Recycled Water Pumping Allocation Impact Analysis

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Background

Seawater intrusion due to groundwater overdraft in the Oxnard Basin has been reported since the 1930s. The Department of Water Resources (DWR) published Bulletin No. 63-1 in 1965, providing a detailed description of historical groundwater overdraft and seawater intrusion since 1930 (DWR, 1965). The United Water Conservation District (UWCD) has published reports on seawater intrusion in recent years (UWCD, 2016; UWCD, 2021a).

In response to groundwater overdraft, the Fox Canyon Groundwater Management Agency (FCGMA) was created by the State of California legislature to manage and protect the aquifers in the southern portion of Ventura County (FCGMA, 2015). To address seawater intrusion, proposals to shift pumping in the coastal area vulnerable to seawater intrusion to inland areas and/or regulate groundwater extraction have been proposed and adopted by FCGMA.

Resolution 2013-02, passed by FCGMA, is one of the management plans aimed at reducing pumping near the coast by supplying advanced treated recycled water (RW) from the City of Oxnard's Groundwater Recovery Enhancement and Treatment Program (GREAT Program). The City of Oxnard received a Recycled Water Pumping Allocation (RWPA) and may exercise the allocation to pump at three sites – UWCD's El Rio facility, Oxnard's Water Yard, and Oxnard's Rice Avenue Facility. The specific extraction locations and the volume of RWPA will be established through annual meetings by FCGMA, the City of Oxnard and UWCD, considering the Forebay groundwater levels and existing hydrologic conditions. Specifically, Attachment A of Resolution 2013-02 states that "[…] if groundwater elevations in the Forebay reach critical depletion levels (80,000 AFY of available storage or 19 feet above sea level) […] It would be prudent to reduce pumping of RWPA water during this time of low water levels". Attachment A of Resolution 2013-02 did not discuss the benefits of pumping reduction along the coastal area by the RWPA program and was focused solely on the potential seawater intrusion by the RWPA program. Since the adoption of Resolution 2013-02, the City of Oxnard has not been able to access RWPA water due to the multi-year drought and the low groundwater level in the Forebay until this year (2023) when the Forebay conditions no longer restrict the City's ability to pump.

At the request of the City of Oxnard, the effect of the RWPA extraction on seawater intrusion and the groundwater level in the Forebay is analyzed with a well calibrated groundwater model developed by UWCD (UWCD, 2018). In this document, the benefits of reducing seawater intrusion in the Oxnard Basin through the RWPA program were quantified. The effect of extracting RWPA water during dry years on the groundwater level and the available storage in the Forebay was also analyzed. The management areas designated by the FCGMA shown in Figure 1 (FCGMA, 2021) are used throughout this document to discuss and analyze the impact.

Simulation Approach

Prior to 2018, UWCD lacked a credible numerical groundwater model for assessing seawater intrusion. The UWCD staff relied on an indicator, the Forebay available storage, to inform the UWCD Board of Directors and the public on the groundwater condition in the Forebay and its implications. The Forebay available storage (measured in acre-ft) is calculated based on the Forebay representative water level (measured in ft) with the following formula:

$$Forebay\ Available\ Storage\ = (87.0 - Forebay\ Representative\ Water\ Level) \times 1176.4706$$

where the Forebay representative water level is determined based on the average water level at two wells (02N22W12R01S and 02N22W22R01S) located in the Forebay.

When the Forebay representative water level is 19 ft, the Forebay available storage is calculated to be 80,000 acre-ft. When the Forebay representative water level falls below 19 ft a.m.s.l. or the Forebay available storage exceeds 80,000 acre-ft, there might be potential seawater intrusion due to a landward gradient. Resolution 2013-02 relied on the Forebay available storage to assess the impact of the RWPA program.

In 2018, UWCD released a numerical groundwater model, known as the Coastal Plain Model, covering the Coastal Plain basins including Oxnard Basin, Pleasant Valley, West Las Posas, and Mound basins. The Coastal Plain Model underwent review by well-known groundwater model experts contracted by UWCD, and consultants hired by FCGMA. Additionally, another consultant conducted a review on behalf of the City of Oxnard. The UWCD and FCGMA reviewers confirmed that the Coastal Plain Model is well calibrated and suitable for analyzing the groundwater resources management on the basin scale (Porcello et al., 2018; Tartakovsky and DUDEK, 2019). The Coastal Plain Model was subsequently used to simulate groundwater conditions for the development of the FCGMA's Groundwater Sustainability Plans (GSPs), in compliance with the requirements of the Sustainability Groundwater Management Act (SGMA).

With the release of a well-calibrated numerical groundwater model by UWCD in 2018, assessing seawater intrusion can now rely on the numerical model rather than depending on a simplistic indicator based on an average groundwater level from two selected wells (02N22W12R01S and 02N22W22R01S) in the Forebay.

It is important to note that the Coastal Plain Model underwent improvements near the coastal area, specifically from Port Hueneme to Point Mugu during UWCD's development of a density-dependent saline intrusion transport model from 2021 to present. This involved recalibrating hydraulic conductivity and refining model layers, which are utilized in this impact analysis (UWCD, 2021b)

During the preparation of its GSPs, FCGMA analyzed various future scenarios. These scenarios are ideally suitable for assessing the impact of the RWPA program. For the sake of simplicity, this analysis focuses on the Baseline GSP alternative scenario, assuming no pumping cutbacks and no projects. The impact analysis utilizes the Baseline scenario under hydrologic conditions from 1930 to 1979, adjusted by DWR's 2070 central tendency climate change factors. This represents the most conservative hydrologic scenario considered as part of the GSP. Based on this data, United's hydrologist estimated the diverted water at Freeman Diversion following United's current operations. It is anticipated that using other GSP scenarios will yield similar conclusions as the Baseline scenario.

In this analysis, it is assumed that the City of Oxnard GREAT program will provide 1,000 acre-ft per year of advanced RW to groundwater users in the Saline Intrusion Management Area (SIMA) and the Pumping Depression Management Area (PDMA), resulting in an annual reduction of 1,000 acre-ft in pumping within the SIMA and PDMA. The pumping reduction accumulates as a pumping allocation or credit for the City of Oxnard to exercise pumping in wells owned by City of Oxnard outside of the SIMA and PDMA during dry years. Based on input from the City of Oxnard (email communication 2023), the extraction is assumed to occur in the dry, below normal, and critical Water Years listed in Table 1. The maximum simulated extraction is 3,000 acre-ft per year. It should be noted that the proposed extraction in dry years is opposite to Resolution 2013-02 which restricts pumping in dry years.

Furthermore, this impact analysis considers the potential increase from the City of Oxnard's Advanced Water Purification Facility (AWPF) to provide 2,000 acre-ft of advanced treated RW to groundwater users in the SIMA and PDMA. This would result in an annual reduction of 2,000 acre-ft in pumping within the SIMA and PDMA, with the reduction accumulating as a pumping allocation or credit for the City of Oxnard to use in the city owned wells outside of the SIMA and PDMA during dry years. With the input from the City of Oxnard, the extraction is assumed to occur in the dry, below normal, and critical Water Years listed in Table 2. The maximum simulated extraction is 6,000 acre-ft per year. It is important to note that in Table 2 the extraction of 6,000 acre-ft per year in continuous critical years (1947 to 1950) represents a worst-case scenario of using the maximum extraction during the driest periods.

Based on records from the City of Oxnard (email communication, 2023), the current users receiving the AWPF RW are in two management areas shown in Figure 1. Roughly 25% of the AWPF water goes to users in or near the SIMA (indicated by red polygons in Figure 1) and 75% goes to users in the PDMA (indicated by blue polygons in Figure 1). In this impact analysis, the same percentage of the AWPF RW delivery to the two management areas is used in eight of the ten model scenarios (P1, P2, P1F, P2F, P1R, P2R, P1RC, and P2RC in Table 3). Additionally, to evaluate the relative benefits of AWPF RW delivery between the two management areas, a different percentage of RW delivery is simulated in the two scenarios (S1 and S2 in Table 3) where 75% of the AWPF water is going to users in/near the SIMA (red polygons in Figure 1) and 25% is going to users in the PDMA (blue polygons in Figure 1).

The City of Oxnard has proposed to exercise the RWPA extraction at two city-owned facilities: the Water Yard and Rice Avenue Facility (both depicted in Figure 1), which is simulated in eight of the ten scenarios listed in Table 3.

In scenarios P1, P2, S1, and S2, RWPA extraction occurs at the Water Yard, specifically in Well 01N22W03F05S (screened in the Hueneme aquifer) and three wells screened in the Oxnard aquifer (01N22W03F07S, 01N22W03F12S, and 01N22W03F13S). The simulated extraction is proportionally distributed among these four wells based on their allocated rates in the GSP Scenario, with 12% going to Well 01N22W03F05S and the remaining 88% to the other three wells.

Scenarios P1R and P2R simulate RWPA extraction at two wells within the city-owned Rice Avenue Facility: Well 02N22W36E02S (screened in both the Hueneme and Mugu aquifers) and Well 02N22W36E03S (screened in the Mugu aquifer). The simulated extraction is proportionally allocated to these two wells based on their GSP Scenario rates, with 37% going to Well 02N22W36E02S and the other 63% to Well 02N22W36E03S.

Scenarios P1RC and P2RC evenly split the RWPA extraction between the Water Yard and the Rice Avenue Facility. Each extraction site receives 50% of the RWPA extraction. Within each extraction site, wells receive the simulated RWPA extraction proportionally allocated as mentioned above based on 50% of the RWPA extraction.

To quantify the effect of RWPA extraction location relative to the coast on seawater intrusion, another location for the extraction wells - specifically, the OH wells owned by UWCD - in the Forebay Management Area (indicated by yellow circles in Figure 1) is simulated in the two scenarios (P1F and P2F in Table 3). Four OH wells (02N22W14P02S, 02N22W23G03S, 02N22W23G04S, and 02N22W23K05S) screened in the Oxnard and Mugu aquifers are used. Scenarios P1F and P2F proportionally allocate the simulated RWPA extraction to these four wells based on their allocated extraction rates from the GSP Scenario. Specifically, Wells 02N22W14P02S, 02N22W23G03S, 02N22W23G04S, and 02N22W23K05S received approximately 22%, 51%, 27%, and 0.3% of the RWPA extraction, respectively. It is worth mentioning that the distribution of the RWPA extraction among the four closely located wells will not have a significant effect on the modeling result.

It's important to clarify that the addition of the extraction wells, the OH wells in the Forebay, does not imply that the City of Oxnard has decided to extract in the Forebay. Instead, the addition of the OH wells in this impact analysis is intended to facilitate future planning of potential extraction in the Forebay.

In summary, this impact analysis evaluates ten scenarios listed in Table 3 in addition to the Baseline GSP scenario with the Coastal Plain Model with revised hydraulic conductivity and model layers to assess the impact of these scenarios.

Modeling Result

To assess the benefits and impact of the RWPA program, the author has analyzed four areas of interest as listed below:

1. The groundwater flow within four segments (A, B, C, and D shown in Figure 1) along the coast of the Oxnard Basin were examined.
2. The groundwater level in the Forebay Management Area and the Forebay available storage.
3. The groundwater levels at four wells near Port Hueneme (Wells 01N22W20J07S/08S and 01N22W27C02S/03S as shown in Figure 1 and recommended by the FCGMA staff).
4. The groundwater level in the Lower Aquifer System (LAS) in the Oxnard Basin and Pleasant Valley.

The four coastal segments (A, B, C, and D) were employed in the coastal groundwater flow calculation for all the GSP scenarios by FCGMA. UWCD recommended these four segments to account for the varying degrees of seawater intrusion along the coast, spanning from the Santa Clara River to Point Mugu. Within these segments, it is worth noting that the northern coastal segments may experience a change of the groundwater flow direction over time, shifting from landward to seaward flow and vice versa, while the southern coastal segments may consistently exhibit landward flow.

Under the Baseline GSP Scenario, the result for the aforementioned areas of interest, except for the LAS groundwater level in the Oxnard Basin and Pleasant Valley, are as follows:

The groundwater flow along the coast of the Oxnard Basin:

Table 4 provides an overview of the annual groundwater flow averaged over the 50-year GSP simulation period. In response to factors such as pumping, stream bed percolation along the Santa Clara River, and United's artificial recharge, which vary with climate cycles, Figure 2 illustrates that the Upper Aquifer System (UAS) coastal groundwater flow changes direction, shifting between landward and seaward (with negative values indicating seaward flow), primarily along Segments A and B. In contrast, the LAS groundwater flow consistently remains landward (with positive values) regardless of the climate cycles. When the coastal groundwater flow is averaged annually over 50 years, it becomes evident that the average groundwater flows in the UAS along the coast from Ormond Beach northward (Segments A and B in Figure 1) are significantly lower than in other coastal segments (as indicated in Table 4).

The groundwater level in the Forebay Management Area and the Forebay available storage:

Like the coastal groundwater flow, in response to the same factors such as pumping, stream bed percolation along the Santa Clara River, and United's artificial recharge, which vary with climate cycles, the groundwater level in the Forebay experiences fluctuations, ranging from -20 feet to 100 ft a.m.s.l. Figure 2 displays the monthly groundwater level averaged over the Forebay Management Area. Figure 3 presents the monthly Forebay available storage.

The groundwater levels at four wells near Port Hueneme:

Figures 4 and 5 show hydrographs from four wells (01N22W20J07S/08S and 01N22W27C02S/03S) near Port Hueneme. It is worth noting that Wells 01N22W20J08S and 01N22W27C03S are screened in the Oxnard aquifer, while Wells 01N22W20J07S and 01N22W27C02S are screened in the Mugu aquifer. From Figure 4, the simulated water level from the Oxnard aquifer (Well 01N22W20J08S) is almost the same as the simulated water level from the Mugu aquifer (Well 01N22W20J07S), while from Figure 5, the simulated water level from the Oxnard aquifer (Well 01N22W27C03S) is noticeably higher than the simulated water level from the Mugu aquifer (Well 01N22W27C02S).

By implementing the pumping outlined in Table 3, the Coastal Plain Model simulated the ten scenarios. For each of these scenarios, the groundwater flow along the four costal segments was calculated and compared with the Baseline scenario. Table 5 summarizes the changes in groundwater flow in the four coastal segments relative to the Baseline scenario, with negative values indicating a reduction in landward groundwater flow (i.e., less seawater intrusion). To assess the impact of the RWPA program on the groundwater level in the Forebay, the groundwater level changes were analyzed (listed in Table 6). Additionally, Figure 3 shows the difference in monthly Forebay available storage resulting from the RWPA extraction. Lastly, Figures 4 and 5 illustrate the groundwater level changes at the four wells (01N22W20J07S/08S and 01N22W27C02S/03S) near Port Hueneme due to the RWPA program, providing an evaluation of the program's impact and benefits on the Oxnard and Mugu aquifers.

The impacts and benefits of the RWPA program on the four areas of interest are detailed in the following subsections.

Coastal groundwater flow impact

The impacts of the ten scenarios on groundwater flow along the coast of the Oxnard Basin, as listed in Table 5, are detailed below:

Scenarios P1 and P2:

In Scenario P1, when an annual pumping of 1,000 acre-ft (25% in SIMA and 75% in PDMA) is moved to the city-owned Water Yard wells in the West Oxnard Plain Management Area (WOPMA) to pump 3,000 acre-ft maximum in dry years, there is an increase in landward groundwater flow in Segments A and B, along with a decrease in landward groundwater flow along Segments C and D in the UAS. In the LAS, the conditions differ slightly. There's a smaller increase in landward groundwater flow in Segment A compared to the UAS, and a decrease in landward groundwater flow along Segments B, C, and D. The net decrease annually is 80 acre-feet in LAS, which is higher than the net increase of 21 acre-feet in UAS. When combining UAS and LAS, the net decrease in landward groundwater flow is 58 acre-feet.

In Scenario P2 (where 2,000 acre-feet is moved to WOPMA to pump a maximum of 6,000 acre-feet in dry years), similar trends are observed, with a net decrease of 160 acre-feet in LAS and a net increase of 40 acre-feet in UAS, resulting in a combined net decrease of 121 acre-feet annually.

Scenarios S1 and S2:

Scenarios S1 and S2 mirror Scenarios P1 and P2, except the percentages of pumping reduction in SIMA and PDMA are reversed. In these scenarios, more pumping is reduced in SIMA (75%) and less in PDMA (25%) compared to Scenarios P1 and P2. The RWPA extraction remains the same as in Scenarios P1 and P2. The model simulations show a reduction in landward groundwater flow in both UAS and LAS. The annual net reduction in UAS and LAS combined is 111 acre-feet (Scenario S1) or 226 acre-feet (Scenario S2), which is approximately double the annual reduction in Scenarios P1 (58 acre-feet) or P2 (121 acre-feet). This highlights that pumping reduction in SIMA reduces landward groundwater flow more significantly than pumping reduction in PDMA.

Scenarios P1F and P2F:

Scenarios P1F and P2F are similar to Scenarios P1 and P2, but the RWPA extraction (3,000 acre-feet or 6,000 acre-feet maximum in dry years) is moved from the City of Oxnard Wells in WOPMA to the OH wells in the Forebay Management Area. The model simulations show a more significant reduction in landward groundwater flow in both UAS and LAS compared to Scenarios P1 and P2. The net reduction in UAS and LAS combined is 124 acre-feet (Scenario P1F) or 254 acre-feet (Scenario P2F), which is more than double the reduction in Scenarios P1 and P2. The scenarios demonstrate that shifting extraction further inland reduces seawater intrusion.

Scenarios P1R and P2R:

Scenarios P1R and P2R mirror Scenarios P1 and P2, with the difference being that the RWPA extraction (3,000 acre-feet or 6,000 acre-feet maximum in dry years) is relocated from the Water Yard wells to the Rice Avenue Facility. Both are located in WOPMA. The model simulations show a slightly more reduction in landward groundwater flow in both UAS and LAS compared to Scenarios P1 and P2. The net reduction in UAS and LAS combined is 98 acre-feet (Scenario P1R) or 202 acre-feet (Scenario P2R), which is over 60% more in reduction than Scenarios P1 and P2. The scenarios demonstrate that shifting extraction further inland reduces seawater intrusion.

Scenarios P1RC and P2RC:

Scenarios P1RC and P2RC represent a hybrid combination of Scenarios P1 and P1R, as well as P2 and P2R, with the difference being that the RWPA extraction (3,000 acre-feet or 6,000 acre-feet maximum in dry years) is evenly split between the Water Yard wells and the Rice Avenue Facility, both located within WOPMA. The model simulations show a slightly less reduction in landward groundwater flow in both UAS and LAS compared to Scenarios P1R and P2R. The net reduction in UAS and LAS combined is 78 acre-feet (Scenario P1RC) or 161 acre-feet (Scenario P2RC), which is over 30% more in reduction than Scenarios P1 and P2. The scenarios demonstrate that shifting extraction further inland reduces seawater intrusion.

Summary of coastal groundwater flow impacts:

In summary, RW delivery to the SIMA (Scenario S1 and S2) will reduce seawater intrusion more than RW delivery to the PDMA (Scenarios P1 and P2). Furthermore, seawater intrusion flow is reduced more when the RWPA is extracted further inland in the Forebay (Scenarios P1F and P2F) than in the WOMPA (Scenarios P1 and P2). Scenarios P1R and P1RC demonstrate an impact that falls somewhere between Scenarios P1 and P1F, and the same applies to Scenarios P2R and P2RC compared with Scenarios P2 and P2F.

It is evident that with the RWPA program, the benefits of reducing seawater intrusion in both LAS and along the southern coast (Segments C and D in Figure 1) in UAS outweighs the effect of the relatively smaller seawater intrusion increase in the northern coast (Segments A and B in Figure 1) in UAS. In the latter, where the coastal groundwater flow becomes seaward during wet years, the potential mitigation of the small increase in landward groundwater flow caused by RWPA extraction should be noted. Importantly, no seawater intrusion has been detected to date inland from Segment A.

The impact on the groundwater level in the Forebay Management Area

Before evaluating the effect on the groundwater level in the Forebay Management Area, it is important to note that groundwater elevations in the Forebay are influenced by pumping, stream bed percolation along the Santa Clara River, and United's artificial recharge. The natural stream bed percolation and artificial recharge may mitigate the transient effect of the RWPA extraction through climate cycles.

The effect of the RWPA extraction on the groundwater level in the Forebay Management Area is analyzed in the following steps:

1. The difference in the simulated groundwater levels in each model cell within the Forebay Management Area between the ten scenarios and the Baseline scenario is calculated for each month over the 50-year simulation.
2. An areal average of the groundwater level difference over the Forebay Management Area is calculated for each month over the 50-year simulation. The areal average monthly groundwater level drawdown is analyzed statistically for the mean, maximum, and standard deviation to represent the temporal fluctuation in the areal average groundwater level, as listed in Table 6.
3. The cell-based difference in the monthly simulated groundwater levels over each model cell within the Forebay Management Area over the 50-year simulation is analyzed statistically for the mean, maximum, and the standard deviation to represent the temporal fluctuation in the cell-based water level over the 50-year simulation, also listed in Table 6.

4. The Forebay available storage is calculated based on the average of the simulated water levels at Wells 02N22W12R01S and 02N22W22R01S. The Forebay available storage and the differences in storage are shown in Figure 3.

The impact of the RWPA extraction on the groundwater level (listed in Table 6) and the available storage (shown in Figure 3) in the Forebay is detailed below:

Scenarios P1, S1, P1R, and P1RC:

When the RWPA water is extracted at the Water Yard, the Rice Avenue Facility, or evenly split between the Water Yard and Rice Avenue Facility wells at a maximum of 3,000 acre-ft annually in dry years, the average drawdown over the Forebay Management Area ranges from 0.5 ft to 0.7 ft, and the maximum areal average groundwater level drawdown in the Forebay ranges from 1.6 ft to 2.0 ft. The local (cell-based) groundwater level drawdown is averaged to be 0.8 to 1.0 ft with a maximum of 2.3 ft to 2.6 ft. These drawdowns are minor compared to the range of simulated monthly groundwater levels in the Forebay, which vary from -20 feet to 100 feet a.m.s.l.

The Forebay available storage will increase due to the RWPA pumping (shown in Figure 3). It is noted that the Forebay available storage increase in Scenarios P1, S1, P1R, and P1RC disappears in 1939, 1942, and 1969 after wet years though the RWPA extraction occurs during 1930 – 1935 and 1949 – 1966 when the Forebay available storage exceeds 80,000 AF.

Scenarios P2, S2, P2R, and P2RC:

When the RWPA water is extracted at the Water Yard, the Rice Avenue Facility, or evenly split between the Water Yard and Rice Avenue Facility wells at a maximum of 6,000 acre-ft annually in dry years, the average and maximum drawdowns (both the areal average and local) show a more pronounced impact, with an areal average monthly drawdown of about 1.0 to 1.4 ft in mean and about 3.0 ft to 3.7 ft in maximum. The local (cell-based) groundwater level drawdown is averaged to be 1.6 to 2.0 ft with a maximum of 4.4 ft to 4.9 ft. However, these drawdowns are still relatively small when considering the overall range of simulated monthly groundwater levels in the Forebay.

The Forebay available storage increase in Scenarios P2, S2, P2R, and P2RC disappears in 1939, 1942, and 1969 after wet years, the same as Scenarios P1, S1, P1R, and P1RC.

Scenarios P1F and P2F:

When the RWPA water is extracted at the OH wells, at a maximum of 3,000 acre-ft maximum in dry years in the Forebay (Scenario P1F), the average drawdown over the Forebay Management Area is approximately 1.1 ft, and the maximum areal average groundwater level drawdown in the Forebay is 3.2 ft (see Table 6). The local (cell-based) groundwater level drawdown is averaged to be 1.6 ft with a maximum of 4.6 ft. These drawdowns are similar to Scenarios P2, S2, P2R, and P2RC.

When the RWPA extraction is doubled from 3,000 acre-ft to 6,000 acre-ft maximum in dry years, at the OH wells in the Forebay (Scenario P2F), the average drawdown over the Forebay Management Area is 2.2 ft in mean and 5.9 in maximum (see Table 6). This level of drawdown may be noteworthy, especially during prolonged drought conditions. The maximum average drawdown of 5.9 ft occurs in the simulated Year 1950 during four consecutive years (1947 - 1950) classified as critical water year types in the GSP simulation period. The local (cell-based) groundwater level drawdown is averaged to be 3.2 ft with a maximum of 8.5 ft which will also be notable particularly in dry years.

The Forebay available storage increase in Scenarios P1F and P2F only disappears in the simulated Year 1942. It is noted that the recovery from the Forebay available storage increase in Scenarios P1F and P2F is slower than Scenarios P1, S1, P1R, P1RC, P2, S2, P2R, and P2RC because the RWPA extraction is in the Forebay.

Summary of Forebay groundwater level impacts:

In summary, except for Scenario P2F, the various scenarios may result in minor to moderate drawdowns in the groundwater levels in the Forebay, and these impacts fall within the range of natural variability in temporal Forebay groundwater levels. Scenario P2F stands out as having the most significant drawdown, particularly during extended drought conditions.

The impact on the groundwater level near the Port Hueneme Area

The analysis of the simulated groundwater level in the UAS (Oxnard and Mugu aquifers) at four wells (01N22W20J07S/08S and 01N22W27C02S/03S shown in Figure 1) from two locations near Port Hueneme in response to the RWPA program is detailed below:

Wells 01N22W20J07S/08S:

From Figure 4, the changes in the water levels due to the RWPA program are similar in the Oxnard and Mugu aquifers. When the RWPA extraction is at maximum 3,000 acre-ft per year, the maximum decrease in the water level ranges from approximately -0.5 ft (Scenario P1F with extraction at the OH wells) to -1.0 ft (Scenarios P1 and S1 with extraction the Water Yard wells) in the simulated Year 1950. The maximum decrease from Scenarios P1R and P1RC falls between Scenarios P1 and P1F. Without the RWPA extraction, the water levels rebound and the change in water level moves from negative values to positive values indicating the RWPA program's benefits in increasing groundwater levels and mitigating saline intrusion along the coast for all scenarios. When the RWPA extraction is doubled to maximum 6,000 acre-ft per year (Scenarios P2, S2, P2R, P2RC, and P2F), the impact and benefits are nearly doubled compared to the 3,000 acre-ft scenarios (P1, S1, P1R, P1RC, and P1F).

Wells 01N22W27C02S/03S:

From Figure 5, the impact of the RWPA program is different in the Oxnard and Mugu aquifers. In the Oxnard aquifer (Well 01N22W27C03S), the maximum decrease in water level ranges from approximately -0.3 ft to -0.8 ft in the simulated Year 1950 for Scenarios P1F, P1RC, P1R, P1, and S1. This variation is attributed to the different extraction locations, with Scenario P1F having a more distant extraction location in the Forebay. When the RWPA extraction is not in operation, the water levels rebound close to 0.5 ft (positive value) indicating the benefits of the RWPA program in increasing the groundwater levels. For the Mugu aquifer (Well 01N22W27C02S), the maximum decrease in the water level is slightly lower, ranging from -0.5 (Scenarios P1) to -0.02 ft (Scenario P1F) in the simulated Year 1950. The maximum increase from Scenarios S1, P1R, and P1RC falls between Scenarios P1 and P1F. Without the RWPA extraction, the water levels rebound higher than in the Oxnard aquifer, 1.0 ft in maximum for Scenario S1 and 0.7 ft in maximum for Scenarios P1, P1R, P1RC, and P1F showing the benefits of the RWPA program in increasing the groundwater level. When the RWPA extraction is doubled to maximum 6,000 acre-ft per year (Scenarios P2, S2, P2R, P2RC, and P2F), the impact and benefits are nearly doubled compared to the 3,000 acre-ft scenarios (P1, S1, P1R, P1RC, and P1F).

Summary of the UAS groundwater level impacts near Port Hueneme:

In summary, the RWPA extraction at 3,000 acre-ft/yr lowers the UAS groundwater levels by approximately one foot or less near Port Hueneme while the annual AWPF RW delivery at 1,000 acre-ft increases the groundwater level by approximately one foot or less when the RWPA extraction is not in operation. When the RWPA extraction doubles to 6,000 acre-ft/yr, in conjunction with the annual AWPF RW delivery at 2,000 acre-ft, the effect on the UAS groundwater level also doubles.

The beneficial impact on the LAS groundwater level in the Oxnard Basin and Pleasant Valley

The pumping reduction in the SIMA and PDMA areas through the RWPA program can ease the LAS groundwater level drawdown (raising the groundwater level) in the region of the cone of groundwater depression spanning the Oxnard Basin and Pleasant Valley Basin. The average and maximum increase in the LAS groundwater level due to the ten scenarios are listed in Table 7. This finding underscores the broader positive effects of the RWPA program on the LAS groundwater levels in adjacent areas. Here are the key points from Table 7:

Beneficial Impact on the LAS Groundwater Level:

The average increase in the LAS groundwater level resulting from the RWPA program ranges from 0.77 ft to more than 2 ft when the City of Oxnard GREAT program provides 1,000 acre-ft per year of advanced RW to groundwater users in the SIMA and PDMA (Scenarios P1, S1, P1R, P1RC, and P1F). The maximum increase in the LAS groundwater level in this context ranges from 1.25 ft to more than 3 ft.

Scaling Benefits with RWPA Program Volume:

When the GREAT program provides 2,000 acre-ft per year of advanced RW to groundwater users in the SIMA and PDMA (Scenarios P2, S2, P2R, P2RC, and P2F), the benefits in raising the groundwater level around the cone of groundwater depression are approximately double those seen in Scenarios P1, S1, P1R, P1RC, and P1F.

In summary, the RWPA program mitigates saline intrusion along the coast by raising the LAS groundwater level, which has broader positive implications for the region of the cone of groundwater depression spanning the Oxnard Basin and Pleasant Valley Basin.

Conclusions

This impact analysis is based on several important assumptions that may not be obvious to non-technical readers. The author wishes to underscore these critical assumptions by emphasizing that this impact analysis relies on the assumptions that water agencies including UWCD will be able to import and divert surface water based on the current regulatory oversight. In the future, if there are any changes in regulatory oversight resulting in a significant reduction in the amount of water diverted or imported by water agencies, this impact analysis should be re-evaluated.

The benefits of the RWPA program have been analyzed and verified through groundwater modeling. This analysis demonstrates that the reduction in landward coastal groundwater flow in the LAS and along the southern coast (Segments C and D) in the UAS is more significant than the increase in landward coastal groundwater flow along the northern coast (Segments A and B, as illustrated in Figure 1). The advantages of reducing persistent seawater intrusion in the LAS and the southern coast of the UAS, both in wet and dry years, outweigh the effect of the smaller increase in coastal groundwater flow along the northern coast (Segments A and B in Figure 1). It's important to note that this increase in coastal groundwater flow along the northern coast may be mitigated when the coastal groundwater flow becomes seaward during wet years, as shown in Figure 2.

The changes in groundwater levels in the Oxnard and Mugu aquifers near Port Hueneme were analyzed for ten different scenarios at four wells located in two areas, as shown in Figures 4 and 5. While the magnitude of the maximum water level decreases exceeds the magnitude of the maximum water level increases for all ten scenarios, it's important to note that there are more years with increased water levels (when there is no RWPA extraction) than years with decreased water levels (when RWPA extraction occurs). In the author's technical opinion, this leads to an overall assessment that the net effect of the RWPA program on water levels in the Oxnard and Mugu aquifers near the Port Hueneme area is neutral to minimal.

With the RWPA program, the groundwater level in the Forebay Management Area is projected to decrease by an average of approximately 0.5 ft to 2.2 feet. The impact of the RWPA program on the groundwater level in the Forebay is categorized into three levels (as outlined in Table 6). The most significant, yet temporary, impact of the RWPA program on the Forebay groundwater level occurs in the simulated Year 1950. In this scenario, RWPA extraction reaches a maximum of 6,000 acre-feet per year, with continuous operation at the OH wells in the Forebay throughout critical water years from 1947 to 1950 within the simulation period.

To aid the FCGMA Board and its staff in assessing the relative benefits and impacts of the RWPA program, the author provides a summary below, categorizing the benefits and impacts of the RWPA program into three categories based on the three levels of impact on the Forebay groundwater level mentioned above (as shown in Table 6):

- Level I

  When the City of Oxnard extracts a maximum of 3,000 acre-ft per year at the two city-owned facilities (the Water Yard, the Rice Avenue Facility wells or both) in Scenarios P1, S1, P1R, and P1RC, the impact is the least among the ten scenarios and is categorized as Level I. At Level I, the areal average groundwater level drawdown over 50 years in the Forebay is approximately 0.5 ft in mean and 1.6 ft at its maximum. The cell-base groundwater level drawdown over 50 years in the Forebay averages about 0.8 ft in mean and reaches a maximum of 2.3 feet. **It is the author's technical opinion that the groundwater level drawdown mentioned above should not raise concerns.**

  At Level I with Scenarios P1, S1, P1R, and P1RC, the LAS will benefit from an average reduction ranging from 80 acre-ft/yr (Scenario P1) to 124 acre-ft/yr (Scenarios S1) in the landward coastal groundwater flow. The UAS will experience changes ranging from an average increase of 21 acre-ft/yr (Scenario P1) to an average decrease of 16 acre-ft/yr (Scenarios P1R) in the landward coastal groundwater flow. The annual net groundwater flow reduction ranging from 58 acre-ft for Scenarios P1 to 111 acre-ft for Scenario S1 amounts to approximately 6% to 11 % of the 1,000 acre-ft annual RWPA RW delivery.

- Level II

When the City of Oxnard extracts 6,000 acre-ft per year at the two city-owned facilities (the Water Yard, the Rice Avenue Facility wells or both) in Scenarios P2, S2, P2R, and P2RC, or extracts 3,000 acre-ft per year at the OH wells in the Forebay (Scenario P1F), the impacts are similar but more significant than Level I and are categorized as Level II.

At Level II, the areal average groundwater level drawdown over 50 years in the Forebay averages approximately 1.0 ft to 1.4 ft in mean and 3.0 ft to 3.7 ft at its maximum. The cell-base groundwater level drawdown over 50 years in the Forebay averages about 1.6 ft to 2.0 ft in mean and 4.4 ft to 4.9 ft at its maximum. **It is the author's technical opinion that the average drawdown of 1.0 to 2.0 ft should not raise concerns, but the cell-based maximum drawdown of 4.4 ft to 4.9 ft may be a concern, particularly during dry years.**

At Level II with Scenarios P2, P2R, P2RC, and S2, the LAS will benefit from an average reduction ranging from 160 acre-ft/yr (Scenario P2) to 249 acre-ft/yr (Scenarios S2) in the landward coastal groundwater flow. The UAS will experience changes ranging from an average increase of 40 acre-ft/yr (Scenario P2) to an average increase of 36 acre-ft/yr (Scenarios P2R) in the landward coastal groundwater flow. The annual net groundwater flow reduction ranging from 121 acre-ft for Scenarios P2 to 226 for Scenario S2 amounts to approximately 6% to 11 % of the 2,000 acre-ft annual RWPA RW delivery.

At Level II with Scenarios P1F, the LAS will benefit from an average reduction of 104 acre-ft/yr in the landward coastal groundwater flow. The UAS will also benefit from an average reduction of 20 acre-ft/yr in the landward coastal groundwater flow. The annual net groundwater flow reduction (124 acre-ft) represents about 12 % of the 1,000 acre-ft annual RWPA RW delivery.

- Level III

The impact on the groundwater level in the Forebay Management Area resulting from RWPA extraction at the OH wells, with a maximum of 6,000 acre-ft per year (Scenarios P2F), is the most significant among the ten scenarios and is categorized as Level III.

At Level III, the areal average groundwater level drawdown over 50 years in the Forebay averages approximately 2.2 ft in mean and reaches a maximum of 5.9 ft. The cell-base groundwater level drawdown over 50 years in the Forebay averages approximately 3.2 ft in mean and reaches a maximum of 8.5 feet. **It is the author's technical opinion that the average drawdown of 2.2 to 3.2 ft may not be a concern during wet and normal water years, but the maximum drawdown of 5.9 to 8.5 ft may warrant further evaluation.**

At Level III with Scenarios P2F, the LAS will benefit from an average reduction of 210 acre-ft/yr in the landward coastal groundwater flow. The UAS will also benefit from an average reduction of 44 acre-ft/yr in the landward coastal groundwater flow. The annual net groundwater flow reduction (254 acre-ft) represents about 13 % of the 2,000 acre-ft annual RWPA RW delivery.

The groundwater model utilized in this impact analysis will be updated and verified with newly available data every five years or periodically by UWCD. It is recommended that this impact analysis be reviewed every five years to ensure that the modeling results and conclusions remain valid. Additionally, it is also suggested that future impact analyses include other pumping programs and users in the Forebay area to provide a comprehensive understanding of the effects of all pumping programs and users in the Forebay.

It's important to note that this impact analysis did not simulate water quality-related issues. Therefore, it is recommended that potential water quality concerns are addressed in the monitoring plan. As a precautionary measure, regular measurements of water levels and chloride concentrations should be conducted along the coastal line and throughout the basin. These measurements should be analyzed periodically to detect any unexpected trends. If an unexpected trend is observed, it is recommended to undertake a comprehensive analysis to evaluate saline intrusion and the impact of overall pumping.

References

DWR (Department of Water Resources, State of California), 1965. Sea-Water Intrusion: Oxnard Plain of Ventura County. Bulletin No. 63-1. October.

FCGMA, 2015. Brief History Overview, Fox Canyon Groundwater Management Agency, January 2015.

FCGMA, 2021. GSP Assessment Staff Report, Oxnard Subbasin (Subbasin No. 4-004.02), to the Department of Water Resources, State of California, submitted by Fox Canyon Groundwater Management Agency, November 18, 2021.

Porcello, J., Rumbaugh, J., and Panday, S., 2018. Expert Panel Review of Version 1.0 of the Ventura Regional Groundwater Flow Model, Ventura County, California, Memorandum. June 29, 2018

Tartakovsky and DUDEK, 2019. Peer Review of the United Water Conservation District and Calleguas Municipal Water District Models for the Oxnard Subbasin, Pleasant Valley Basin, and Las Posas Valley Basin, prepared for Fox Canyon Groundwater Management Agency, submitted by Professor Daniel Tartakovsky, Stanford University and DUDEK, March 2019.

UWCD (United Water Conservation District), 2010, Oxnard Plain Time Domain Electromagnetic Study for Saline Intrusion, Open-File Report 2010-003.

UWCD (United Water Conservation District), 2016, Saline intrusion update, Oxnard Plain and Pleasant Valley basins, United Water Conservation District Open-File Report 2016-04.

UWCD (United Water Conservation District), 2018. Ventura Regional Groundwater Flow Model and Updated Hydrogeologic Conceptual Model: Oxnard Plain, Oxnard Forebay, Pleasant Valley, West Las Posas, and Mound Groundwater Basins. Open-File Report 2018-02. July

UWCD (United Water Conservation District), 2021a. Saline intrusion and 2020 Groundwater Conditions Update, Oxnard and Pleasant Valley basins, United Water Conservation District Open-File Report 2021-03. November.

UWCD (United Water Conservation District), 2021b. Extraction Barrier and Brackish Water Treatment Project Feasibility Study: Groundwater Modeling, December 2021.

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Table 1. The simulated allocation pumping of maximum 3,000 acre-ft annually by the City of Oxnard over 50 years. The allocation pumping highlighted in yellow is assumed to be in the dry, below normal, or critical years (Water Year type).

WY	WYT	SP Precip	Credit	Accrual	Extraction	WY	WYT	SP Precip	Credit	Accrual	Extraction
				6000		1955	Below Normal	13.38	1000	3000	0
1930	Dry	11.59	1000	4000	3000	1956	Below Normal	15.33	1000	4000	0
1931	Dry	14.19	1000	2000	3000	1957	Below Normal	11.91	1000	5000	0
1932	Below Normal	20.54	1000	3000	0	1958	Wet	31.37	1000	6000	0
1933	Below Normal	11.15	1000	4000	0	1959	Above Normal	6.67	1000	7000	0
1934	Dry	14.94	1000	2000	3000	1960	Critical	11.43	1000	5000	3000
1935	Below Normal	21.39	1000	3000	0	1961	Critical	6.62	1000	3000	3000
1936	Below Normal	16.32	1000	4000	0	1962	Above Normal	25.7	1000	4000	0
1937	Wet	26.49	1000	5000	0	1963	Below Normal	13.69	1000	5000	0
1938	Wet	28.02	1000	6000	0	1964	Dry	9.42	1000	6000	0
1939	Wet	15.68	1000	7000	0	1965	Dry	13.46	1000	4000	3000
1940	Dry	13.29	1000	5000	3000	1966	Above Normal	17.24	1000	5000	0
1941	Wet	38.11	1000	6000	0	1967	Wet	22.52	1000	6000	0
1942	Wet	14.19	1000	7000	0	1968	Above Normal	14.42	1000	7000	0
1943	Wet	28.98	1000	8000	0	1969	Wet	30.58	1000	8000	0
1944	Wet	24.37	1000	9000	0	1970	Wet	13.95	1000	9000	0
1945	Above Normal	15.13	1000	10000	0	1971	Below Normal	17.93	1000	7000	3000
1946	Below Normal	11.32	1000	11000	0	1972	Dry	9.11	1000	5000	3000
1947	Below Normal	13.29	1000	10000	2000	1973	Above Normal	23.32	1000	6000	0
1948	Critical	8.27	1000	8000	3000	1974	Wet	15.88	1000	7000	0
1949	Critical	9.79	1000	6000	3000	1975	Above Normal	18.06	1000	8000	0
1950	Critical	13.57	1000	4000	3000	1976	Below Normal	11.87	1000	6000	3000
1951	Critical	8.15	1000	2000	3000	1977	Dry	12.88	1000	4000	3000
1952	Wet	31.91	1000	3000	0	1978	Wet	36.08	1000	5000	0
1953	Above Normal	10.82	1000	4000	0	1979	Wet	22.17	1000	6000	0
1954	Dry	14.37	1000	2000	3000	SUM			50000		50000

Table 2. The simulated allocation pumping of maximum 6,000 acre-ft annually by the City of Oxnard over 50 years. The allocation pumping highlighted in yellow is assumed to be in the dry, below normal, or critical years (Water Year type).

WY	WYT	SP Precip	Credit	Accrual	Extraction	WY	WYT	SP Precip	Credit	Accrual	Extraction
				6000		1955	Below Normal	13.38	2000	0	4000
1930	Dry	11.59	2000	2000	6000	1956	Below Normal	15.33	2000	2000	0
1931	Dry	14.19	2000	4000	0	1957	Below Normal	11.91	2000	4000	0
1932	Below Normal	20.54	2000	0	6000	1958	Wet	31.37	2000	6000	0
1933	Below Normal	11.15	2000	2000	0	1959	Above Normal	6.67	2000	8000	0
1934	Dry	14.94	2000	4000	0	1960	Critical	11.43	2000	4000	6000
1935	Below Normal	21.39	2000	0	6000	1961	Critical	6.62	2000	0	6000
1936	Below Normal	16.32	2000	2000	0	1962	Above Normal	25.7	2000	2000	0
1937	Wet	26.49	2000	4000	0	1963	Below Normal	13.69	2000	4000	0
1938	Wet	28.02	2000	6000	0	1964	Dry	9.42	2000	6000	0
1939	Wet	15.68	2000	8000	0	1965	Dry	13.46	2000	2000	6000
1940	Dry	13.29	2000	4000	6000	1966	Above Normal	17.24	2000	4000	0
1941	Wet	38.11	2000	6000	0	1967	Wet	22.52	2000	6000	0
1942	Wet	14.19	2000	8000	0	1968	Above Normal	14.42	2000	8000	0
1943	Wet	28.98	2000	10000	0	1969	Wet	30.58	2000	10000	0
1944	Wet	24.37	2000	12000	0	1970	Wet	13.95	2000	12000	0
1945	Above Normal	15.13	2000	14000	0	1971	Below Normal	17.93	2000	8000	6000
1946	Below Normal	11.32	2000	16000	0	1972	Dry	9.11	2000	4000	6000
1947	Below Normal	13.29	2000	12000	6000	1973	Above Normal	23.32	2000	6000	0
1948	Critical	8.27	2000	8000	6000	1974	Wet	15.88	2000	8000	0
1949	Critical	9.79	2000	4000	6000	1975	Above Normal	18.06	2000	10000	0
1950	Critical	13.57	2000	0	6000	1976	Below Normal	11.87	2000	6000	6000
1951	Critical	8.15	2000	2000	0	1977	Dry	12.88	2000	2000	6000
1952	Wet	31.91	2000	4000	0	1978	Wet	36.08	2000	4000	0
1953	Above Normal	10.82	2000	6000	0	1979	Wet	22.17	2000	6000	0
1954	Dry	14.37	2000	2000	6000	SUM			100000		100000

Table 3. The scenarios for different extraction rates, well location, and AWPF recycled water delivery percentage

Scenario	Maximum Annual Extraction (acre-ft)			Annual AWPF Recycled Water Delivered (acre-ft)	Percentage of AWPF Recycled Water Delivery	
	City of Oxnard's Water Yard	City of Oxnard's Rice Avenue Facility	OH Wells in Forebay		to Saline Intrusion Management Area	to Pumping Depression Management Area
P1	3,000	0	0	1,000	25%	75%
P2	6,000	0	0	2,000	25%	75%
S1	3,000	0	0	1,000	75%	25%
S2	6,000	0	0	2,000	75%	25%
P1F	0	0	3,000	1,000	25%	75%
P2F	0	0	6,000	2,000	25%	75%
P1R	0	3,000	0	1,000	25%	75%
P2R	0	6,000	0	2,000	25%	75%
P1RC	1,500	1,500	0	1,000	25%	75%
P2RC	3,000	3,000	0	2,000	25%	75%

Table 4. The annual average groundwater flow (acre-ft) along the coast in Oxnard Basin over 50 years in the Baseline GSP Scenario.

Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)
UAS	**553.9**	**544.0**	**601.3**	**1877.1**	**3022.4**	**3576**
LAS	**1824.4**	**1618.1**	**1248.9**	**1267.8**	**4134.9**	**5959**
SUM	**2378**	**2162**	**1850**	**3145**	**7157**	**9535**

Table 5. The changes in annual groundwater flow (acre-ft) along the coast of Oxnard Basin for the ten RWPA extraction scenarios. Negative values indicate a decrease in landward flow relative to the Baseline scenario.

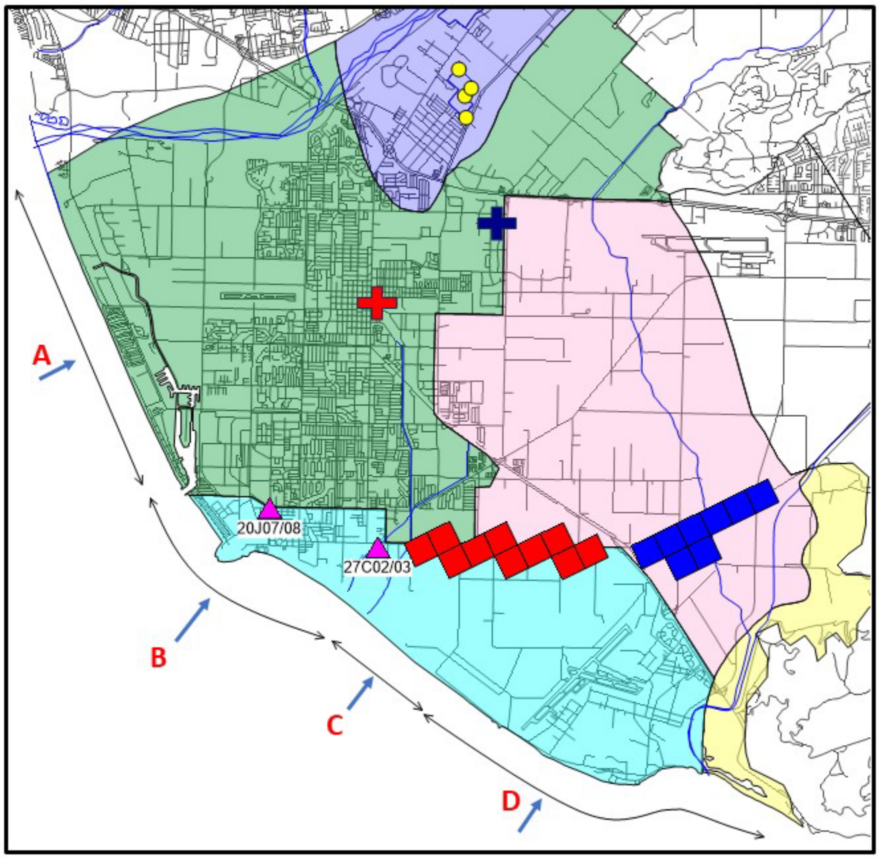
P1							P2						
Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)	Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)
UAS	74.0	29.7	-9.9	-72.4	-52.7	21	UAS	146.6	58.7	-20.1	-145.6	-107.0	40
LAS	11.2	-16.8	-32.0	-41.9	-90.7	-80	LAS	21.9	-33.9	-64.1	-84.1	-182.2	-160
SUM	85	13	-42	-114	-143	-58	SUM	168	25	-84	-230	-289	-121
S1							**S2**						
Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)	Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)
UAS	72.1	25.8	-16.8	-67.8	-58.8	13	UAS	142.7	50.8	-33.8	-136.3	-119.3	23
LAS	4.2	-33.3	-54.1	-40.7	-128.0	-124	LAS	7.9	-66.9	-108.4	-81.5	-256.8	-249
SUM	76	-8	-71	-108	-187	-111	SUM	151	-16	-142	-218	-376	-226
P1F							**P2F**						
Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)	Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)
UAS	60.1	12.5	-15.3	-77.3	-80.1	-20	UAS	118.5	24.2	-31.0	-155.5	-162.4	-44
LAS	-1.6	-25.2	-34.2	-43.3	-102.7	-104	LAS	-3.8	-50.7	-68.7	-86.8	-206.2	-210
SUM	58	-13	-50	-121	-183	-124	SUM	115	-27	-100	-242	-369	-254
P1R							**P2R**						
Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)	Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)
UAS	52.9	14.0	-12.4	-70.7	-69.2	-16	UAS	104.3	27.2	-25.2	-142.4	-140.4	-36
LAS	8.1	-17.7	-31.4	-41.1	-90.2	-82	LAS	15.7	-35.8	-63.0	-82.5	-181.3	-166
SUM	61	-4	-44	-112	-159	-98	SUM	120	-9	-88	-225	-322	-202
P1RC							**P2RC**						
Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)	Aquifer System	A	B	C	D	B+C+D	SUM (A+B+C+D)
UAS	63.4	21.8	-11.2	-71.6	-60.9	3	UAS	125.4	42.9	-22.7	-144.0	-123.7	2
LAS	9.7	-17.3	-31.7	-41.5	-90.5	-81	LAS	18.8	-34.9	-63.6	-83.3	-181.7	-163
SUM	73	5	-43	-113	-151	-78	SUM	144	8	-86	-227	-305	-161

Table 6. The reduction in groundwater level in the Forebay relative to the Baseline scenario.

Scenario	**Forebay Management Area**						
	Areal Average Monthly Groundwater Level Drawdown (ft) over 50 Years			**Cell-Based Monthly Groundwater Level Drawdown (ft) Over 50 Years**			**Impact**
	Mean	**Maximum**	**Standard Deviation**	**Mean**	**Maximum**	**Standard Deviation**	
P1	0.52	1.64	0.42	0.81	2.30	0.62	I
S1	0.51	1.63	0.42	0.81	2.28	0.62	I
P1R	0.70	2.02	0.51	0.99	2.58	0.67	I
P1RC	0.61	1.83	0.46	0.89	2.40	0.64	I
P1F	1.11	3.17	0.78	1.63	4.58	1.18	II
P2	1.02	3.04	0.76	1.60	4.42	1.16	II
S2	1.01	3.01	0.75	1.59	4.37	1.15	II
P2R	1.38	3.73	0.92	1.95	4.89	1.25	II
P2RC	1.20	3.39	0.84	1.75	4.56	1.18	II
P2F	2.20	5.86	1.43	3.24	8.53	2.21	III

Table 7. The increase (ft) in the monthly groundwater level in the lower aquifer system (LAS) in different management areas relative to the Baseline scenario.

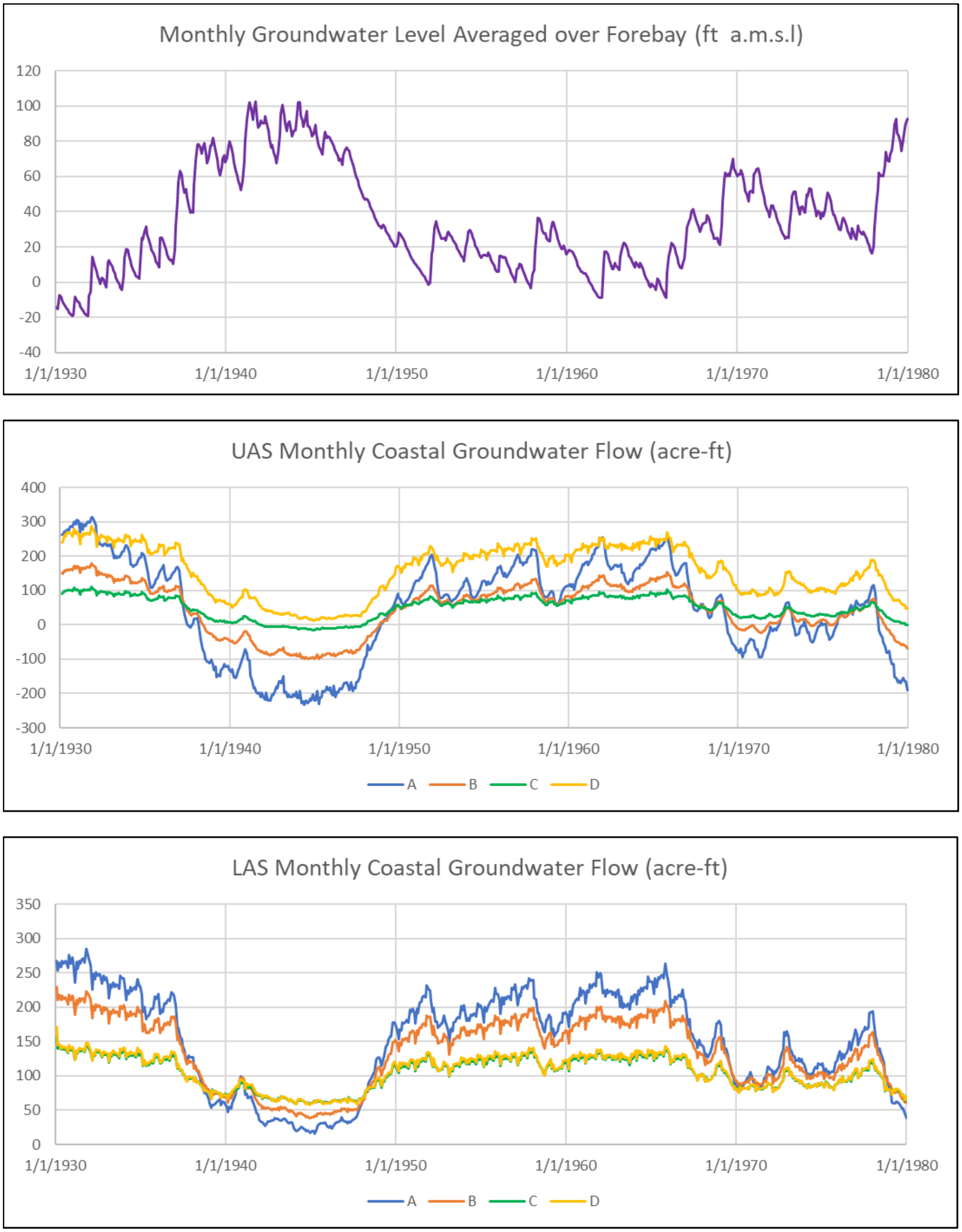
Scenario	Average			Maximum		
	Oxnard Basin		**Pleasant Valley**	**Oxnard Basin**		**Pleasant Valley**
	Saline Intrusion Management Area	**Pumping Depression Management Area**	**Pumping Depression Management Area**	**Saline Intrusion Management Area**	**Pumping Depression Management Area**	**Pumping Depression Management Area**
P1	1.61	2.00	1.43	2.36	3.41	2.24
S1	1.92	1.42	0.77	2.48	2.15	1.25
P1R	1.59	1.86	1.26	2.30	3.30	2.10
P1RC	1.60	1.93	1.34	2.33	3.35	2.17
P1F	1.70	2.12	1.46	2.26	3.27	2.12
P2	3.23	4.02	2.87	4.72	6.80	4.45
S2	3.84	2.85	1.55	4.95	4.28	2.48
P2R	3.21	3.74	2.52	4.60	6.57	4.18
P2RC	3.42	3.88	2.70	4.66	6.69	3.32
P2F	3.19	4.25	2.93	4.51	6.54	4.18



Letter	Coastline
A	North to Channel Islands Harbor
B	Channel Islands Harbor to Ormond Beach
C	Ormond Beach to Arnold Road
D	Mugu Canyon

The Saline Intrusion Management Area
The Pumping Depression Management Area
The West Oxnard Plain Management Area
The Forebay Management Area
The East Oxnard Plain Management Area
Users in or near the Saline Intrusion Management Area
Users in the Pumping Depression Management Area
The City of Oxnard's Rice Avenue Facility
The City of Oxnard's Water Yard
OH Wells owned by UWCD
20J07/08: Wells 01N22W20J07S/08S
27C02/03: Wells 01N22W27C02S/03S

Figure 1. The location of the AWPF recycled water users and the proposed extraction wells for RWPA extraction



Note: In LAS, the grey line representing C is overlapped with (hidden behind) the yellow line representing D.

Figure 2. The monthly average Forebay groundwater level and coastal groundwater flow from the Baseline GSP scenario

Figure 3. The Forebay available storage and the RWPA extraction over time

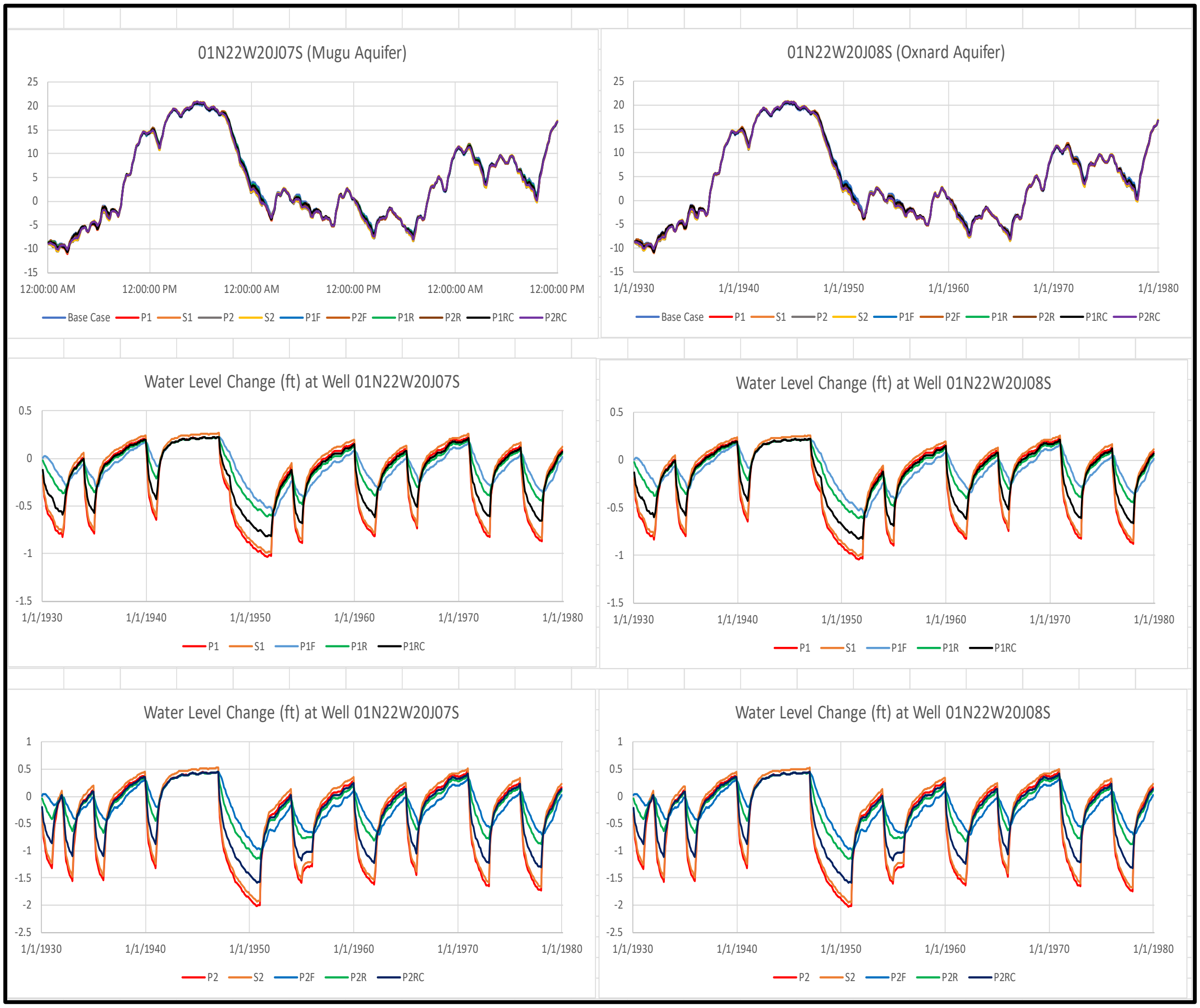


Figure 4. The simulated groundwater level at Wells 01M22W20J07S/08S over time

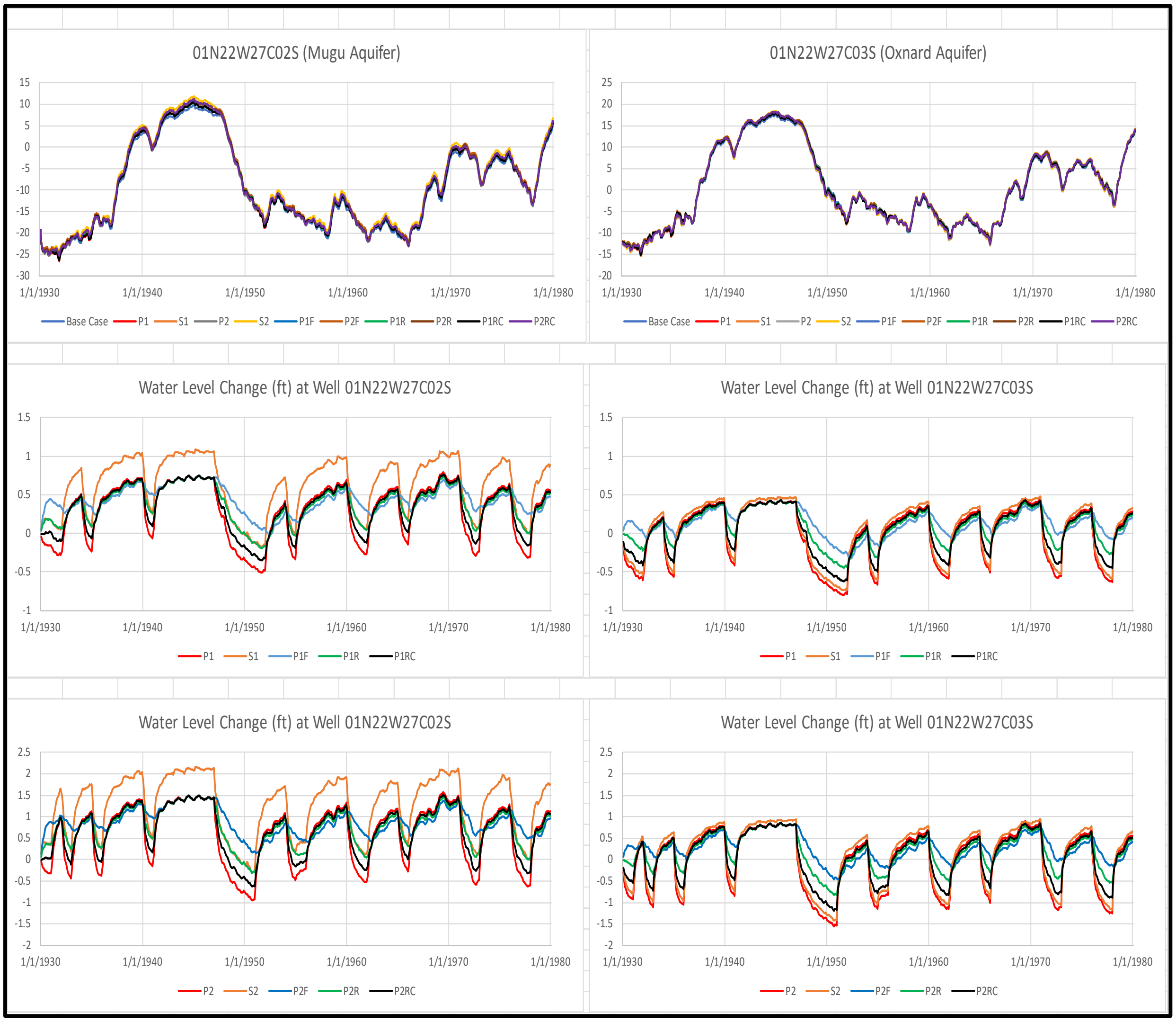


Figure 5. The simulated groundwater level at Wells 01M22W27C02S/03S over time