ANACAPA PROJECT FEASIBILITY STUDY

United Water Conservation District

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PREPARED BY

GROUNDWATER RESOURCES DEPARTMENT
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BASED UPON FUTURE ANALYSIS AND EVALUATION

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EXECUTIVE SUMMARY / ABSTRACT

This feasibility study describes the Anacapa Project, a proposed concept of United Water Conservation District (United). The goal of the project is to maximize the beneficial use of groundwater on the coastal Oxnard Plain of Ventura County, CA. Specifically, the Anacapa Project would pump groundwater from the Upper Aquifer System (UAS) (shallow aquifers) in the northwest portion of the Oxnard Plain near the coast (study area) and deliver this water to benefit other parts of the basin. The project is intended to operate only during years of normal and above-normal, precipitation when groundwater elevations are relatively high and groundwater flows from the inland areas across the Oxnard Plain towards the coastline. When these conditions exist, groundwater that is not being removed via wells (i.e., pumped) would otherwise flow past the coastline and be lost to the offshore portion of the aquifer system. The aquifers underlying the northwest portion of the Oxnard Plain are known to extend four to five miles offshore. The Anacapa Project would include: 1) a well field in the study area to capture groundwater that otherwise would flow offshore, and 2) a pipeline to convey that water back to the inland areas of the basin so that it can be put to beneficial use.

As part of this effort, United's Ventura Regional Groundwater Flow Model (VRGWFM or United Model) was used to simulate the operation of the Anacapa Project and evaluate the impacts of project options. The United Model simulated groundwater elevations for a base case scenario, representing conditions without the operation of the Anacapa Project and four pumping scenarios over a thirty one year period (1985-2015). The pumping scenarios simulated the operation of the Anacapa Project pumping 5,000 acre-feet (AF) in the study area and delivery of the project water to four different optional locations. The four delivery options are: 1) the City of Oxnard's potable water system, 2) United's Saticoy Recharge Facility, 3) United's Pumping Trough Pipeline (PTP) and 4) United's El Rio Recharge Facility. Options 2 and 4 are both located in the Oxnard Forebay basin, which is the primary recharge area for the Oxnard Plain.

The United Model results indicate that groundwater elevations declined in the study area from the increased pumping during implementation of the Anacapa Project. All pumping scenarios, with the exception of the PTP scenario, resulted in increased UAS groundwater elevations in the Oxnard Forebay basin. In the PTP scenario, groundwater delivered to the eastern side of the Oxnard plain resulted in increased UAS and LAS groundwater levels. A review of water quality data suggests that project water would not likely improve the water quality for any of the delivery options.

The United Model was used to simulate groundwater flux at the coast and quantify the volume of groundwater moving offshore and onshore over the thirty one year period (1985-2015). Results from the base case scenario show that without the operation of the Anacapa Project, the overall average groundwater flux in the UAS over the thirty one year period was onshore in aquifers that extend off the coast, despite intermittent periods of artesian conditions in this part of the basin. This is a different conclusion than what was drawn from the review of regional groundwater

elevation contour maps depicting spring and fall conditions over the last forty years. Groundwater elevations in the northwestern part of the Oxnard Plain were observed predominantly higher than in other parts of the coastal basin, and high enough to suggest groundwater flows offshore in this area most years. The United Model showed that large volumes of groundwater flow onshore during periods of drought when groundwater levels underlying the Oxnard Plain are suppressed. In all pumping scenarios, onshore groundwater flow increased as a result of implementing the Anacapa Project.

The United Model results show that groundwater flux in the base case scenario was predominantly offshore during three periods 1993-2003, 2005-2008, and 2011-2012, that the Anacapa Project was simulated in operation. However, the increased pumping in the study area was sufficient to change groundwater flow direction and create onshore flow conditions where project water was delivered to the Saticoy Recharge Facility and the PTP. When project water was delivered to the City of Oxnard and the El Rio Recharge Facility, offshore groundwater flow in the study area was greatly reduced.

United’s ability to divert surface water from the Santa Clara River into the Forebay is now less than in prior years due to regulatory constraints associated with the Endangered Species Act. The region continues to experience drought conditions with groundwater elevations across much of the coastal Oxnard plain below mean sea level. Even when wet conditions do return to the area, the recovery of groundwater storage in the coastal basins is expected to be slower than it was after the last major drought in the early 1990s. With less surface water diversions during future wet periods, groundwater levels might not increase as high as observed in the past, hence limiting the opportunities to implement the Anacapa Project.

Based on data analysis presented in this feasibility study, the Anacapa Project is not recommended due to the potential to cause onshore groundwater flow, and therefore seawater intrusion. The United Model results indicate that onshore movement of groundwater has been dominant for over thirty years during the study period and the additional pumping by the Anacapa Project would increase onshore groundwater flow. Maintaining an offshore groundwater flow direction is critical to keeping the seawater/freshwater interface away from the coast and the Anacapa Project would reduce groundwater flow offshore thereby, weakening the ability to buffer against seawater intrusion.

1 INTRODUCTION

United Water Conservation District (United) is a public agency that encompasses nearly 213,000 acres of central and southern Ventura County, California. United covers the downstream (Ventura County) portion of the Santa Clara River valley, as well as the coastal Oxnard Plain and serves as a steward for managing the surface water and groundwater resources for all or portions of eight interconnected groundwater subbasins (Figure 1-1). United is evaluating various strategies to maximize use of water resources and promote mutually beneficial programs. As part of this strategy, United is considering the Anacapa Project, the concept of pumping groundwater in the north western part of the Oxnard Plain basin and delivering this water to benefit other parts of the basin. This document provides an assessment on the feasibility of the Anacapa Project and includes the evaluation of measured hydrologic data in the study area. It also uses United's Ventura Regional Groundwater Flow Model (VRGWFM or United Model) to simulate the Anacapa Project and different delivery options. The United Model simulated four delivery options being considered, which are: 1) the City of Oxnard's potable water system, 2) United's Saticoy Recharge Facility, 3) United's Pumping Trough Pipeline (PTP) and 4) United's El Rio Recharge Facility (Figure 1-2).

The Oxnard Forebay basin "Forebay" is the main source of recharge to the Oxnard Plain basin (Figure 1-1). Groundwater stored in the Forebay slowly moves out to the outlying areas, flowing naturally from areas of high elevation to areas of lower elevation on the Oxnard Plain and near the coast. This flow of groundwater serves to raise or sustain groundwater elevations in wells in the down-gradient areas. It is intended that the Anacapa project operate only during normal and above normal precipitation years, when groundwater elevations are high and groundwater flows from the Forebay and across the Oxnard Plain towards the coastline. When these conditions exist, groundwater in the study area not captured (i.e., pumped) would otherwise flow past the coastline and into the offshore portion of the aquifer system. The Anacapa Project would include: 1) a well field in the study area to capture groundwater that otherwise would flow offshore, and 2) a pipeline to convey that water back to the inland areas of the basin so that it can be put to beneficial use.

1.1 PURPOSE AND SCOPE

The purpose of this study is to provide a quantitative analysis and supporting information to United's management and Board of Directors for their consideration of the Anacapa Project. In particular, it is intended to summarize key information relevant to the proposed project, including current hydrologic conditions in the study area, potential impacts of the project and give recommendations on project feasibility.

In support of the objective, the scope of work for this evaluation included the following tasks:

- Background information;
- Evaluation of potential locations for supplemental water use;
- Analysis of existing hydrologic conditions;
- United Model scenarios, results and discussion; and
- Conclusions and recommendations.

2 BACKGROUND INFORMATION

2.1 HYDROSTRATIGRAPHIC UNITS

The two regional aquifer systems under the Oxnard Coastal Plain are referred to as the Upper Aquifer System (UAS) and the Lower Aquifer System (LAS). The UAS consists of the Oxnard and Mugu Aquifers, and the LAS consists of the Hueneme, Fox Canyon, and Grimes Canyon Aquifers (Grimes Canyon Aquifer not present in the study area). Figure 2-1 is a schematic of the major UAS and LAS aquifers underlying the Oxnard Plain, showing their subsurface sequence, formation and age. The figure also shows representative depths in feet, and includes the layering used in the United Model.

The aquifers of the Oxnard Plain contain gravel and sand deposited along the ancestral Santa Clara River from three different sources, (1) alluvial fans along the flanks of the mountains; (2) a coastal plain/delta complex at the terminus of the Santa Clara River; and (3) marine deposits from transgressional seas. The highly-permeable deposits of the UAS are relatively flat and lie across approximately the upper 400 feet of the Oxnard Plain. Deposits of the LAS are generally finer-grained than those of the UAS and have been deformed by folding and faulting in many areas. Beneath the LAS lie older sedimentary and volcanic rocks, generally considered to be non-water bearing (Mukae and Turner, 1975). In addition, a shallow, unconfined semi-perched aquifer located just below land surface and overlying the UAS is present across much of the Oxnard Plain basin.

2.2 DIVERSION AND RECHARGE ACTIVITIES

The Forebay is hydraulically connected with the aquifers of the Oxnard Plain basin (Figure 1-1). Many of the confining clays present in the aquifer systems of the Oxnard Plain are absent or discontinuous in the Forebay, creating a window for recharge to other down-gradient aquifers. The aquifers of the Oxnard Plain basin are overlain by an extensive confining clay layer and therefore the primary recharge to the Oxnard Plain basin is from underflow from the Forebay, rather than the deep percolation of water from surface sources on the Plain. Natural and artificial recharge to the Forebay serves to raise groundwater elevations in this up-gradient area of the groundwater flow system for the Oxnard Plain. Changes in the volume of stored groundwater in the Forebay impacts the hydrostatic pressure in the confined aquifers extending from the margins of the Forebay to the coastal and offshore extensions of these aquifer. High groundwater elevations in the Forebay are desirable, as they are required to maintain offshore pressure gradients from the Forebay to coastal areas. While the physical movement of groundwater out of the Forebay is fairly slow, the pressure response in the confined aquifers distant from the Forebay responds rapidly to significant recharge events in the Forebay.

The Freeman Diversion is located on the Santa Clara River about 10.5 miles upstream from its mouth at the Pacific Ocean (Figure 1-2). It is a permanent concrete structure that redirects surface water from the Santa Clara River to United's recharge facilities, which include the El Rio, Saticoy, Noble, and Rose recharge basins. The routing of surface water to these recharge basins effectively recharges the aquifers underlying the Forebay and the Oxnard coastal plain. The Freeman Diversion also provides bypass flows for the upstream and downstream migration of endangered Southern California steelhead. The 2009 and 2010 Freeman Diversion Bypass Flow Plans implemented new rules for bypass flows, designed to increase the magnitude and extended the duration of the flows for upstream steelhead migration. It also provided downstream passage for young steelhead (smolts) to the estuary when conditions are favorable. While achieving the goals set forth for the migration of steelhead, potential surface water diversions have been reduced by about 20% to accommodate these new regulations. Santa Clara surface water flows have also diminished during the current drought since the regulations have been in place. United's average annual diversion of surface water from the Santa Clara River near Saticoy (27 year average, 1991-2017) is around 62,000 AF. Much of United's infrastructure is designed to maximize the use of surface water from the watershed of the Santa Clara River, but this infrastructure is of limited use when the river is dry or flows are minimal. Even when wet conditions do return to the area, the recovery of groundwater storage in the coastal basins is expected to be slower than it was after the last major drought (early 1990s). This is because United's ability to divert water at the Freeman Diversion is now less than in prior years due to the regulatory constraints associated with endangered species issues.

Figure 2-2 shows groundwater elevations from six UAS wells in the study area plotted with the annual groundwater pumped and recharged by United in the Forebay. The figure shows increased groundwater elevations in the study area during years with higher amounts of recharge in the Forebay. This illustrates the influence groundwater recharge in the Forebay has on aquifers in the Oxnard Plain along the coast. Three of the wells in the study area show artesian conditions.

2.3 GROUNDWATER EXTRACTIONS

The groundwater resources of the Oxnard Plain are heavily utilized to support overlying land uses. The area is famous for its highly-productive agriculture, supporting year-round production of a wide variety of agricultural products. Groundwater supports much of the agriculture on the Oxnard Plain but surface water deliveries also service some areas in the central and eastern portions of the Oxnard coastal plain. The Oxnard Plain also has an extensive urban population, which borders the study area to the east and south. The Cities of Oxnard and Ventura maintain active wells on the Oxnard Plain, but also rely on other sources of water for residential, commercial, and industrial uses.

The distribution of reported pumping in 2017 from wells screened in the UAS and wells screened in both aquifer systems (UAS and LAS) is shown on Figure 2-3. The results are typical of pumping patterns in recent years. The City of Oxnard operates several wells at its main well field to the east of the study area, near Third Street and Oxnard Blvd., in addition to a smaller well field and blending station located two miles to the northeast (near Gonzales Road and Rice Ave) shown on Figure 2-3. Aside from these city wells, UAS pumping is uncommon in the urban areas of the Oxnard Plain.

The distribution of LAS pumping on the Oxnard Plain is concentrated in the eastern half of the basin, as shown on Figure 2-4. The near-absence of LAS pumping in the northwest portion of the basin and the study area is notable. Within the study area, agriculture is the predominant land use and groundwater is pumped extensively from the UAS. Near the northern Oxnard Plain basin boundary and north of the Santa Clara River, the City of Ventura operates two LAS wells at the Buenaventura Golf Course and exports water to the Mound basin for municipal use.

Figure 2-5 shows available pumping data plotted along with UAS groundwater elevation data from 1979 through 2017 in order to evaluate the effect that pumping has had on groundwater elevations in the study area. Three of the wells in the study area show artesian conditions. As expected, pumping for agricultural uses far exceeds municipal applications, with annual municipal groundwater extractions not exceeding 500 AF since 1979. The amount of agricultural pumping is typically greater in years of below-average rainfall, as less irrigation demand is satisfied by rainfall. This was observed during the drought of the late 1980's and early 1990's, when the amounts of pumping were relative high and groundwater elevations were low. However, there has been a general decline in groundwater extractions within the study area throughout the last 30 years. The same relationship between pumping and groundwater levels is not as clear after 2012 when groundwater elevations began to decline but pumping remained relatively stable. The general decline in pumping may be attributed to more efficient irrigation practices or types of crops cultivated. Based on reported 2017 pumping from the study area, approximately 78% of the produced groundwater was sourced from the UAS, 17% from wells screened in both the UAS and the LAS, and 2% from the LAS only.

2.4 PRECIPITATION AND GROUNDWATER CONDITIONS

As mentioned in other sections of this report, natural and artificial recharge to the Forebay serves to raise groundwater elevations in this up-gradient area of the groundwater flow system for the Oxnard Plain. During periods of below average precipitation, the lack of significant storm events results in low flows in the Santa Clara River and limits the amount of water available for recharge in the Forebay. Available records show that groundwater elevations commonly decline during periods of below average rainfall.

Three years were selected to present examples of groundwater conditions on the Oxnard Plain during years of above-average precipitation (wet), average precipitation (typical) and below-average precipitation (dry). The precipitation measured from a gauge station at United's El Rio

Recharge Facility was calculated at 15.46 inches on average and used as the criterion to designate an above average, average and below average precipitation. The year 2006 was used as an example of groundwater conditions as a result of above average precipitation. In 2006, precipitation was measured at 16.3 inches and the year before in 2005, precipitation was recorded at 25.16 inches, about 163% of average. Typical groundwater conditions were represented in 2011 when precipitation was measured at about 75% of average (11.66 inches). The four years prior to 2011 had precipitation rates ranging from 60% to 149% of average. 2015 represented groundwater conditions as a result of below average precipitation, when precipitation was measured about 34% of average (5.27 inches). The year 2015 was the fourth-consecutive year of drought, with precipitation rates during the previous three years ranging from 21% to 67% of the long-term average.

The following sections provide a detailed review of contour maps from 2006 (above average precipitation), 2011 (average precipitation) and 2015 (below average precipitation). The figure below shows the range of UAS groundwater elevation contours mapped for each year. Groundwater elevations are observed at or above mean sea level (msl) across the Oxnard Plain during 2006 and 2011, with contours ranging from msl (0 ft.) to 130 feet above msl during spring and fall. Groundwater conditions during 2015 showed groundwater elevations were below msl in much of the Forebay and virtually all the Oxnard Plain. Groundwater elevation contours ranged from 30 feet below msl to 50 feet above msl during spring and fall.

Figure 2.4-1. The range of groundwater elevation contours mapped for the Forebay and Oxnard Plain during spring and fall of 2006, 2011 and 2015. Direction of groundwater flow is from the Forebay to the coast of the Oxnard Plain.

2.4.1 ABOVE AVERAGE PRECIPIATION - 2006

Figures 2-6 and 2-7 show the groundwater elevations contoured for UAS wells in the Forebay and Oxnard Plain for spring and fall of 2006, as an example of groundwater elevations during an above average precipitation period. Contouring shows that groundwater flows radially from recharge areas in the Forebay to surrounding areas throughout the Oxnard Plain (Figure 2-6). Significant natural and artificial recharge occurred in the Forebay during 2005 and 2006 and caused mounded groundwater conditions. In the north and western areas of the basin, groundwater elevations were above msl, with a 30-foot elevation contour was relatively close to the coast. Artesian conditions existed in coastal areas of the north and central Oxnard Plain. In fall 2006, UAS groundwater elevations were about ten feet lower than they were in the spring, however remained above msl at the coastline (Figure 2-7). This is typical for groundwater levels in the confined aquifers of the Oxnard Plain and exhibit a distinct annual signature. Increased pumping and lower rainfall results in lower groundwater elevations in the summer and fall of the year followed by some degree of recovery the following winter and spring. When groundwater elevations are high across the basin, groundwater may flow past the coastline to the offshore extension of the Oxnard Plain aquifers, or exit the groundwater flow system as discharge to the sea at the near-shore Hueneme submarine canyon.

Groundwater elevations from LAS wells contoured for the spring and fall of 2006 for the Oxnard Plain and Pleasant Valley basins are presented in Figures 2-8 and 2-9. During the spring when groundwater elevations are typically higher, groundwater elevations in the northern and western areas of the basin were above msl, with a 20-foot elevation contour along the coast. The southern and eastern portions of the Oxnard Plain remained below msl. During fall of 2006, groundwater levels were lower than in spring, and remained above msl near the study area.

2.4.2 AVERAGE PRECIPIATION - 2011

Figures 2-10 and 2-11 show the groundwater elevation contours for UAS wells in the Forebay and Oxnard Plain basins for spring and fall of 2011 as an example of a typical precipitation year. Contouring of recorded spring UAS groundwater elevations show that groundwater flows radially from recharge areas in the Forebay to surrounding areas (Figure 2-10). Significant natural and artificial recharge occurred in the Forebay and caused mounded groundwater conditions. Artesian conditions also existed in coastal areas of the northern and southwestern Oxnard Plain. In the north and western areas of the basin, groundwater elevations were above msl, with a 20-foot elevation contour was relatively close to the coast (Figure 2-10). In fall 2011, UAS groundwater elevations in most areas of the Oxnard Plain were similar to what they were in the spring, suggesting that between spring and fall the amount of groundwater pumped on the Plain was replenished by water moving from the Forebay to the Plain (Figure 2-11). In the northwestern part of the Oxnard Plain, groundwater elevations remained above msl, with the 10-foot contour mapped through the study area and extending into the Mound basin to the north.

The groundwater elevations in the LAS were contoured for the spring and fall of 2011 for the Forebay, Oxnard Plain and Pleasant Valley basins (Figures 2-12 and 2-13). Groundwater elevation records and associated contouring shows that in the aquifers of the LAS, groundwater flows from the Forebay to the large pumping depression in the eastern Oxnard Plain and the Pleasant Valley basin. Measured groundwater elevations in LAS wells in the study remained above msl.

2.4.3 BELOW AVERAGE PRECIPIATION - 2015

Figures 2-14 and 2-15 show the groundwater elevations contoured for UAS wells in the Forebay and Oxnard Plain basins for spring and fall of 2015, as an example of a year with below average precipitation. Conditions are far from typical, with heads in much of the Forebay and virtually all the Oxnard Plain measured below msl. Between spring 2012 and spring 2015 the zero-elevation contour moved about ten miles inland, from near Mugu lagoon to the northern portion of the Forebay. The negative 10-foot contour is drawn within about a mile of the coast across the entire Oxnard Plain coastline, indicating onshore gradients at all locations (Figure 2-14). A zero-elevation contour is positioned along a small section on the northern coast in the study area, indicating slightly higher groundwater elevations here. Groundwater elevations in the interior portions of the basin were quite flat, with a few minor pumping depressions. By fall 2015, UAS groundwater elevations were lower than in the spring, with the negative 20-foot contour drawn near the coast all along the margin of the basin (Figure 2-15). A negative 10-foot contour is drawn along the northern coast from the basin boundary, through the study area and to the Port Hueneme harbor.

Groundwater elevations from LAS wells contoured for the spring and fall of 2015 for the Oxnard Plain and Pleasant Valley basins are presented in Figures 2-16 and 2-17. In the spring of 2015, a pumping depression centered near the Oxnard Plain/Pleasant Valley basin was clearly visible. Groundwater elevations in the north and western portions of the basin were quite flat, with groundwater elevations below msl. In fall 2015, the depression is much deeper and broader, having expanded to the east in the Pleasant Valley basin. The northern and western portions of the basin remained flat, with groundwater elevations recorded about ten feet lower than in spring.

3 LOCATIONS FOR SUPPLEMENTAL WATER USE

Supplemental water produced through the Anacapa Project could be delivered to other areas of the Oxnard Plain to be put to beneficial use. The United Model was utilized to asses both the groundwater level impacts in the project area and the benefit in areas where water is delivered. The locations being considered to deliver project water are: (1) delivery to the City of Oxnard; (2) the Saticoy Recharge Facility; (3) the Pumping Trough Pipeline (PTP) system; and (4) the El Rio Recharge Facility (Figure 1-2). A brief discussion of each location is provided in the following sections. At the end of the discussion, Table 3-1 is presented as a summary of possible benefits for each location.

3.1 CITY OF OXNARD

United's municipal wells at the El Rio Recharge Facility produce water for the Oxnard – Hueneme (O-H) pipeline that supplies drinking water to the cities of Oxnard and Port Hueneme, a number of mutual water companies, and Naval Base Ventura County. The O-H system supplies water from the Forebay, rather than pumping individual wells in coastal areas of the Oxnard Plain that may be subject to seawater intrusion. The City of Oxnard is United's largest O-H customer. The City's other two sources of water include water from their own wells on the Oxnard Plain and imported State Water purchased from Calleguas Municipal Water District.

The benefit of delivering Anacapa Project water to the City of Oxnard would be to lessen the water supply demand on the El Rio facility's O-H wells. By delivering water to the City of Oxnard, groundwater underlying the El Rio Recharge Facility would not be pumped and would remain in the ground.

3.2 SATICOY RECHARGE FACILITY

The Freeman Diversion, constructed in 1991, is located on the Santa Clara River about 10.5 miles upstream from its mouth at the Pacific Ocean. The Saticoy Recharge Facility is located near the Freeman Diversion and receives surface water diverted from the Santa Clara River. The Facility includes the Saticoy, Noble, and Rose recharge basins and allows recharge of the aquifers underlying the Forebay and the Oxnard coastal plain.

Lower volumes of water were recharged in the Saticoy Recharge Facility the last few years due in part to the lower flows in the Santa Clara River, resulting in less surface water available for the Freeman Diversion. The prioritizing of recharge at the El Rio Facility to dilute high nitrate concentrations in its underlying UAS groundwater has also contributed to lower recharge totals at the Saticoy Recharge Facility.

If this option was chosen to receive Anacapa Project water, project water would be delivered to the Saticoy Recharge Facility spreading basins. With diminishing opportunities to divert surface water, the Anacapa project water would serve as another source of recharge to the Saticoy facility. Recharge at this facility would help increase groundwater elevations in the Forebay and the Oxnard Plain basins.

3.3 PUMPING TROUGH PIPELINE (PTP)

The Pumping Trough Pipeline (PTP) was designed to serve surface water from the Santa Clara River to an area of the Oxnard Plain located east of the City of Oxnard. In the 1970s the aquifers of the UAS were severely over-drafted in this vicinity, and there were fears that seawater would be drawn from coastal areas to this central portion of the Oxnard Plain, and eventually to the Forebay. Five LAS wells were constructed along the PTP pipeline to balance pipeline pressures and provide additional water to the system when surface water supplies are incapable of meeting demand. Water from the Saticoy well field (and occasionally water from O-H wells #12 and #13) can also be used when groundwater elevations are high near United's recharge facilities.

During the current drought conditions, nearly all demands on the PTP system have been met by pumping groundwater from the District's wells. Any surface water available for diversions has recharged El Rio basins whenever possible, due to the need to reduce nitrate concentrations in El Rio UAS wells. As a result, the PTP system has struggled to meet demand at times in recent years, and a number of growers have used their own UAS wells in the PTP service area.

If this option was chosen, then Anacapa Project water would be delivered directly to PTP customers. The supplemental water would lessen the water supply demand on the five LAS PTP system wells and the customer's wells. When surface water is available, it would be the preferred source of water for the PTP. However, when groundwater elevations in the study area are high, but surface water is not available, then project water could be delivered in lieu of pumping the PTP wells.

3.4 EL RIO RECHARGE FACILITY

The El Rio Recharge Facility, including the El Rio recharge basins, is located approximately two miles southwest of the Saticoy Recharge Facility, and adjacent to the community of El Rio. Surface water diverted from the Santa Clara River delivered to El Rio can be distributed among ten recharge basins by using United's infrastructure of pipelines, distribution canals and control gates.

The Forebay is vulnerable to nitrate contamination for some of the same reasons the basin is valued for water resource projects. The coarse alluvial sediments common to the area allow the rapid vertical transport of water from the near-surface to the water table. Nitrate loading to the groundwater is principally related to land uses within the Forebay, with the most significant sources being agricultural fertilizers and septic systems. Nitrate levels in the El Rio area have fluctuated widely through time, with highest nitrate levels commonly observed during and following drought periods, while relatively low nitrate levels are often recorded during wet periods (UWCD, 1998). Nitrate levels tend to stay relatively low during wet periods when low-nitrate Santa Clara River water is spread by United in the El Rio recharge basins and natural recharge to the basin is abundant. However, when there is not sufficient river water to spread at El Rio, nitrate levels in wells often rise, particularly in the northeastern (up-gradient) portion of the spreading grounds. Wells at the El Rio facility produce water for the O-H pipeline, which delivers potable water to the City of Oxnard, the Port Hueneme Water Agency and other users in coastal areas of the Oxnard Plain. Nitrate is a primary health standard and nitrate concentrations in delivered water must remain below 45 mg/l nitrate at all times.

The well field at El Rio Recharge Facility includes both Upper and Lower Aquifer wells, allowing a blending of sources for water quality purposes. In practice, the LAS wells are rarely used, as they are primarily used as alternative wells when the shallower UAS wells have high nitrate concentrations. However, due to drought conditions, the LAS wells have been used extensively in the last few years. While nitrate concentrations in the LAS wells are low, the wells commonly produce water that exceeds the secondary health standards for iron and manganese. Precipitation of iron and manganese results in a high Silt Density Index (SDI) that poses operational challenges for the Port Hueneme Water Agency, who operate a reverse osmosis (RO) system to treat water purchased from United. United is currently designing an iron and manganese treatment facility at El Rio with plans to start construction at the end of 2019.

If this option was chosen to receive Anacapa Project water, project water would be delivered to the El Rio Recharge Facility spreading basins. Having an additional source of water with low nitrates would be beneficial to the El Rio facility and the O-H water users. Although when groundwater elevations are lower in El Rio, they are likely also low throughout the Oxnard Plain, including the study area. Therefore, the Anacapa Project water would normally not be available when high nitrate levels were an issue. The project water would serve more as a source of water to help increase groundwater elevations during wet periods so when groundwater does decline, it would not be as severe.

3.5 SUMMARY OF BENEFITS

Table 3-1 is presented as a brief summary of possible benefits for each delivery location.

Table 3-1. Summary of anticipated water supply benefits at each location considered to receive supplemental water through the Anacapa Project

Delivery Option	Location	Summary of Anticipated Water Supply Benefits
1	City of Oxnard	Lessen the water supply demand on the El Rio facility's O-H wells, which the City of Oxnard is the largest customer. By delivering water to the city of Oxnard, groundwater underlying the El Rio Recharge Facility would not be pumped and would remain in the ground.
2	Saticoy Recharge Facility	With diminishing opportunities to divert surface water, another source of recharge to the Saticoy recharge facility would help groundwater elevations in the Forebay and Oxnard Plain basins.
3	Pumping Trough Pipeline	Lessen the water supply demand on the PTP system wells and the customer's wells in the PTP service area.
4	El Rio Recharge Facility	With diminishing opportunities to divert surface water, another source of recharge to the El Rio recharge facility would help groundwater elevations in the Forebay and Oxnard Plain basins. Additional recharge at El Rio would also help mitigate the high nitrate concentrations that are common in the O-H well field.

4 HYDROGEOLOGIC EVALUATION IN STUDY AREA

4.1 GROUNDWATER GRADIENTS

Groundwater elevation contour maps produced by United (for the years 1975 to 2017) were examined to assess historic groundwater levels and common direction of groundwater flow in the study area. The review included comparison of groundwater elevation contours and a density-corrected elevations for the UAS and LAS. A density-corrected elevation is necessary to account for the higher density of seawater (2.5%) relative to freshwater. It represents an approximate elevation that groundwater inland from the seawater/freshwater interface needs to maintain in order to counteract the pressure head exerted by seawater. This elevation is high enough to create a neutral to offshore hydraulic gradient, which theoretically prevents seawater intrusion onto the Oxnard Plain. In reality, the processes involved with seawater intrusion in freshwater aquifers are more complex than just a density-dependent hydrostatic balance, but this simplified approach is suitable for this preliminary evaluation.

As an example of our approach, groundwater elevations in the Oxnard aquifer, which is mapped to a depth of approximately 250 feet below msl, would have to be 256.25 feet above that depth, or 6.25 feet above msl to counter the higher density of seawater. Note: 2.5 feet of additional freshwater head is required per 100 feet of aquifer depth to prevent seawater intrusion in to the freshwater coastal aquifers. In the LAS, the Hueneme aquifer has a depth of approximately 1,100 feet below msl in the study area. Therefore, freshwater head would have to be 1,127.5 feet above that depth or 27.5 feet above msl to counter the higher density of seawater. One aquifer was chosen in the UAS and the LAS and used to calculate a density corrected groundwater elevation. The density-corrected groundwater elevation of the Oxnard aquifer was used to compare to the historic UAS groundwater elevation contour maps. Likewise, the density–corrected groundwater elevation of the Hueneme aquifer was used to compare to historic LAS groundwater elevation contour maps. When groundwater elevations were below the required density-corrected elevation, it was assumed that groundwater flow was onshore. Conversely, if groundwater contours were above the density-corrected elevation, then offshore groundwater flow was assumed in the study area.

4.1.1 HORIZONTAL GROUNDWATER GRADIENTS

A review of available groundwater elevation contour maps produced by United showed that generally groundwater elevations in the study area have been higher than other coastal areas of the Oxnard Plain. Groundwater elevation contour maps were reviewed during a 43-year time period from 1975 through 2017. During this period, UAS groundwater levels in the study area were observed at or above the density-corrected elevation for approximately 30 of the years in the spring (70% of years) and 26 years during the fall (or 60% of years). Time periods when UAS groundwater elevations were noticeably low include the late 1970s, the early 1990s and the recent period of drought. Groundwater levels in the LAS were never observed at or above the density-corrected elevation, suggesting onshore groundwater flow is typical in the LAS.

4.1.2 VERTICAL GROUNDWATER GRADIENTS

Vertical gradients commonly exist between aquifer units on the Oxnard Plain, resulting in water movement through or around the low-permeability units located between most of the major aquifers. When LAS groundwater elevations are significantly lower than UAS groundwater elevations (creating a downward gradient), there is substantial leakage of UAS water into the LAS through the various aquitards that separate the aquifer units. A downward-pressure gradient also commonly exists between the Semi-perched aquifer and the Oxnard aquifer, as heads in the shallow confined Oxnard aquifer may be lowered regionally by drought conditions diminished recharge or locally by the pumping of wells. The movement of poor quality water from the Semi-perched aquifer to the Oxnard aquifer has been documented in some locations of the Oxnard Plain, with abandoned or improperly constructed wells being one notable pathway for this downward flow (Izbicki, 1992; Stamos et al., 1992).

Some hydraulic connection between the UAS and the shallower units of the LAS is thought to exist in the north western part of the Oxnard Plain. The clay layers (aquitards) separating the Oxnard-Mugu and Mugu-Hueneme aquifers are thin or discontinuous at several locations within the study area. The Oxnard-Mugu aquitard thickness ranges from 0 to 35 feet throughout the study area. The Mugu-Hueneme aquitard ranges from 0 to 25 feet in the north western part of the study area, increasing in thickness to about 85 feet further south, as shown in aquitard thickness contours featured on Figure 4-1. Where aquitards are thin or discontinuous, the opportunity exists for water to move more easily through these units. This allows an increase in water passage between the UAS and the shallower units of the LAS. Figure 4-2 displays recorded groundwater elevations in the study area from UAS wells plotted along with two monitoring wells screened in the Hueneme aquifer (the uppermost aquifer of the LAS). Three of the wells in the study area show artesian conditions. The artesian pressures in some wells are not commonly measured, therefore an arbitrary elevation of 50 feet above msl was used to clearly denote unmeasured artesian conditions. It was observed that despite the deeper screened interval of the LAS wells, the groundwater elevations were similar to those of shallower wells in the study area, especially during periods when groundwater levels were lower. The similar groundwater elevations suggest hydraulic connection between the UAS and the shallower units of the LAS.

Nearby LAS wells close to Victoria Avenue and the northern boundary of the Oxnard Plain have also recorded groundwater elevations similar to nearby UAS wells (UWCD, 2010). However, the Mugu-Hueneme aquitard in this area is interpreted to be about 25 feet thick, and it is uncertain if the similar groundwater elevations result from a thin aquitard or well seal issues that fail to isolate the UAS from the LAS.

4.2 GROUNDWATER ELEVATIONS

The following sections present information on the groundwater elevations from UAS and LAS wells in the study area. Available groundwater elevation data from seven UAS wells in the study area are presented in this report. Two wells are monitoring wells, and the remaining UAS wells are production wells used for agriculture, industrial or domestic use. There are few LAS wells in the northwestern part of the Oxnard Plain, therefore little LAS groundwater level data is available in the study area. Available groundwater elevation data from three LAS monitoring wells are presented in this report.

4.2.1 UPPER AQUIFER SYSTEM WELLS

A map of historical groundwater elevation records from UAS wells within the study area are shown in Figure 4-1. Included in the figure are the Mugu-Hueneme aquitard thickness contours, distinguished by different colors shown in the legend. Wells that are in areas with little to no aquitard between the lower UAS and the upper units of the LAS include monitoring well 01N23W01C05S (CM3-145) and wells 02N23W36C04S and 02N23W25G02S. The remaining UAS wells with groundwater elevation records are located in areas where the Mugu-Hueneme aquitard is thicker (about 20-30 feet). It is typical for groundwater levels in the confined aquifers of the Oxnard Plain to exhibit a distinct annual signature. This is observed in all the wells with lower groundwater elevations in the summer and fall of the year due to increased pumping and lower rainfall followed by some degree of recovery the following winter and spring. The absence of notable recharge to the basin in recent winters resulted in near-continuous groundwater elevation declines in many wells over the past six years. Another period of drought, around 1989 to 1991 is evident in the records, with groundwater elevations similar to what exist today. Wells with older records show a notable decline in groundwater elevations from about 1976 to 1978. Other than these three periods of decline, records show that UAS wells in the study area generally sustained groundwater levels above the density-corrected elevation. Two wells (02N23W36C04S and 02N23W25G02S) located in the northwest corner of the study area show artesian conditions. These two wells are closest to the mouth of the Santa Clara River where the river meets the Pacific Ocean.

The groundwater elevation data collected from monitoring well CM3-145 is significantly different when compared to other wells screened nearby in the same aquifer, as shown in Figure 4-1. The groundwater elevation does not rise or fall in well CM3-145 as much as the other UAS wells in the study area. This effect is most obvious during the years of extreme precipitation, such as years of drought and above average rainfall. It is unknown at this time why the groundwater elevation in well CM3-145 is different than other wells in the area with the same screened aquifer.

Figure 4-3 displays the groundwater elevations plotted together from the UAS wells screened in the Oxnard aquifer within the study area. These are the same wells as presented in Figure 4-1, however, the hydrographs for each well are shown separately in Figure 4-1. In addition to mean sea level shown in red, the density-corrected elevation for the Oxnard aquifer in the UAS is shown in green. Available data from 1972 to 2017 show groundwater elevations above the density-corrected elevation for approximately 28 years or 61% of the time, namely during the periods between the major droughts of the late 1970s, early 1990s, and the present drought starting in 2012. Three of the wells in the study area show artesian conditions.

Coastal UAS monitoring well CM3-145, located in the study area and screened in the Oxnard aquifer, has a pressure transducer installed, which is an instrument that allows groundwater elevations to be recorded at frequent time intervals. The transducer was programed to collect head measurements at 15-minute intervals for a month and a half period (from February 5th to March 19th, 2018) to evaluate tidal influences. The record shows a rise and fall of groundwater elevations corresponding with tidal fluctuations (Figure 4-4).

4.2.2 LOWER AQUIFER SYSTEM WELLS

Few LAS wells exist in the northern part of the Oxnard basin. A map of historical groundwater elevation records from LAS monitoring wells within the study area are shown on Figure 4-5. United regularly monitors the nested monitoring well CM3, which has three LAS wells, with two wells screened in the Hueneme aquifer and one in the Fox Canyon aquifer. Periods of drought (notably 1989-1991 and 2012-present) are clearly evident, with measured groundwater elevation declines of around 60 feet. Annual groundwater level fluctuations of greater than thirty feet are common for the confined conditions of the LAS in this vicinity.

Figure 4-6 displays groundwater elevation data since 1989 from two monitoring wells screened in the Hueneme aquifer within the study area. Over the past 30 years groundwater elevations were above msl for the majority of time, however, they only rose above the density-corrected elevation line for three years in well CM3-695. The deeper of the two Hueneme aquifer wells (CM3-1065) never recorded groundwater elevations above the density-corrected line. Monitoring well CM3-1490 is screened in the Fox Canyon aquifer and shows similar results, with groundwater levels never rising above the density-corrected elevation of 40.63 feet above msl (aquifer depth approximately -1,625 feet msl). This suggests that onshore hydraulic gradients in the LAS aquifer are typical in this vicinity.

4.3 WATER QUALITY

Groundwater quality is somewhat variable among wells on the Oxnard Plain but generally is adequate for most agricultural and municipal/industrial uses. Groundwater tends to be somewhat mineralized (TDS, sulfate, iron, manganese) due to the marine deposition of many of the aquifers but contamination by organic contaminants is uncommon (Burton et al., 2011). Nuisance concentrations of iron and manganese are most commonly associated with LAS wells where reducing conditions are present. In areas impacted by direct seawater intrusion, or various other forms of saline intrusion, water quality is commonly degraded such that it is not suitable for beneficial use. Saline intrusion has not been recognized in the Anacapa project area (UWCD 2016).

Water quality data for groundwater samples collected since 1950 from wells within the study area and screened in the UAS are shown in Figure 4-7. United regularly collects water quality samples from the CM3 nested monitoring wells in the study area, shown in Figure 4-1. Water quality data from other wells in the study area were collected by other agencies. One well, 02N23W25G02S, has noticeably higher concentrations of parameters than the rest of the samples from UAS wells in the study area. This well is screened in the semi-perched/Oxnard aquitard and the poor quality water from the Semi-perched aquifer may be the source. Because of the difference in water quality, data from this well was not included in the discussion or in Table 4-1 below. Seawater intrusion does not seem to be an issue in the study area as the sodium and chloride levels have been largely similar to native concentrations in the basins of the Santa Clara River valley. Sodium concentrations have been measured from approximately 80 to 150 mg/l and chloride concentrations have generally been below 80 mg/l. Four wells have shown chloride concentrations measuring above 80 mg/l, with one well peaking at 130 mg/l in 2002. Chloride levels in all wells have been below 80 mg/l since 2012. Most samples from wells have nitrate concentrations below 40 mg/l, which are below the California Department of Public Health standard of 45 mg/l. Samples from three wells show nitrate concentrations above 40 mg/l, however have been below 40 mg/l since 1999. Total Dissolved Solids (TDS) has generally ranged from 750 to 1,500 mg/l. Sodium adsorption ratio (SAR) is an irrigation water quality parameter used as an indicator of suitability of water for agricultural use. SAR values in samples from UAS wells range from 1.7 to 2.6, and is considered a low hazard for irrigation.

As mentioned earlier, there are few wells in the study area screened in the LAS, therefore limited water quality data exists for the deeper aquifers here. Water quality data from CM3 nested monitoring wells and one other well located in the study area from 1985 to 2017 are plotted on Figure 4-8. Sampling of these wells show generally similar or lower concentrations of chloride, nitrate, TDS and sodium when compared to UAS samples. SAR values in the LAS wells are low and range from 1.7 to 2, with the exception of CM3-1490, which has had SAR values around 4.3, which is considered a slight hazard for irrigation use.

Table 4-1, below, summarizes the water quality from wells in the study area and selected locations considered to receive water from the Anacapa Project. Two concentration ranges are displayed for each water quality parameter and contain data from two timeframes, including (1) all available data, which includes sampling during both dry and wet periods and (2) a subset of all available data that includes only data collected during three time periods (1993 to 2003, 2005 to 2008, and 2011 to 2012), years selected for the hypothetical operation of the Anacapa Project in simulated scenarios. More information on the United Model and simulated scenarios are provided in

Section 5. The concentration ranges for Nitrate include data as "not detected", which is reported when a concentration is below the stated reporting level for that test. The stated reporting level is commonly 0.4 mg/l but has also been as high as 2 mg/l when samples are diluted before analysis.

Table 4-1. Water quality from wells in study area and selected locations considered to receive supplemental Anacapa Project water

Locations	Data Collection Timeframes	Concentration Ranges (mg/l)			
		Sodium	Chloride	Nitrate	TDS
Study Area UAS groundwater	1950-2017	82-166	29-130*	ND-66**	733-1,460
	Anacapa Project	83-155	37-130*	ND-59.6**	770-1,460
Study Area LAS groundwater	1985-2017	76-130	30-62	ND-24.8	446-1,150
	Anacapa Project	76-130	30-62	ND-24.8	446-1,150
Delivery options for supplemental Anacapa Project water					
City of Oxnard O-H Delivered Water (blended and treated)	1981-2017	71-110	32-74	1.3-41	670-1,220
	Anacapa Project	71-110	34-74	1.3-37	670-1,200
Saticoy Recharge Facility UAS Groundwater	1991-2017	58-226	24-153	ND-42	564-2,080
	Anacapa Project	58-102	25-82	ND-42	564-1,290
PTP wells LAS Groundwater	1990-2017	62-158	35-69	ND-8.7	833-992
	Anacapa Project	62-158	35-67	ND-8.7	833-992
El Rio Recharge Facility UAS Groundwater	1956-2017	60-156	20-97	ND-176	600-1,910
	Anacapa Project	60-116	23-80	ND-86.7	600-1,270
Santa Clara River surface water collected at the Freeman Diversion	1991-2017	33-199	4.9-180	ND-16.4	340-2,080
	Anacapa Project	53-180	4.9-106	ND-16.4	400-1,630

* Data show that chloride concentrations have generally been below 80 mg/l

** Data show that nitrate concentrations have generally been below 40 mg/l

ND= Not Detected; measured concentrations are below the stated reporting level.

When comparing the water quality between the two data collection timeframes, the El Rio and Saticoy Recharge Facility and the surface water collected at the Freeman Diversion show improved water quality during the years of Anacapa Project operation. The water quality of the Santa Clara River water varies a great deal depending on river conditions. For example, the mineral content of water in the river exhibits a strong negative correlation with flow, where higher flows are less mineralized. Santa Clara River water is diverted to recharge the aquifers underlying the El Rio and Saticoy facilities, which extend across the Oxnard Plain. The UAS wells at El Rio are known to produce groundwater with high levels of nitrate, especially during drought periods.

In general, UAS groundwater in the study area has concentrations of sodium, chloride, nitrate and TDS that are similar or elevated when compared to other sources of water, as shown in Table 4-1. Data suggests that the water produced by the Anacapa Project would not likely improve the water quality at any of the delivery options. Because of the potential for a higher range of water quality parameters in the study area, it may be better for project water to be used for groundwater recharge rather than direct use.

5 UNITED MODEL ANALYSIS AND RESULTS

5.1 INTRODUCTION

United has developed the Ventura Regional Groundwater Flow Model (VRGWFM or United Model), a numerical groundwater flow model for the aquifers within United's service area (UWCD, 2018). The current active domain of the United Model includes the Forebay, Mound, Oxnard Plain, Pleasant Valley, and West Las Posas basins, part of the Santa Paula basin, and the offshore areas of the principal aquifers that underlie the Oxnard Plain and Mound basins. The active model domain spans approximately 176,000 acres (275 square miles). Efforts are currently underway to expand the model to include the groundwater basins of the Santa Clara River Valley, including the Santa Paula, Fillmore, and Piru basins. The domain of the Model was subdivided into finite-difference grid cells and layers such that basin-scale hydrogeologic features, boundaries, and flow patterns could be simulated at an acceptable level of resolution. This was accomplished while keeping model run-times to a reasonable length during calibration and sensitivity analysis. At present, the model-grid spacing is divided into 13 layers representing the seven recognized aquifers and six aquitards present in the model area, as shown in Figure 2-1.

The United Model was used to evaluate the effects of hypothetical pumping scenarios on groundwater elevations in the study area and the different locations on the Oxnard Plain being considered to receive project water. Modeling results were reviewed to determine the impact of increased pumping in the study area and its effect on coastal groundwater flow movement.

5.2 SCENARIOS

United's model is calibrated from 1985 to 2015 and used as the base period for the Anacapa Project scenarios. Each pumping scenario consisted of simulating 1985 to 2015 basin conditions, with increased groundwater extractions in the study area by 5,000 AF/yr. Specific years chosen for the hypothetical operation of the Anacapa Project were 1993 to 2003, 2005 to 2008, and 2011 to 2012. During these years, it was observed that groundwater elevations in UAS wells in the study area were higher than the density-corrected elevation and groundwater flow was considered to be offshore. For the years of operation, the Anacapa Project pumped groundwater throughout the calendar year for all scenarios, with the exception of the scenario where water was delivered to the PTP. In the PTP scenario, the Anacapa Project did not operate during January through March or in September, when surface water is usually available and a preferred source of water for the PTP. All pumping was simulated from the UAS Mugu aquifer for the modeled scenarios.

Four hypothetical well sites in the study area were located about a half mile inland from Harbor Blvd near West Gonzales Rd. and were selected to pump groundwater for the Anacapa Project (Figure 5-1). All scenarios pumped 5,000 AF/yr. from the Mugu aquifer when the Project was in operation. Ultimately the pumping scenarios differ by the location where the Anacapa Project water was delivered.

The scenarios that were simulated include:

Base Case Scenario – The United Model was calibrated to historic manual groundwater elevation measurements and is used to compare to the delivery options of the Anacapa Project. These simulated groundwater elevations were used as the basis for comparing potential impacts of the subsequent hypothetical pumping scenarios, rather than actual measured groundwater elevations. This is because the model provides discrete results for head (groundwater elevation) in each aquifer, during every month, across the entire modeled area.

Scenario 1 (City of Oxnard) –Under this scenario, 5,000 AF/yr. of water produced by the Anacapa project was delivered to the City of Oxnard's potable distribution system in lieu of groundwater being pumped at El Rio and delivered through the O-H pipeline. Therefore, this scenario allows the groundwater in the Oxnard Forebay near the El Rio Recharge Facility to remain in the basin.

Scenario 2 (Saticoy Recharge Facility) – Under this scenario, 5,000 AF/yr. of water produced by the Anacapa project was delivered to the recharge basins at the Saticoy Recharge Facility. This scenario increases the amount of water recharged to the groundwater aquifers underlying the Saticoy facility in the up-gradient area of the Forebay.

Scenario 3 (PTP) –Under this scenario, 5,000 AF/yr. of water produced by the Anacapa project was delivered to the PTP in lieu of groundwater being pumped from the LAS PTP wells. Some years the PTP wells did not pump at least 5,000 AF in a year because surface water was available to meet most of the PTP demand. In those years, the surplus Anacapa Project water (difference between PTP production and 5,000 AF) was delivered to El Rio Recharge Facility for groundwater recharge. Since the PTP receives Santa Clara River surface water when available, this scenario was programed to not operate the Anacapa Project during January through March and the month of September, when surface water would normally be available.

Scenario 4 (El Rio Recharge Facility) - Under this scenario, 5,000 AF/yr. of water produced by the Anacapa project was delivered to the spreading grounds at the El Rio Recharge Facility. This scenario increases the amount of water recharged to the groundwater aquifers underlying the El Rio facility in the down-gradient area of the Forebay.

5.3 MODEL RESULTS

This section summarizes model-forecasted impacts to groundwater elevations resulting from the Anacapa Project pumping scenarios. The groundwater elevations simulated by the base case scenario are used to evaluate the impacts and benefits of the various hypothetical pumping and delivery scenarios. Results are illustrated using time series hydrographs shown on Figures 5-2 through 5-6, and groundwater elevation contour maps shown on Figures 5-7 through 5-26. Groundwater flow rates and hydraulic gradients at the coast are also discussed under the Flow Budget section below.

5.3.1 GROUNDWATER ELEVATIONS

Groundwater elevations in the base case scenario show groundwater elevations similar to the measured groundwater elevations in the study area from 1985 through 2015 and therefore appear to be calibrated accurately (Figure 5-2). This similarity was expected, as the model is calibrated to (and simulates a repetition of) 1985 through 2015 climatic conditions, pumping, and recharge rates. However, one noticeable difference between the measured and simulated groundwater elevations is the artesian conditions in three wells. Artesian conditions were observed at times, however artesian heads were commonly unmeasured, and therefore an arbitrary elevation (50 feet above msl) was chosen to distinguish when artesian conditions were present. In the simulated base case scenario groundwater elevations were modeled for these wells during artesian conditions. Another notable difference is the groundwater elevation in monitoring well CM3-145, which is different when compared to other wells in the area with the same screened aquifer. Under the base case scenario, simulated groundwater elevations for monitoring well CM3-145 plot more consistently with levels in surrounding Oxnard aquifer wells in the study area.

Simulated groundwater elevations for UAS wells in the study area were compared to the base case scenario elevations, shown in Figures 5-3 through 5-6. When the Anacapa Project was in operation, UAS groundwater elevations in all scenarios declined up to six feet when compared to the base case. Lowering of groundwater elevations in some cases reduced the amount of time that groundwater was above the density corrected line, suggesting groundwater flow direction may have changed to onshore conditions for some time. A more detailed analysis of the impact the Anacapa Project would have on coastal hydraulic gradients and flow conditions is further described in the Flow Budget section below.

Maps showing groundwater elevations forecasted for each scenario were prepared for spring and fall of 2006 and 2011, representing an above-average and average precipitation years, respectively (Figures 5-7 through 5-26). Detailed inspection of model results indicate that groundwater elevations in the Mugu aquifer were typically within a few inches to a few feet of those in the Oxnard aquifer. Also, forecasted groundwater elevations in the Hueneme and Grimes Canyon aquifers were within a few feet of those in the Fox Canyon aquifer. Therefore, to conduct the evaluations efficiently, results for only the Oxnard and Fox Canyon aquifers were used to make the groundwater elevation contour maps, but are generally representative of the other aquifers in the UAS and LAS, respectively. Table 5-1 below displays the modeled results comparing groundwater elevation contours for each simulated pumping scenario to the base case scenario for 2006 and 2011. Results are shown for the study area as well as the Forebay and the eastern side of the Oxnard Plain, where delivery options of the Anacapa Project are located and an impact to groundwater elevations was observed. The change in groundwater elevations is summarized into three ranges, 2 to 4 ft., 4 to 6 ft., and 6 to 10 ft. and illustrated with one, two or three plus or minus signs, respectively. A plus sign indicates an increase in groundwater elevation and a minus sign indicates a decrease in groundwater elevation. Any change in groundwater elevation less than two feet was considered minimal and the data cell was left blank in the table below.

Table 5-1. Comparison of groundwater elevations for pumping scenarios (1-4) and the base case scenario.

Locations	Scenario 1 City of Oxnard		Scenario 2 Saticoy		Scenario 3 PTP (UAS)		Scenario 3 PTP (LAS)		Scenario 4 El Rio	
	spring	fall	spring	fall	spring	fall	spring	fall	spring	fall
2006										
Study Area	-	-	- -	- -		- - -			-	-
Forebay	+	+	+++	++					+	+
Eastern OP					+	+	+	++		
2011										
Study Area	-	-	- -	- -		- -			-	-
Forebay	+	+	++	+++					+	+
Eastern OP					+	+		++		

Notes: Change in groundwater elevations: 2-4 ft. (-/+); 4-6 ft. (- -/++); 6-10 ft. (- - -/+++); OP = Oxnard Plain

Below is a discussion of the impact the simulated operation of the Anacapa Project had on groundwater elevations.

Scenario 1 (City of Oxnard): UAS groundwater elevations for the spring and fall of 2006 and 2011 are shown in Figures 5-7 to 5-10. Groundwater elevations in the study area show an approximate decline of up to four feet under Scenario 1. Project water was delivered to the City of Oxnard, therefore 5,000 AF/yr. of groundwater was not pumped from the O-H wells for pipeline delivery, and remained in the ground. An impact is observed in the southern half of the Forebay, where groundwater elevations in the vicinity at the El Rio Recharge Facility rose two to four feet. The groundwater elevation contours in the eastern portion of the Oxnard Plain basin did not show any impact from Scenario 1.

Scenario 2 (Saticoy Recharge Facility): UAS groundwater elevations for the spring and fall of 2006 and 2011 are shown in Figures 5-11 to 5-14. Groundwater elevations in the study area show an approximate four to six-foot decline under Scenario 2. Project water was delivered to the spreading grounds at Saticoy Recharge Facility and recharged the underlying aquifers. An impact was observed in the up-gradient (northern) portions of the Forebay, where groundwater elevations near the Saticoy Recharge Facility rose up to eight feet. The southern half of the Forebay showed a four-foot increase in groundwater elevations. The eastern portion of the Oxnard Plain basin did not show any impact from Scenario 2.

Scenario 3 (PTP) - UAS: UAS groundwater elevations for the spring and fall of 2006 and 2011 are shown in Figures 5-15 to 5-18. Groundwater elevations in the study area show little change during the spring, but declined up to eight feet during the fall. The PTP produced less than 5,000 AF during 2006 and 2011 and the surplus project water was delivered to the El Rio Recharge Facility. The amount delivered to the facility did not change groundwater elevations considerably in the Forebay. The PTP wells, located in the eastern part of the basin, did not pump groundwater from the LAS. The groundwater elevations on the eastern side show little impact in the UAS during the spring, however, heads increased two to four feet during the fall.

Scenario 3 (PTP) - LAS: LAS groundwater elevations for the spring and fall of 2006 and 2011 are shown in Figures 5-19 to 5-22. Groundwater elevations in the study area show little change under Scenario 3. The PTP wells pumped less than 5,000 AF during 2006 and 2011 and the surplus project water was delivered to the El Rio Recharge Facility. The amount delivered to the facility did not change groundwater elevations considerably in the Forebay. The PTP wells, located in the eastern part of the basin, did not pump any groundwater from the LAS. The eastern portion of the Oxnard Plain basin show more of an impact during the fall with groundwater elevations increasing by up to six feet.

Scenario 4 (El Rio Recharge Facility): UAS groundwater elevations for the spring and fall of 2006 and 2011 are shown in Figures 5-23 to 5-26. Groundwater elevations in the study area show an approximate two to four-foot decline under Scenario 4. Project water was delivered to the spreading grounds at El Rio Recharge Facility and recharged the underlying aquifers. UAS groundwater elevations show a two to four foot increase around the facility, with no impact observed in the eastern portion of the Oxnard Plain basin.

5.3.2 FLOW BUDGET

The flow budget from the United Model serves as an important tool to better understand groundwater flow dynamics. The area examined for the flow budget is the zone at the coast in the study area, extending from the boundary with the Mound basin to the Channel Islands Harbor. The flow budget calculates UAS groundwater flux (onshore and offshore flows) at the coastline. The model output includes monthly flow measurements from January 1985 through December

2015 for each aquifer layer. For the purposes of this study, a flow budget was generated for the UAS aquifer layers (Oxnard and Mugu aquifers). From the monthly measurements, average monthly and annual groundwater fluxes were calculated and compared between the base case scenario and the various pumping scenarios. In addition to examining results from the entire model period (1985-2015), only the years that the Anacapa Project was simulated in operation were evaluated separately.

Table 5-2 summarizes the flow budget for UAS aquifers and provides an approximate description of groundwater interaction at the coast in the study area. Positive numbers represent onshore flow and conversely, negative numbers represent offshore flow.

Table 5-2. UAS Coastal Groundwater Flow Budget in Study Area

United Model Flow Budget	Simulated Coastal Groundwater Flux, AF/yr.				
	Base Case	Scenario 1 Oxnard City	Scenario 2 Saticoy	Scenario 3 PTP	Scenario 4 El Rio
1985-2015, UAS					
Average annual groundwater flux	713	1,205	1,254	1,291	1,205
Difference between base case and scenario		492	541	578	492
Anacapa Project Operational Years (1993-2003, 2005-2008, 2011-2012), UAS					
Average annual groundwater flux	-919	-56	30	37	-56
Difference between base case and scenario		863	949	956	863

Notes: Units in AF, negative flow values indicate offshore flux.

Results from the base case scenario show that without the operation of the Anacapa Project, the net coastal groundwater flux in the UAS over the thirty one year period has been onshore, averaging 713 annually. The monthly quantities of groundwater flux in the flow budget show that during average and above average precipitation years, groundwater flow can be predominantly offshore, but there still may be onshore groundwater conditions for a few months out of the year. During these years, larger volumes of groundwater (over 100 AF) do not flow in any one direction for a long period of time, instead shifting on and offshore throughout the year. However, during drought periods when lower groundwater elevations are prevalent for longer periods of time, larger quantities of water (over 100 AF) per month have been shown to flow onshore for several years.

Onshore groundwater flux increased in the study area during all the simulated pumping scenarios due to the additional pumping by the Anacapa Project. The average increase in UAS onshore groundwater flow ranged from 492 to 578 AF annually, for all scenarios. The impact in the study area from Scenario 1 and 4 is the same, suggesting that reduced pumping (leaving the groundwater in the ground) or recharging the same amount of groundwater at El Rio Recharge Facility, produces the same outcome for groundwater elevations at the coast. Scenario 3 had a slightly higher amount of groundwater flowing onshore at the coast in the study area. This is likely because most of the Anacapa Project water was used in the eastern part of the Oxnard Plain basin, which had little impact on groundwater elevations in the study area as much as recharge activities in the Forebay did under the other scenarios.

The Anacapa Project was simulated to operate during periods when higher groundwater elevations were observed in UAS wells within the study area. When evaluating only the years that the Anacapa Project was in operation, the coastal UAS groundwater flux in the study area was calculated to be offshore, averaging 919 AF annually. Scenario 1 and 4 had the same impact in the study area, with offshore groundwater flow reduced by an average of 863 AF annually. Scenarios 2 and 3 reduced offshore groundwater flow by an average of 949 and 956 AF annually, which was sufficient to switch groundwater flow direction at the coastline, resulting in onshore conditions.

6 CONCLUSIONS AND RECOMMENDATIONS

The Anacapa Project has been evaluated in this feasibility study in an effort to explore projects that maximize the use of water resources. The Anacapa Project would pump groundwater in the northwest portion of the Oxnard Plain near the coast and deliver this water to benefit other parts of the basin. Four locations considered in this feasibility study to receive supplemental groundwater from the Anacapa Project include delivering to (1) the City of Oxnard; (2) the Saticoy Recharge Facility; (3) the Pumping Trough Pipeline (PTP); and (4) the El Rio Recharge Facility. In all the modeled pumping scenarios presented below, changes in groundwater elevations were compared to the base case scenario during the spring and fall of 2006 and 2011. The conclusions are as follows:

1) Preliminary analysis of groundwater elevation contour maps and groundwater elevations in the study area concluded that upper aquifer system (UAS) groundwater elevations in the study area have been predominantly higher than other parts of the Oxnard Plain basin and high enough to suggest offshore groundwater flow movement at the coast.

2) The groundwater elevation data collected from monitoring well CM3-145 is significantly different when compared to other wells screened nearby in the same aquifer. The groundwater elevation does not rise or fall in well CM3-145 as much as the other UAS wells in the study area. This effect is most obvious during the years of extreme precipitation, such as years of drought and above average rainfall. It is unknown at this time why the groundwater level in well CM3-145 is different than other wells in the area with the same screened aquifer. This well has been used for regional mapping of groundwater conditions in the past, but going forward, this well will not be used to characterize UAS groundwater conditions on the Oxnard Plain because of the difference in water elevations identified in this study.

3) Water quality results show that generally, groundwater from the study area had concentrations of sodium, chloride, nitrate and TDS that are similar or elevated compared to other sources of water at the potential delivery locations. Data suggests that the water produced by the Anacapa Project would not likely improve the water quality for any of the delivery options. Because of the potential for a higher range of water quality parameters in the study area, it may be better for project water to be used for groundwater recharge rather than direct use. Seawater intrusion has not been an issue in the study area despite the fact that the onshore movement of water has been dominant for over thirty years.

4) Referring to the Anacapa Project Scenario 1: By delivering project water directly to the City of Oxnard, groundwater would not be pumped from the El Rio Recharge Facility and delivered through the Oxnard-Hueneme pipeline. As a result of this option, groundwater elevations in the vicinity of the El Rio Recharge Facility rose approximately two to four feet. In the study area, increased pumping by the Anacapa Project caused groundwater elevations to decline

approximately four feet. When considering the flow budget during the years the Anacapa Project was simulated to be in operation, Scenario 1 would impact the study area by reducing offshore UAS groundwater flow by 863 AF/yr. This reduction in offshore flow was not enough to cause an onshore flow direction.

5) Referring to the Anacapa Project Scenario 2: By delivering project water to the Saticoy Recharge Facility, water would increase recharge to the underlying aquifers. As a result, groundwater elevations in the vicinity at the Saticoy Recharge Facility rose approximately six to eight feet. In the study area, increased pumping by the Anacapa Project caused groundwater elevations to decline approximately four to six feet. When considering the flow budget during the years the Anacapa Project was simulated to be in operation, Scenario 2 would impact the study area by reducing offshore UAS groundwater flow by 949 AF/yr. This was enough to change direction of groundwater flow along the coast and to create onshore groundwater flow conditions.

6) Referring to the Anacapa Project Scenario 3: By delivering project water directly to the PTP, groundwater would not be pumped from the PTP lower aquifer system (LAS) wells to deliver to customers. As a result, groundwater elevations in the vicinity of the PTP rose approximately one to four feet in the UAS and two to six feet in the LAS. In the study area, increased pumping by the Anacapa Project caused groundwater elevations to decline up to ten feet. When considering the flow budget during the years the Anacapa Project was simulated to be in operation, Scenario 3 would impact the study area by reducing offshore UAS groundwater flow by 956 AF/yr. This was enough to change direction of groundwater flow along the coast and to create onshore groundwater flow conditions.

7) Referring to the Anacapa Project Scenario 4: By delivering project water to the El Rio Recharge Facility, water would increase recharge to the underlying aquifers. As a result, groundwater elevations in the vicinity at the El Rio Recharge Facility rose approximately two to four feet. In the study area, increased pumping by the Anacapa Project caused groundwater elevations to decline approximately two to four feet. When considering the flow budget during the years the Anacapa Project was simulated to be in operation, Scenario 4 would impact the study area by reducing offshore UAS groundwater flow by 863 AF/yr. This reduction in offshore flow was not enough to cause an onshore flow direction.

8) Considering Conclusions 4 through 7 above, it would be preferential to deliver project water to the El Rio Recharge Facility (Scenario 4). This is because the results of the flow budget showed that delivering project water to El Rio did not reverse the groundwater flow from offshore to onshore conditions along the coast as a result of the Anacapa Project. This is important because pronounced onshore flow of groundwater may create and/or exacerbate seawater intrusion. Also, water quality results suggest project water would have less of an impact when used to recharge El Rio's underlying aquifers rather than being used directly by customers (Scenarios 1 and 3).

9) Results from the base case scenario show that without the operation of the Anacapa Project, the overall average groundwater flux in the UAS over the thirty years during the study period was onshore within aquifers that extend off the coast. In all pumping scenarios of the Anacapa Project, onshore groundwater flow increased when compared to the base case scenario. Maintaining groundwater flow offshore is critical to keep the seawater/freshwater interface away from the coast. Therefore, the increased pumping by the Anacapa Project would reduce offshore groundwater flow, weakening the basin's ability to buffer against seawater intrusion.

10) United's ability to divert surface water from the Santa Clara River into the Forebay is less than in prior years due to new regulatory constraints associated with the Endangered Species Act. The region continues to experience drought conditions with groundwater elevations across much of the coastal Oxnard plain below sea level. Even when wet conditions do return to the area, the recovery of groundwater storage in the coastal basins is expected to be slower than it was following the last major drought in the early 1990s. With less surface water diversions likely to occur during future wet periods, groundwater elevations might not increase as high as observed in the past, hence limiting the opportunities to implement the Anacapa Project.

Recommendations:

Based on the conclusions and data analysis presented in this feasibility study, the Anacapa Project is not recommended due to the potential to cause onshore groundwater flow, and therefore seawater intrusion. Results from the United Model show that onshore movement of groundwater has been dominant for over thirty years during the study period and the additional pumping by the Anacapa Project would increase onshore groundwater flow.

A Groundwater Sustainability Plan (GSP) is currently being developed for the Oxnard Plain and will be completed by January 31, 2020. The GSP will identify specific measures to ensure that the basin is being operated within its sustainable yield. The implementation of this Plan will likely have an impact on the groundwater conditions of the Oxnard Plain basin. If groundwater conditions change so that groundwater elevations rise high enough to sustain offshore flow in the study area, then future reconsideration of the Anacapa Project may be warranted.

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FIGURES

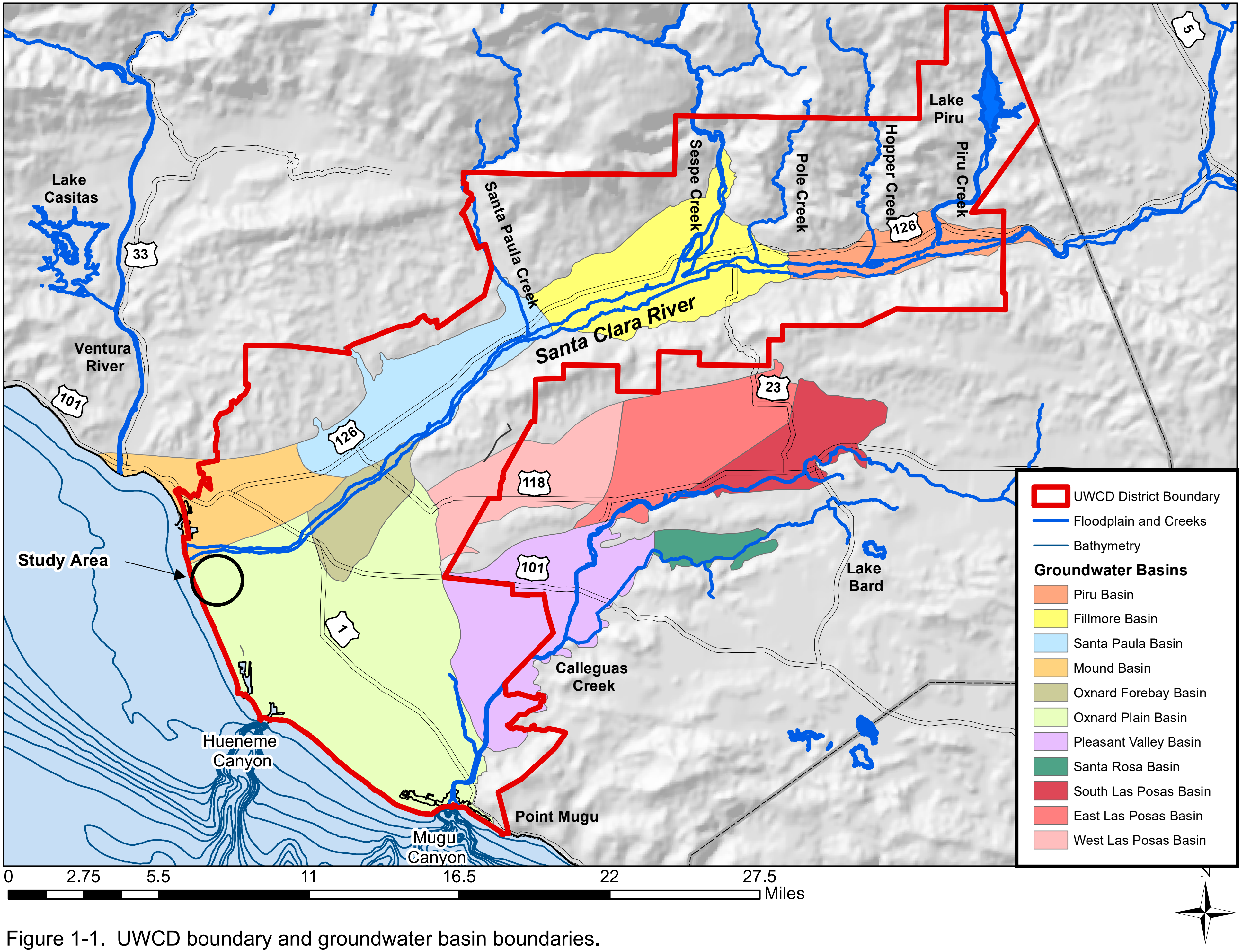
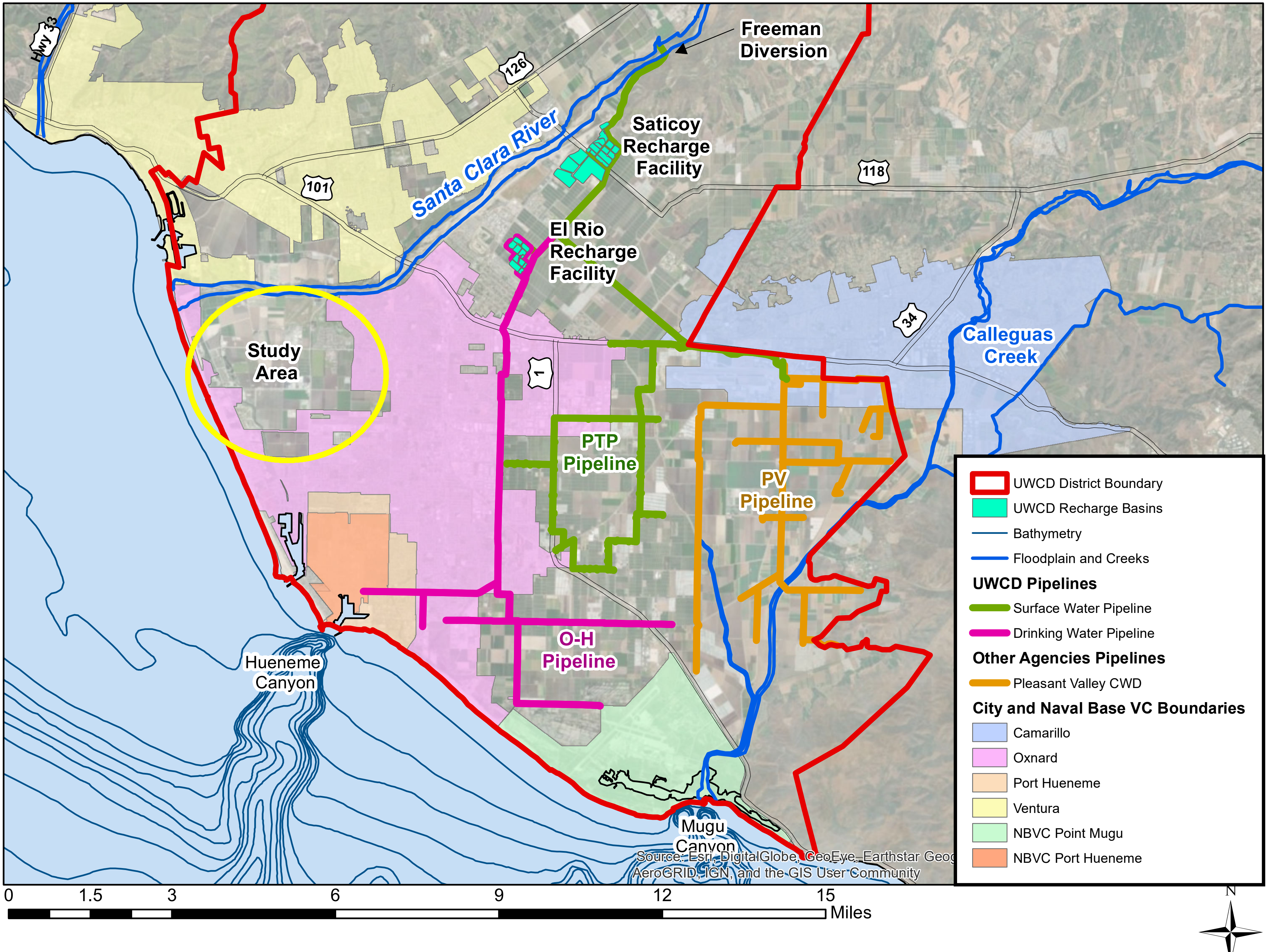
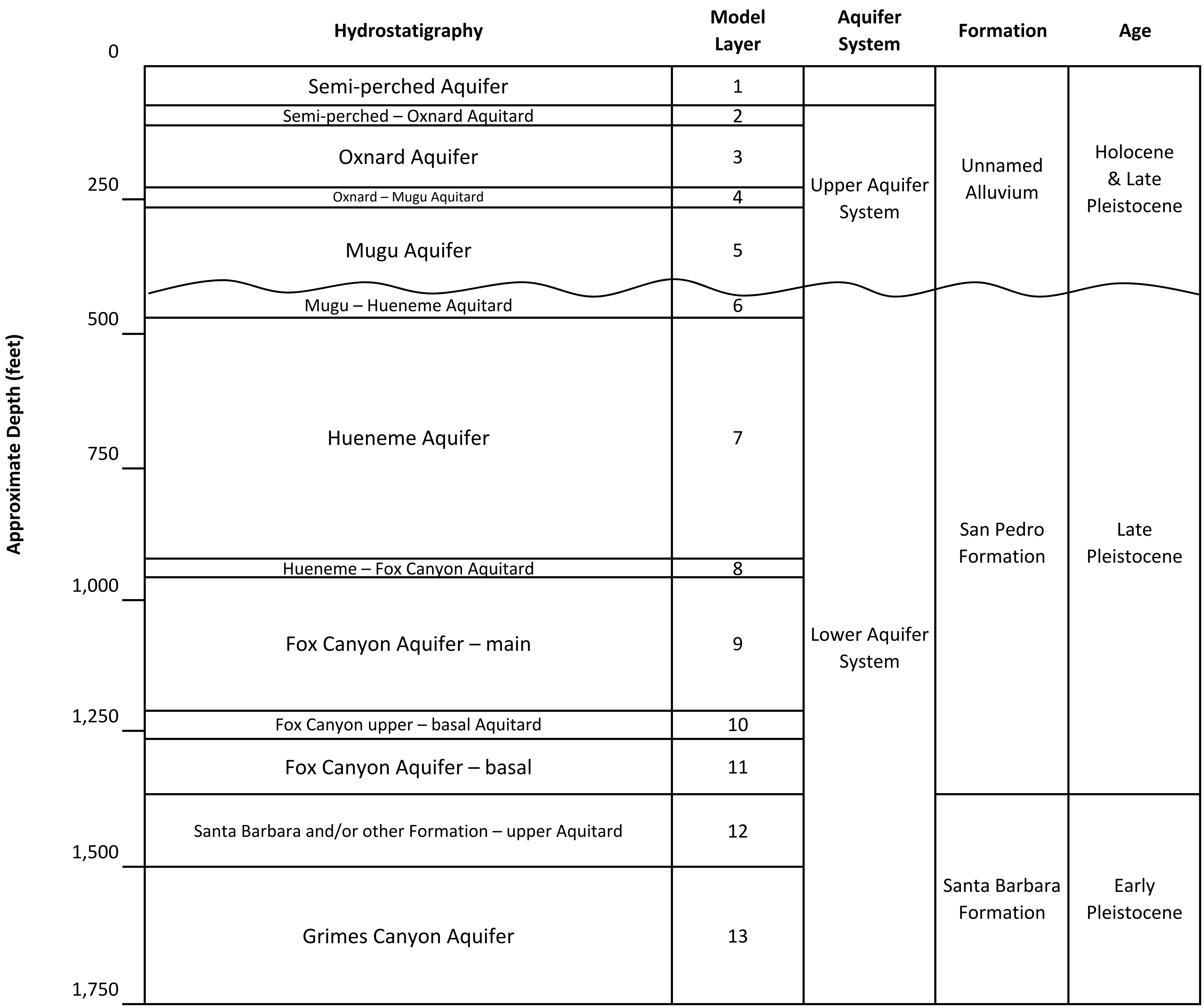


Figure 1-1. UWCD boundary and groundwater basin boundaries.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geog
AeroGRID, IGN, and the GIS User Community

Figure 1-2. UWCD facilities and pipelines on the Oxnard Plain.



Hydrostatigraphy	Model Layer	Aquifer System	Formation	Age
Semi-perched Aquifer	1		Unnamed Alluvium	Holocene & Late Pleistocene
Semi-perched – Oxnard Aquitard	2	Upper Aquifer System		
Oxnard Aquifer	3			
Oxnard – Mugu Aquitard	4			
Mugu Aquifer	5			
Mugu – Hueneme Aquitard	6			
Hueneme Aquifer	7	Lower Aquifer System	San Pedro Formation	Late Pleistocene
Hueneme – Fox Canyon Aquitard	8			
Fox Canyon Aquifer – main	9			
Fox Canyon upper – basal Aquitard	10			
Fox Canyon Aquifer – basal	11			
Santa Barbara and/or other Formation – upper Aquitard	12		Santa Barbara Formation	Early Pleistocene
Grimes Canyon Aquifer	13			

Figure 2-1. Schematic of Upper and Lower Aquifer Systems with model layers.

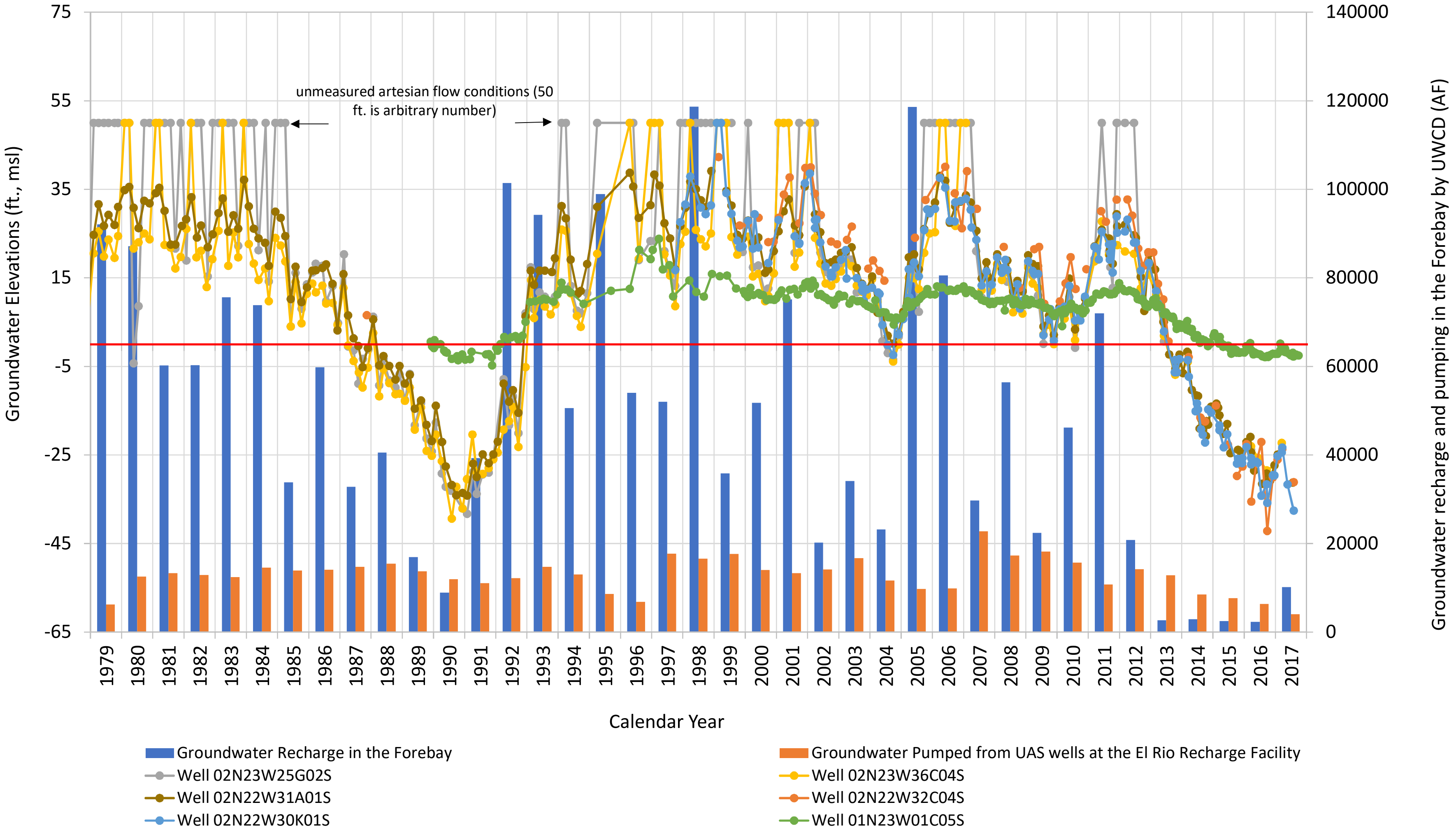


Figure 2-2. United's annual groundwater recharge and UAS pumping in Forebay plotted with UAS groundwater elevations in the study area.

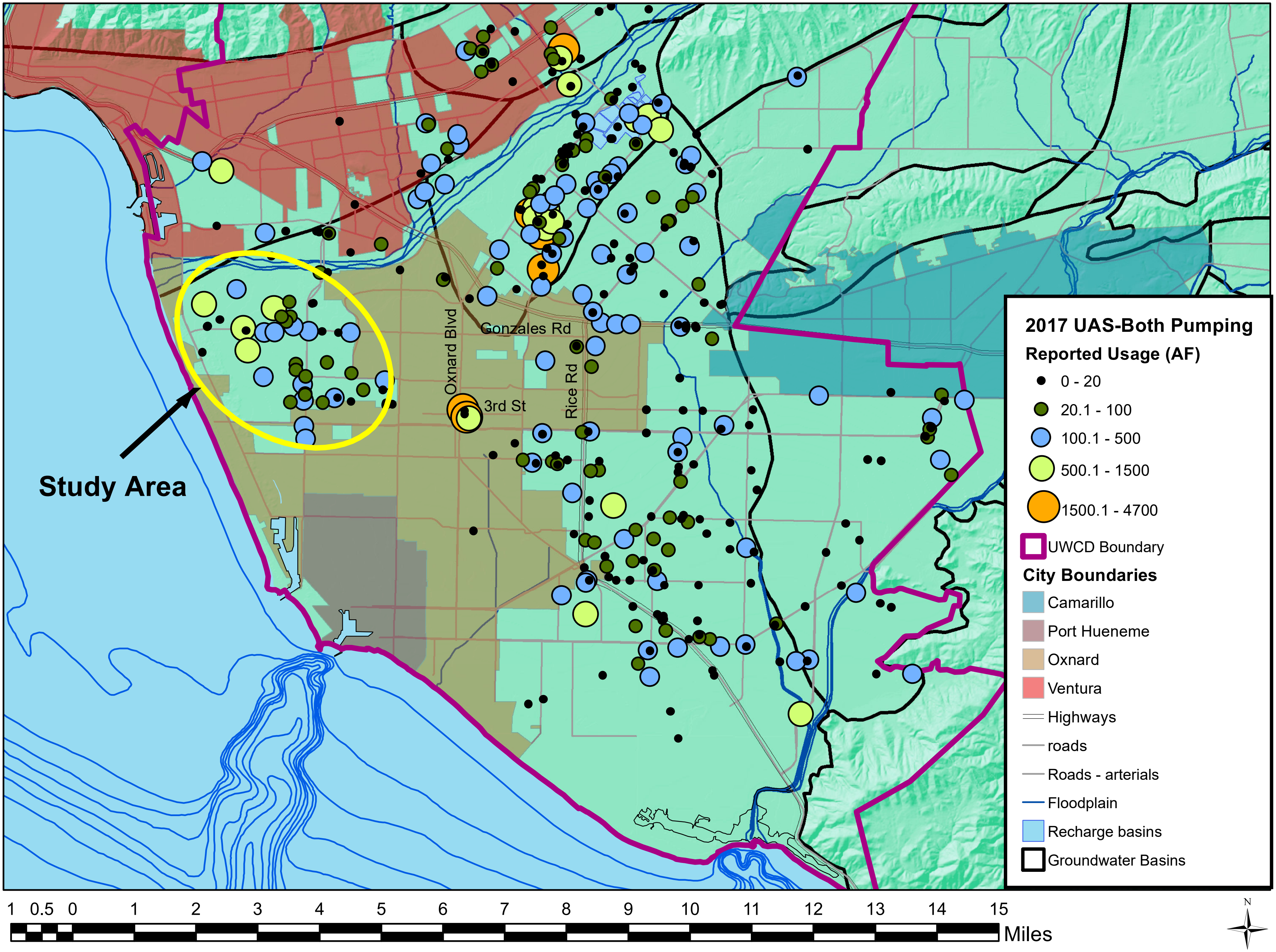


Figure 2-3. Reported calendar year pumping for 2017 in UAS wells in Oxnard Forebay, Oxnard Plain, and surrounding areas.

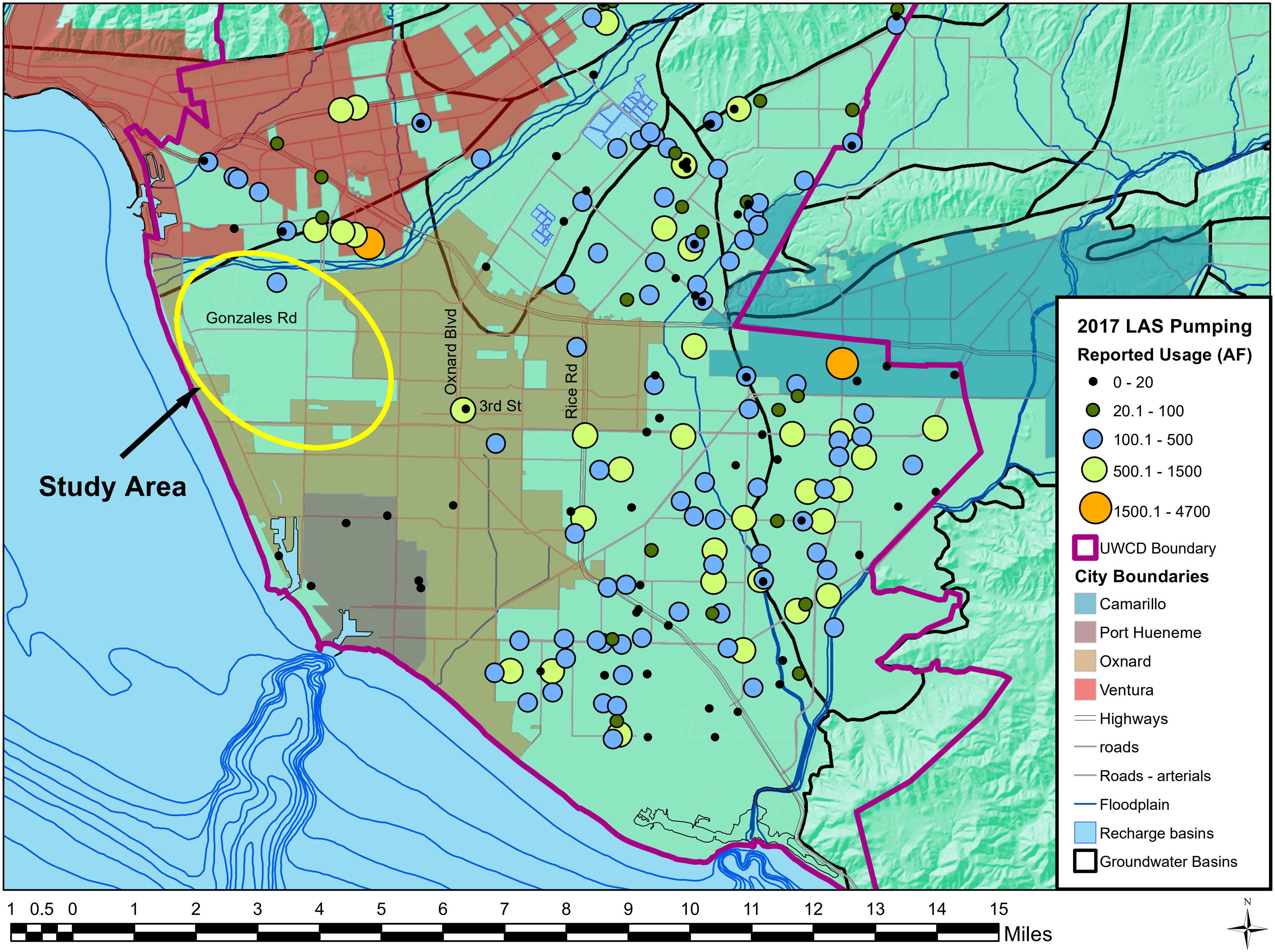


Figure 2-4. Reported calendar year pumping for 2017 in LAS wells in Oxnard Forebay, Oxnard Plain, and surrounding areas.

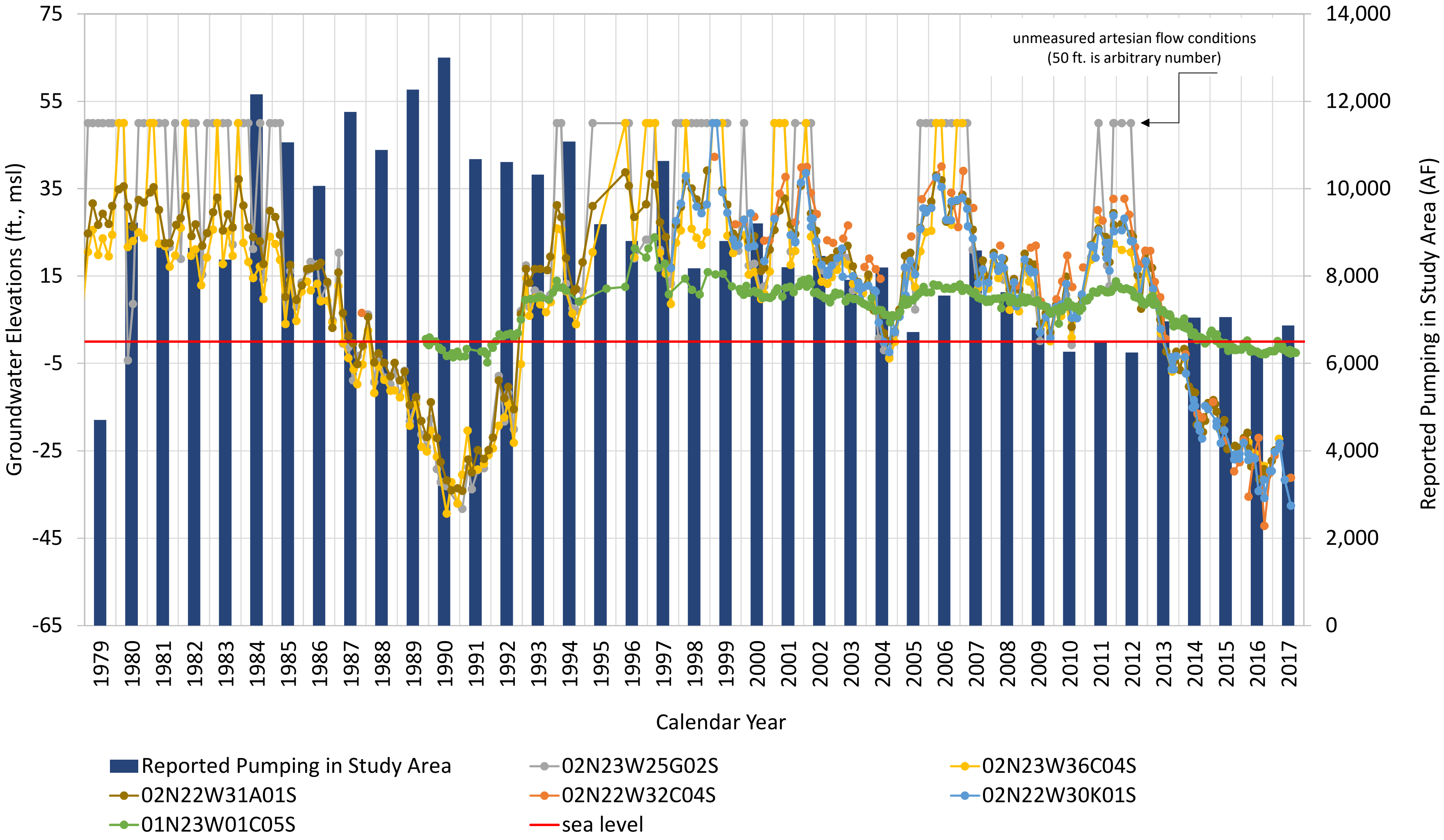


Figure 2-5. Historical annual groundwater extractions from study area and UAS groundwater elevations in study area.

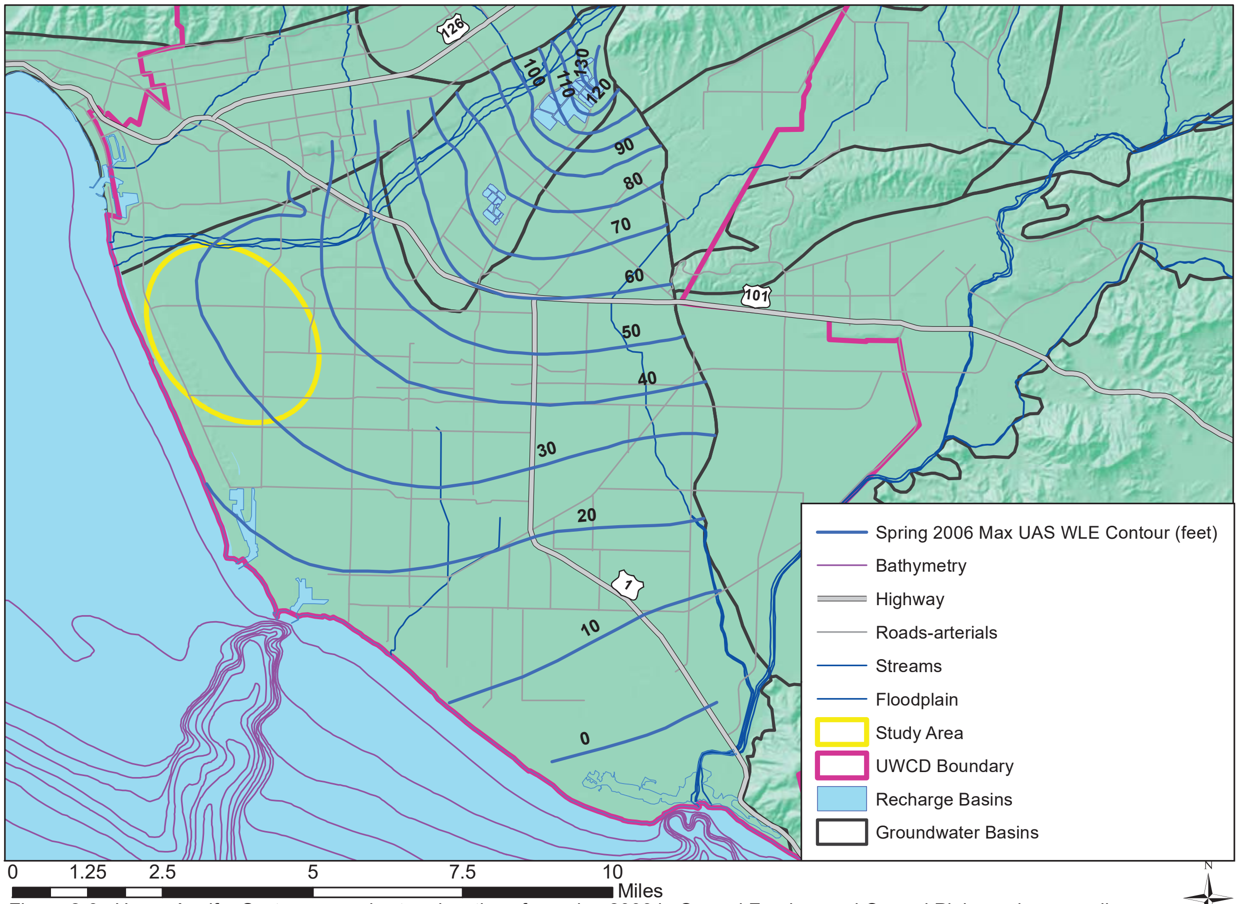


Figure 2-6. Upper Aquifer System groundwater elevations for spring 2006 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

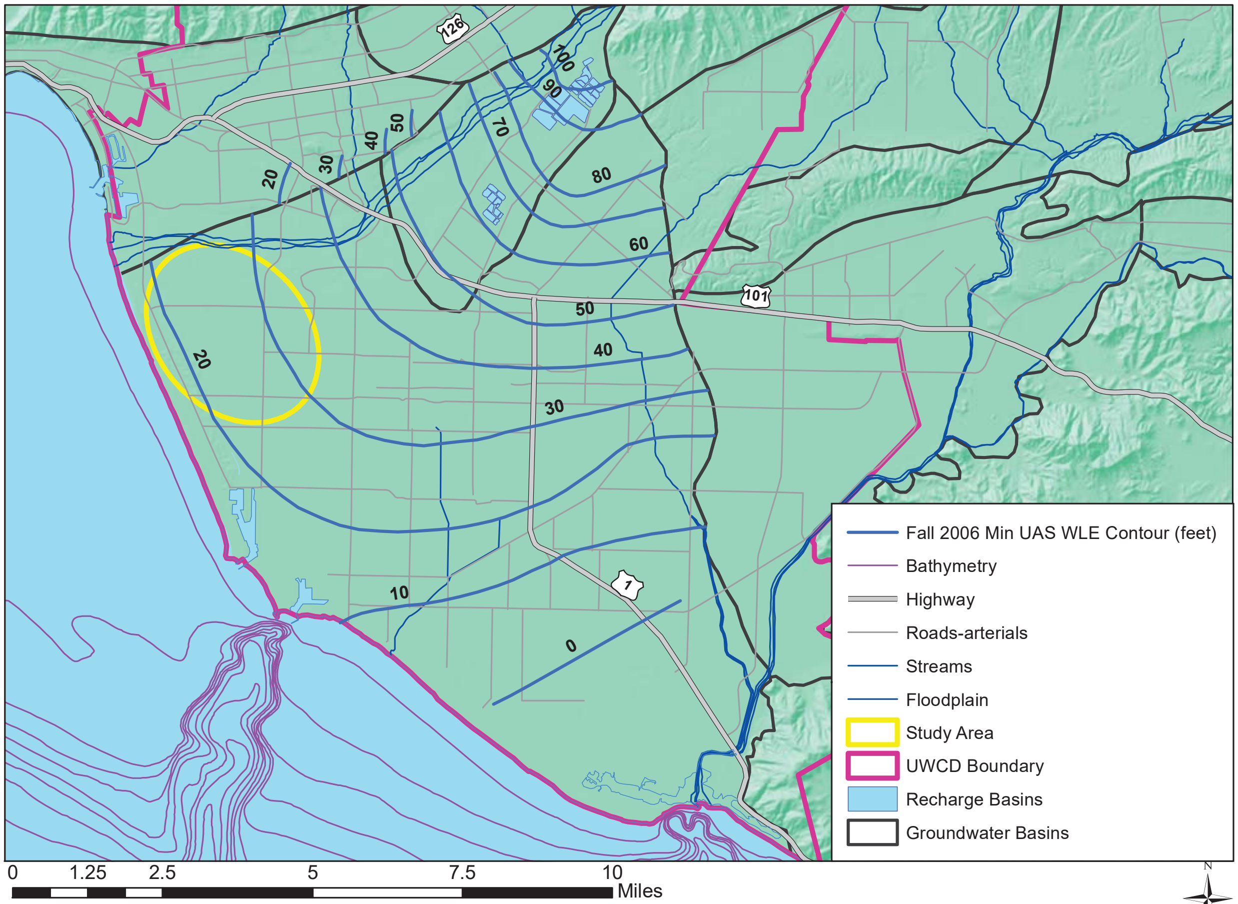


Figure 2-7. Upper Aquifer System groundwater elevations for fall 2006 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

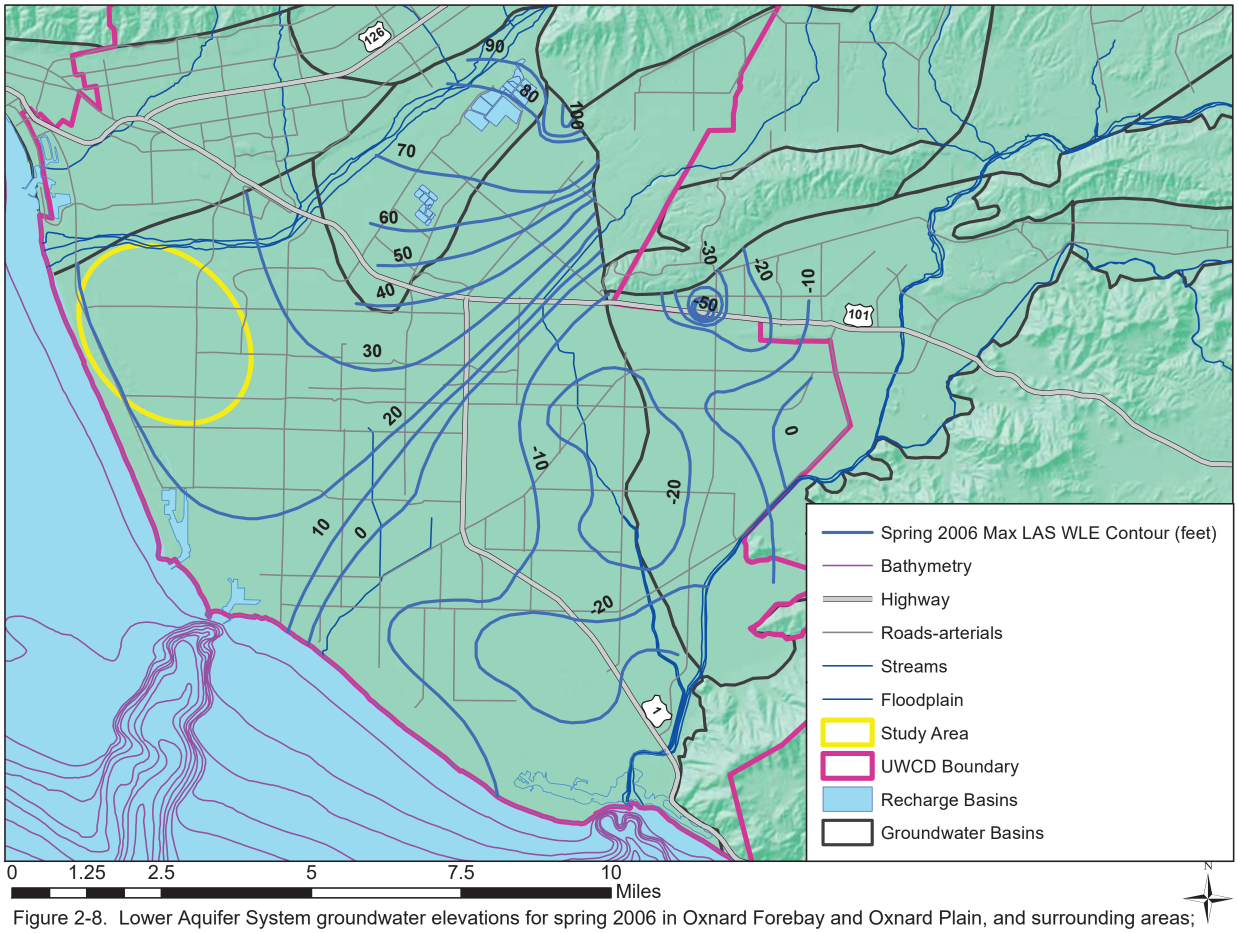


Figure 2-8. Lower Aquifer System groundwater elevations for spring 2006 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

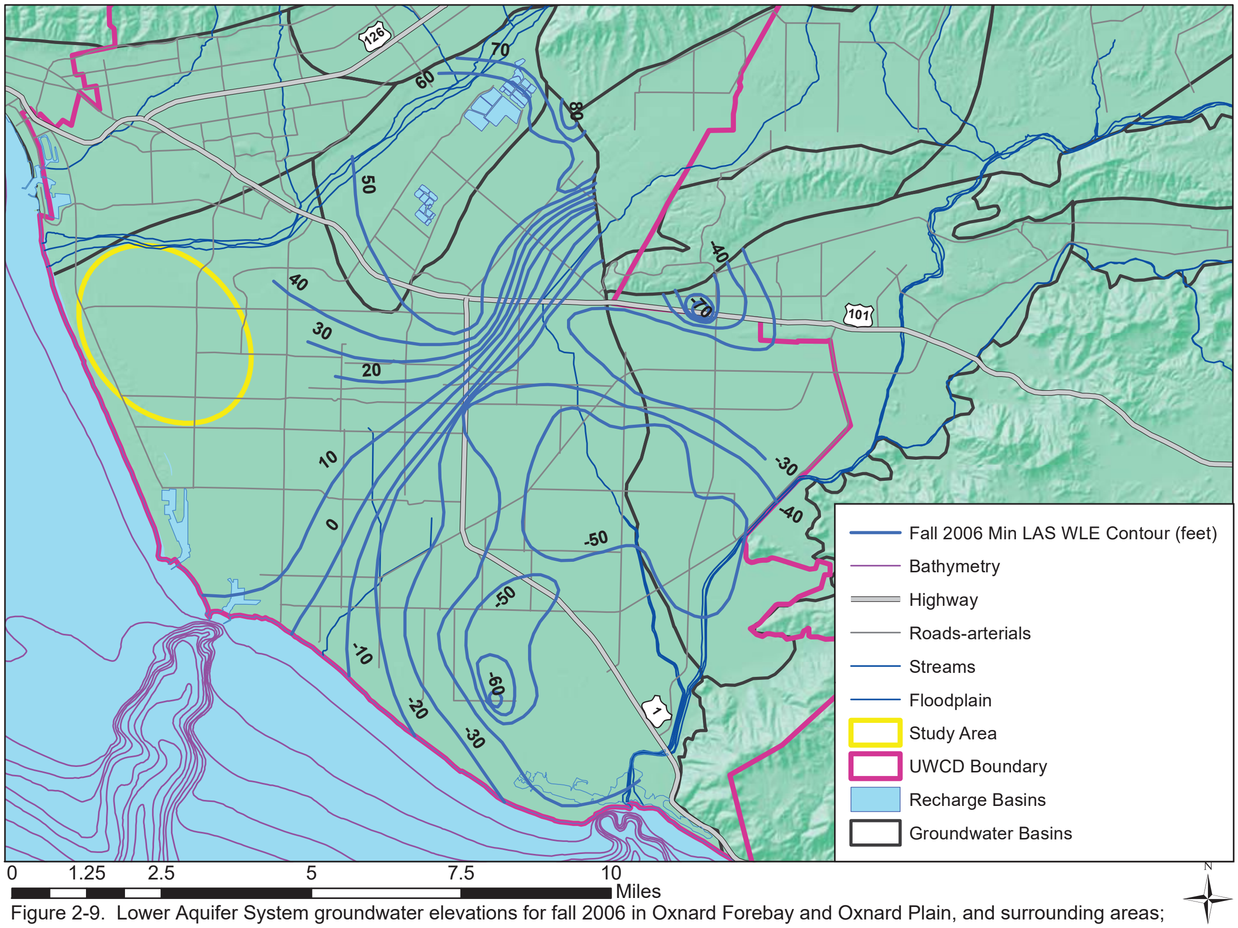


Figure 2-9. Lower Aquifer System groundwater elevations for fall 2006 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

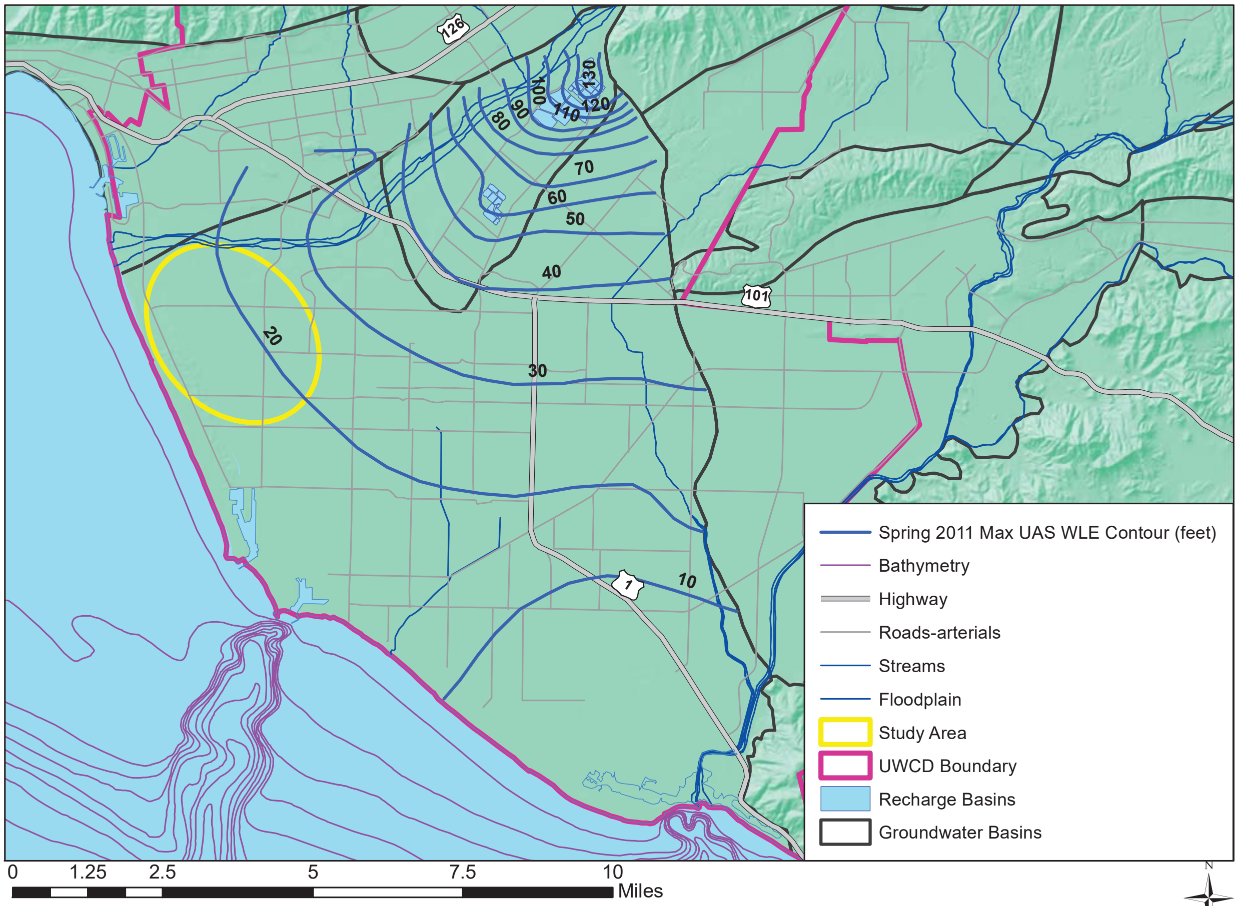


Figure 2-10. Upper Aquifer System groundwater elevations for spring 2011 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of typical year.

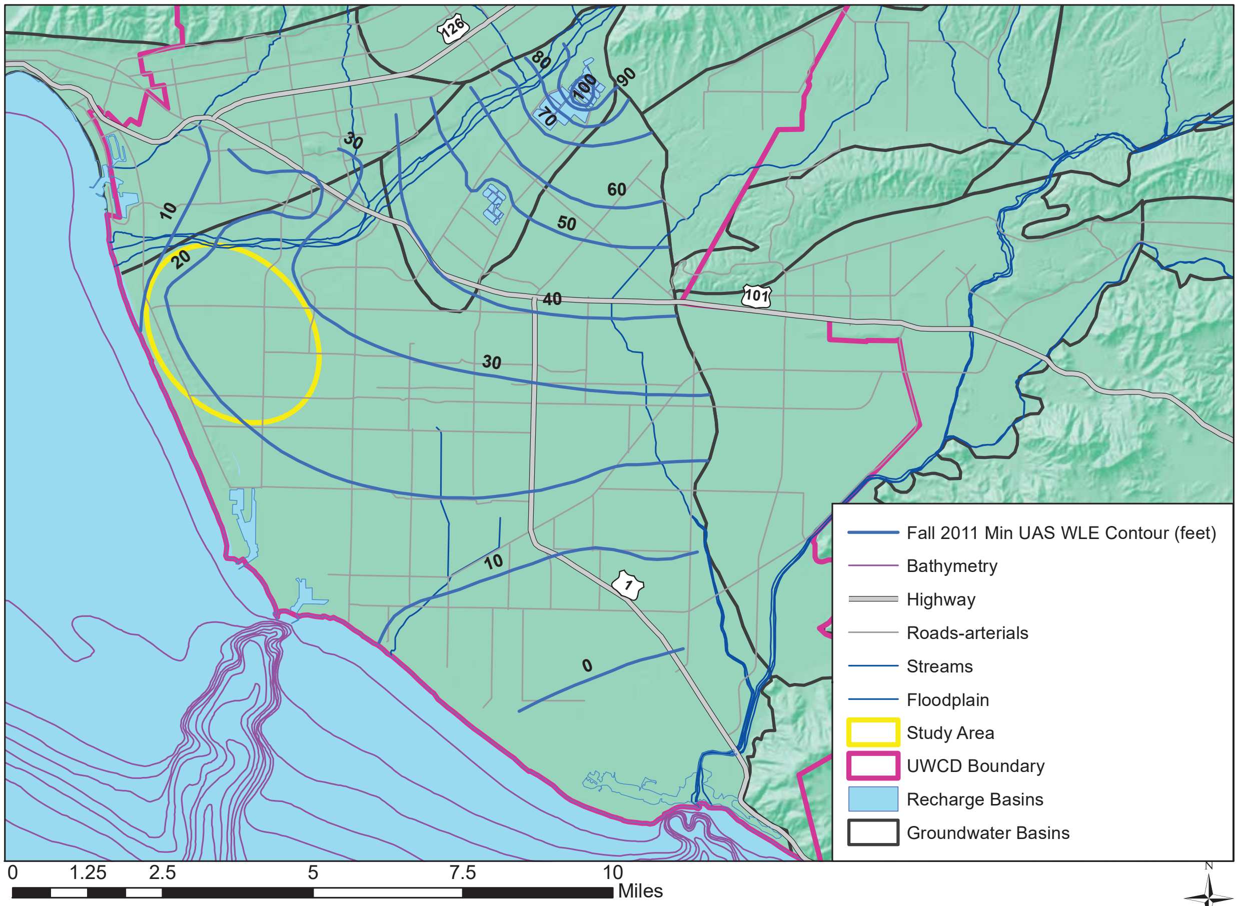


Figure 2-11. Upper Aquifer System groundwater elevations for fall 2011 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of typical year.

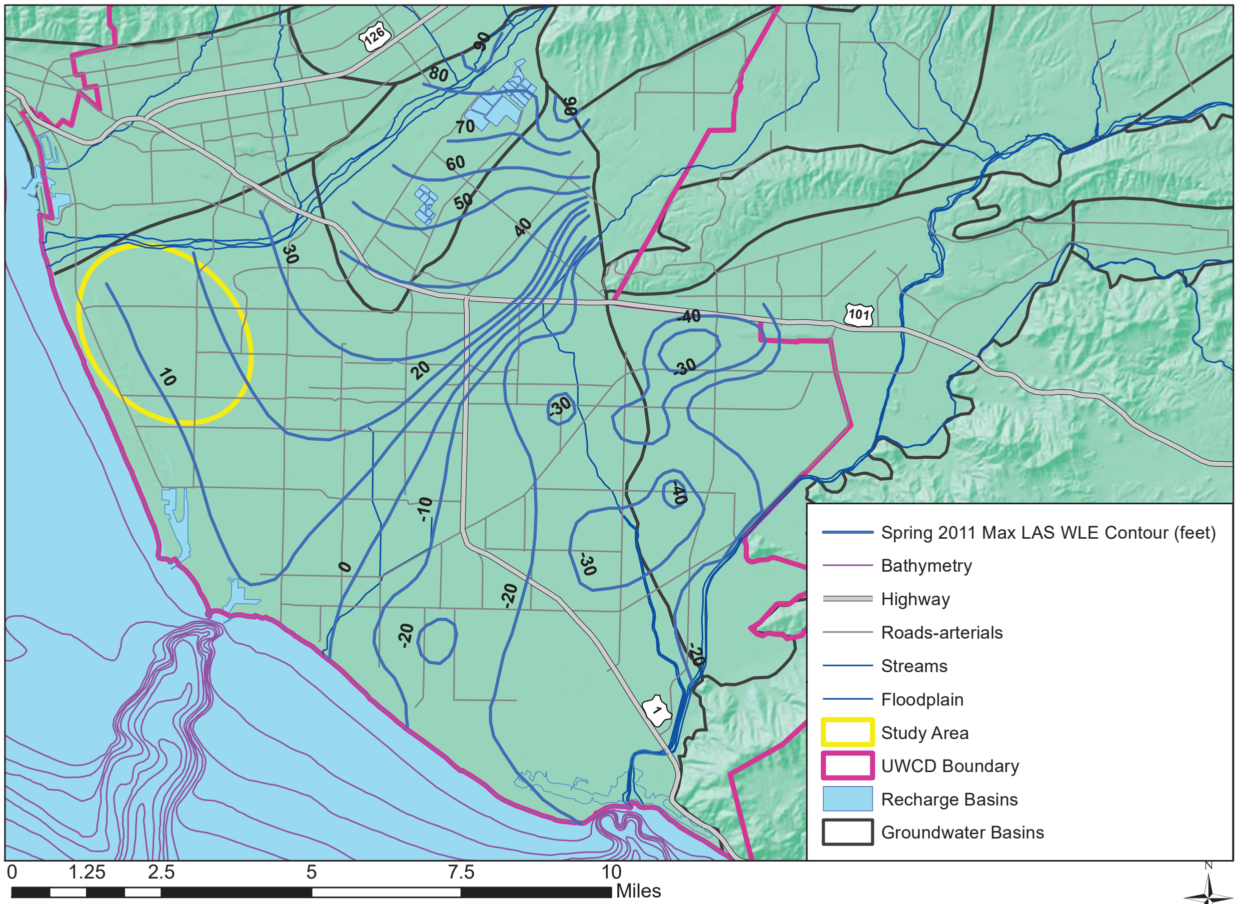


Figure 2-12. Lower Aquifer System groundwater elevations for spring 2011 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of typical year.

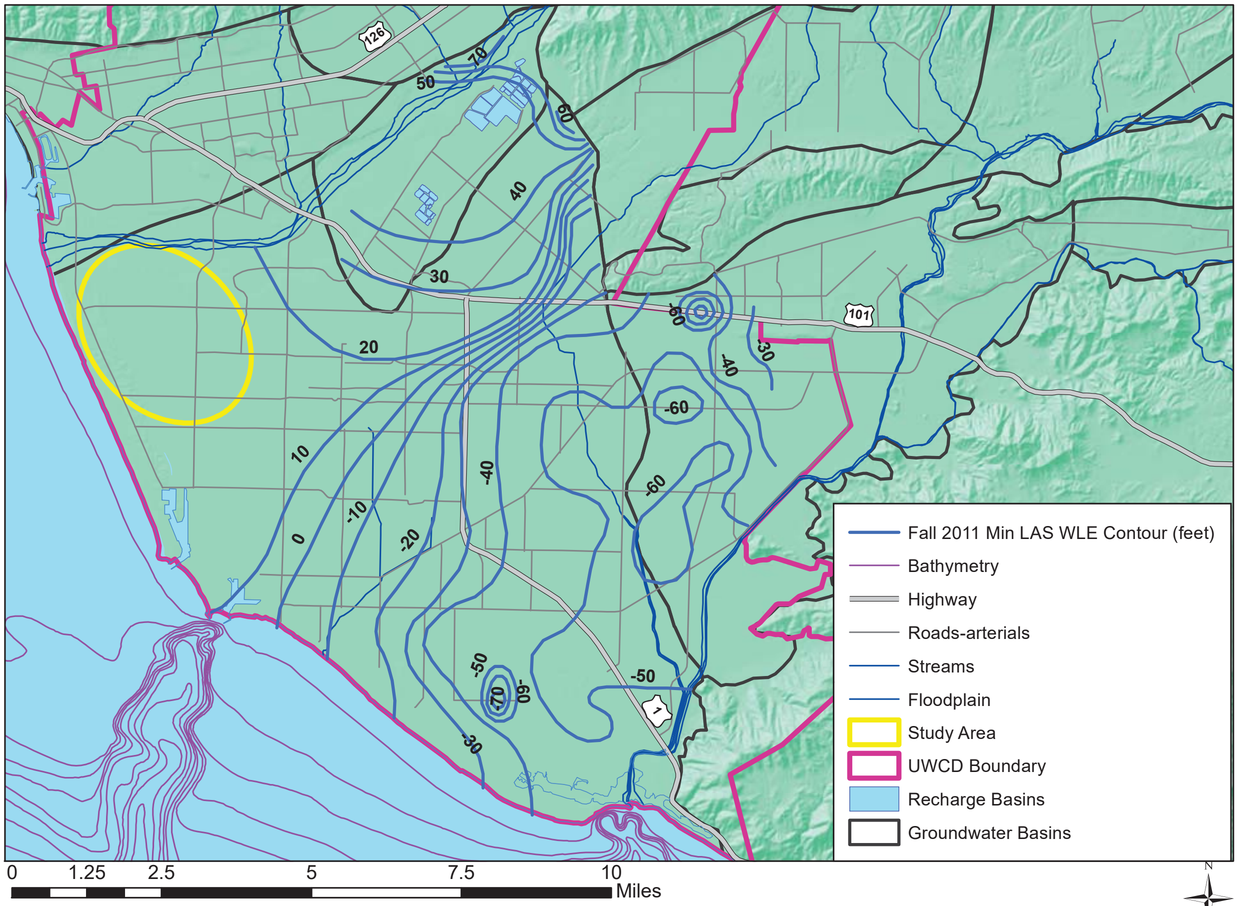


Figure 2-13. Lower Aquifer System groundwater elevations for fall 2011 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of typical year.

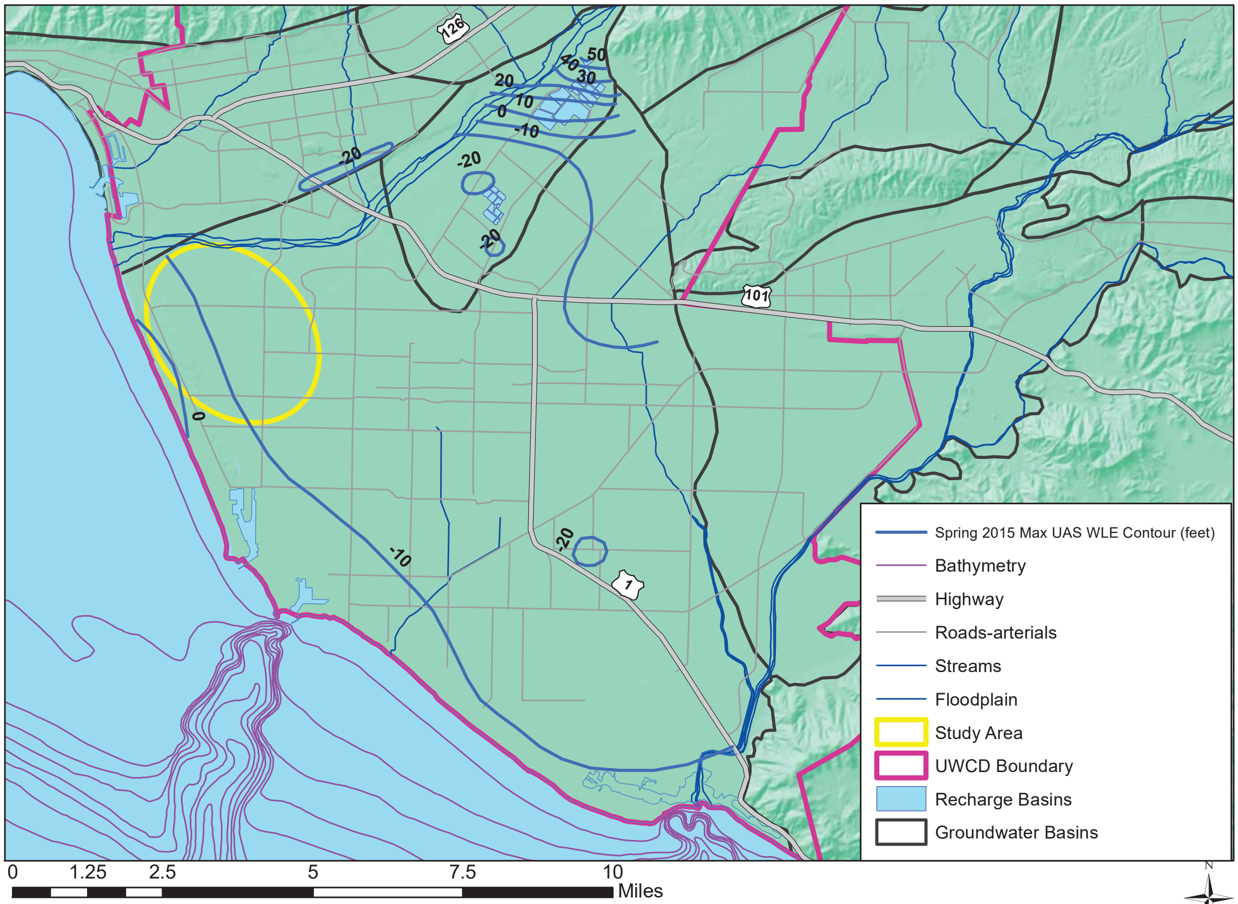


Figure 2-14. Upper Aquifer System groundwater elevations for spring 2015 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of dry year.

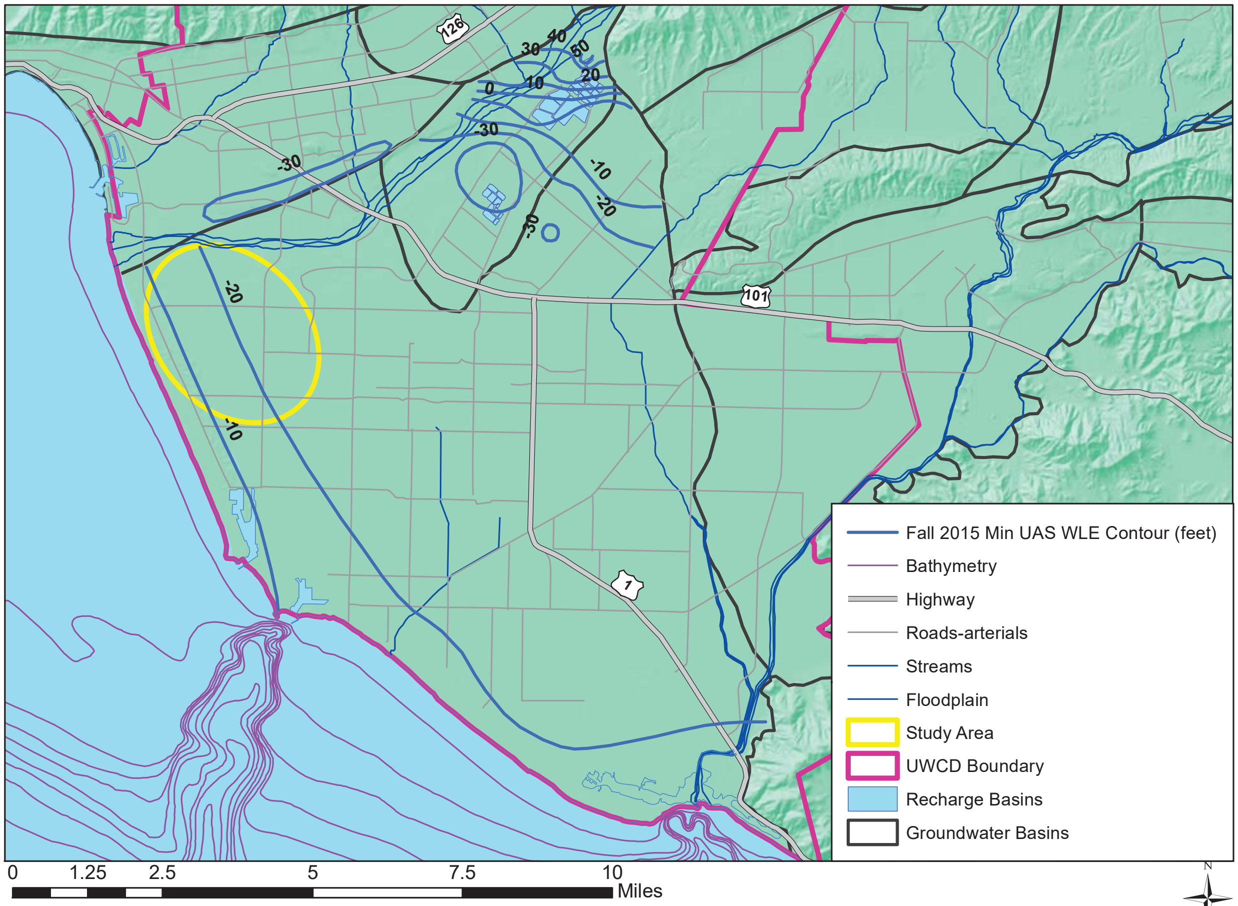


Figure 2-15. Upper Aquifer System groundwater elevations for fall 2015 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of dry year.

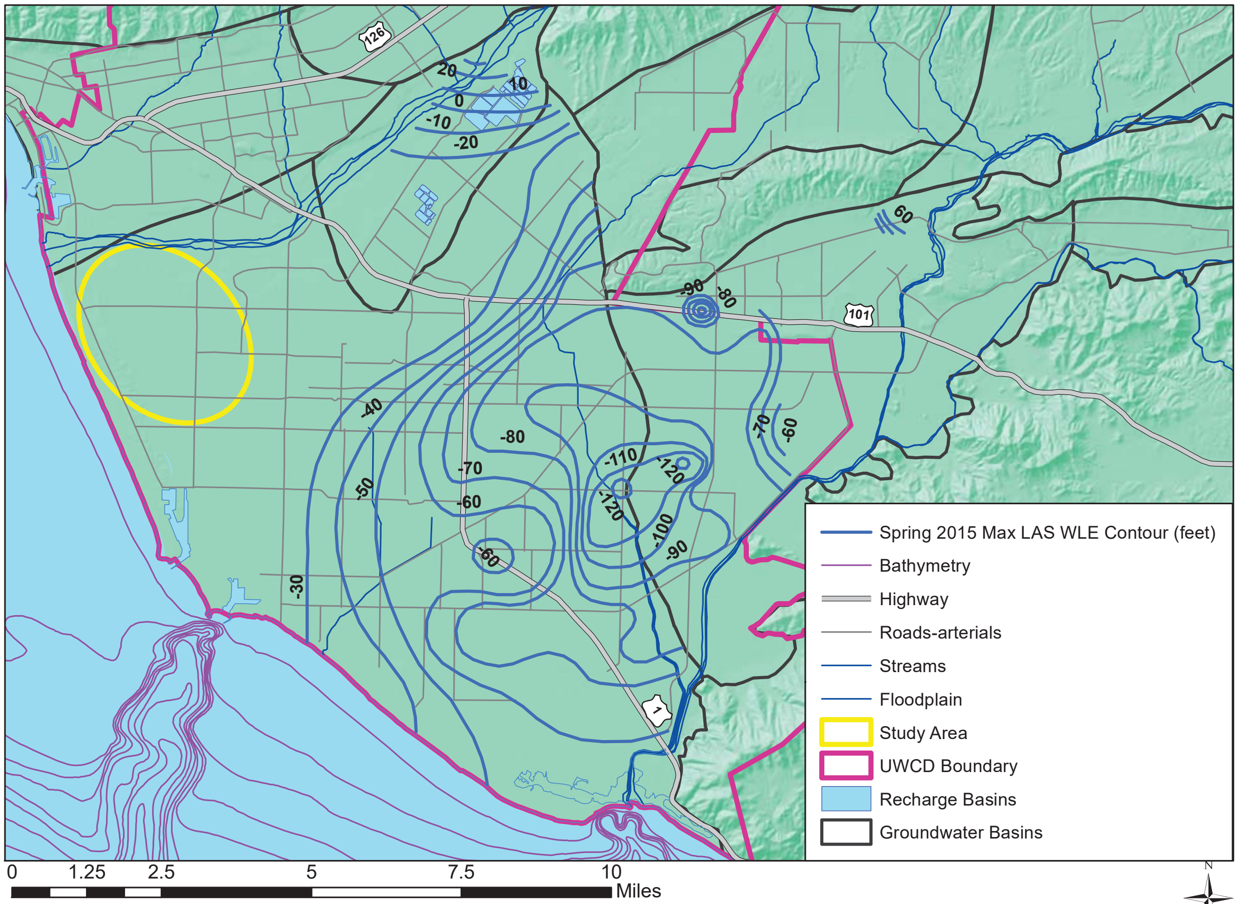


Figure 2-16. Lower Aquifer System groundwater elevations for spring 2015 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of dry year.

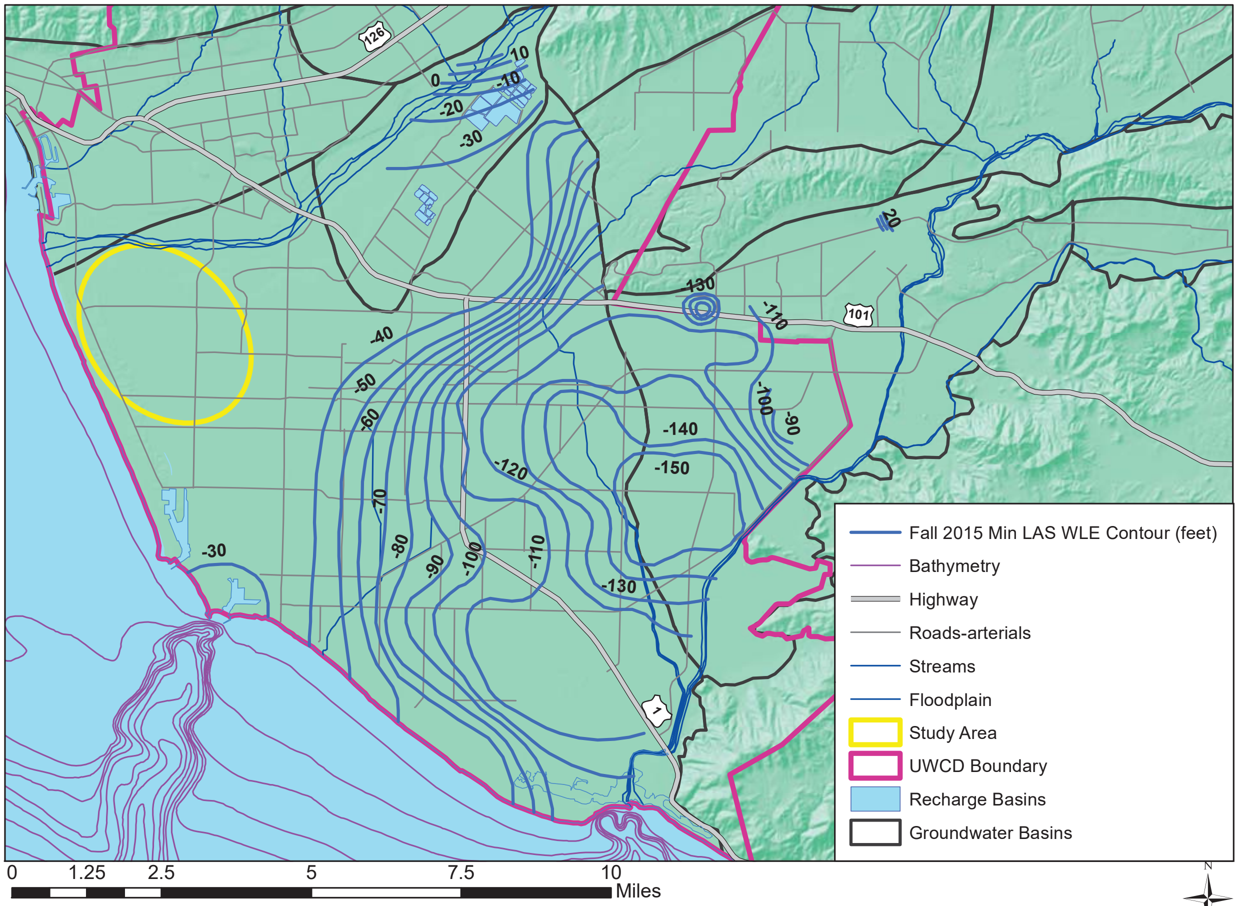


Figure 2-17. Lower Aquifer System groundwater elevations for fall 2015 in Oxnard Forebay and Oxnard Plain, and surrounding areas; example of dry year.

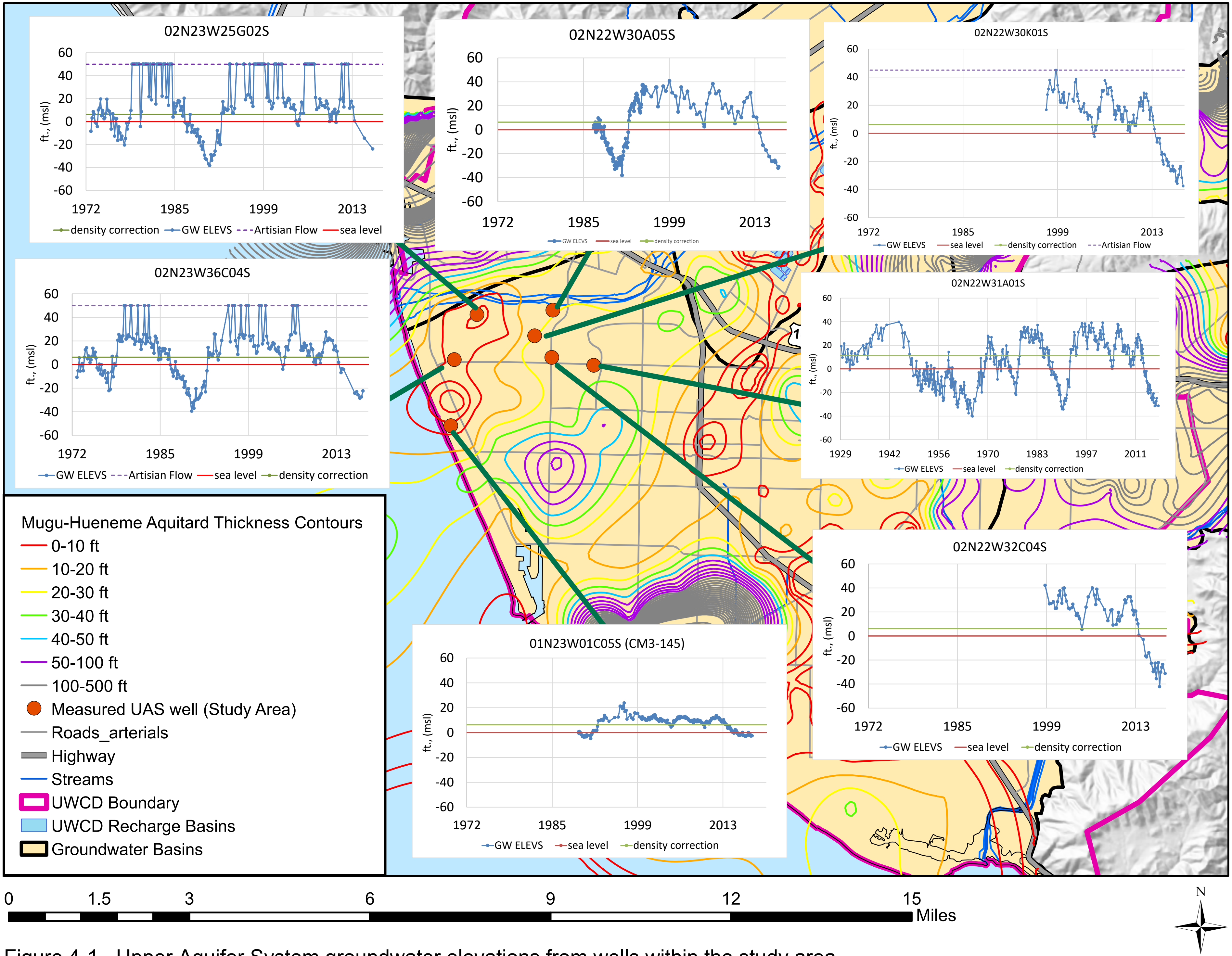


Figure 4-1. Upper Aquifer System groundwater elevations from wells within the study area.

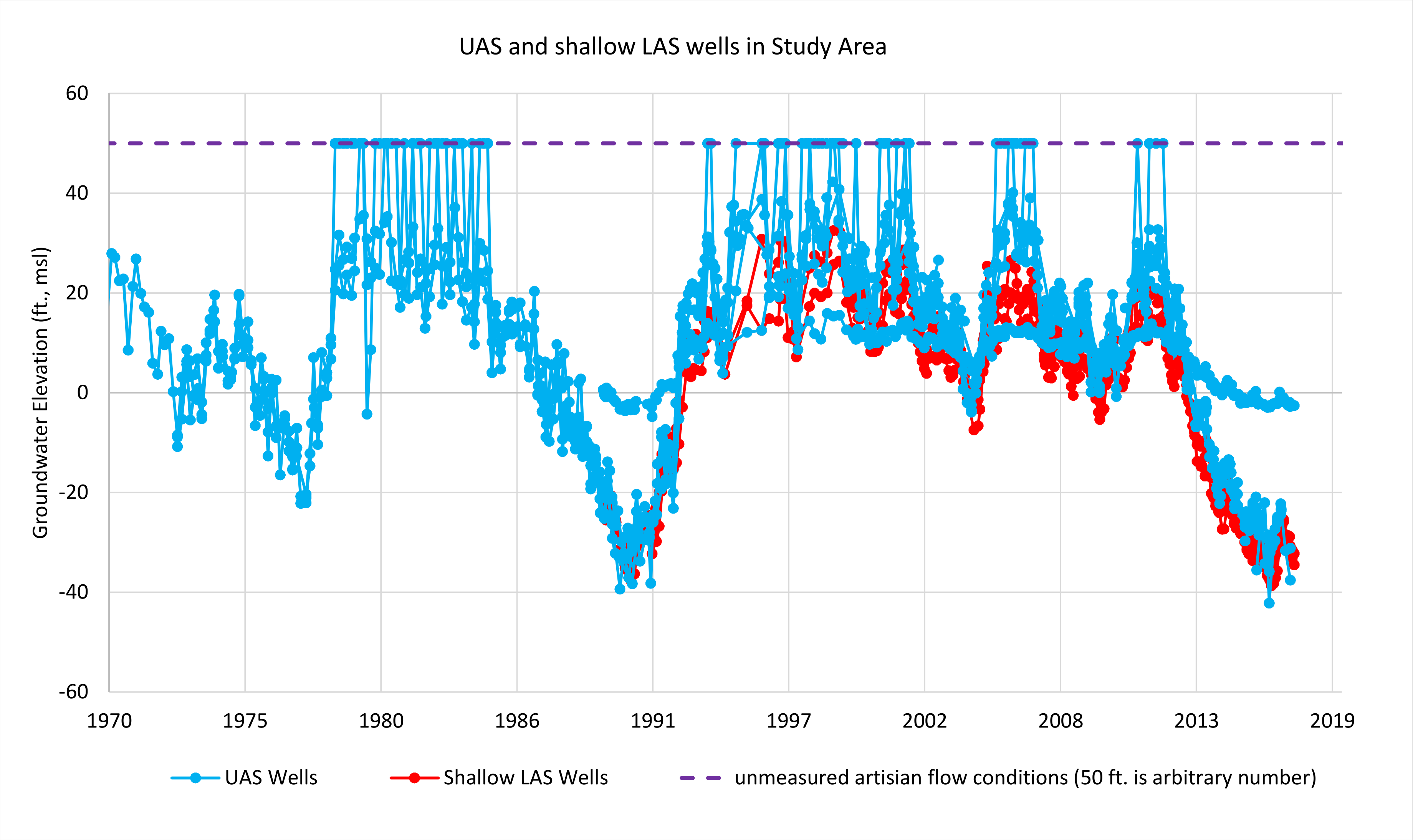


Figure 4-2. Comparison of Upper Aquifer System and shallow Lower Aquifer System groundwater elevations in the study area.

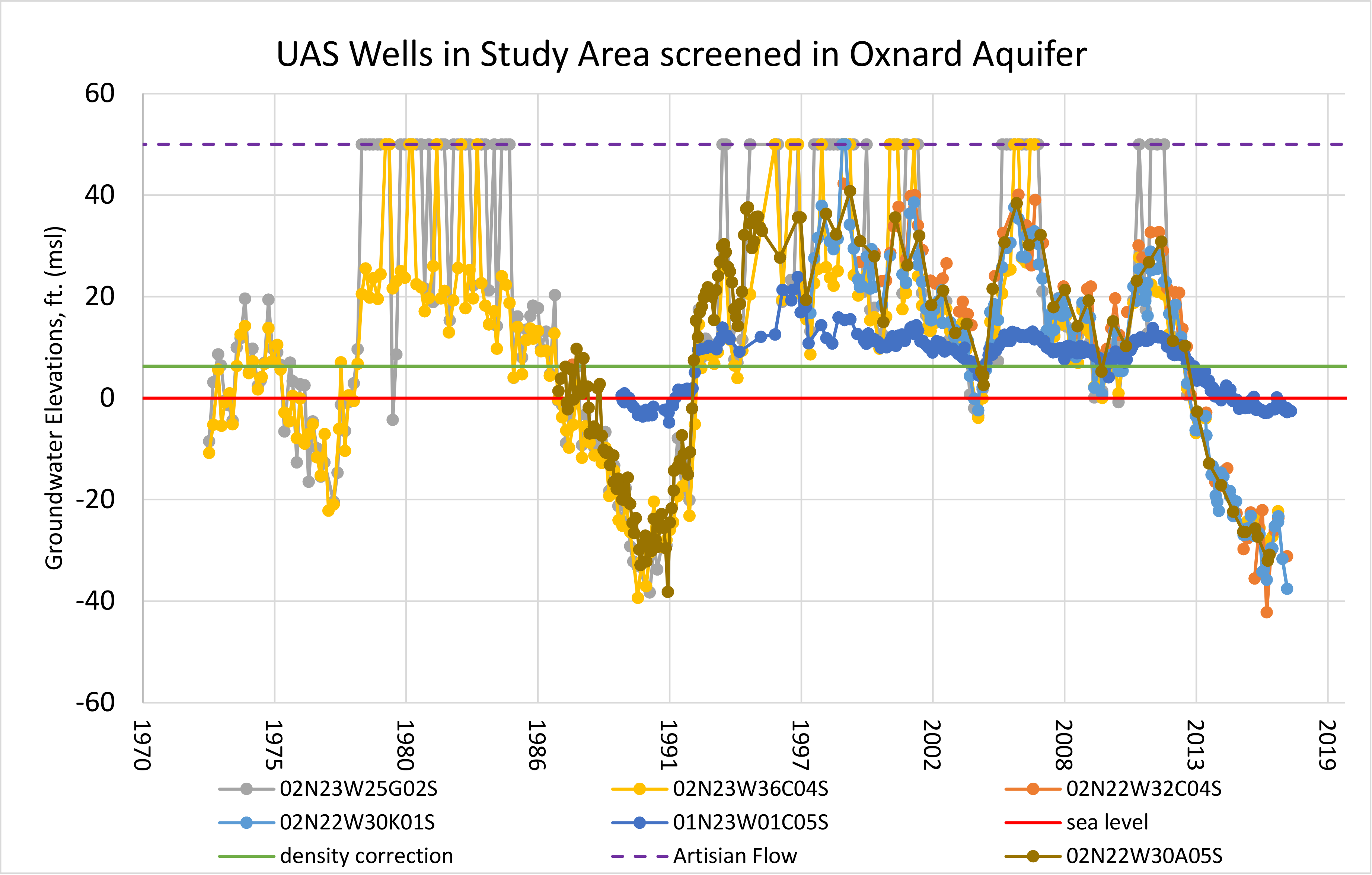


Figure 4-3. Groundwater elevations for wells within the study area screened in the Oxnard Aquifer.

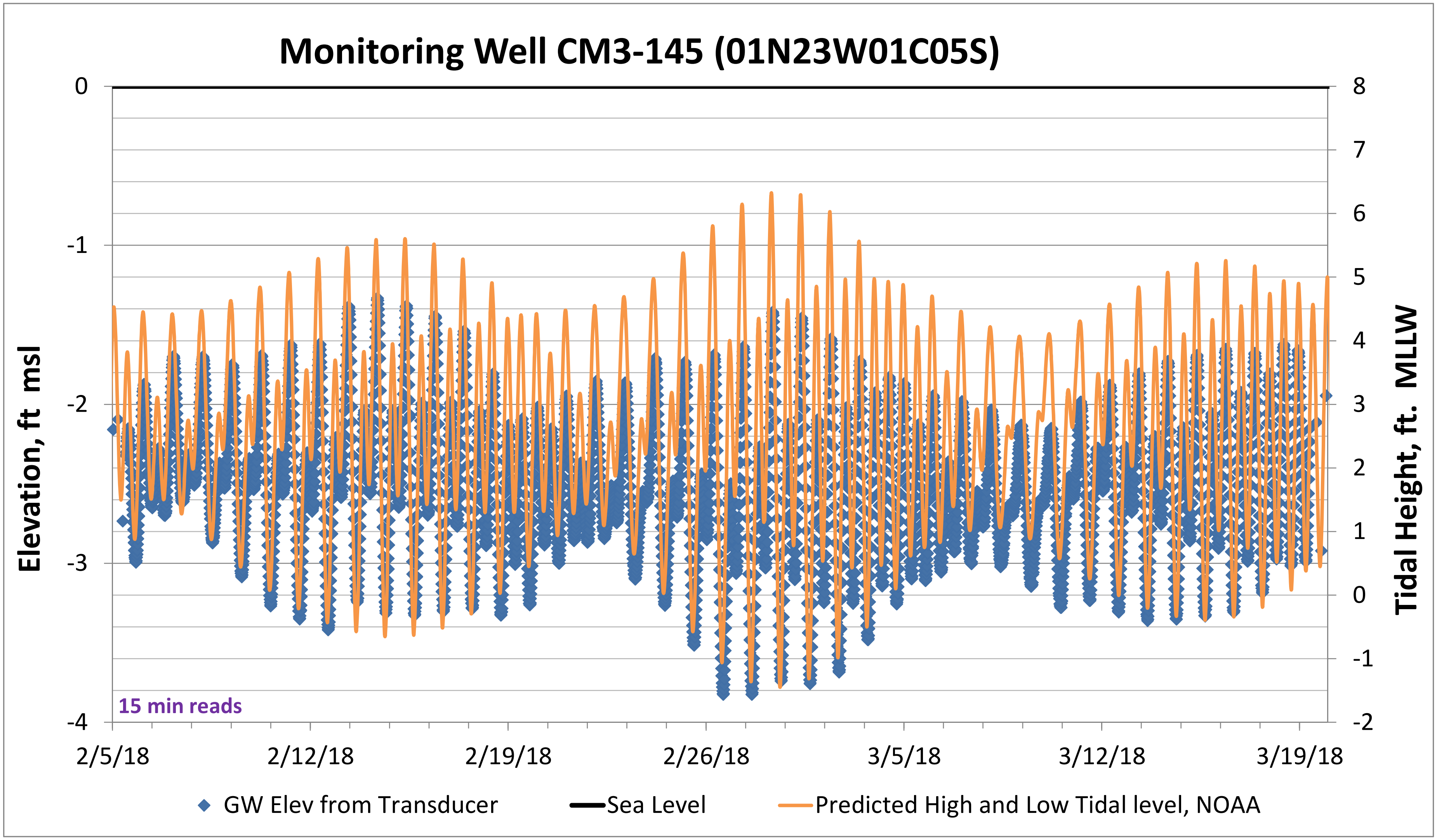


Figure 4-4. Tidal influence with UAS groundwater elevations in monitoring well, CM3-145.

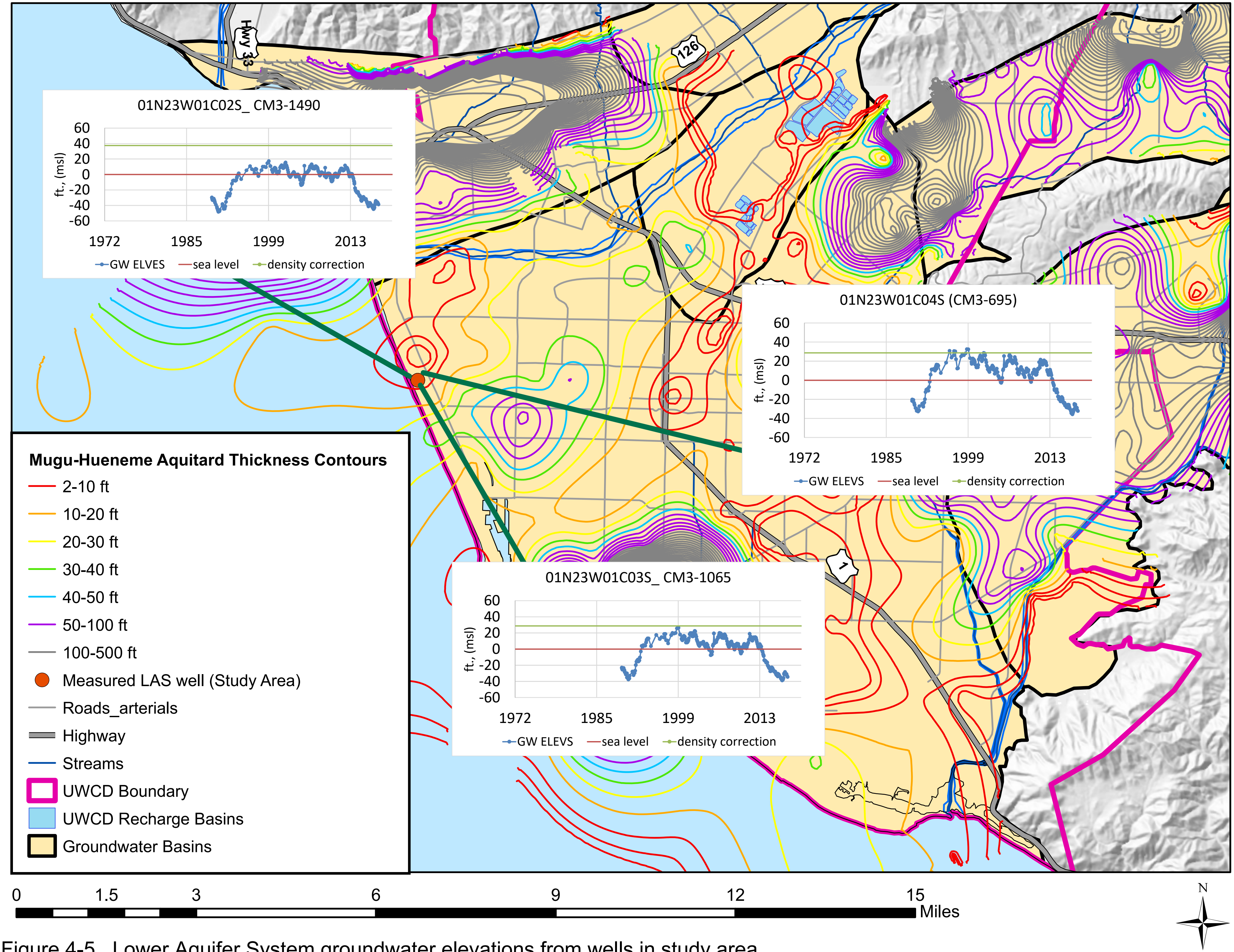


Figure 4-5. Lower Aquifer System groundwater elevations from wells in study area.

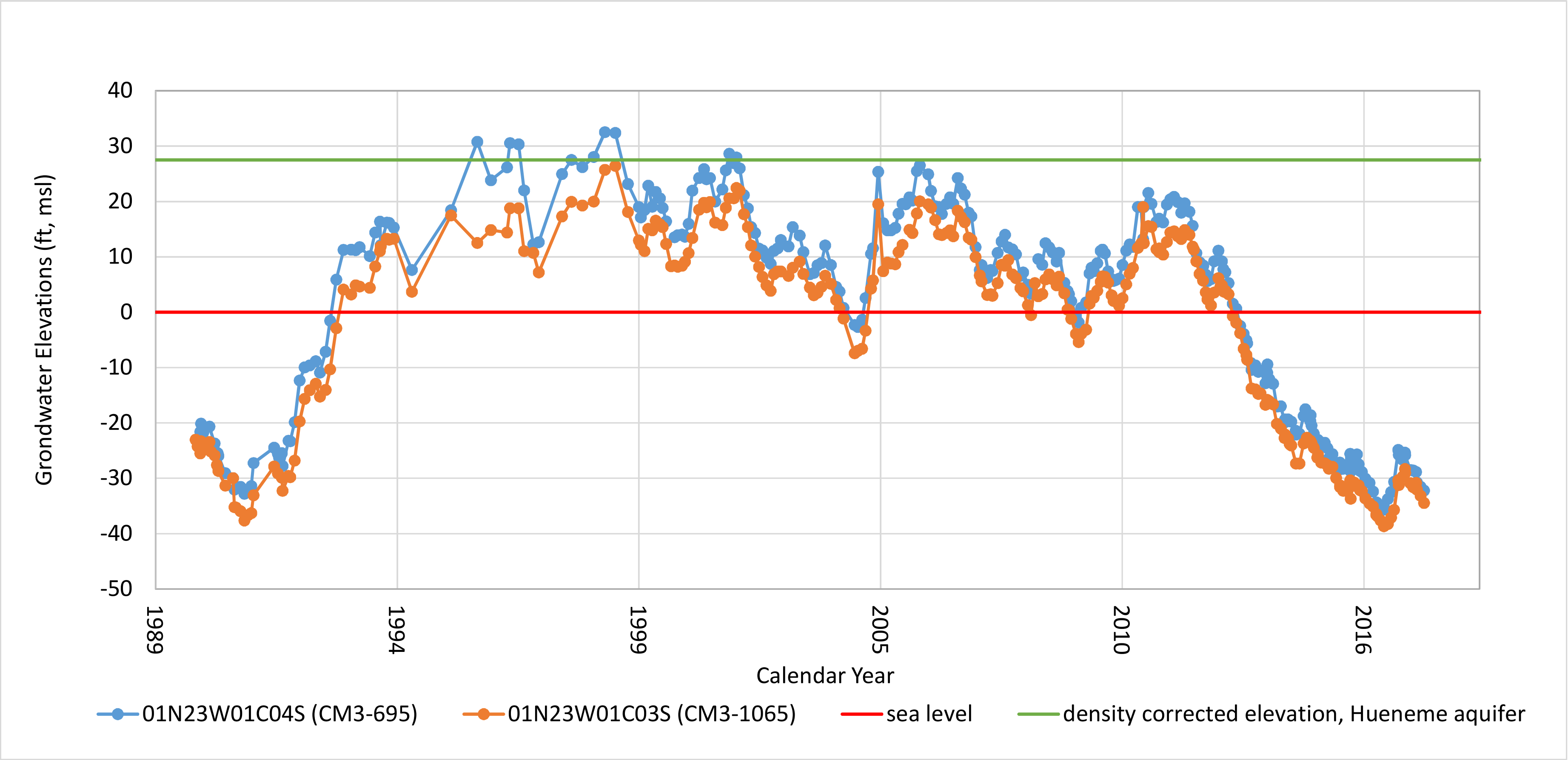


Figure 4-6. Groundwater elevations for wells within the study area screened in the Hueneme Aquifer.

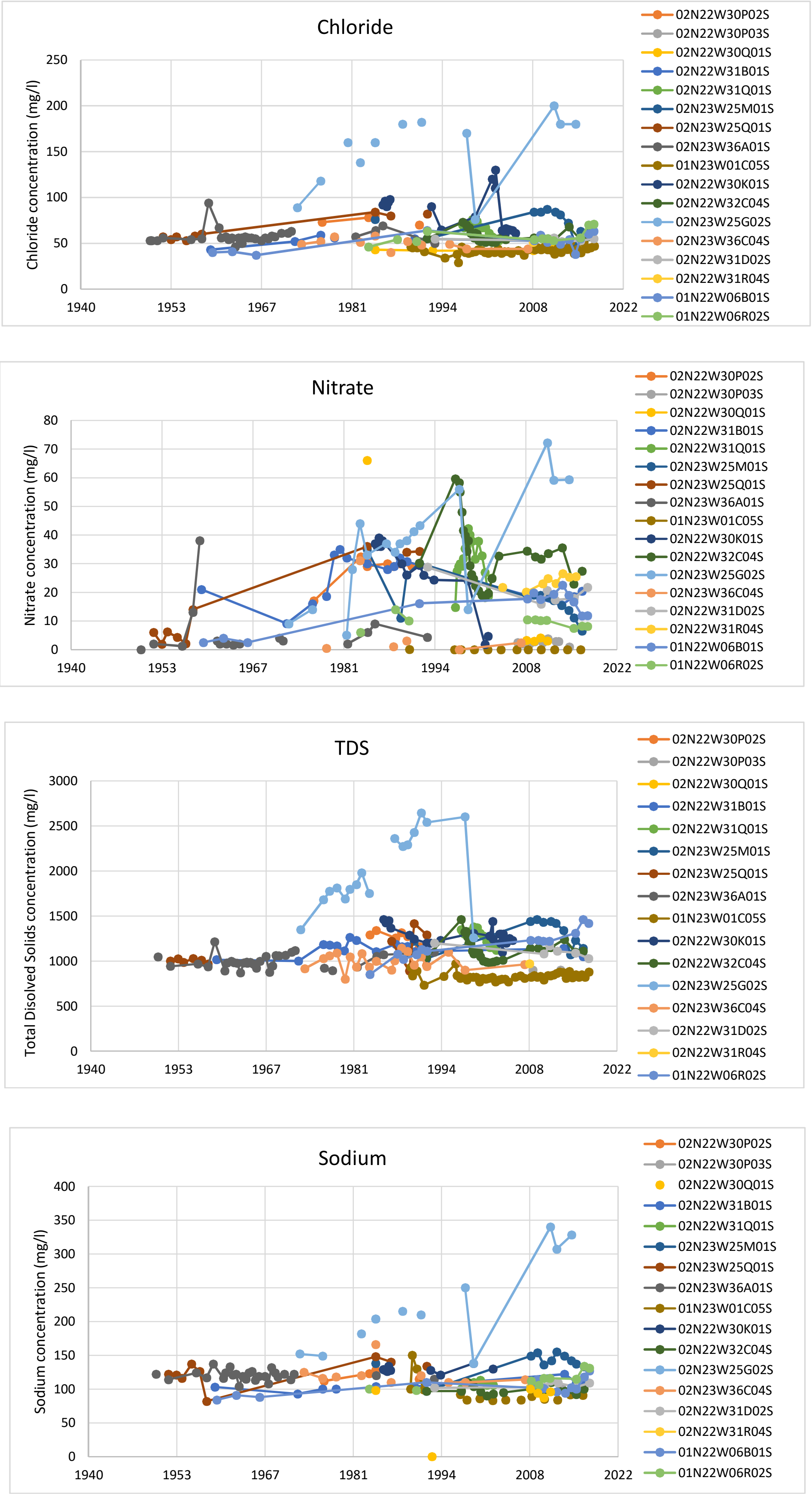


Figure 4-7. Groundwater quality from UAS wells within the study area.

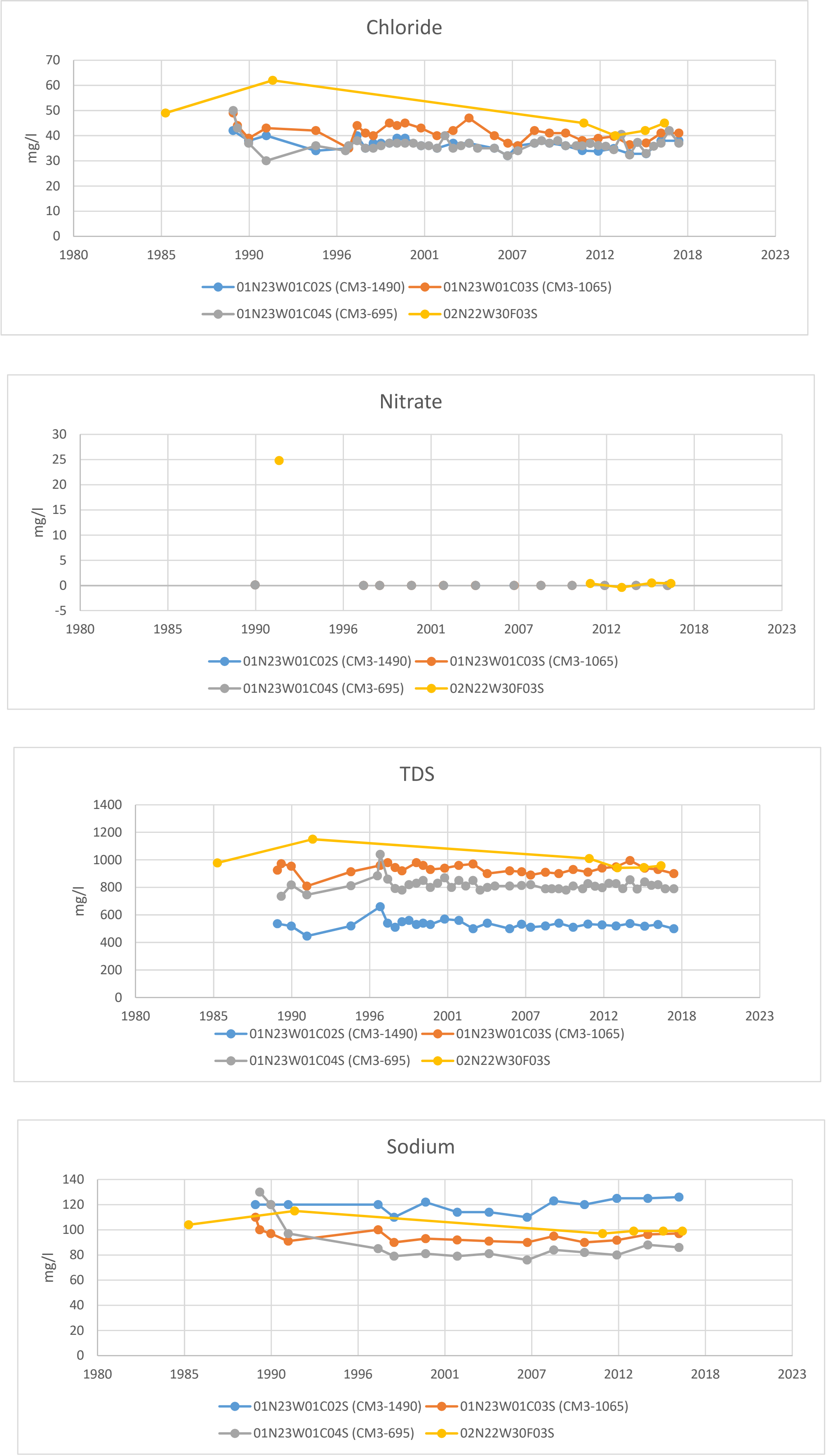


Figure 4-8. Groundwater quality from LAS wells within the study area.

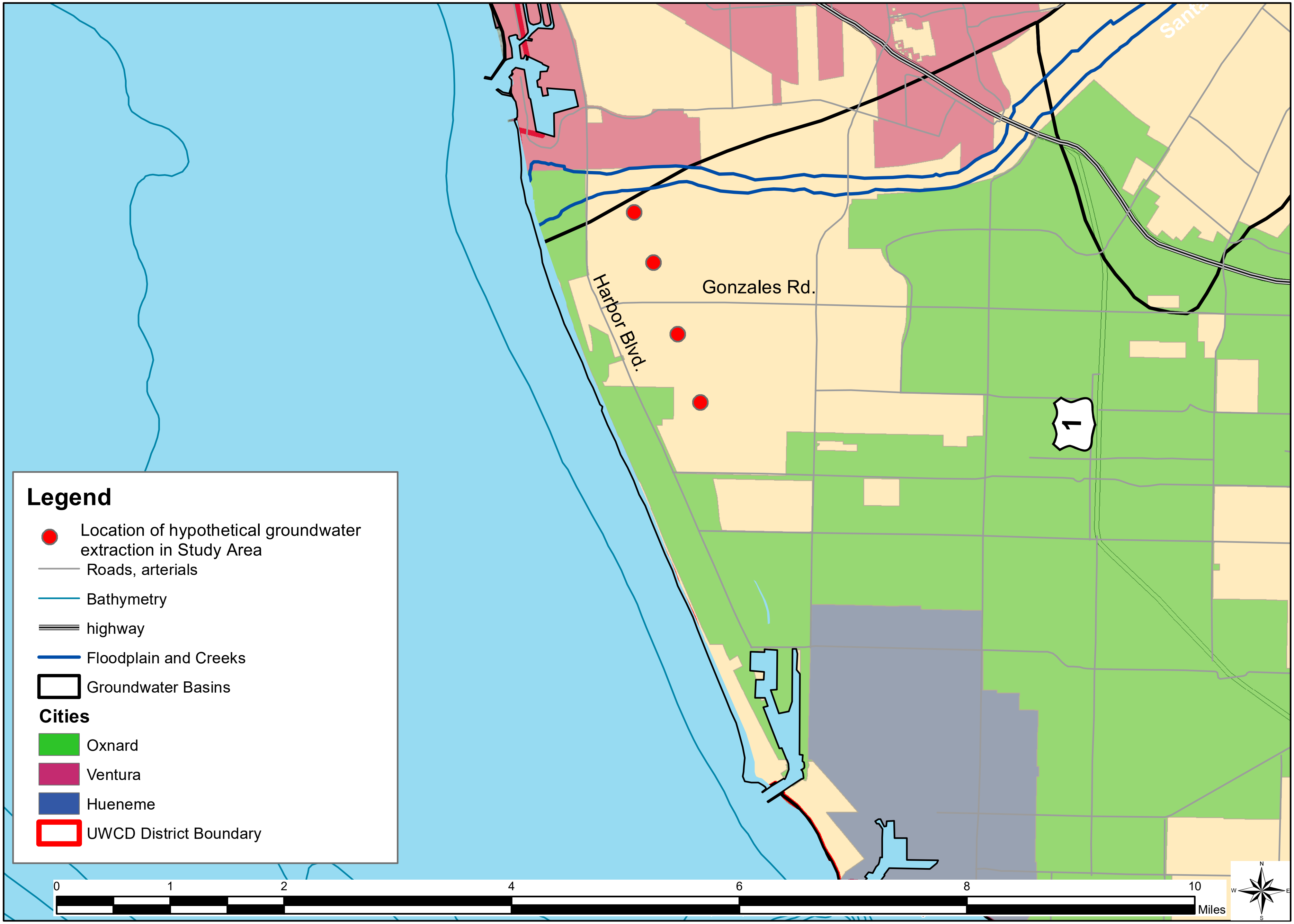


Figure 5-1. Locations of groundwater extraction in the study area used for the United Model pumping scenarios.

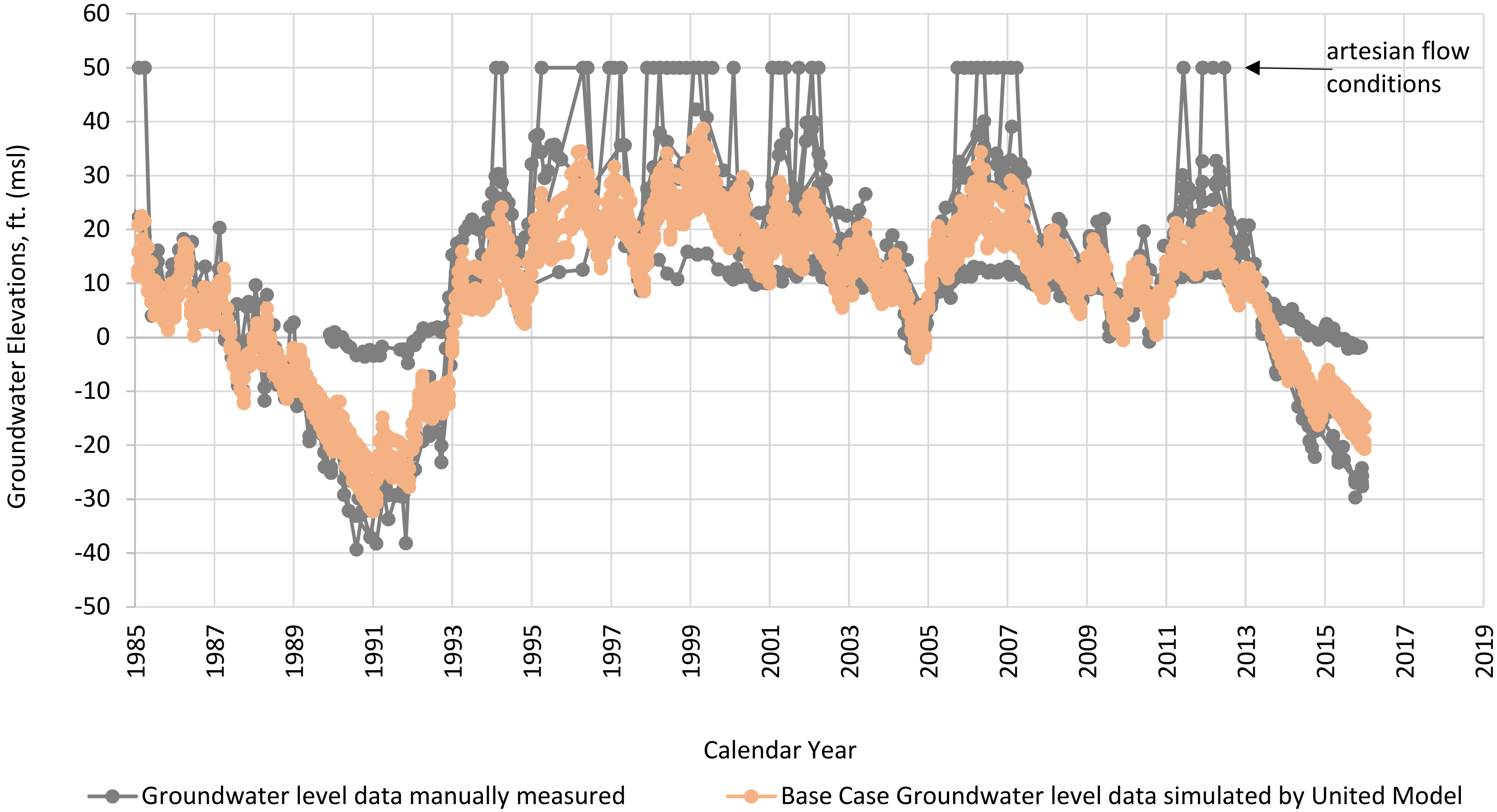


Figure 5-2. Manual measurements of groundwater elevations compared to groundwater elevation data simulated for base case scenario.

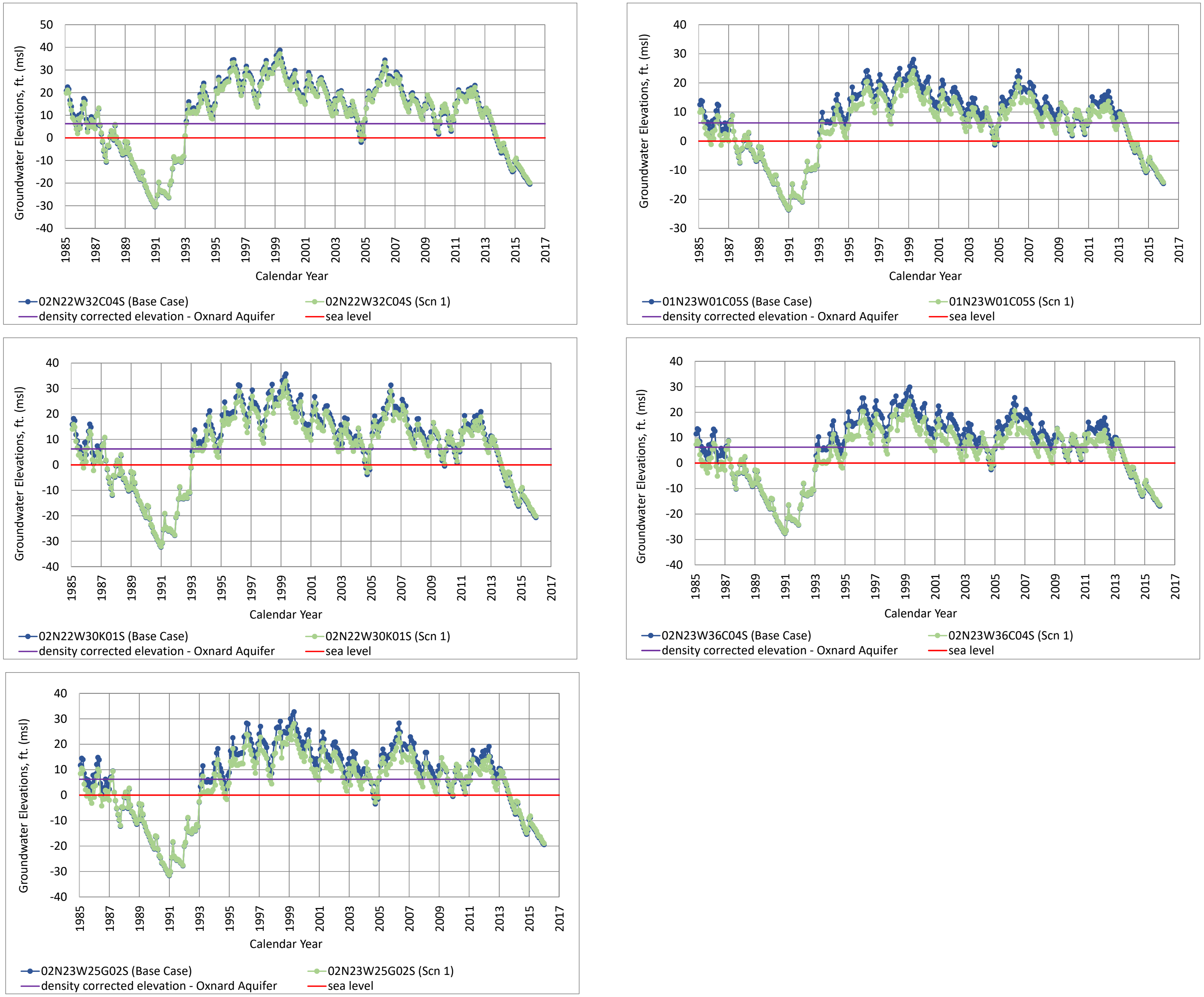


Figure 5-3. Groundwater elevations in UAS wells in study area, base case scenario compared to Scenario 1.

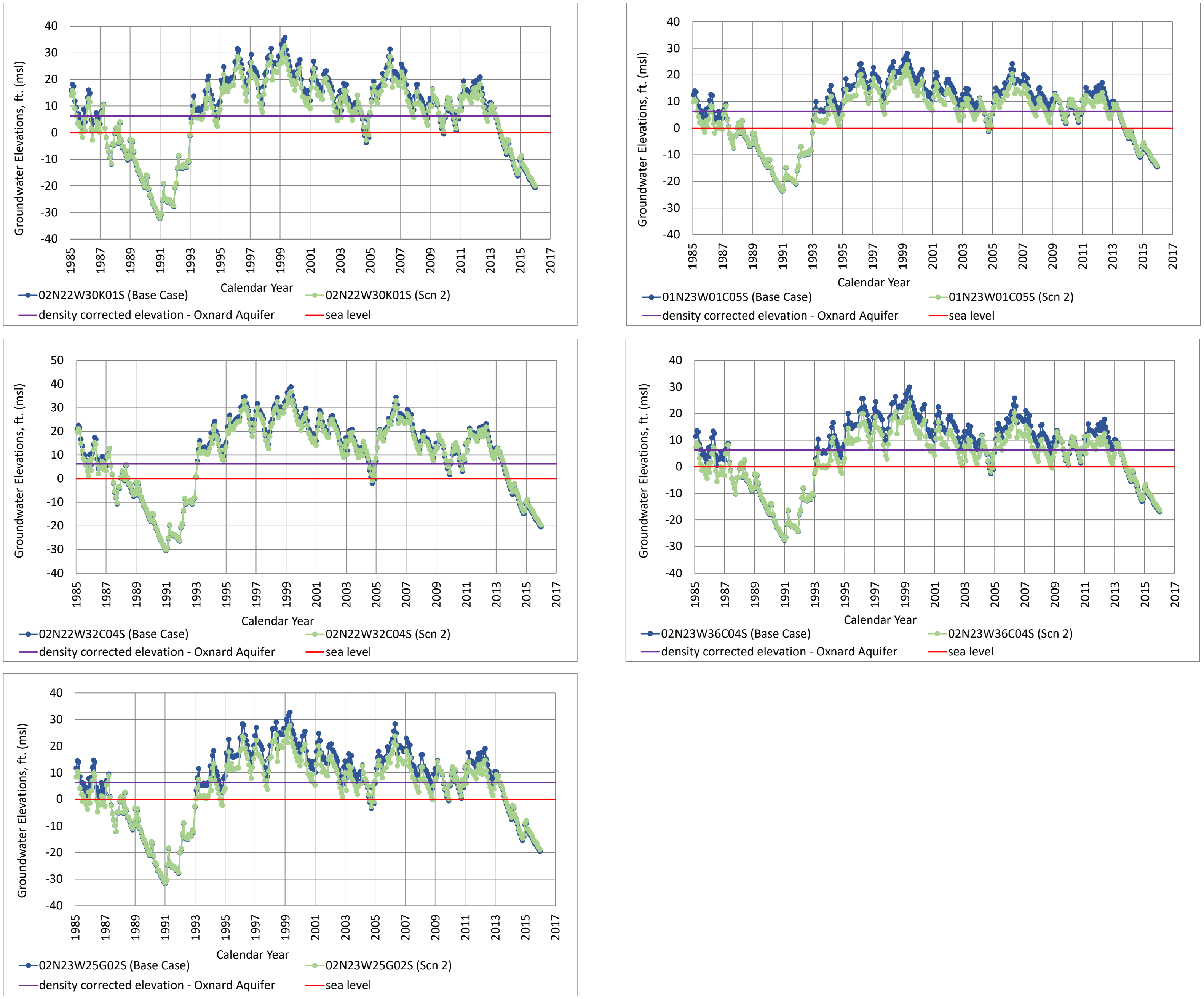


Figure 5-4. Groundwater elevations in UAS wells in study area, base case scenario compared to Scenario 2.

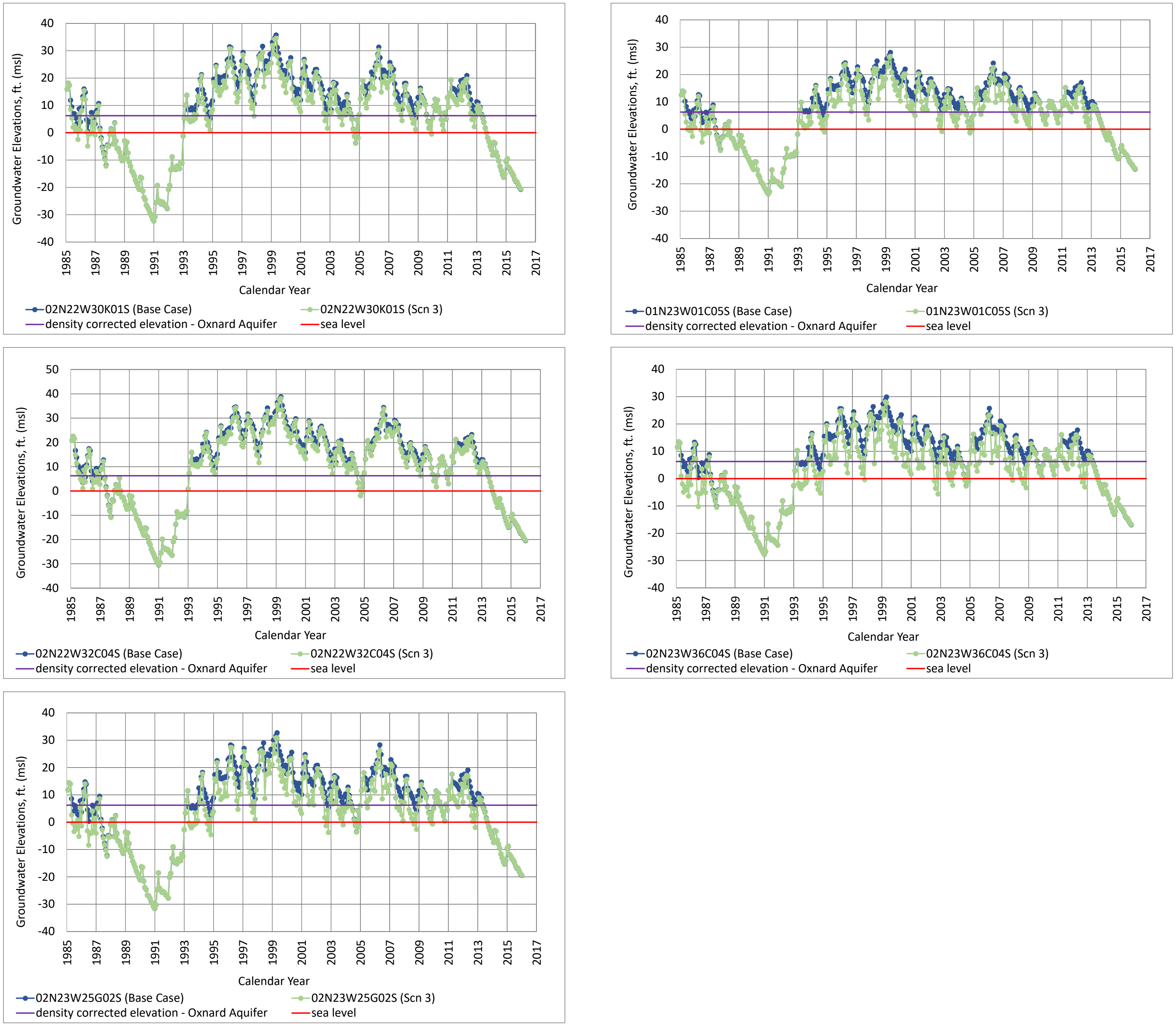


Figure 5-5. Groundwater elevations in UAS wells in study area, base case scenario compared to Scenario 3.

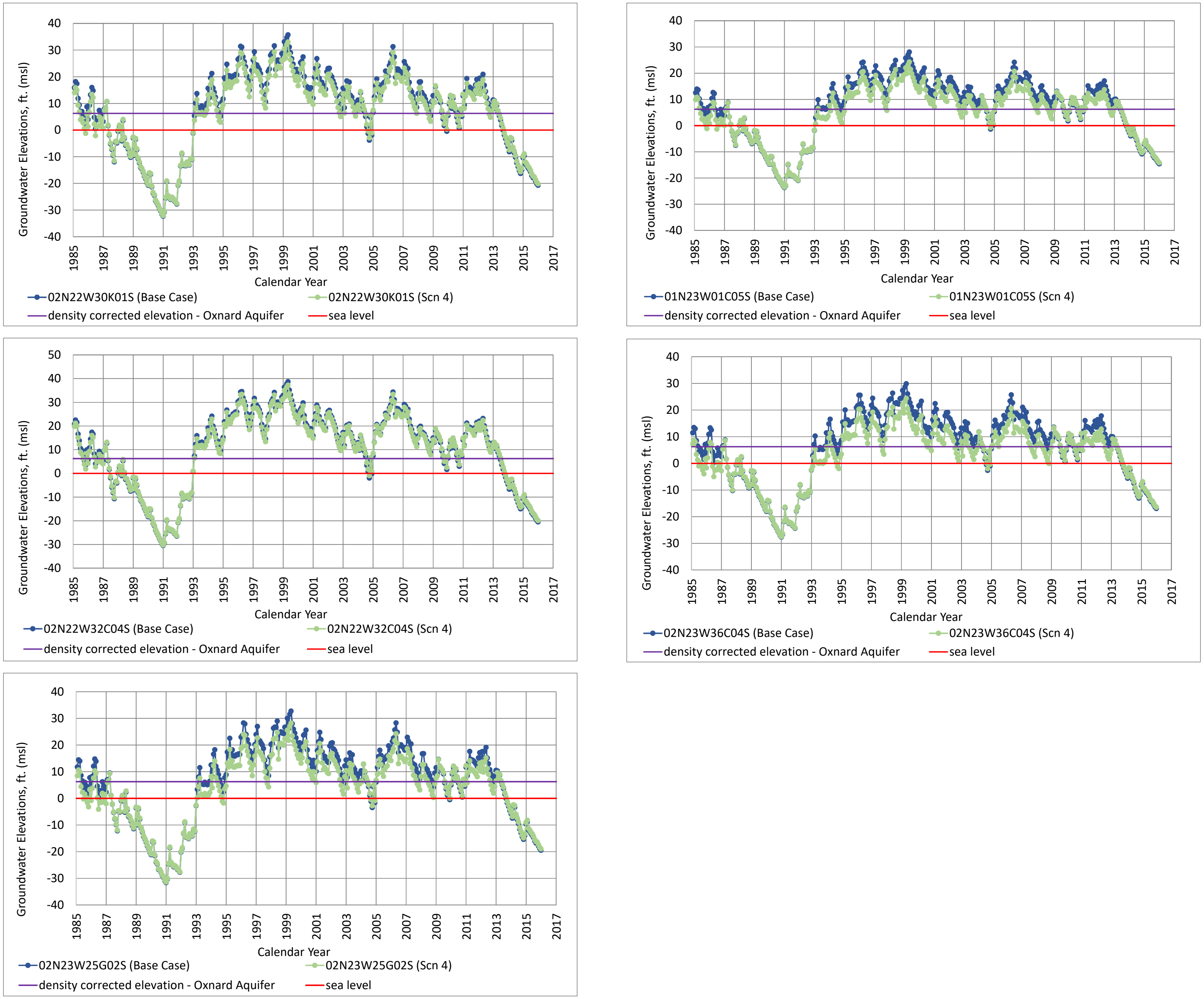


Figure 5-6. Groundwater elevations in UAS wells in study area, base case scenario compared to Scenario 4.

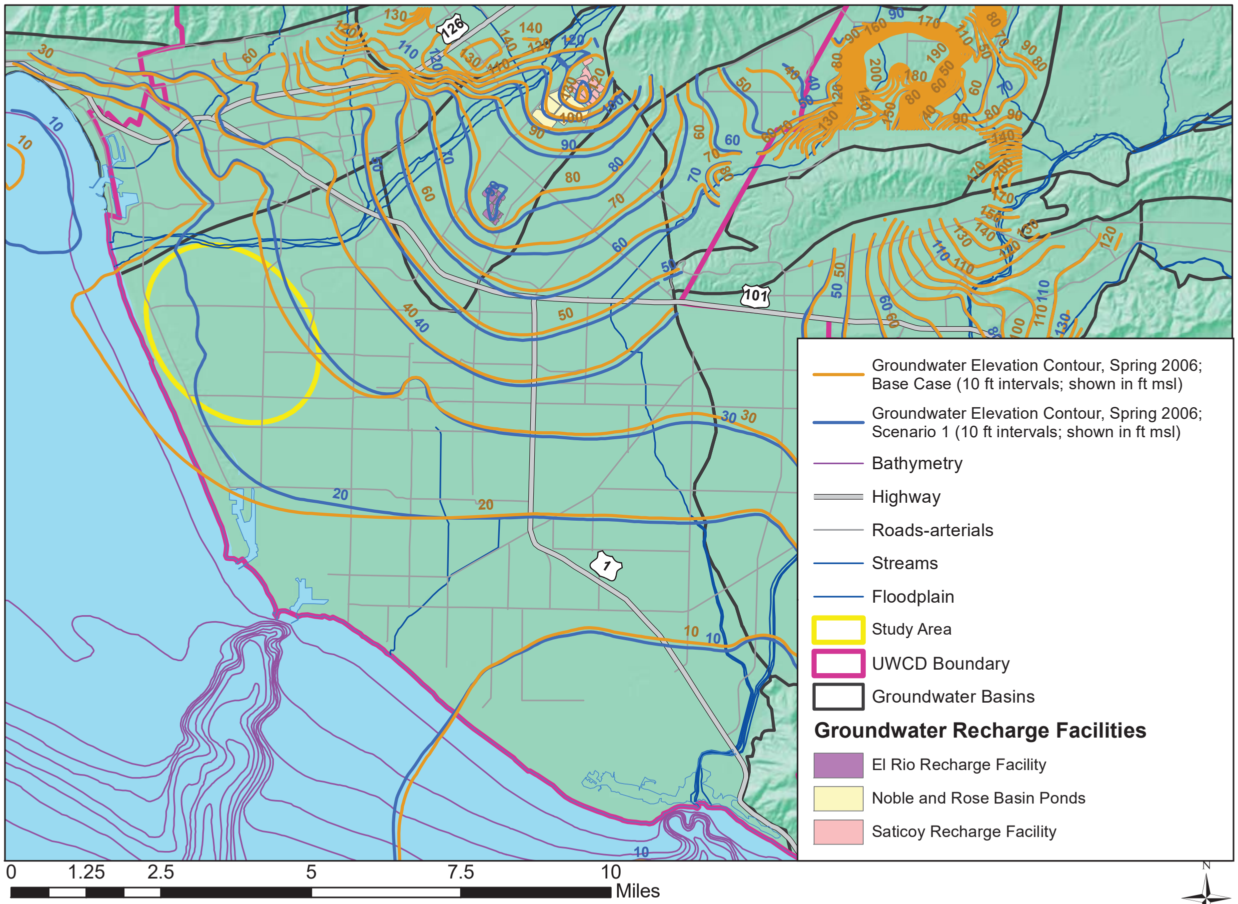


Figure 5-7. Upper Aquifer System groundwater elevations for spring 2006, Base Case Scenario compared to Scenario 1; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

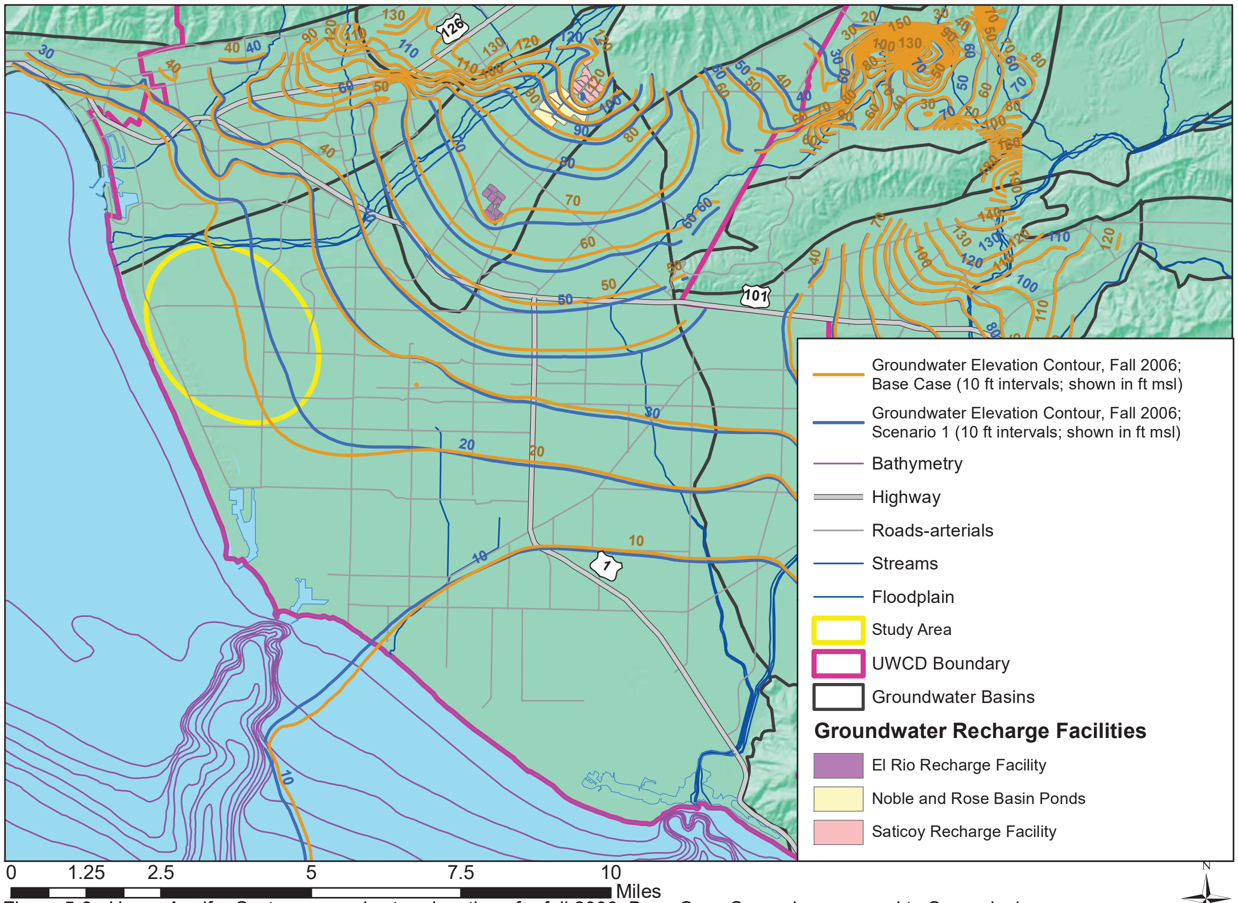


Figure 5-8. Upper Aquifer System groundwater elevations for fall 2006, Base Case Scenario compared to Scenario 1; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

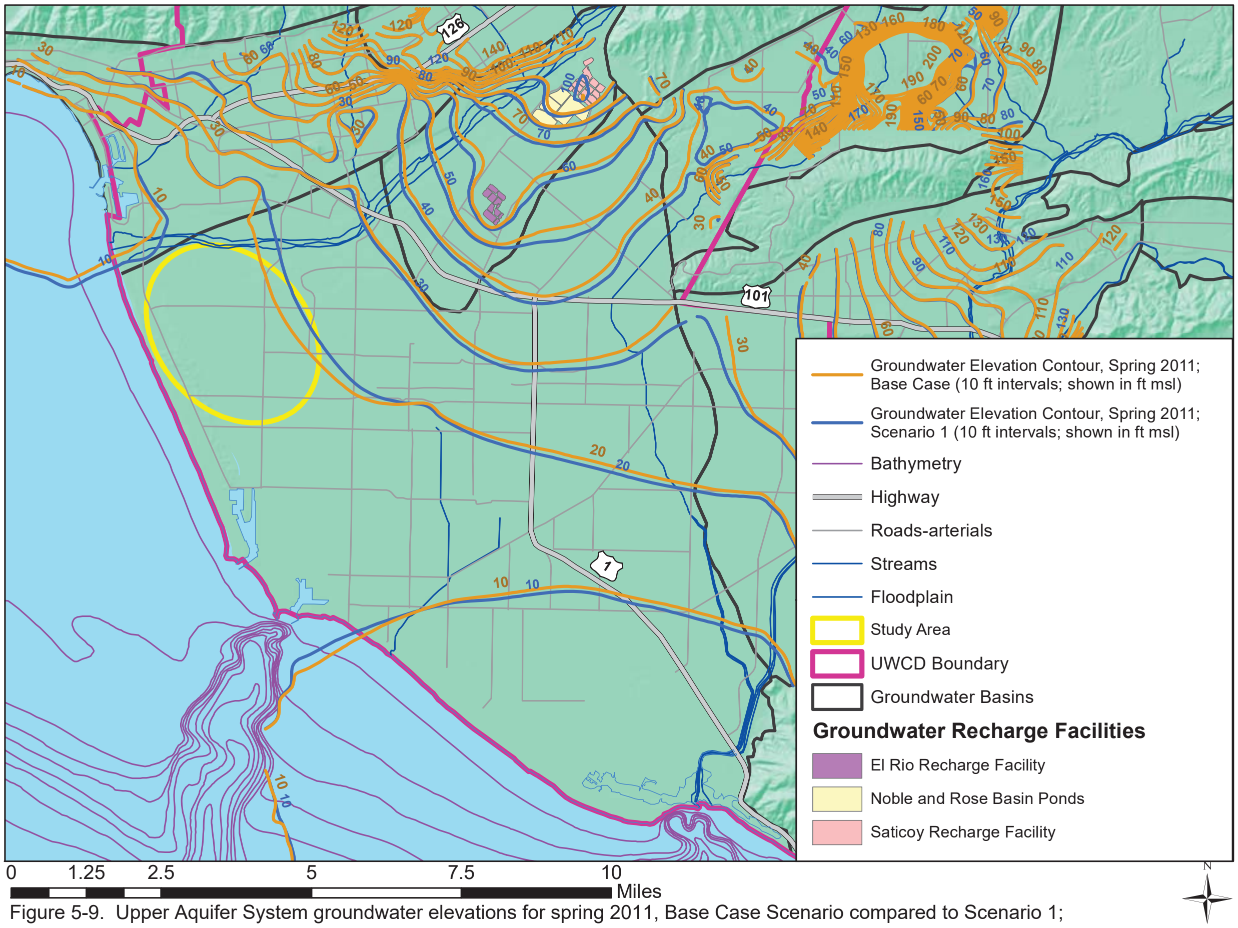


Figure 5-9. Upper Aquifer System groundwater elevations for spring 2011, Base Case Scenario compared to Scenario 1; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

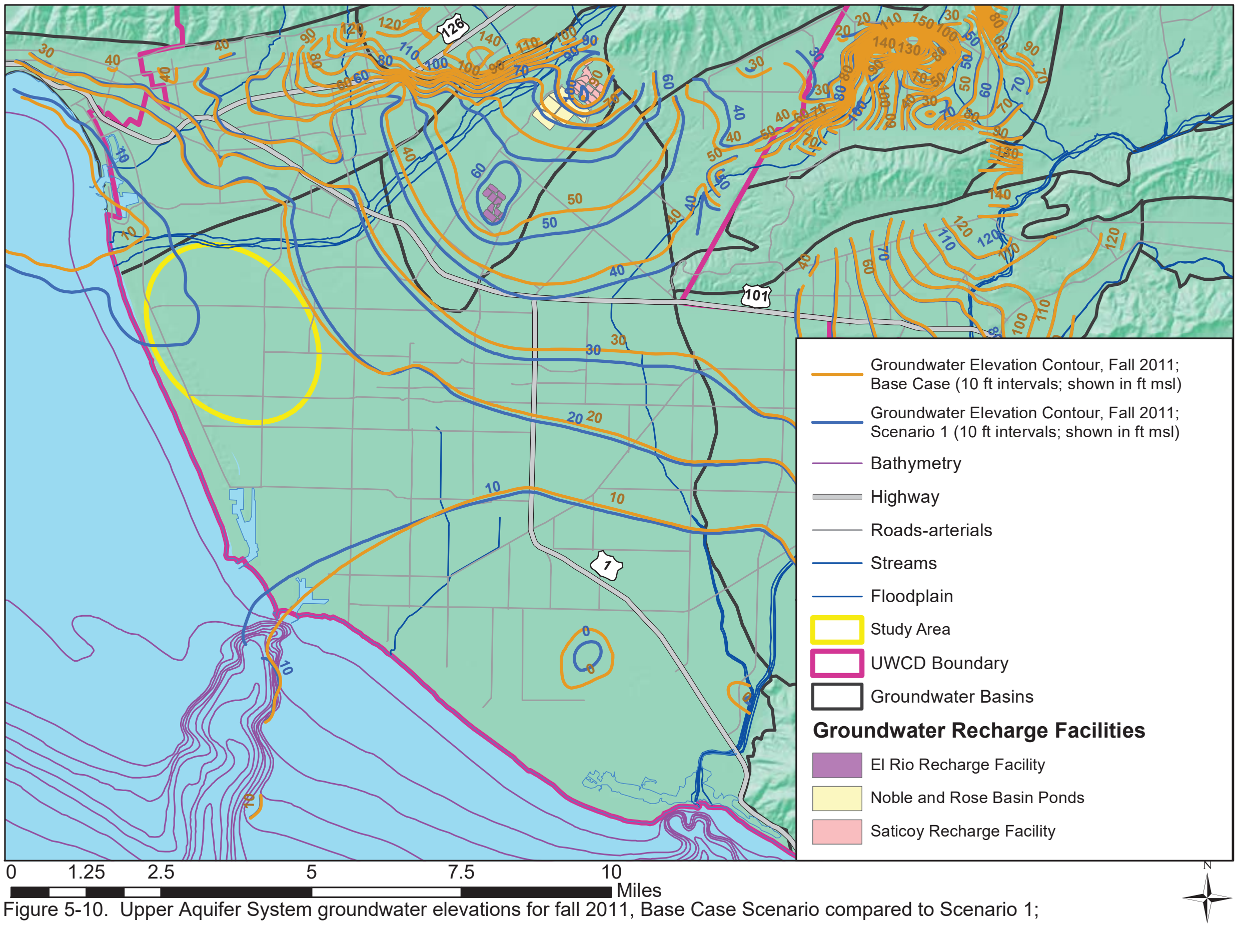


Figure 5-10. Upper Aquifer System groundwater elevations for fall 2011, Base Case Scenario compared to Scenario 1; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

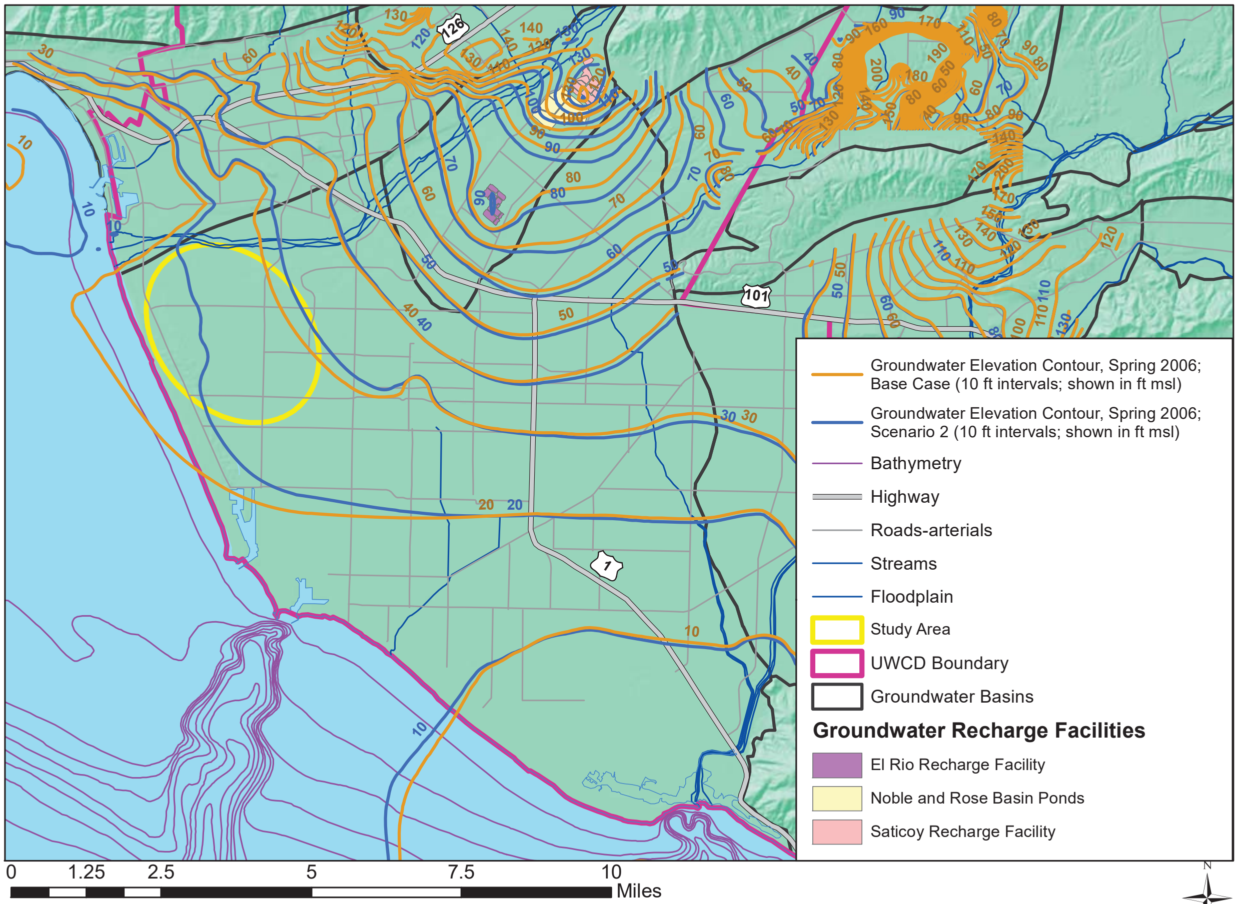


Figure 5-11. Upper Aquifer System groundwater elevations for spring 2006, Base Case Scenario compared to Scenario 2; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

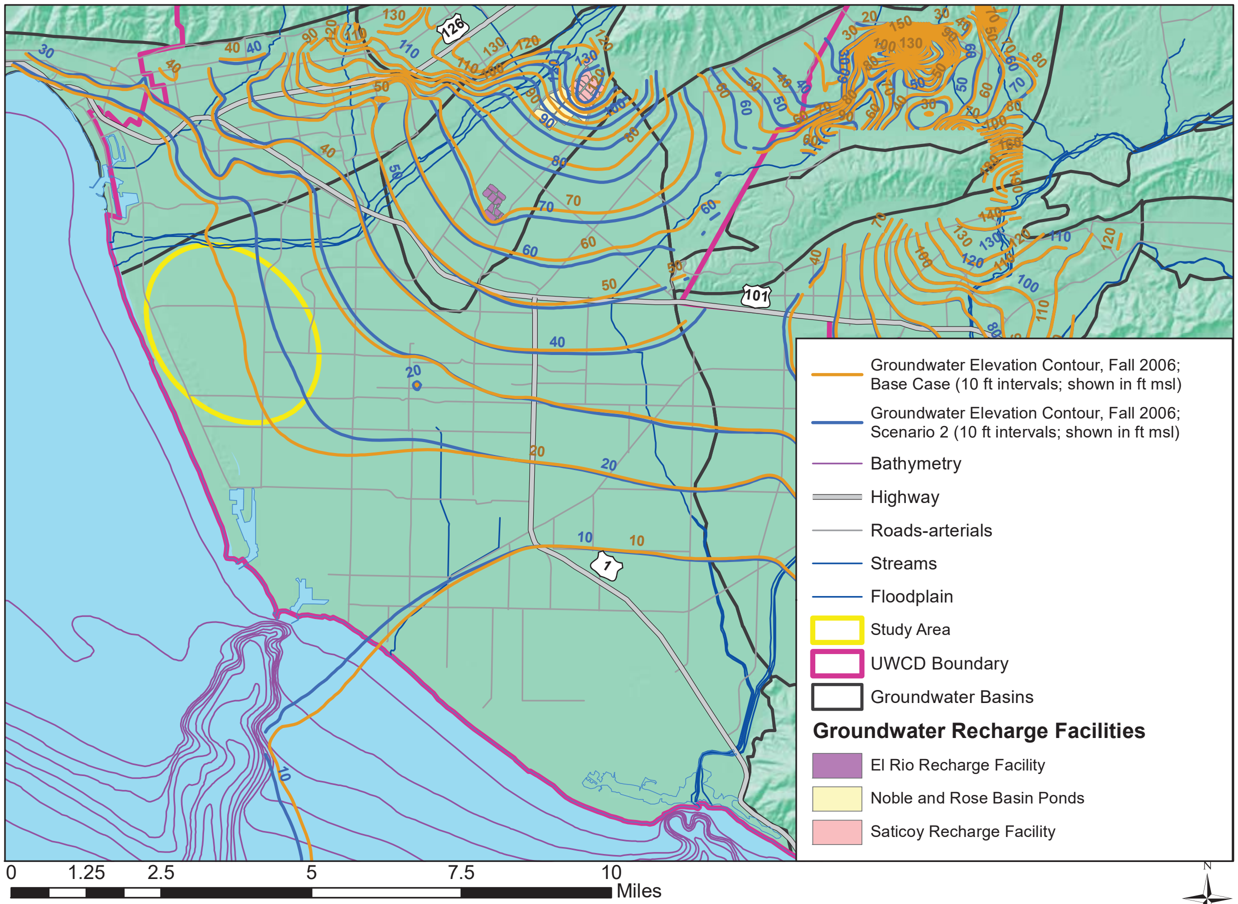


Figure 5-12. Upper Aquifer System groundwater elevations for fall 2006, Base Case Scenario compared to Scenario 2; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

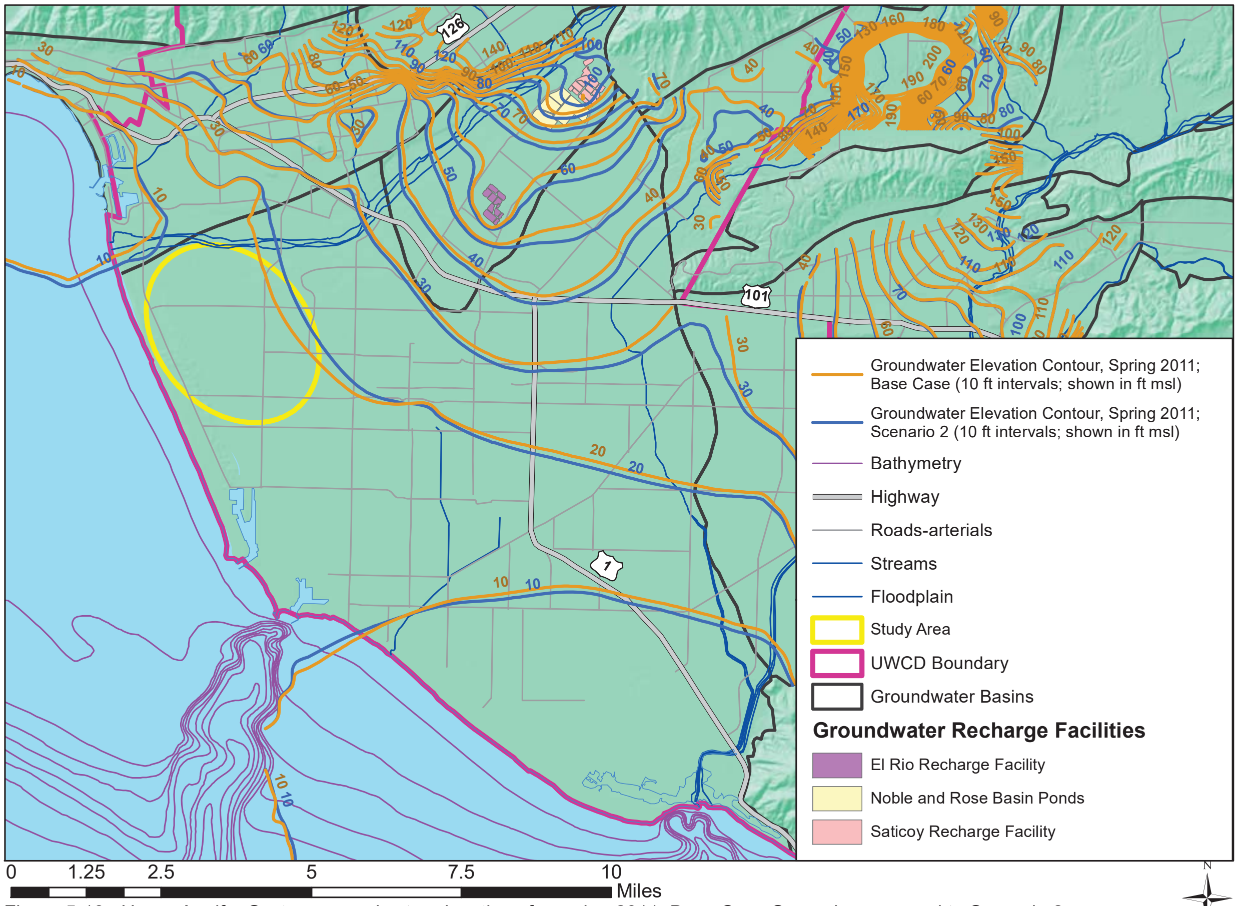


Figure 5-13. Upper Aquifer System groundwater elevations for spring 2011, Base Case Scenario compared to Scenario 2; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

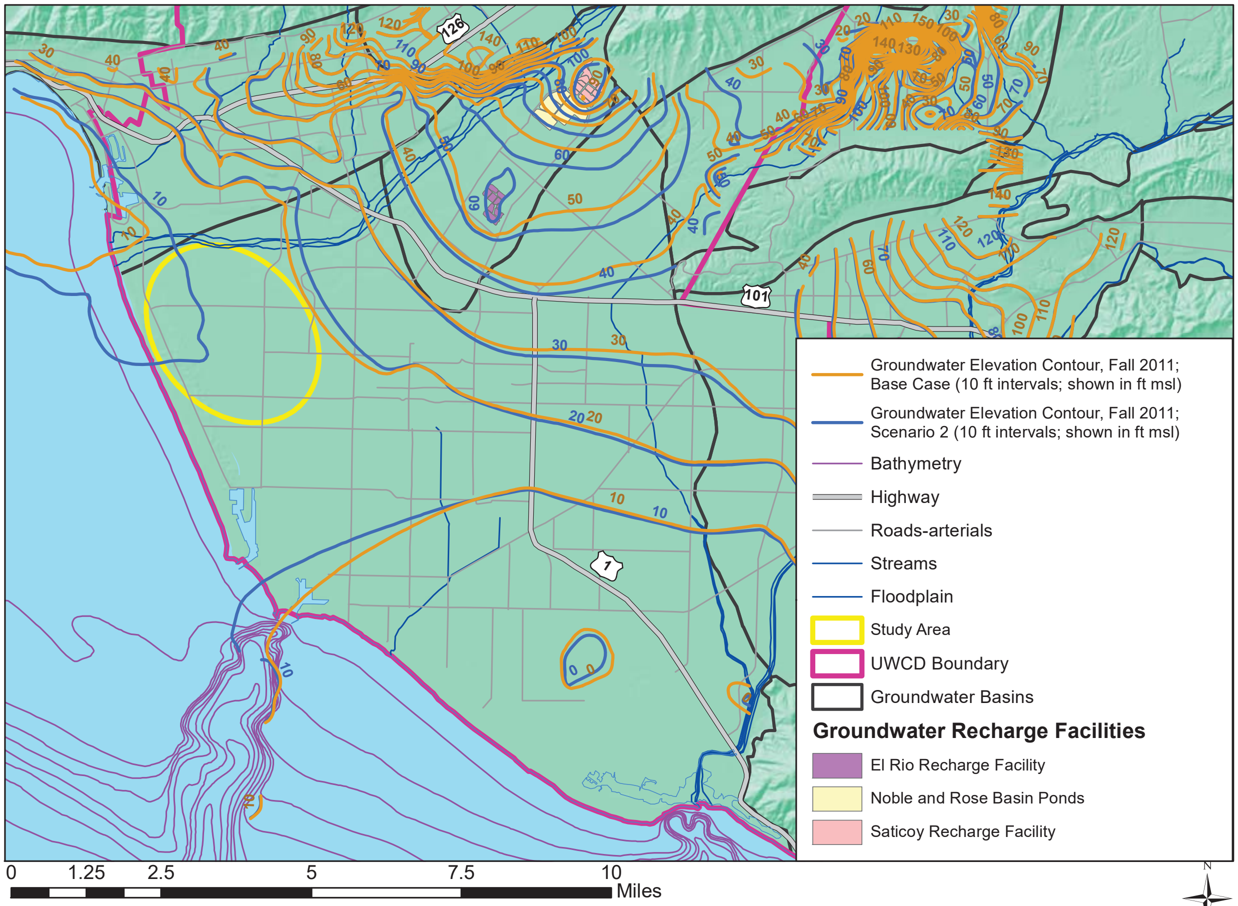


Figure 5-14. Upper Aquifer System groundwater elevations for fall 2011, Base Case Scenario compared to Scenario 2; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

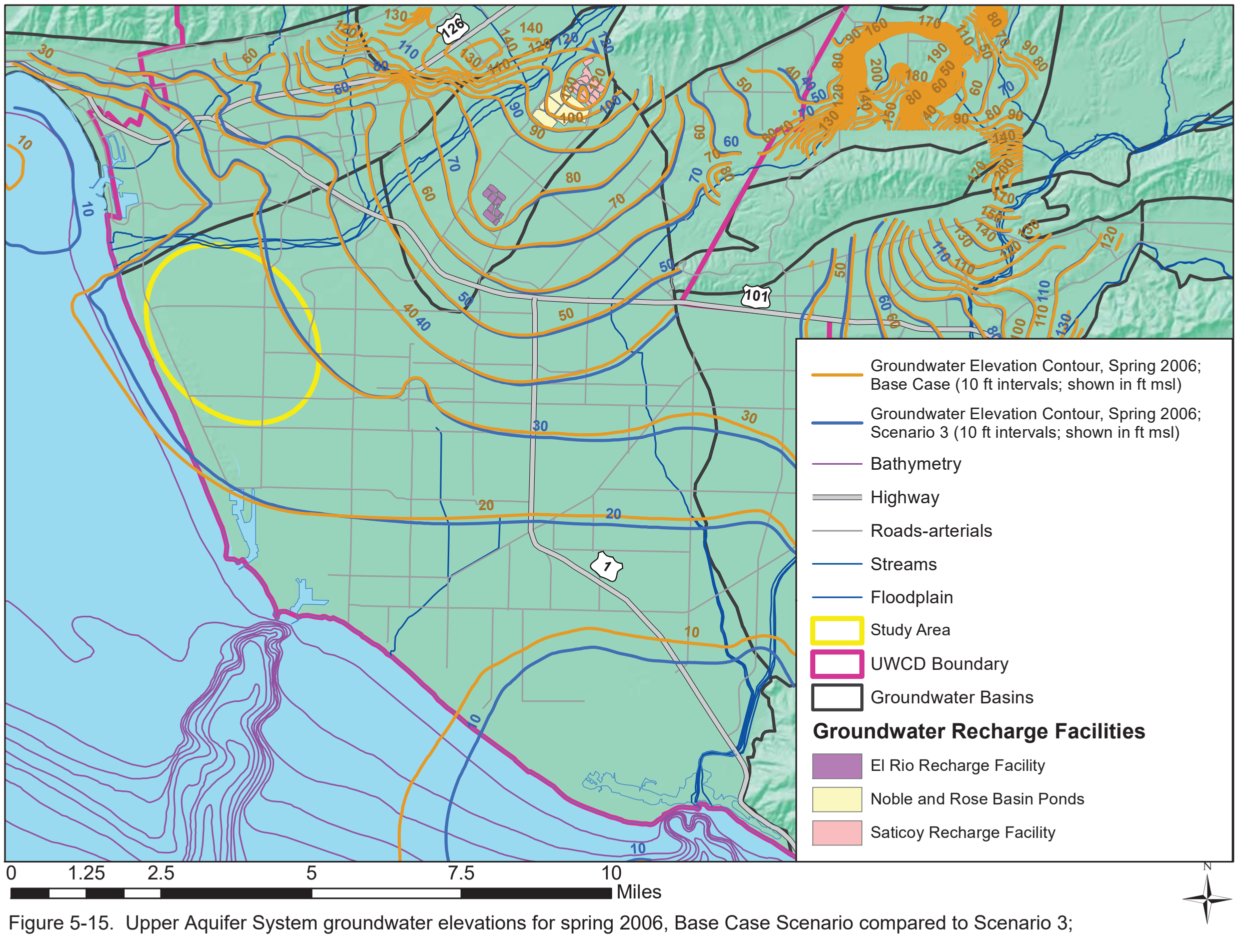


Figure 5-15. Upper Aquifer System groundwater elevations for spring 2006, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

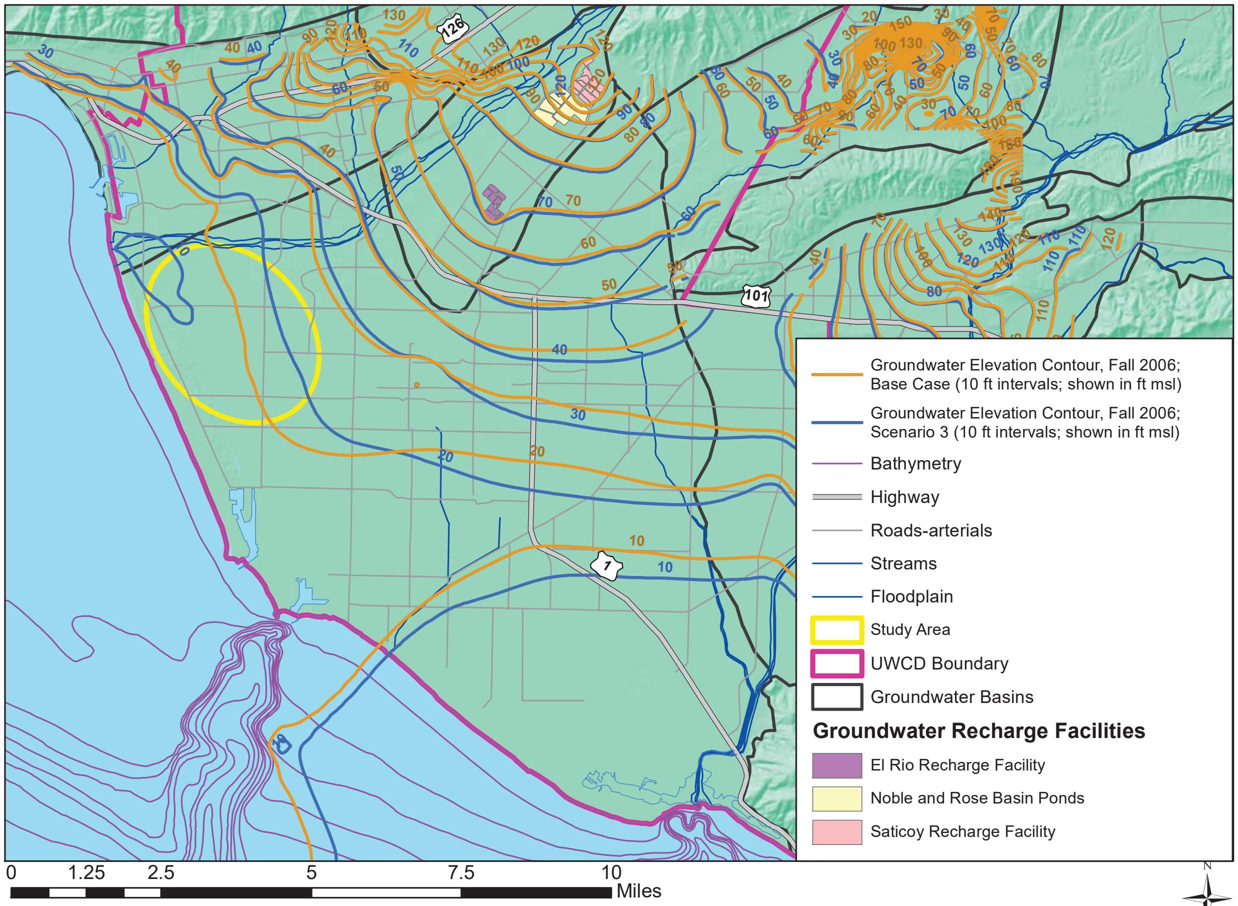


Figure 5-16. Upper Aquifer System groundwater elevations for fall 2006, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

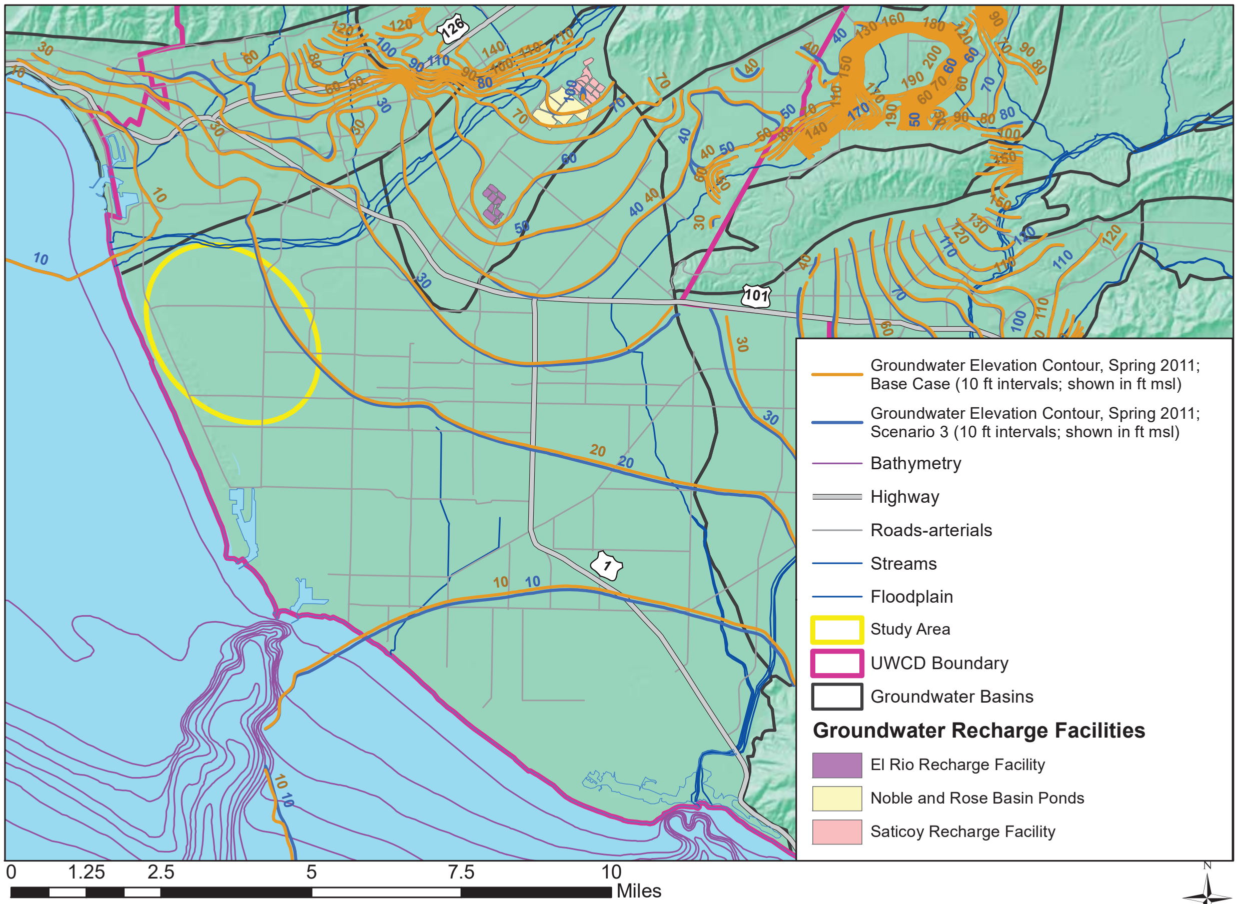


Figure 5-17. Upper Aquifer System groundwater elevations for spring 2011, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

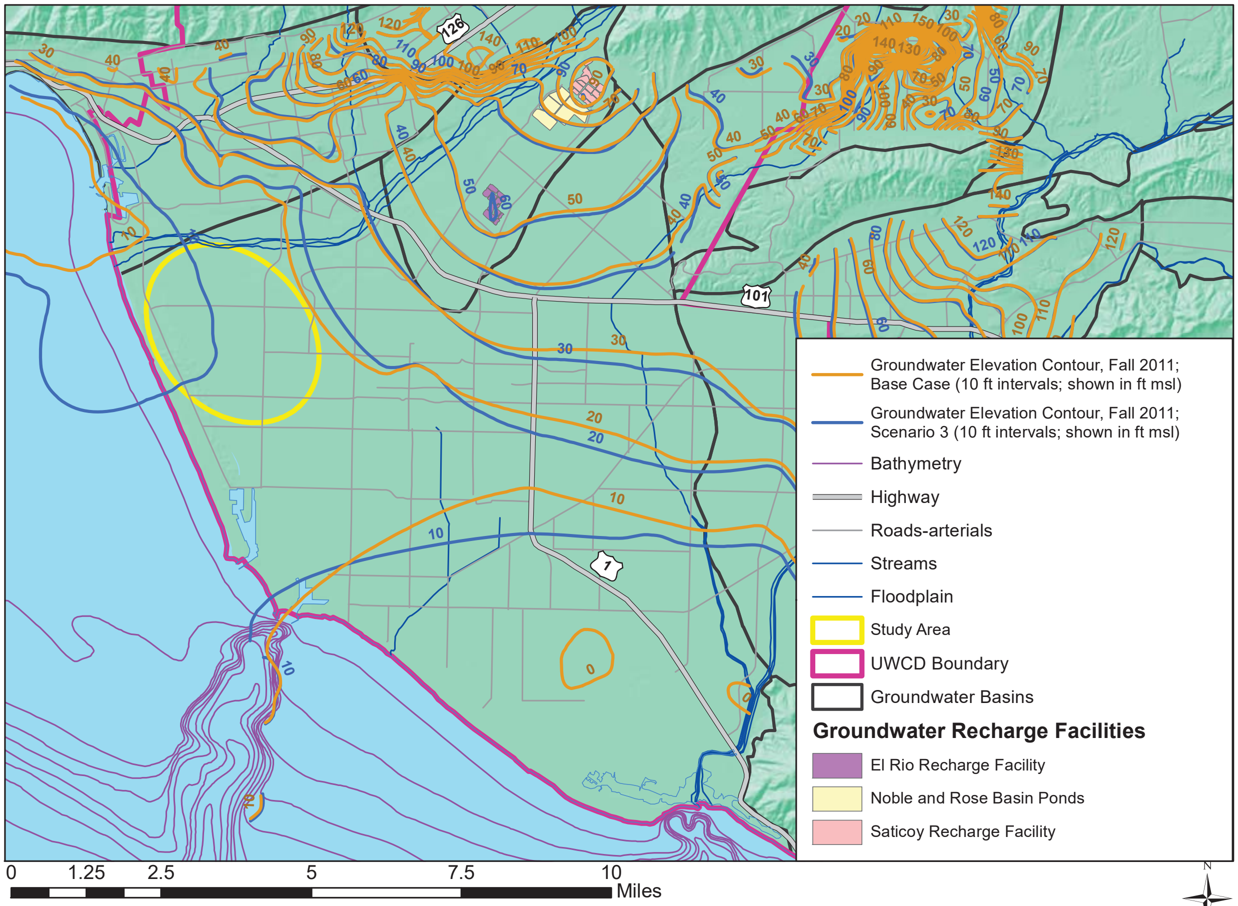


Figure 5-18. Upper Aquifer System groundwater elevations for fall 2011, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

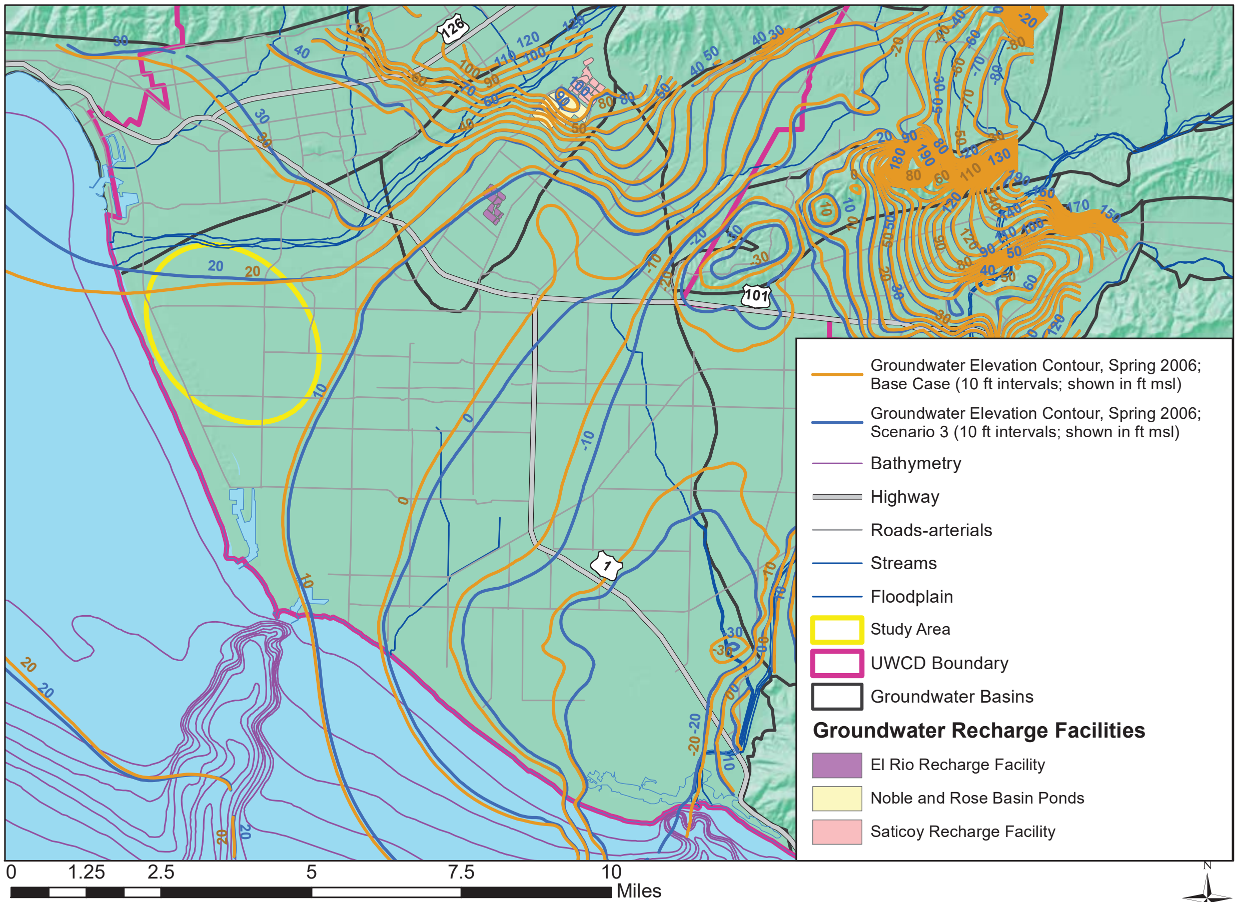


Figure 5-19. Lower Aquifer System groundwater elevations for spring 2006, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

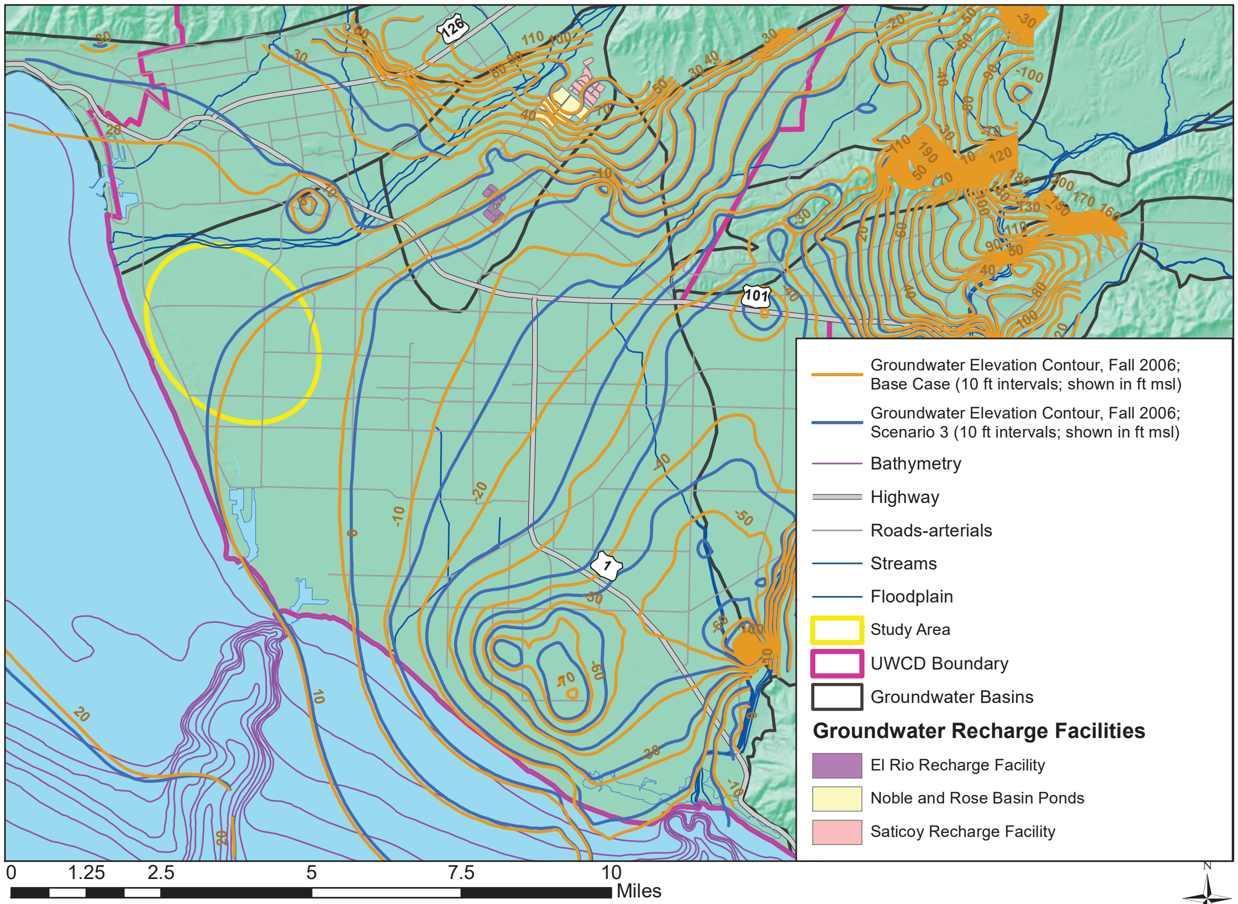


Figure 5-20. Lower Aquifer System groundwater elevations for fall 2006, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

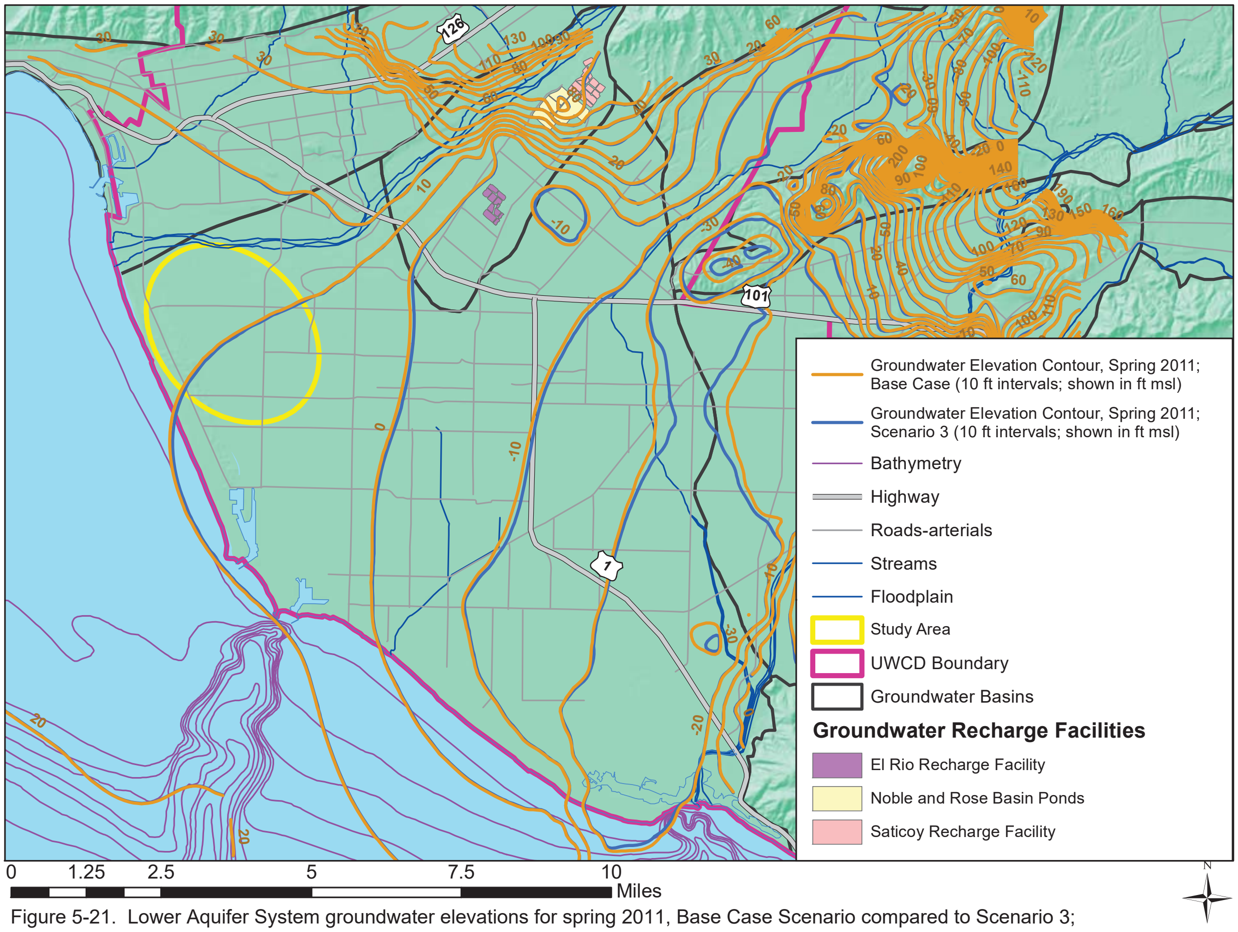


Figure 5-21. Lower Aquifer System groundwater elevations for spring 2011, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

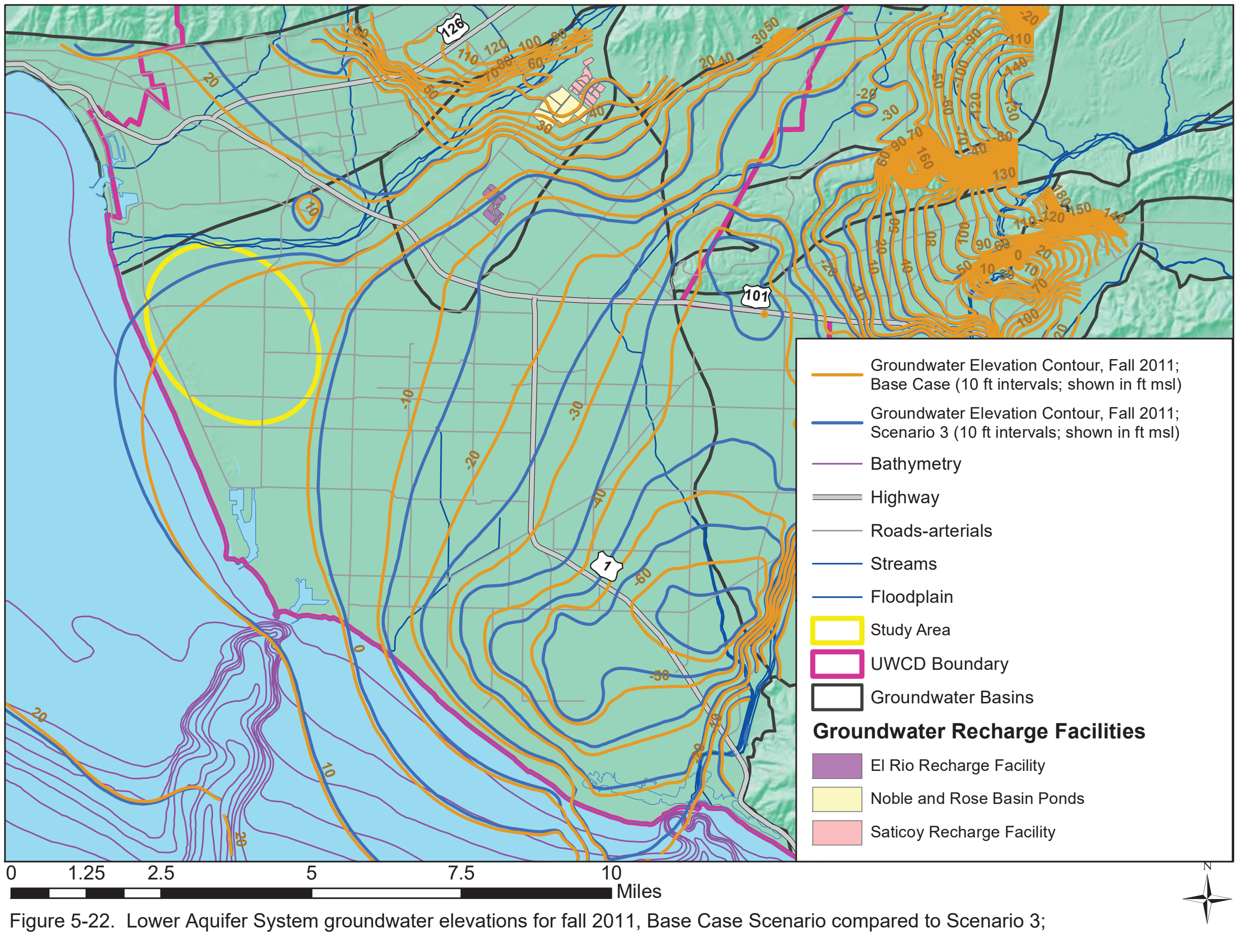


Figure 5-22. Lower Aquifer System groundwater elevations for fall 2011, Base Case Scenario compared to Scenario 3; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

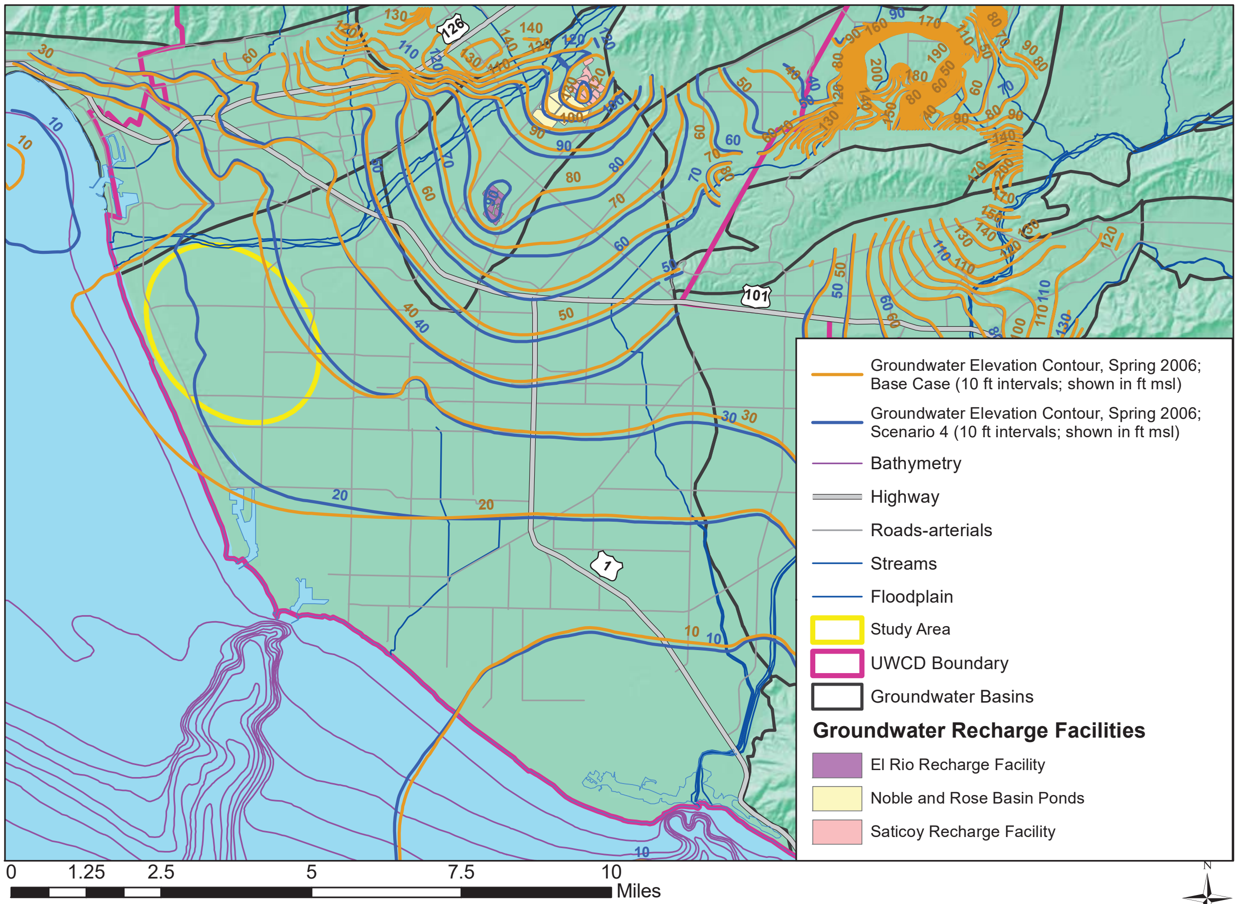


Figure 5-23. Upper Aquifer System groundwater elevations for spring 2006, Base Case Scenario compared to Scenario 4; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

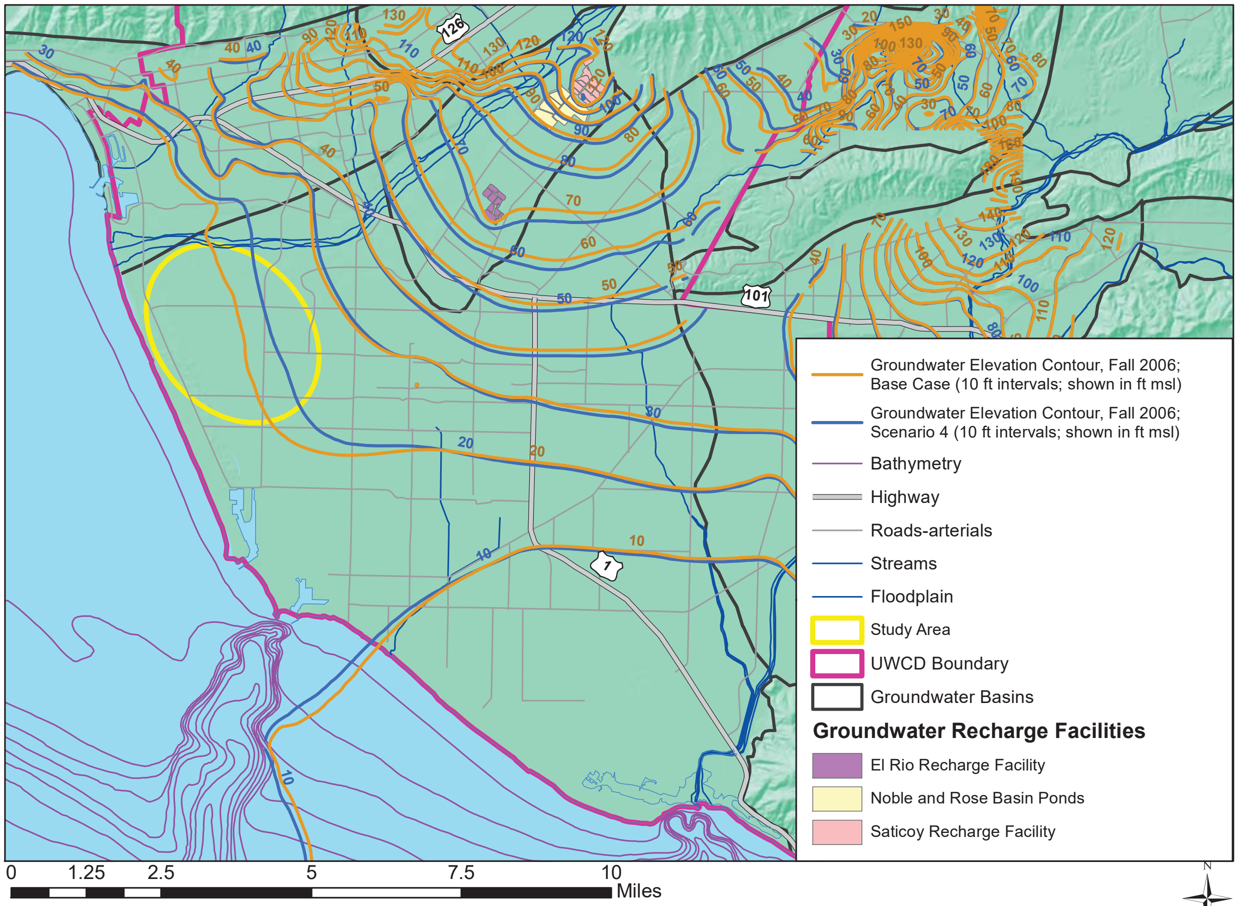


Figure 5-24. Upper Aquifer System groundwater elevations for fall 2006, Base Case Scenario compared to Scenario 4; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

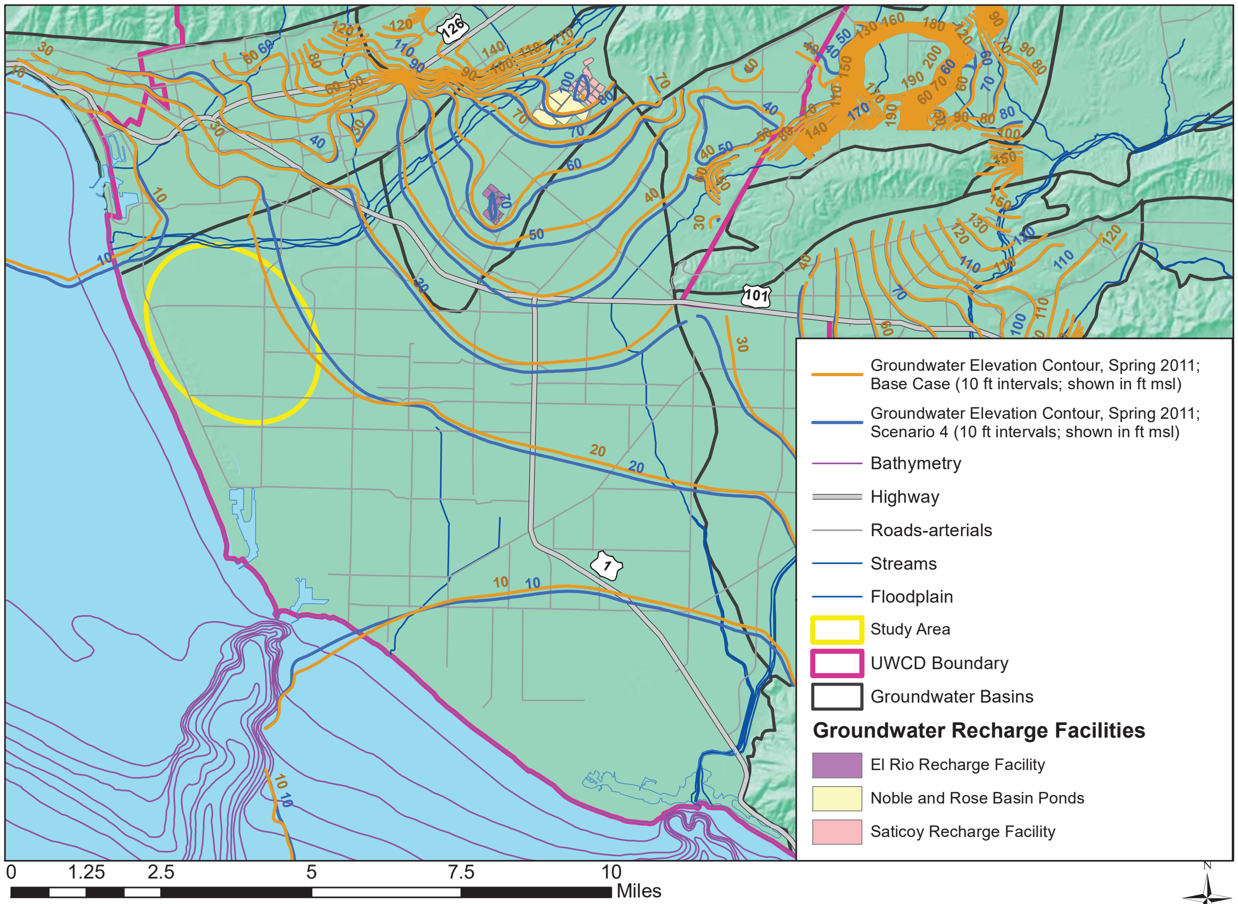


Figure 5-25. Upper Aquifer System groundwater elevations for spring 2011, Base Case Scenario compared to Scenario 4; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.

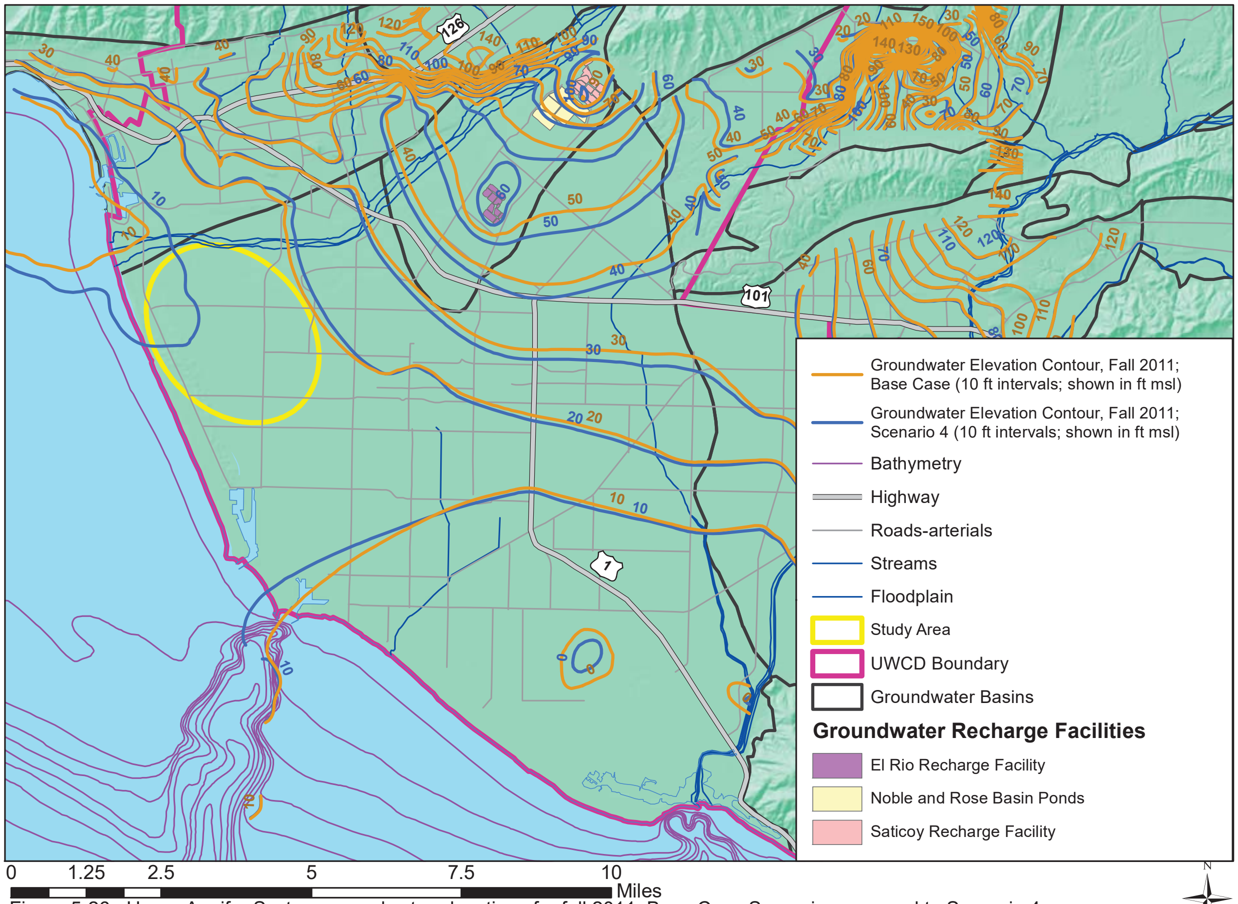


Figure 5-26. Upper Aquifer System groundwater elevations for fall 2011, Base Case Scenario compared to Scenario 4; Oxnard Forebay and Oxnard Plain, and surrounding areas; example of wet year.