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BOARD DRAFT TECHNICAL MEMORANDUM

DATE: September 1, 2022 PROJECT #: 9150.0507

TO: Bob Jaques, Technical Program Manager, Seaside Basin Watermaster

FROM: Pascual Benito, Ph.D.

PROJECT: Seaside Basin Watermaster

SUBJECT: Executive Summary of Replenishment Modeling & Analysis of Alternate Supply & Demand Assumptions

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INTRODUCTION

Background

In April 2013, HydroMetrics Water Resources Inc. (now acquired by Montgomery & Associates) completed a groundwater modeling study that evaluated 3 potential future scenarios:

- **Scenario 1**: A 25-year groundwater overpumping replenishment program proposed by California American Water (Cal-Am) which replenishes their overpumping by in-lieu recharge through reducing pumping from their Seaside Basin wells production wells
- **Scenario 2**: A set of pumping reductions by Standard and Alternative Producers to achieve protective groundwater levels over a 25-year period
- **Scenario 3**: Cal-Am's replenishment plan coupled with additional injection into the Santa Margarita aquifer to achieve protective elevations in 25 years

Scenario 1 did not achieve protective elevations as 700 acre-feet per year (AFY) is not enough replenishment to raise groundwater levels to protective elevations at coastal wells, therefore this option was not included as part of this updated modeling of replenishment options.

Under Scenario 2, a pumping reduction by Standard and Alternative Producers of just over 2,000 AFY (including Cal Am's 700 AFY reduction) was needed to achieve protective groundwater levels at the coast. Since Scenario 2 is not a practical solution because Standard and Alternative producers do not have access to supplemental sources of water, it was not included as part of this updated modeling of replenishment options.

The results of Scenario 3 showed that when combined with Cal-Am's 25-year repayment schedule of 700 AFY, protective groundwater elevations can be achieved by injecting an additional 1,000 AFY of water into existing Aquifer Storage & Recovery (ASR) wells. Recharged water is left in the basin to replenish the over drafted aquifers and is not pumped by Standard or Alternative producers. This approach requires less supplemental water to implement than the pumping reduction approach for Scenario 2.

The predictive simulation for the 2013 scenarios only considered historical Carmel River ASR by Monterey Peninsula Water Management District (MPWMD) and not Pure Water Monterey (PWM), since in early 2013 PWM was only in the beginning planning stages.

Updated Analysis

This executive summary provides an overview of the findings of groundwater modeling and water budget analysis of replenishment options documented in two technical memorandums (TM's) prepared this year:

1. Replenishment modeling documented in the Technical Memorandum titled "Updated Modeling of Seaside Basin Replenishment Options", dated January 28, 2022 (M&A, 2022a). This study used the Seaside Watermaster groundwater model to estimate how much replenishment water would be needed to achieve protective elevations in the Watermaster's coastal protective elevation wells. Modeling included a revised and updated baseline simulation of future conditions with no additional replenishment, future projections of pumping and incorporating currently planned projects in the basin and projected sea level rise.

2. The second TM, titled "Hybrid Water Budget Analyses of Basin Replenishment Options & Alternate Assumptions", dated August 5, 2022 (M&A 2022b), extends the work done in the January TM by adding:

    a. A detailed water budget analysis of the January 2022 Baseline and 1,000- AFY Replenishment scenario simulations.

    b. Development of an alternative set of baseline supply and demand assumptions based primarily on Cal-Am's Urban Water Management Plan (UWMP), with some additional assumptions provided by Cal-Am and the City of Seaside. This alternate baseline is referred to Alternative Scenario 1.

    c. Development and results of a hybrid water-budget approach to evaluate the impact the alternate set of future supply and demand assumptions has on the volume of replenishment water that would be needed to reach protective elevations in the coastal monitoring wells.

The two TM's are included as attachments to this document.

BASELINE SIMULATION ASSUMPTIONS

In this TM the term "Baseline simulation" refers to the simulation of future conditions assuming only operation of currently planned projects with no additional replenishment added. Baseline simulation represents recent conditions from water year (WY) 2018 through 2021 based on actual measured pumping, injection, and hydrology; and projected potential future conditions from WY 2022 through WY 2050 based on MPWMD's projected pumping, currently planned projects, and a repeated historical hydrology record. The Baseline simulation hydrology (rainfall, recharge, and streamflow) is illustrated on Figure 1.

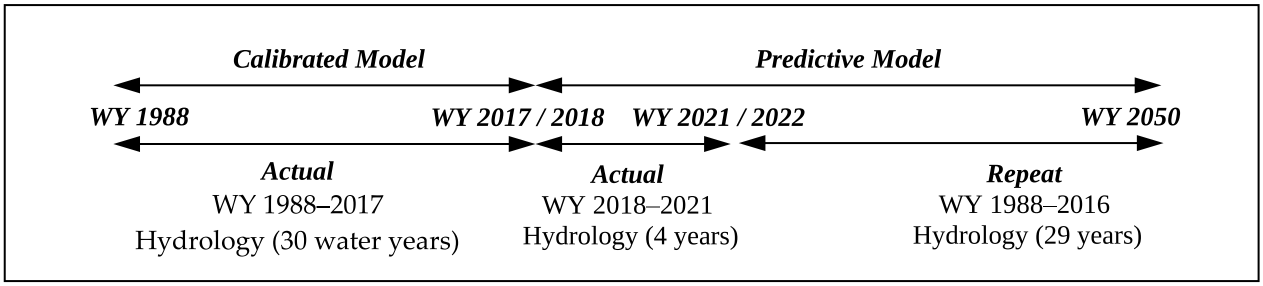

Figure 1: Repetition of Hydrology for Predictive Model

The Baseline simulation includes:

- A new extended hydrology period with 2 multi-year drought periods
- Projected mean sea level rise of up to 1.3 feet by 2050
- Seaside Aquifer Storage and Recovery (ASR) injection of Carmel River water with monthly volumes based on the cycled hydrology and a 20 acre-feet per day (AFD) diversion rate that assumes the proposed upgrades to the Cal-Am Carmel Valley wellfield[1], are completed by WY 2024

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[1] A 20 AFD diversion rate is based on assumption that needed improvements to the Carmel Valley well field are made (J. Lear, personal communication 1/21/2022). Else it would be somewhere between 12-15 AFD based on historical diversion data. Plans to improve and expand the Carmel Valley well field, including a new well on the former Rancho Canada Golf Course are outlined the California American Water 2021, 2022, and 2023 General Rate Case submitted to CPUC: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M425/K808/425808218.PDF

- Cal-Am's 25 year 700 AFY overpumping payback replenishment program begins in WY 2024
- Pure Water Monterey (PWM) Expansion project (tied to the new hydrology) begins deliveries in WY 2024 and delivers an annual average of 5,750 AFY
- Other planned projects including the City of Seaside's replacement of groundwater with recycled water for golf course irrigation and the construction of the Security National Guaranty (SNG) and Campus Town developments in the City of Seaside
- No other sources of replenishment water are provided to the basin
- The assumption that no proposed Groundwater Sustainability Plan (GSP) projects are implemented in the neighboring Monterey and 180/400 Foot Subbasins, and that groundwater levels along the northern boundary of the Model (located close to the boundary between those two subbasins) remain unchanged as currently represented in the Model boundary conditions

ALTERNATIVE SCENARIO 1 BASED ON CAL-AM URBAN WATER MANAGEMENT PLAN SUPPLY & DEMAND ASSUMPTIONS AND UPDATED CITY OF SEASIDE ASSUMPTIONS

Alternative Scenario 1 evaluates the impact of an alternate set of future supply and demand assumptions on the volume of replenishment water needed to achieve protective groundwater levels at the coastal monitoring wells. The alternate demand and supply assumptions are based primarily on Cal-Am's 2020 Urban Water Management Plan (UWMP) (WSC, 2021), and additional assumptions provided by Cal-Am and the City of Seaside. The set of assumptions is referred to as Alternative Scenario 1 in this Technical Memorandum.

Updated Assumptions for City of Seaside Golf Course use of Recycled Water & New Well Location

The City of Seaside requested that the following revised assumptions be used:

1. Assume City of Seaside golf courses use 491.4 AFY of recycled water.
2. Assume City pumps an in-lieu amount of 491.4 AFY from the deep aquifer from a new well located at Latitude = 36.615304°, Longitude = 121.826278° (Which is generally in the location of the Lincoln-Cunningham Park in Seaside).
3. Convert 26 AFY of golf course allocation from Alternate Producers (APA) to Standard Producers (SPA). New golf course APA allocation = 540 – 26 = 514 AFY.
4. The remaining unused balance of 514 – 491.4 = 22.6 AFY would be held as a reserve and/or for flushing of greens and tee boxes.

The current Baseline simulation already incorporates the assumptions that the City of Seaside golf courses switch to using recycled water in WY 2023 and stops pumping from their two Paso Robles (Shallow Aquifer) irrigation wells at that time. However, the Baseline simulation accounted only for 301.1 AFY of the 514 AFY golf course allocation to be re-allocated to supply the planned Campus Town Development project, in addition to the existing City of Seaside's municipal pumping SPA allocation currently supplied by pumping of Seaside Muni Well #4. So conservatively if the full 514 AFY of APA allocation is pumped from the new well, this leaves 514-301.1 = 212 AFY of additional pumping that is not currently included in the Baseline simulation and will need to be accounted for in the Alternative Scenario 1 water budget analysis.

Assumptions Requested by Cal-Am

Cal-Am requested that the following assumptions be used:

1. 15 AFD will be used as the average daily amount of ASR diversion, not the 20 AFD that was used in the January 2022 modeling. [*In keeping the current cycled Carmel River hydrology record this assumption results in a 25 percent reduction in the projected annual ASR diversion volumes but does not alter the temporal pattern of when ASR injection occurs during the simulation.*]
2. Cal Am's Urban Water Management Plan (UWMP) demand figures rather than MPWMD's demand figures will be used for Cal Am's projected water demands.
3. The MPWSP Desalination Plant will begin operation in 2030 in accordance with the UWMP. *[The UWMP assumes the Desal plant will produce 6,252 AFY for the Monterey Peninsula].*

4. Cal Am’s in-lieu repayment of 700 AFY will not begin until its desalination plant begins operation in 2030, in accordance with the UWMP. *[For comparison, the original baseline assumes the repayment period starts in 2024, concurrent with the PWM Expansion project.]*

5. The Pure Water Monterey Expansion Project will begin operation in 2024, the same as previously simulated in the January 2022 replenishment modeling.

6. To provide a factor of safety, the amount of water that the Pure Water Monterey Expansion Project will deliver will be reduced from 5,700 acre-feet to the *“Minimum Allotment”* of 4,600 acre-feet per year as set forth in the “*Amended and Restated Water Purchase Agreement”* executed between Cal Am, MPWMD, and M1W in late 2021.

7. Cal-Am will make-up any shortfall between supply and demand by over pumping its Seaside Basin allocation of 1,474 AFY. *[If the Desal Plant is built in 2030, even though PWM Expansion is assumed to have reduced deliveries per Cal Am assumption 6 above, there will be no supply shortfall after 2030 because the UWMP indicates that the expected capacity of the Desal plant is sufficient to make up for the reduced PWM Expansion deliveries.]*

Alternative Scenario 1 assumptions were incorporated into the monthly supply-demand spreadsheet model developed by MPWMD that is used to assign and distribute simulated monthly Cal-Am pumping and ASR injection in the groundwater model. The supply-demand model incorporates the cycled Carmel River historical hydrology used for the determination of the monthly ASR diversions. Projected ASR injection and Seaside pumping data was then aggregated on a water year basis for comparison and integration with the water budget analysis from the existing Baseline replenishment model run.

CONCLUSIONS

Baseline and 1,000 AFY Replenishment Scenarios:

1. Under the 1,000 AFY replenishment scenario, protective groundwater elevations are reached, at least initially, in all protective elevation wells within 11 years. Average annual groundwater levels remain above protective elevations for over 50% of the water years during the 25-year replenishment period, except at monitoring well MSC Shallow, at which the protective elevation is reached only once, in WY 2035. After this year, groundwater levels stop increasing and slowly decline due to the drought years in the projected hydrologic cycles that reduces the availability of water for ASR and PWM injection and increases recovery of ASR and PWM water in storage.

2. A water budget analysis of the net inflow of water from offshore areas into the basin indicates the 1,000 AFY scenario maintains and enhances the reversal of flow from a net inflow of water from offshore to a net outflow of water to offshore, even when protective elevations are not being met at all protective elevation wells. The additional replenishment water adds an additional buffer to maintain strong net offshore outflows even in drought years.

3. Increasing replenishment to 1,500 AFY results in only slight improvement at MSC Shallow, and only marginal increases in protective elevation metrics at the other protective elevation wells. Because both the other shallow aquifer protective elevation monitoring wells, (PCA-W Shallow and CDM MW-4), start off already meeting protective elevations, suggesting that there is limited benefit in continuing to raise groundwater levels at MSC Shallow by increasing injection in the deeper Santa Margarita Formation. Rather, as illustrated by the results of Scenario 4, other alternatives could be considered and evaluated such as redistributing pumping from wells screened completely or partially in the Paso Robles aquifer, increased use of recycled water for irrigation purposes, such as at Mission Memorial Park, and simulating additional recharge directly to the Paso Robles aquifer.

4. The original 2013 replenishment modeling (Hydrometrics WRI, 2013) did not explicitly account for impacts of drought on the availability of Carmel River water for ASR injection and other Cal-Am use. Instead, it used a constant average injection and recovery rate each year rather having it fluctuate with hydrologic cycles. The results of the updated model scenarios that couple ASR and PWM operations to the hydrology illustrate the significant impact that multi-year droughts, and even just below normal periods, can have on the availability of water for ASR and PWM recharge and on the timing of reaching and maintaining protective elevations.

5. Simulated groundwater levels rise quickly in response to replenishment during periods of Normal and Above Normal water years following the prolonged drought at the start of the simulated replenishment period, suggesting that levels would rebound again after the drought at the end of the simulation period. However, the rapid rebound is also a function of the assumption that Cal-Am will extract ASR water as its last source of supply, after exhausting available water from its native groundwater rights and PWM water. This assumption has the consequence that a very large portion of the injected ASR water is left in storage in the Basin.

6. The 2009 modeling that established the protective elevations assumed steady-state conditions that have no time component to them, and essentially assumes that sufficient time has passed that conditions have equilibrated to fixed state. The modeling did not directly consider and does not inform or suggest for how long a period groundwater levels can stay below protective elevations without greatly increasing the risk of sea water intrusion. This is something that could be evaluated with additional modeling.

7. In addition to the constant 1,000 AFY replenishment, additional “booster” injections could be considered following protracted drought periods to make up the lost water.

8. The modeling simulation period ends just as Cal-Am’s 25-year repayment period ends. It is likely that additional replenishment water would be needed to offset the resumption of extraction at Cal-Am’s full native groundwater allocation.

9. The increased frequency and duration of extreme weather events associated with climate change will have an impact on the ability to maintain protective elevations. Additional modeling of projected future climate scenarios could be used to evaluate this.

Water Budget Analysis

1. An important finding from the water budget analysis of the Baseline Scenario on an aquifer-by-aquifer basis is that Shallow Aquifer recharge from percolation of rainfall and irrigation return flows during periods of higher-than-normal rainfall plays a large role in driving the large steady increases in groundwater levels simulated in the Shallow Aquifer in the first 15 years of the simulation period. The temporal pattern and magnitudes of inflow from deep percolation in the Shallow Aquifer is highly correlated with the temporal pattern of total annual rainfall in the basin. Recharge from percolation in the Shallow Aquifer thus plays a role analogous to that of ASR injection in the Deep Aquifer because the simulated Carmel River hydrology record drives the rapid increase in water levels in the Deep Aquifer during this period.

2. Net injection of ASR and PWM water to the Deep Aquifer itself does not appear to be a significant driver for simulated increases in groundwater levels in the Shallow Aquifer observed during the Baseline Scenario. Rather the increase appears to be driven by the following.

    - The reduction by more than half of pumping from wells screened in the Paso Robles aquifer (Shallow Aquifer), due to the City of Seaside’s switch to recycled water for golf course irrigation in WY 2023 and Cal-Am’s switch to new higher capacity, Deep Aquifer production wells as part of the PWM Expansion project, in combination with:

        - a multi-year period of normal or higher than normal annual rainfall, and

        - the ongoing recharge of PWM water through the shallow vadose zone wells and backflush percolation ponds.

3. A net annual volume of between 200 to 500 AFY flows out from the Shallow Aquifer to the Monterey Subbasin once water levels in the Shallow Aquifers begin to rise, driven by the increasing relative gradients between the groundwater levels in the Northern Coastal Subarea and the lower groundwater levels in the Monterey Subbasin. A similar magnitude of net outflow occurs to the offshore portions of the Shallow Aquifer.

4. The water budget analysis of the Deep Aquifer shows a larger magnitude of net outflows to the Monterey Subbasin (600-1,700 AFY) as groundwater levels rise, and surprisingly, even a small amount of net out flow to the overlying Shallow Aquifer as Deep Aquifer during peak periods when Deep Aquifer groundwater levels rise above the levels in the Shallow Aquifer. The contribution of flow from the Deep Aquifer to the Shallow Aquifer increases in the 1,000-AFY Replenishment Scenario, though is still relatively small contribution compared with the inflows to the Shallow Aquifer from percolation of rainfall during wet years.

5. Under the assumption that groundwater levels in the Monterey Subbasin do not rise, the analysis shows that outflows to the Monterey Subbasin will increase in all aquifers as groundwater levels in the Seaside Subbasin rise. An initial net inflow of water from the offshore region into the Seaside subbasin reverses to a net outflow in all aquifers as groundwater levels increase, with the largest net outflows occurring in the Aromas Sands and Older Dune Deposits, and the next largest net outflows to offshore region being in the Shallow Aquifer. Projected sea level rise is not a significant driver of inland flows relative to the larger changes in water levels associated with changes in injection and extraction in the subbasin.

6. The implications of the strong dependence on recharge from percolation of rainfall for raising the Shallow Aquifer levels are two-fold:

    a. First it may be advisable to consider and evaluate options for direct recharge of the Shallow Aquifer, rather than relying only on replenishment to the Deep Aquifer via injection wells in the Santa Margarita Formation, in addition to considering other reductions to pumping in the Shallow Aquifer, such as constructing replacement wells only in the Deep Aquifer and switching other irrigation operations to use recycled water (e.g., Mission Memorial).

    b. Secondly, this strong dependence on direct percolation from rainfall for increasing Shallow Aquifer water levels suggests that simply assuming a lower Carmel River ASR diversion rate while maintaining the same cycled hydrology record is not a substitute for more a comprehensive evaluation on the impact of climate change on hydrologic inputs to the subbasin. The complex interplay and alternating cross-flows seen through the water budget analysis suggests that there are limits to the type of alternate scenarios that could be evaluated using the hybrid water budget approach and that this approach is better suited to evaluating changes in net supply and demand, rather than on evaluating alternate climate conditions.

7. The results of the water budget analysis highlight that assumptions regarding groundwater conditions in the adjacent Monterey Subbasin have a big effect on the amount of replenishment water needed. For the simulated conditions, outflow to the Monterey Subbasin is the single largest net outflow from the Seaside Subbasin in most years. The boundary conditions for the Baseline Scenario assumed water levels along the boundary between the Monterey Subbasin and the 180-400 Foot Aquifer subbasin stay fixed at recent levels and does not assume any management actions are taken to increase groundwater levels in these neighboring subbasins during the simulation period. As groundwater levels in the Seaside subbasin begin to rise in response to increased recharge, steeper gradients develop towards the Monterey Subbasin, producing increased outflows to the Monterey Subbasin. A fraction of the injected water that would otherwise go towards raising groundwater levels and increasing outflows to the Offshore region, instead flows out to increase groundwater levels along the boundary the Monterey Subbasin. This reduces the effectiveness of replenishment activities and necessitates greater volumes of injection to reach protective elevations than would be needed if water levels in the Monterey Subbasin were also increasing over time. In this regard, the estimated volumes of needed replenishment water are therefore conservative if future water levels in the Monterey Subbasin do not continue to drop.

8. The results of the water budget analysis also indicate that there is likely a spatial and temporal component to maximizing the efficiency of injection for the purpose of achieving protective elevations. As groundwater levels rise, the increased water levels drive flow out laterally towards surrounding areas with lower groundwater levels. The water that flows out does not disappear however, rather it begins to raise the groundwater levels in the portion of the Monterey Subbasin adjacent to the Seaside recharge wells, as part of a growing groundwater mound around centered on the recharge facilities. Continuing to grow this groundwater mound is analogous to the process of building up a mound of dry sand by pouring sand onto the tip of the mound. Not all the sand we pour at the tip goes to increasing the height of the mound, rather a portion flows down along the slopes of the mound to build up the base and sides of the mound. In our analogy, the pile of sand is sitting on an inclined platform with some flows towards the downgradient production wells and the offshore region and some flows towards the Monterey Subbasin. Increasing the replenishment rate while keeping the recharge focused in a narrow strip of the Seaside subbasin likely results in very steep localized mound that quickly starts spilling over, so to speak, into the Monterey Subbasin. It may be that spreading the increased replenishment volume out spatially over a broader area further from the subbasin boundary could deliver the same volume of water while reducing the rate of loss.

Hybrid Water Budget Analysis of Alternative Scenario 1

1. The hybrid water budget analysis suggests that the large and rapid increases in Deep Aquifer groundwater levels simulated from WY 2024 to WY 2035 under the Baseline Simulation assumptions would not occur under the supply and demand assumptions of Alternative Scenario 1 without very large quantities of additional replenishment water injected to the basin during this period of the simulation (ranging between 1,200 and 3,700 AFY). Despite using the same hydrology, the reduced ASR diversion rate and lower PWM Expansion yield coupled with higher demand assumptions requires an average annual injection of 2,600 AFY of additional replenishment injection to have the equivalent net recharge as in the Baseline scenario.

2. It is unclear exactly what would happen to groundwater levels in the Shallow Aquifer under the Alternative Scenario 1 with no additional replenishment water injected given the new understanding that the initial rapid increases in Shallow Aquifer groundwater levels observed in the Baseline Simulation are largely driven by percolation of rainfall during wet years, rather than exclusively because of injection to the Deep Aquifer. On the one hand, simulated recharge from rainfall would stay the same, which could result in similar Shallow Aquifer groundwater level increases, but on the other hand, there would likely be net leakage downward to the Deep Aquifer because deep groundwater levels would stay below the

Shallow Aquifer levels, potentially offsetting inflows from percolation. This would require additional analysis and/or modeling to confirm. The results, however, do emphasize the large role that the assumptions on future climate conditions have on predicting how quickly groundwater levels can be raised, and how much additional replenishment water would be needed.

3. The amounts of replenishment water needed to achieve protective elevations under the Alternative Scenario 1 assumptions is significantly greater than under the Baseline Scenario assumptions. An annual average replenishment rate of 3,700 AFY, ranging from 2,200 to 4,700 AFY is needed, compared to the 1,000 AFY of replenishment needed under the Baseline assumptions. This highlights the sensitivity of predicted groundwater conditions in the Seaside basin to the assumptions that are made about future water demands, future rainfall patterns, and the availability of water supplied from outside the subbasin, including Carmel River ASR diversion, the expanded Pure Water Monterey Project, and the MPWSP Desalination Plant.

4. The effects of climate change are already visible in the changing frequency of hydrologic flows in the region. The last 100 years of Carmel River stream flow data show a marked shift in the last 50 years towards more frequent occurrence of Critically Dry and Extremely Wet water years, and fewer Normal water years, as compared to the previous 50 years. This shift will see a greater volume of water become available for ASR diversion during extreme high flow events as opposed to spread out over longer periods. The impact of a reduced ASR diversion rate in the Alternative Scenario 1 analysis makes it clear that the necessary infrastructure in terms of facilities for increased diversion capacity in the Carmel River and ideally for increased recharge capacity in the Seaside Subbasin would need to be in place to be able to capture and store these high flows when they occur.

REFERENCES

Montgomery & Associates, Inc., 2022a. Technical Memorandum, Updated Modeling of Seaside Basin Replenishment Options, January 2022.

Montgomery & Associates, Inc., 2022b. Technical Memorandum, Hybrid Water Budget Analyses of Basin Replenishment Options & Alternate Assumptions , August 2022.

Water Systems Consulting, Inc. (WSC), 2021. California American Water Central Division – Monterey County District, 2020 Urban Water Management Plan, June 2020.

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DRAFT TECHNICAL MEMORANDUM

DATE: January 28, 2022 **PROJECT #:** 9150.0504

TO: Bob Jaques, Technical Program Manager, Seaside Basin Watermaster

FROM: Pascual Benito, Ph.D. and Georgina King, P.G, C.Hg.

PROJECT: Seaside Basin Watermaster

SUBJECT: Updated Modeling of Seaside Basin Replenishment Options

INTRODUCTION

Background

In April 2013, HydroMetrics Water Resources Inc. (now acquired by Montgomery & Associates) completed a groundwater modeling study that evaluated 3 potential future scenarios:

- **Scenario 1**: A 25-year groundwater overpumping replenishment program proposed by California American Water (Cal-Am) which replenishes their overpumping by in-lieu recharge through reducing pumping from their Seaside Basin wells production wells
- **Scenario 2**: A set of pumping reductions by Standard and Alternative Producers to achieve protective groundwater levels over a 25-year period
- **Scenario 3**: Cal-Am's replenishment plan coupled with additional injection into the Santa Margarita aquifer to achieve protective elevations in 25 years

Scenario 1 did not achieve protective elevations as 700 acre-feet per year (AFY) is not enough replenishment to raise groundwater levels to protective elevations at coastal wells, therefore this option was not included as part of this updated modeling of replenishment options.

Under Scenario 2, a pumping reduction by Standard and Alternative Producers of just over 2,000 AFY (including Cal Am's 700 AFY reduction) was needed to achieve protective groundwater levels at the coast. Since Scenario 2 is not a practical solution because Standard and Alternative producers do not have access to supplemental sources of water, it was not included as part of this updated modeling of replenishment options.

The results of Scenario 3 showed that when combined with Cal-Am's 25-year repayment schedule of 700 AFY, protective groundwater elevations can be achieved by injecting an additional 1,000 AFY of water into existing Aquifer Storage & Recovery (ASR) wells.

Recharged water is left in the basin to replenish the over drafted aquifers and is not pumped by Standard or Alternative producers. This approach requires less supplemental water to implement than the pumping reduction approach for Scenario 2.

The predictive simulation for the 2013 scenarios only considered historical Carmel River ASR by Monterey Peninsula Water Management District (MPWMD) and not Pure Water Monterey (PWM), since in early 2013 PWM was only in the beginning planning stages.

UPDATED BASELINE MODEL

Baseline Project

In this Technical Memorandum the term "baseline simulation" refers to the simulation of future conditions assuming only operation of currently planned projects with no additional replenishment added. The baseline simulation includes:

- Using the new hydrology described in the section below
- ASR injection - tied to the new hydrology
- Cal-Am's 25 year 700 AFY in-lieu replenishment
- PWM Expansion project (tied to the new hydrology)
- All the other planned projects described in the section below titled "Existing and Planned Projects" (e.g., Seaside Golf Courses shift to recycled water, Security National Guaranty (SNG) and Campus Town developments, etc.)
- No other sources of replenishment water

In other words, the baseline represents the "do nothing" scenario without the addition of any replenishment water.

Extend and Update Baseline Period and Hydrology

Previous predictive model simulations have been based on repeating the historical hydrology from the original 22-year model calibration period of 1987–2008 (referred to hereafter as "the historical model"). Previous predictive simulations run from 2009 through 2042. While maintaining this approach allows for direct comparison between new and previous simulations, it does not take advantage of the additional 9 years of hydrologic and climatic data that have been incorporated into the historical model. The historical model was updated in 2014 and 2018, and now includes a continuous 31-year hydrologic record from January 1987 through December 2017 (HydroMetrics WRI, 2014, 2018). Significantly, this 31-year hydrologic record includes both the 1987–1991 drought and the recent 2012–2015 drought. Climate change models predict increasing variability in temperature and precipitation, and using this extended historical hydrology and climate dataset as the basis for all predictive modeling incorporates a broader range of potential climate variability into the simulations. While previous predictive groundwater models used a calendar year basis, the updated predictive model is now based on water year (WY).

The updated baseline model simulates a 33-year period from October 2017 through the end of September 2050 (WY 2018–2050). The hydrology (rainfall, recharge, and streamflow) for WY 2018–2021 is based on measured values, while the hydrology for WY 2022–2050 is simulated by repeating the hydrology record from WY 1988–2016, as illustrated on Figure 1 and detailed in Table 3.

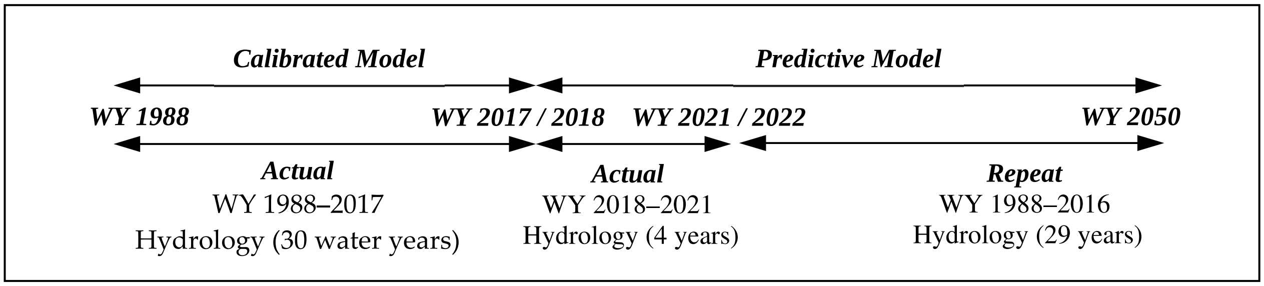

Figure 1: Repetition of Hydrology for Predictive Model

The 2013 replenishment modeling effort assumed protective groundwater elevations must be reached within 25 years from the time supplemental water is available to offset pumping (assumed at that time to begin in 2016) thereby resulting in protective elevations being reached in 2041. Per the TAC’s direction for this model update of replenishment options, the model is used to determine how much replenishment water is needed to achieve protective coastal groundwater elevations in 20 years. Extending the hydrology to WY 2050 covers the 20-year target to be used for evaluating replenishment volumes that achieve protective elevations and also covers the entire 25-year Cal-Am repayment period.

Actual hydrology and measured pumping and injection rates are used for WY 2018–2021, with the following WY 2022–2050 period using projected production and injection rates as described in the sections below.

The update of hydrology also included an update of the estimated shallow groundwater recharge from percolation of precipitation based on the new updated hydrology cycle, while the irrigation return flow, ponds, system losses, and septic systems are based on the previously modeled estimates.

Incorporating of Sea Level Rise at Ocean Boundaries

Estimates of projected sea level rise (SLR) through WY 2050 are incorporated into the predictive model simulation by adjusting the freshwater equivalent head boundary conditions specified along the ocean boundary. The mean sea level rise (MSLR) estimate is based on one of the scenarios of the projected MSLR for Monterey Bay from the 2018 update of the State of California Sea-Level Rise Guidance document recently released by the California Ocean Protection Council (OPC, 2018), shown on Figure 2. The State of California considers the SLR projections in the OPC guidance document to represent the current best available science. The OPC guidance presents projections for 2 different possible future greenhouse gas emissions scenarios: a low emissions scenario, RCP 6.2, which would result in lower future MSLR, and a high emissions scenario, RCP 8.5, which would generally result in higher future SLR. The term "RCP" is short for Representative Concentration Pathway, and in combination with the number, 6.2 or 8.5, refers to a specific carbon emissions scenario included in the Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC, 2014). RCP 8.5 is considered the high-end "business-as-usual" fossil fuel intensive scenario and is chosen for incorporation in the updated baseline groundwater model simulation to represent a conservative emissions scenario that will maximize potential future SLR.

The SLR projections from the OPC guidance document are developed by running many simulations (an ensemble) of global climate models based on a specific assumption on the global response to climate change (e.g., how quickly we cut emissions). Each individual simulation results in a specific SLR prediction, and when the results from this ensemble of predictions are looked at statistically, a probability of SLR exceeding a certain level can be defined. For a given emissions scenario, the probability value, *p*, shown in the legend entries of Figure 2 represents the likelihood that SLR will meet or exceed the sea level value shown on the chart. So for example, looking at the curve for the medium risk (*p*=5%) projection this can be understood as saying that for the RCP 8.5 emissions scenario there is a 1-in-20 chance that SLR will be equal to or greater than the values shown on the chart each year. In contrast, the *p* = 0.5% curve represents that there is a 1-in-500 chance that seal level rise will meet or exceed the values on that curve. In consultation with the TAC, the High Emissions, Medium Risk Aversion scenario (blue trianlges on Figure 2) was selected, which projects a mean SLR of at least 1.3 feet by 2050. As the protective head elevations are tied to mean sea level, a simple equivalent adjustment to the protective head elevations is made by increasing the protective elevations by the projected SLR over time. For WY 2018–2021 measured values of actual MSLR for the Monterey Bay (NOAA, 2021) are used, while projected MSLR is used for WY 2022–2050.

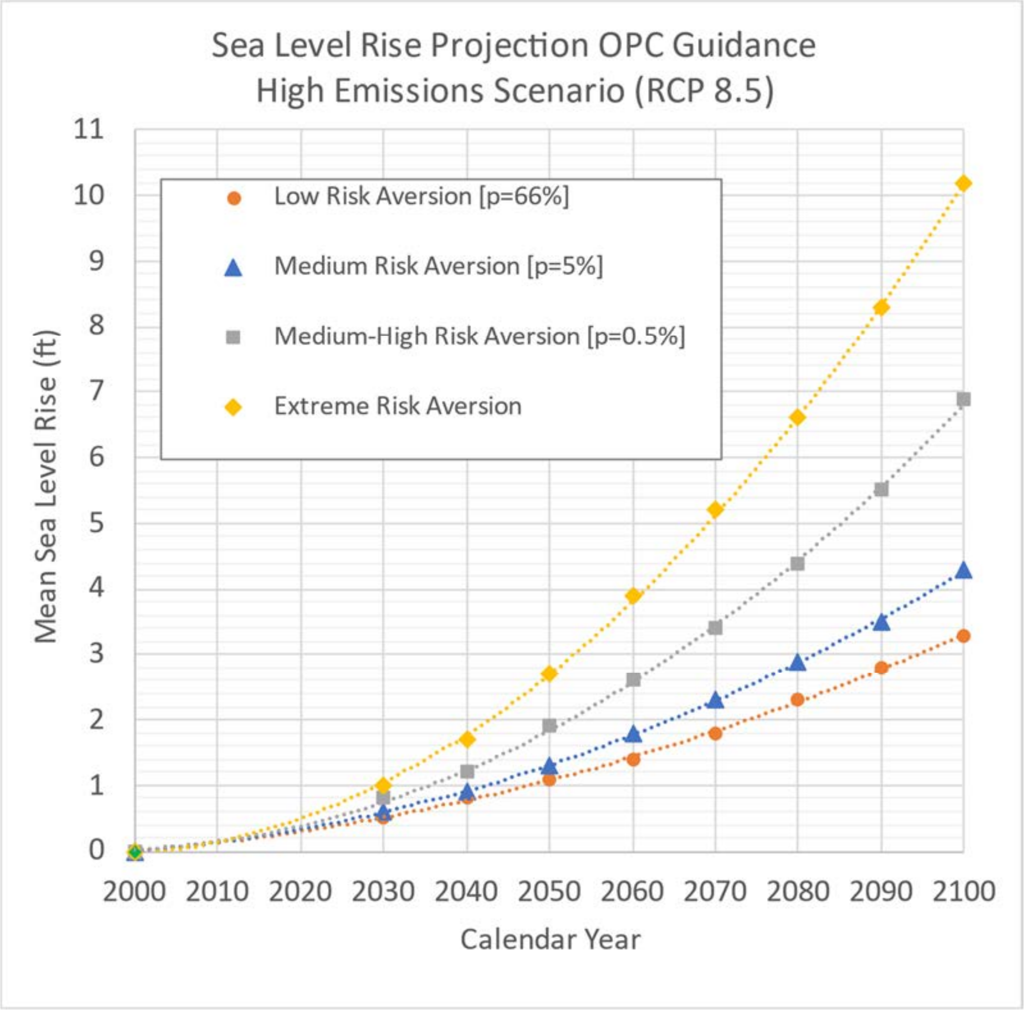

Figure 2. Projections of Rise in Mean Sea Level

Projected Groundwater Pumping

The assumptions used for projected groundwater pumping are:

1. Actual reported pumping within the Seaside basin is used for WY 2017–2021. Projected Standard and Alternative Producer pumping are set at the 5-year average of measured WY 2017–2021 pumping shown in Table 1 from WY 2022 and onward, with a few specific exceptions described in the next section. This assumption means that some of the producers are assumed to pump less than their allocations. Projected pumping for all Standard Producer and Alternative Producers stays within their safe yield allocations of native Seaside basin groundwater from WY 2022 onward, except for City of Seaside, whose 5-year WY 2017–2021 average of 182 AFY exceeds their current municipal allocation of 120 AFY.

Table 1. Five-Year Average (WY 2017-2021) Standard and Alternative Producer Pumping

Sub-Area and Producer	WY2017-2021 Average (AFY)	Natural Safe Yield Allocation (AFY)
Coastal and Northern Inland	**2,741***	**2,367**
Calabrese	0	9
Cal-Am	2,048*	1,474
Mission Memorial Park	22	31
City of Seaside (golf course)	487	540
City of Seaside (municipal)	182	120
SNG	1	149
Sand City	1	9
Granite Rock Company	0	11
DBO Development No. 30	0	21
Laguna Seca	**575**	**644**
Cal-Am**	153	0
LS County Park	19	41
LS Golf Resort (Bishop)	206	320
The Club at Pasadera	181	251
York School	16	32

*Includes non-native PWM & ASR recovery
** Set to 0 AFY in WY2022 and onward

2. Cal-Am ceases pumping from the Ryan Ranch and Bishop Units in the Laguna Seca subarea starting in WY 2021. Pumping continues from the Hidden Hills Unit which is located just outside the Laguna Seca subarea.

3. Cal-Am's projected demand and pumping schedule for WY 2022–2050 is based on an updated version of the spreadsheet supply-demand forecast model originally developed by MPWMD for use in the 2019 PWM Expansion Supplemental Environmental Impact Report (SEIR) modeling (MPWMD, 2019). This is described in more detail below.

4. Private pumping within the Seaside Basin was based on repeating the estimated WY2017 rates for private produces from the calibrated Seaside historical model.

5. Pumping rates for adjacent subbasins remain as they currently are and do not assume that any projects included in their respective GSPs are implemented.

6. Pumping outside the Seaside basin in the Corral de Tierra and Toro Creek areas of the Monterey Subbasin is based on repeating the most recently estimated pumping rates from the

calibrated Seaside historical model period, with the exception of Cal-Am Hidden Hills pumping which is based on the 5-year average of reported pumping for WY 2017–2021 of 128 AFY.

7. Pumping by the Marina Coast Water District (MCWD) is not explicitly simulated in the model but is represented by proxy via the prescribed constant head boundary along the model boundary in the Marina/Ord area. These are assumed to remain the same as in the calibrated historical model, and do not reflect any impacts from GSP projects.

8. Golf course irrigation pumping both within and outside the Seaside basin matches the historical pumping aligned with the cycled historical hydrology. In a few cases where the historical pumping record was not consistent or complete, an average rate is used. Another exception is the change in the City of Seaside golf course water supply described in the next section.

Existing and Planned Projects

Assumptions regarding existing and planned projects are:

1. Carmel River ASR injection quantities are assumed to be the same as current operations based on cycled historical Carmel River hydrology. Projected Carmel River diversion and ASR injection schedule is described in more detail in a subsequent section.

2. The Pure Water Monterey (PWM) base injection averages 3,500 AFY beginning in WY 2020 with the PWM Expansion project increasing to an annual average of 5,750 AFY assumed to start in WY 2024. Actual measured monthly injection rates for WY 2020–2021 are used followed by a projected injection schedule for the remainder of the simulation, using the injection delivery spreadsheet previously developed for the PWM project modeling and updated for the simulated future hydrology. The PWM recharge assumptions are described in more detail in a subsequent section of this technical memorandum.

3. Cal-Am’s 700 AFY reduction in pumping of native groundwater as part of its 25-year groundwater over-pumping replenishment program is assumed to start in WY 2024, following completion of the PWM Expansion Project. The repayment period stops at the end of WY 2048. Note that Cal Am’s agreement with the Watermaster requires it to repay all of its overpumping since the date of issuance of the Adjudication Decision. The amount that must be repaid may require the pumping reduction to extend beyond 25 years.

4. The SNG development is supplied water from Cal-Am wells under an agreement with Cal-Am. As part of the agreement, Cal-Am uses SNG’s native groundwater water right of

149.7 AFY to meet the project demand. The SNG development is assumed to be completed in 2025 with usage starting at 25 AFY in 2025 and ramping up to 30 AFY in 2026, 50 AFY in 2027, and 70 AFY from 2028 onward. Annual usage is allocated monthly based on the historical monthly demand percentages the Cal-Am Monterey District used in the MPWMD Cal-Am Demand-Supply model developed for the PWM Expansion SEIR.

5. The City of Seaside replaces its golf course irrigation with PWM recycled water starting in WY 2023 and through its agreement with the Watermaster uses its 540 AFY golf course irrigation allocation to augment their municipal water system's allocation to meet demand of the Campus Town development project. The groundwater model assumes that this pumping will be produced by their municipal Well #4. This results in a decrease in pumping of approximately 480 AFY from the 2 irrigation wells screened in the shallow Paso Robles aquifer but will result in an increase in pumping in the deeper Santa Margarita aquifer[1]. Based on information provided by the City of Seaside on projected total water use and construction timeline, the Campus Town project is assumed to begin in WY 2023 with usage starting at 100 AFY in 2023, 130 AFY in 2024, 215 AFY in 2025, and reaching a maximum of 301.1 AFY in 2026. The annual usage was allocated monthly based on the historical monthly demand percentages for the Cal-Am Monterey District used in the MPWMD Cal-Am Demand-Supply model developed for the PWM Expansion SEIR and was added to the projected existing City of Seaside municipal pumping demand projections.

Predicted Carmel River Flow Diversions and ASR Injection Assumptions

The amount of Carmel River water available for diversion for ASR injection and for Cal-Am's Table 13[2] diversions used to meet Cal-Am system demand for the predictive simulation period is based on historical streamflow records. Because the future simulated hydrology is based on the historical hydrology of WY 1988–2016, the projected streamflow is taken as being the same as the historical streamflow and used as the basis for determining when and if diversions can occur. As part of the PWM Expansion SEIR modeling (MPWMD, 2019a), MPWMD staff compared historical daily streamflow between WY 1987 and WY 2008 with daily minimum streamflow requirements. This allowed MPWMD to identify how many days in each month ASR water could be diverted from the Carmel River. Using an assumed daily diversion rate of 20 AF per

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[1] In the Seaside model, the Muni #4 is represented as being screened in both the Paso Robles and the Santa Margarita formations, although there is some uncertainty as to whether Seaside Muni #4 is in fact screened in both aquifers, or only one of them (J. Lear, personal communication., September 2021).

[2] Table 13 diversions refers to a streamflow-dependent water right that Cal-Am can use in its Carmel River well fields as identified in Table 13 of SWRCB Decision 1632 (1995). It is in addition to Cal-Am's entitled 3,376 AFY water right from the Carmel Valley basin with no streamflow restrictions.

day[3], MPWMD estimated the volume of Carmel River water that could be injected into the ASR system each month. The analysis has been updated as part of this study and extended to include Carmel River streamflow data through WY 2021 and used to develop a revised projected monthly Carmel River diversion schedule for the baseline model. The Carmel River water available for injection was divided between the ASR 1&2 Well Site and the ASR 3&4 Well Site according to the historic division of injection. The projected annual ASR injection and Cal Am Table 13 diversions are shown below on Figure 3. The projected period starts off during a multi-year drought[4], such that there are almost no diversions in the first 4 projected water years, followed by a period that includes multiple years of Above Normal and Extremely Wet conditions which allow for very high amounts of diversion. Table 1 lists the average number of projected annual diversion days, total ASR diversions, and Table 13 diversions for each Carmel River water year type, based on the analysis of historical daily stream flows from WY 1987–2021. Note that the allowable diversion for ASR injection can easily drop by half even in just in going from a Normal water year to a Below Normal water year.

Note that the approach of tying the ASR injection volumes directly to the cycled hydrology period differs from the previous 2013 replenishment modeling where a constant average annual ASR injection volume of 1,445 AFY, characteristic of Normal water year conditions was assumed.

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[3] Historically, the diversion rate has been between 10–15 AF per day. The 20 AF diversion capacity assumes that planned improvements to increase the capacity of the Cal-Am Carmel River well field are implemented (Jon Lear, personal communication, January 21, 2022).

[4] Corresponding to the historical 1987–1991 drought

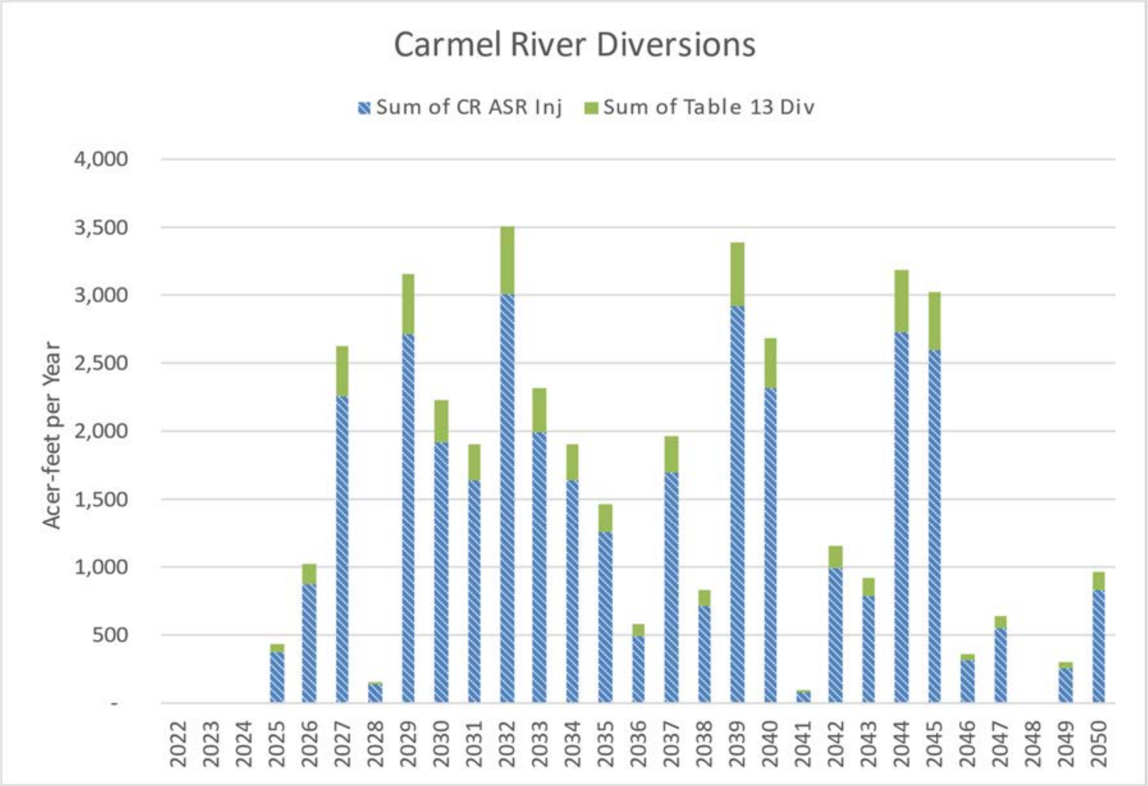

Figure 3. Projected Annual Carmel River Diversion for ASR Injection and Cal-Am Table 13 Diversions (CR = Carmel River)

Table 2. Projected Average Annual Carmel River Diversions by Water Year Type

Carmel River Water Year Type	Average Number Diversion Days	Average ASR Diversions (AFY)	Average Table 13 Diversions (AFY)	Average Total Diversions (AFY)
Extremely Wet	142	2,847	463	3,309
Wet	125	2,500	406	2,906
Above Normal	105	2,108	343	2,451
Normal	64	1,274	207	1,481
Below Normal	33	655	106	761
Dry	19	380	62	442
Critically Dry	3	51	8	60

Table 3. Annual Summary of Updated Baseline Simulation Water Year Types, Data Sources, and Major Project Events

Sim Year	Water Year	Carmel River WY Type	Hydrology Source WY	Pumping & Injection	Cal-Am Repayment Period	Projects Timeline
1	2018	Below Normal	Actual	Actual		
2	2019	Extremely Wet	Actual	Actual		
3	2020	Normal	Actual	Actual		**PWM Base Project Begins (3,500 AFY)**
4	2021	Critically Dry	Actual	Actual		**Cal-Am ceases pumping in Laguna Seca**
5	2022	Critically Dry	1988	Projected		**PWM ramps up to 4,100 AFY**
6	2023	Critically Dry	1989	Projected		**Seaside Golf Courses shift to PWM water**, Campus Town starts up (100 AFY)
7	2024	Critically Dry	1990	Projected	1	**PWM Expansion Begins (5,750 AFY)**, Campus Town ramp up (130 AFY)
8	2025	Dry	1991	Projected	2	SNG starts up (25 AFY), Campus Town ramps up (215 AFY)
9	2026	Normal	1992	Projected	3	SNG ramps up (30 AFY), Campus Town full capacity (301 AFY)
10	2027	Wet	1993	Projected	4	SNG ramps up (50 AFY)
11	2028	Critically Dry	1994	Projected	5	SNG full Capacity (70 AFY)
12	2029	Extremely Wet	1995	Projected	6	
13	2030	Above Normal	1996	Projected	7	
14	2031	Above Normal	1997	Projected	8	
15	2032	Extremely Wet	1998	Projected	9	
16	2033	Normal	1999	Projected	10	
17	2034	Above Normal	2000	Projected	11	
18	2035	Normal	2001	Projected	12	
19	2036	Below Normal	2002	Projected	13	
20	2037	Normal	2003	Projected	14	
21	2038	Below Normal	2004	Projected	15	
22	2039	Wet	2005	Projected	16	
23	2040	Wet	2006	Projected	17	
24	2041	Critically Dry	2007	Projected	18	
25	2042	Normal	2008	Projected	19	
26	2043	Normal	2009	Projected	20	
27	2044	Above Normal	2010	Projected	21	
28	2045	Above Normal	2011	Projected	22	
29	2046	Dry	2012	Projected	23	
30	2047	Dry	2013	Projected	24	
31	2048	Critically Dry	2014	Projected	25	**Potential Final Year of Cal-Am Repayment Period**
32	2049	Dry	2015	Projected		
33	2050	Below Normal	2016	Projected		

Pure Water Monterey Project Recharge Assumptions

Pure Water Monterey Base Project WY 2020–2023

The PWM project is a recycled water supply project that became operational in March 2020. It injects and stores purified recycled water in the Seaside basin temporarily for use as source of municipal water supply. Once injected into the Seaside Basin, the purified water mixes with native groundwater in the aquifers and is stored for future extraction and use. PWM currently provides 3,500 AFY of supply for Cal-Am to deliver to its customers in the Monterey Service district, allowing Cal-Am to reduce its diversions from the Carmel River system by that same amount.

The PWM Project also includes a drought reserve component to support the use of recycled water for agricultural irrigation during dry years. The project provides an additional 200 AFY of purified water that will be injected in the Seaside Basin in wet and normal years for up to 5 consecutive years. This will result in a banked drought reserve totaling up to 1,000 AF. During dry years, the project will inject less than 3,500 AF of water in the Basin; however, Cal-Am will be able to extract the banked water to make up the difference in supply. Recycled water that would have otherwise been purified and injected during these dry years when the drought reserve is in use will be sent to augment the Castroville Seawater Intrusion Project's (CSIP) agricultural irrigation supply in the Salinas Valley. Because the drought reserve component has not yet been agreed to by the CSIP growers, it is not currently active. However, it is assumed in the model to start in WY 2024 when the Expansion Project is projected to come online.

PWM purified water is recharged through 4 deep injection wells (DIW) screened in the Santa Margarita Formation (deep aquifer), and 2 vadose zone wells (VZW) screened in the Aromas Sands that recharge the Paso Robles Formation (shallow aquifer). PWM water from back-flushing of the DIW wells as part of weekly maintenance operations is discharged to percolation ponds also recharging the shallow aquifer. In the model, recharge to the shallow aquifer from the VZW wells and the percolation ponds is simulated by applying it as additional percolation at the water table beneath the recharge locations.

The PWM base project is simulated from WY 2020 through WY 2023. For WY 2020–2021 the simulation uses the actual monthly recharge volumes to the 4 currently operational recharge wells, DIW-1; DIW-2; VZW-1; and VZW-2, and to the percolation ponds used for discharging backflush water. It should be noted that as originally planned, 70% of the recharged water (~2,450 AFY) would recharge the Santa Margarita Formation and 30% (~1,050 AFY) would recharge the Paso Robles Formation. However, once injection operations began in spring of 2020 it was found that the VZW wells had a much lower capacity than originally planned for, and the recharge distribution is currently closer to 95% to the Santa Margarita aquifer and only 5% to the Paso Robles aquifer. The updated model takes this new distribution into account.

For WY 2022–2023, the model uses projected recharge rates developed for recent modeling of the PWM project included in the recently submitted Addendum to the PWM Title 22 Engineering Report (M&A, 2021). This period includes a planned ramp up from an annual recharge rate of 3,500 AFY to include an additional 600 AFY of recharge for total of 4,100 AFY [5]. The modeling also includes bringing online the 2 additional recently constructed deep injection wells, DIW-3 and DIW-4, assumed to become operational in WY 2022. The actual and projected injection rates to the DIW wells and to the VZW wells backflush percolation ponds are shown below on Figure 4. Recharge at the VZW wells is assumed to remain at the same monthly rates as in WY 2021. Additional backflush water for each additional DIW well is also added to percolation pond recharge volumes in the simulation.

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[5] A brief description of the proposed ramp up is found in the recent request to Water Board to amend the PWM operating permit: “Submittal of Report of Waste Discharge, Amendment of Pure Water Monterey WDRs–WRRs,” October 2021: https://documents.geotracker.waterboards.ca.gov/regulators/deliverable_documents/2069074332/M1W%20PWM%20cover%20letter%20ROWD%2029Oct2021_.pdf

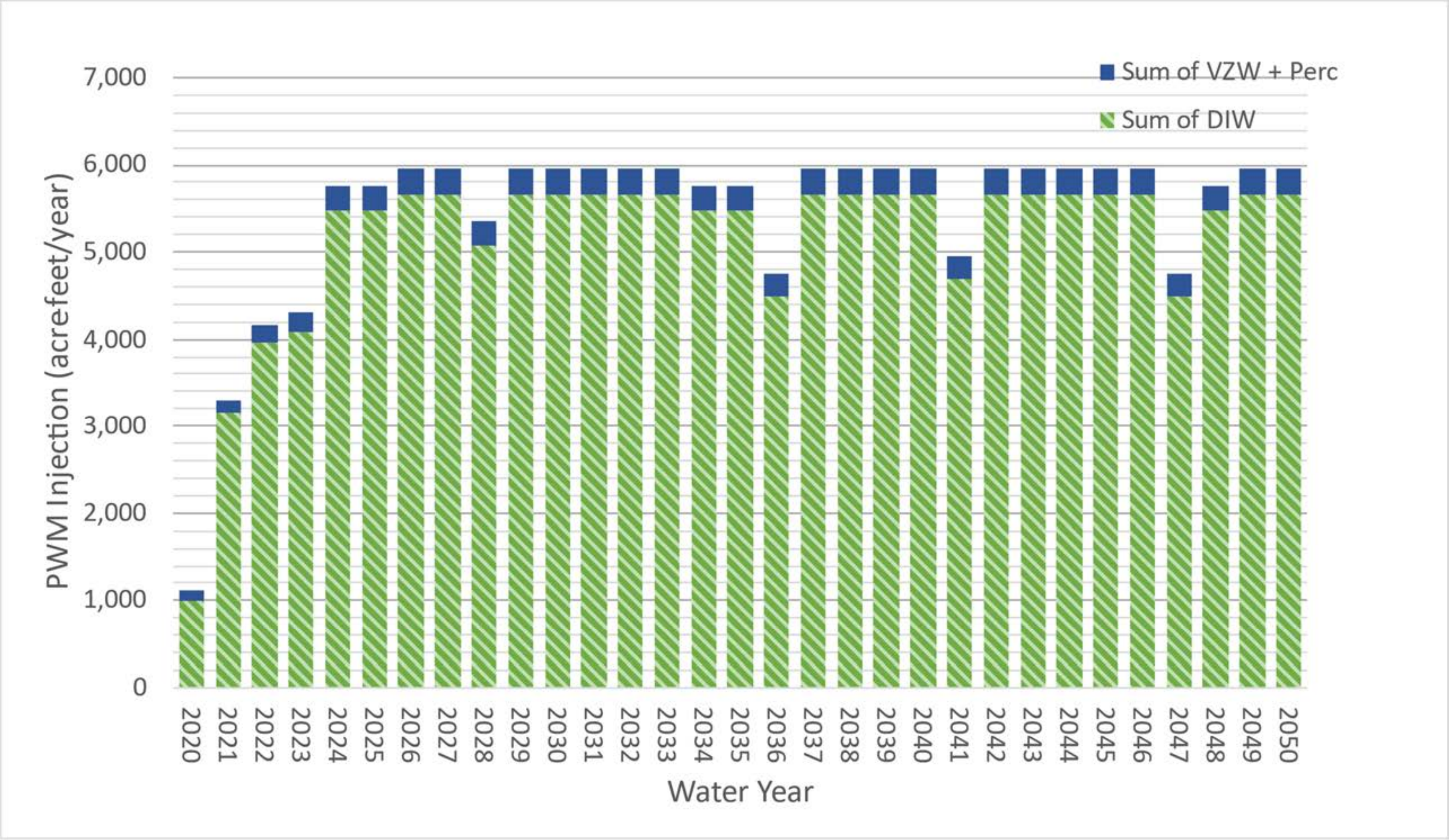

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Figure 4. Actual and Projected Annual PWM Recharge to the Deep Aquifer (DIW wells) and the Shallow Aquifer (VZW & Percolation Ponds)

Pure Water Monterey Expansion Project (WY 2024-2050)

The proposed PWM Expansion project is assumed to come online in WY 2024 and includes an expanded capacity of the advanced water purification facility and an increase of recharge to the Seaside Basin by an additional 2,250 AFY for a total average yield of 5,750 AFY. Up to 3 additional deep injection wells and an additional backflush basin are proposed for the expansion project.

For Cal-Am to extract additional injected groundwater, deliver it to meet its system demands at all times, and also provide system redundancy, 4 new extraction wells and associated infrastructure would be constructed. These include 2 new extraction wells located at Seaside Middle School (EW-1 and EW-2), and 2 new extraction wells located off General Jim Moore Boulevard (EW-3 and EW-4). The location of these additional wells and pond are shown on Figure 5.

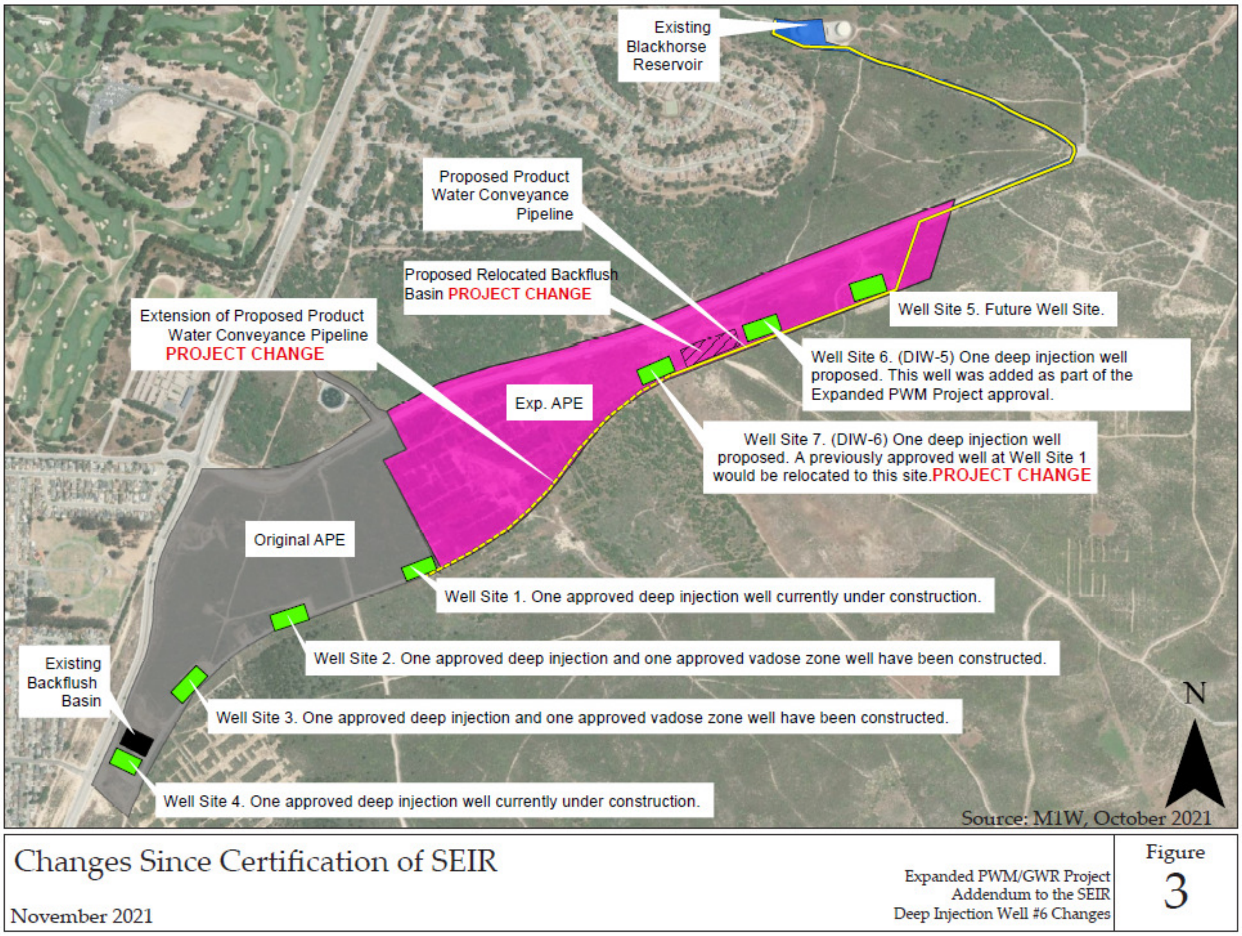

Figure 5. Pure Water Monterey Expansion Injection Facilities (source: M1W, 2021)

The PWM Expansion project recharges varying volumes of water each year, with an average of 5,750 AF recharged per year. The amount of water recharged annually depends on whether the projected hydrology is in a drought or non-drought year, and on the rules for banking and delivering water to the CSIP for irrigation use in the Salinas Valley. The drought year classification is based on percent deviation from long term average total annual precipitation data in the CSIP area. A monthly recharge schedule that includes an accounting and description of the CSIP banking and delivery program is shown in Table 10. The recharge schedule and the water year classification are updated and extended to align with the new baseline model hydrology period, and so for this reason, it differs from the delivery schedule used for the PWM Expansion SEIR modeling (M&A, 2019b). Locations of the planned wells have also been changed since the 2019 SEIR modeling so the expansion DIW well locations in the baseline model were updated to align with the latest planned locations (M1W, 2021). Injection well DIW-7 is assumed to not be constructed. Additionally, it was found during the 2019 PWM Expansion SEIR modeling that injected water was being lost to the neighboring Monterey Subbasin, and that M1W is planning on allocating less injection volumes to the northernmost DIW wells to try to minimize how much injected water is lost out of the basin. Because this could impact the evaluation of the protective elevations, this revised plan is incorporated in the updated baseline model by adjusting the percentage of recharge water that each well receives. The recharge at the VZW wells was kept at WY 2021 rates. Of the total recharge water injected, 98.5% is injected into the Santa Margarita aquifer through the deep injection wells, and the remaining 1.5% is injected into the Paso Robles aquifer through the vadose zone wells[6]. Monthly recharge via backflush basins was also simulated based on estimated backflush rates reported in the recent addendum to the PWM Expansion Project SEIR (M1W, 2021).

The assumed PWM Expansion Project Scenario allocation of recharge between different well sites is shown below in Table 4, and the annual injection volumes for the WY 2024–2050 period are shown on Figure 4. Significant reductions in recharge of up to 1,000 AFY occur during drought years when recycled water is delivered to CSIP (e.g., WY 2027; 2036; 2042; and 2047).

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[6] Note that this differs substantially from the assumptions used in the PWM Expansion SEIR modeling, where the split was 90% (~5,1750 AFY) Santa Margarita and 10% Paso Robles (~575 AFY).

Table 4. Allocation of Recharge to Deep Injection Wells and Vadose Zone Wells for Expanded PWM Expansion Project

Percent of Total Recharge	**Deep Injection Wells**						**Vadose Zone Wells**	
	98.5%						**1.5%**	
Well Site	**DIW-1**	**DIW-2**	**DIW-3**	**DIW-4**	**DIW-5**	**DIW-6**	**VZW-1**	**VZW-2**
Percent of Deep Recharge	30%	20%	20%	5%	10%	15%	-	-
Percent of Vadose Zone Recharge	-	-	-	-	-	-	63%	37%
Percent of Total Recharge	29.6%	19.7%	19.7%	4.9%	9.9%	14.8%	0.9%	0.6%

Cal-Am Supply and Demand Projections

Projected Cal-Am pumping in the Seaside basin for WY 2022–2050 is estimated using an updated version of the supply-demand forecast spreadsheet model developed by MPWMD for the 2019 PWM Expansion SEIR modeling (MPWMD, 2019a). The demand model was updated for the revised and expanded hydrologic period, and to incorporate the Cal-Am wells supplying the water demand of the SNG project when it is completed. The demand forecast has a uniform increase in demand over time, is tied to the hydrology cycle, and accounts for all of Cal-Am's water rights and allocations and demand/supply sources (Carmel River Table 13 diversion, Sand City Desal, native groundwater, ASR, and PWM) to determine the projected monthly Seaside Basin pumping demand which is then distributed to Cal-Am extraction wells. The demand model also accounts for the reduction of Cal-Am's wellfield pumping capacity that occurs during the 2 months following ASR injection operations when ASR wells cannot be used for extraction, and during which extraction shifts to other wells. The demand model incorporates Cal-Am's 700 AF replenishment payment and the Cease-and-Desist Order (CDO) restricting Cal-Am's diversion of Carmel River water. It is assumed that the 25-year 700 AFY replenishment begins in WY 2024 and finishes at the end of WY 2048, unless it needs to be extended as mentioned earlier.

Cal-Am's projected total annual water demand in WY 2022 is assumed to be 9,300 AF and to increase linearly to 11,700 AF through the end of WY 2050. The assumed starting volume is based on the 5-year average of Cal-Am's historical demand for WY 2016–2020 as reported in Cal-Am's 2020 Urban Water Management Plan (WSC, 2021). The 2050 demand is based on the upper demand projection from Figure 4 of the 2019 MPWMD supply and demand memo (MPMWD, 2019b). The monthly distribution of Cal-Am's annual deliveries, provided by

MPWMD, is used to estimate future monthly demand, and is based on monthly averages of Cal-Am deliveries from 2007 to 2017. The demand model estimates that roughly two-thirds of the total Cal-Am demand can be satisfied by extraction of native groundwater, injected Carmel River water, and injected PWM water from the Seaside Basin. Extraction from Carmel Valley[7], Cal-Am's Carmel River Table 13 diversion, and the Sand City Desalination plant. The demand model assumes that Cal-Am will first exhaust available water from its native groundwater right (which drops from 1,474 AFY to 774 AFY during the repayment period), followed by recovery of Pure Water Monterey water, and then finally recovery of ASR water from storage.

Total projected Cal-Am annual demand is shown on Figure 6, broken out by water source. It includes the very small additional 70 AFY to supply SNG. Projected total annual Cal-Am Seaside Basin groundwater extracted is shown in Figure 7. Most of the pumping demand is supplied by recovery of PWM water (red), while ASR recovery (green) is primarily used during drought years. Cal-Am's 25-year 700 AFY over-production repayment is visible in the drop in Native groundwater right (blue) from WY 2024 to 2048.

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[7] Cal-Am has a total entitled right of 3,376 AFY from the Carmel River Aquifer that is not reliant on seasonal diversion minimum flow requirements as is the case with the Table 13 water rights diversions.

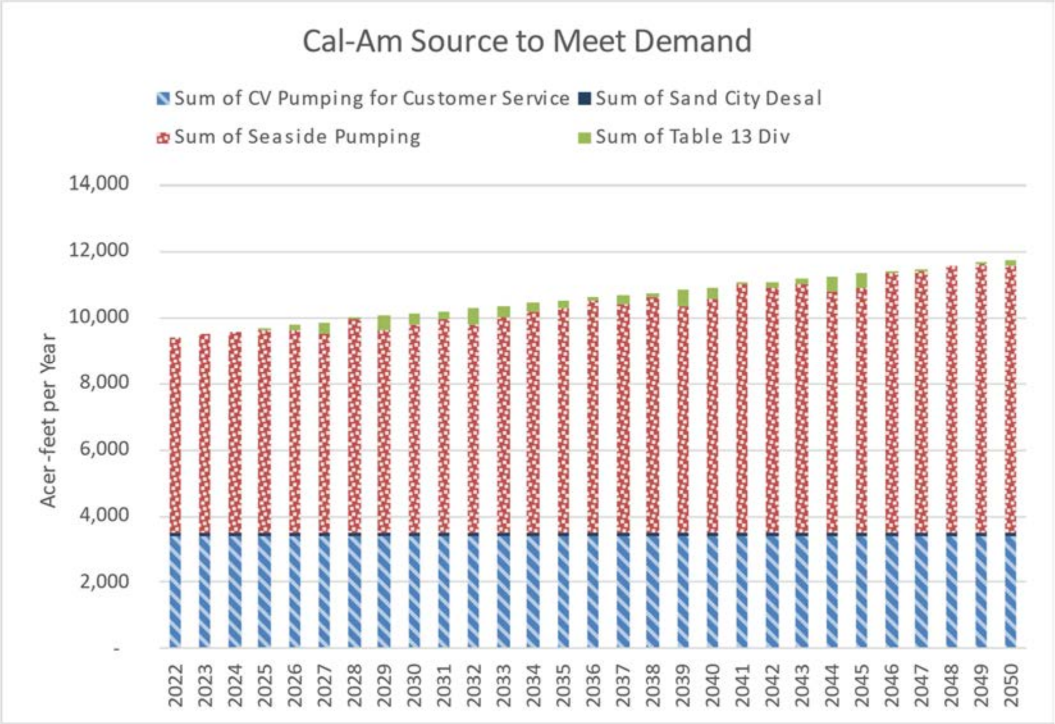

Figure 6. Total Cal-Am Annual Demand and Source to Meet Demand (CV = Carmel Valley)

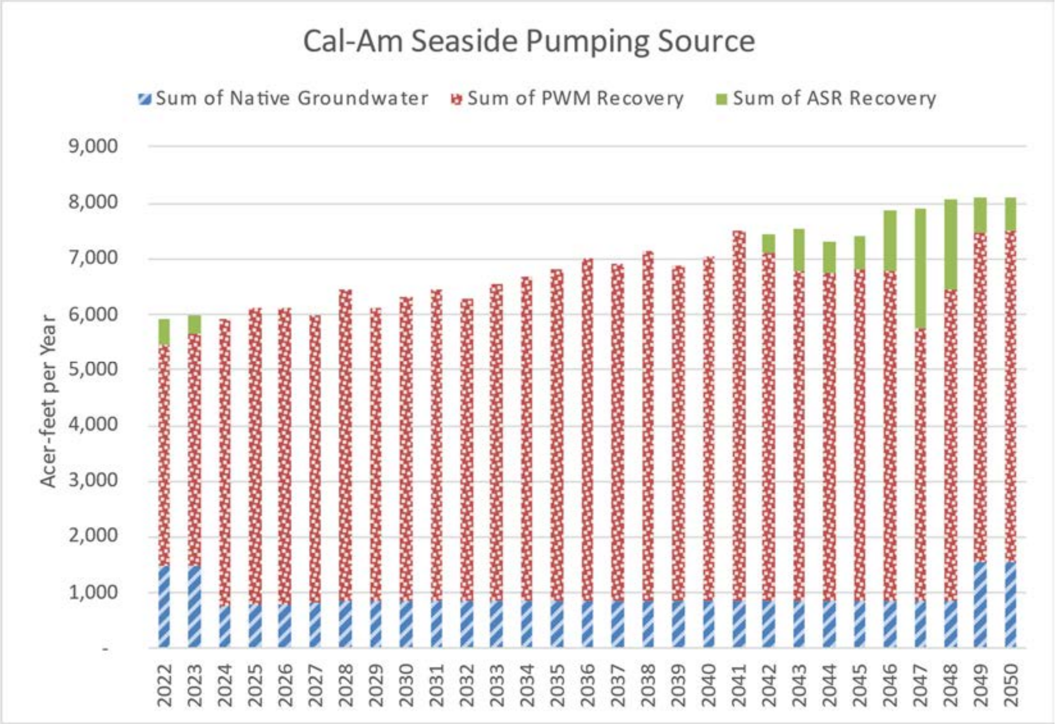

Figure 7. Projected Cal-Am Seaside Basin Pumping by Water Right

Updated Aquifer Parameters in the Vicinity of PWM Project Wells

The updated baseline model incorporates modifications made in 2019 to the model's hydrogeologic parameters in the region of the PWM project wells to incorporate data from aquifer tests conducted in the 2 existing deep injection wells DIW-1 and DIW-2, 4 MPMWD ASR wells, and the Paralta well. Data from those tests were used to adjust horizontal hydraulic conductivity, aquifer storativity, and aquifer thickness (M&A, 2019a). These updates are also now incorporated into the historical model.

Initial Conditions

Simulated groundwater levels for September 2017 from the historical model are used as the initial conditions for groundwater levels in the baseline model.

REPLENISHMENT SCENARIOS

In addition to the baseline scenario detailed above, which includes the 25-year Cal-Am 700 AFY in-lieu replenishment and the PWM Expansion project both starting in WY 2024, 4 additional scenarios were run to evaluate the impact on achieving protective elevations:

1. Providing 500 acre-feet of replenishment water per year starting in WY 2024
2. Providing 1,000 acre-feet of replenishment water per year starting in WY 2024
3. Providing 1,500 acre-feet of replenishment water per year starting in WY 2024
4. Providing 1,500 acre-feet of replenishment water per year starting in WY 2024 while also reducing pumping in the shallow Paso Robles aquifer starting that same year by assuming that Mission Memorial Park switches to irrigating with recycled water instead of groundwater, and that the City of Seaside shifts all municipal pumping from Muni #4 to a new deeper well screened only in the Santa Margarita Formation

For the additional replenishment scenarios, the water is assumed to be injected into the Santa Margarita Formation at the 6 PWM DIW wells. The total annual additional replenishment volume is assumed to be distributed throughout the year in the same monthly proportions as the PWM injection rates at each DIW well. The additional replenishment injections do not affect the projected recovery of PWM water by Cal-Am.

MODEL RESULTS

Model assumptions for the scenarios discussed above are integrated into the Seaside Basin groundwater flow model and the model is run separately for each scenario. Results of the model runs are presented in the subsections below. The first subsection discusses the ability of each simulated scenario to reach protective elevations at coastal monitoring wells. The second subsection discusses changes in simulated net inflow of water to the basin from offshore.

Groundwater Levels at Coastal Monitoring Wells

- The simulated groundwater elevations for the updated baseline and for each scenario are evaluated in the 6 monitoring wells used for establishing protective elevations against seawater intrusion (HydroMetrics LLC, 2009). These monitoring wells are: MSC Deep, MSC Shallow, PCA-West Deep, PCA-West Shallow, Sentinel Well 3 (also referred to as SBMW-3), and CDM MW-4 (Figure 11).

- Simulated water levels for the updated baseline simulation in the 3 monitoring wells screened in the deep aquifer (Santa Margarita or Purisima Formation), along with the simulated change in mean sea level are shown in Figure 8, and the same data for the 3 monitoring wells screened in the shallow aquifer (Paso Robles Formation) are shown in Figure 9.

The groundwater levels in both the deep and shallow wells rise and fall seasonally with changes in seasonal demand and climatic conditions. These seasonal fluctuations are superimposed on the longer-term water level trends related both to dry and wet cycles and to changes in pumping and aquifer recharge. The protective water level elevations were established based on modeling that assumes steady-state conditions that have no time component to them. This steady-state assumption can be thought of as considering long-term averages of water levels, rather than considering shorter-term seasonal fluctuations. For this reason, for the purposes of comparing the changes in simulated groundwater levels to the protective elevations and to compare between scenarios more easily, annually averaged simulated groundwater levels are used in the following figures and analysis rather than the highest or lowest groundwater level within a given year.

- Hydrographs of the annually averaged simulated groundwater levels at the 6 monitoring wells where protective elevations are established are shown on Figure 12 through Figure 17 for the updated baseline simulation and replenishment scenarios 1 through 3, along with the protective elevation adjusted for SLR for each well. For comparison with actual current conditions the hydrographs also show the most recent groundwater levels measured at each well from WY 2018–2021.

For all 3 replenishment scenarios, and at all the protective elevation monitoring wells, except for CDM MW-4[8], the annual average groundwater levels rise steadily starting in WY 2024 (when both the PWM Expansion and the Cal-AM replenishment repayment period begin) through WY 2033. After WY 2033 mean annual groundwater levels begin to either level off and/or drop to varying degrees in response to periods of drought. During years when the Carmel River water year is classified as Below Normal, Dry, or Critically Dry, the volumes of both ASR injection and Table 13 Carmel River diversions to meet Cal-Am Monterey District demand are greatly reduced, as previously shown on Figure 3. Similarly, drought conditions in the CSIP service area result in a marked reduction in injected PWM water (shown on Figure 4), as source water is diverted to augment the CSIP irrigation supply and also as Cal-Am recovers credited water from the "banked" drought reserve. In all the scenarios, groundwater levels drop markedly in the last several years of the simulation period (WY 2046–2050) because of the impacts of a simulated

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[8] As has been observed in previous modeling, because of its very shallow depth and position in the basin, the groundwater levels at CDM MW-4 are largely insensitive to injection in the Santa Margarita Formation.

multi-year drought period[9] during which both ASR and PWM injection are greatly reduced, Table 13 diversions are reduced and Cal-Am begins recovering banked ASR water credits to meet their system demand. The last 2 years of this period also coincides with the end of Cal-Am's repayment period, such that Cal-Am can exercise their full native groundwater rights during WY 2049–2050.

The direct correlation of decreased Carmel River diversions for ASR and decreased PWM injection during these dry years and the sharp drops in groundwater level can be clearly seen in Figure 10 which shows the annually averaged groundwater levels in each of the wells, overlain with the total replenishment from ASR injection and PWM injection during the baseline scenario, as well as the periods and annual volumes when Cal-Am is projected to recover stored ASR water.

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[9] The WY 2046–2050 drought is based on the repeated hydrology of the recent 2012–2015 drought

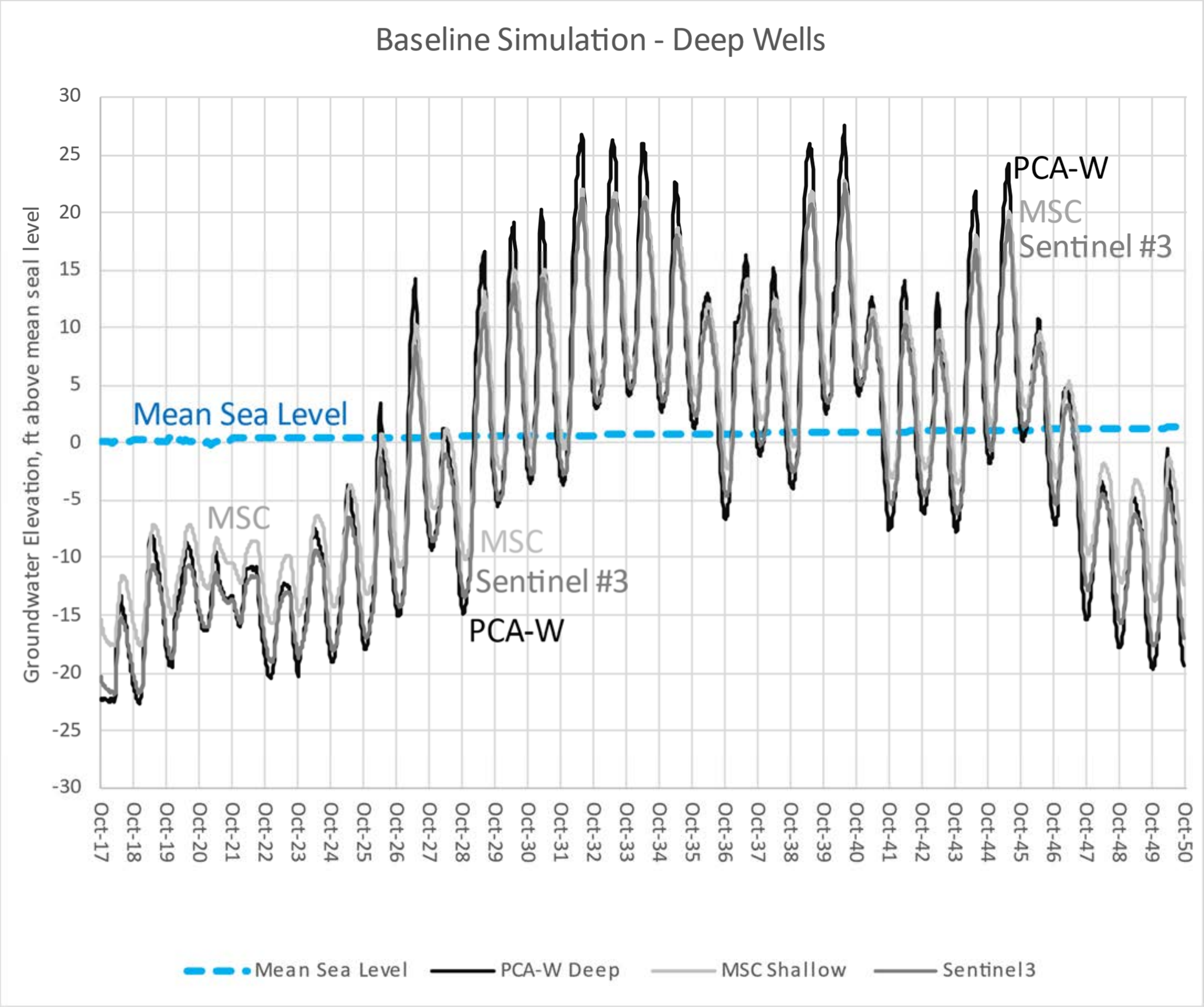


Figure 8. Simulated Groundwater Elevation in Deep Monitoring Wells for Updated Baseline Simulation

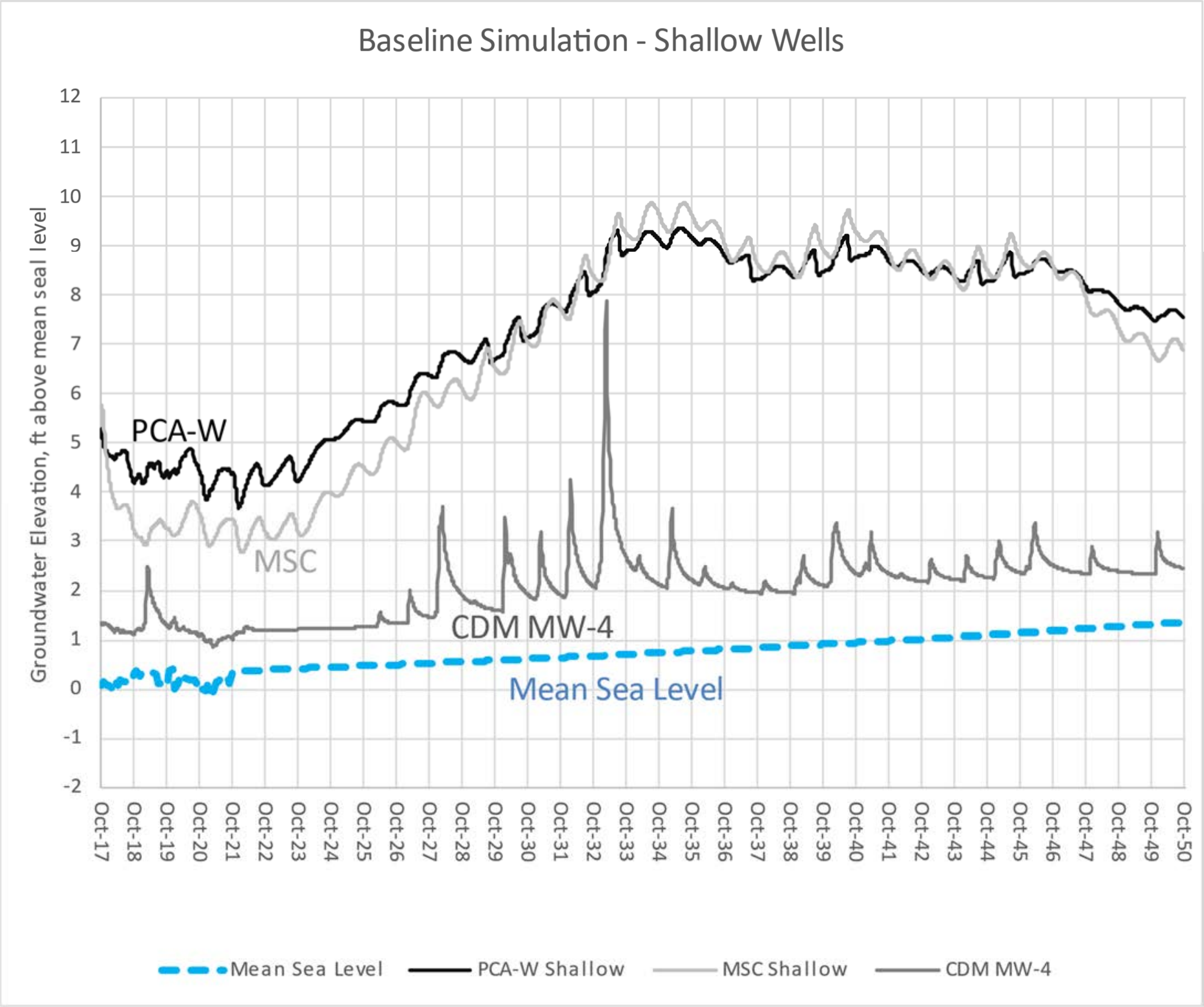
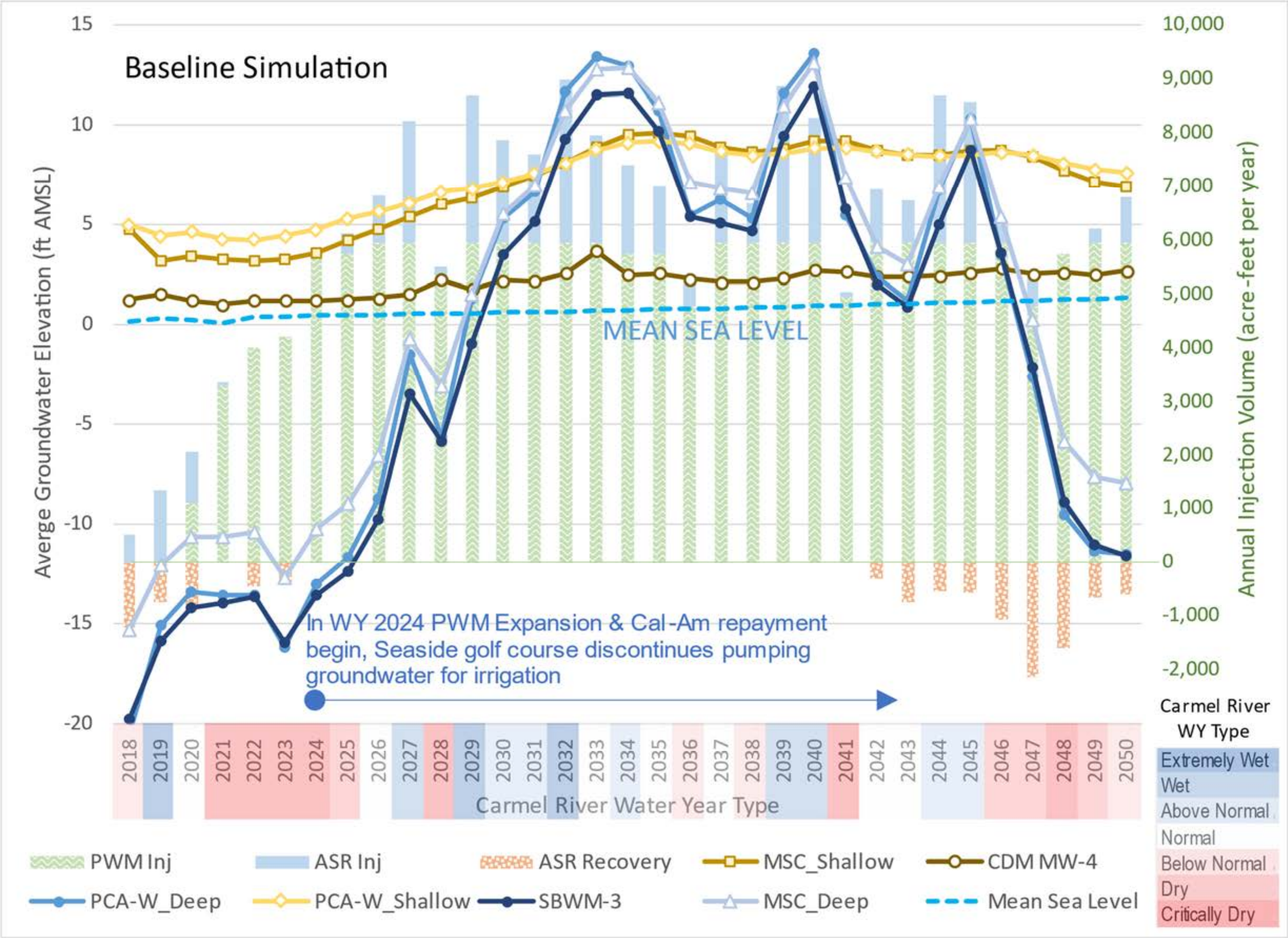


Figure 9. Simulated Groundwater Elevation in Shallow Protective Elevation Monitoring Wells for Updated Baseline Simulation



In WY 2024 PWM Expansion & Cal-Am repayment begin, Seaside golf course discontinues pumping groundwater for irrigation

Figure 10. Annually Averaged Groundwater Elevations in Protective Elevation Wells (Left Axis) and Annual PWM and ASR Injection and ASR Recovery Volumes (Right Axis) for the Baseline Scenario

Table 5 through Table 9 present summary values for a range of metrics for comparing the success of different replenishment amounts in achieving protective elevations at each of the monitoring wells. The metrics are calculated for the 25-year Cal-Am repayment period from WY 2024–2048. For each scenario, the tables identify:

- during which water year the protective elevation is first reached at the well
- the number of years it takes to reach the protective elevation
- the number of water years during which the annually averaged groundwater level is at or above the protective elevation (within ± 3/4 foot)
- the percentage of years during the 25-year period that the protective elevation is achieved or exceeded
- the maximum head difference between the initial average groundwater level at the start of the 25-year period and the groundwater levels during the replenishment period
- the increase in the maximum head difference for the scenario relative to the head difference during the baseline simulation
- the incremental change in max head difference per each additional 500 AF increase in the annual replenishment amount

The sections below will focus primarily on the results of the first 3 replenishment scenarios. The results of Scenario 4, which expands Scenario 3 by also including some redistribution of pumping away from the Paso Robles aquifer, will be addressed primarily in the context of evaluating if water levels at MSC Shallow, screened in the Paso Robles, could be further or more efficiently raised without additional injection in the Santa Margarita.

Sentinel 3 (Deep aquifer)

Groundwater levels in Sentinel 3 start off below its protective elevation but quickly rise above it in all the scenarios, as well as the baseline. The protective elevation is reached within 7 years from the start the PWM Expansion project for the baseline scenario, and incrementally sooner with each additional increase in annual replenishment volume, to as short as within 3 years for the 1,500 AFY replenishment scenario. As described above, however, the average annual groundwater levels plateau and then start fluctuating in response to periodic drought conditions and the protective elevation is not maintained for the entire 25-year period. However, even in the baseline scenario, the protective elevation is achieved during 52% (13 years) of the 25-year period, and 88% of the time for both the 1,000 AFY and 1,500 AFY replenishment scenarios. The biggest incremental increase in groundwater levels occurs between the 500 AFY scenario and the 1,000 AFY scenario.

PCA-West (Deep) and MSC (Deep)

The groundwater level response in PCA-West (Deep) and MSC (Deep) is very similar to that of Sentinel 3, with similar ranges of average groundwater level increases of between 26 and 48 feet relative to the initial levels at start of the repayment period. However, because of the higher protective elevations designated for these wells, the protective elevation is never reached in the baseline scenario, though the protective elevation is achieved in all the replenishment scenarios, albeit less frequently than in Sentinel 3. Protective elevations in both wells are achieved within 9 years for the 500 AFY scenario but are only achieved for 8%-12% of the 25-year period. Protective elevations are achieved at both wells 52%-56% of the years during the 1,000 AFY scenario, and between 68%-72% of the years for the 1,500 AFY scenario. As in the case of Sentinel 3, the biggest incremental increase in groundwater levels and in frequency of maintaining protective elevations occurs in the 1,000 AFY replenishment scenario.

PCA-West (Shallow)

The general pattern of the groundwater level response in PCA-West (Shallow) is similar to that in the deep wells, but at a lesser scale. Maximum annual average head differences are only on the order of 5–6 feet. The groundwater levels start off already above the protective elevation and remain so for the entire 25-year period, for all the scenarios including the baseline.

MSC (Shallow)

MSC Shallow also follows the same general pattern as the other wells, though with slightly greater increases in groundwater levels of between 6 and 8.5 feet. However, because of the higher protective elevation for this well, the average annual groundwater level never reaches the protective elevation for either the baseline or the 500 AFY scenario. During the 1,000 AFY scenario, the protective elevations are achieved in WY 2035 after 11 years of replenishment, but the protective elevation is only maintained for 1 year. With the 1,500 AFY scenario, the protective elevation is reached within 10 years and is achieved for 5 of the 25 years (20% of the simulation period). Scenario 4 was developed primarily to evaluate if water levels at MSC Shallow could be further raised without the need for injecting additional replenishment water into the Santa Margarita. Like Scenario 3 it consists of 1,500 AFY of replenishment to the Santa Margarita but also includes a reduction in pumping in the Paso Robles by means of assuming the conversion of landscape irrigation water at Mission Memorial Park from the current shallow groundwater source (22 AFY) to recycled water and moving City of Seaside municipal pumping (~580 AFY) from well Muni #4, which is screened across both the Lower Paso Robles and the Santa Margarita, to a new well screened only in the deeper Santa Margarita. The results of Scenario 4 show that the in-lieu replenishment resulting from reducing pumping in the Paso

Robles was able to increase the percent of years that protective elevations are achieved in MSC Shallow to 40% as compared to only 20% for Scenario 3.

CDM MW-4 (Shallow Aquifer)

The groundwater level response in CDM MW-4 is very different from all the other wells. As described in previous modeling studies the sharp spikes in groundwater level in the well are responses to shallow recharge events at the land surface. The large spike in 2032 for example, corresponds to response to a very wet year. Because of its very shallow depth and position in the Southern Coastal subarea of the basin the groundwater levels are insensitive to changes in recharge activities in the Northern Inland and Northern Coastal Santa Margarita aquifer. The groundwater levels in the well also appear to be heavily influenced by SLR, as the base groundwater level follows the SLR trend visible in the adjusted protective elevation curve. Although the simulated groundwater levels at CDM MW-4 are slightly below the protective elevation, comparison with measured groundwater levels in the well indicates that the model generally underpredicts the groundwater levels at the well by about a foot, and that the simulated groundwater levels in the well would be at or above the protective elevation for the entire 25-year period.

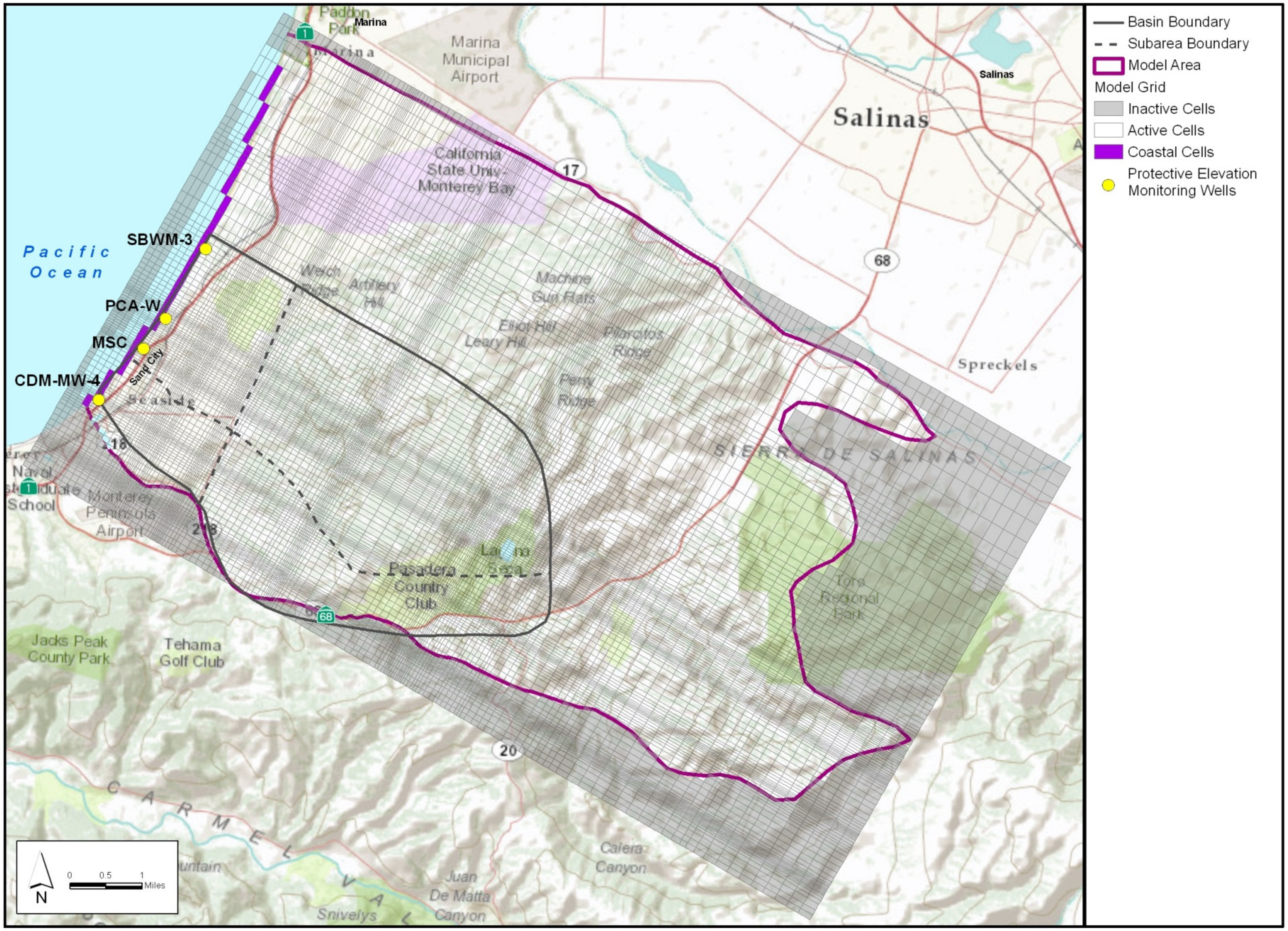


Figure 11. Location of Protective Elevation Monitoring Wells

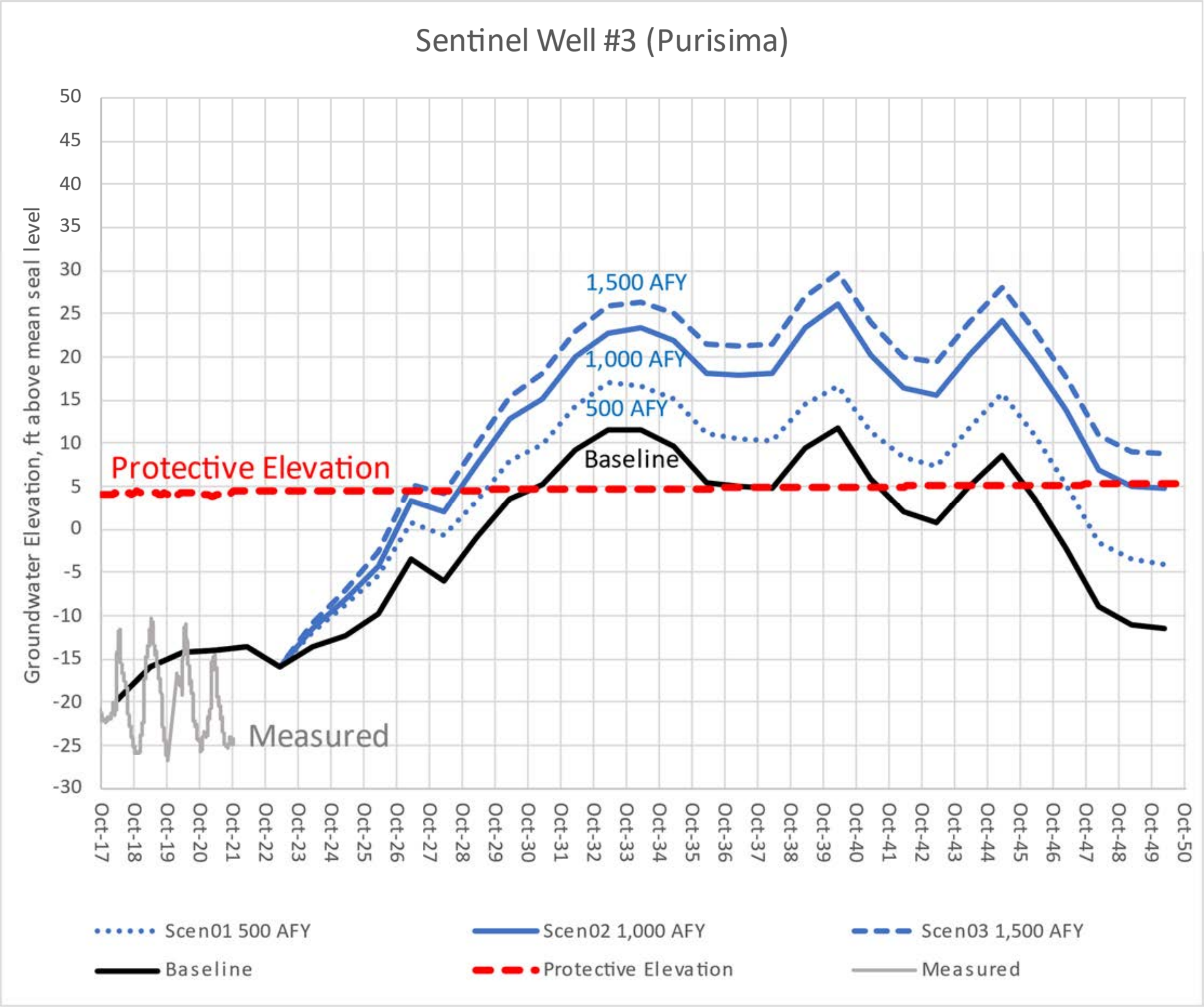


Figure 12. Simulated Groundwater Elevations and Protective Elevation at Sentinel Well #3

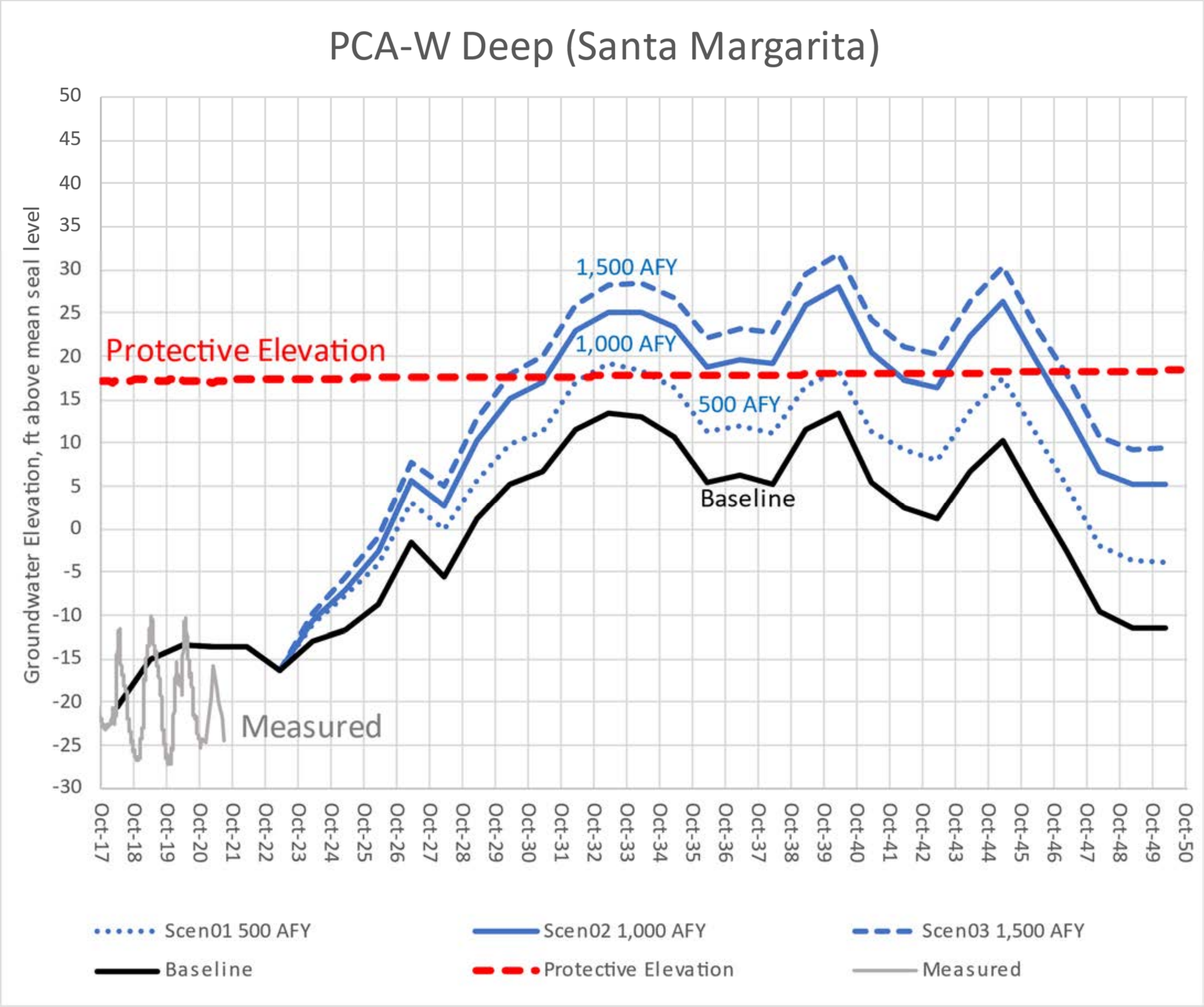


Figure 13. Annualy Averaged Simulated Groundwater Elevations and Protective Elevation at PCA-West Deep

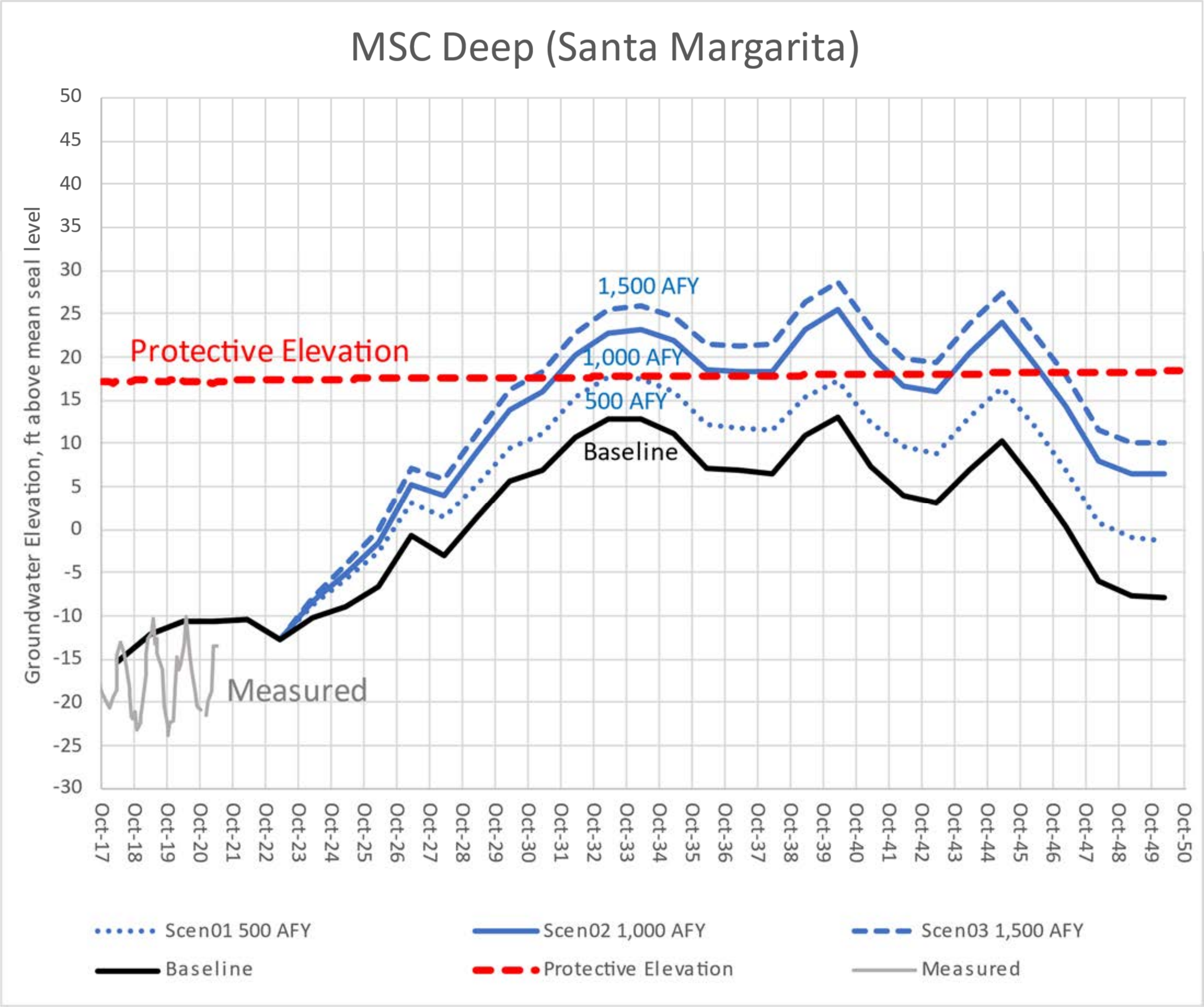


Figure 14. Annualy Averaged Simulated Groundwater Elevations and Protective Elevation at MSC Deep

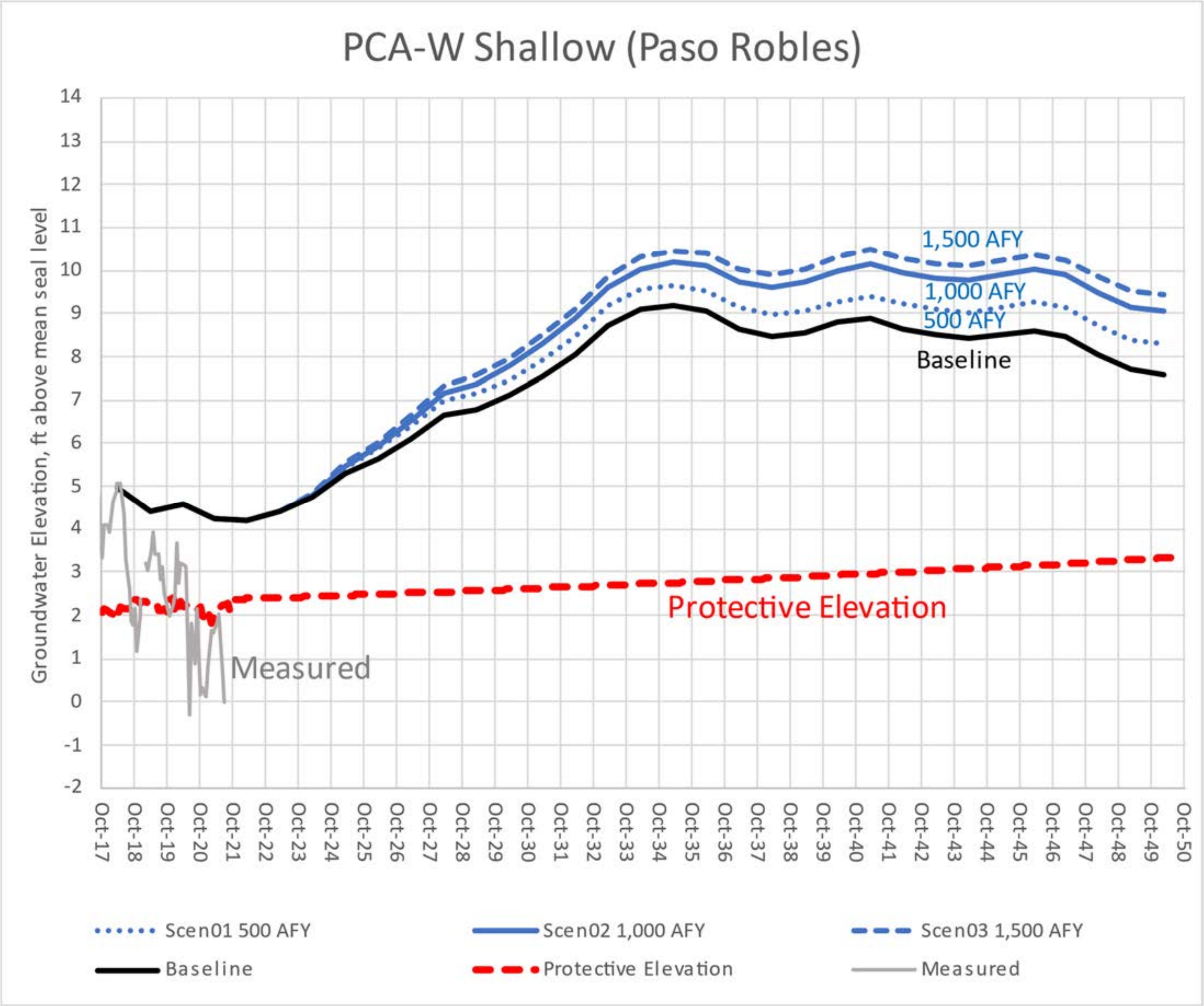


Figure 15. Annualy Averaged Simulated Groundwater Elevations and Protective Elevation at PCA-West Shallow

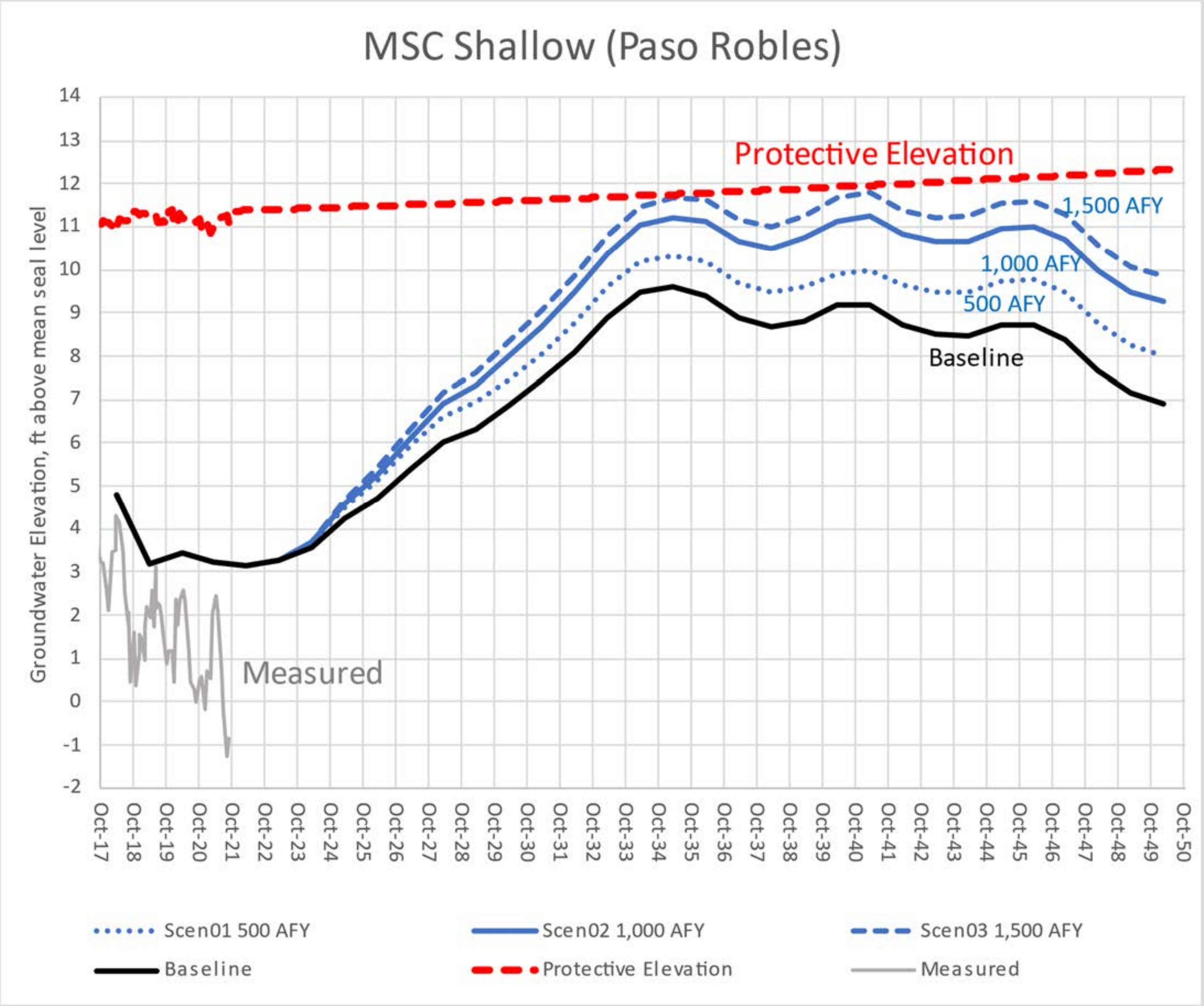


Figure 16. Annualy Averaged Simulated Groundwater Elevations and Protective Elevation at MSC Shallow

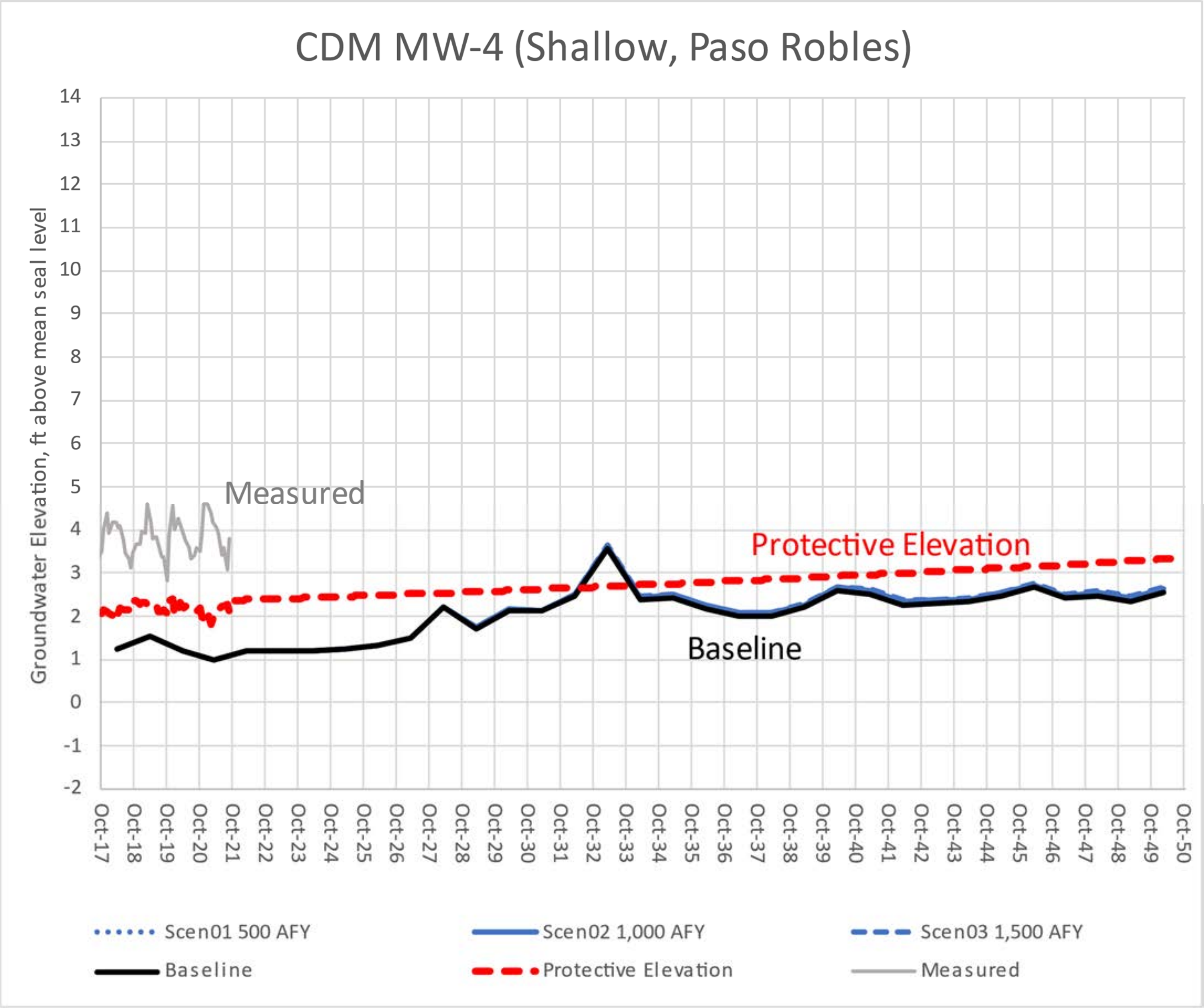


Figure 17. Annualy Averaged Simulated Groundwater Elevations and Protective Elevation at CDM MW-4

Table 5. Number of Years from WY2024 for Average Groundwater Level to Reach Protective Elevation and Year Reached

Scenario	Sentinel 3 (Deep)	PCA-W (Deep)	MSC (Deep)	PCA-W (Shallow)	MSC (Shallow)	CDM MW-4 (Shallow)
Baseline	7 (2031)	not reached	not reached	already reached	not reached	already reached
1) 500 AFY	6 (2030)	9 (2033)	9 (2033)	already reached	not reached	already reached
2) 1,000 AFY	5 (2029)	7 (2031)	8 (2032)	already reached	11* (2035)	already reached
3) 1,500 AFY	3 (2027)	6 (2030)	6 (2030)	already reached	10 (2034)	already reached
4) 1,500 AFY + Q Redist.	3 (2027)	7 (2031)	7 (2031)	already reached	9 (2033)	already reached

*within 0.75 foot

Table 6. Percent and Number of Years from WY2024-2048 that Average Groundwater Level Achieves Protective Elevation

Scenario	Sentinel 3 (Deep)	PCA-W (Deep)	MSC (Deep)	PCA-W (Shallow)	MSC (Shallow)	CDM MW-4 (Shallow)
Baseline	52% (13)	not reached	not reached	100% (25)	not reached	100% (25)
1) 500 AFY	72% (18)	12% (3)	8% (2)	100% (25)	not reached	100% (25)
2) 1,000 AFY	88% (22)	56% (14)	52% (13)	100% (25)	4%* (1)	100% (25)
3) 1,500 AFY	88% (22)	72% (18)	68% (17)	100% (25)	20% (5)	100% (25)
4) 1,500 AFY + Q Redist.	84% (21)	64% (16)	64% (16)	100% (25)	40% (10)	100% (25)

*within 0.75 foot

Table 7. Maximum Average Groundwater Level Increase from WY2024 to WY2048 in Feet

Scenario	Sentinel 3 (Deep)	PCA-W (Deep)	MSC (Deep)	PCA-W (Shallow)	MSC (Shallow)	CDM MW-4 (Shallow)
	Maximum Average Groundwater Elevation Increase, Feet					
Baseline	28	30	26	4.8	6.3	2.4
1) 500 AFY	33	35	30	5.2	7.1	2.4
2) 1,000 AFY	42	44	38	5.8	8.0	2.4
3) 1,500 AFY	46	48	41	6.0	8.5	2.4
4) 1,500 AFY + Q Redist.	44	46	40	6.3	8.7	2.5

Table 8. Maximum Average Groundwater Level Increase over Baseline Scenario

Scenario	Sentinel 3 (Deep)	PCA-W (Deep)	MSC (Deep)	PCA-W (Shallow)	MSC (Shallow)	CDM MW-4 (Shallow)
	Maximum Average Groundwater Elevation Increase, Feet					
Baseline	-	-	-	-	-	-
1) 500 AFY	5	6	5	0.4	0.8	0
2) 1,000 AFY	14	15	13	1.0	1.7	0
3) 1,500 AFY	18	18	16	1.2	2.2	0
4) 1,500 AFY + Q Redist.	16	16	14	1.5	2.4	0.1

Table 9. Increase in Average Groundwater Level per Each Additional 500 AFY of Replenishment

Scenario	Sentinel 3 (Deep)	PCA-W (Deep)	MSC (Deep)	PCA-W (Shallow)	MSC (Shallow)	CDM MW-4 (Shallow)
	Average Groundwater Elevation Increase, Feet					
Baseline	-	-	-	-	-	-
1) 500 AFY	5	6	5	0.4	0.8	0
2) 1,000 AFY	9	9	8	0.6	0.9	0
3) 1,500 AFY	4	4	3	0.2	0.5	0
4) 1,500 AFY + Q Redist.*	2	2	2	0.5	0.7	0.1

*For Scenario 4, values are compared to Scenario 2

Change in Net Inflow to the Basin from Offshore

In addition to evaluating how the replenishment scenarios succeed in raising groundwater levels to protective elevations, the water budget analysis of the model results in Figure 18 shows the net annual inflow of groundwater into the Seaside Basin from the offshore portions of the aquifer for the updated baseline simulation and Scenario 2 (1,000 AFY replenishment). Positive values represent net inflow of groundwater moving from offshore across the coastline into the basin. Negative values represent net outflow of water from the onshore aquifers into the offshore region. The solid dark blue line represents the net inflow into the Northern Coastal subarea of the basin for the baseline scenario, and it shows that prior to the start of the repayment period in WY2024 there is a net inflow of water from the offshore areas into the basin along the coastal boundary associated with the multi-year drought period. While not necessarily implying seawater intrusion, because there may be freshwater stored offshore in the aquifer, this represents a condition that would increase the potential for sea water intrusion. In WY2024 when both the PWM Expansion and the Cal-Am repayment period begins, groundwater levels in the basin begin to rise and simulated flows change to reflect a net outflow of groundwater from the basin in the offshore direction. The net outflow reaches a peak in WY2033 following a series of wet and extremely wet years (identified by dates with blue shading), and then begins to decrease in magnitude and hovers around a constant level before starting to move back in the direction decreased flow to the offshore areas as the simulation passes through the final multi-year drought. This trend is maintained in Scenario 2 as shown by the dashed blue line, but with the injection of the additional 1,000 AFY of replenishment water creates an additional buffer of offshore outflow. Increased offshore groundwater flow minimizes the potential for seawater intrusion. The orange line represents the Southern Coastal subarea, which as would be expected appears to be largely insensitive to the replenishment projects in the Northern subareas. This analysis suggests that even if protective elevations are not maintained 100% of the time because of periods of drought, the basin would still maintain a net outflow to the ocean during the 1,000 AFY replenishment scenario. This analysis considers the total net flow over the entire coastal boundary of each coastal subarea and for all the layers combined, however, and so may not show differences in trends that could be spatially localized along the coast or at different depths. The model results could be further broken out in the future to look at potential variability by depth and location along the coastline.

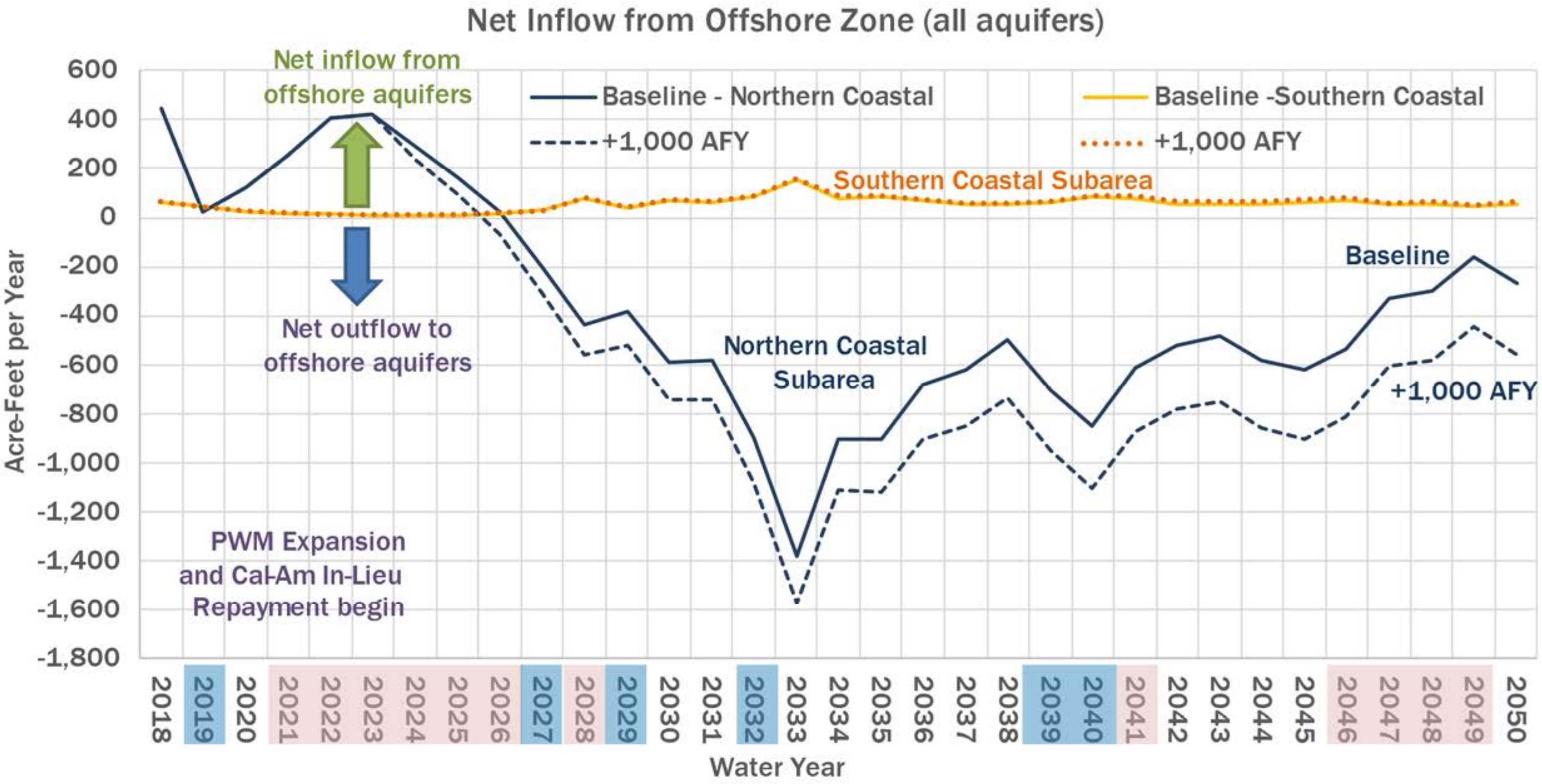


Figure 18. Net Groundwater Inflow to the Seaside Basin from Offshore for the Baseline and 1,000 AFY of Replenishment Water Scenario)

Conclusions & Considerations

1. Under the 1,000 AFY replenishment scenario, protective groundwater elevations are reached, at least initially, in all protective elevation wells within 11 years. Average annual groundwater levels remain above protective elevations for over 50% of the water years during the 25-year replenishment period, except at MSC Shallow, at which the protective elevation is reached only once, in WY 2035. After this year, groundwater levels stop increasing and slowly decline due to the drought years in the projected hydrologic cycles that reduces the availability of water for ASR and PWM injection and increases recovery of ASR and PWM water in storage.

2. A water budget analysis of the net inflow of water from offshore areas into the basin indicates the 1,000 AFY scenario maintains and enhances the reversal of flow from a net inflow of water from offshore to a net outflow of water to offshore, even when protective elevations are not being met at all the wells. The additional replenishment water adds an additional buffer to maintain strong net offshore outflows even in drought years.

3. Increasing replenishment to 1,500 AFY results in only slight improvement at MSC Shallow, and only marginal increases in protective elevation metrics at the other protective elevation wells. Because both the other shallow aquifer protective elevation monitoring wells, (PCA-W Shallow and CDM MW-4), start off already meeting protective elevations, this suggests that there is limited benefit in trying to continue to raise the groundwater levels at MSC Shallow by increasing injection in the deeper Santa Margarita Formation. Rather, as illustrated by the results of Scenario 4, other alternatives could be considered and evaluated such as redistributing pumping from wells screened completely or partially in the Paso Robles, increased use of recycled water for irrigation purposes, such as at Mission Memorial Park, and simulating additional recharge directly to the Paso Robles aquifer.

4. The original 2013 replenishment modeling (Hydrometrics WRI, 2013) did not explicitly account for impacts of drought on the availability of Carmel River water for ASR injection and other Cal-Am use. Instead, it used a constant average injection and recovery rate each year rather having it fluctuate with hydrologic cycles. The results of the updated model scenarios that couple ASR and PWM operations to the hydrology illustrate the significant impact that multi-year droughts, and even just below normal periods, can have on the availability of water for ASR and PWM recharge and on the timing of reaching and maintaining protective elevations.

5. Simulated groundwater levels rose quickly in response to replenishment during periods of Normal and Above Normal water years following the prolonged drought at the start of the

simulated replenishment period, suggesting that levels would rebound again after the drought at the end of the simulation period. However, this rapid rebound is also a function of the assumption that Cal-Am will extract ASR water as its last source of supply, after exhausting available water from their native groundwater rights and PWM water. This assumption has the consequence that a very large portion of the injected ASR water is left in storage in the Basin.

6. The 2009 modeling that established the protective elevations assumed steady-state conditions that have no time component to them, and essentially assumes that sufficient time has passed that conditions have equilibrated to fixed state. That modeling did not directly consider and does not inform or suggest for how long a period groundwater levels can stay below protective elevations without greatly increasing the risk of sea water intrusion. This is something that could be evaluated with additional modeling.
7. In addition to the constant 1,000 AFY replenishment, additional “booster” injections could be considered following protracted drought periods to make up the lost water.
8. The modeling simulation period ends just as Cal-Am’s 25-year repayment period ends. It is not clear what impact the end of the repayment period will have on water levels.
9. It is also not clear how climate change and the potential increased frequency and duration of extreme weather events will impact the ability to maintain protective elevations. Additional modeling of projected future climate scenarios could be used to evaluate this.

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Table 10. Projected PWM Expansion Project Water Injection Schedule and CSIP Storage and Delivery Operation

Water Year	Simulated Historical Climate Water Year	Salinas Station Precipitation (% of Average)	Drought Year Criteria (<75% of Average)	Injection Delivery Schedule	Injection Volume (acre-feet)	Annual Recycled Water to CSIP (acre-feet)	Drought Reserve Change (acre-feet)	Cumulative Drought Reserve (acre-feet)	Injection Delivery Schedule (acre-feet)												
									Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
2023	1989	69%	Drought		4,100	-	-	0													
2024	1990	64%	Drought	G	5,750	200	-	0	607	610	641	625	569	621	348	349	337	348	353	343	5,750
2025	1991	73%	Drought	G	5,750	200	-	0	607	610	641	625	569	621	348	349	337	348	353	343	5,750
2026	1992	83%		A	5,950	-	200	200	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2027	1993	125%		A	5,950	-	200	400	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2028	1994	66%	Drought	E	5,350	600	(400)	0	607	610	641	625	569	621	282	281	271	280	285	278	5,350
2029	1995	130%		A	5,950	-	200	200	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2030	1996	103%		A	5,950	-	200	400	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2031	1997	131%		A	5,950	-	200	600	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2032	1998	247%		A	5,950	-	200	800	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2033	1999	104%		A	5,950	-	200	1000	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2034	2000	116%		B	5,750	-	-	1000	573	577	607	591	538	587	381	383	369	382	387	376	5,750
2035	2001	102%		B	5,750	-	-	1000	573	577	607	591	538	587	381	383	369	382	387	376	5,750
2036	2002	55%	Drought	H	4,750	1,000	(1,000)	0	573	577	607	591	538	587	217	214	205	213	218	212	4,750
2037	2003	80%		A	5,950	-	200	200	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2038	2004	84%		A	5,950	-	200	400	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2039	2005	159%		A	5,950	-	200	600	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2040	2006	125%		A	5,950	-	200	800	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2041	2007	74%	Drought	C	4,950	1,000	(800)	0	607	610	641	625	569	621	217	214	205	213	218	212	4,950
2042	2008	79%		A	5,950	-	200	200	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2043	2009	89%		A	5,950	-	200	400	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2044	2010	141%		A	5,950	-	200	600	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2045	2011	125%		A	5,950	-	200	800	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2046	2012	81%		A	5,950	-	200	1000	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2047	2013	74%	Drought	H	4,750	1,000	(1,000)	0	573	577	607	591	538	587	217	214	205	213	218	212	4,750
2048	2014	54%	Drought	G	5,750	200	-	0	607	610	641	625	569	621	348	349	337	348	353	343	5,750
2049	2015	89%		A	5,950	-	200	200	607	610	641	625	569	621	381	383	369	382	387	376	5,950
2050	2016	117%		A	5,950	-	200	400	607	610	641	625	569	621	381	383	369	382	387	376	5,950

Prior Water Year Drought Reserve (acre-feet)	Purified Water Delivery Schedule for Injection (acre-feet[AF])			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
NA	Normal/Wet Building Reserve	wet/normal year	A	607	610	641	625	569	621	381	383	369	382	387	376	5,950
1000	Normal/Wet Full Reserve	wet/normal year	B	573	577	607	591	538	587	381	383	369	382	387	376	5,750
800	before drought reserve complete	drought year (1,000 AF to CSIP)	C	607	610	641	625	569	621	217	214	205	213	218	212	4,950
600	before drought reserve complete	drought year (800 AF to CSIP)	D	607	610	641	625	569	621	250	248	238	247	251	245	5,150
400	before drought reserve complete	drought year (600 AF to CSIP)	E	607	610	641	625	569	621	282	281	271	280	285	278	5,350
200	before drought reserve complete	drought year (400 AF to CSIP)	F	607	610	641	625	569	621	315	315	304	314	319	310	5,550
0	before drought reserve complete	drought year (200 AF to CSIP)	G	607	610	641	625	569	621	348	349	337	348	353	343	5,750
1000	Drought Full Reserve	drought year (1,000 AF to CSIP)	H	573	577	607	591	538	587	217	214	205	213	218	212	4,750

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BOARD DRAFT TECHNICAL MEMORANDUM

DATE:	August 5, 2022	**PROJECT #:** 9150.0507
TO:	Bob Jaques, Technical Program Manager, Seaside Basin Watermaster	
FROM:	Pascual Benito, Ph.D.	
PROJECT:	Seaside Basin Watermaster	
SUBJECT:	Hybrid Water Budget Analyses of Basin Replenishment Options & Alternate Assumptions	

INTRODUCTION

This technical memorandum (TM) documents:

1) Results of a water budget analysis of the January 2022 Baseline and 1,000-AFY Replenishment scenario simulations (M&A, 2022a; 2022b).

2) Development of an alternative set of baseline supply and demand assumptions based primarily on Cal-Am's Urban Water Management Plan (UWMP), with some additional assumptions provided by Cal-Am and the City of Seaside.

3) Development and results of a hybrid water-budget approach to evaluate the impact the alternate set of future supply and demand assumptions has on the volume of replenishment water that would be needed to reach protective elevations in the coastal monitoring wells.

The hybrid water-budget analysis leverages information derived from recent replenishment modeling documented in the Technical Memorandum titled "Updated Modeling of Seaside Basin Replenishment Options", dated January 28, 2022 (M&A, 2022a). That study used the Seaside Watermaster groundwater model to estimate how much replenishment water would be needed to achieve protective elevations in the Watermaster coastal protective elevation wells. These well locations are shown on Figure 1.

The water budget analysis provides an overview of the net inflows and outflows to the Shallow and Deep Aquifers in the Northern Coastal Subarea[1], which are then used to evaluate the impacts of different demand and supply assumptions on the estimated amounts of replenishment water needed to achieve the same degree of groundwater level increases in the coastal protective elevation wells already simulated in the Baseline which are shown on Figure 2.

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[1] The Northern Coastal Subarea is the subarea in which all but one (CDM-MW4) of the six protective elevation monitoring wells are located, is the only subarea that sees notable response to the simulated replenishment operations and is the subarea at greatest risk from seawater intrusion.

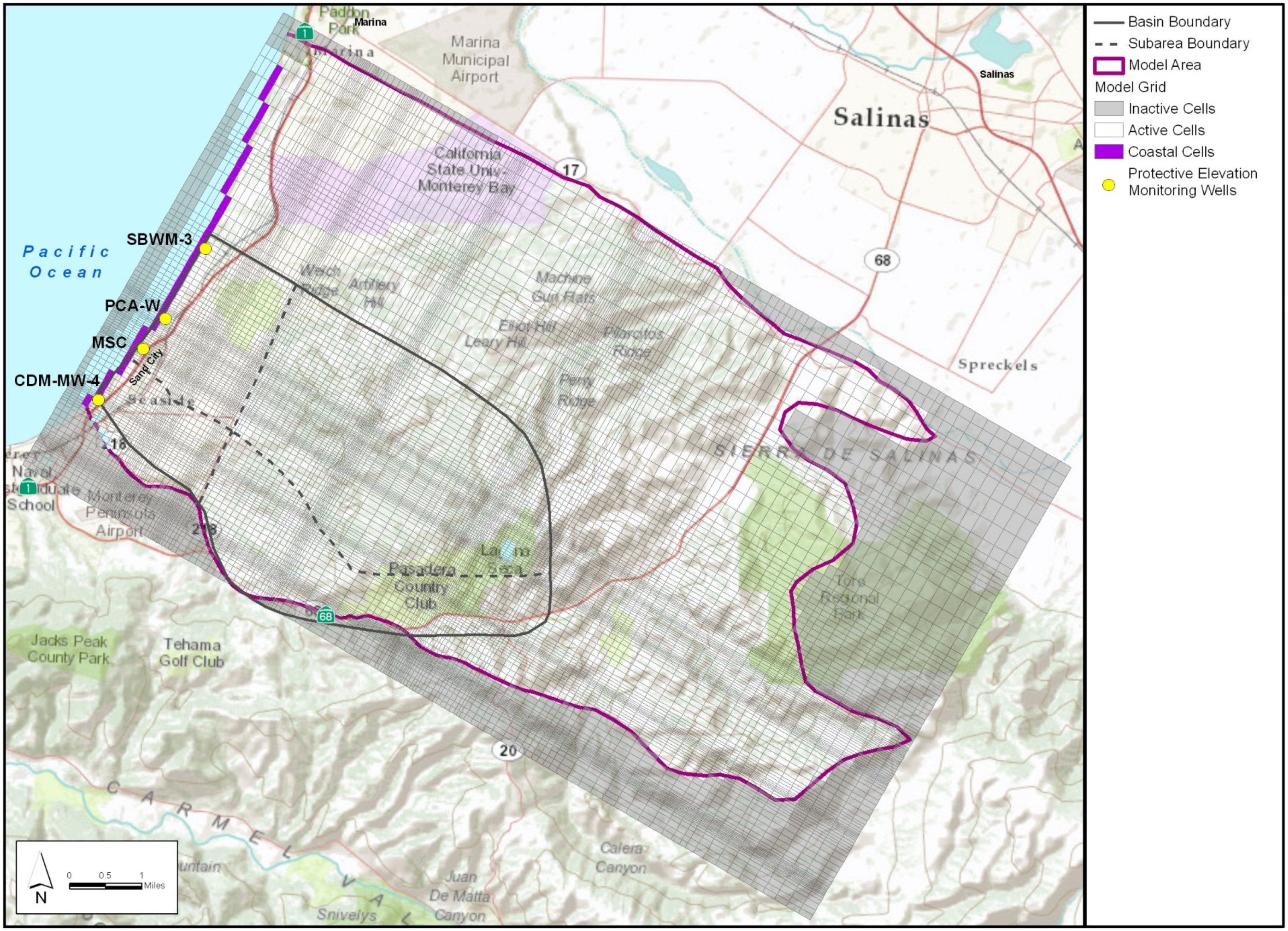

Figure 1. Location of Protective Elevation Monitoring Wells

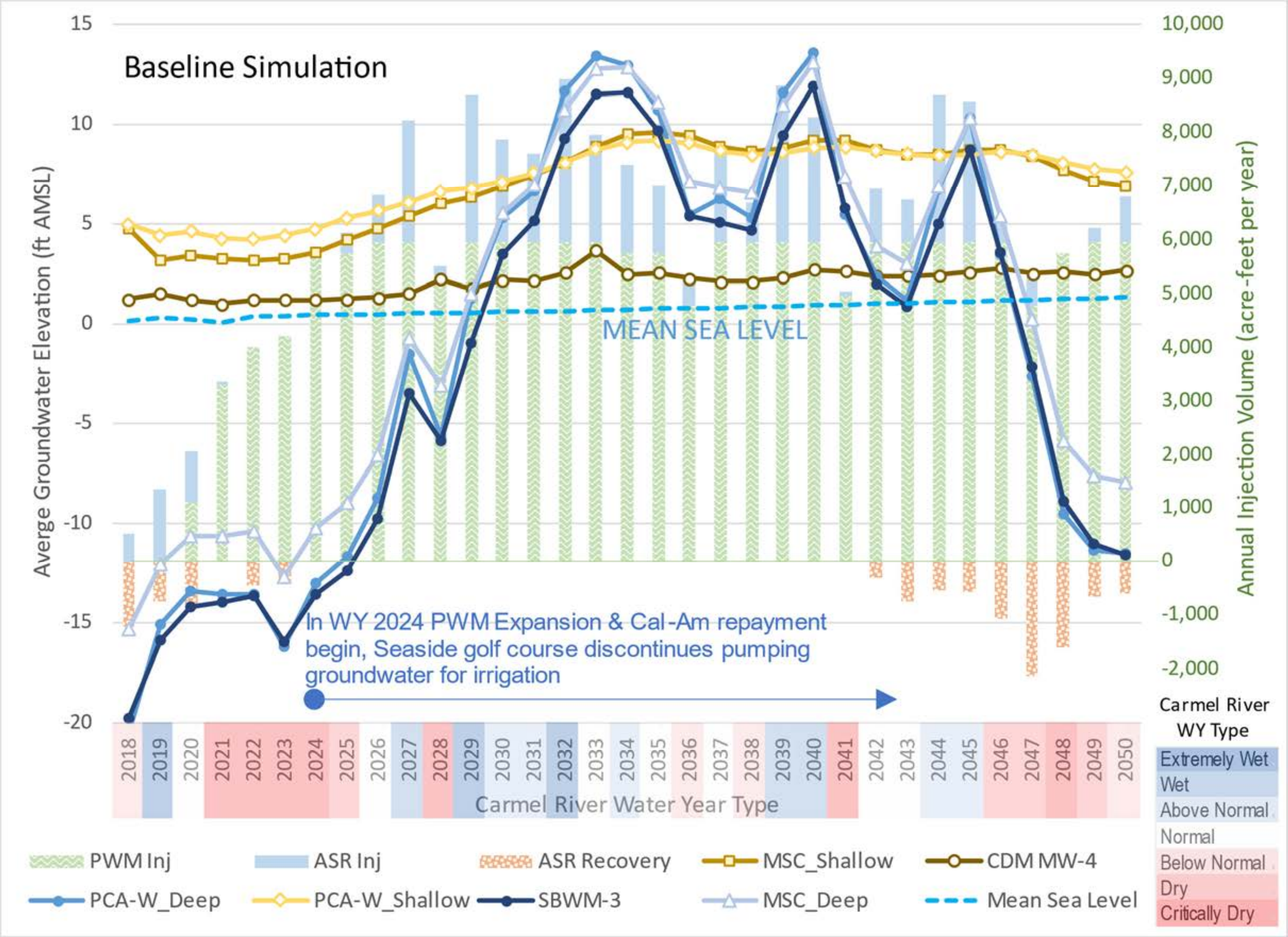

Figure 2. Annually Averaged Groundwater Elevations in Protective Elevation Wells (Left Axis) and Annual PWM and ASR Injection and ASR Recovery Volumes (Right Axis) for the Baseline Simulation

For context a summary of the main assumptions and setup of the Baseline model simulation are provided below.

ASSUMPTIONS FOR BASELINE SIMULATION

In this TM the term “Baseline simulation” refers to the simulation of future conditions assuming only operation of currently planned projects with no additional replenishment added. Baseline simulation represents recent conditions from water year (WY) 2018 through 2021 based on actual measured pumping, injection, and hydrology; and projected potential future conditions from WY 2022 through WY 2050 based on MPWMD’s projected pumping, currently planned projects, and a repeated historical hydrology record. The Baseline simulation hydrology (rainfall, recharge, and streamflow) is illustrated on Figure 3.

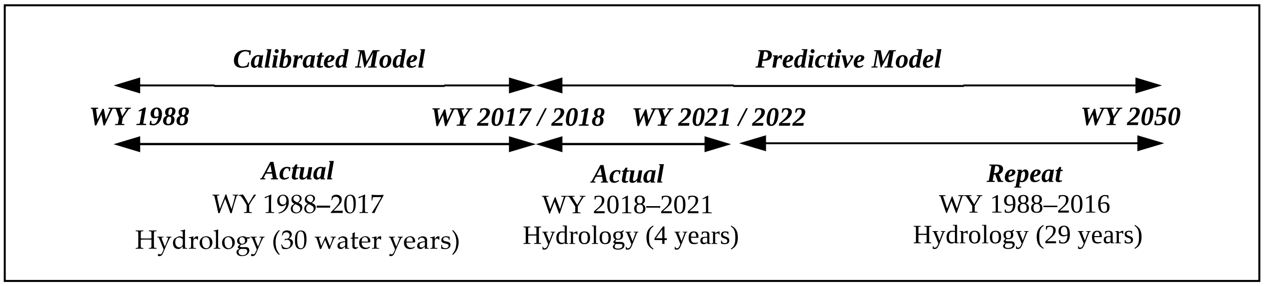

Figure 3: Repetition of Hydrology for Predictive Model

The Baseline simulation includes:

- A new extended hydrology period with 2 multi-year drought periods
- Projected mean sea level rise of up to 1.3 feet by 2050
- Seaside Aquifer Storage and Recovery (ASR) injection of Carmel River water with monthly volumes based on the cycled hydrology and a 20 AFD diversion rate that assumes the proposed upgrades to the Cal-Am Carmel Valley wellfield[2], are completed by WY 2024

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[2] A 20 AFD diversion rate is based on assumption that needed improvements to the Carmel Valley well field are made (J. Lear, personal communic. 1/21/2022). Else it would be somewhere between 12-15 AFD based on historical diversion data. Plans to improve and expand the Carmel Valley well field, including a new well on the former Rancho Canada Golf Course are outlined the California American Water 2021, 2022, and 2023 General Rate Case submitted to CPUC: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M425/K808/425808218.PDF

- Cal-Am's 25 year 700 AFY overpumping payback replenishment program begins in WY 2024
- Pure Water Monterey (PWM) Expansion project (tied to the new hydrology) begins deliveries in WY 2024 and delivers an annual average of 5,750 AFY
- Other planned projects including the City of Seaside's replacement of groundwater with recycled water for golf course irrigation and the construction of the Security National Guaranty (SNG) and Campus Town developments in the City of Seaside occur on the dates shown in Table 1
- No other sources of replenishment water are provided to the basin
- The assumption that no proposed Groundwater Sustainability Plan (GSP) projects are implemented in the neighboring Monterey and 180/400 Foot Subbasins, and that groundwater levels along the northern boundary of the Model (located close to the boundary between those two subbasins) remain unchanged as currently represented in the Model boundary conditions.

Table 1 provides a listing of the simulated Carmel River Water Year types, data sources, and major project events. The color coding of the Carmel River Water Year Type classification (blues for wet and above normal water years, white for normal years, and reds for below normal and dry years), is used throughout the figures to identify water year types. A complete description of the baseline simulation assumptions and output is provided in the recent replenishment modeling and seawater intrusion travel time modeling technical memorandums (M&A, 2022a and 2022b).

Table 1. Annual Summary of Updated Baseline Simulation Water Year Types, Data Sources, and Major Project Events

Sim Year	Water Year	Carmel River WY Type	Hydrology Source WY	Pumping & Injection	Cal-Am Repayment Period	Projects Timeline
1	2018	Below Normal	Actual	Actual		
2	2019	Extremely Wet	Actual	Actual		
3	2020	Normal	Actual	Actual		**PWM Base Project Begins (3,500 AFY)**
4	2021	Critically Dry	Actual	Actual		**Cal-Am ceases pumping in Laguna Seca**
5	2022	Critically Dry	1988	Projected		**PWM ramps up to 4,100 AFY**
6	2023	Critically Dry	1989	Projected		**Seaside Golf Courses shift to PWM water**, Campus Town starts up (100 AFY)
7	2024	Critically Dry	1990	Projected	1	**PWM Expansion Begins (5,750 AFY)**, Campus Town ramp up (130 AFY)
8	2025	Dry	1991	Projected	2	SNG starts up (25 AFY), Campus Town ramps up (215 AFY)
9	2026	Normal	1992	Projected	3	SNG ramps up (30 AFY), Campus Town full capacity (301 AFY)
10	2027	Wet	1993	Projected	4	SNG ramps up (50 AFY)
11	2028	Critically Dry	1994	Projected	5	SNG full Capacity (70 AFY)
12	2029	Extremely Wet	1995	Projected	6	
13	2030	Above Normal	1996	Projected	7	
14	2031	Above Normal	1997	Projected	8	
15	2032	Extremely Wet	1998	Projected	9	
16	2033	Normal	1999	Projected	10	
17	2034	Above Normal	2000	Projected	11	
18	2035	Normal	2001	Projected	12	
19	2036	Below Normal	2002	Projected	13	
20	2037	Normal	2003	Projected	14	
21	2038	Below Normal	2004	Projected	15	
22	2039	Wet	2005	Projected	16	
23	2040	Wet	2006	Projected	17	
24	2041	Critically Dry	2007	Projected	18	
25	2042	Normal	2008	Projected	19	
26	2043	Normal	2009	Projected	20	
27	2044	Above Normal	2010	Projected	21	
28	2045	Above Normal	2011	Projected	22	
29	2046	Dry	2012	Projected	23	
30	2047	Dry	2013	Projected	24	
31	2048	Critically Dry	2014	Projected	25	**Potential Final Year of Cal-Am Repayment Period**
32	2049	Dry	2015	Projected		
33	2050	Below Normal	2016	Projected		

TASK 1. WATER BUDGET ANALYSIS OF BASELINE SCENARIO AND 1,000-AFY REPLENISHMENT SCENARIO

The water budget analysis is focused on the portion of the Seaside subbasin delineated by the Northern Coastal Subarea and a smaller triangular wedge of the adjacent Northern Inland Subarea that includes the entire footprint of the Pure Water Monterey wells and its proposed Expansion injection facilities and backflush percolation ponds. This water budget zone is shaded red on Figure 4. For simplicity, this combined zone is referred to hereafter simply as the Northern Coastal Subarea. The map also shows the other water budget zones defining the adjacent subareas of the Seaside subbasin, the neighboring Monterey Subbasin, and the Offshore region. The Northern Coastal Subarea water budget zone was further divided vertically based on the model layering[3] into the Aromas Sands & Older Dune Deposits (model layer 1), the Shallow Aquifer (consisting of model layers 2-4 representing the Upper, Middle, and Lower Paso Robles Formations), and the Deep Aquifer (consisting of model layer 5, representing the Santa Margarita and Purisima Formation). The groundwater model results of the Baseline simulation and the 1,000-AFY Replenishment scenario were processed to calculate and track all the different inflows and outflows of water to and from each water balance zone over the entire simulation period. The monthly inflows and outflows to each zone were then aggregated over each water year for presentation. The results for each scenario are presented below.

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[3] Layer 1 = Aromas Sands & Older Dune Deposits; Layer 2 = Upper Paso Robles, Layer 3 = Middle Paso Robles; Layer 4 = Lower Paso Robles; Layer 5 = Santa Margarita & Purisima

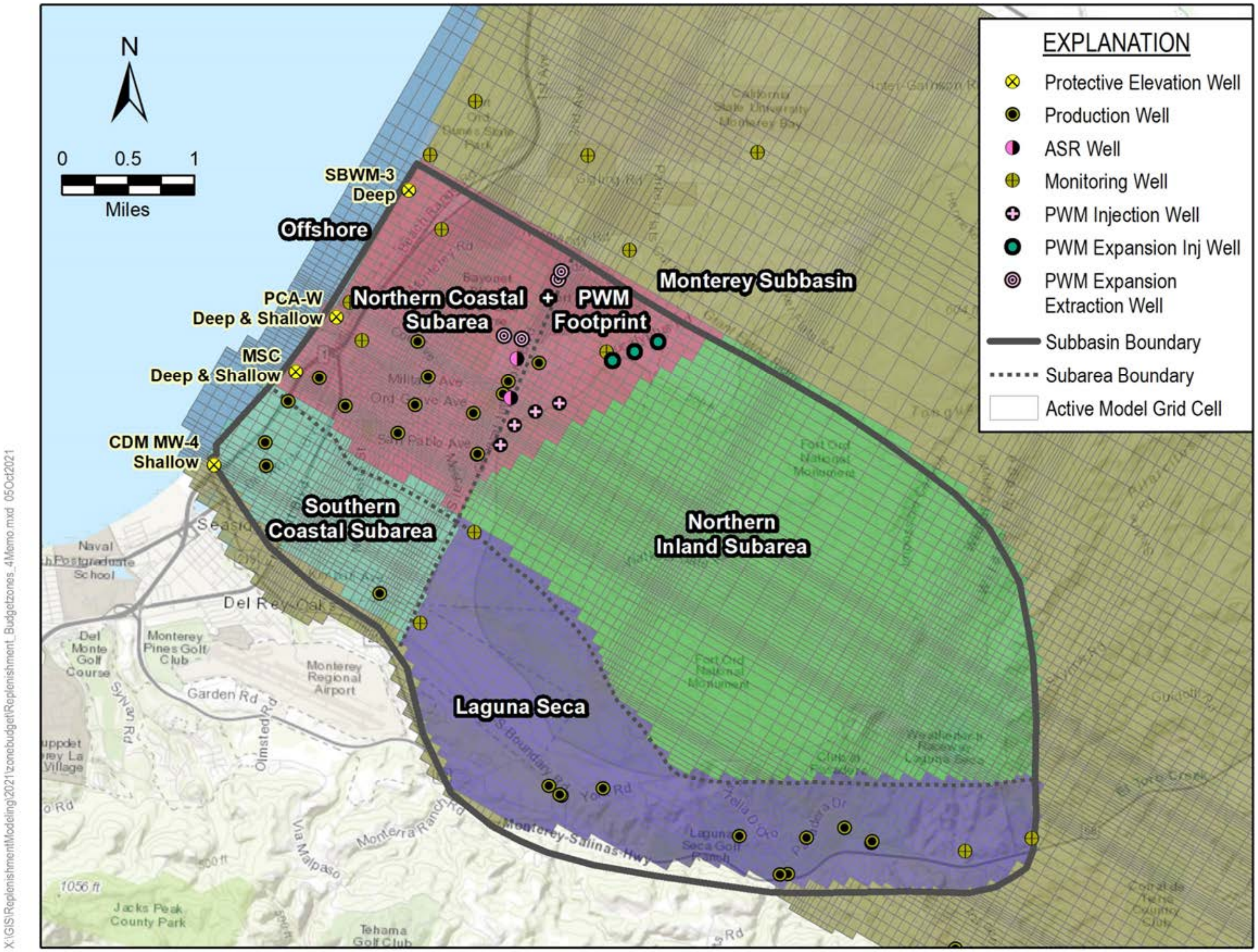

Figure 4. Map of Water Budget Zones used for Water Budget Analysis

Baseline Scenario

Unconfined Aquifers Water Budget in the Northern Coastal Subarea

Note: In this Technical Memorandum the term "Shallow Aquifer" refers to the Paso Robles Formation, and the term "Unconfined Aquifers" refers to both the overlying Aromas Sands & Older Dune Deposits and the Paso Robles Formation combined.

Net Flows

Figure 5 show the net flows to and from the combined Unconfined Aquifers, in the Northern Coastal Subarea. Figure 6 and Figure 7 show these same net flows broken out for the Aromas Sands & Older Dune Deposits and the Shallow Aquifer (Paso Robles) individually[4].

The flow components include:

- Percolation from infiltration of rainfall, irrigation return flow, and system losses
- Vadose Zone Recharge from PWM vadose zone wells and percolation ponds
- Pumping from extraction wells
- Flow to/from the Northern Inland Subarea upgradient of the PWM project wells
- Flow to/from the Southern Coastal Subarea
- Flow to/from the Offshore regions of the Shallow Aquifer
- Flow to/from the underlying Deep Aquifer
- Flow to/from the neighboring Monterey Subbasin

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[4] The purpose for including the water budget of the two unconfined aquifers combined is primarily to allow for a comparison between the relative contribution of recharge from the PWM vadose recharge and recharge from direct percolation of rainfall and system losses. In the model both of these sources of recharge are applied through a single combined monthly recharge value applied at the top of the water table. The aquifer formation to which the recharge is applied changes spatially and temporally throughout the simulation as the water table moves up and down. They are not tracked separately in the model water budget output, so for simplicity of accounting, the PWM contribution is broken out separately only for the combined unconfined aquifers.

For each flow component, net flow is calculated as the difference between total inflow and total outflow, such that positive values represent net inflows to the aquifers and negative values represent net outflows. The direction of flow to/from adjacent areas or aquifers is dependent on the relative head gradient between the aquifers and the adjacent areas or aquifers, and so can change flow directions as groundwater levels change. The black line on each figure shows the total net inflow, which represents the difference between all net inflows and all net outflows. Positive values of total net inflow indicate net inflows are greater than net outflows for that water year, and negative values indicate that net outflows were bigger.

Net Inflows

Generally, the largest inflows to the Unconfined Aquifers are from rainfall dominated percolation (percolation of rainfall, irrigation return flows and transmission system losses) and inflows from the upgradient Northern Inland Subarea, followed by recharge from the PWM vadose zone wells and backflush percolation ponds, and a very small amount of inflow from the Southern Coastal Subarea. At the beginning of the simulation, when groundwater levels have not substantially risen yet and there is a multiyear period of drought conditions, there is also net inflow from the Offshore region of the aquifer. Later in the simulation, during a few periods when groundwater levels in the Deep Aquifer have risen higher than groundwater levels in Shallow Aquifer, there is also a small amount of upward inflow from the underlying Deep Aquifer.

The magnitude and temporal trend of recharge from percolation and inflows from the upgradient Northern Inland Subarea is strongly correlated with annual precipitation in the basin, as can be seen on the graph of total simulated annual rainfall on Figure 8. The peaks and troughs in annual rainfall correspond with peaks and troughs of percolation and inflow from the Northern Inland Subarea, with the peak recharge occurring in WY 2033 which has 38 inches of total rainfall[5], resulting in 3,281 AF of deep percolation and 1,456 AF of inflow from the Northern Inland Subarea that year. The figure also shows the simulated median annual rainfall for comparison with a “normal” year. The peaks and troughs in annual rainfall for the basin do not always coincide with the Carmel River Water Year type classification color scale at the bottom top of the chart which is based on classification of streamflow in the Carmel River rather than on rainfall in the Seaside Basin.

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[5] The hydrology of simulated WY 2033 is based on the historical hydrology from WY 1999.

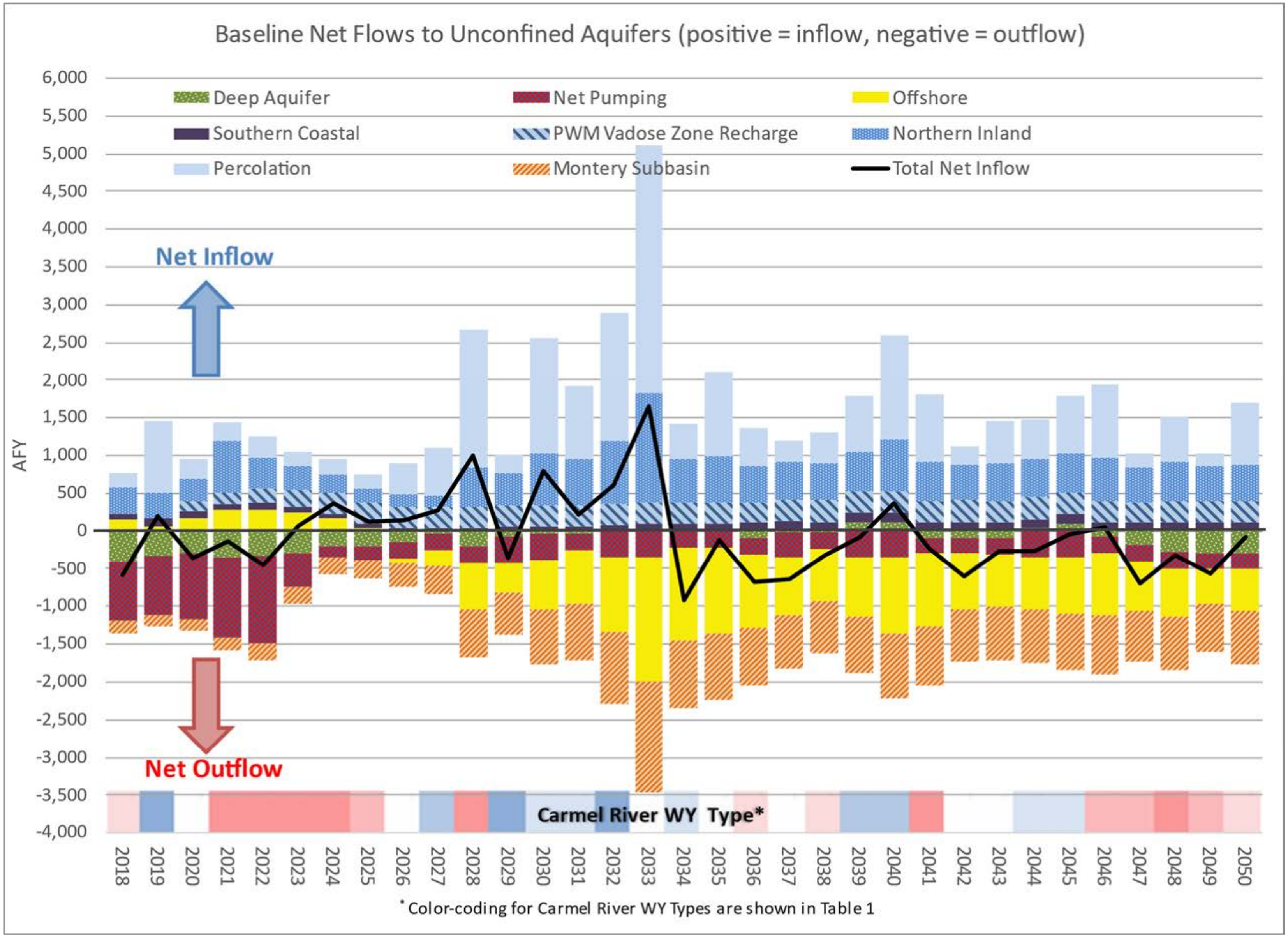


Figure 5. Net Flows to/from the Combined Unconfined Aquifers (Aromas Sands & Older Dune Deposits and Paso Robles) for Baseline Scenario

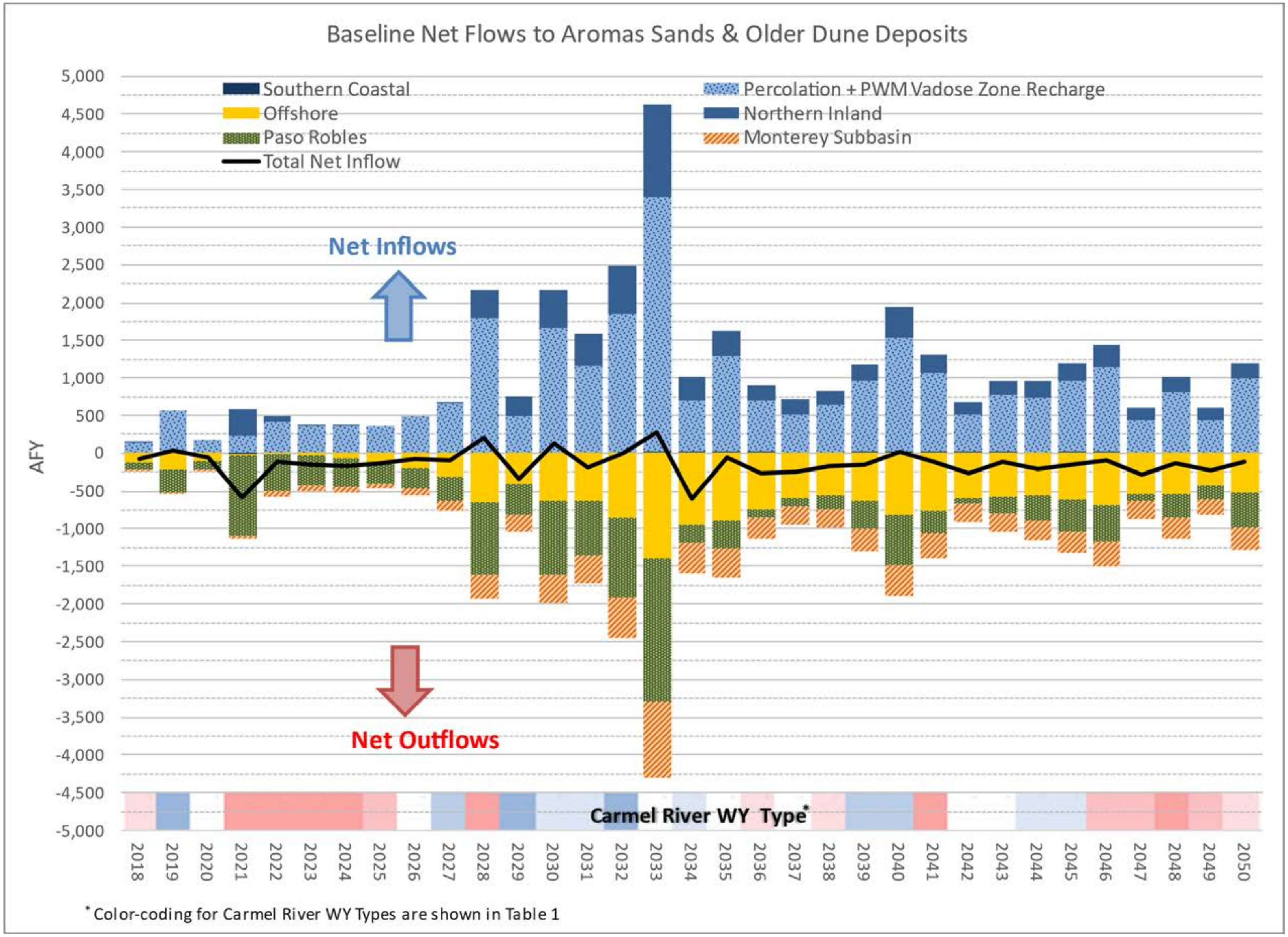
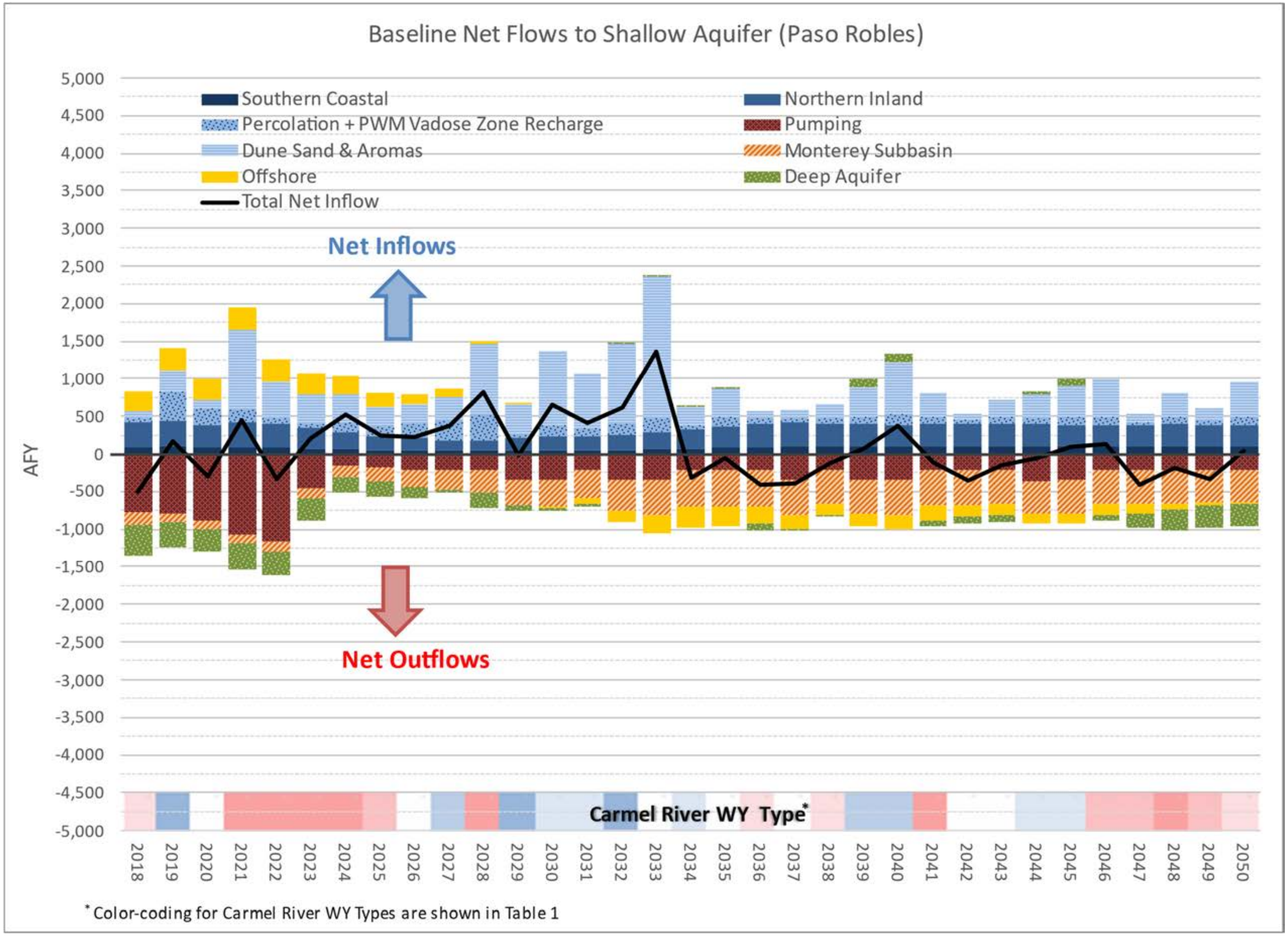


Figure 6. Net Flows to/from the Aromas Sands & Older Dune Deposits for Baseline Scenario



* Color-coding for Carmel River WY Types are shown in Table 1

Figure 7. Net Flows to/from the Shallow Aquifer (Paso Robles) for Baseline Scenario

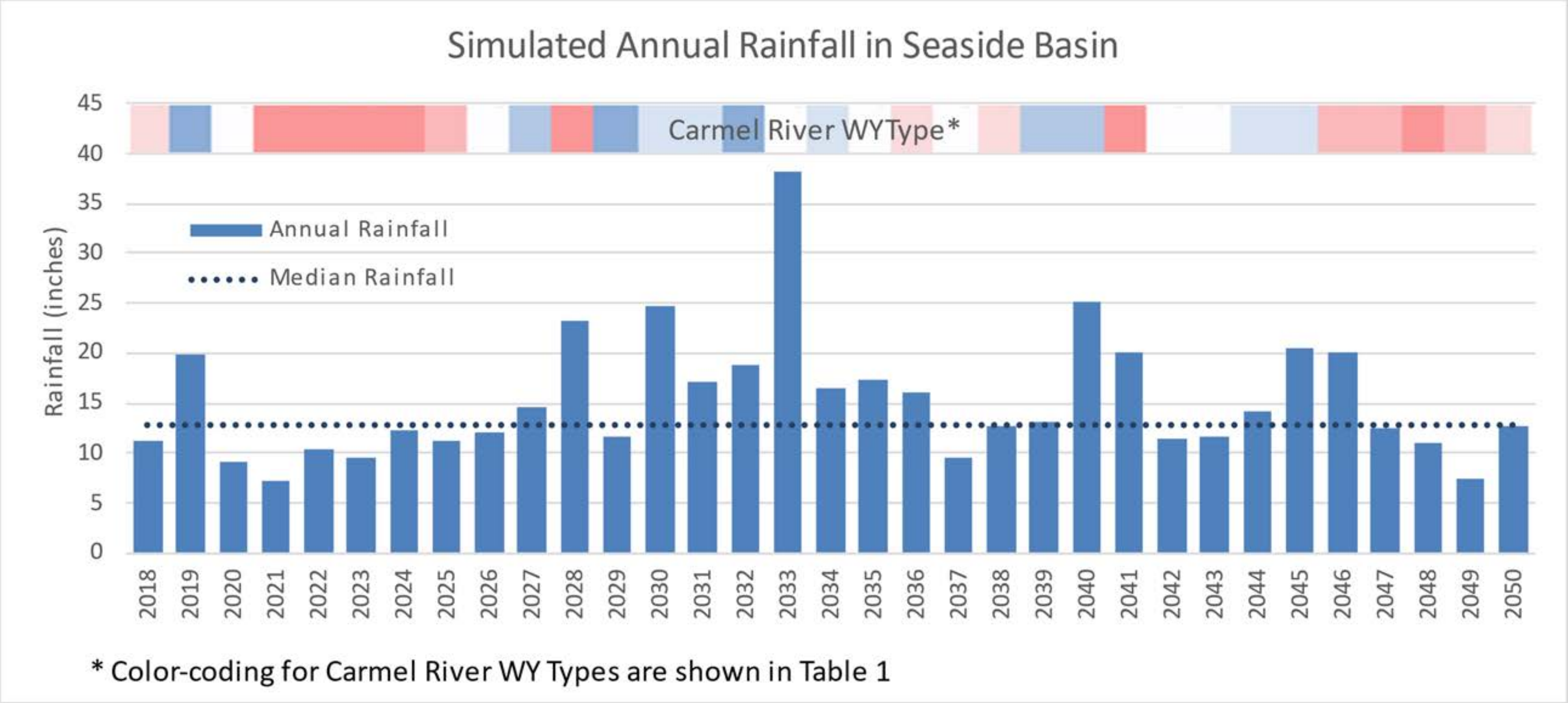


Figure 8. Simulated Annual Rainfall and Median (50th Percentile) Rainfall

Net Outflows

The large magnitude of the net outflows from the Aromas Sands & Older Dune Deposits shown on Figure 6 shows that almost all the net inflows flow either down into the Shallow Aquifer, to the offshore regions, and to adjacent Monterey Subbasin. The large head dependent downward flows from the Aromas Sands and Older Dune Deposits to the Shallow Aquifer during periods when groundwater levels are lower in the Shallow Aquifer illustrates that downward flow of intruded seawater from the Aromas Sands and Dune Deposits would pose a potential pathway for seawater intrusion into the Shallow Aquifer.

Figure 7 shows that the first four years of the simulation represents current drought conditions, where pumping for municipal and irrigation use makes up the largest outflow component from the Shallow Aquifer (780-1,200 AFY), followed by leakage to the underlying Deep Aquifer (300-400 AFY), and a smaller amount of outflow to the Monterey Subbasin (~150 AFY). During this period outflows from the Shallow Aquifer exceed inflows, with the exception of WY 2019 which had very high rainfall, and groundwater levels remained low. A large reduction in irrigation pumping occurs in 2023 when the City of Seaside is assumed to begin irrigation of their golf courses with recycled water. A further reduction in Shallow Aquifer pumping occurs in WY 2024 as the PWM Expansion project comes online and Cal-Am pumping shifts from smaller capacity production wells screened in the Shallow Aquifer to new higher capacity extraction wells in the Deep Aquifer.

Change in Storage

Groundwater levels can only rise when total inflows exceed total outflows. Conversely, when outflows exceed inflows, groundwater levels will drop. In the parlance of water budgets, when inflows exceed outflows and groundwater levels increase, we refer to this as an increase in storage. When inflows are less than outflows and groundwater levels drop, we call this a reduction in storage. A positive net change in storage occurs when net inflows exceed net outflows and a negative net change in storage occurs when outflows exceed inflows. Figure 9 shows the net change of water in storage (orange columns and left-hand vertical axis) and the cumulative net change in storage (blue line, right-hand vertical axis) in the Shallow Aquifer. These changes in storage (orange columns in plot) can be conceptualized as deposits and withdrawals to/from the storage savings account. The cumulative change in storage (blue line) represents the running total, or account balance, of the net changes of groundwater in storage (relative to the beginning of the simulation). The shape of the cumulative net change in storage curve closely follows the trends of the simulated groundwater levels in the shallow monitoring wells shown on the hydrographs in Figure 2.

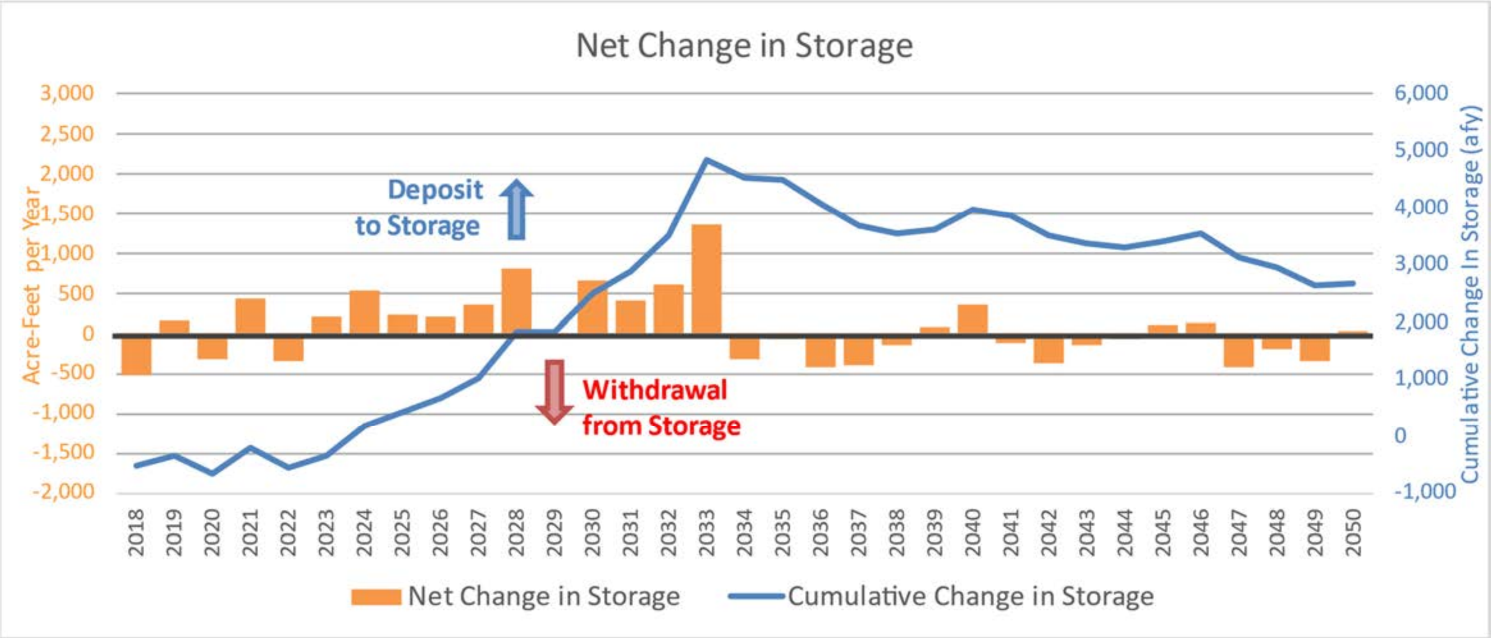


Figure 9. Net Change in Storage (Net Inflow – Net Outflows) and Cumulative Net Change in Storage in the Shallow Aquifer for the Baseline Scenario

Deep Aquifer Water Budget in the Northern Coastal Subarea

Note: In this Technical Memorandum the term "Deep Aquifer" refers to the Santa Margarita and Purisima Formations.

Net Flows

Figure 10 shows net flows to and from the Deep Aquifer in the Northern Coastal Subarea. The flow components include:

- Net pumping (injection or extraction) from wells in the Deep Aquifer is represented as the difference between the total injection of PWM and ASR water and the total extraction of native groundwater and recovery of PWM and ASR water. When total annual injections exceed the total extractions net pumping is positive and represents a net inflow. When total annual extractions exceed the total injections net pumping is negative and represents a net outflow.
- Flow to/from the Northern Inland Subarea upgradient of the PWM project area
- Flow to/from the Southern Coastal Subarea
- Flow to/from the Offshore regions of the Shallow Aquifer
- Flow to/from the overlying Shallow Aquifer
- Flow to/from the neighboring Monterey Subbasin

For each of the flow components, net flows are calculated as the difference between total inflows and total outflows, such that positive values represent net inflows to the Deep Aquifer and negative values represent net outflows.

The largest net flows to and from the Deep Aquifer are from injection and extraction at wells, respectively. There are also significant "cross-flows" to and from the overlying Shallow Aquifer, the adjacent Southern Coastal Subarea, Northern Inland Subarea, the neighboring Monterey Subbasin, and the Offshore regions of the Deep Aquifer. Positive values represent net inflows to the Northern Coastal Subarea and negative values represent net outflows. After net injection the largest net inflow is from the upgradient Northern Coastal Subarea. After net outflows from extraction, the next largest outflow of water from the Northern Coastal Subarea is outflow to the neighboring Monterey Subbasin.

The magnitude and direction of these "cross-flows" depends on the relative hydraulic gradients between the Deep Aquifer and the adjacent areas. There is a net flow from the overlying Shallow

Aquifer to the Deep Aquifer during periods when the groundwater levels in the Deep Aquifer are lower than the groundwater levels in the Shallow Aquifer.

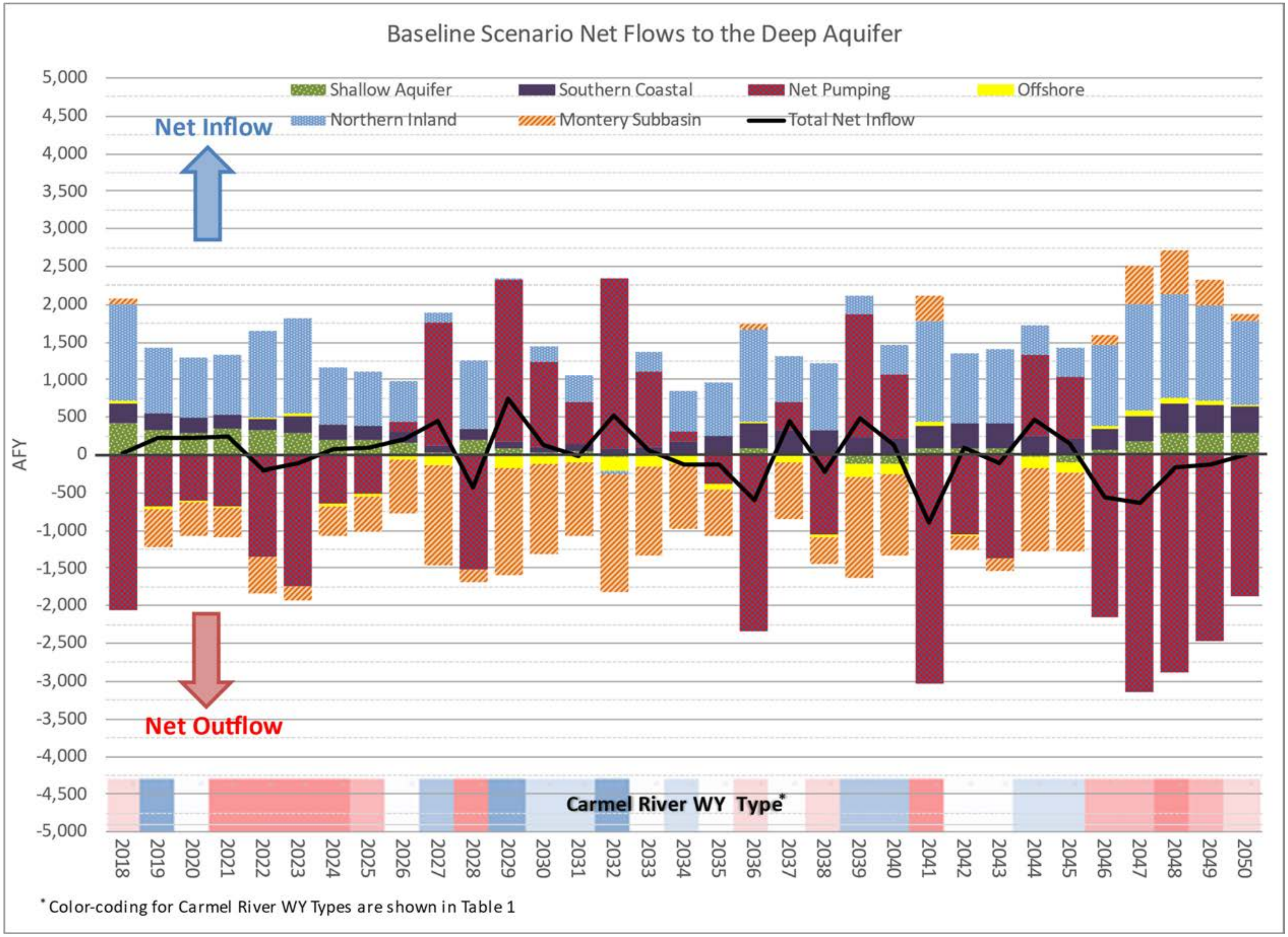


Figure 10. Net Flows to/from the Deep Aquifer (Positive = Inflow, Negative = Outflow) for the Baseline Scenario

The simulated head dependent downward flows from the Shallow Aquifer to the Deep Aquifer during periods when groundwater levels are lower in the Deep Aquifer illustrate that downward flow of intruded seawater from the Shallow Aquifer would pose a potential pathway for seawater intrusion into the Deep Aquifer. The relatively small magnitude of net flows from the Offshore region to and from the Deep Aquifer relative to the larger magnitude of net inflow from the overlying Shallow Aquifer are also consistent with the modeled conceptualization that the Deep Aquifer is not well connected to the ocean.

Net Pumping

Figure 11 shows only the annual net pumping (injection – extraction) in the Deep Aquifer. Positive values represent years when the total injection of PWM and ASR water to the Deep Aquifer exceeds the total extraction of native groundwater and recovered PWM and ASR water. On an annual basis the net injection and extraction form the largest net volumetric inflows and outflows to the Deep Aquifer.

For example, WY 2032 (classed as an Extremely Wet Carmel River water year type) saw the highest simulated annual net injection of close to 2,300 AF. This net injection volume represented approximately 3,000 AF of ASR injection plus almost 6,000 AF of PWM Expansion injection[6] for total injection of 9,000 AF, with a combined total of City of Seaside and Cal-Am native groundwater extraction and Cal-Am PWM recovery volume of close to 6,700 AF. However, the record high net injection does not mean that the entire volume of net-injection went into storage to raise groundwater levels. Rather, only about 500 AF went into storage and raised groundwater levels. 1,800 AF of water flowed out of the subarea, with 1,600 AF to the Monterey Subbasin and 200 AF flowing offshore. This means only about 23% of the net inflow contributed to increasing groundwater levels in the Northern Coastal Subarea. By contrast, WY 2029 was also an Extremely Wet Water Year with a net injection also close to 2,300 AF, but in this case 740 AF went into storage increasing groundwater levels, with only 1,600 AF flowing out, representing a higher recharge efficiency of 32%. This difference can be attributed to the fact that in WY 2029, groundwater levels are lower than in WY 2032, and so there was less of a hydraulic gradient driving outflows to the offshore region and towards the Monterey Subbasin.

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[6] The PWM Expansion project will inject an average of 5,750 AFY, but the injection volume will be lower in drought years when water goes to CSIP, and higher in other wet years when the drought reserve is being built up again, with a maximum injection of up to 5,950 AFY.

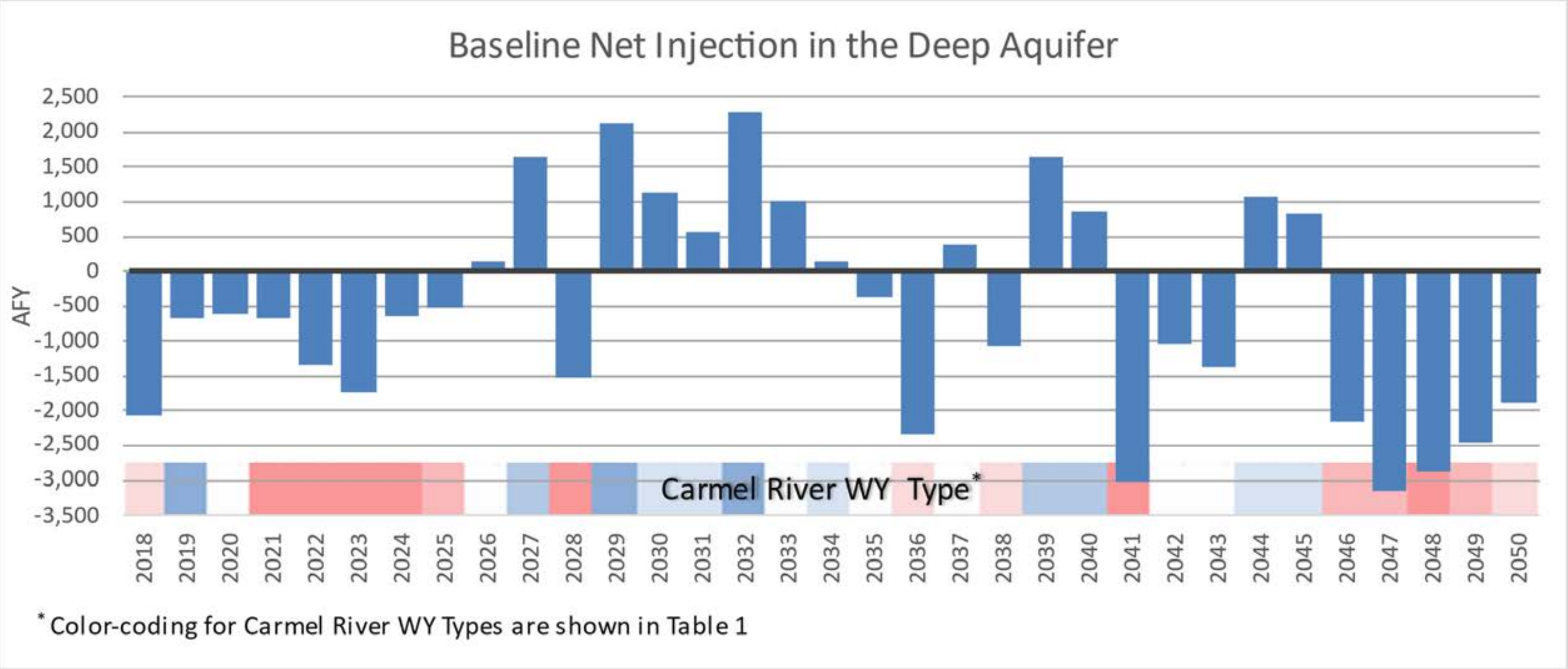


Figure 11. Annual Net Pumping (Positive = Net Injection, Negative = Net Extraction) in the Deep Aquifer for Baseline Scenario

This suggests that there is a spatial and temporal component to maximizing the efficiency of injection for the purpose of achieving protective elevations. As groundwater levels rise, the increased head drives flow out laterally towards areas with lower groundwater levels. In the case of offshore flows, outward flows continue for as long as inland groundwater levels are sufficiently above sea level to overcome the saltwater density effects. The simulation includes projected sea level rise, but this increase is relatively small compared to the simulated onshore changes in groundwater levels making it so that sea level rise alone is not a dominant driver controlling offshore flow or driving the amount of water needed for achieving protective elevations. In contrast, the future groundwater levels in the Monterey Subbasin could rise or fall significantly in response to the combination of water management actions taken in the Monterey Subbasin, the 180-400 Foot Subbasin and the Seaside Subbasin. The amount of outflow lost from the Seaside Subbasin will increase or decrease accordingly. Any time water levels in the Monterey Subbasin are lower than in the Seaside Subbasin, there is no way to inject replenishment water without some fraction of that volume flowing to the Monterey Subbasin. The water that flows out does not disappear however, rather it begins to raise the groundwater levels in the portion of the Monterey Subbasin adjacent to the Seaside recharge wells, as part of a growing groundwater mound around centered on the recharge facilities. Continuing to grow this groundwater mound is analogous to the process of building up a mound of dry sand by pouring sand onto the tip of the mound. Not all the sand we pour at the tip goes to increasing the height of the mound, rather a portion flows down along the slopes of the mound to build up the base and sides of the mound. In our analogy, the pile of sand is sitting on an inclined platform with some flows towards the downgradient production wells and the offshore region and some flows towards the Monterey Subbasin.

Net Change in Storage

Figure 12 shows the net change of water in storage (orange columns and left-hand vertical axis) and the cumulative net change in storage (blue line, right-hand vertical axis) in the Deep Aquifer. Changes in storage (orange columns in plot) can be conceptualized as deposits and withdrawals to/from the Deep Aquifer storage savings account. The cumulative change in storage (blue line) represents the running total, or account balance, of the net changes of water in storage (relative to the beginning of the simulation). The shape of the cumulative net change in storage curve closely tracks the trends of the simulated groundwater levels in deep monitoring wells shown on Figure 2, showing the same rises and falls.

If the Northern Coastal Subarea were a closed system separated from the Monterey Bay, the Monterey Subbasin, and the other Seaside subareas, the change in storage would directly reflect the changes in net injection and extraction. However, because of the connection to these other areas, the actual behavior is more complicated and dynamic, as illustrated by the changing net flows shown on Figure 10.

For example, during the simulated period from 2026 to 2033, which is generally a period of net positive injection into the basin, not all the injected water goes into storage to raise local groundwater levels. Rather, as groundwater levels start to rise in response to increased injection, the higher gradient drives increased outflows to the Monterey Subbasin and the offshore regions. In addition, inflows from the neighboring subareas drop because of the reduced hydraulic gradient relative to the groundwater levels in those areas. Similarly, in the simulated extended drought period from 2046 to 2050, when net extraction becomes very large, groundwater levels do not drop as low as they would otherwise have dropped if the basin were a closed system, because the depressed groundwater levels start to induce increased inflows from the Northern Inland Subarea, the Southern Coastal Subarea, the Offshore region, and even produce a significant net inflow from the Monterey Subbasin.

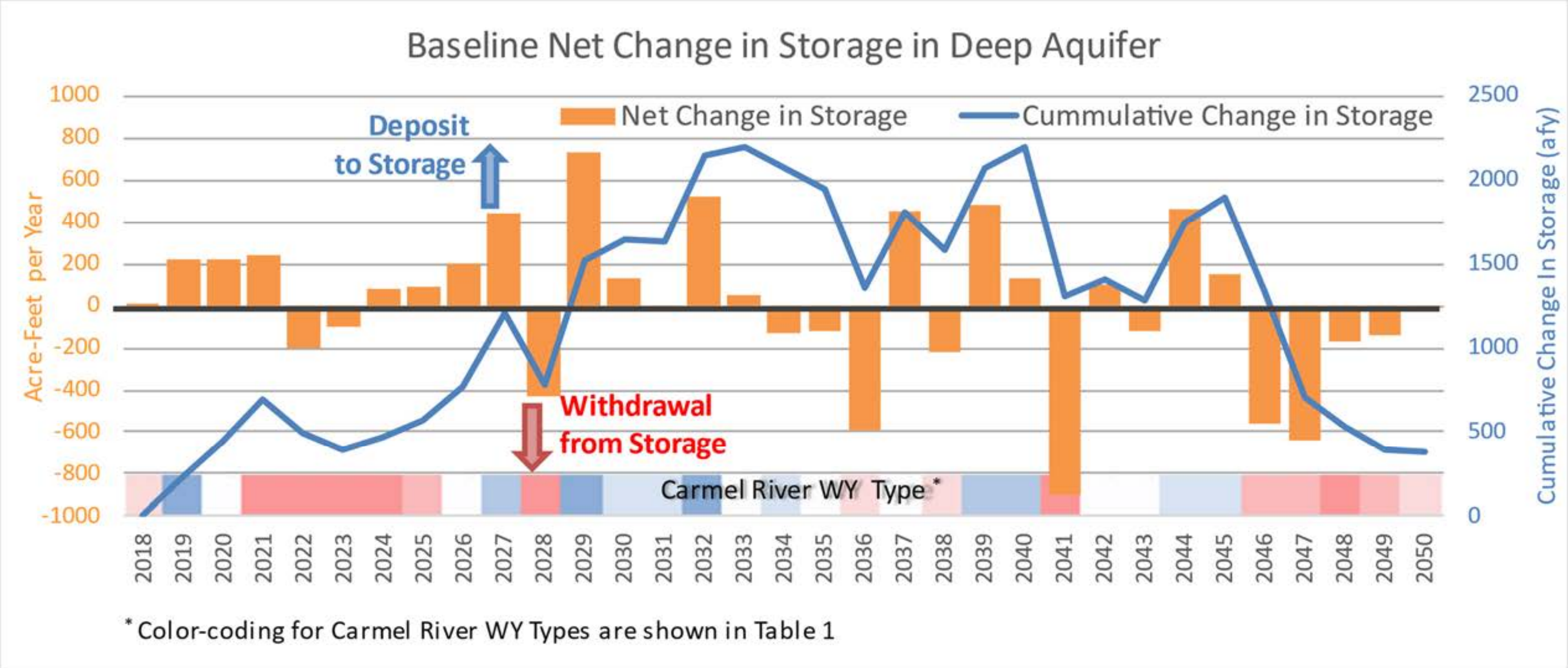


Figure 12. Net Change in Storage (Net Inflow – Net Outflows) (Left Axis) and Cumulative Net Change in Storage in Deep Aquifer (Right Axis)

Changes in Net Flows from the 1,000-AFY Replenishment Scenario

The same water budget analysis was conducted on the model results from Scenario 2 of the January 2022 replenishment modeling TM (M&A, 2022a), in which 1,000 AFY of replenishment water is injected into the Deep Aquifer starting in WY 2024 when the PWM Expansion Project begins. The purpose of this Scenario was to understand how additional replenishment water affects crossflows with the Monterey Subbasin, the Offshore regions and the adjacent Subareas, and the amount of water going into storage to raise groundwater levels, relative to the Baseline simulation in which no replenishment water is injected. The results, in terms of change in net flows compared to the Baseline scenario, are shown for the Deep Aquifer on Figure 13 and for the Shallow Aquifer on Figure 14. These figure show both the difference in the individual flow components (colored bars) as well as the difference in the total net inflow (black line).

In the Deep Aquifer (Figure 14), the 1,000-AFY increase in net injection initially results in a substantial increase of water going into storage (shown in the black “Total Net Inflow” line) raising groundwater levels, but the magnitude of increase subsides as groundwater levels rise, because this promotes increased outflows to all the adjacent areas. As the injection mounds grow, the greatest increase in outflows occur to the Monterey Subbasin, Northern Inland Area upgradient of the PWM injection facilities, and upwards into the Shallow Aquifer. The increase in net flow to the Shallow Aquifer occurs more gradually as this requires increasing groundwater levels in the Deep Aquifer above the groundwater levels in the Shallow Aquifer. There is also a smaller but consistent increase in the outflow to the Offshore area and to the Southern Coastal Subarea.

Figure 14 shows the changes in net flows that occur in the Shallow Aquifer as a result of adding 1,000 AFY of replenishment water injection. The most significant change is the steady increase of inflow from the underlying Deep Aquifer. Increased inflow is driven by increasing groundwater levels in the Deep Aquifer relative to groundwater levels in the Shallow Aquifer. A portion of the increased inflow goes to increased net storage (represented by the black “Total Net Inflow” line), which raises groundwater levels in the Shallow Aquifer. This in turn leads to increased outflow to the Offshore Area, and to a smaller degree increased outflow to the Monterey Subbasin. The changes to the net flows to/from the upgradient Northern Inland Subarea appear to fluctuate with changes in rainfall.

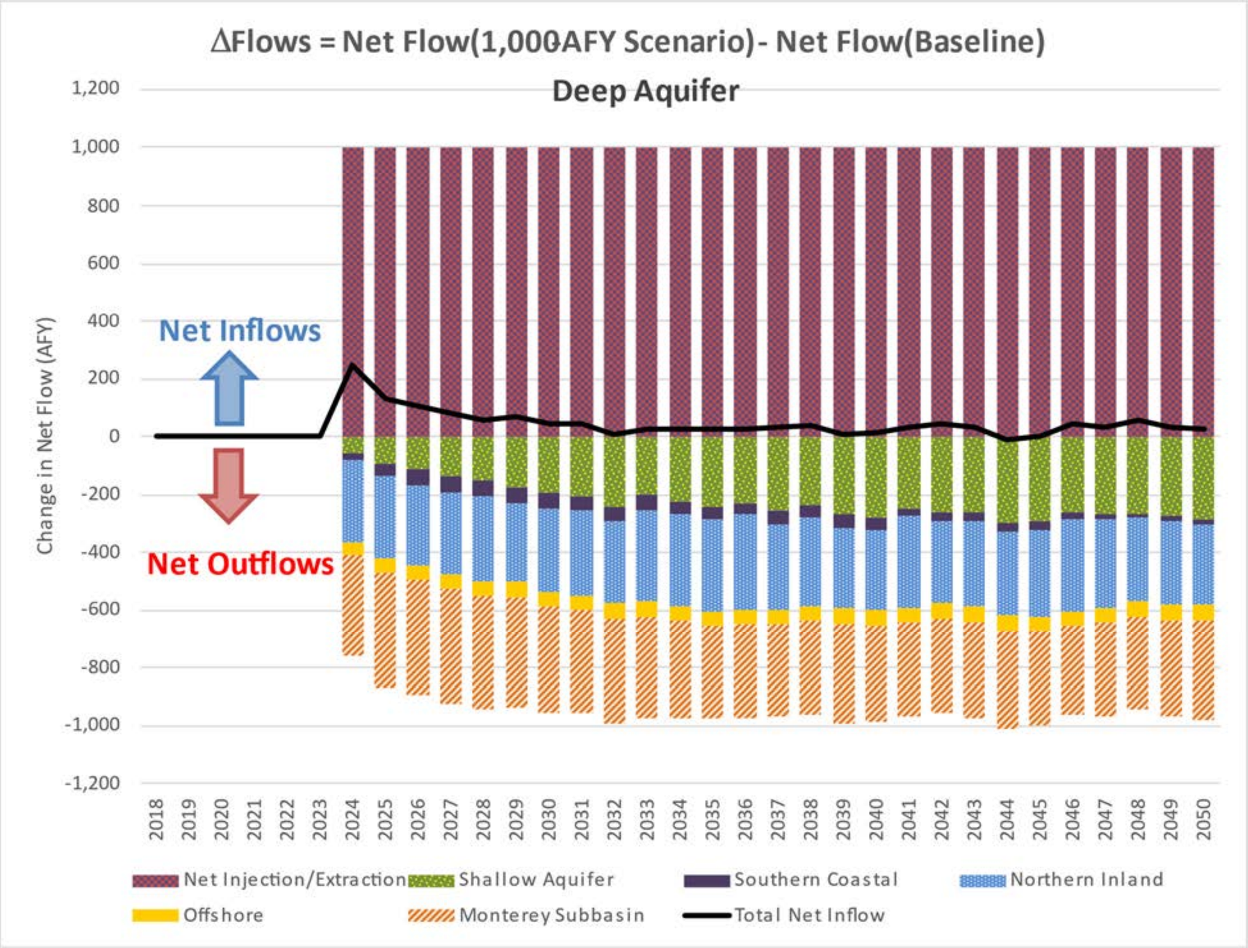


Figure 13. Deep Aquifer: Change in Net Flows between Baseline and 1,000-AFY Replenishment Scenarios

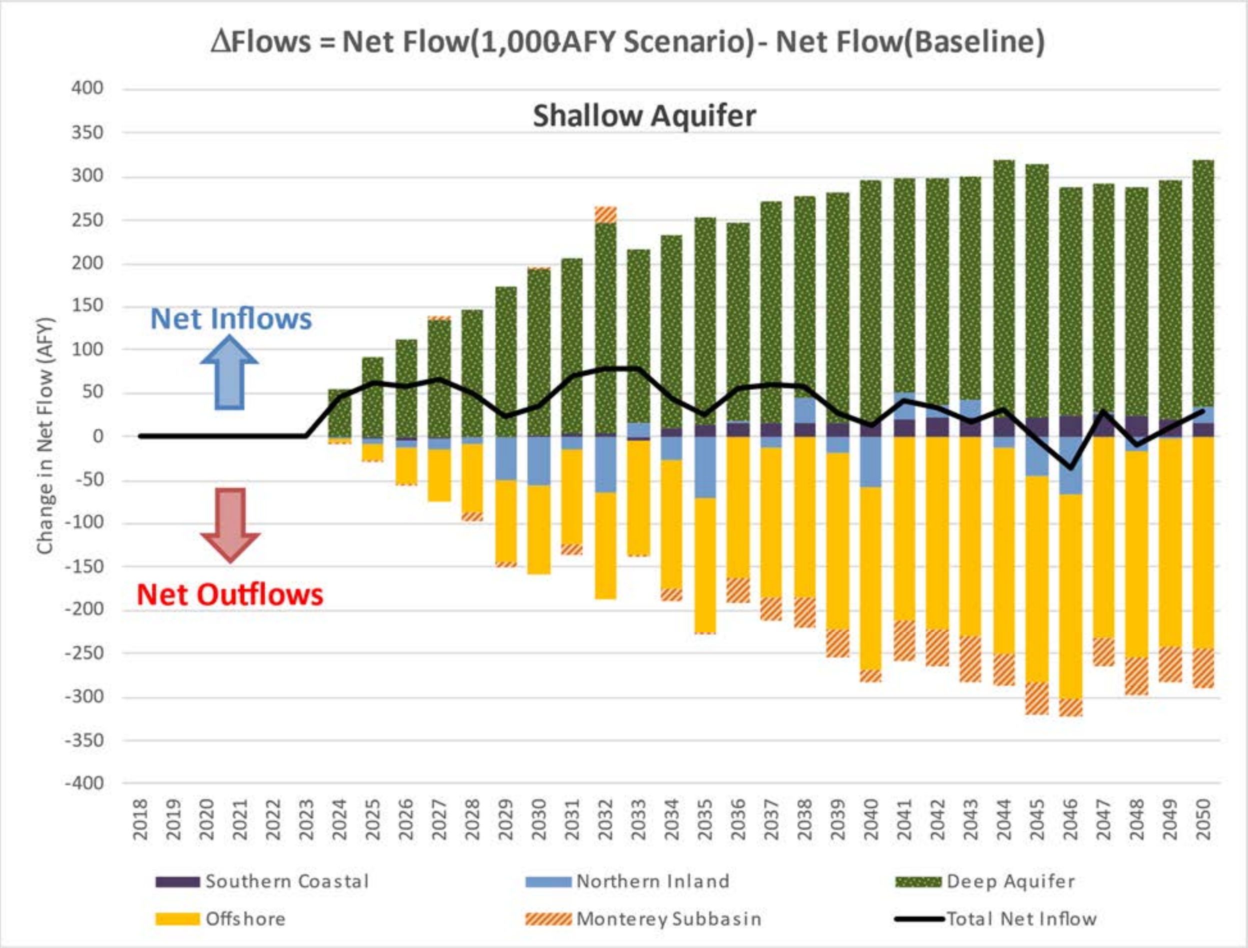


Figure 14. Shallow Aquifer: Change in Net Flows between Baseline and 1,000 AFY Replenishment Scenarios

TASK 2. DEVELOP ALTERNATIVE SCENARIO BASED ON CAL-AM URBAN WATER MANAGEMENT PLAN SUPPLY & DEMAND ASSUMPTIONS AND UPDATED CITY OF SEASIDE ASSUMPTIONS

This Alternative Scenario evaluates the impact of an alternate set of future supply and demand assumptions on the volume of replenishment water needed to achieve protective groundwater levels at the coastal monitoring wells. The alternate demand and supply assumptions are based primarily on Cal-Am's 2020 Urban Water Management Plan (UWMP) (WSC, 2021), and additional assumptions provided by Cal-Am and the City of Seaside. The set of assumptions is referred to as Alternative Scenario 1 in this Technical Memorandum.

Updated Assumptions for City of Seaside Golf Course use of Recycled Water & New Well Location

The City of Seaside requested that the following revised assumptions be used:

1. Assume City of Seaside golf courses use 491.4 AFY of recycled water.
2. Assume City pumps an in-lieu amount of 491.4 AFY from the deep aquifer from a new well located at Latitude = 36.615304°, Longitude = 121.826278° (Which is generally in the location of the Lincoln-Cunningham Park in Seaside).
3. Convert 26 AFY of golf course allocation from Alternate Producers (APA) to Standard Producers (SPA). New golf course APA allocation = 540 – 26 = 514 AFY.
4. The remaining unused balance of 514 – 491.4 = 22.6 AFY would be held as a reserve and/or for flushing of greens and tee boxes.

The current Baseline simulation already incorporates the assumptions that the City of Seaside golf courses switch to using recycled water in WY 2023 and stops pumping from their two Paso Robles (Shallow Aquifer) irrigation wells at that time. However, the Baseline simulation accounted only for 301.1 AFY of the 514 AFY golf course allocation to be re-allocated to supply the planned Campus Town Development project, in addition to the existing City of Seaside's municipal pumping SPA allocation currently supplied by pumping of Seaside Muni Well #4. So conservatively if the full 514 AFY of APA allocation is pumped from the new well, this leaves 514-301.1 = 212 AFY of additional pumping that is not currently included in the Baseline simulation and will need to be accounted for in the Alternative Scenario 1 water budget analysis.

Assumptions Requested by Cal-Am

Cal-Am requested that the following assumptions be used:

1. 15 AF per day will be used as the average daily amount of ASR diversion, not the 20 acre-feet per day that was used in the January 2022 modeling. [*In keeping the current cycled Carmel River hydrology record this assumption results in a 25 percent reduction in the projected annual ASR diversion volumes but does not alter the temporal pattern of when ASR injection occurs during the simulation.*]
2. Cal Am's *Urban Water Management Plan* (UWMP) demand figures rather than MPWMD's demand figures will be used for Cal Am's projected water demands.
3. The MPWSP Desalination Plant will begin operation in 2030 in accordance with the UWMP. *[The UWMP assumes the Desal plant will produce 6,252 AFY for the Monterey Peninsula].*
4. Cal Am's in-lieu repayment of 700 AFY will not begin until its desalination plant begins operation in 2030, in accordance with the UWMP. *[For comparison, the original baseline assumes the repayment period starts in 2024, concurrent with the PWM Expansion project.]*
5. The Pure Water Monterey Expansion Project will begin operation in 2024, the same as previously simulated in the January 2022 replenishment modeling.
6. To provide a factor of safety, the amount of water that the Pure Water Monterey Expansion Project will deliver will be reduced from 5,700 acre-feet to the *"Minimum Allotment"* of 4,600 acre-feet per year as set forth in the "*Amended and Restated Water Purchase Agreement"* executed between Cal Am, MPWMD, and M1W in late 2021.
7. Cal-Am will make-up any shortfall between supply and demand by over pumping its Seaside Basin allocation of 1,474 AFY. *[If the Desal Plant is built in 2030, even though PWM Expansion is assumed to have reduced deliveries per Cal Am assumption 6 above, there will be no supply shortfall after 2030 because the UWMP indicates that the expected capacity of the Desal plant is sufficient to make up for the reduced PWM Expansion deliveries.]*

These Alternative Scenario 1 assumptions were incorporated into the monthly supply-demand spreadsheet model developed by MPWMD and that is used to assign and distribute simulated monthly Cal-Am pumping and ASR injection in the groundwater model. These demands are shown on Figure 13. This supply-demand model incorporates the cycled Carmel River historical hydrology used for the determination of the monthly ASR diversions. Projected ASR injection and Seaside pumping data was then aggregated on a water year basis for comparison and integration with the water budget analysis from the existing Baseline replenishment model run.

Reduced ASR and PWM Injection

Applying the lower 15 AF per day ASR diversion capacity assumption while keeping the existing cycled historical Carmel River hydrology record results in a 25% reduction in the projected annual ASR injection volumes but does not alter the temporal pattern of when ASR injection occurs during the simulation period. Table 2 provides a comparison of the average annual ASR diversion volumes for the original Baseline diversion rate and the reduced Alternate Scenario 1 diversion rate, grouped by Carmel River Water Year Type when applying the minimum instream flow requirements to determine when ASR diversions can occur in the cycled hydrology record.

Table 2. Average ASR Dibversions by Carmel River Water Year Type for Baseline and Alternative Scenario 1 Diversion Rate Assumptions

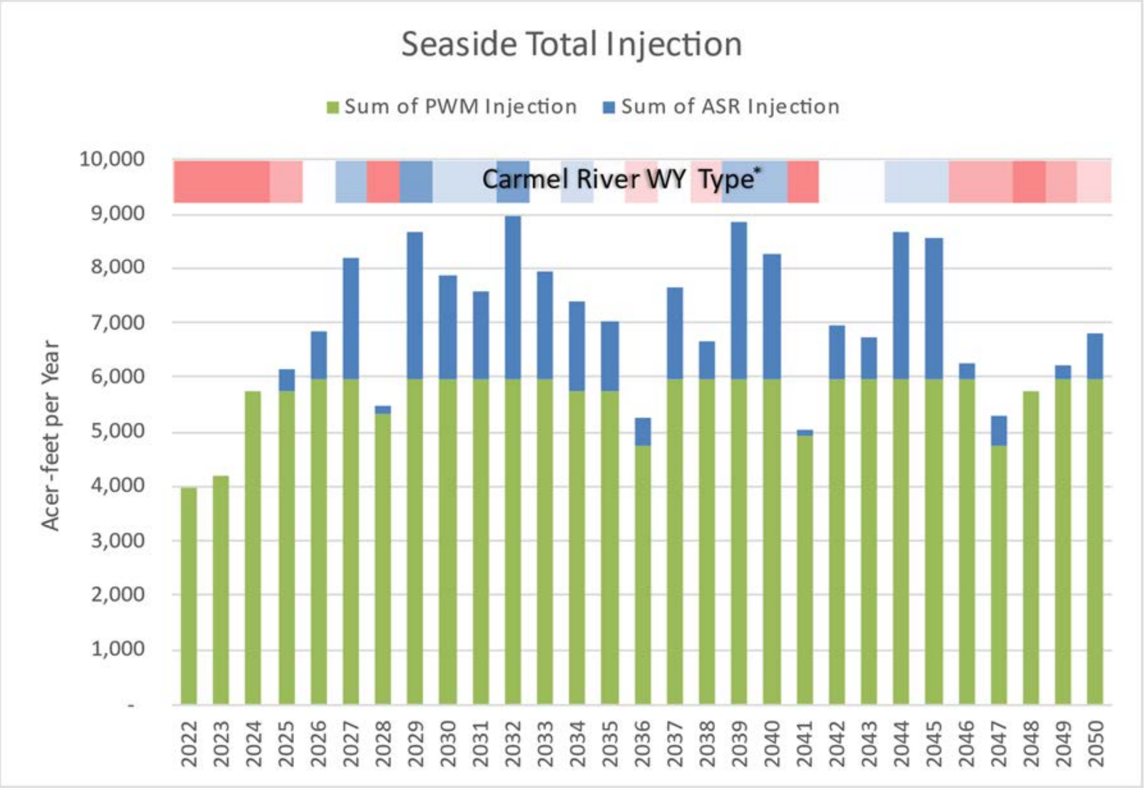
Carmel River Water Year Type	Average Number Diversion Days per Year	Average ASR Diversions w/20 AFD Capacity (AFY)	Average ASR Diversions w/15 AFD Capacity (AFY)
Extremely Wet	142	2,840	2,130
Wet	125	2,500	1,875
Above Normal	105	2,100	1,575
Normal	64	1,280	960
Below Normal	33	660	495
Dry	19	380	285
Critically Dry	3	60	45

Table 2 shows the projected annual ASR injection and PWM injection volumes for the Baseline simulation and the new Alternative Scenario 1. Regardless of water year type, the Alternative Scenario 1 assumptions deliver only 75% of the ASR injection volume of the Baseline volume, and the PWM injection is only 4,600 AF/5,750 AF = 80% of the Baseline PWM injection volume. Note that in Alternative Scenario 1 the PWM injection volume still has a dependence on drought conditions in the CSIP Delivery area and so while the average annual delivery is 4,600 AFY, wet years deliver higher volumes and in drought years lower volumes, consistent with how the PWM deliveries are simulated in the Baseline simulation.

Cal-Am Demand and Supply Assumptions

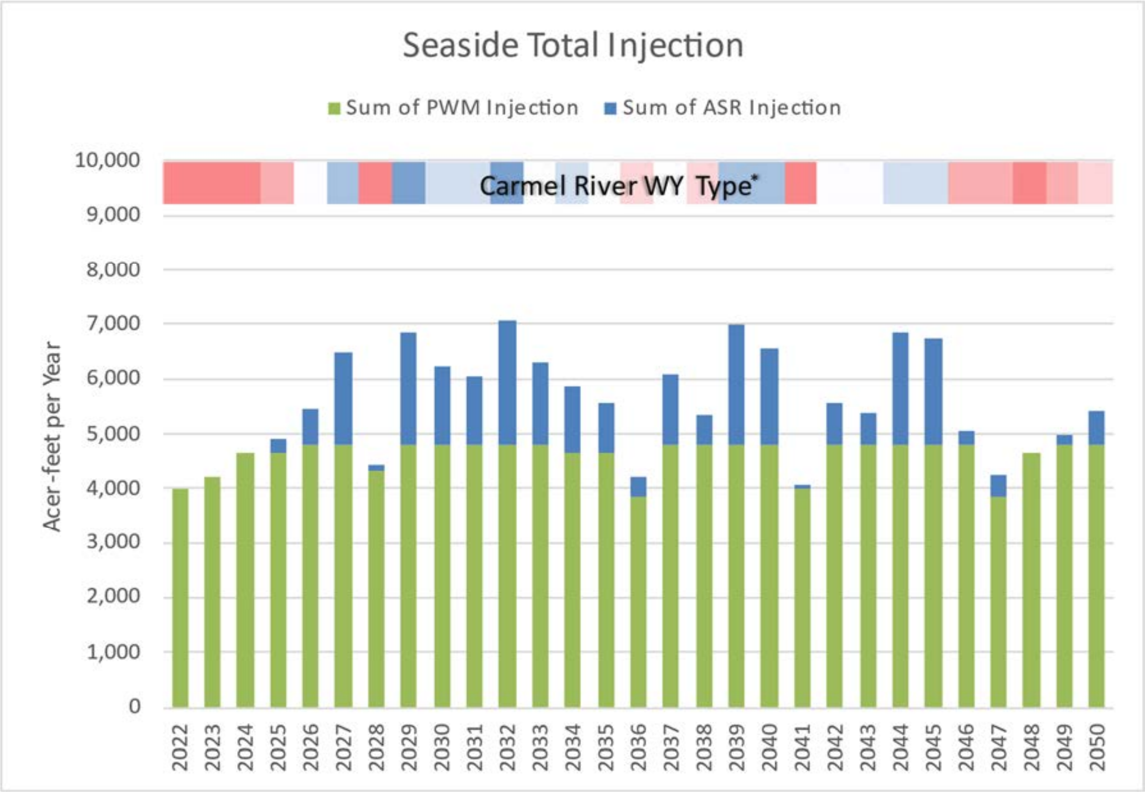
The 2020 Cal-Am UWMP provides historical total annual demand for the Monterey Main system from WY 2006 to WY 2020 and provides five-year projections for 2025 through 2045. To establish a full set of projected annual demand for the entire simulation period, the annual UWMP annual demand values were linearly interpolated from 2020 through 2045, and then extrapolated from 2045 through 2050 using the same slope as between 2035 and 2040. The historical and projected annual total system demands are shown on Figure 16. The Baseline simulation uses historical reported production and ASR + PWM injection data for WY 2018 through 2021, so the use of projected demand is only used in the model for WY 2022 forward.

Baseline



*Color-coding for Carmel River WY Types shown in Table 1.

Alternative Scenario 1



*Color-coding for Carmel River WY Types shown in Table 1.

Figure 15. Projected Total Annual Injection of PWM and Carmel River ASR Water for Baseline and Alternative Scenario 1

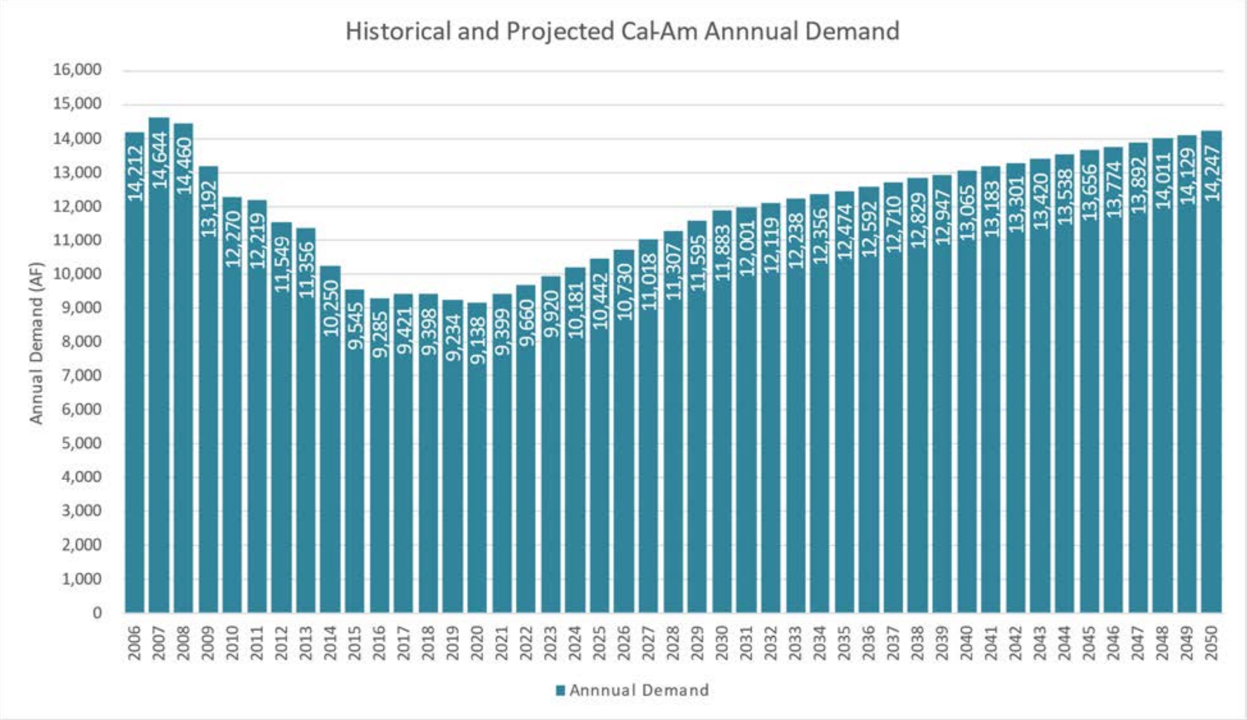


Figure 16. Historical (WY 2006-2020) and Projected (WY 2020-2050) Cal-Am Total System Demand Based on 2020 UWMP Assumptions

In the Supply-Demand model, the total annual system demand is distributed to monthly demands by use of historical monthly usage factors. For each month the Supply-Demand model then allocates available water sources to meet the demand. The Baseline model sources water from Carmel Valley Pumping water rights, Sand City Desal, Table 13 Diversions of Carmel River Water, and pumping of native groundwater and injected PWM and ASR water from the Seaside basin. For Alternative Scenario 1 this was extended so that water can also be sourced from the new MPWSP Desalination Plant from WY 2030 onward to meet any excess demand that cannot be supplied by the other sources. Figure 17 shows a side-by-side comparison of the projected total system demand for the Baseline and Alternative Scenario 1, also showing what portion of the demand each year is supplied from each source. In Alternative Scenario 1, From 2030 onward the Desalination Plant plays an increasingly larger role in supplying the increasing annual demand.

Figure 18 shows the projected annual Seaside basin pumping for the Baseline and Alternative Scenario 1, broken out by water source: native groundwater, PWM recovery, and ASR recovery. For the Baseline scenario, the 25-year Cal-Am in-lieu repayment period is clearly visible in the drop in native groundwater extraction from 2024 through 2048. In the Alternative Scenario 1, the repayment period does not start until 2030 and Cal-Am continues to pump their full 1,474 AFY native groundwater allocation up until that year. Because of the combination of the assumed higher system demand, and assumptions on reduced volumes of ASR and PWM injection during this early simulated drought period, there is a supply shortfall from 2023-2029 until the MPWSP Desalination Plant comes online. The supply shortfall is met by pumping beyond Cal-Am's 1,474 AFY native groundwater allocation. The simulated multiyear period of normal and wet years starting in 2029 allows for the injection of a considerable amount of ASR which is recovered immediately to supply the increasing system demand and the reduction of native groundwater pumping because of the in-lieu repayment period that starts in 2030. Compared to the Baseline scenario, there is much greater reliance on recovery of ASR water, even in non-drought years, such that there is very little unrecovered ASR. Interestingly, after 2030 when the MPWSP Desalination Plant comes online, despite the increased system demand, the average total pumping from the Seaside basin is lower than in the Baseline Scenario, because an increasing portion of the higher demand is supplied directly by the Desalination Plant. This is especially evident during the simulated drought period towards the end of the simulation, where a large portion of the demand is met by the Desalination Plant instead of pumping because there is not a built-up bank of ASR water to recover.

Figure 19 shows the annual net injection of PWM and ASR water for both scenarios, defined as the difference between the total annual ASR and PWM injections and the amount of recovered ASR and PWM water in that same year. The figure illustrates how the combination of assumed lower ASR diversion rate, reduced PWM Expansion delivery volume, and increased system demand results in no ASR water being banked in the basin after the end of the simulated multiyear wet period in 2034.

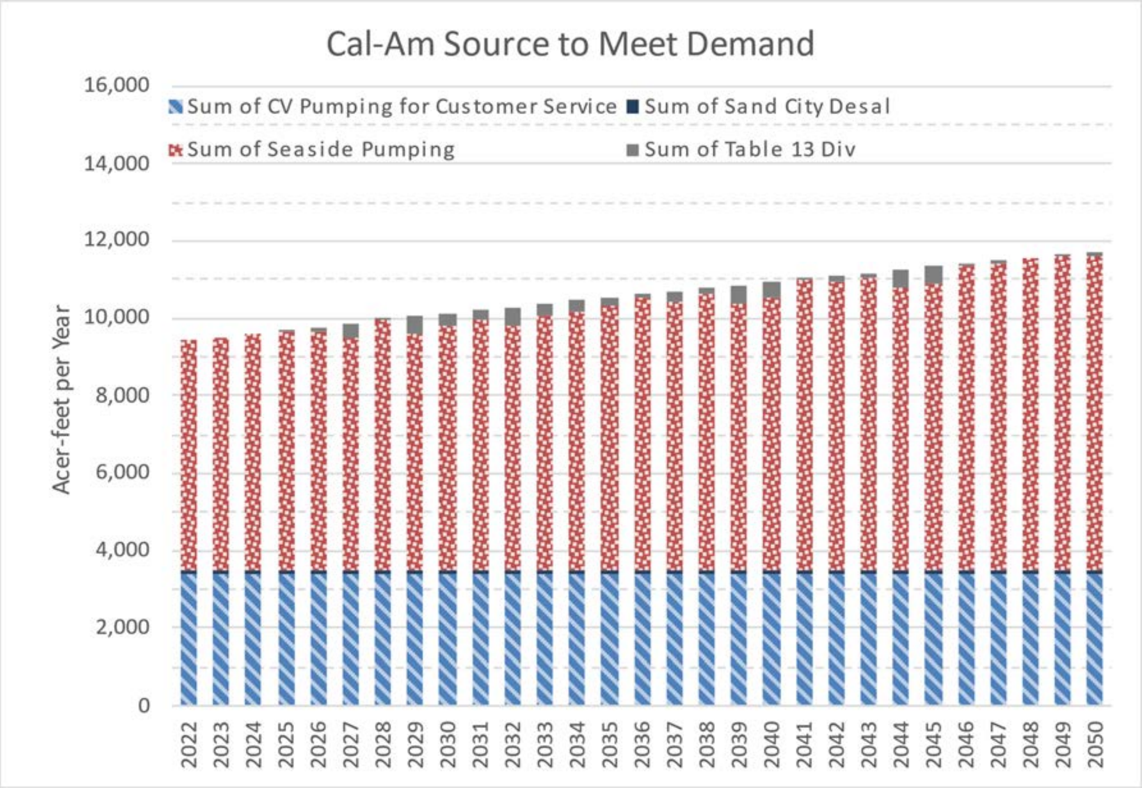
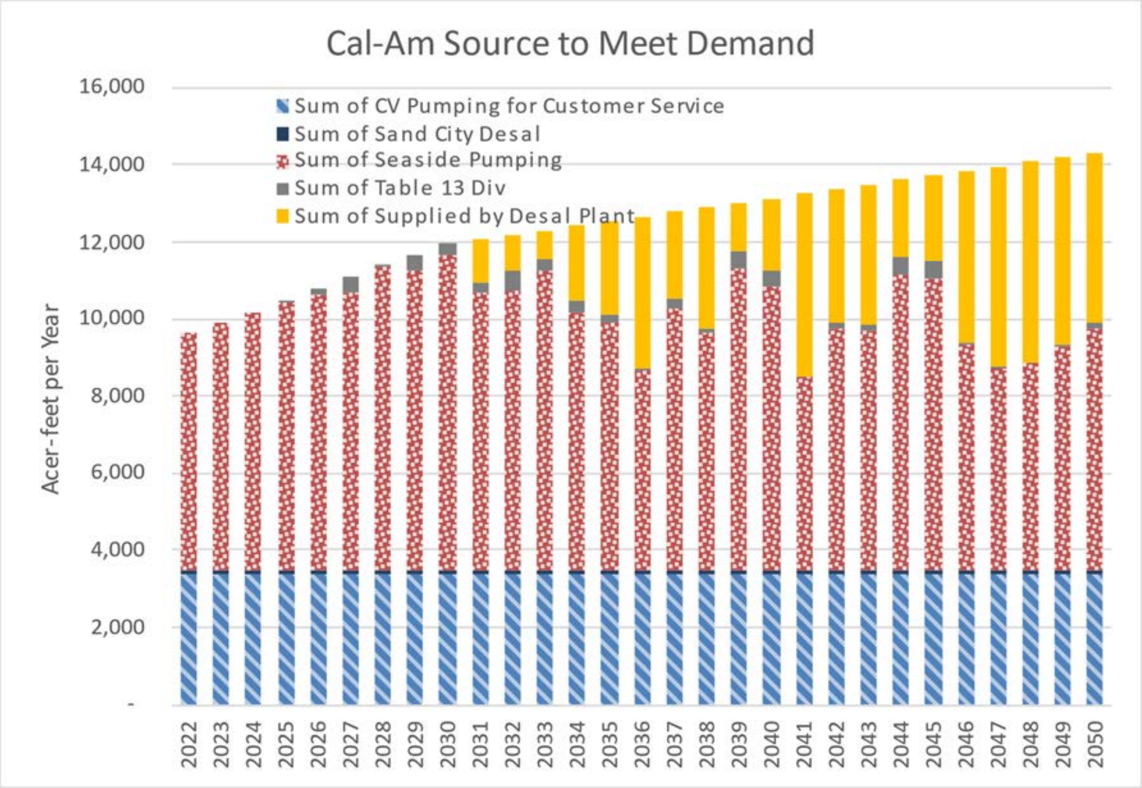
Baseline	Alternative Scenario 1
	

Figure 17. Projected Cal-Am Total Annual System Demand and Water Supply Source for Baseline and Alternative Scenario 1

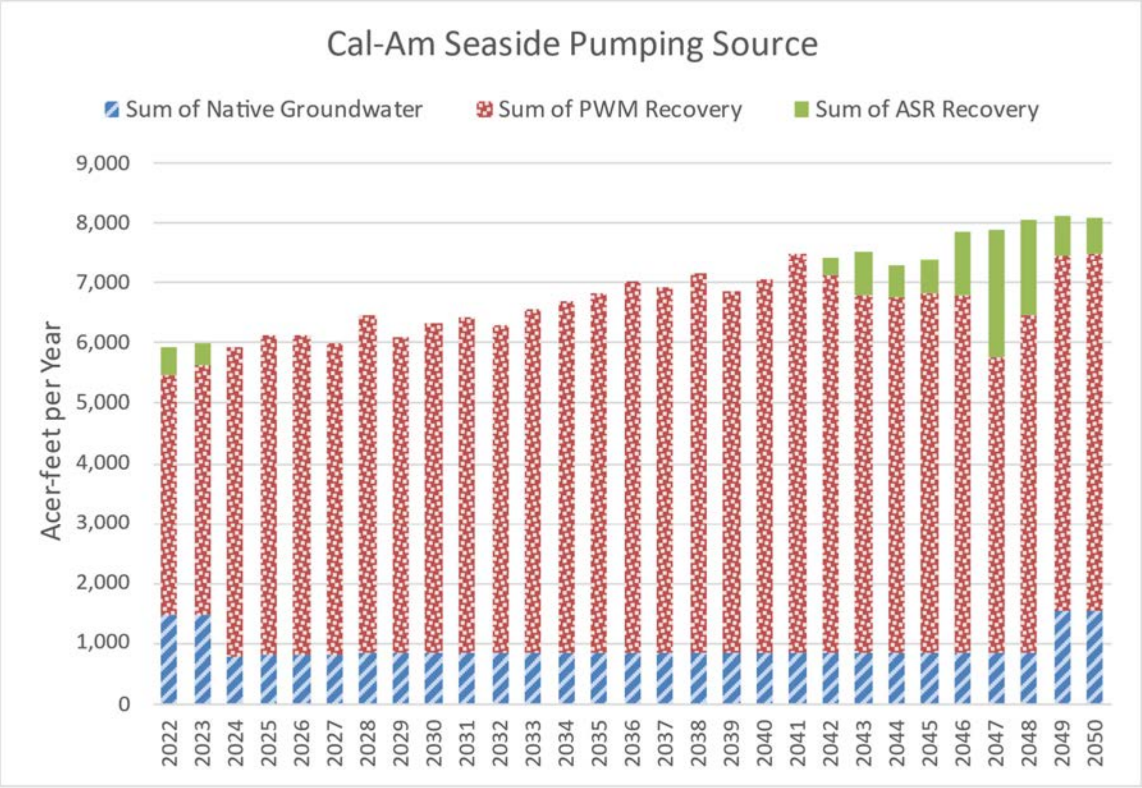
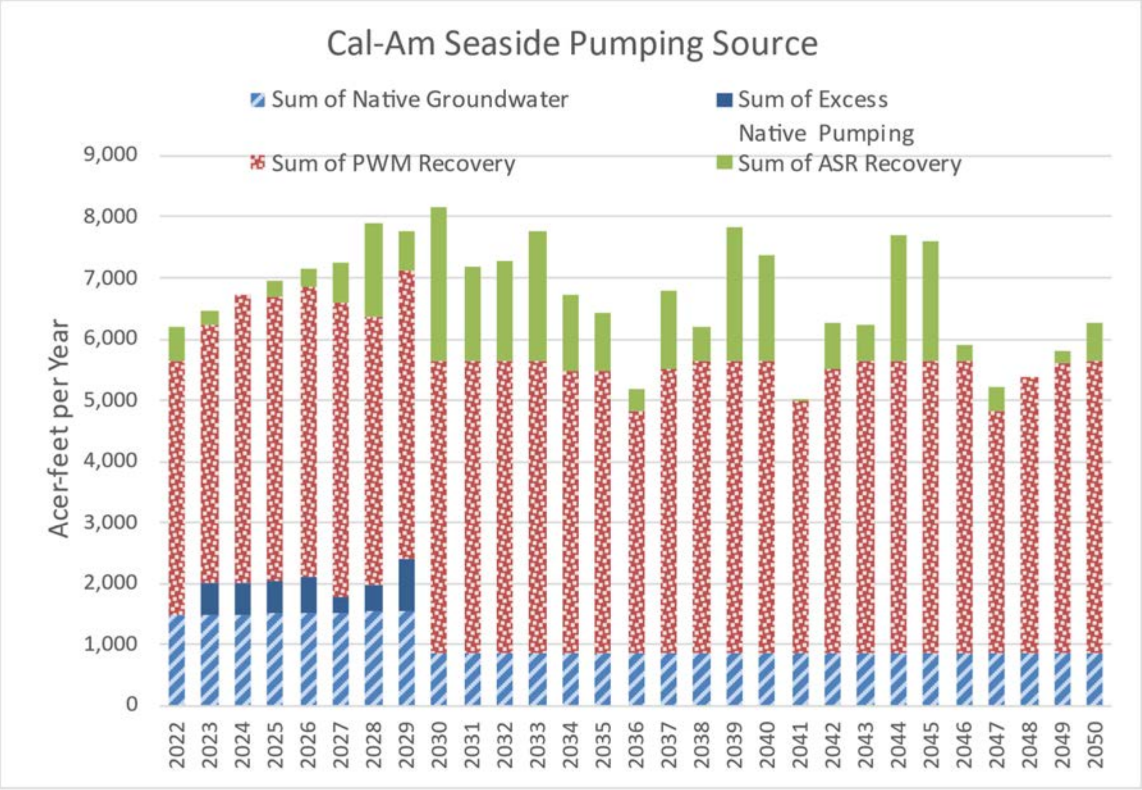
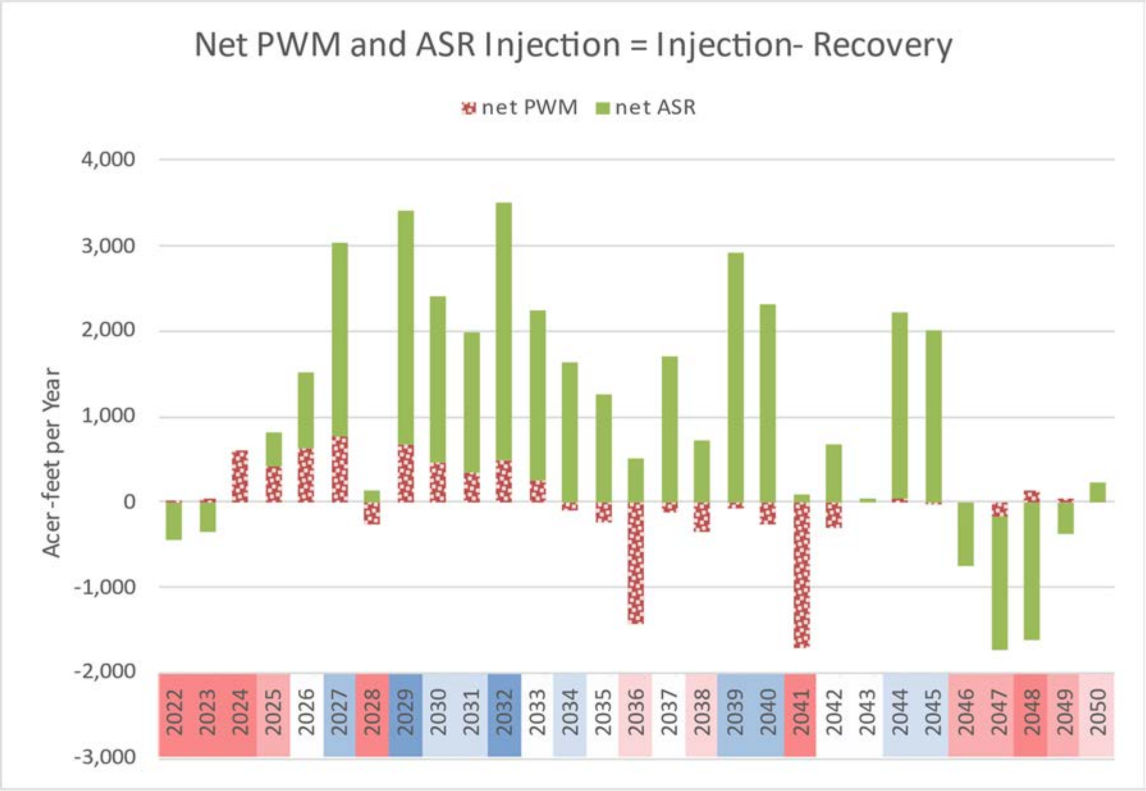
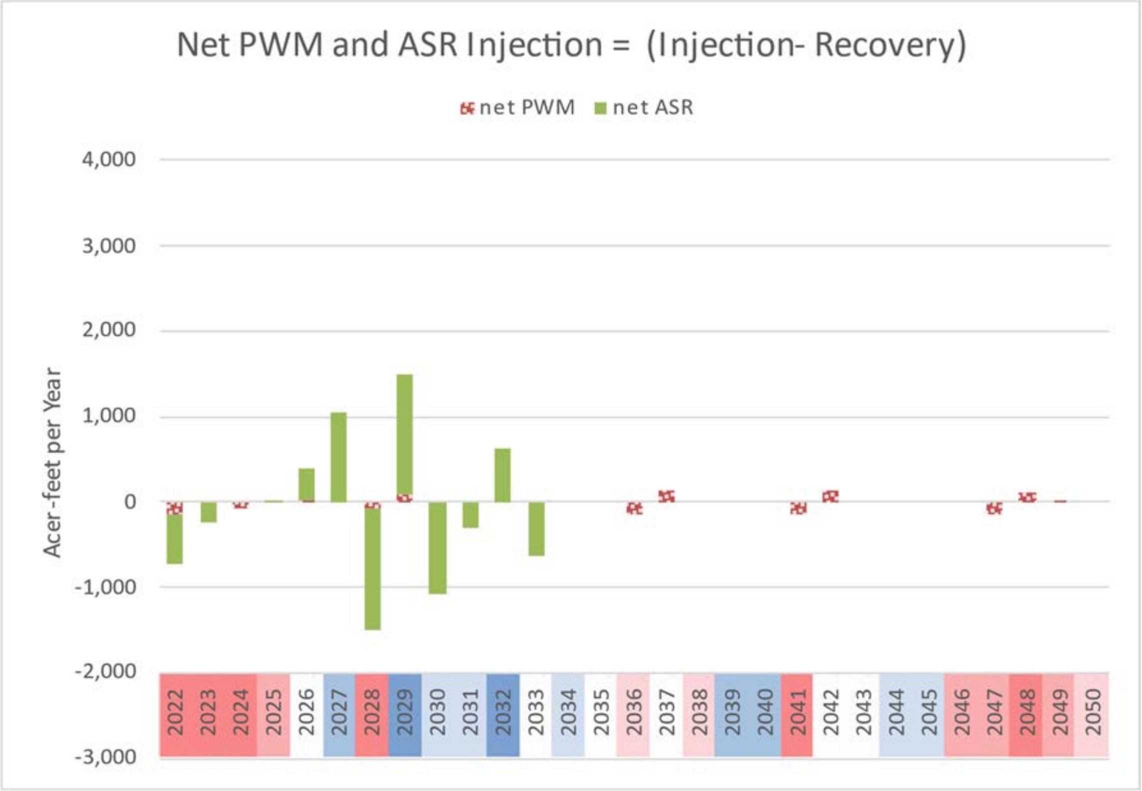
Baseline	Alternative Scenario 1
	

Figure 18. Projected Cal-Am Seaside Pumping by Water Source for Baseline and Alternative Scenario 1

<table>
<tr><th>Baseline</th><th>Alternative Scenario 1</th></tr>
<tr><td>


<u>Note:</u> Water years color-coded by Carmel River WY Types shown in Table 1
</td><td>


<u>Note:</u> Water years color-coded by Carmel River WY Types shown in Table 1
</td></tr>
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Figure 19. Projected Net PWM and ASR Injection for Baseline and Alternative Scenario 1 (With No Added Replenishment Water in Either Scenario)

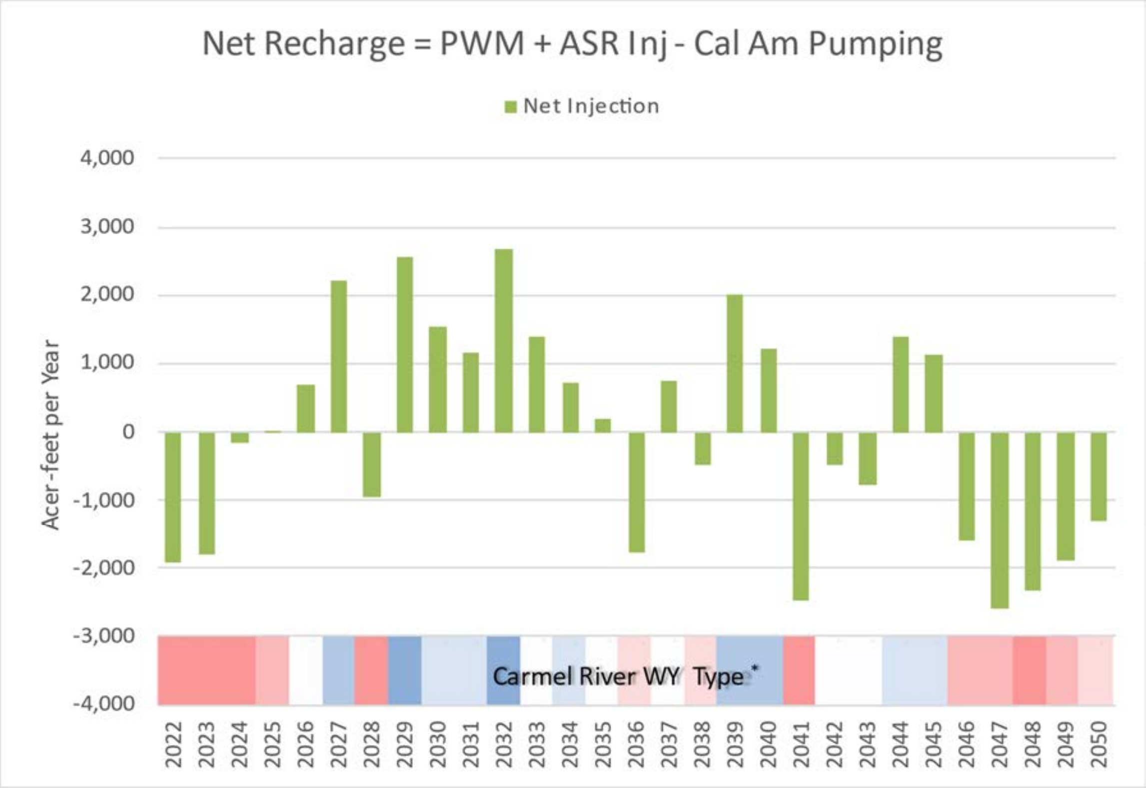
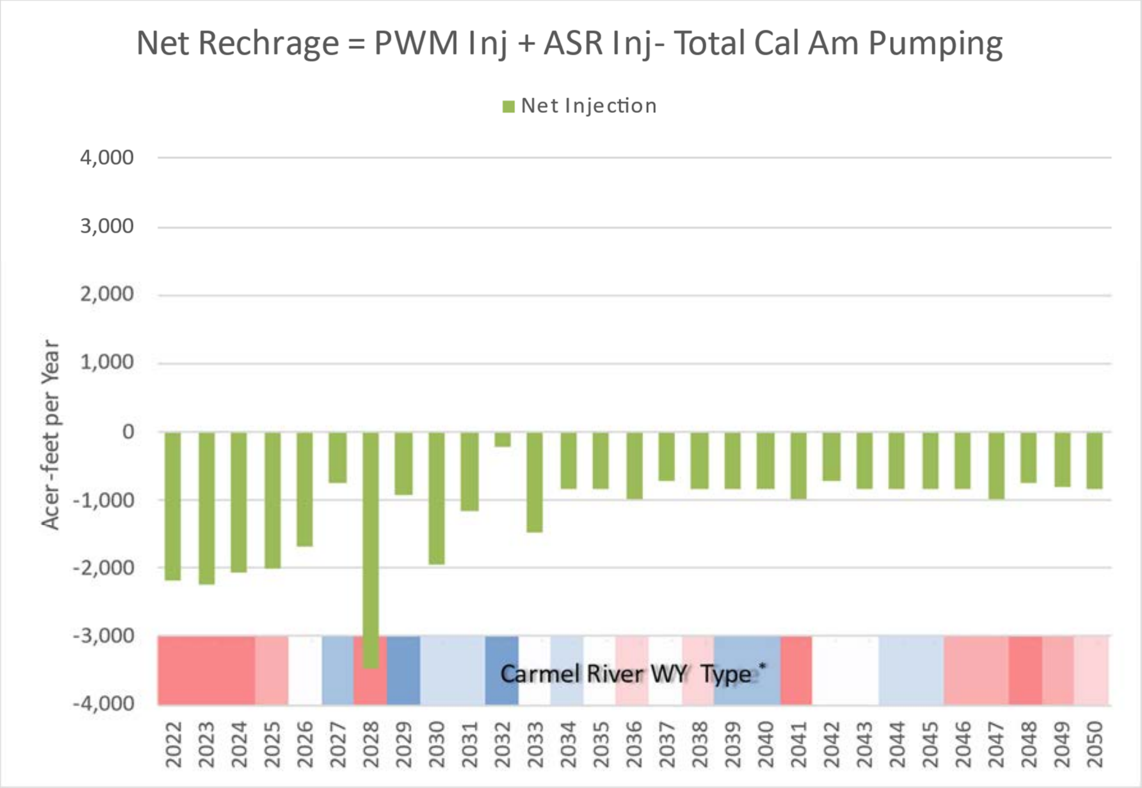
Baseline	**Alternative Scenario 1**
 * Color-Coding for Carmel River WY Types shown in Table 1	 * Color-Coding for Carmel River WY Types shown in Table 1

Figure 20. Projected Net Recharge for Baseline and Alternative Scenario 1 (With No Added Replenishment Water in Either Scenario)

TASK 3. HYBRID WATER BUDGET ANALYSIS TO SHOW EFFECTS OF DIFFERENT DEMAND/SUPPLY ASSUMPTIONS ON VOLUME OF REPLENISHMENT WATER NEEDED

Running additional alternative baseline modeling simulations with different supply/demand assumptions in the Alternate Scenario 1 and then determining what volumes of replenishment are needed to meet protective elevations for each alternative scenario is not the only way to evaluate the impacts of differences between the Cal-Am and MPWMD demand/supply assumptions on the estimate of the volume of replenishment water needed.

An alternative to running multiple additional demand/supply modeling scenarios is to use a more cost-effective hybrid water-budget-based approach leveraging information available from the already-run Baseline modeling simulation and combining it with Alternative Scenario 1 demand and supply assumptions to estimate the replenishment volume needed to achieve protective elevations. This approach is spreadsheet-based and serves as a framework to develop estimates of the annual replenishment volumes needed under the different demand & supply assumptions. The same approach could also be used to incorporate the impacts of potential reductions in future ASR water availability due to climate change. This is achieved without having to setup, re-run, and analyze multiple additional model scenarios

The approach takes advantage of available model scenarios indicating how much net-recharge is needed in the vicinity of the PWM and ASR well fields to raise groundwater levels at coastal monitoring wells to varying degrees. For this purpose, the net recharge is defined as follows:

$$\begin{array}{c} \textit{Net} \\ \textit{Recharge} \end{array} = \begin{array}{c} \textit{PWM} \\ \textit{Injection} \end{array} + \begin{array}{c} \textit{ASR} \\ \textit{Injection} \end{array} + \begin{array}{c} \textit{Replenishment} \\ \textit{Injection} \end{array} - \begin{array}{c} \textit{Total Cal-Am \& City of} \\ \textit{Seaside Production} \end{array}$$

For the Baseline Scenario and Alternative Scenario 1, the amount of Replenishment Injection is equal to zero. This definition of Net Recharge is also generally equivalent to the Net Pumping term presented earlier in the water budget analysis section.

Based on the findings from the January 2022 modeling, it is apparent that that the rapid initial rise in simulated groundwater levels in the original baseline simulation (see Figure 2) is due primarily to a sequence of wetter years in the simulated cycled hydrology that allows for a prolonged period of significant injection and storage of ASR water. If future climate conditions cannot provide the amounts of ASR injection shown each year in the January 2022 modeling, or if there is increased system demand that requires the injected water to be recovered rather than banked, then that “missing” amount of injected water will have to be supplied by an external replenishment source to achieve the same groundwater level increase that has already been simulated in the Baseline.

The differences between the Cal-Am and MPWMD demand/supply assumptions does not change the total amount of net recharge needed to raise groundwater levels. Rather, they only change the distribution between the three components of Net Recharge. For example, if there is higher assumed demand, then there will be more pumping, and thus more replenishment water will be needed to offset the higher pumping while still achieving the same groundwater level rise. Similarly, a lower demand assumption would result in less pumping and would require less replenishment water. So as the demand assumptions are changed, varying amounts of replenishment water will be needed.

This analysis assumes that protective elevations are met to the same degree and within the same time frames as in the January 2022 replenishment modeling. If the Watermaster wishes to explore alternative time frames for reaching protective elevations, then additional groundwater modeling will be required.

One of the factors that allows for this the hybrid water budget analysis approach is the fact that the injection and recovery and extraction wells are generally all located within close proximity to each other within the same aquifer in a well-defined region along the boundary between the Northern Coastal Subarea and the Northern Inland Subarea. If the extraction wells were located very far from the injection wells, or in a different aquifer than the injection wells, or in different portions of the subbasin, or if the recovery wells were upgradient of the injection wells, then it would be less appropriate to use the hybrid water budget approach for this analysis. The hybrid approach is a simplified analytical approach with some limitations and should be considered as providing a general order-of-magnitude type evaluation rather than as a complete substitute for actual modeling of alternate scenarios.

Figure 20 shows the calculated annual Net Recharge (as defined above) for the Baseline Simulation and Alternative Scenario 1. For the Alternative Scenario 1, assumptions on increased demand and reduced supply of PWM and ASR water result in significantly reduced Net Recharge, with Net Recharge being negative for all water years, even during the earlier wet period.

The amount of additional replenishment water that is needed each year in the Alternative Scenario 1 to have the same Net Recharge as the Baseline Scenario is calculated by the difference between the Net Recharge for each scenario:

$$\textit{Additional Replenishment Water Needed} = \textit{Net Recharge (Baseline Scenario)} - \textit{Net Recharge (Alternative Scenario 1)}$$

Figure 21 shows a graph of the amount of additional replenishment needed each year under Alternative Scenario 1 to achieve the same water level increases as in the Baseline Scenario (green bars), and to achieve the same level of protective elevations as in the 1,000-AFY Replenishment Scenario (blue line with circle markers). Despite WY 2022 and 2023 being critically dry years, only a smaller amount of additional replenishment is needed to match the Baseline during these years because the only real difference between the Baseline and Alternative Scenario 1 during these years is the slightly higher projected annual demand, which in Alternative Scenario 1 is met by a combination of recovery of previously banked ASR water and pumping of native groundwater in excess of Cal-Am’s allocation. Starting in WY 2024, however, substantial volumes of additional replenishment water would need to be injected into the Deep Aquifer (between 1,000 and 3,500 AFY) to achieve the same increases in Deep Aquifer groundwater levels as those that occur between 2024 and 2035 in the Baseline Scenario, with an average annual replenishment of 2,600 AFY. These large volumes are needed even during normal and wet years because of the combination of the assumed increasing annual demand and reduced PWM Expansion yields and reduced ASR injections. To achieve protective elevations during this same period an additional 1,000-AFY on top of this is needed. As Figure 21 shows, under Alternative Scenario 1 in some years the amount of replenishment water needed to achieve protective elevations would be more than 4,500 AFY, with an average of 3,600 AFY of total replenishment needed from 2024-2035.

Prior to the MPWSP Desal plant coming online in WY 2030, even during the very wet period there is no multi-year banking of ASR water stored because any ASR injection during wet years is withdrawn the following year to meet the increasing demand. Even after the Desal Plant comes online in 2030, any ASR water injected is withdrawn that same year to keep pace with the increasing demand, and Desal water is only used when all banked ASR has been withdrawn.

Surprisingly, in the later part of the simulation, less additional replenishment would be needed, and there are even years with surplus Net Recharge relative to the Baseline Scenario. This appears to result from water from the MPWSP Desal plant supplying the higher demands during the simulated prolonged drought period at the end of the simulation, whereas in the Baseline simulation that water must come from the withdrawal of banked ASR and/or PWM water. The surplus would not offset the much larger volumes that would need be added to offset the net deficit from the first part of the simulation period, but it does show how the additional supply of

MPWSP Desal water could be used in the future to reduce having to withdraw all the banked water during prolonged drought periods.

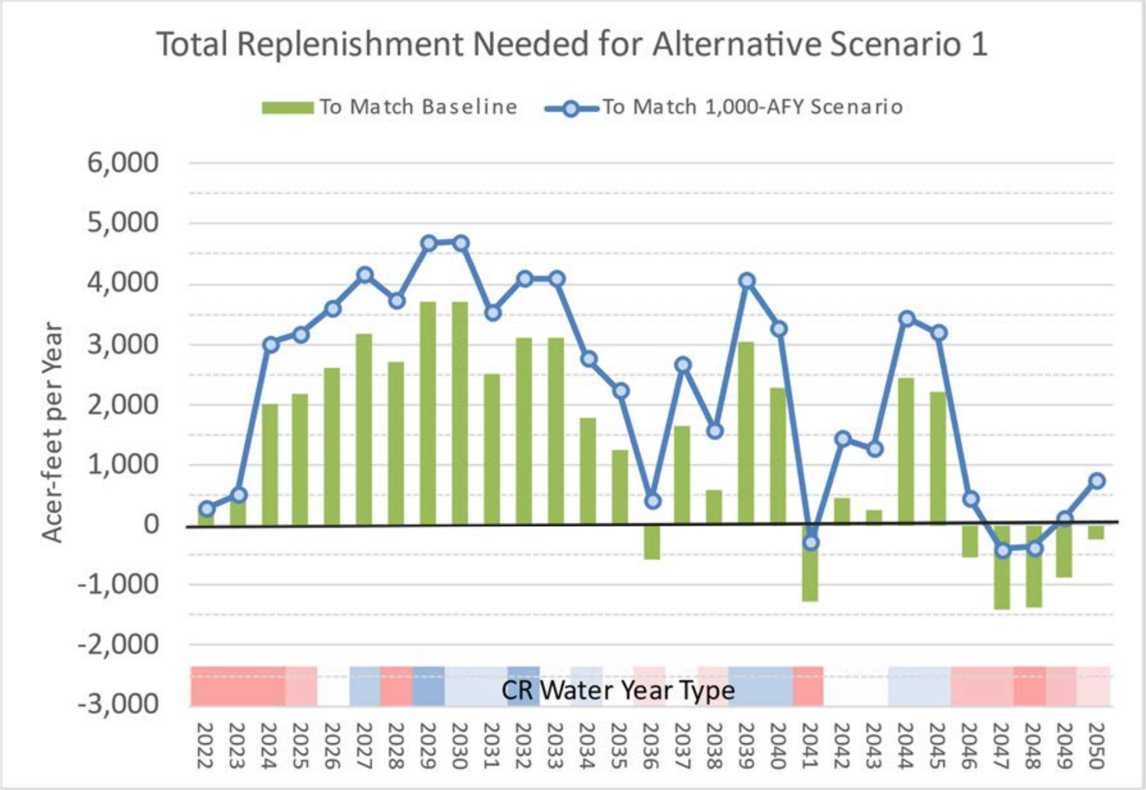


Figure 21. Additional Annual Replenishment Needed for Alternative Scenario 1 to Match Baseline Net Recharge

CONCLUSIONS

Water Budget Analysis

1. An important finding from the water budget analysis of the Baseline Scenario on an aquifer-by-aquifer basis is that Shallow Aquifer recharge from percolation of rainfall and irrigation return flows during periods of higher-than-normal rainfall plays a large role in driving the large steady increases in groundwater levels simulated in the Shallow Aquifer in the first 15 years of the simulation period. The temporal pattern and magnitudes of inflow from deep percolation in the Shallow Aquifer is highly correlated with the temporal pattern of total annual rainfall in the basin. Recharge from percolation in the Shallow Aquifer thus plays a role analogous to that of ASR injection in the Deep Aquifer because the simulated Carmel River hydrology record drives the rapid increase in water levels in the Deep Aquifer during this period.

2. Net injection of ASR and PWM water to the Deep Aquifer itself does not appear to be a significant driver for simulated increases in groundwater levels in the Shallow Aquifer observed during the Baseline Scenario. Rather the increase appears to be driven by the following.
    - The reduction by more than half of pumping from wells screened in the Paso Robles aquifer (Shallow Aquifer), due to the City of Seaside's switch to recycled water for golf course irrigation in WY 2023 and Cal-Am's switch to new higher capacity, Deep Aquifer production wells as part of the PWM Expansion project, in combination with:
        - a multi-year period of normal or higher than normal annual rainfall, and
        - the ongoing recharge of PWM water through the shallow vadose zone wells and backflush percolation ponds.
3. A net annual volume of between 200 to 500 AFY flows out from the Shallow Aquifer to the Monterey Subbasin once water levels in the Shallow Aquifers begin to rise, driven by the increasing relative gradients between the groundwater levels in the Northern Coastal Subarea and the lower groundwater levels in the Monterey Subbasin. A similar magnitude of net outflow occurs to the offshore portions of the Shallow Aquifer.
4. The water budget analysis of the Deep Aquifer shows a larger magnitude of net outflows to the Monterey Subbasin (600-1,700 AFY) as groundwater levels rise, and surprisingly, even a small amount of net out flow to the overlying Shallow Aquifer as Deep Aquifer during peak periods when Deep Aquifer groundwater levels rise above the levels in the Shallow Aquifer. The contribution of flow from the Deep Aquifer to the Shallow Aquifer increases in the 1,000-AFY Replenishment Scenario, though is still relatively small contribution compared with the inflows to the Shallow Aquifer from percolation of rainfall during wet years.
5. Under the assumption that groundwater levels in the Monterey Subbasin do not rise, the analysis shows that outflows to the Monterey Subbasin will increase in all aquifers as groundwater levels in the Seaside Subbasin rise. An initial net inflow of water from the offshore region into the Seaside subbasin reverses to a net outflow in all aquifers as groundwater levels increase, with the largest net outflows occurring in the Aromas Sands and Older Dune Deposits, and the next largest net outflows to offshore region being in the Shallow Aquifer. Projected sea level rise is not a significant driver of inland flows relative to the larger changes in water levels associated with changes in injection and extraction in the subbasin.

6. The implications of the strong dependence on recharge from percolation of rainfall for raising the Shallow Aquifer levels are two-fold:
    a. First it may be advisable to consider and evaluate options for direct recharge of the Shallow Aquifer, rather than relying only on replenishment to the Deep Aquifer via injection wells in the Santa Margarita Formation, in addition to considering other reductions to pumping in the Shallow Aquifer, such as constructing replacement wells only in the Deep Aquifer and switching other irrigation operations to use recycled water (e.g., Mission Memorial).
    b. Secondly, this strong dependence on direct percolation from rainfall for increasing Shallow Aquifer water levels suggests that simply assuming a lower Carmel River ASR diversion rate while maintaining the same cycled hydrology record is not a substitute for more a comprehensive evaluation on the impact of climate change on hydrologic inputs to the subbasin. The complex interplay and alternating cross-flows seen through the water budget analysis suggests that there are limits to the type of alternate scenarios that could be evaluated using the hybrid water budget approach and that this approach is better suited to evaluating changes in net supply and demand, rather than on evaluating alternate climate conditions.
7. The results of the water budget analysis highlight that assumptions regarding groundwater conditions in the adjacent Monterey Subbasin have a big effect on the amount of replenishment water needed. For the simulated conditions, outflow to the Monterey Subbasin is the single largest net outflow from the Seaside Subbasin in most years. The boundary conditions for the Baseline Scenario assumed water levels along the boundary between the Monterey Subbasin and the 180-400 Foot Aquifer subbasin stay fixed at recent levels and does not assume any management actions are taken to increase groundwater levels in these neighboring subbasins during the simulation period. As groundwater levels in the Seaside subbasin begin to rise in response to increased recharge, steeper gradients develop towards the Monterey Subbasin, producing increased outflows to the Monterey Subbasin. A fraction of the injected water that would otherwise go towards raising groundwater levels and increasing outflows to the Offshore region, instead flows out to increase groundwater levels along the boundary the Monterey Subbasin. This reduces the effectiveness of replenishment activities and necessitates greater volumes of injection to reach protective elevations than would be needed if water levels in the Monterey Subbasin were also increasing over time. In this regard, the estimated volumes of needed replenishment water are therefore conservative if future water levels in the Monterey Subbasin do not continue to drop.

8. The results of the water budget analysis also indicate that there is likely a spatial and temporal component to maximizing the efficiency of injection for the purpose of achieving protective elevations. As groundwater levels rise, the increased water levels drive flow out laterally towards surrounding areas with lower groundwater levels. The water that flows out does not disappear however, rather it begins to raise the groundwater levels in the portion of the Monterey Subbasin adjacent to the Seaside recharge wells, as part of a growing groundwater mound around centered on the recharge facilities. Continuing to grow this groundwater mound is analogous to the process of building up a mound of dry sand by pouring sand onto the tip of the mound. Not all the sand we pour at the tip goes to increasing the height of the mound, rather a portion flows down along the slopes of the mound to build up the base and sides of the mound. In our analogy, the pile of sand is sitting on an inclined platform with some flows towards the downgradient production wells and the offshore region and some flows towards the Monterey Subbasin. Increasing the replenishment rate while keeping the recharge focused in a narrow strip of the Seaside subbasin likely results in very steep localized mound that quickly starts spilling over, so to speak, into the Monterey Subbasin. It may be that spreading the increased replenishment volume out spatially over a broader area further from the subbasin boundary could deliver the same volume of water while reducing the rate of loss.

Hybrid Water Budget Analysis of Alternative Scenario 1

1. The hybrid water budget analysis suggests that the large and rapid increases in Deep Aquifer groundwater levels simulated from WY 2024 to WY 2035 under the Baseline Simulation assumptions would not occur under the supply and demand assumptions of Alternative Scenario 1 without very large quantities of additional replenishment water injected to the basin during this period of the simulation (ranging between 1,200 and 3,700 AFY). Despite using the same hydrology, the reduced ASR diversion rate and lower PWM Expansion yield coupled with higher demand assumptions requires an average annual injection of 2,600 AFY of additional replenishment injection to have the equivalent net recharge as in the Baseline scenario.

2. It is unclear exactly what would happen to groundwater levels in the Shallow Aquifer under the Alternative Scenario 1 with no additional replenishment water injected given the new understanding that the initial rapid increases in Shallow Aquifer groundwater levels observed in the Baseline Simulation are largely driven by percolation of rainfall during wet years, rather than exclusively because of injection to the Deep Aquifer. On the one hand, simulated recharge from rainfall would stay the same, which could result in similar Shallow Aquifer

groundwater level increases, but on the other hand, there would likely be net leakage downward to the Deep Aquifer because deep groundwater levels would stay below the Shallow Aquifer levels, potentially offsetting inflows from percolation. This would require additional analysis and/or modeling to confirm. The results, however, do emphasize the large role that the assumptions on future climate conditions have on predicting how quickly groundwater levels can be raised, and how much additional replenishment water would be needed.

3. The amounts of replenishment water needed to achieve protective elevations under the Alternative Scenario 1 assumptions is significantly greater than under the Baseline Scenario assumptions. An annual average replenishment rate of 3,700 AFY, ranging from 2,200 to 4,700 AFY is needed, compared to the 1,000 AFY of replenishment needed under the Baseline assumptions. This highlights the sensitivity of predicted groundwater conditions in the Seaside basin to the assumptions that are made about future water demands, future rainfall patterns, and the availability of water supplied from outside the subbasin, including Carmel River ASR diversion, the expanded Pure Water Monterey Project, and the MPWSP Desalination Plant.

4. The effects of climate change are already visible in the changing frequency of hydrologic flows in the region. The last 100 years of Carmel River stream flow data show a marked shift in the last 50 years towards more frequent occurrence of Critically Dry and Extremely Wet water years, and fewer Normal water years, as compared to the previous 50 years. This shift will see a greater volume of water become available for ASR diversion during extreme high flow events as opposed to spread out over longer periods. The impact of a reduced ASR diversion rate in the Alternative Scenario 1 analysis makes it clear that the necessary infrastructure in terms of facilities for increased diversion capacity in the Carmel River and ideally for increased recharge capacity in the Seaside Subbasin would need to be in place to be able to capture and store these high flows when they occur.

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