimate should be considered the base estimate of sustainable yield. The GSPs clearly articulate that additional projects should be developed and implemented to increase the water supplies and sustainable yield of the basins" (FCGMA, 2021).

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4 POST-GSP DEVELOPMENT OF WATER-SUPPLY PROJECTS IN OPV BASINS

Several new or expanded water supply projects were proposed by various water agencies in 2018 and 2019 as the GSPs for the OPV basins were being prepared, but were deemed to be insufficiently developed for inclusion in the GSPs (FCGMA, 2021). By early 2022 some of these projects were considered sufficiently developed to be incorporated by the FCGMA into the 2021 annual GSP update reports for the Oxnard and Pleasant Valley basins (Dudek, 2022a and 2022b). The public process by which these new projects were developed, and a summary of the yields and benefits of each project, are summarized in this section.

4.1 PROJECTS COMMITTEE OF OPV STAKEHOLDERS

Water users in the OPV basins expressed concern about the likely economic, environmental, and social consequences from reducing groundwater extractions by 35 percent in the Oxnard Basin, and 20 percent in the Pleasant Valley and Western Management Area of the Las Posas Valley basins, unless more water supply projects were added to the GSPs. In response, an *ad hoc* Projects Committee was formed by the FCGMA from “core stakeholders” in the OPV basins in September 2020 to identify “a cost-effective portfolio of projects and optimization measures that align with the GSP objectives and respond to regional water needs,” and “recommend a cohesive strategy to bring these projects into fruition” (Consensus Building Institute [CBI], 2020a).

The Projects Committee met eight times between August and December 2020, and ultimately recommended that several projects, listed in Table 2 of this report, “move forward for further analysis.” Combined, these projects were expected to achieve sustainable yield and provide sufficient water supplies to meet current demand in the OPV basins. United used its groundwater flow and surface-water distribution models to simulate a suite of projects referred to as the “Hybrid Scenario,” because they included a seawater-intrusion barrier, optimization of pumping throughout the OPV basins, and new or expended water supplies to achieve sustainable yield (CBI, 2020b).

United began modeling the combined effects of the projects in the Hybrid Scenario in February 2021, and presented initial results to FCGMA staff, the FCGMA Operations Committee, and the FCGMA Board of Directors during a series of meetings in May 2021. United staff also presented the results to United’s Water Resources Committee and Board of Directors during meetings in June 2021, and at United’s “Water Sustainability Summit” with stakeholders and state agencies in October 2021. Key conclusions from the initial modeling completed to that point were that:

- The Hybrid Scenario would stop and ultimately reverse seawater intrusion in most areas along the coast, potentially reducing the area of existing seawater intrusion by one or more square miles.

- However, there were small areas of continued seawater intrusion forecasted in the LAS near Port Hueneme and Point Mugu that would require modification of the simulated locations for extraction wells (or possibly use of injection wells) to improve control over seawater intrusion.
- During periods of abundant rainfall, it could be difficult to make full use of recycled water under the pipeline and pumping scenarios considered, due to lack of demand.

Also during 2021, the design and implementation of United's Extraction Barrier and Brackish Water Treatment Project (EBB Water) and Freeman Expansion projects were advancing. Therefore, United continued to revise the modeling assumptions regarding timeline and yield of the projects included in the Hybrid Scenario through early 2022. Results of modeling the Hybrid Scenario will be provided in a subsequent open-file report by United.

4.2 PROJECTS ADDED TO OPV GROUNDWATER SUSTAINABILITY PLANS IN 2021 ANNUAL UPDATE REPORTS

In December 2021, DWR solicited proposals for Round 1 of its "Sustainable Groundwater Management" (SGM) grant, which offered up to $7.6 million per basin using California Proposition 68 and 2021 Budget Act funding to design and implement water-supply projects in critically overdrafted basins, including the OPV basins. One of the requirements of the SGM grants is that the proposed water-supply projects must be included in the GSPs or in annual GSP update reports. In response, the FCGMA asked stakeholders in the OPV basins to provide grant proposals for new projects that had been developed subsequent to preparation of the Oxnard and Pleasant Valley Basin GSPs. The *ad hoc* Projects Committee was reconvened by the FCGMA in January 2022 to evaluate the grant proposals submitted by proponents and rank them by order of preference for SGM grant funding. Also in January 2022, the FCGMA's Board of Directors approved adding several water-supply projects that were not included in the original Oxnard and Pleasant Valley Basin GSPs to the 2021 annual GSP update reports (Dudek, 2022a and 2022b), and updating information on yields, timing or benefits of previously proposed projects. The projects included in the 2021 annual GSP update reports that are expected to increase yield of the basins are summarized in Table 3. In addition to the water-supply projects listed in Table 3, five feasibility studies proposed by the City of Camarillo were included in the Pleasant Valley Basin Annual GSP Update report for potential new stormwater recharge projects and expansion of the North Pleasant Valley Desalter project. Anticipated timelines or additional yields of these potential projects were not provided by the City of Camarillo, thus are not included in the Hybrid Scenario at this time.

5 SEAWATER INTRUSION IN THE OPV BASINS

Seawater intrusion has long been the primary groundwater sustainability concern in the OPV basins. Past efforts to increase yield of, and limit groundwater extractions from, the OPV basins have slowed the advance of seawater intrusion. However, additional projects to improve sustainable yield and provide sources of water other than groundwater will be needed if major reductions in the total available water supply to the OPV basins are to be avoided (Dudek, 2019a and 2019b). Without new projects, the GSPs for the OPV basins indicate that groundwater withdrawals would have to be reduced by approximately 30,000 AFY to hold the seawater intrusion fronts in each aquifer at their current positions, assuming that the reductions in pumping would be applied uniformly in wells across the Oxnard, Pleasant Valley, and western Las Posas Valley basins (Dudek, 2019a, 2019b, and 2019c).

The 30,000 AFY reduction in pumping envisioned in the GSPs to achieve sustainable yield is significantly larger than the 13,000 to 14,000 AFY net imbalance between groundwater inflows and outflows in the Oxnard Basin described in Section 3 of this report. The reason for that difference is because simply achieving an overall balance between inflow to and outflow from the OPV basins will not prevent localized inland hydraulic gradients from persisting along the coastline. Local hydraulic gradients can still draw seawater into the aquifers toward wells inland from the Mugu and Hueneme submarine canyons, unless there is a barrier to seawater intrusion. If seawater intrusion is mitigated with a barrier, then the primary driver for sustainable yield will become eliminating the 13,000 to 14,000 AFY long-term-average deficit between groundwater inflows and outflows in the Oxnard Basin, as noted above.

Despite the chronic challenges in achieving safe or sustainable yield described in previous sections of this report, the efforts by agencies and stakeholders over the past seven decades (1950s to present) have helped to limit seawater intrusion to a significant degree compared to the SWRCB (1979) forecasts. Figure 3 shows the SWRCB's 1979 projections for advancement of the seawater intrusion front, which was forecasted to reach to within ½ mile of U.S. Highway 101 near Camarillo by year 2000 (moving northward approximately 4 miles from Hueneme Road over a period of 20 years). Fortunately, as described below, seawater intrusion has largely been held to the area south of Hueneme Road and Port Hueneme since 1979, with some minor advances and retreats that vary by location and time.

The USGS was one of the first agencies to map the extent of saline intrusion (including both seawater intrusion and migration of brines out of fine-grained sediments) back to the 1950s (Izbicki, 1996). Figure 4 shows the USGS estimates of the extent of saline intrusion in the UAS from 1955 through 1989 (significant saline intrusion had not been detected in the LAS as of 1989, due in part to limited monitoring wells in the LAS before the early 1990s). These maps show two "plumes" of saline groundwater in the Oxnard Basin, expanding inland from the heads of the Mugu and Hueneme submarine canyons from 1955 until 1975. From 1975 to 1989, the USGS maps don't show substantial additional northward migration of saline groundwater in the UAS—rather, the plumes appear to merge together in the southern Oxnard basin. One reason that the saline intrusion front didn't advance northward significantly during this period was construction of the Freeman Diversion (1990) and the PTP system in 1987. These projects allowed for more surface water delivery in the OPV basins to be used *in lieu* of pumping groundwater, and successfully mitigated the persistent UAS pumping depression located east of the City of Oxnard that was drawing saline water inland. As noted in the 2007 GMP Update (FCGMA and others, 2007):

> *"One of the most effective management strategies in reducing overdraft is to supply water directly to overdrafted areas. This in-lieu strategy has been very effective in the Upper Aquifer System, where Santa Clara River water delivered through the Pumping Trough Pipeline has helped to alleviate the pumping trough that has been present for several decades beneath the south Oxnard Plain."*

It was recognized in the late 1980s and early 1990s that construction of new aquifer-specific monitoring wells and development of a method to delineate seawater intrusion from other sources of brine that contributed to salinity of groundwater would help improve understanding of the extents and rates of seawater intrusion. New clusters of aquifer-specific monitoring wells were constructed in the southern Oxnard Basin in the early 1990s, and the USGS relied upon analysis of minor and trace elements (most importantly bromide) to help determine the sources of elevated chloride concentrations detected in groundwater in the area.

Approximately a decade later, the FCGMA and United worked together to improve and update the USGS mapping of seawater intrusion in the OPV basins. In the 2007 GMP Update, the "progression of seawater intrusion beneath the south Oxnard Plain" was mapped using available data in 5-year intervals in the UAS from 1920-24 through 1995-99, and in the LAS from 1940-44 through 1995-99. The 2007 GMP Update also included maps of seawater intrusion in the UAS and LAS prepared by United for water year 2005-06.

The maps in the 2007 GMP Update show the first appearance of a plume (a contiguous area of elevated concentrations detected at multiple monitoring locations) of seawater intrusion in the UAS in 1950-54, and the first appearance of a plume of seawater intrusion in the LAS in 1990-94. It should be noted that salinity data near the coast were sparse prior to 1980; therefore, some seawater intrusion may have been present in the aquifers of the Oxnard Basin prior to when it first appeared in wells and was depicted on maps. The maps from the 2007 GMP Update that show plumes of seawater intrusion are included in Appendix A of this report. Review of these maps indicates that seawater intrusion in the UAS did not advance a significant distance northward during the mid-1970s through the 1990s, although in the Oxnard Aquifer the lateral merging of the Hueneme and Mugu plumes is apparent. Northward expansion of the area of seawater intrusion between the 1995-99 and 2005-06 maps (Figures 44 and 14 in Appendix A) is apparent, but limited in extent. The depictions of seawater intrusion in the LAS do not suggest significant expansion of the Hueneme and Mugu plumes from 1990-94 to 2005-06 (Figures 55 and 15 in Appendix A).

United has periodically prepared maps of saline intrusion within each aquifer system (UAS and LAS) or aquifer (Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon Aquifers) since 1994. Appendix A includes United's saline intrusion maps for 2003, 2015, and 2020 as representative examples of the changing extents and interpretations of chloride-impacted groundwater underlying the OPV basins during the past 20 years. The United maps shown in Appendix A were prepared using available data at the time, including a surface-geophysical (time-domain electromagnetic, or TDEM) survey conducted in 2010. United's maps show limited northward advancement of the seawater intrusion front in some aquifers, particularly at the southeastern margin of the basin near NBVC Point Mugu, but the plumes in this area do not appear to have advanced north of Hueneme Road except near Port Hueneme, where saline intrusion in the UAS has been consistently mapped slightly north of Hueneme Road since the late 1950s.

In 2022, United used its new MODFLOW-USG groundwater flow and transport model (United, 2021a) of the Oxnard coastal plain to estimate the location of the seawater-intrusion front in each aquifer of the Oxnard Basin from 1985 through 2019 (the model calibration period). Figures 5 through 9 show the 2019 modeled chloride concentrations in the Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon Aquifers. The 100 milligram per liter (mg/L) chloride contour is used to represent the seawater intrusion front in each aquifer. The 2019 chloride concentration maps developed using the calibrated MODFLOW-USG Transport model have a significant advantage compared to chloride concentration maps prepared solely from available data in each aquifer: that is, where data are limited by a paucity of monitoring points, the positions of the seawater intrusion fronts are estimated based on physical processes occurring in each aquifer, rather than simple interpolation between, or extrapolation beyond, known data points.

Comparison of the modeled 2019 seawater intrusion fronts (Figures 5 through 9) to United's 2020 estimates for seawater intrusion fronts that were based solely on available chloride data (Appendix A) shows that the two methods provide generally similar results, except for the area immediately south from the intersection of Hueneme Road and Rice Avenue. In this area, the modeled seawater intrusion front include previously unrecognized lobes of elevated chloride concentrations (100 to 500 mg/L) in the Mugu, Hueneme, and Fox Canyon Aquifers (Figures 6 through 8). Review of MODFLOW-USG transport model results indicates that if these lobes do indeed exist, they are a result of downward hydraulic gradients and thinning of confining units between aquifers that allow downward migration of saline groundwater from the Oxnard Aquifer to deeper aquifers. United is currently developing plans to construct additional monitoring wells in this area to confirm the model results. United currently samples and monitor water levels in about 70 monitoring wells in coastal areas of the Oxnard basin (United, 2021b). However, these wells are located at only 15 distinct locations, as many of the wells are collocated as nested wells in a single borehole. It should be noted that these lobes do not necessarily represent rapid "expansion" in recent years of the seawater intrusion front; rather, the lobes may represent previously unrecognized (due to a lack of monitoring in the immediate vicinity) areas of elevated chloride concentrations. Persistent downward vertical gradients between the UAS and the LAS in recent decades have likely limited the inland movement of seawater intrusion in the Oxnard aquifer, and impacts are being realized in deeper aquifers in certain areas (United, 2021b).

6 SUMMARY AND CONCLUSIONS

Residents, stakeholders, and public agencies have been concerned about potential overdraft (groundwater discharge, especially pumping, in excess of recharge) in the OPV and adjacent basins for nearly 100 years, since the 1920s. Investigations of "safe" or "basin" yield in the 1950s (Mann, 1959), 1980s (VCPWA, 1985), and 2000s (FCGMA and others, 2007) each concluded that, indeed, groundwater discharge (chiefly extractions) in the OPV basins exceeds recharge. The most significant effect of this imbalance between discharge and recharge on groundwater conditions has been seawater intrusion in the Oxnard basin, which has advanced farthest and fastest in the Oxnard Aquifer. However, mitigating seawater intrusion would not—by itself—result in achieving sustainable yield in the OPV basins. The decades-old challenge of regional overdraft will also need to finally be resolved. If seawater intrusion was stopped in the OPV basins without addressing the imbalance between pumping and recharge, new sustainability challenges would develop, initially including excessive drawdown and reductions in groundwater storage, potentially followed by groundwater-quality degradation and land subsidence. Therefore, projects or management actions that bring groundwater discharge and recharge into overall balance in the OPV basins must accompany seawater-intrusion mitigation actions. The largest source of recharge to the OPV basins, by far, is surface water diverted from the Santa Clara River by United and artificially recharged in the Saticoy and El Rio spreading grounds (Figure 2), comprising 45,000 AFY of recharge, on average, since Freeman Diversion was constructed in 1990, with another 13,000 AFY of surface-water deliveries from the Santa Clara River to agricultural users in the OPV basins in lieu of pumping over that same timeframe. This source of local water supply has lower total dissolved solids and nitrate than much of the naturally occurring groundwater in the region, and requires very little energy (and associated greenhouse gas emissions) compared to most of the other existing and proposed new sources.

The largest and most effective water-supply and conjunctive-use projects in the history of the OPV basins were constructed following the safe-yield investigations of the 1950s and 1980s, which coincided with periods of drought. In contrast, the 2007 GMP update (FCGMA and others, 2007) followed the wettest decade in Ventura County history, and although it included a number of recommended new water-supply and conjunctive-use projects, subsequent progress on those projects has been slow.

The water-supply and conjunctive-use projects built following the 1950s and 1980s safe-yield investigations were largely successful at increasing recharge in the basin and decreasing pumping in the areas of large groundwater-level depressions in the eastern Oxnard basin (PTP area) and western Pleasant Valley basin (PVP area). As a result, additional northward expansion of the seawater intrusion fronts in the UAS and LAS has been limited, although lateral migration from Port Hueneme southeastward along the coastline toward NBVC Point Mugu has continued. The seawater intrusion fronts in most aquifers have not advanced north of Hueneme Road except near Port Hueneme, where saline intrusion in the UAS has been consistently mapped slightly north of Hueneme Road since the late 1950s. However, increased reliance on groundwater production from the aquifers of the LAS has resulted in increased flow of both fresh and saline groundwater from the Oxnard Aquifer down to deeper aquifers. Given the current inland extent of seawater intrusion, even if groundwater extractions in the OPV basins were reduced or recharge volumes were increased, such that overall balance between recharge and discharge in the basins were achieved (eliminating overdraft at the basin scale), it is likely that local hydraulic gradients would continue to induce some continued inland advancement of the seawater intrusion front at certain locations and depths. At other locations and depths, intruded seawater (together with some fresh water) would likely migrate back into the Pacific Ocean, consistent with basin-wide average groundwater recharge being in balance with discharges. One noteworthy example of such a condition is the "Reduction with Projects" scenario that is included in the GSPs for the OPV basins (Dudek, 2019a and 2019b). Under this GSP scenario, groundwater elevations are forecasted to rise substantially in most areas of the basin, as a result of long-term average recharge exceeding discharge. In addition, groundwater discharge from the UAS to the Pacific Ocean is expected to increase along the coastline of the Oxnard basin. However, seawater intrusion is forecasted to continue in the LAS, with the seawater intrusion front forecasted to advance farther inland in the Hueneme and Fox Canyon Aquifers near Port Hueneme and NBVC Point Mugu, respectively. Therefore, bringing recharge and discharges in the OPV basins into overall balance (ending decades of overdraft) is not necessarily sufficient, by itself, to halt seawater intrusion at a local scale.

In response to SGMA, the FCGMA had GSPs prepared for the OPV basins and submitted them to DWR in January 2020 (Dudek, 2019a and 2019b). The GSPs concluded that the combined sustainable yield of the OPV basins is 50,600 AFY, assuming a limited number of new water-supply projects are constructed and pumping distribution (i.e., depths and locations of wells) in the basins remains constant. This sustainable yield estimate is based on pumping rates required to avoid "significant and unreasonable effects" on groundwater conditions (primarily seawater intrusion), rather than simply achieving overall balance between discharge and recharge of groundwater. Therefore, it is not surprising that this value is lower than past estimates of "safe" or "basin" yield. The sustainable yield estimates provided in the 2019 GSPs for the OPV basins appear to be reasonable when compared to previous estimates of "safe yield" or "basin yield," considering the shifts in basin boundaries, changing definitions of "basin yield," "safe yield," and "sustainable yield," and the differences in climatic conditions during the timeframes represented by each estimate.

Water users in the OPV basins expressed concern about the consequences of reducing available groundwater supplies by up to 35 percent to achieve sustainable yield. An *ad hoc* Projects Committee formed by the FCGMA from stakeholders in the OPV basins was convened in summer 2020 to develop additional projects that could be included in a future GSP update, with the goal of achieving sustainable yield without pumping reductions in the OPV basins. In January 2022, the FCGMA's Board of Directors approved adding several new water-supply projects to the 2021 annual update reports for the Oxnard and Pleasant Valley basin GSPs (Dudek, 2022a and 2022b). Modeling conducted by United of a "Hybrid Scenario," which included many of the proposed new projects, demonstrated that the projects would stop and ultimately reverse seawater intrusion in most areas along the coast, while increasing sustainable yield and new water supplies sufficiently to allow water use in the OPV basins to continue at current rates throughout the 50-year GSP planning horizon. Results of modeling the Hybrid Scenario have been presented at several FCGMA and United board and committee meetings, and will be the subject of a subsequent open-file report by United.

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REFERENCES

Consensus Building Institute, 2020a, Projects Committee Charge, v. 12/14/20. December.

Consensus Building Institute, 2020b, OPV Projects Committee Recommendations. December.

Dudek, 2019a, Groundwater Sustainability Plan for the Pleasant Valley Basin. December.

Dudek, 2019b, Groundwater Sustainability Plan for the Oxnard Subbasin. December.

Dudek, 2019c, Groundwater Sustainability Plan for the Las Posas Valley Basin. December.

Dudek, 2022a, Oxnard Subbasin Groundwater Sustainability Plan 2022 Annual Report: Covering Water Year 2021. January.

Dudek, 2022b, Pleasant Valley Basin Groundwater Sustainability Plan 2022 Annual Report: Covering Water Year 2021. January.

DWR (California Department of Water Resources), 2021a, Groundwater Sustainability Plan Assessment Staff Report for Oxnard Subbasin (attachment to letter from Paul Gosselin, Deputy Director for Sustainable Groundwater Management, to Kimball Loeb, FCGMA, dated November 18, 2021). November.

DWR, 2021b, Groundwater Sustainability Plan Assessment Staff Report for Pleasant Valley Basin (attachment to letter from Paul Gosselin, Deputy Director for Sustainable Groundwater Management, to Kimball Loeb, FCGMA, dated November 18, 2021). November.

Edmonston, A.D., 1956, State Water Resources Board Bulletin No. 12, Ventura County Investigation. Original prepared 1953, revised in October 1956.

Fox Canyon Groundwater Management Agency, United Water Conservation District, and Calleguas Municipal Water District, 2007. 2007 Update to the Fox Canyon Groundwater Management Agency Groundwater Management Plan. May.

Fox Canyon Groundwater Management Agency, 2021. Memorandum to OPV Stakeholder Group—Sustainable Yield of the Oxnard and Pleasant Valley Basins. February.

Hanson, R.T., Martin, P. and Koczot, K.M., 2003, Simulation of Groundwater-Water/Surface-Water Flow in the Santa Clara-Calleguas Ground-Water Basin, Ventura Country, California, U.S. Geological Survey, Water-Resources Investigation Report 02-4136.

Hasan, A.A., Kleinecke, D.C., Johanson, S.J., and Pierchala, C.E., 1974, Mathematical Modeling of Water Quality for Water Resources Management, Volume 1: Development of the Ground Water Quality Model, California Department of Water Resources, Southern District, District Report. August.

Izbicki, J.A., 1996, Seawater Intrusion in a Coastal California Aquifer. U.S. Geological Survey Fact Sheet 125-96. July.

John F. Mann Jr. and Associates, 1959, A Plan for Groundwater Management—United Water Conservation District.

Mukae, M. and Turner, J.M., 1975, Ventura County Water Resources Management Study-Geologic Formations, Structures and History in the Santa Clara Calleguas Area. January.

Perliter & Soring, Consulting Engineers, 1960, City of Oxnard Supplemental Water Supply. October.

Prickett, T.A. and Lonnquist, C.G., 1971, Selected Digital Computer Techniques for Groundwater Resource Evaluation. State Water Survey Division, 55, 8-61.

Reichard, E.G., Crawford, S.M., Paybins, K.S., Martin, P., Land, M., and Nishikawa, T., 1998, Evaluation of Surface-Water/Ground-Water Interactions in the Santa Clara River Valley, Ventura County, California: U.S. Geological Survey Water-Resources Investigations Report 98-4208, Prepared in Cooperation with United Water Conservation District.

State Water Resources Control Board Division of Water Rights, 1979, Oxnard Plain Groundwater Study–Water Code Section 2100.

United Water Conservation District, 2017, Preliminary Evaluation of Impacts of Potential Groundwater Sustainability Indicators on Future Groundwater Extraction Rates – Oxnard Plain and Pleasant Valley Groundwater Basins, United Water Conservation District Open-File Report 2017-02. April.

United Water Conservation District, 2021a. Technical Memorandum 2021-05—Extraction Barrier and Brackish Water Treatment Project Feasibility Study: Groundwater Modeling. December.

United Water Conservation District, 2021b. Open-File Report 2021-03—Saline Intrusion and 2020 Groundwater Conditions Update, Oxnard and Pleasant Valley Basins. November.

Ventura County Public Works Agency (Flood Control and Water Resources Department), 1985, Fox Canyon Groundwater Management Agency Planning Study, Task 86-3, Groundwater Management Plan for the Fox Canyon Groundwater Management Agency, dated September 1985.

TABLES

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Table 1. Summary of Selected Management Strategies Included in FCGMA's 2007 Groundwater Management Plan (GMP) Update that Remain Relevant Today

Selected 2007 Groundwater Management Plan Update Strategy	Relevance to Current Groundwater Sustainability Plans	Status/Progress
"5-Year Strategies" (assumed implementation by 2012):		
Shift some pumping from the LAS back to the UAS	The Oxnard Basin GSP noted that the sustainable yield of the LAS was much smaller than sustainable yield of the UAS—shifting some pumping of the current pumping from the LAS to the UAS may improve overall basin sustainable yield.	The optimization modeling described in this report includes shifting PTP pumping by United from the LAS to the UAS.
Protect current sources of recharge, specifically the Santa Clara River and Calleguas Creek	Diversions from these two streams provide a large portion of recharge of surface water to the OPV basins, at relatively low cost and greenhouse-gas emissions.	United is developing an MSHCP and developing an improved fish passage at Freeman Diversion to protect its right to divert surface water for artificial recharge and *in lieu* conjunctive use projects.
Shift pumping northward (away from the coast, to the Forebay area)	Pumping near the coast can exacerbate conditions that promote seawater intrusion, lowering sustainable yield.	The optimization modeling described in this report includes evaluation of benefits of shifting some pumping away from the coast, to the Forebay area.
Use FCGMA penalty charges to purchase replacement water (i.e., SWP imports)	Importing more SWP water can provide more recharge or reduce pumping in the OPV basins.	In 2019, the FCGMA used some of its penalty charges to purchase 15,000 AF of SWP Article 21 water at low cost, which was directed to United's facilities in the Forebay, resulting in a sharp rise in groundwater levels and improvements in groundwater quality
Conserve water and make full use of available recycled water	Conservation and use of recycled water (for agriculture) can reduce groundwater pumping.	Total water use declined approximately 14 percent in the OPV basins from 2011 through 2020. Oxnard has delivered modest amounts of recycled AWPF water for agricultural use since 2015, but with the completion of the Hueneme Rd. pipeline should be able to produce much more. Both United and PVCWD are working with State agencies to permit the PTP and PVP systems for addition of recycled water.
"10-Year Strategies" (assumed implementation by 2017):		
Extend/expand "in-lieu recharge" (conjunctive use) in the southern Oxnard Coastal Plain	The 2007 GMP Update states that "One of the most effective management strategies in reducing overdraft is to supply water directly to overdrafted areas," specifically citing the PTP for its effectiveness.	The optimization modeling described in this report includes evaluation of benefits of increasing surface-water deliveries for conjunctive use through the PTP and PVP systems.

Selected 2007 Groundwater Management Plan Update Strategy	Relevance to Current Groundwater Sustainability Plans	Status/Progress
Import additional SWP water	Additional SWP water can be used to increase recharge or replace pumped groundwater as a source of water supply, especially for M&I use.	United imported an additional 25,000 AF of SWP water (beyond its normal SWP Table A allocation) to the OPV basins from 2019 through 2021. The City of Ventura is expected to complete construction of its SWP Interconnect Pipeline by 2025, allowing it to import additional SWP water.
"15-Year Strategies" (assumed implementation by 2022):		
Barrier wells in southern Oxnard Coastal Plain to protect against seawater intrusion	Seawater intrusion is the primary driver for potential pumping reductions described in the GSPs for the OPV basins. Building a barrier to seawater intrusion, or even better—reversing seawater intrusion, could significantly increase sustainable yield of the OPV basins.	The optimization modeling described in this report includes evaluation of benefits of building an extraction barrier to halt and reverse seawater intrusion. United and the US Navy have made significant progress in designing an extraction barrier and brackish-water treatment system, and are currently selecting specific sites for wells, pipelines, and a treatment plant. United's consultant has completed a preliminary evaluation of potential pipeline alignments for distribution of treated brackish groundwater to maximize sustainability and other benefits.
Increase diversions from the Santa Clara River at Freeman Diversion	Freeman Diversion could potentially divert more high flows from the Santa Clara River, which could be recharged or delivered for conjunctive use to the PTP or PVP systems, at relatively low cost and greenhouse-gas emissions.	United is in various stages of design or construction to eliminate "bottlenecks" in its recharge and conveyance structures. Construction is expected to be completed of the first phase of Freeman Expansion by 2025. A second phase of Freeman Expansion, further increasing diversion capacity, is currently in design and anticipated to be completed by 2036.
"Greater than 15-Year Strategies" (assumed implementation after 2022):		
Additional reductions in pumping allocations	Major reductions of pumping in the OPV basins were shown by modeling presented in the GSPs for the OPV basins to limit seawater intrusion and other undesirable results related to groundwater sustainability.	The FCGMA has passed an allocation ordinance for groundwater (including in lieu deliveries of surface water) for the OPV basins, and indicated that the ordinance would be amended to include rampdown of pumping to achieve sustainable yield if sufficient additional water supplies are not developed through new projects.

Table 2. Water Supply Projects Recommended by Projects Committee of OPV Stakeholders for Further Evaluation Using United's Groundwater Flow Model

Project Name (and Proponent)	Estimated Yield when Proposed in December 2020 (AFY)	Notes
Recycled Water to Farms (City of Oxnard)	4,600	Consistent with "GREAT Program Advanced Water Purification Facility (AWPF)" project identified in Oxnard Basin GSP (more detail is provided in Section 2.2 of this report).
Incentivized Fallowing (FCGMA)	2,700	Consistent with "Temporary Agricultural Land Fallowing" project identified in GSPs for OPV basins (more detail is provided in Section 2.2 of this report).
SWP Interconnect Flushing (United and Ventura Water)	Up to 500	A new project that was not included in the GSPs for the OPV basins. The project consists of artificial recharge by United of imported water flushed or occasionally purchased from the City of Ventura's planned SWP Interconnect pipeline.
Freeman Diversion Expansion Phase 1 (United)	4,000	The first phase of an updated version of the "Freeman Expansion Project" identified in the Oxnard Basin GSP (more detail is provided in Section 2.2 of this report).
Freeman Diversion Expansion Phase 2 (United)	4,000	The second phase of an updated version of the "Freeman Expansion Project" identified in the Oxnard Basin GSP (more detail is provided in Section 2.2 of this report).
SWP Article 21 Purchases, Exchanges, and Transfers (United)	6,000	A new project that was not included in the GSPs for the OPV basins. The project consists of United purchasing Article 21 water from the SWP (when available),or making transfer and exchange agreements with other SWP contractors, with the goal of increasing the volume of imported water conveyed down the Santa Clara River and diverted at Freeman Diversion for artificial recharge or delivery as surface water via pipeline to users.
Optimization of Pumping, Phase 1 (United)	4,000	The first phase of a new project that was not included in the GSPs for the OPV basins. The project consists of reducing pumping near the coast by providing alternative sources (recycled water or expanded surface-water deliveries via pipeline) to reduce the rate of seawater intrusion, thereby increasing sustainable yield.
Optimization of Pumping, Phase 2 (United)	1,000	The second phase of a new project that had not been proposed in the GSPs for the OPV basins. The project consists of expanding groundwater withdrawals in the Forebay when groundwater levels there are relatively high, and delivering that groundwater to the PTP and PVP areas to reduce pumping from the LAS in those areas. This project also includes shifting PTP pumping from the LAS to the UAS. By shifting pumping to the Forebay and the UAS, this project has the potential to increase sustainable yield of the OPV basins by 1,000 AFY or more without reducing total groundwater use an equivalent amount.

Project Name (and Proponent)	Estimated Yield when Proposed in December 2020 (AFY)	Notes
Extraction Barrier and Brackish (EBB) Water Treatment, Phase 1 (United)	12,000 to 16,000	A new project that was proposed by United in 2018 for inclusion in the GSPs for the OPV basins, but was not sufficiently developed at that time for acceptance by the FCGMA. This project would increase sustainable yield of the basins by use of extraction wells to intercept and remove seawater from aquifers near NBVC Point Mugu (seawater intrusion is the primary sustainability criteria driving the sustainable yields estimated for the OPV and Las Posas Valley basins in their GSPs). This project would also provide a new source of fresh water for the basins via treatment of the extracted brackish water.
Reduce Pumping (FCGMA)	Not applicable	Would be implemented if the above projects were insufficient to achieve sustainable yield (prevent "undesirable results" in the OPV basins).

Table 3. Selected Water-Supply Projects Added by FCGMA to the 2021 Annual GSP Update Reports for the Oxnard and Pleasant Valley Basins

Project Name (and Proponent)	Additional Yield (AFY)	Description
Oxnard Basin:		
AWPF Phase II (City of Oxnard)	2,400	Expand recycled-water production capacity to 7,000 AFY (from 4,600 AFY existing capacity), to be used to "support the regional water management actions to increase the sustainable yield of the Subbasin" (Oxnard Basin).
EBB Water (United)	12,000	Construct extraction wells to intercept and remove brackish groundwater along the coast resulting from seawater intrusion, and construct a brackish-water treatment plant to produce fresh water from the extracted brackish groundwater. The sustainable yield increase resulting from produced fresh water and interception of seawater intrusion is anticipated to be approximately 15,000 AFY combined for the Oxnard and Pleasant Valley basins.
Freeman Diversion Expansion (United)	8,000	Construct facilities capable of diverting surface water at higher flow rates and with higher sediment loads than currently possible. Total anticipated yield increase is approximately 10,000 AFY combined for the Oxnard and Pleasant Valley basins in two phases.
Ferro Rose Artificial Recharge (United)	2,000 to 3,000	A component of the Freeman Diversion Expansion project, formerly referred to as "Freeman Expansion Phase 1." The 2,000 to 3,000 AFY yield improvement of this project constitutes a portion of the total yield of the Freeman Diversion Expansion project described above.
Laguna Road Recycled Water Pipeline Interconnection (United)	1,500	A new pipeline interconnection between United's PTP system and PVCWD's distribution system, to enable use of recycled water from a variety of sources within the PTP system.
Nauman Road Recycled Water Pipeline Interconnection (United)	1,500 (alternative to Laguna Rd. project described above, not an additional 1,500)	A new pipeline interconnection between United's PTP system and Oxnard's Hueneme Road recycled-water pipeline, to enable use of recycled water from Oxnard's AWPF within the PTP system. This project is currently envisioned as an alternative to the Laguna Road pipeline, and would not necessarily result in additional yield to the basin if the Laguna Road pipeline were also built.
Purchase of Supplemental SWP Water (United)	6,000 (long-term average; highly variable from year to year)	United, with financial support of stakeholders, would purchase supplemental SWP water (in addition to United's existing Table A allocation) for artificial recharge in the Oxnard Basin or delivered to users on the PTP and PVCWD systems.
Seawater Intrusion Injection Barrier (FCGMA)	To be determined	Potentially design and construct an injection barrier near Port Hueneme to prevent further inland intrusion of seawater in that area, potentially as a companion project to United's EBB Water project. No estimate of potential yield or sources of water to be injected was provided by FCGMA.
Pleasant Valley Basin:		
Private Reservoir Program (PVCWD)	500 to 1,000	Incentivize the use of existing--and construction of new--privately owned and operated reservoirs for capture of surface water during rain events.

Project Name (and Proponent)	Additional Yield (AFY)	Description
Recycled Water Connection Pipeline (PVCWD)	1,000 to 2,000	Connect the east and west zones of PVCWD’s distribution system to allow more effective distribution of recycled water from the City of Oxnard’s AWPF and surface water from the Conejo Creek. This project would also connect the PVCWD distribution system to United’s PTP system.
EBB Water (United)	3,000	Same as described above for Oxnard Basin; included in Pleasant Valley Basin GSP to reflect that this project will benefit both basins.
Freeman Diversion Expansion (United)	2,000	Same as described above for Oxnard Basin; included in Pleasant Valley Basin GSP to reflect that this project will benefit both basins.
Laguna Road Recycled Water Pipeline Interconnection (United)	To be determined	Same as described above for Oxnard Basin; included in Pleasant Valley Basin GSP to reflect that this project will benefit both basins.
Purchase of Supplemental SWP Water (United)	To be determined	Same as described above for Oxnard Basin; included in Pleasant Valley Basin GSP to reflect that this project will benefit both basins.
Indoor Grow Facility RO Brine Recovery (Houweling Nursery)	320	Use new technology to recover 99 percent of reverse-osmosis (RO) effluent used in a hydroponic plant nursery. This project is anticipated to reduce groundwater extractions in the Pleasant Valley Basin by approximately 320 AFY

FIGURES

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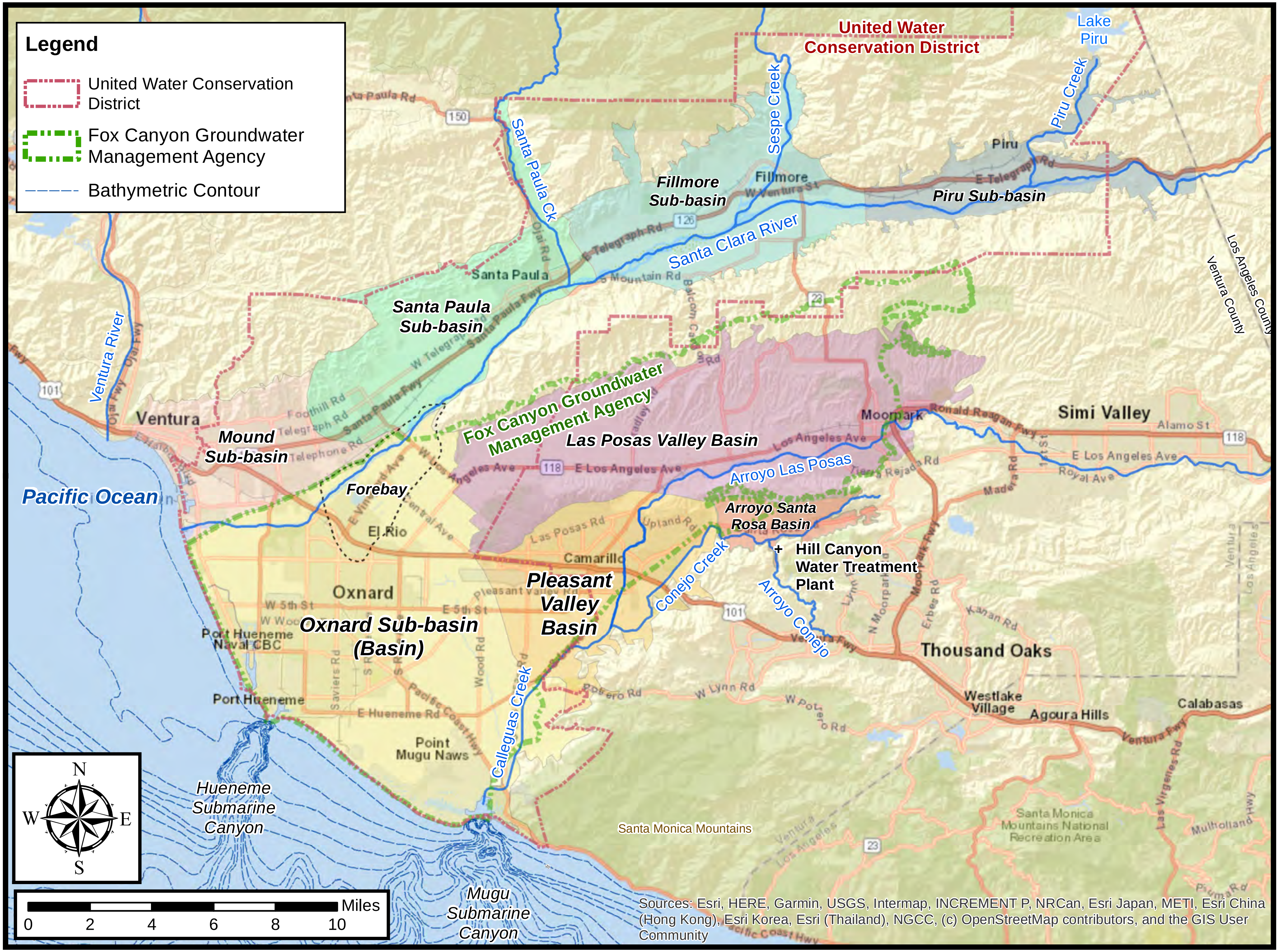

Figure 1. Regional Map of Hydrologic Features and Groundwater Basins

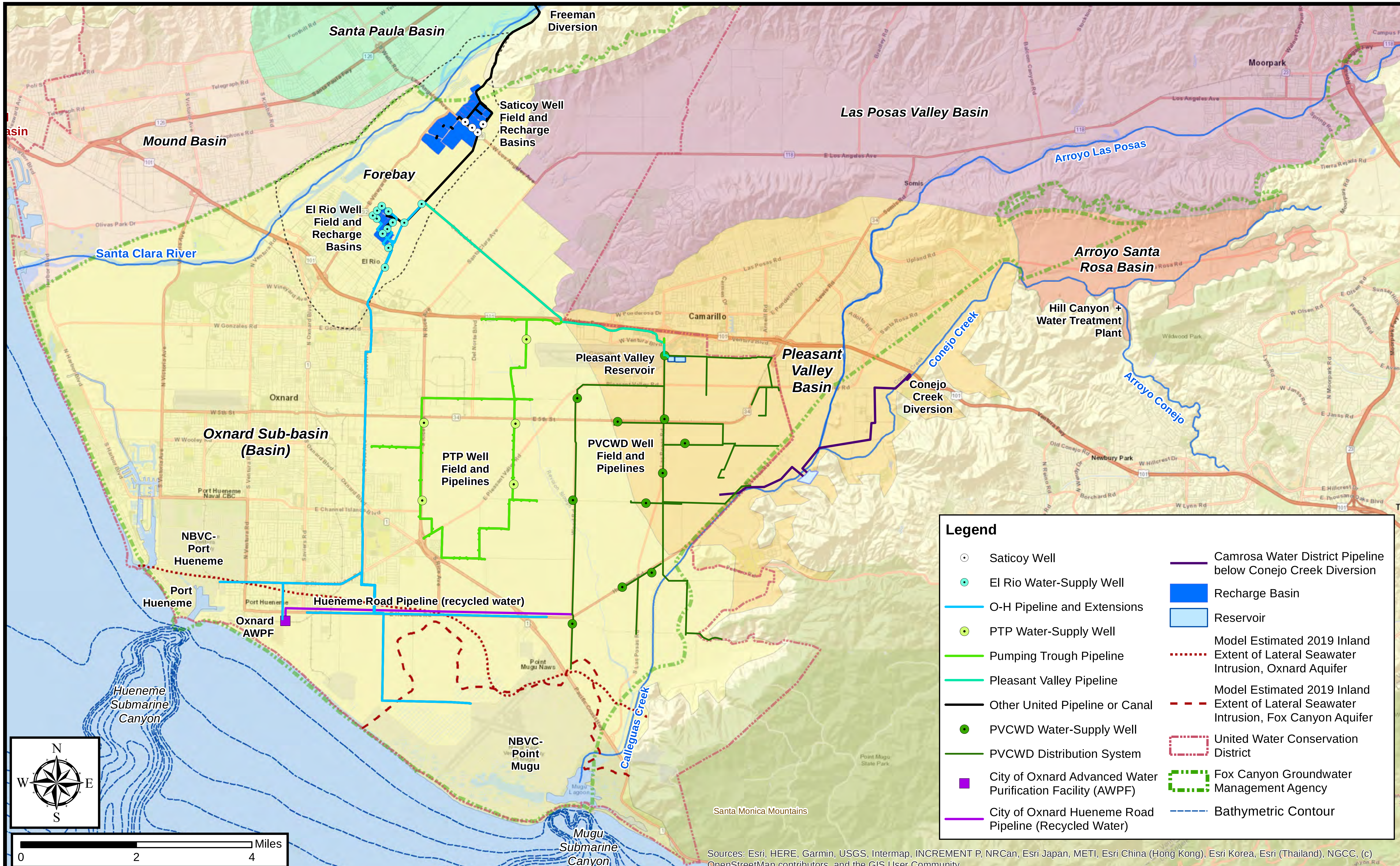

Figure 2. Map of Key Artificial Recharge, Conjunctive Use, and Recycled Water Infrastructure in OPV Basins

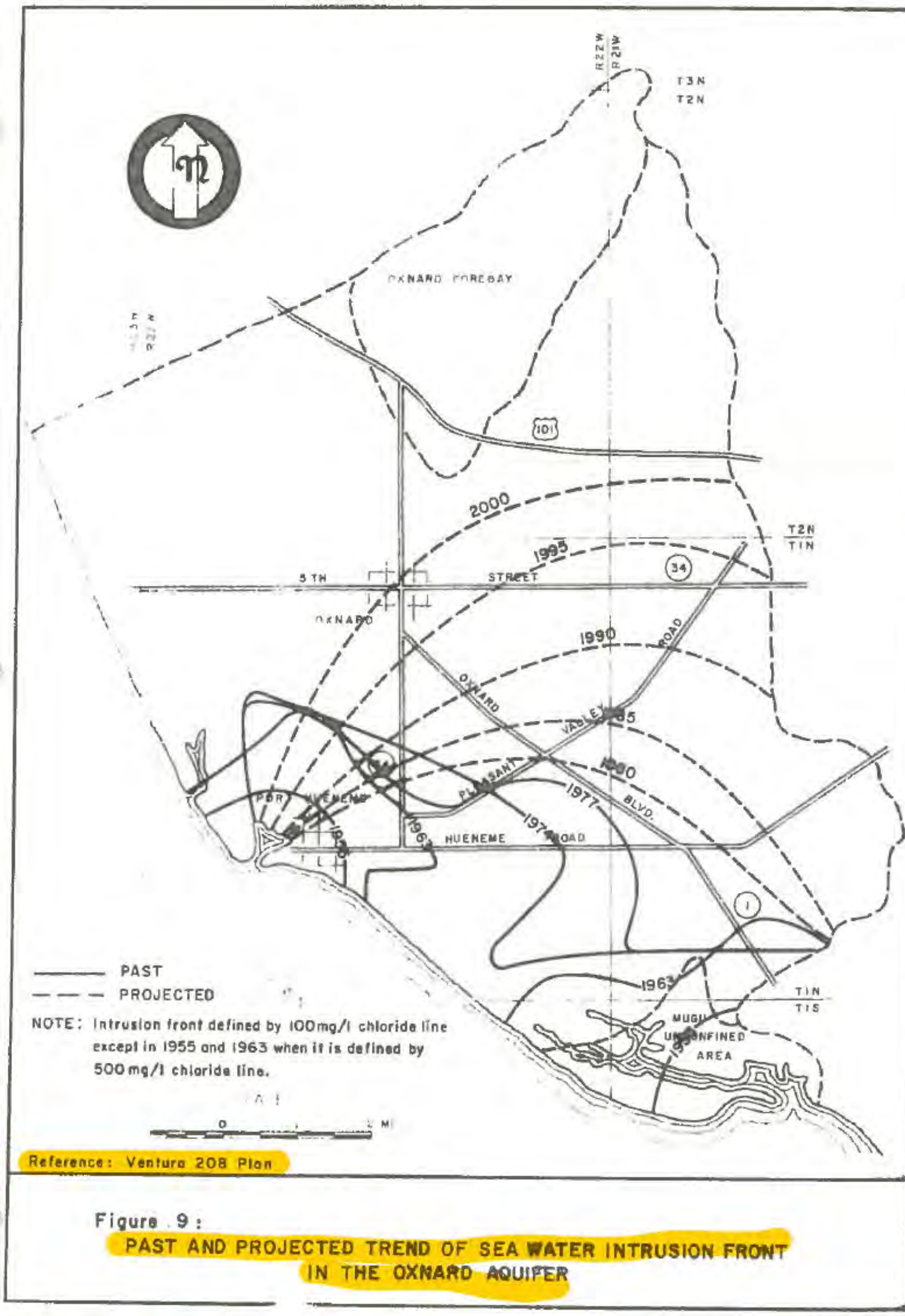

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Figure 3. Projected Advance of Seawater Intrusion Front from 1980 through 2000 Presented by the State Water Resources Control Board in 1979

(copied from SWRCB, 1979)

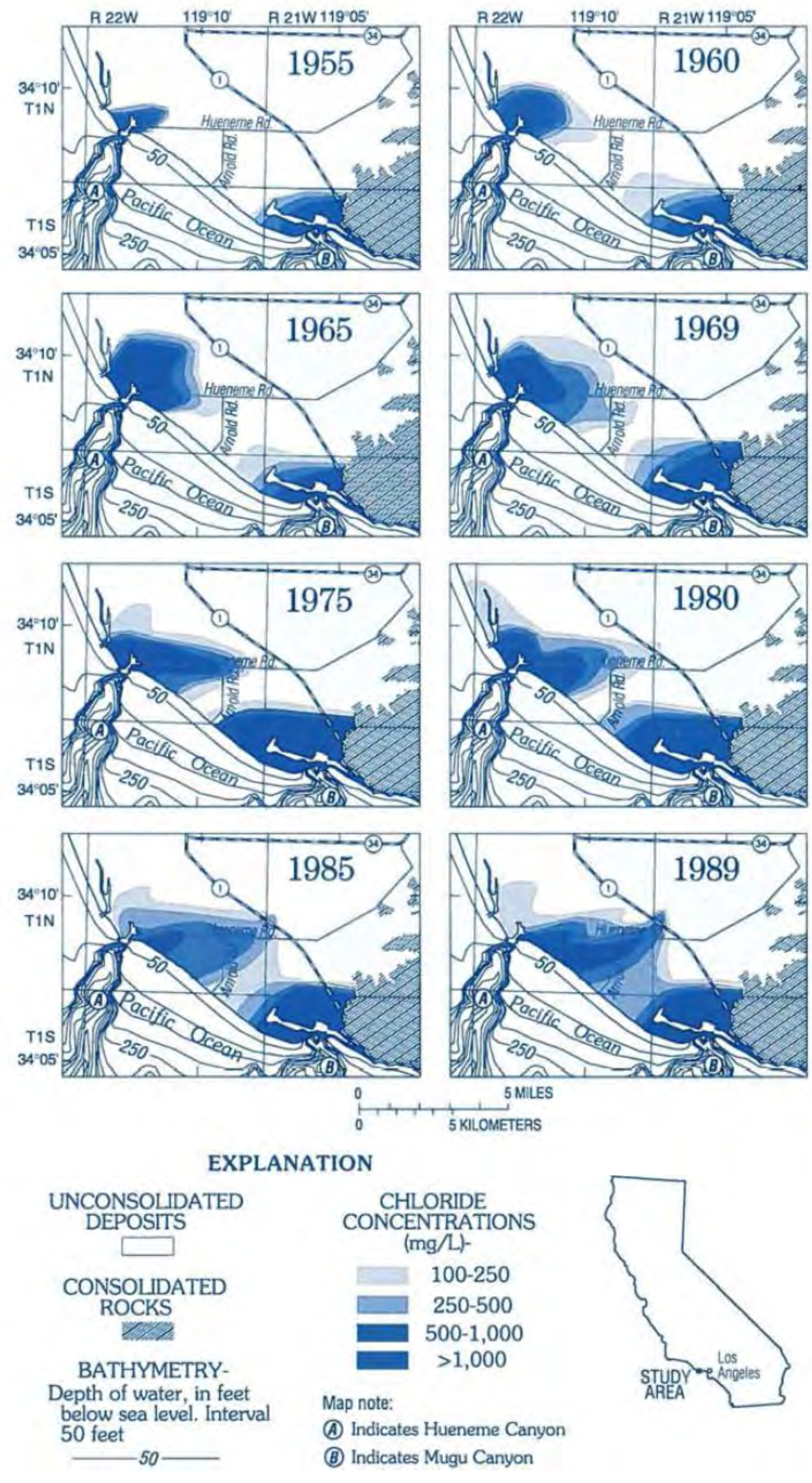

Figure 4. Chloride Concentrations in Groundwater Samples from Wells Screened in the Upper Aquifer System in the Oxnard Basin, 1955-1989

(copied from Izbicki, 1996; data reportedly from California Department of Water Resources and County of Ventura Public Works Agency)

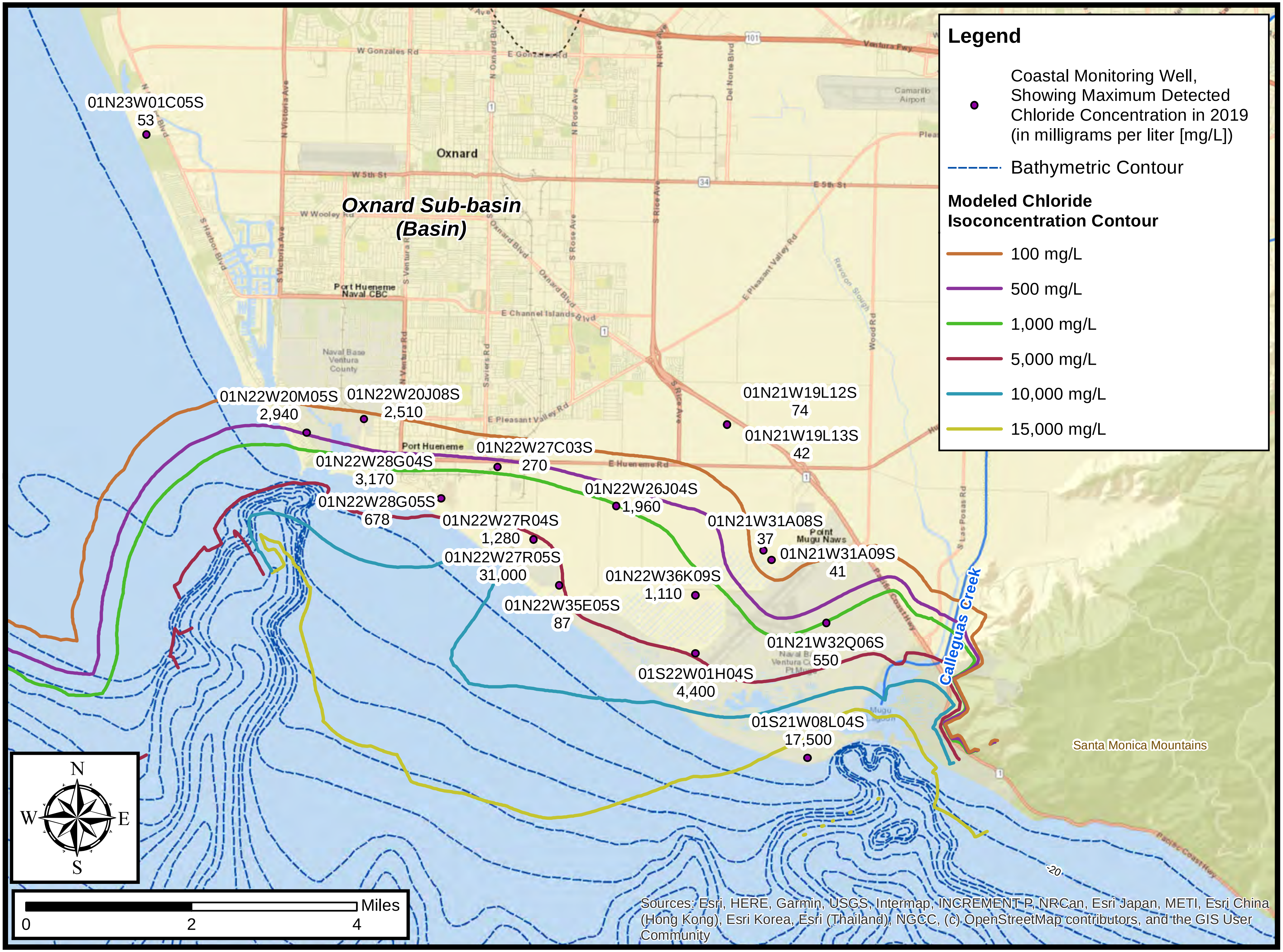

Figure 5. Modeled Chloride Concentrations in Oxnard Aquifer, December 2019

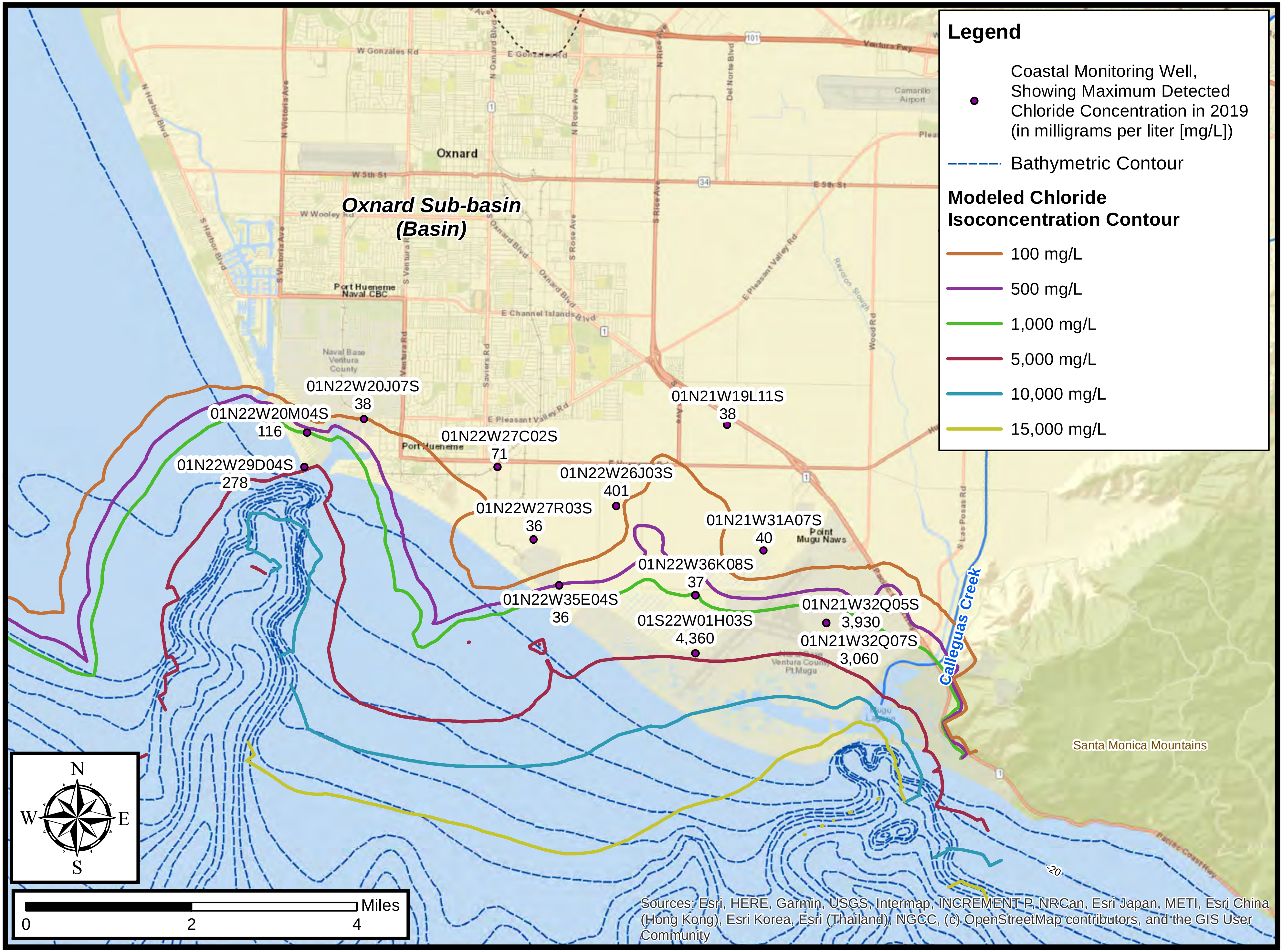

Figure 6. Modeled Chloride Concentrations in Mugu Aquifer, December 2019

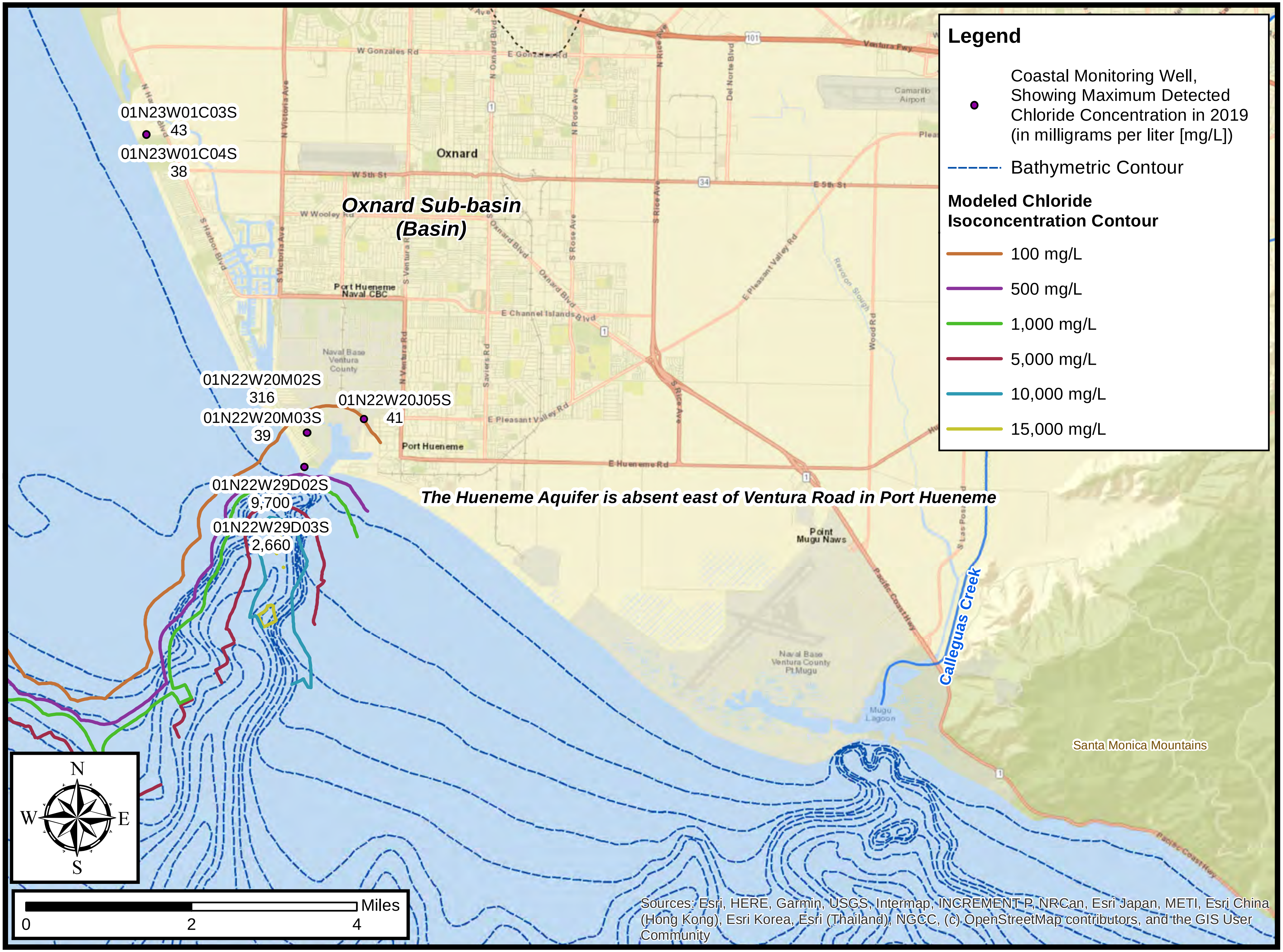

Figure 7. Modeled Chloride Concentrations in Hueneme Aquifer, December 2019

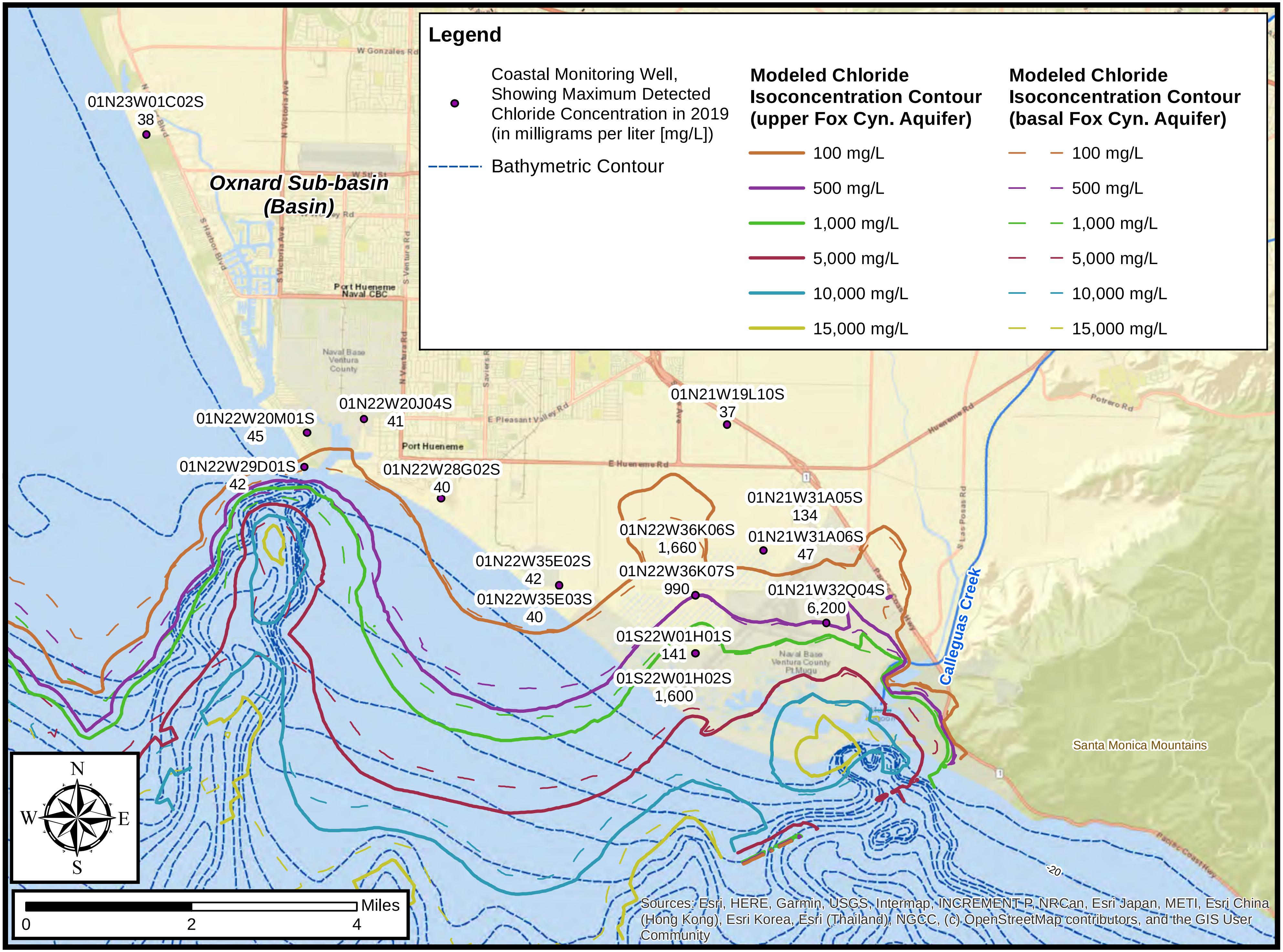

Figure 8. Modeled Chloride Concentrations in Upper and Basal Layers of Fox Canyon Aquifer, December 2019

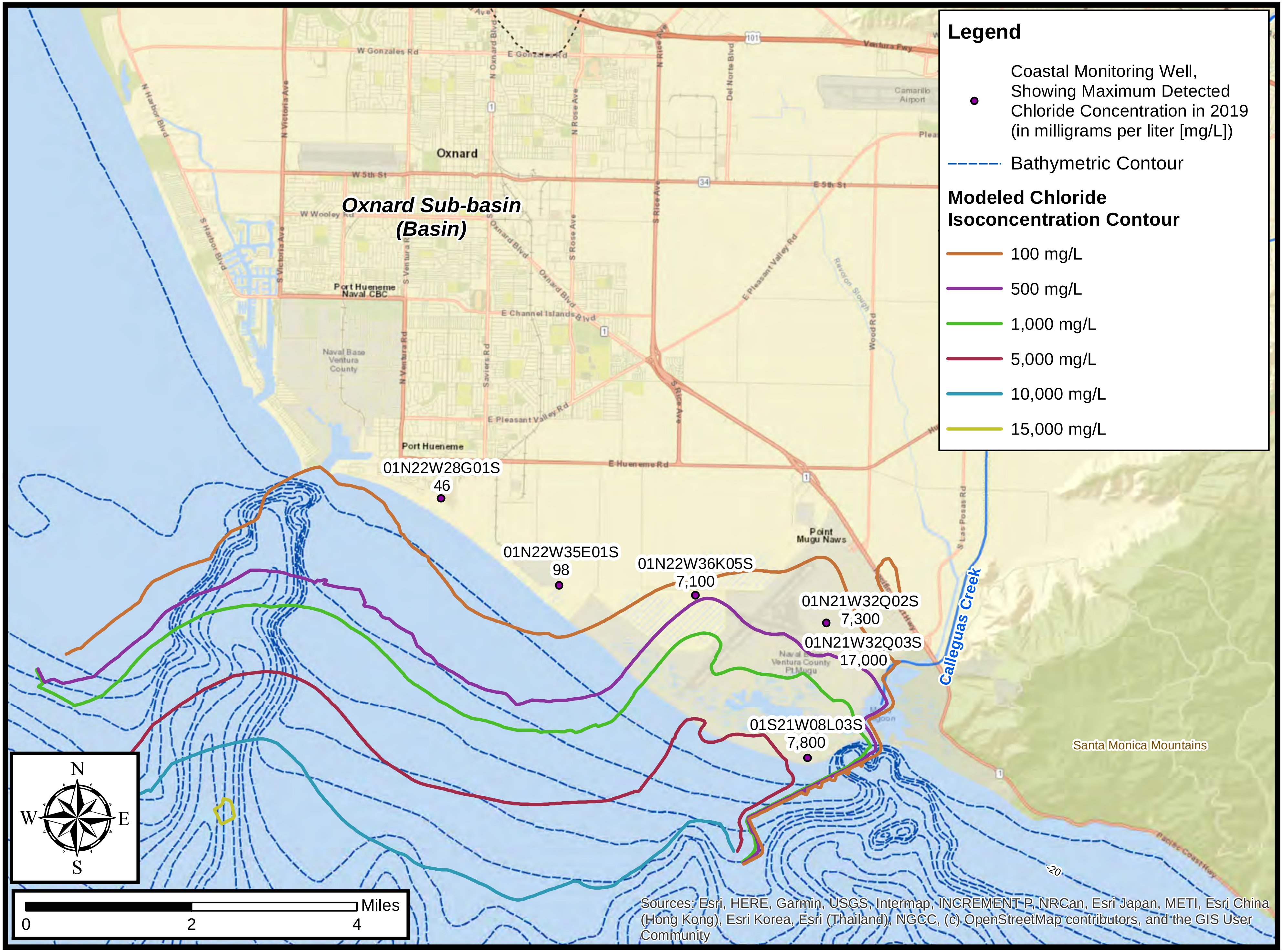

Figure 9. Modeled Chloride Concentrations in Grimes Canyon Aquifer, December 2019

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APPENDIX A—MAPS OF HISTORICAL CHLORIDE CONCENTRATIONS IN THE OPV BASINS

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This appendix contains copies of selected figures from previous reports by the Fox Canyon Groundwater Management Agency (FCGMA) and United Water Conservation District (United or UWCD) illustrating the historical extents of elevated chloride concentrations in the aquifers of the Oxnard and Pleasant Valley (OPV) basins from 1950 through 2020. Three primary sources of uncertainty affect the relevance and reliability of some older chloride data for mapping the extent of seawater intrusion, particularly data collected prior to installation of new monitoring wells by the U.S. Geological Survey (USGS) and United in the early 1990s near the Pacific Ocean coastline:

1. The number and spatial distribution of wells available to sample for saline intrusion were more limited in the 1950s through the 1980s compared to the 1990s through 2020; for this reason, there are significant areal "gaps" in the available salinity data prior to 1980.

2. Some of the wells historically sampled for saline intrusion have long well screens that may extend across the complete thickness of an aquifer, or extend across portions of more than one aquifer. This tends to "average out" high chloride concentrations that may be present in the leading edge of a zone of seawater intrusion in those wells, while wells with shorter screens (particularly the purpose-built monitoring wells constructed by the USGS in the 1990s) more accurately represent salinity within a specific depth interval of each aquifer. As a result, pre-1990s saline-intrusion data may not be directly comparable with more recent data.

3. Salinity in groundwater can be a result of seawater intrusion, but other sources of salinity, including migration of naturally-occurring brines out of fine-grained sediments present between or within aquifers, can also cause elevated chloride concentrations. It can be difficult or impossible to determine the source of chloride with confidence unless other data (such as bromide concentrations) were collected at the same time as samples were taken for chloride. Beginning in the 1990s, the USGS and United began collecting data for several constituents (including bromide) in addition to chloride from coastal wells, with the express purpose of determining whether any elevated chloride concentrations detected were a result of seawater intrusion, brine migration, or another cause.

Despite these sources of uncertainty, the historical maps do provide some general bounds on when and where seawater intrusion has occurred in the OPV basins in the past, and approximately how fast it has moved inland.

A. 1. FCGMA MAPS OF CHLORIDE CONCENTRATIONS FROM 1950 THROUGH 1999

The maps below were copied from the FCGMA's 2007 Update to their Groundwater Management Plan (FCGMA and others, 2007). Not all maps presented in the 2007 GMP Update are included here—only those that depict saline intrusion into the OPV basins, beginning with the FCGMA's map showing chloride concentrations detected in the Upper Aquifer System (UAS) between 1950 and 1954 and their map showing chloride concentrations detected in the Lower Aquifer System (LAS) between 1985 and 1989. Note that on the maps depicting chloride concentrations detected after 1990, the FCGMA began using different colors to represent areas of seawater intrusion versus areas of elevated salinity caused by migration of naturally occurring brines present in fine-grained sediments.

The figure numbers provided in the captions below each map represent the original figure numbers used in the 2007 GMP Update, and begin with Figure 29.

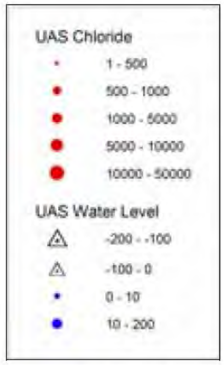

Figure 29. Legend for Figure 30 to Figure 44 for Upper Aquifer System time slices. Chloride concentrations are in mg/L, water level is elevation above or below mean sea level. All maps are oriented with north to the top of the page. Area of map coincides with location map in Figure 2 in section 2.0 *Background of Groundwater Management and Overdraft Within the FCGMA.*

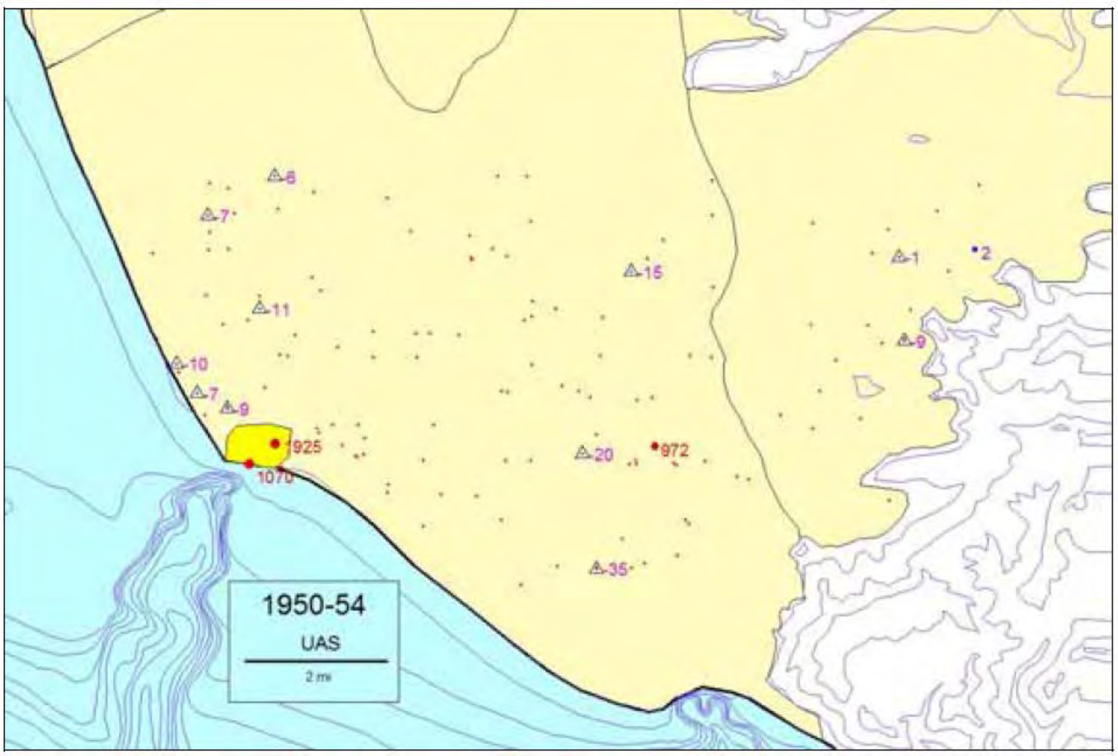

Figure 35. Upper Aquifer System groundwater levels and chloride levels, 1950 to 1954. Legend is shown in Figure 29. Bright yellow area is intruded by seawater near Hueneme Submarine Canyon. Line in title block is two miles in length.

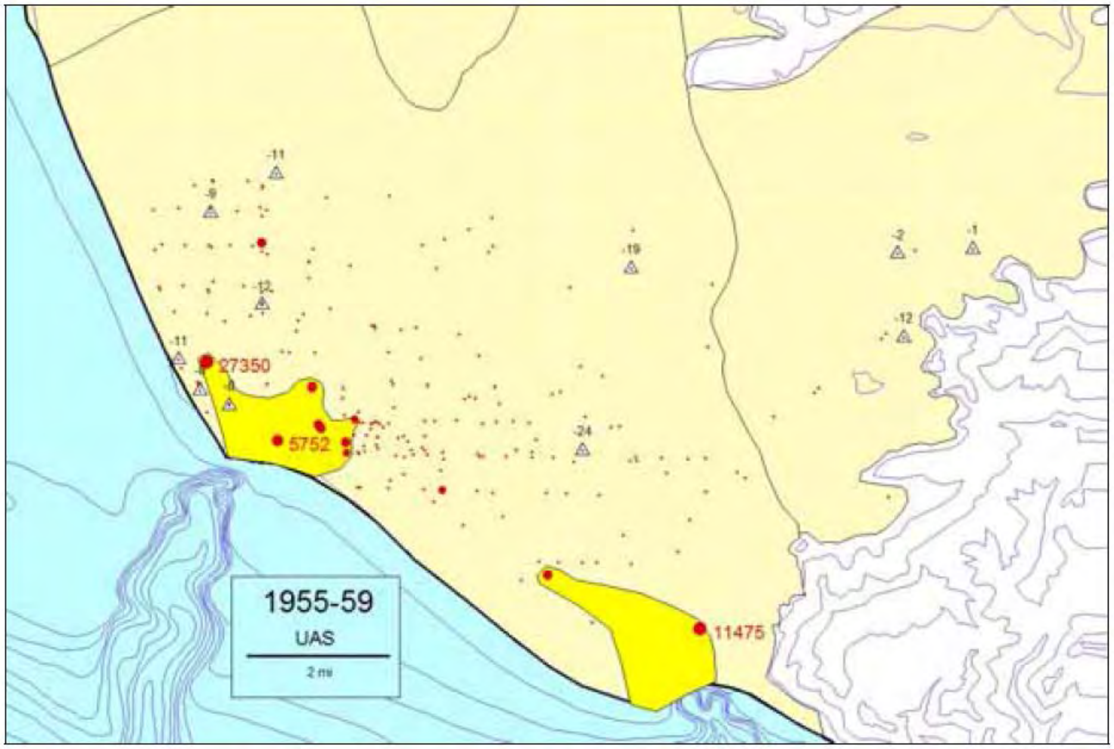

Figure 36. Upper Aquifer System groundwater levels and chloride levels, 1955 to 1959. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

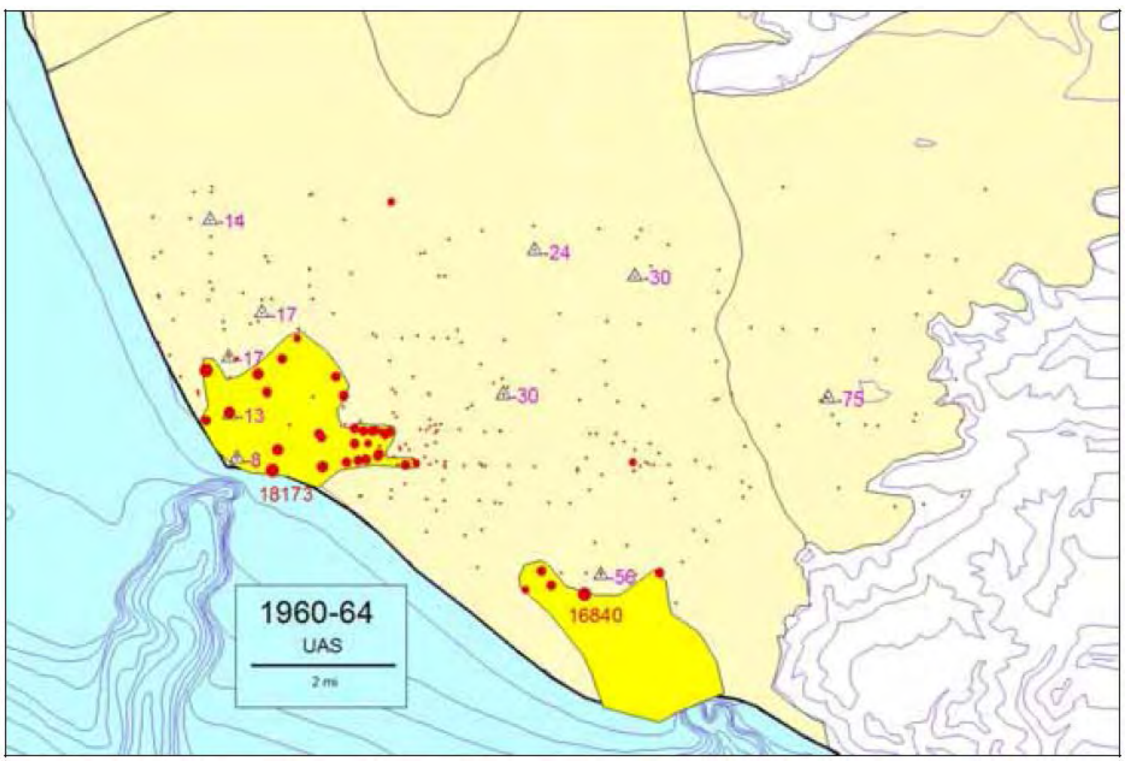

Figure 37. Upper Aquifer System groundwater levels and chloride levels, 1960 to 1964. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

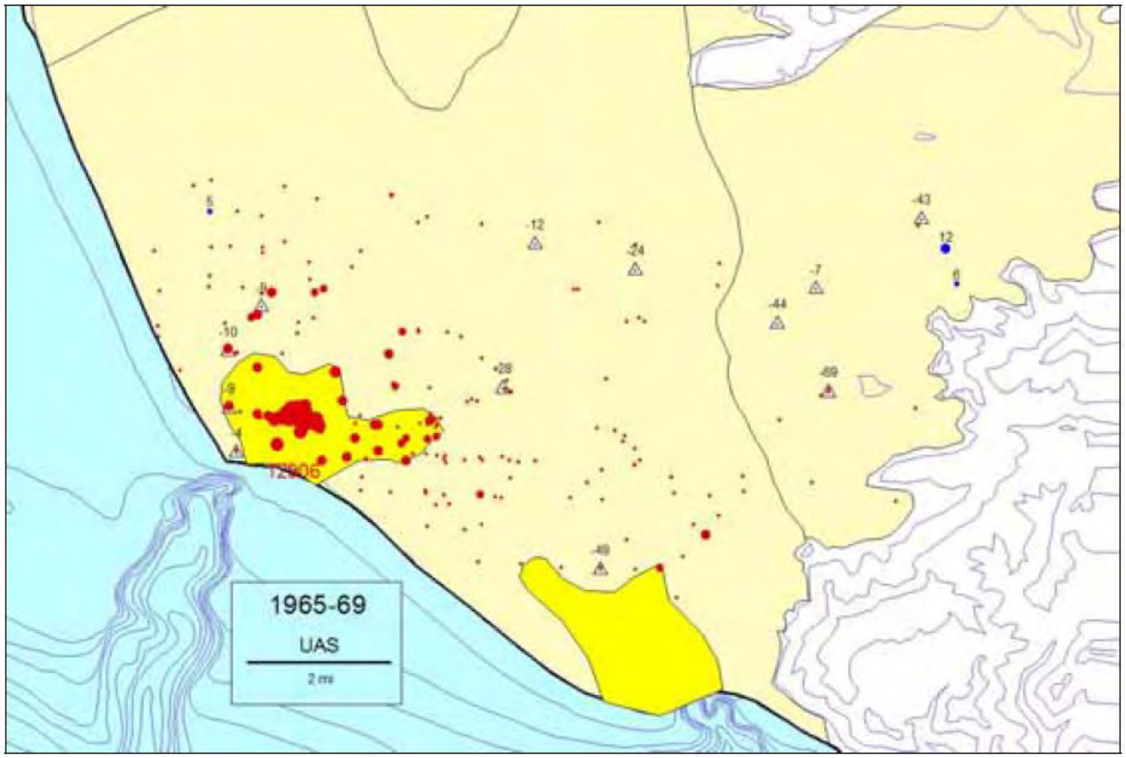

Figure 38. Upper Aquifer System groundwater levels and chloride levels, 1965 to 1969. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

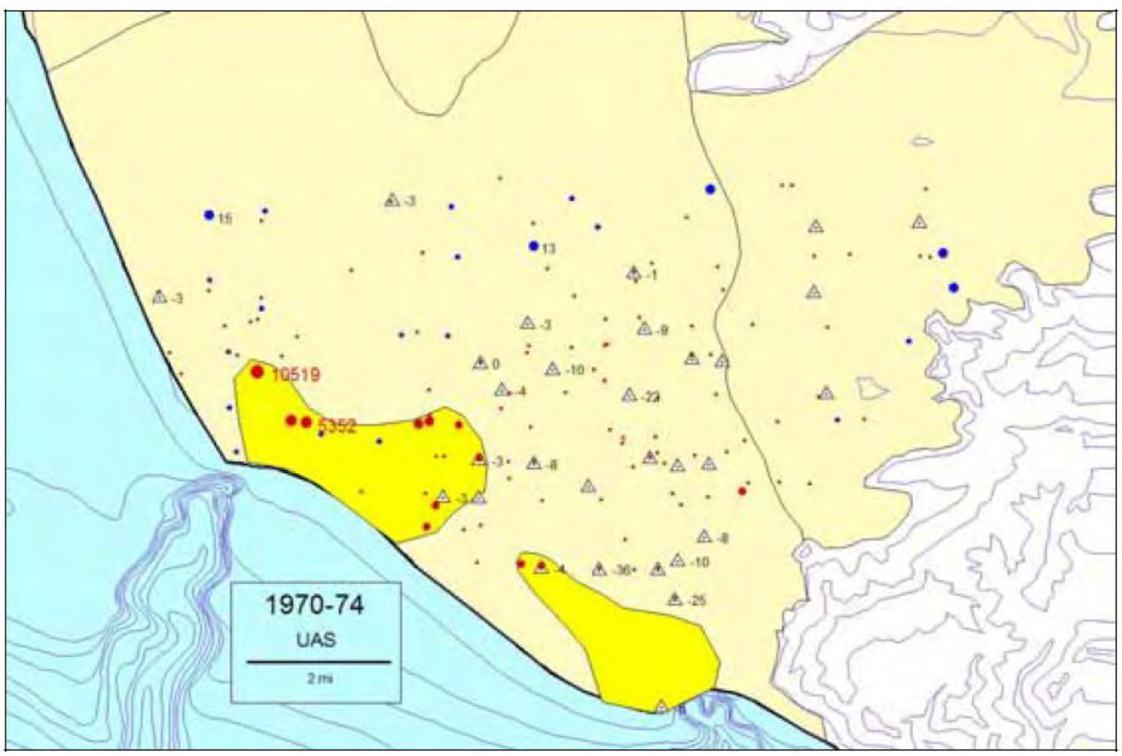

Figure 39. Upper Aquifer System groundwater levels and chloride levels, 1970 to 1974. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

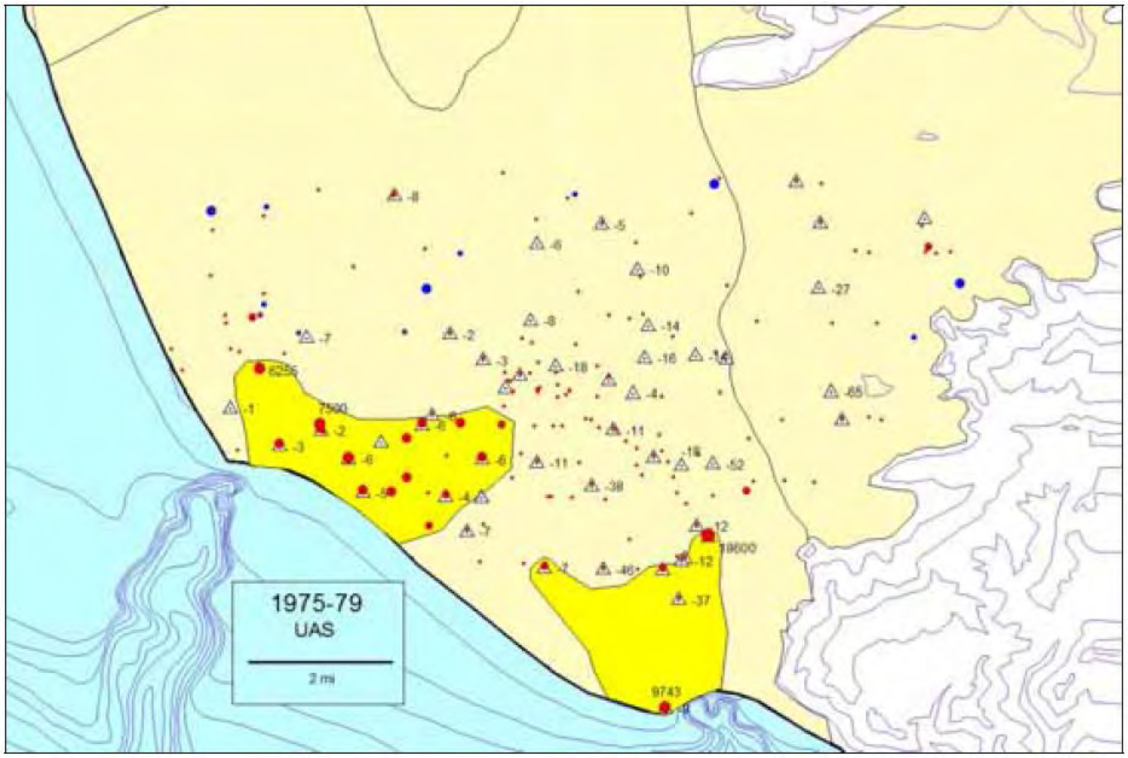

Figure 40. Upper Aquifer System groundwater levels and chloride levels, 1975 to 1979. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

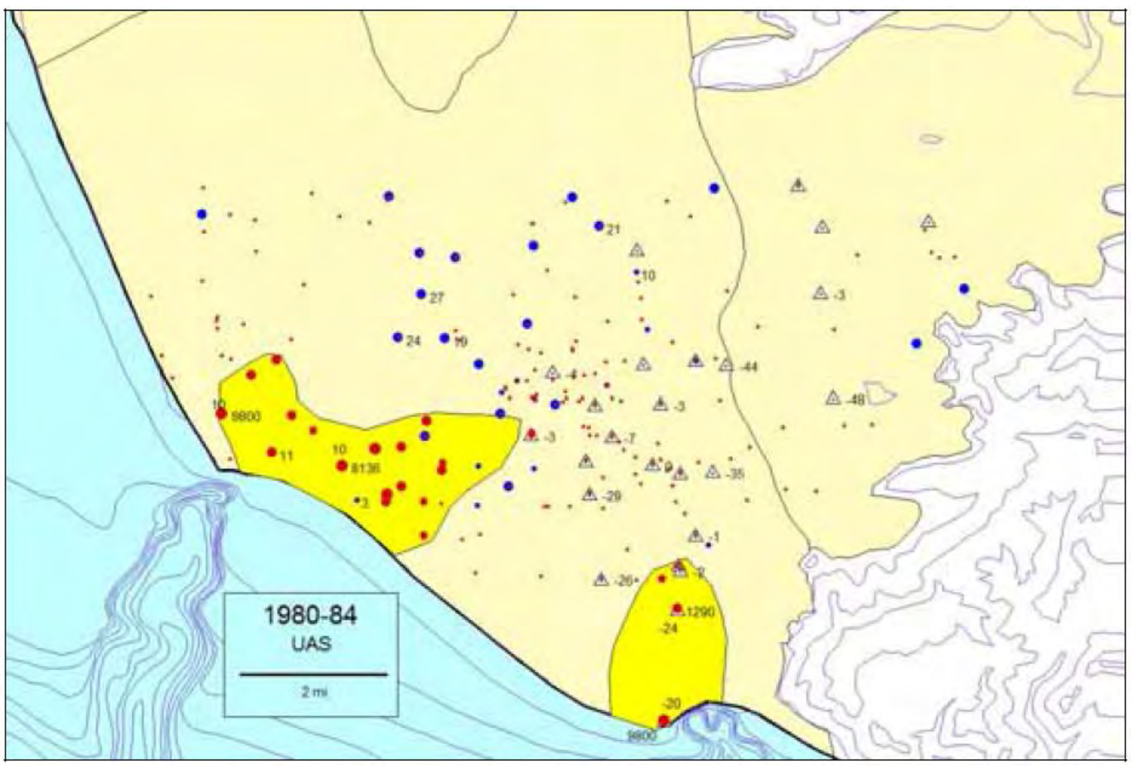

Figure 41. Upper Aquifer System groundwater levels and chloride levels, 1980 to 1984. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

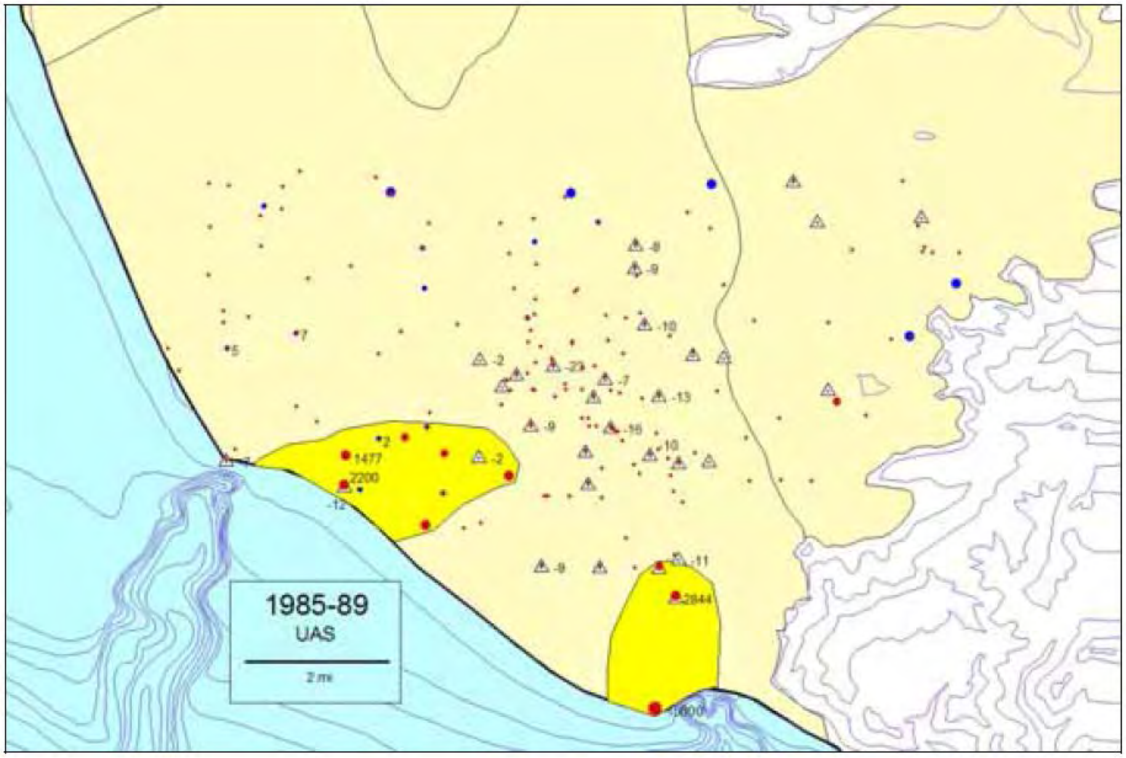

Figure 42. Upper Aquifer System groundwater levels and chloride levels, 1985 to 1989. Legend is shown in Figure 29. Bright yellow areas are intruded by saline waters. Line in title block is two miles in length.

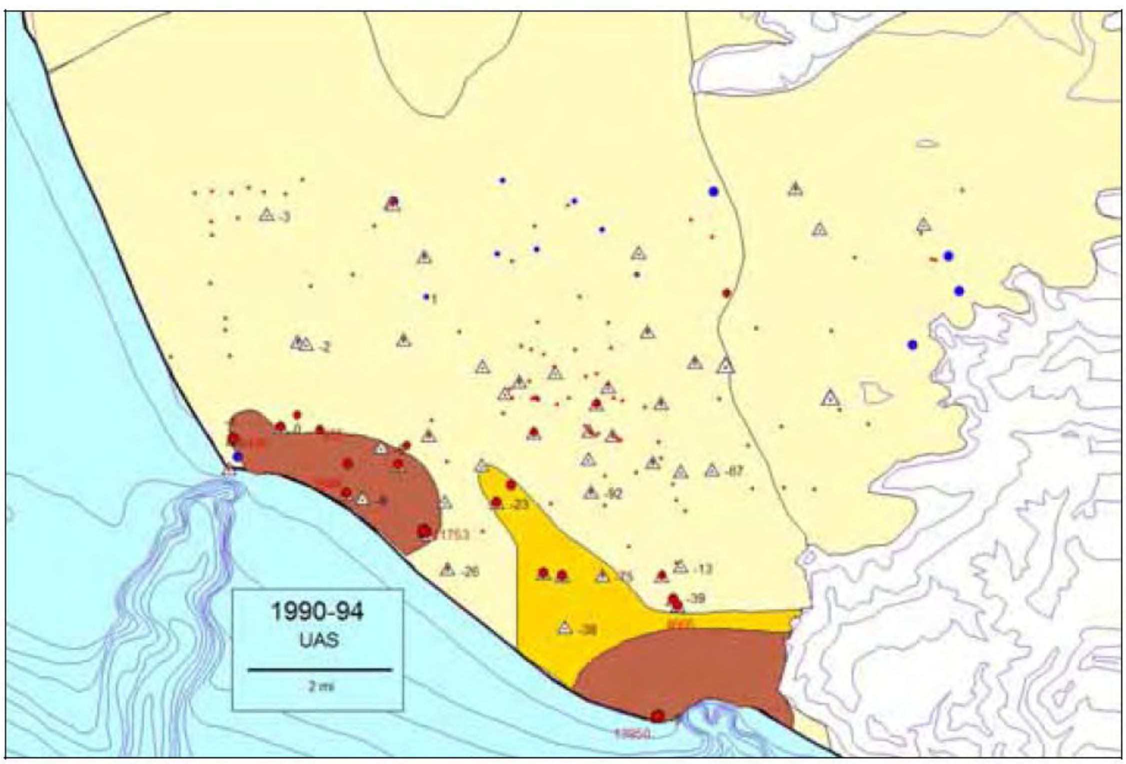

Figure 43. Upper Aquifer System groundwater levels and chloride levels, 1990 to 1994. Legend is shown in Figure 29. Source of saline intruded areas: reddish brown is from seawater; yellow-orange is from sediments. Line in title block is two miles in length.

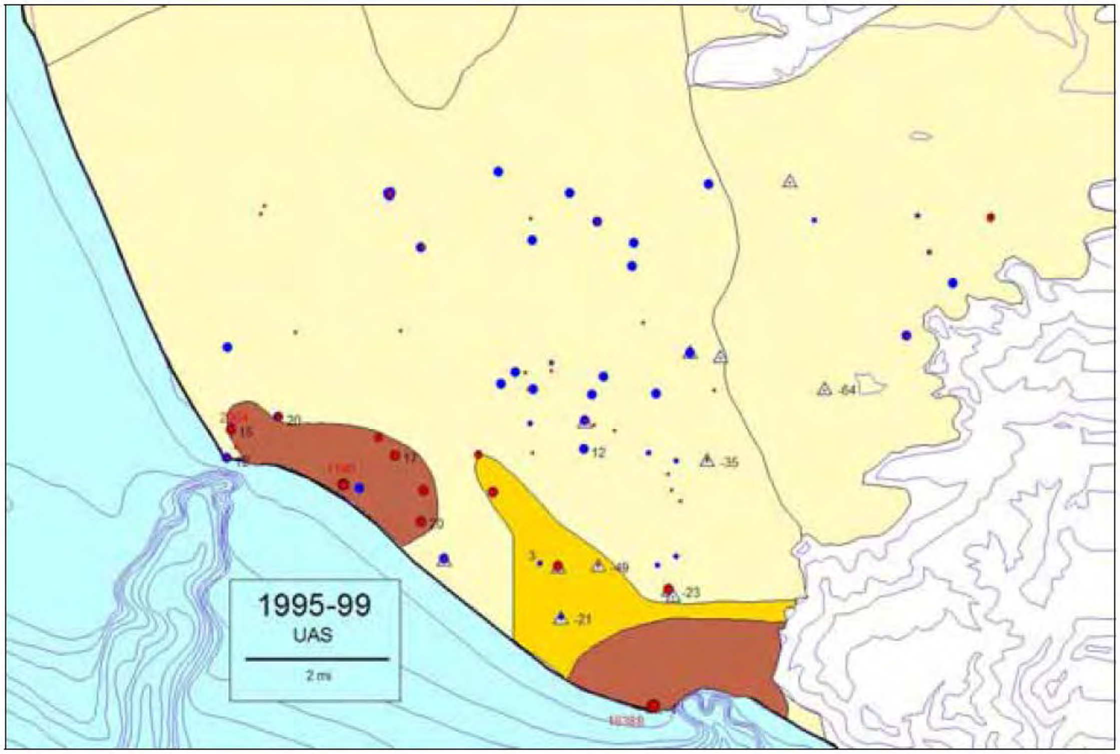

Figure 44 Upper Aquifer System groundwater levels and chloride levels, 1995 to 1999. Legend is shown in Figure 29. Source of saline intruded areas: reddish brown is from seawater; yellow-orange is from sediments. Line in title block is two miles in length.

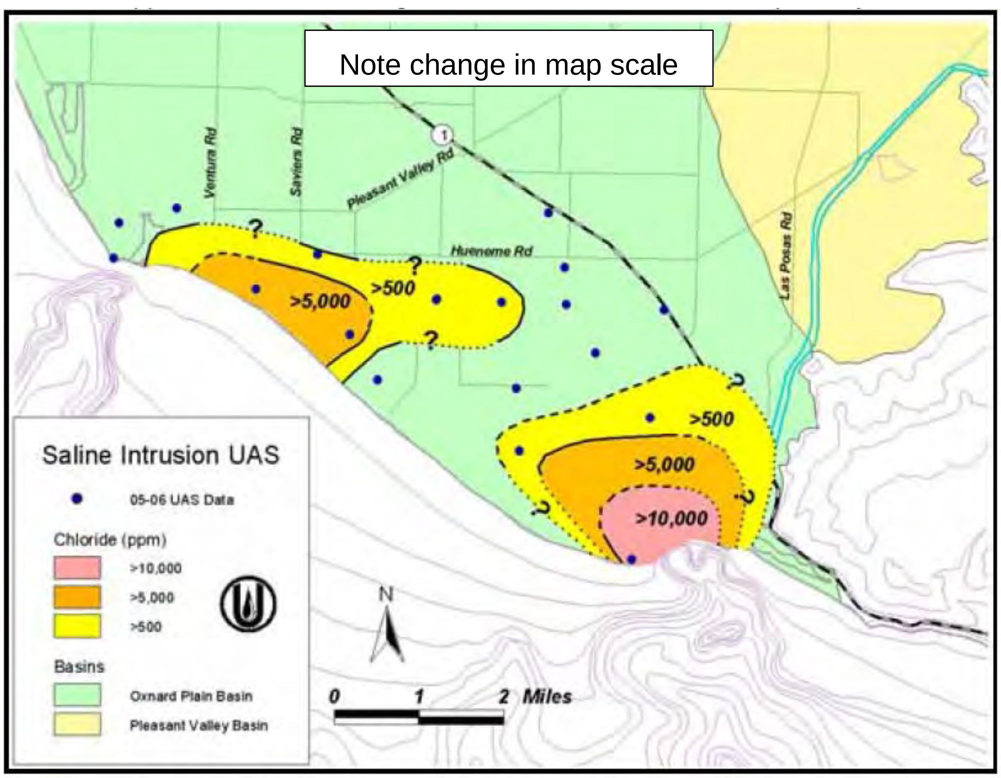

Figure 14. Areas of saline intrusion in the Upper Aquifer System of the Oxnard Plain in 2005-06. Contours of chloride concentrations indicate the maximum extent of the UAS saline intrusion – individual aquifers within the UAS may be less intruded. Contour lines are dashed where inferred and queried where uncertain. Bathymetric contour lines indicate the offshore submarine canyons where the aquifers are eroded along the canyon walls and exposed to seawater.

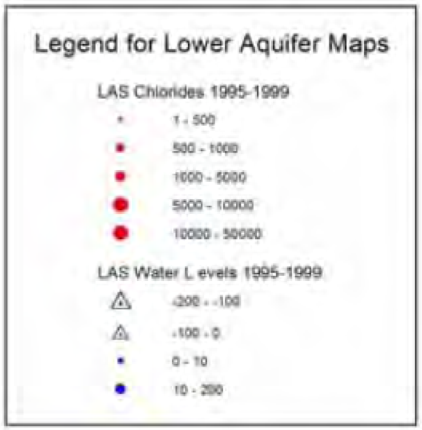

Figure 45. Legend for Figure 46 to Figure 56 for Lower Aquifer System time slices. Chloride concentrations are in mg/L, water level is elevation above or below mean sea level. All maps are oriented with north to the top of the page. Area of map coincides with location map in Figure 2 in section 2.0 *Background of Groundwater Management and Overdraft Within the FCGMA*.

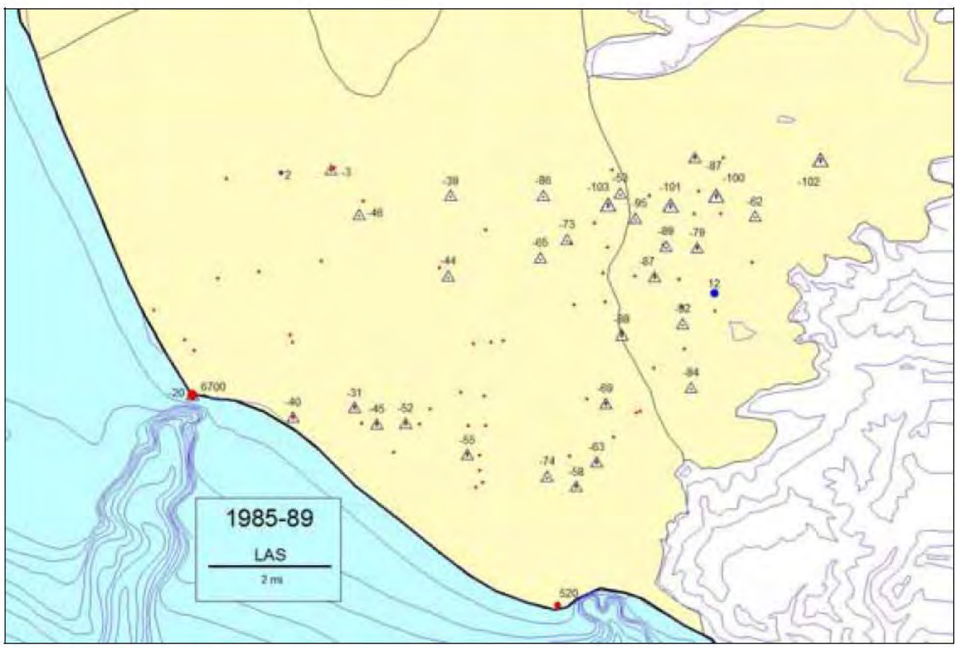

Figure 54. Lower Aquifer System groundwater levels and chloride levels, 1985 to 1989. Legend is shown in Figure 45. Note start of seawater intrusion (red dot) at head of Hueneme Submarine Canyon. Line in title block is two miles in length.

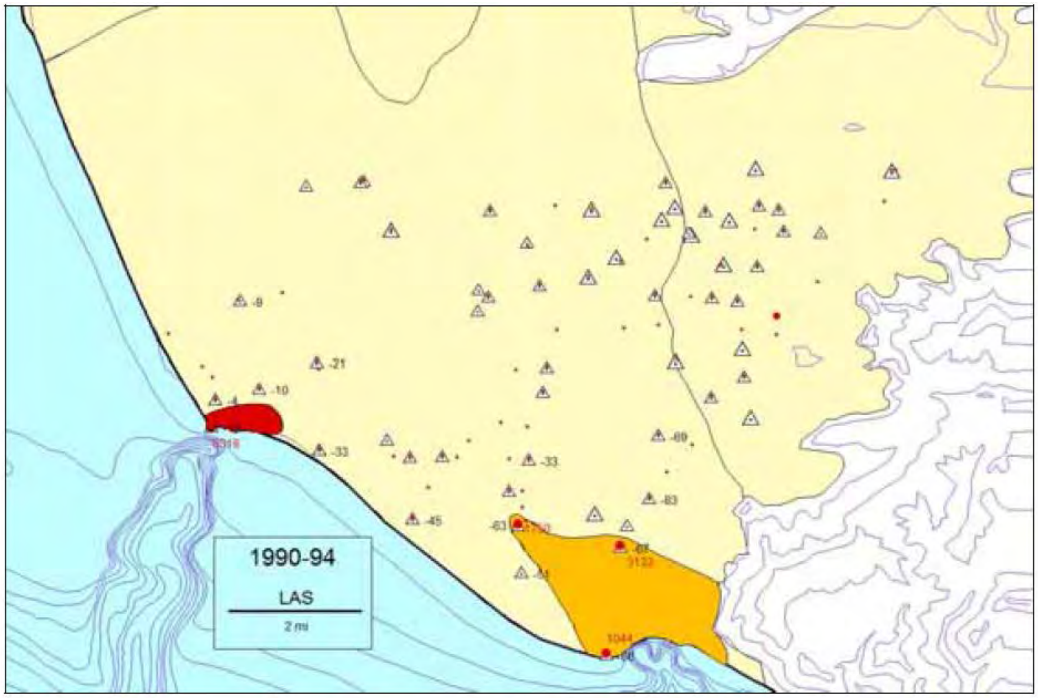

Figure 55. Lower Aquifer System groundwater levels and chloride levels, 1990 to 1994. Legend is shown in Figure 45. Source of saline intruded areas: reddish brown is from seawater; yellow-orange is from sediments. Line in title block is two miles in length.

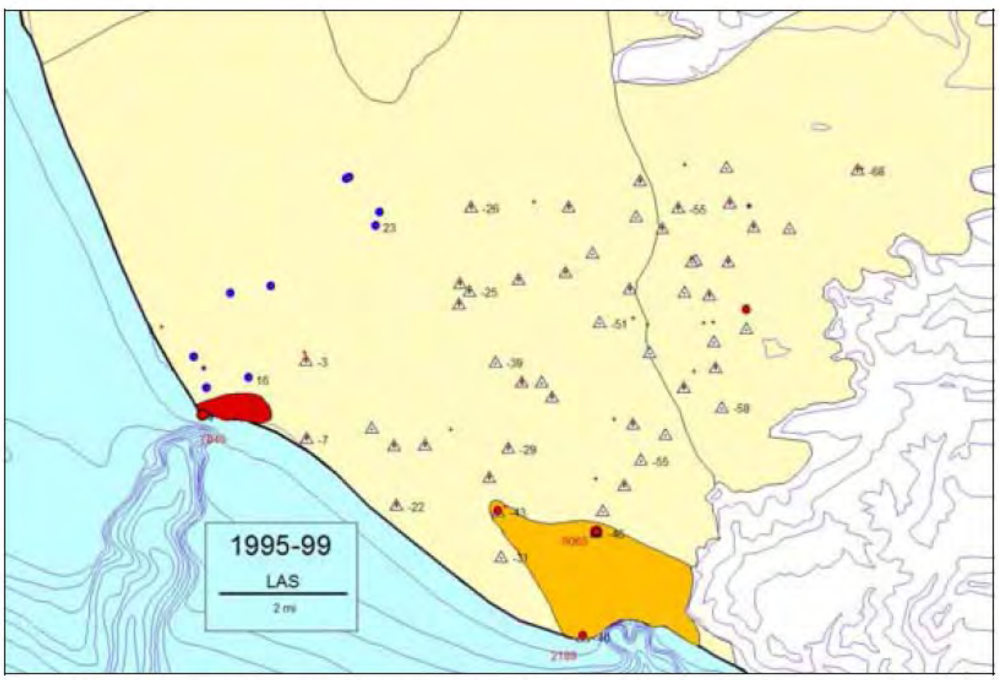

Figure 56. Lower Aquifer System groundwater levels and chloride levels, 1995 to 1999. Legend is shown in Figure 45. Source of saline intruded areas: reddish brown is from seawater; yellow-orange is from sediments. Line in title block is two miles in length.

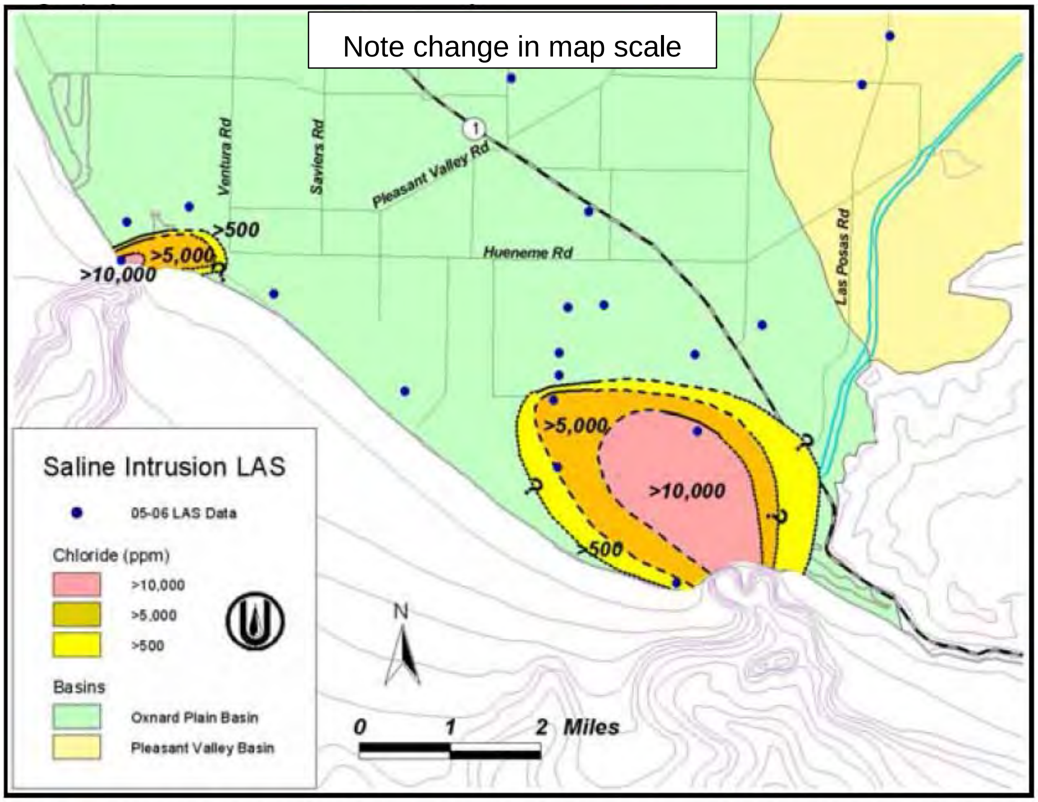

Figure 15. Areas of saline intrusion in the Lower Aquifer System of the Oxnard Plain in 2005-06. Contours of chloride concentrations indicate the maximum extent of the LAS saline intrusion – individual aquifers within the LAS may be less intruded. Contour lines are dashed where inferred and queried where uncertain. Bathymetric contour lines indicate the offshore submarine canyons where the aquifers are eroded along the canyon walls and exposed to seawater.

A. 2. UNITED MAPS OF CHLORIDE CONCENTRATIONS FROM 2003 THROUGH 2019

The maps below were copied from United's periodic saline intrusion reports, which were intermittently prepared from 1994 through 2020. The maps produced by United in the 1990s show similar chloride extents as those prepared by the FCGMA during the 1990s, and are not copied in this report. Chloride maps from the 2003, 2015, and 2020 saline intrusion reports (United, 2003, 2016, and 2020) that show notable changes in seawater intrusion since year 2000 are included below. The United maps depict chloride concentrations for specific depth zones or aquifers, not just average or maximum concentrations in the UAS and LAS. Similar to the FCGMA's maps of chloride concentrations, United's 2003 maps use different colors to represent areas of seawater intrusion versus areas of elevated salinity caused by migration of naturally occurring brines out of fine-grained sediments.

The figure numbers provided in the captions below each map represent the original figure numbers used in United's salinity intrusion reports.

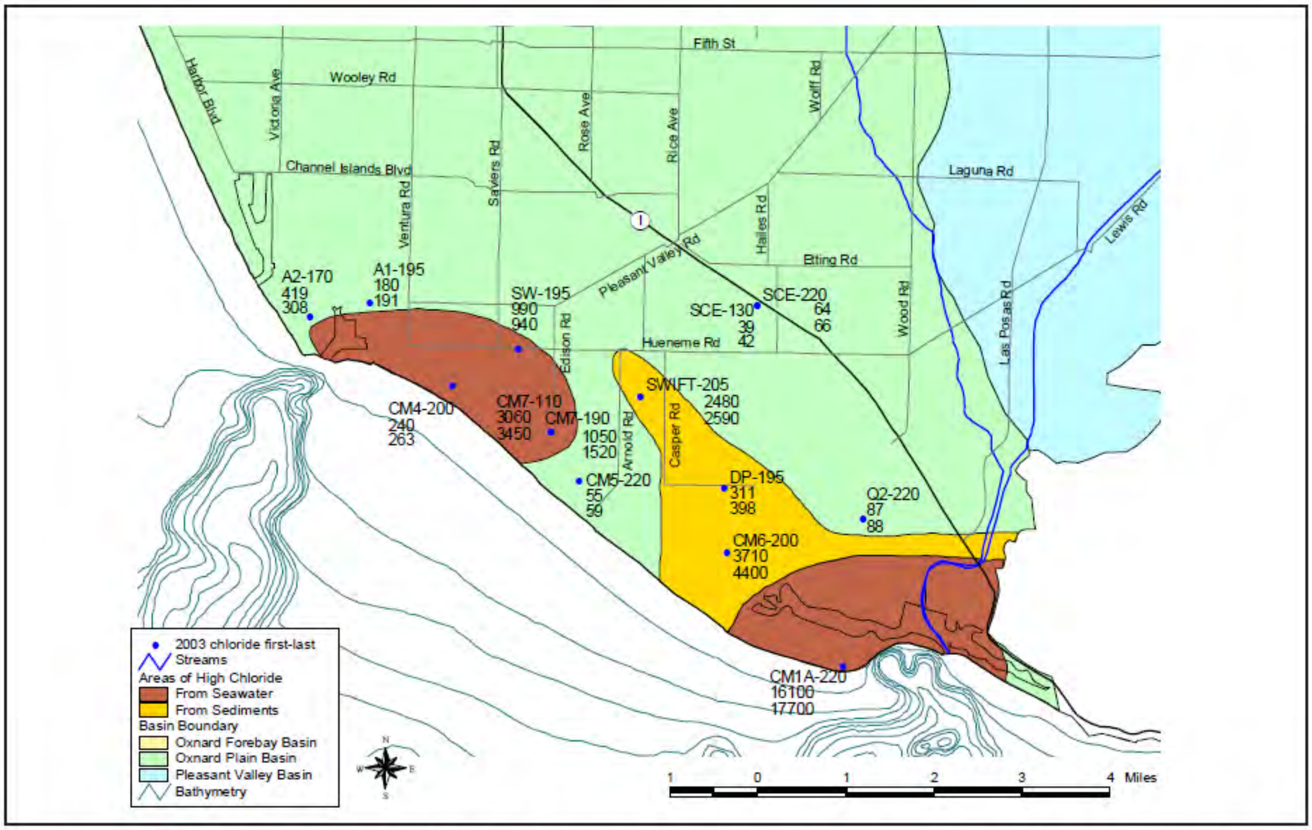

Figure 4-1. Oxnard Aquifer (100-220 ft.) chloride concentrations (mg/l), 2003 water year; first record plotted over last record (typically fall 2002 and fall 2003)

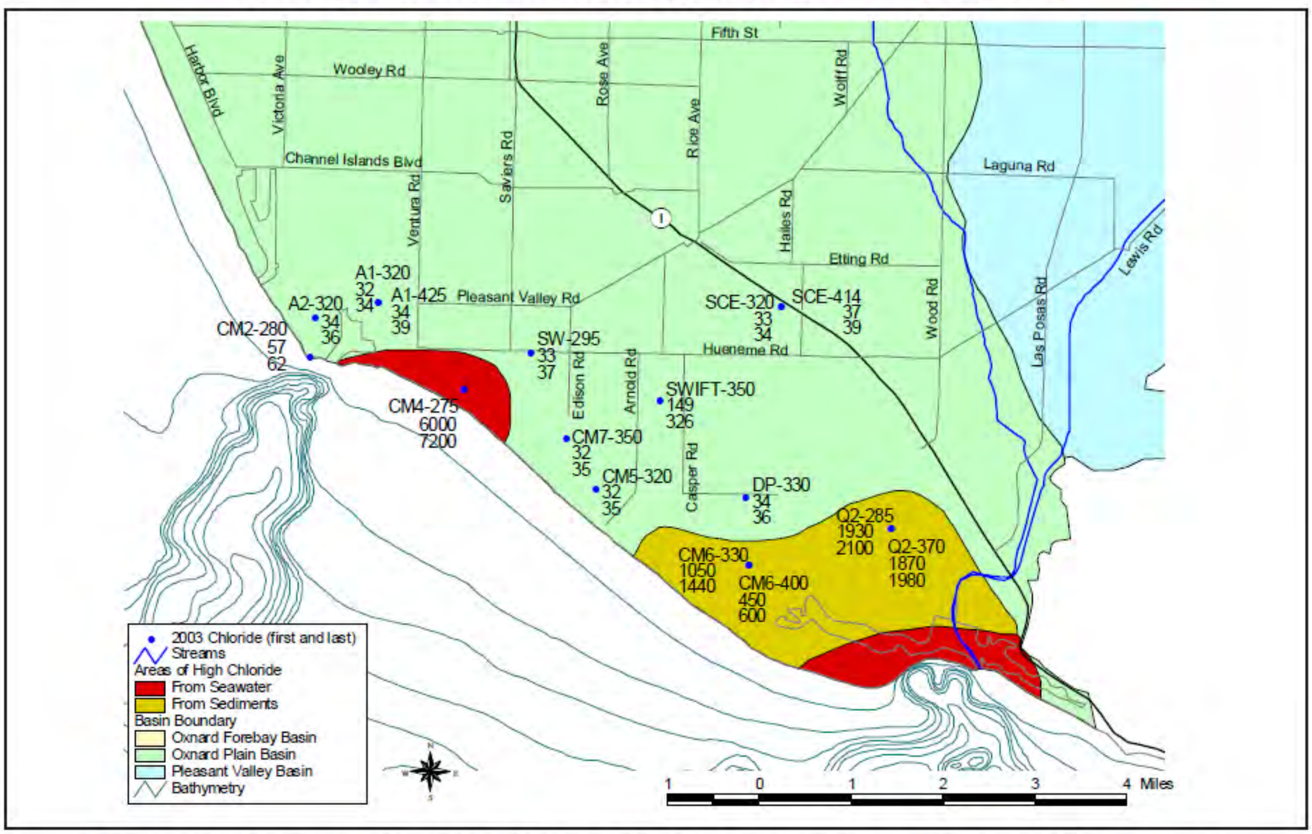

Figure 4-2. Mugu Aquifer (255-425 ft.) chloride concentrations (mg/l), 2003 water year; first record plotted over last record (typically fall 2002 and fall 2003)

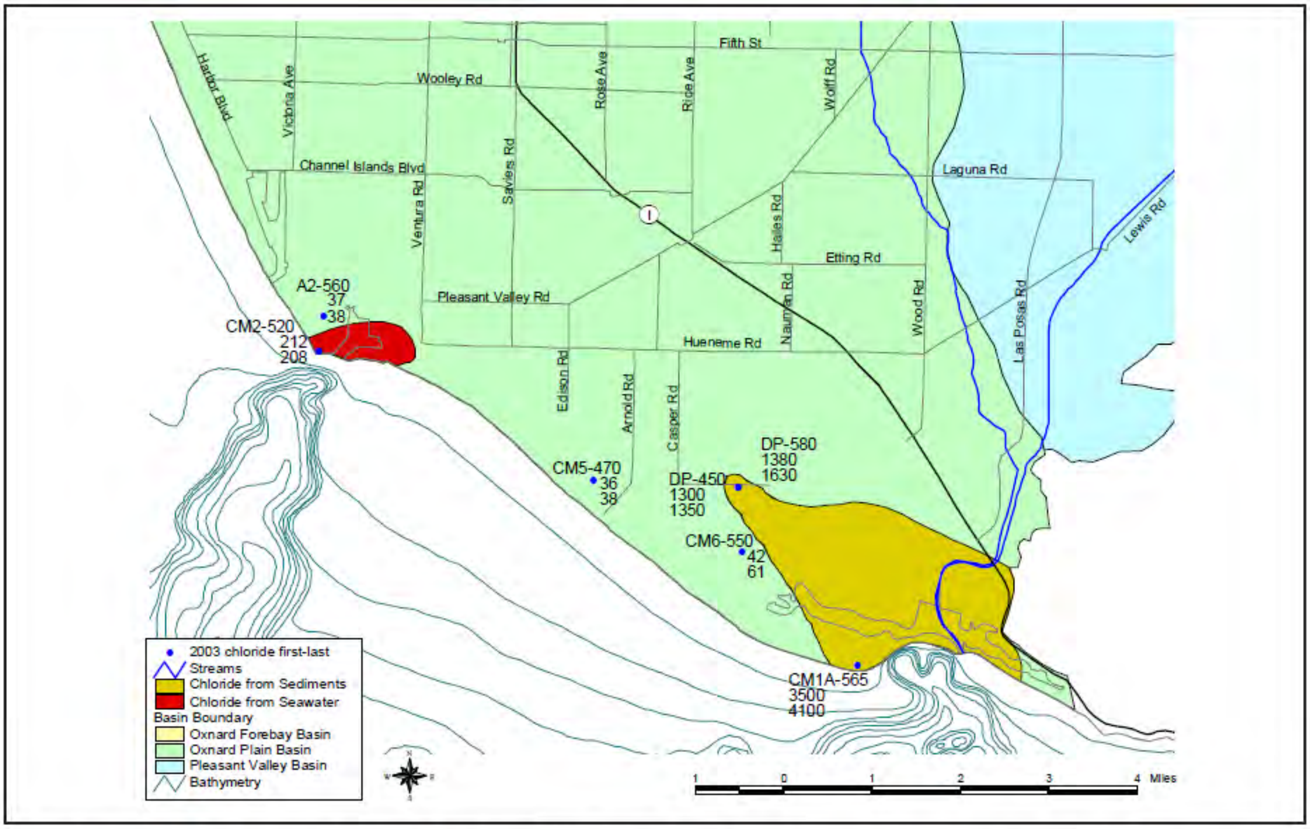

Figure 4-3. Lower Aquifer System (410-580 ft.) chloride concentration (mg/l), 2003 water year; first record plotted over last record (typically fall 2002 and fall 2003)

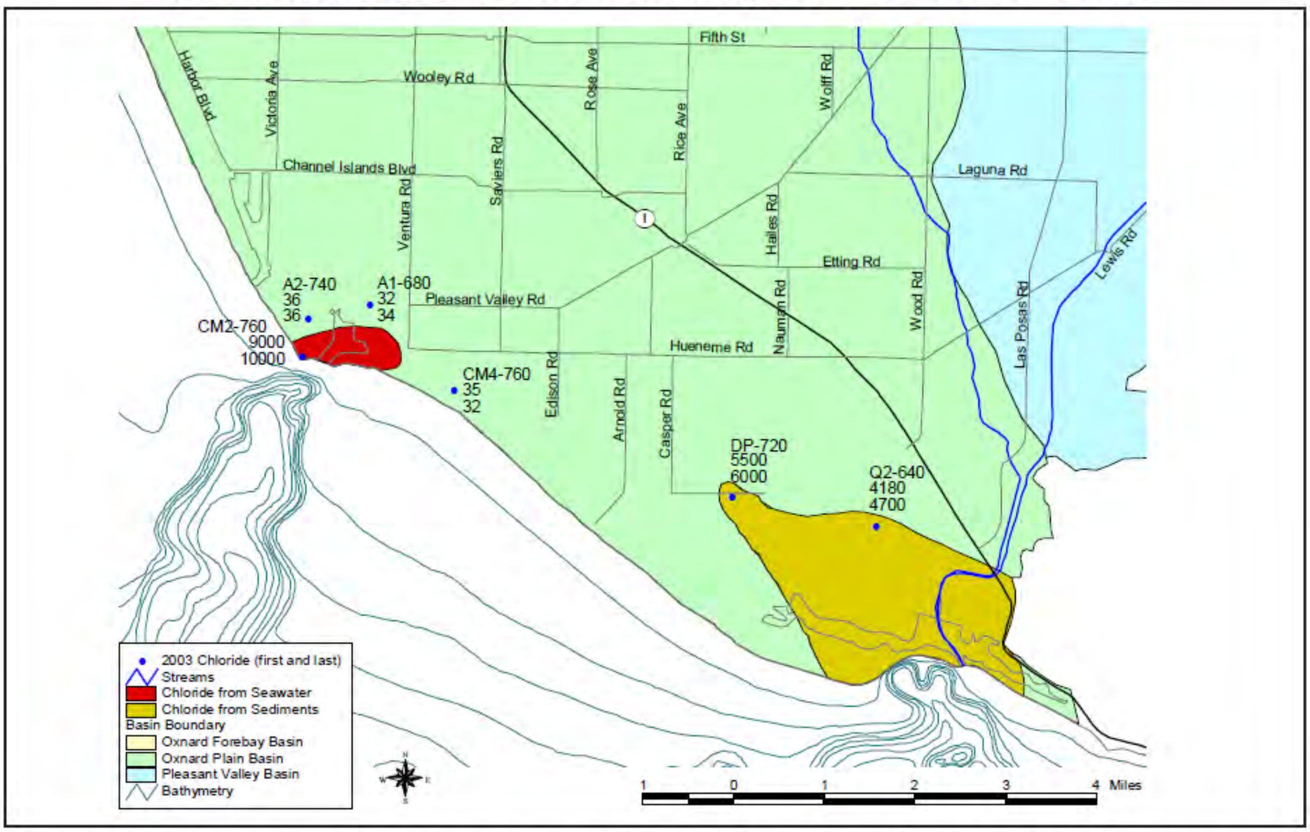

Figure 4-4. Lower Aquifer System (600-760 ft.) chloride concentrations (mg/l), 2003 water year; first record plotted over last record (typically fall 2002 and fall 2003)

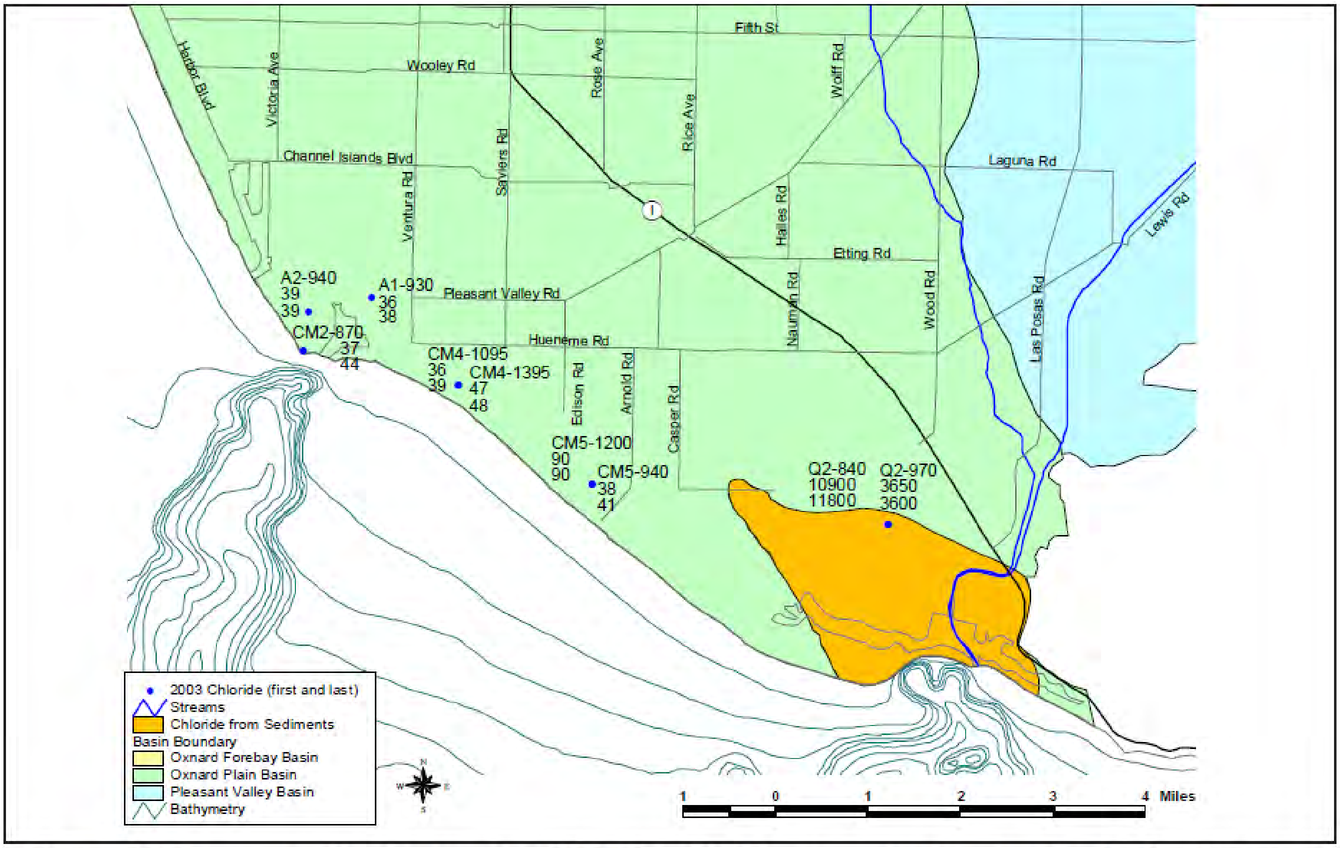

Figure 4-5. Lower Aquifer System (800-1395 ft.) chloride concentrations (mg/l), 2003 water year; first record plotted over last record (typically fall 2002 and fall 2003)

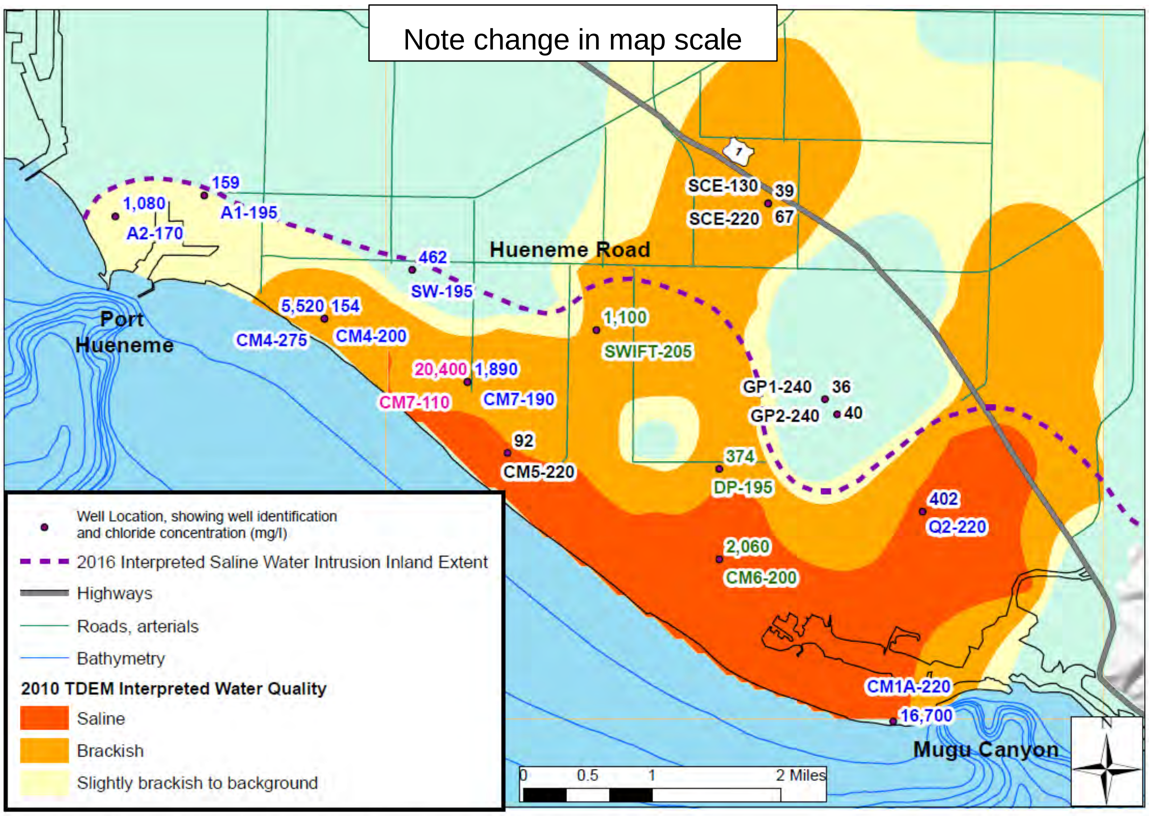

Figure 4.3.2. Oxnard aquifer chloride concentrations, coastal monitoring wells, fall 2015.
Interpreted source of elevated chloride levels key: Green label = Sediments; Blue label = Seawater; Pink label = Semi-perched water; Black label = Background level.

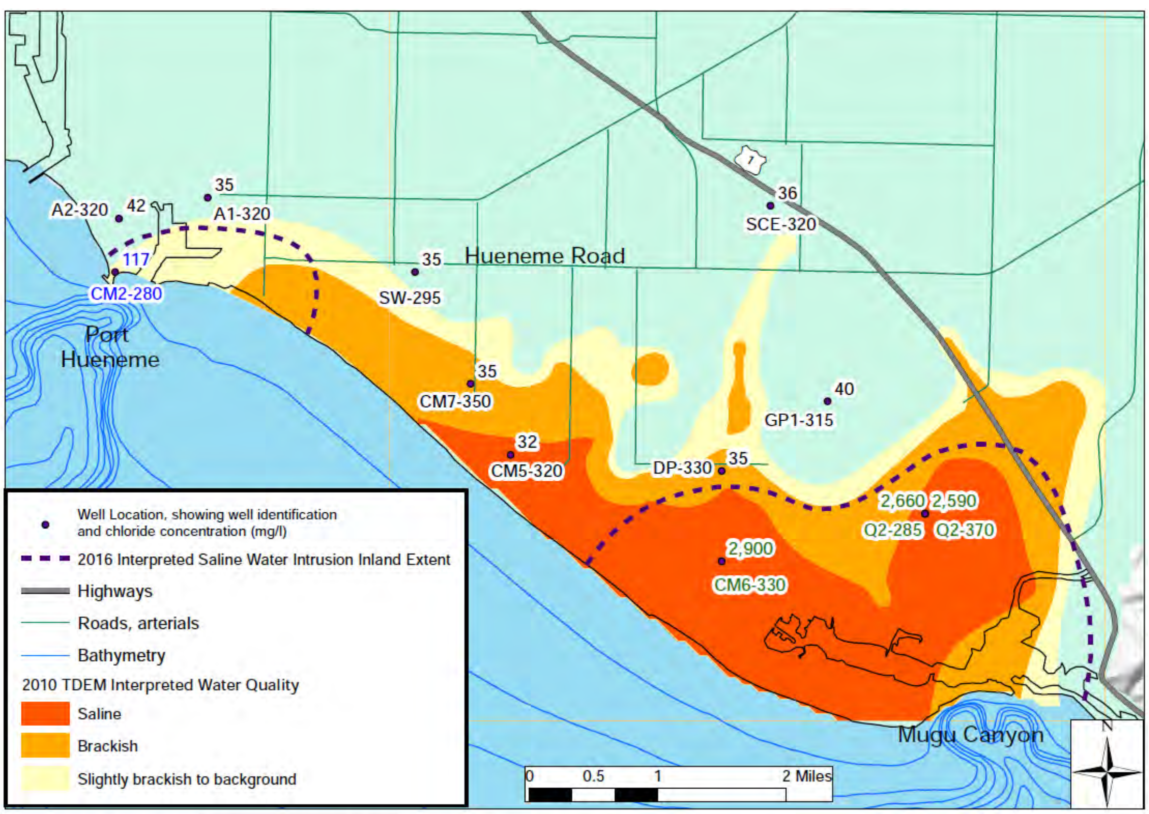

Figure 4.3.3. Mugu aquifer chloride concentrations, coastal monitoring wells, fall 2015.
Interpreted source of elevated chloride levels key: Green label = Sediments; Blue label = Seawater; Black label = Background level.

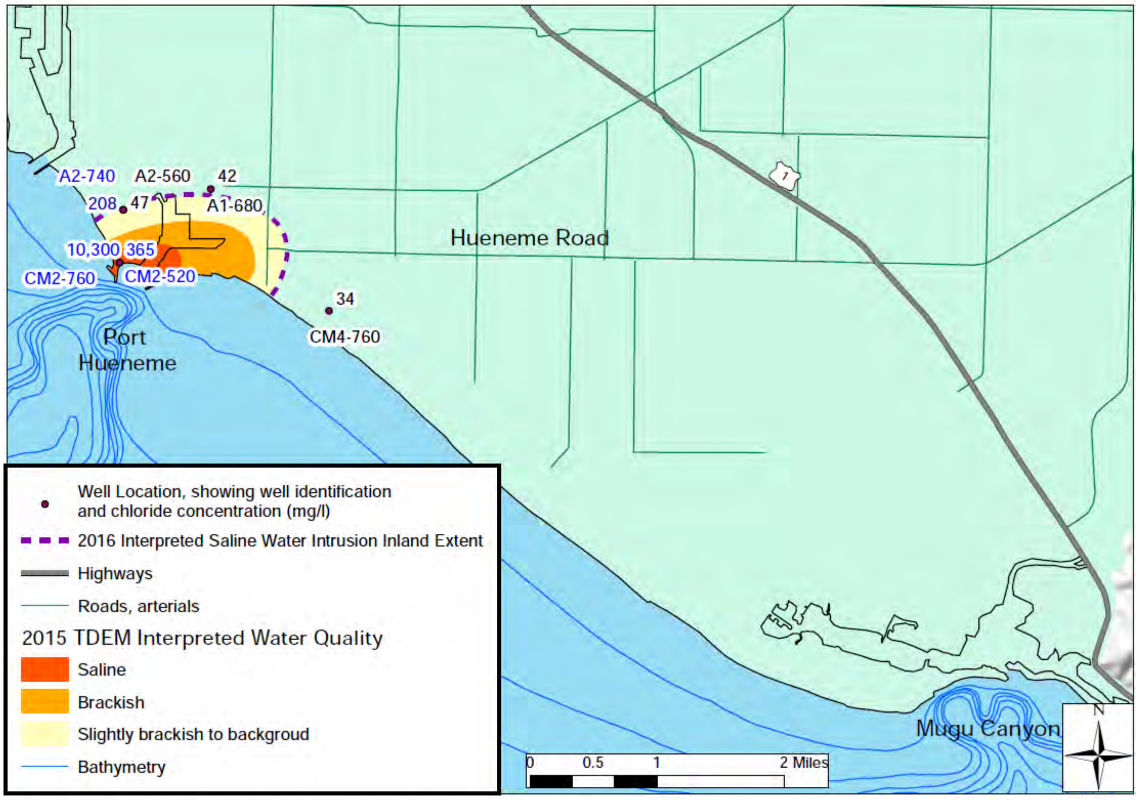

Figure 4.3.4. Hueneme aquifer chloride concentrations, coastal monitoring wells, fall 2015.
Interpreted source of elevated chloride levels key: Blue label = Seawater; Black label = Background level.

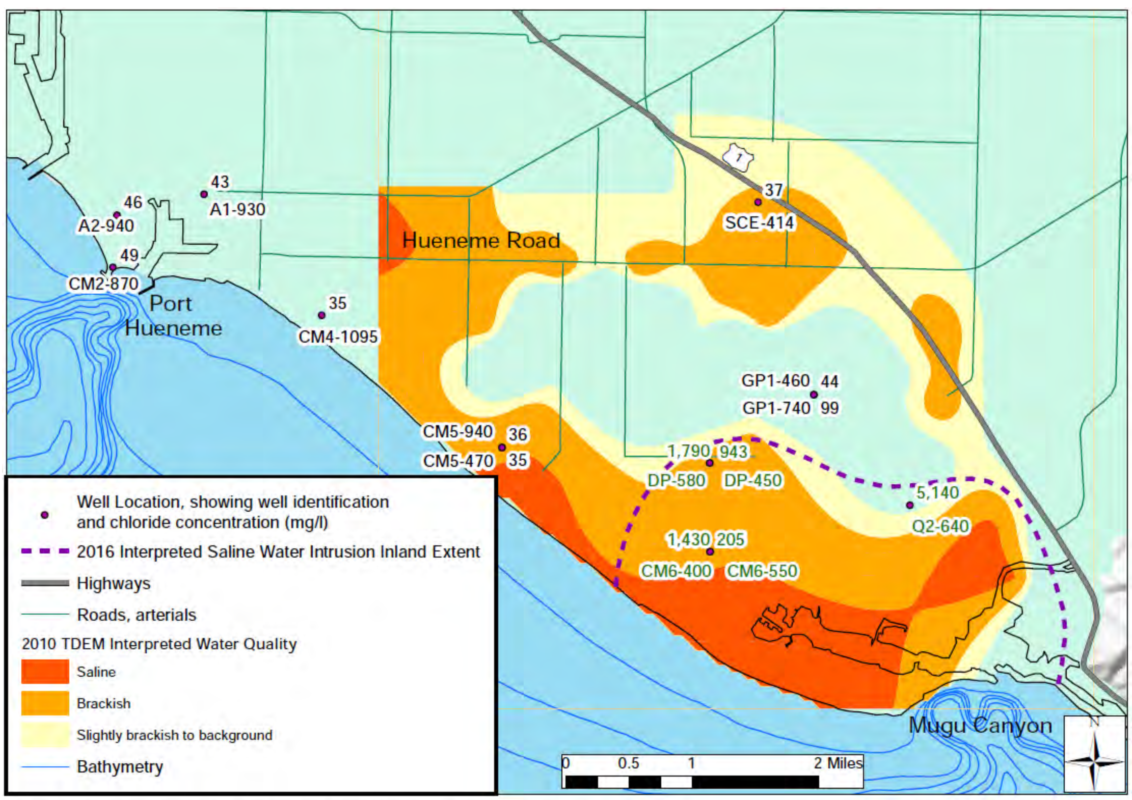

Figure 4.3.5. Fox Canyon aquifer chloride concentrations, coastal monitoring wells, fall 2015.
Interpreted source of elevated chloride levels key: Green label = Sediments; Black label = Background level.

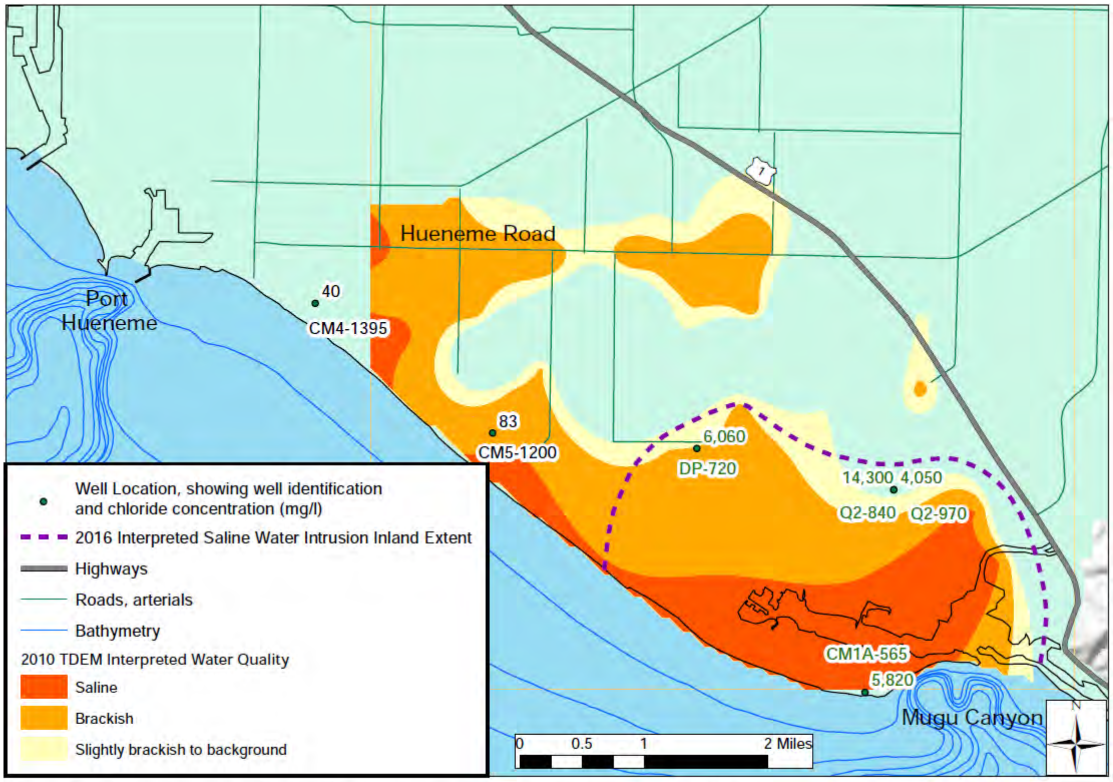

Figure 4.3.6. Grimes Canyon aquifer chloride concentrations, coastal monitoring wells, fall 2015.
Interpreted source of elevated chloride levels key: Green label = Sediments; Black label = Background level.

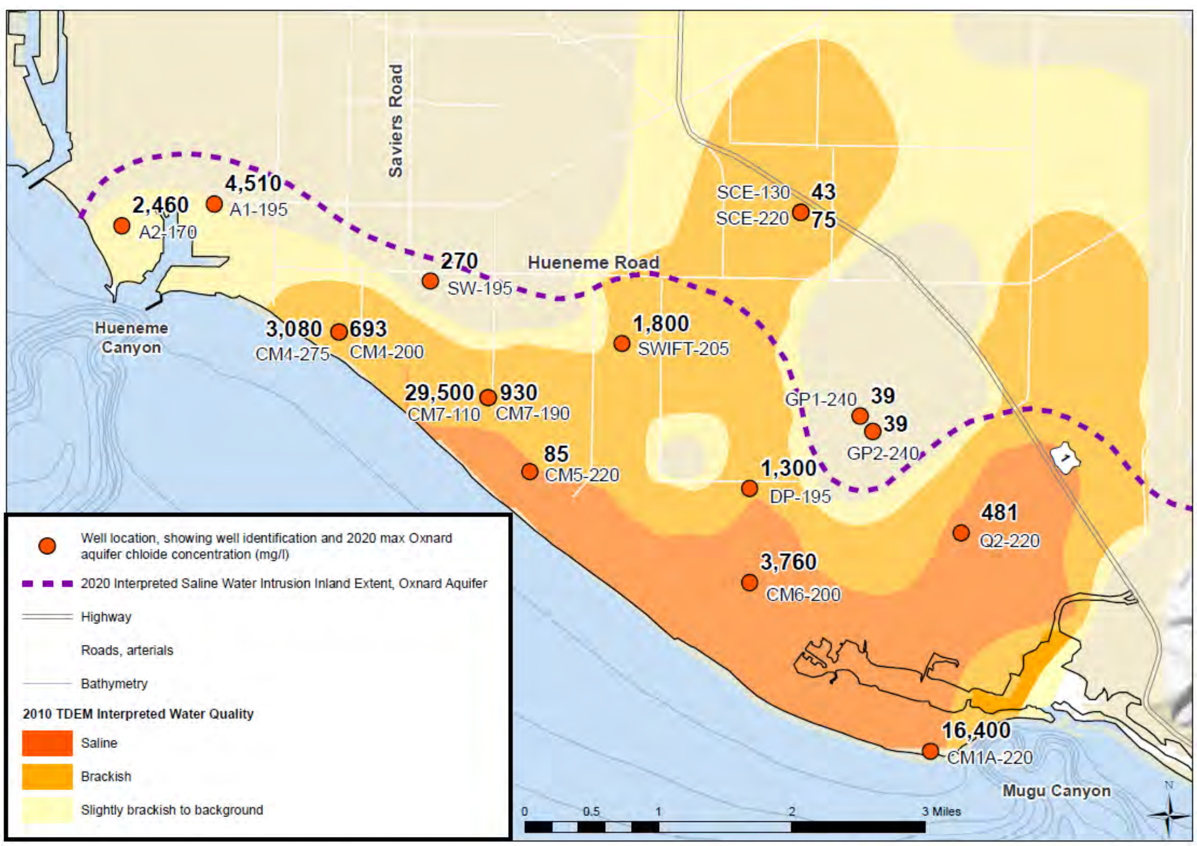

Figure 4.3.4. Oxnard aquifer maximum-recorded chloride concentrations, coastal monitoring wells, 2020.

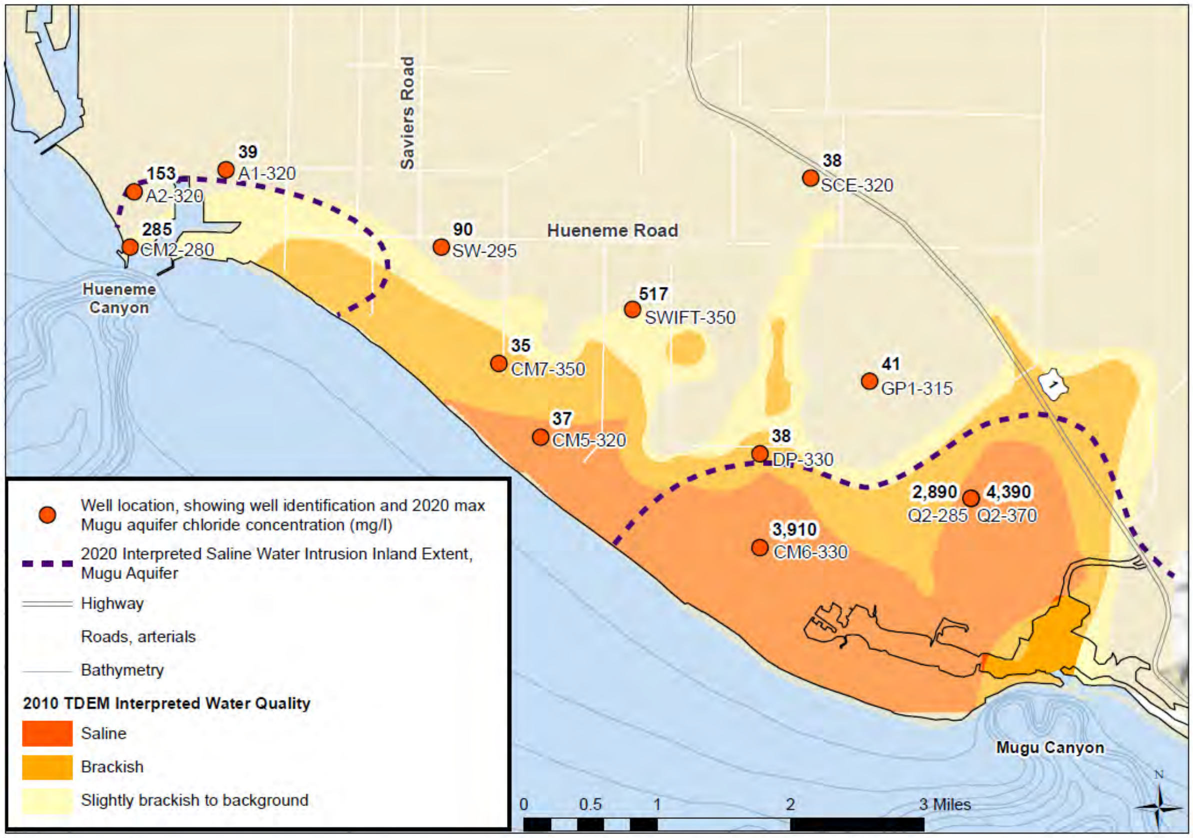

Figure 4.3.6. Mugu aquifer maximum-recorded chloride concentrations, coastal monitoring wells, 2020.

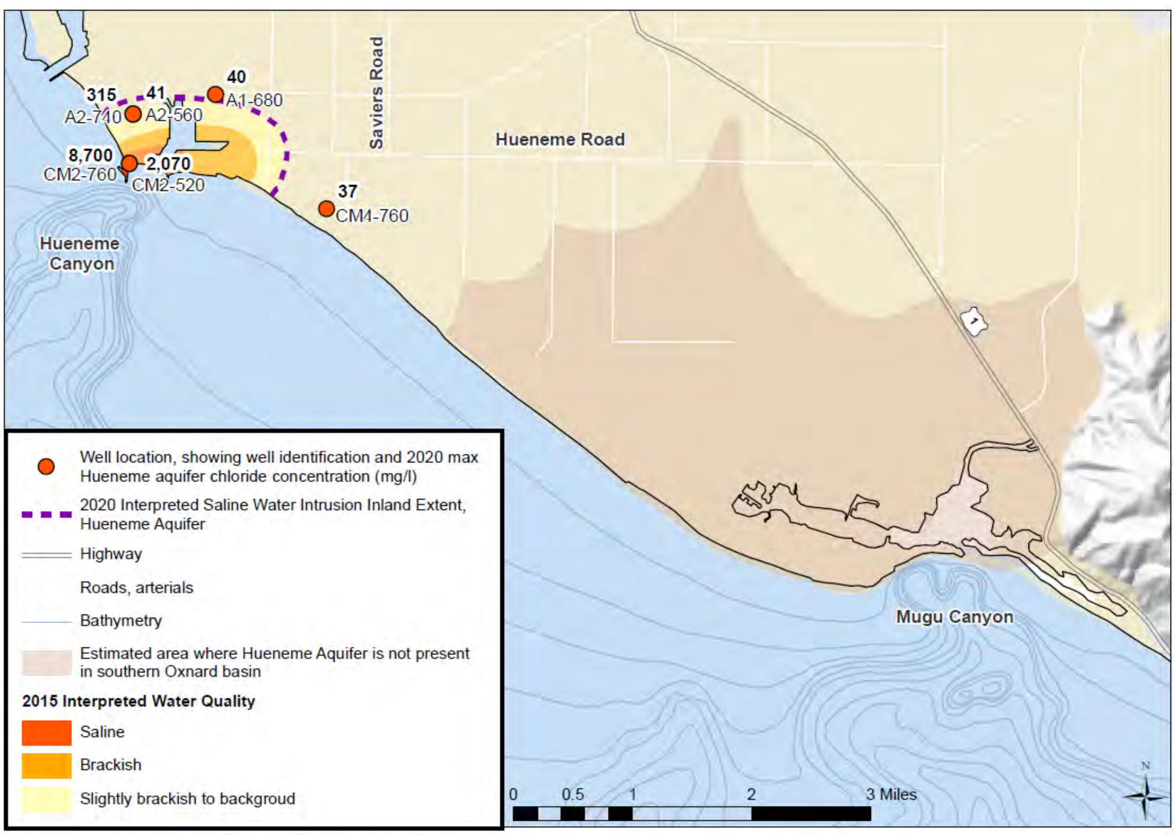

Figure 4.3.8. Hueneme aquifer maximum-recorded chloride concentrations, coastal monitoring wells, 2020.

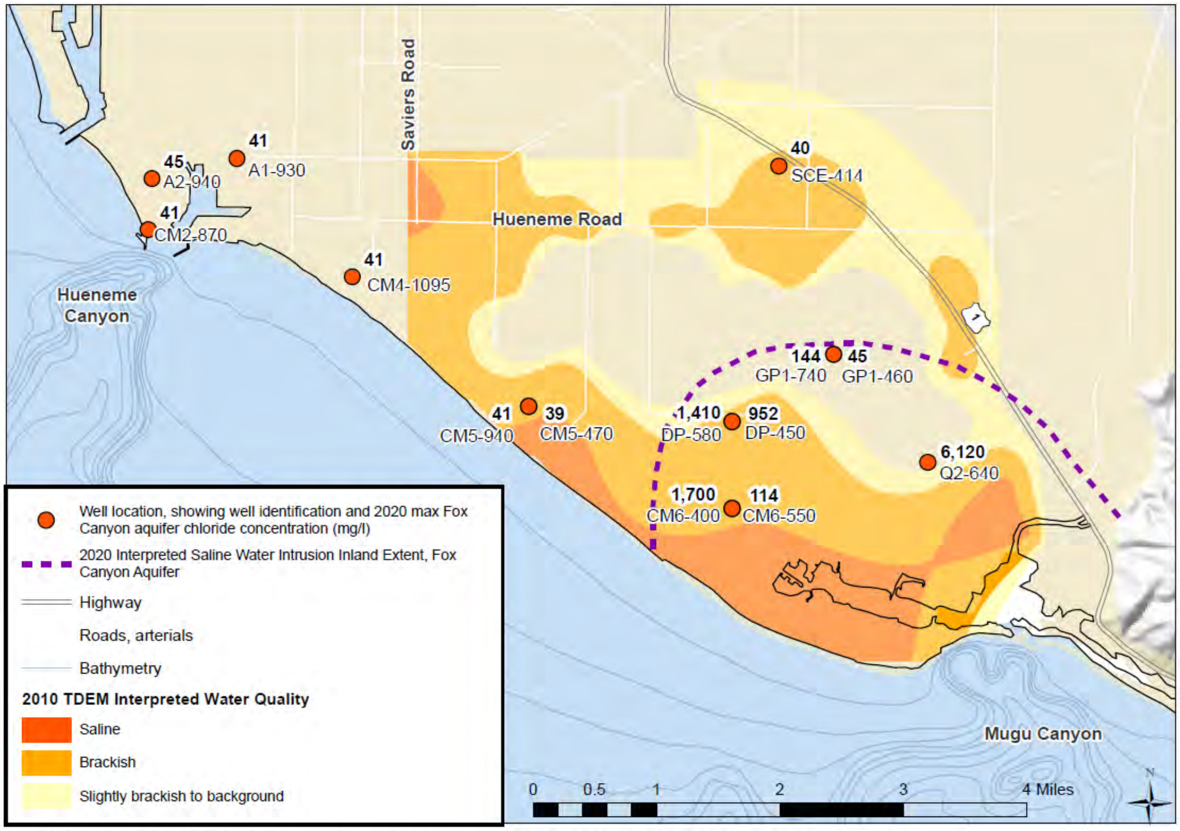

Figure 4.3.10. Fox Canyon aquifer maximum-recorded chloride concentrations, coastal monitoring wells, 2020.

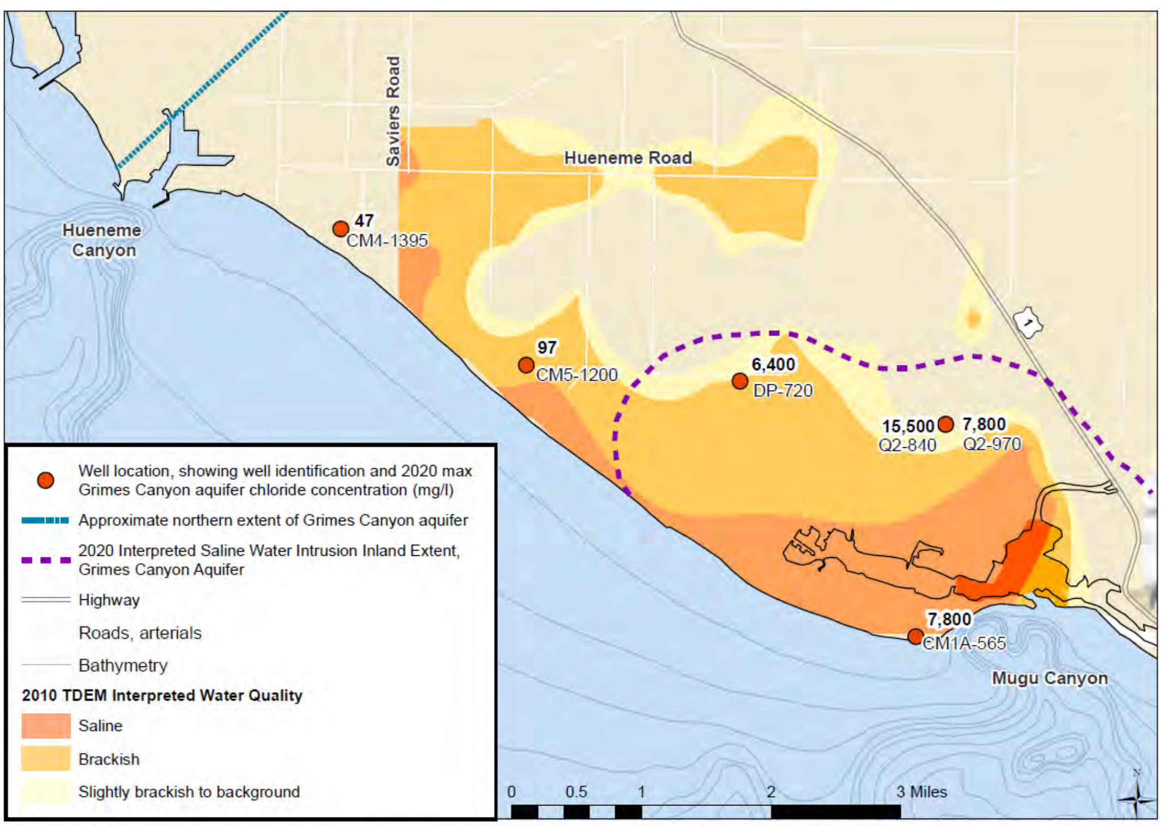

Figure 4.3.12. Grimes Canyon aquifer maximum-recorded chloride concentrations, coastal monitoring wells, 2020.

A. 3. REFERENCES

FCGMA and others, 2007. 2007 Update to the Fox Canyon Groundwater Management Agency Groundwater Management Plan. Prepared by Fox Canyon Groundwater Management Agency, United Water Conservation District, and Callegaus Municipal Water District. May.

United (United Water Conservation District), 2003, Inland Saline Intrusion Assessment Project Report submitted to the California Department of Water Resources. June.

United, 2016, Saline Intrusion Update, Oxnard Plain and Pleasant Valley Basins, United Water Conservation District Open-File Report 2016-04. October.

United, 2020, Saline Intrusion and 2020 Groundwater Conditions Update, Oxnard and Pleasant Valley Basins, United Water Conservation District Open-File Report 2021-03. November.

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