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 of 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 Draft 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 injection would be needed to achieve protective elevations in the Watermaster coastal protective elevation wells. Well locations are shown on Figure 1.

The water budget analysis framework provides an overview of the net inflows and outflows to the Shallow and Deep Aquifers in the Northern Coastal Subarea, 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 (shown on Figure 2).
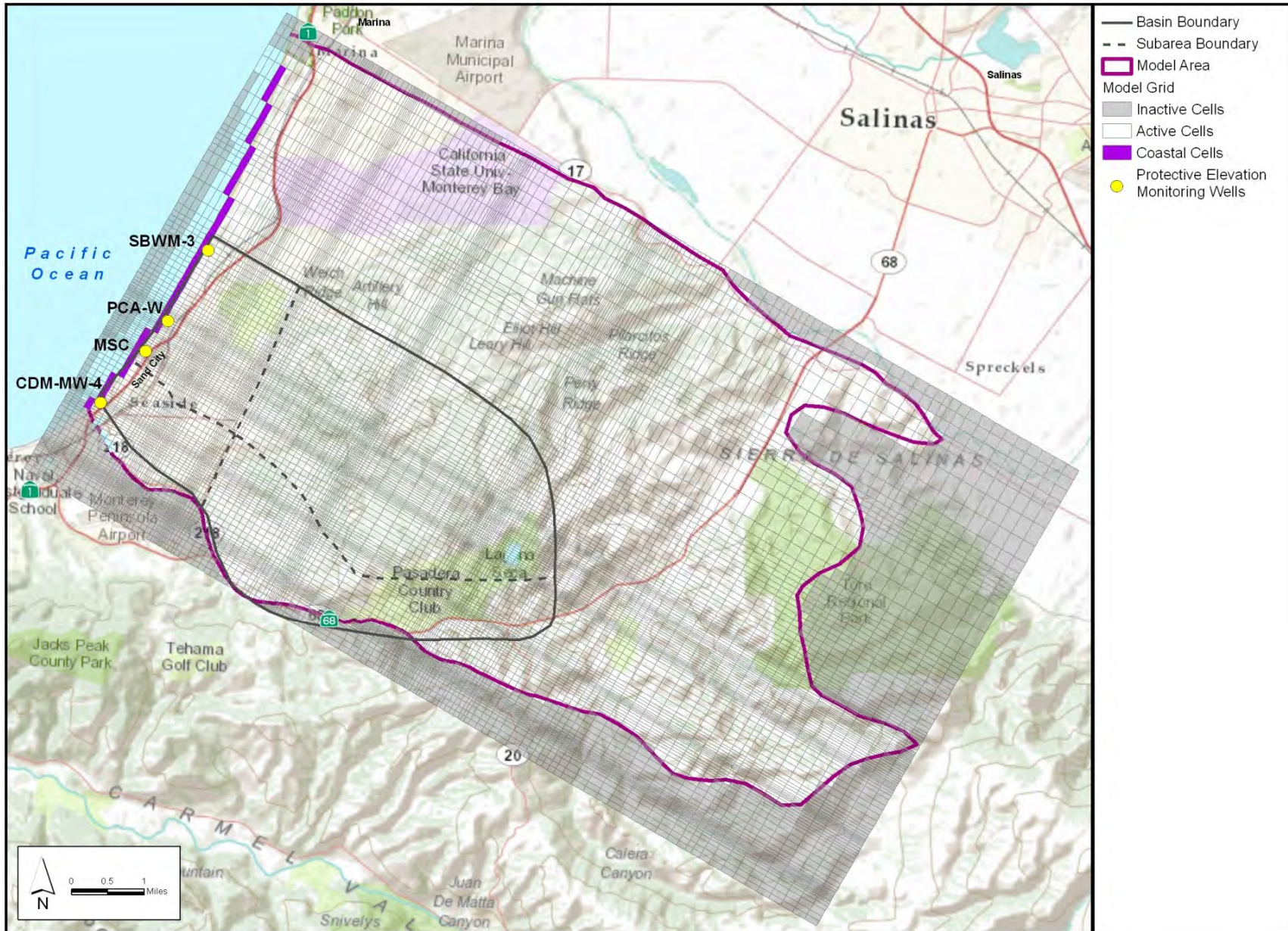
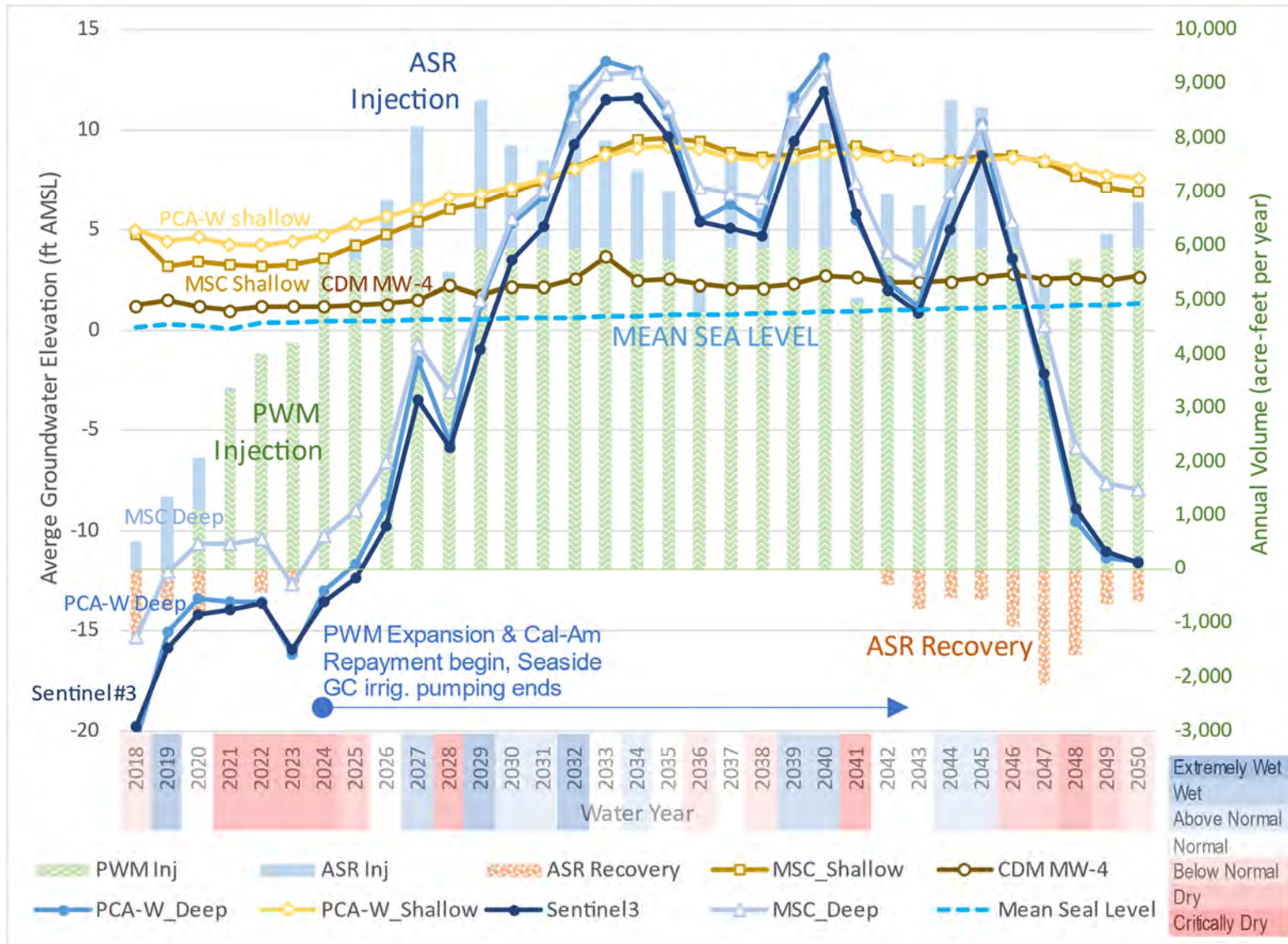Figure 1. Location of Protective Elevation Monitoring Wells

Figure 2. Annually Averaged Groundwater Elevations in Protective Elevation Wells Compared to PWM and ASR Injection and ASR Recovery (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 projected pumping, currently planned projects, and a repeated historical hydrology record. The Baseline simulation hydrology (rainfall, recharge, and streamflow) is illustrated on Figure 3.
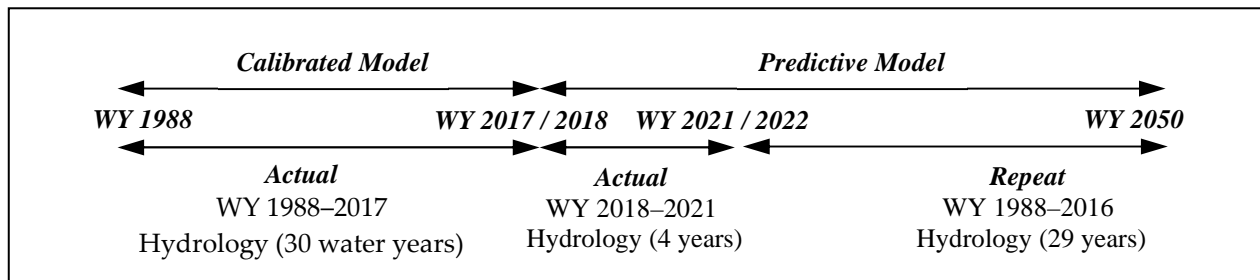
Figure 3: Repetition of Hydrology for Predictive Model

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, which is tied to the cycled hydrology and the assumption that planned upgrades to the Cal-AM Carmel Valley wellfield are completed by WY 2024

- Cal-Am's 25 year 700 AFY in-lieu replenishment begins in WY 2024

- Pure Water Monterey (PWM) Expansion project (tied to the new hydrology) begins deliveries in WY 2024 and delivers and annual average of 5,700 AFY

- Other planned projects including the City of Seaside's replacement of groundwater with recycled water for golf course irrigation in WY 2024 and the construction of the Security National Guaranty (SNG) and Campus Town developments in the City of Seaside occur

- 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 coastal Monterey and 180/400 Foot Subbasins, such 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 AF&)**
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 SIMULATION AND 1,000-AFY REPLENISHMENT SCENARIO

The water budget analysis is focused on a 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 Base and its proposed Expansion injection facilities and backflush percolation ponds. This water budget zone is shaded red on Figure 4. 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. This water budget zone was further divided vertically based on the model layering[1] into the Shallow Aquifers (consisting of model layers 1-4) and the Deep Aquifer (consisting of model layer 5). 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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[1] 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
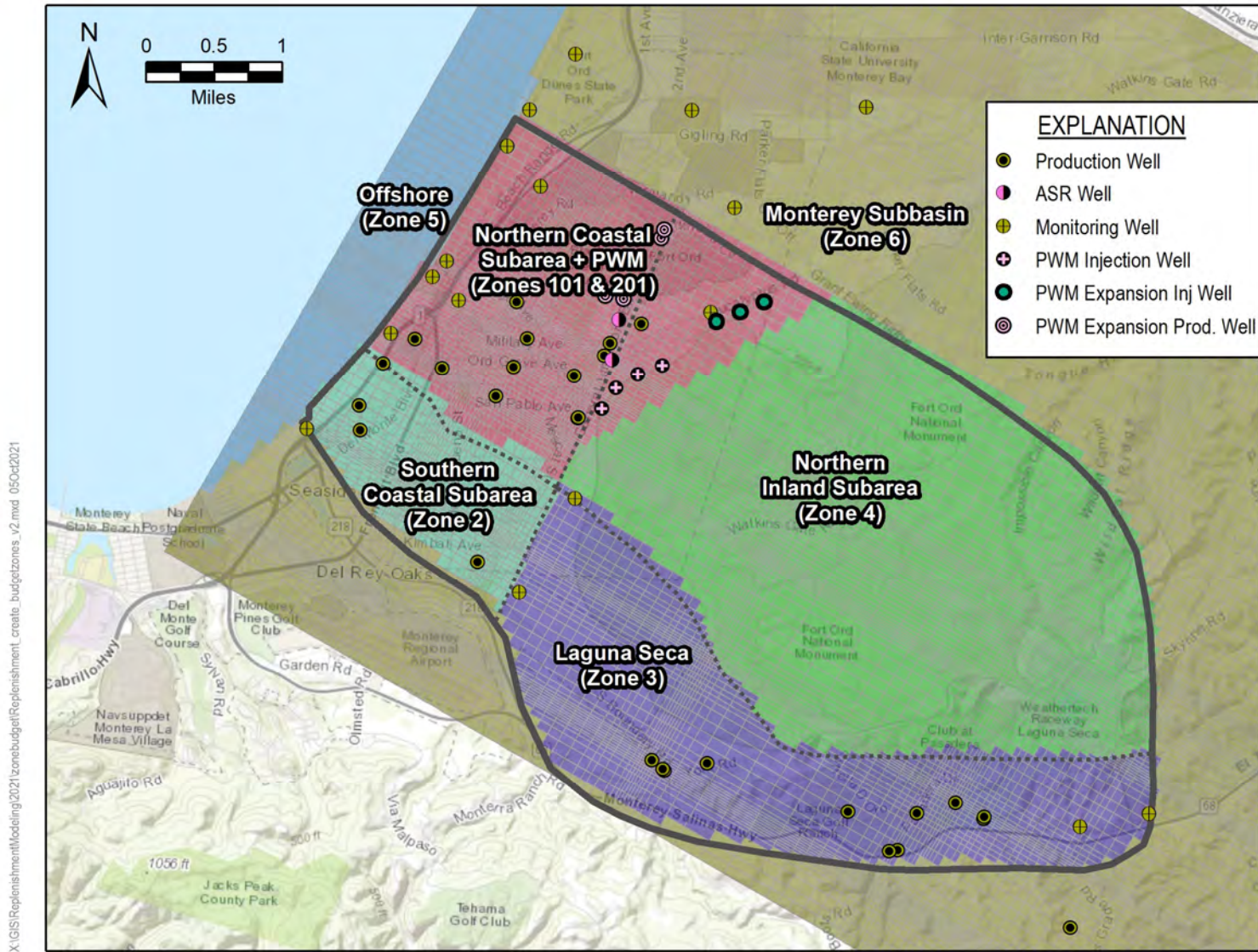
Figure 4. Map of Water Balance Zones used for Water Budget Analysis

Baseline Scenario

Shallow Aquifers Water Budget

Net Flows

Figure 5 shows the net flows to and from the Shallow Aquifer in the Northern Coastal Subarea and PWM Expansion area. The flow components include:

- Deep 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

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 Shallow 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 Shallow Aquifers and those areas or aquifers, and so can change flow directions and groundwater levels.
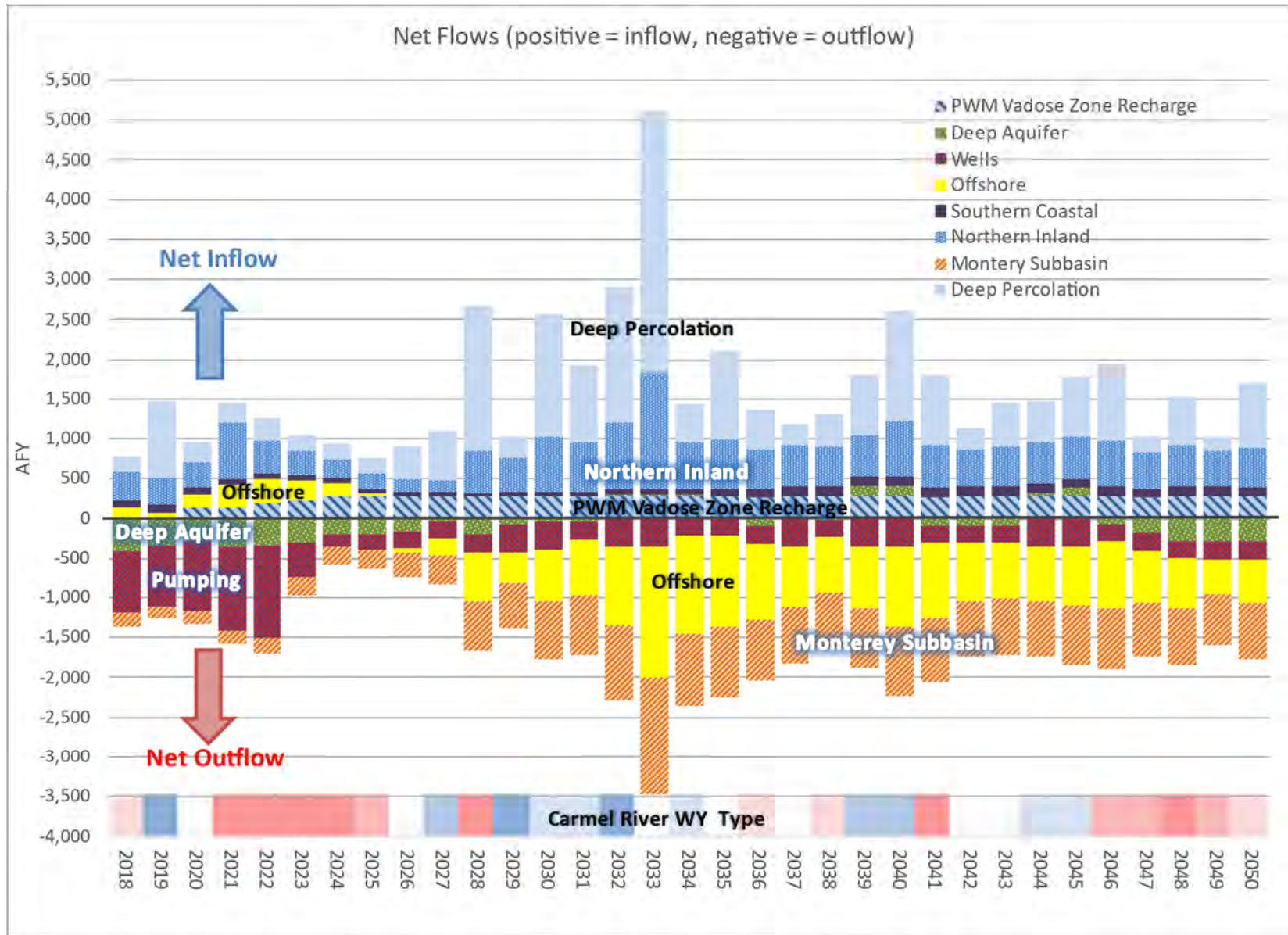
Figure 5. Net Flows to/from the Shallow Aquifers

Net Inflows

Generally, the largest inflows to the Shallow Aquifer are from rainfall dominated deep percolation and inflows from upgradient portions of the Shallow Aquifer in the Northern Inland Subarea, followed by recharge from the PWM vadose zone wells and stormwater 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 deep percolation and inflows from Northern Coastal Subarea is strongly correlated with annual precipitation in the basin, as can be seen in the graph of total simulated annual rainfall on Figure 6. The peaks and troughs in annual rainfall correspond with peaks and troughs of deep percolation and inflow from the Northern Inland Subarea[2], with the peak recharge occurring in WY 2033 which has 38 inches of total rainfall[3], resulting in 3,281 AF of deep percolation and 1,456 AF of inflow from the Northern Coastal Subarea that year. Figure 6 also shows the cumulative rainfall departure curve (CRD), which represents the cumulative sum of rainfall over the simulation period, zeroed to the mean annual rainfall during the simulation period. The trend of the peaks and valley in the CRD curve largely follow the groundwater level trends observed in the hydrographs of the Shallow Aquifer wells.

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[2] Note that 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 of the charts which is based on streamflow in the Carmel River rather than on rainfall in the Seaside Basin.
[3] The hydrology of simulated WY 2033 is based on the historical hydrology from WY 1999.
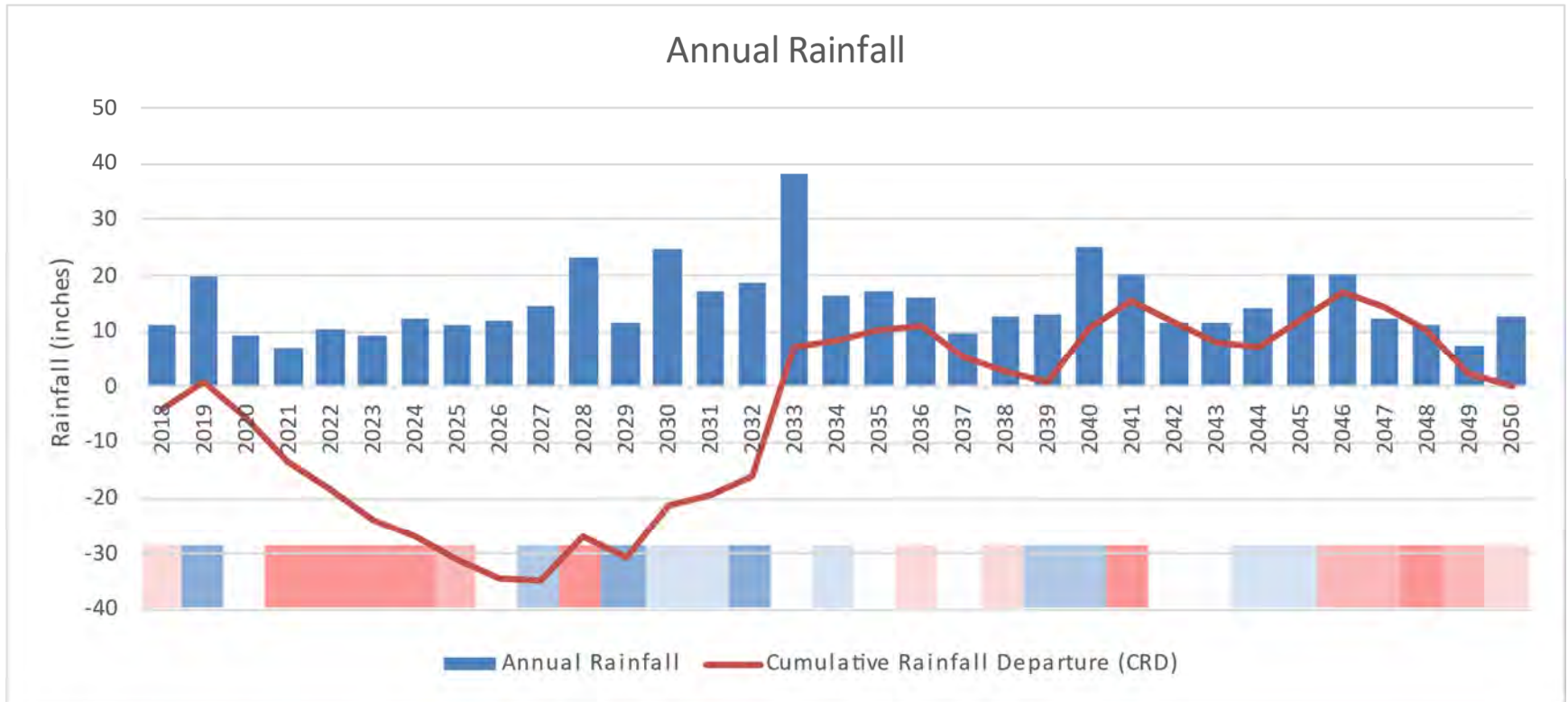
Figure 6. Simulated Annual Rainfall and Cumulative Rainfall Departure

Net Outflows

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 exceed inflows, with exception of WY 2019 which had high rainfall, and groundwater levels remain 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 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 7 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.
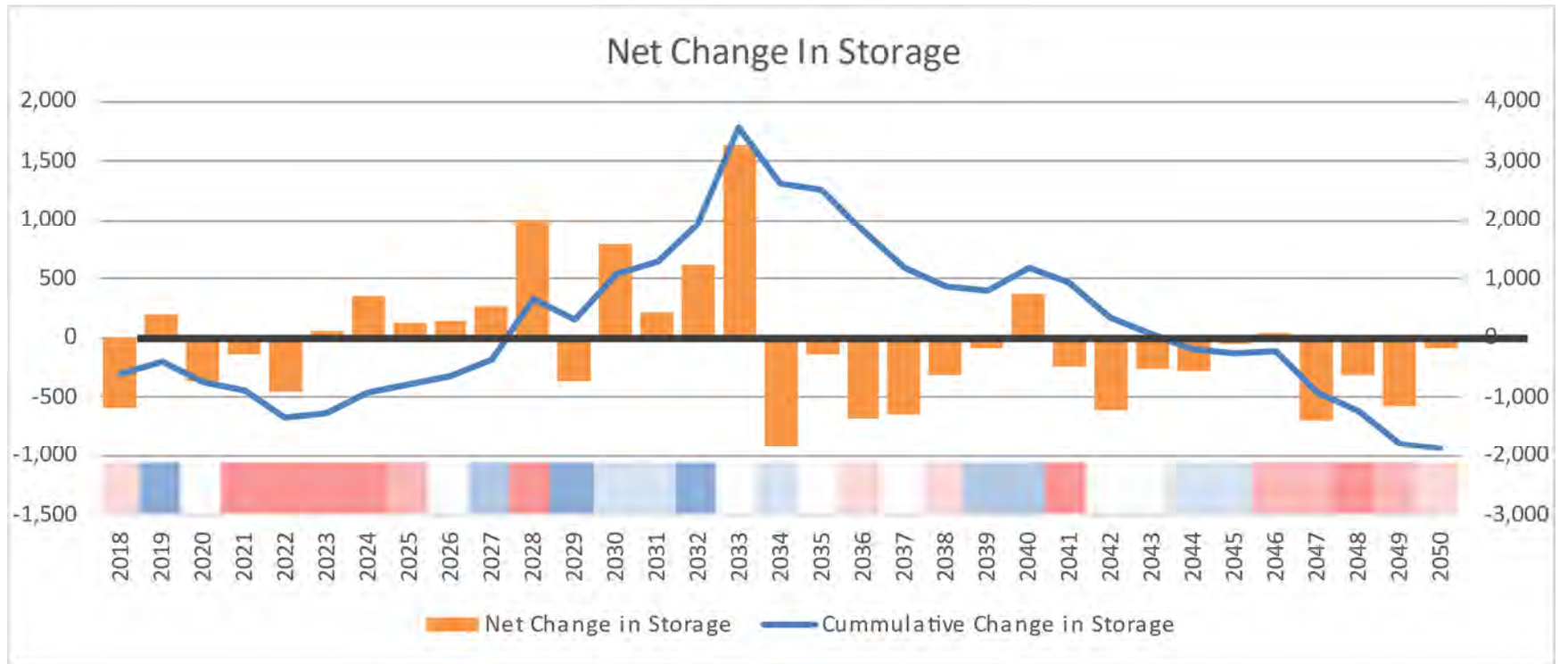
Figure 7. Net Change in Storage (Net Inflow – Net Outflows) and Cumulative Net Change in Storage in Shallow Aquifers

Deep Aquifer Water Budget

Net Flows

Figure 8 shows net flows to and from the Deep Aquifer in the Northern Coastal and PWM Expansion subarea. The flow components include:

- Net pumping (injection or extraction) from wells in the Deep Aquifer, represented as the difference between the total injection of PWM and ASR water and total extraction of native groundwater and recovery of PWM and ASR water. Net pumping is positive and represents a net inflow when total annual injections exceed the total extraction, and is negative (a net outflow) when annual extraction exceeds annual injection

- 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 from outflows 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 Deep Aquifer during periods when the groundwater levels in the Deep Aquifer are lower than the groundwater levels in the Shallow Aquifer
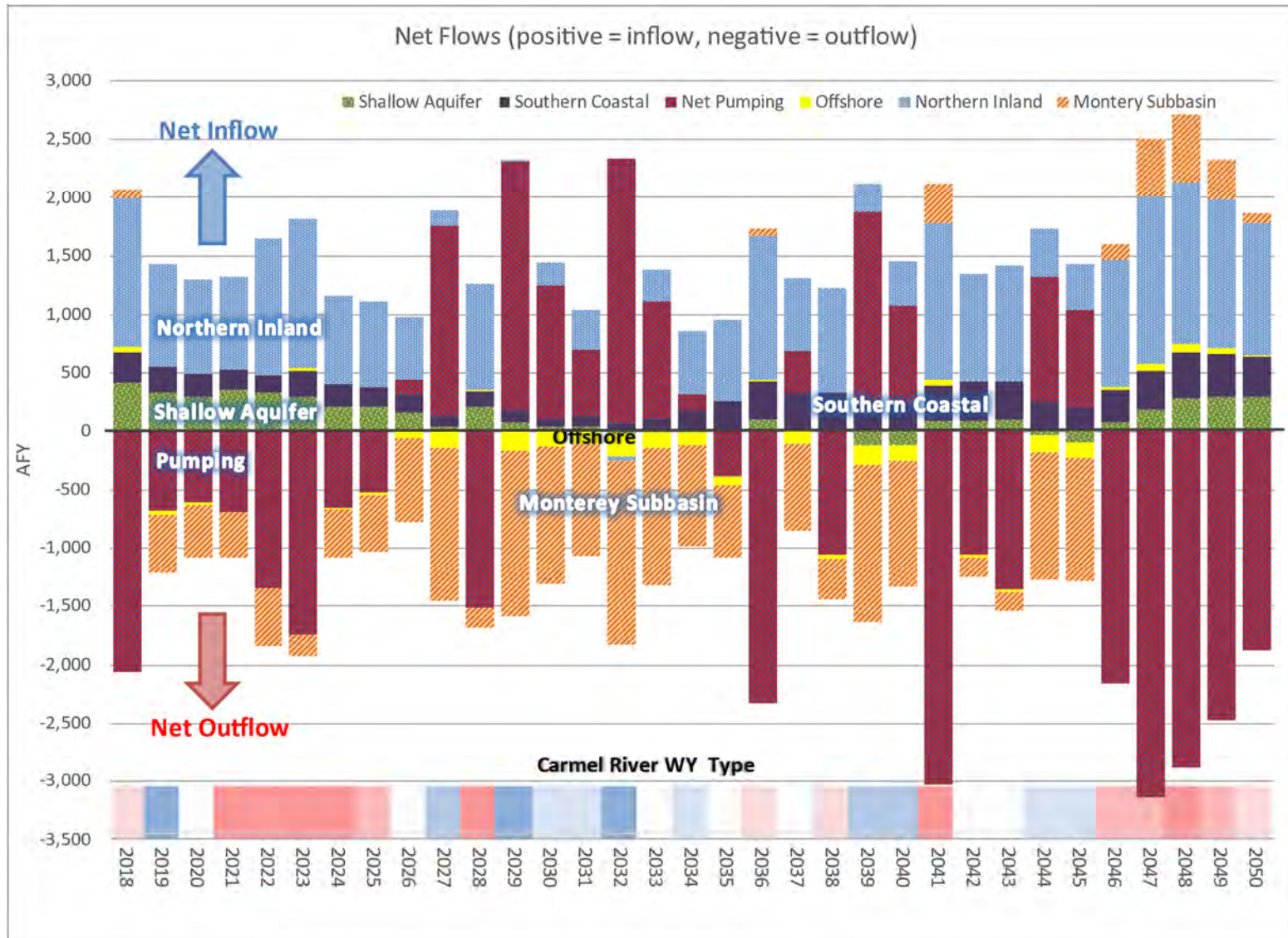
Figure 8. Net Flows to/from the Deep Aquifer (Positive = Inflow, Negative = Outflow)

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 are consistent with the conceptualization that downward flow of saltwater intrusion from Shallow Aquifer poses a potential pathway for saltwater intrusion. The relatively small magnitude of net flows from the Offshore region to and from the Deep Aquifer relative to larger magnitude of net inflow from the overlying Shallow Aquifer are also consistent with the modeled conceptualization that Deep Aquifer is not well connected to the ocean.

Net Pumping

Figure 9 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 Extremely Wet) 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 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 correspond to the entire volume of net-injection going into storage to raise groundwater levels. Rather, only about 500 AF went towards the net increase in storage to raise groundwater levels, while 1,800 AF of water flows 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 Subarea. By contrast, WY 2029 was also an Extremely Wet Carmel River water year with a net injection also close to 2,300 AF, but in this case, a larger volume of 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 outflow offshore region and towards the Monterey Subbasin.
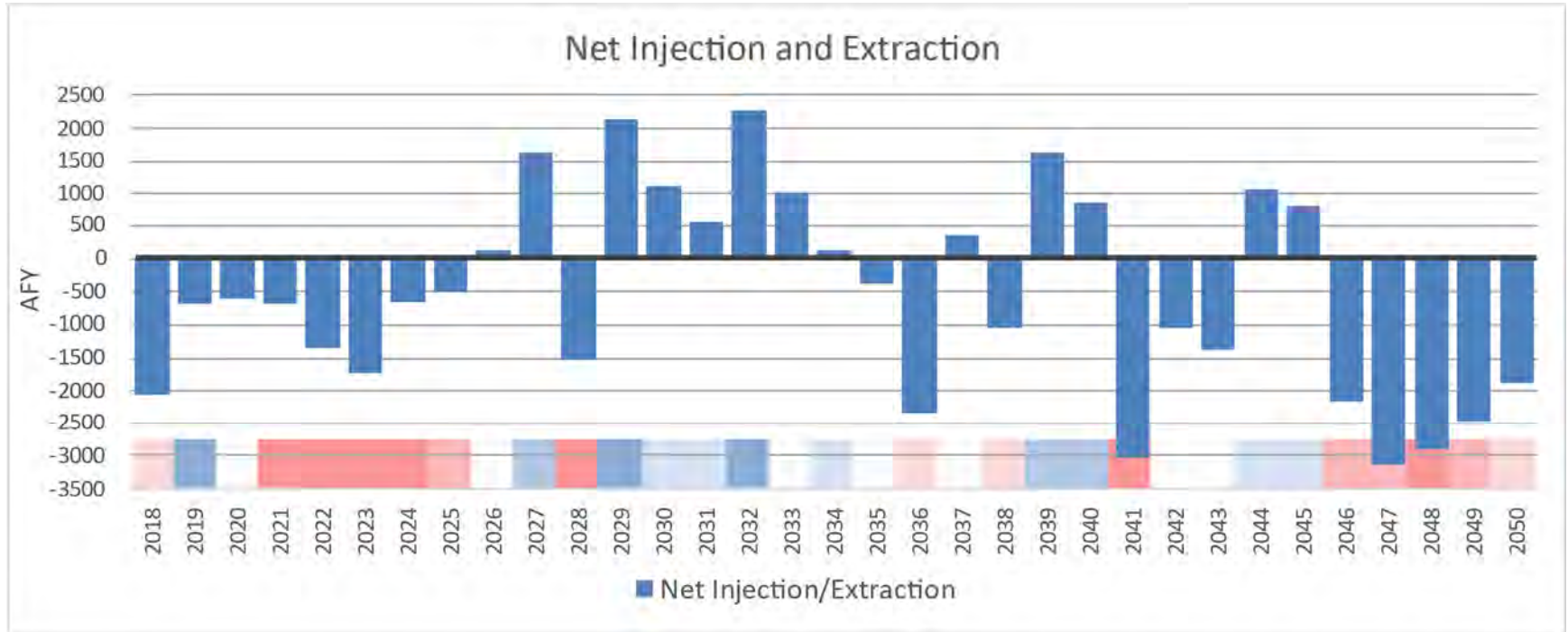
Figure 9. Annual Net Pumping (Positive = Net Injetion, Negative = Net Extraction)

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, the groundwater level is essentially pinned by sea level, and so outward flows continues as long as inland groundwater levels are greater. In the Monterey Subbasin, however, groundwater levels are not pinned. So as groundwater levels in Monterey Subbasin rise or fall, either in response to the outflows coming from the Seaside Basin or because of water management actions taken in the Monterey Subbasin, the amount of outflow lost from the Seaside Basin will increase or decrease.

Net Change in Storage

Figure 10 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 the hydrographs in Figure 2, showing the same rises and falls.

If the Northern 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 8.

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. And inflows from the neighboring subareas drop, because of reduced gradient relative to the groundwater levels in those area. 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 closed, because the depressed groundwater levels start to induce increased inflows from upgradient in the Northern Inland Subarea, the Southern Coastal Subarea, Offshore region, and even produce a significant net inflow from the Monterey Subbasin.
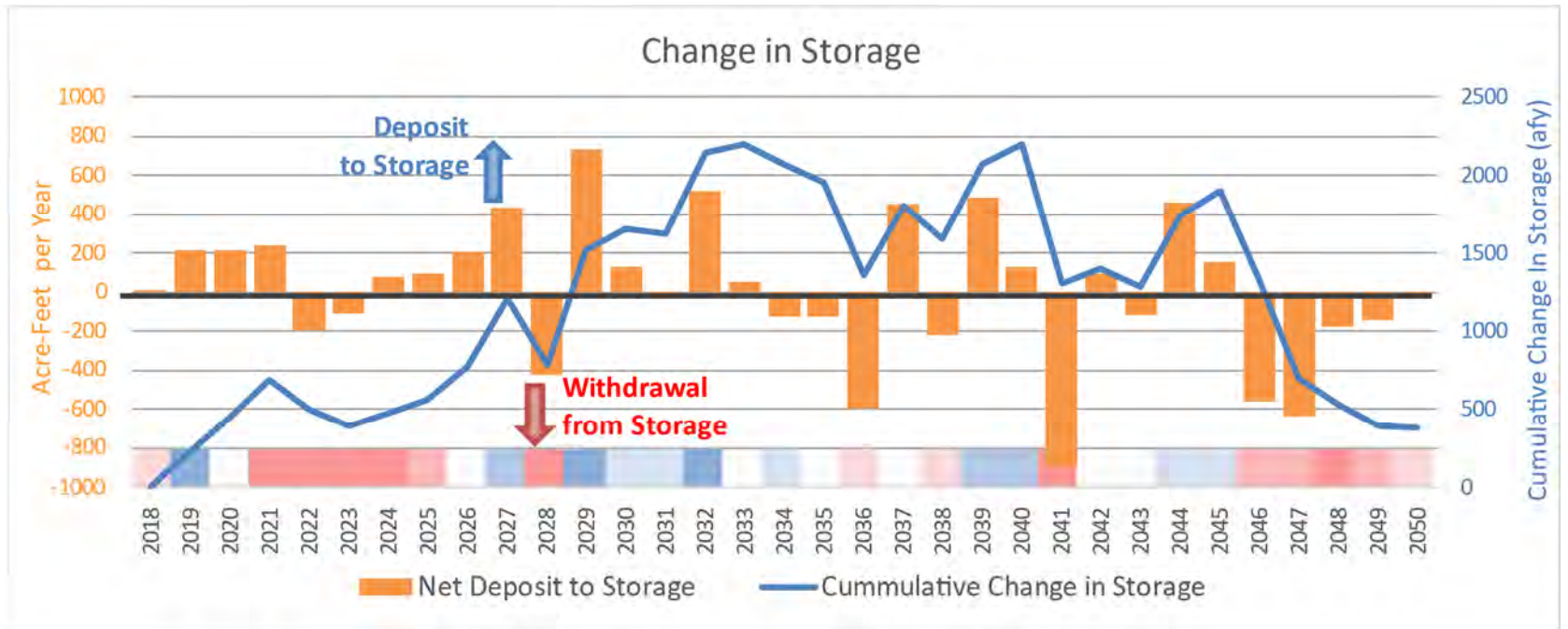
Figure 10. Net Change in Storage (Net Inflow – Net Outflows) and Cumulative Net Change in Storage in Deep Aquifer

Changes in Net Flows from 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 are injected into the Deep Aquifer starting in WY 2024 when the PWM Expansion Project begins. The purpose of this is to understand how additional replenishment affects crossflows with the Monterey Subbasin, Offshore regions and adjacent Subareas, and the amount of water going into storage to raise groundwater levels, relative to the Baseline simulation. The results, in terms of change in net flows compared to the Baseline scenario, are shown for the Deep Aquifer on Figure 11 and for the Shallow Aquifer on Figure 12.

In the Deep Aquifer (Figure 12), the 1,000 AFY increase in net-injection initially results in a substantial increase of water going into storage (orange columns) raising groundwater levels, but the magnitude of increase subsides as groundwater levels rise, which in turn 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 12 shows the changes in net flows that occur in the Shallow Aquifer as a result of adding 1,000 AFY of replenishment 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, which results in further increased groundwater levels in the Shallow Aquifer. Most of the inflow translates into increased outflows to the Offshore Area, and to a smaller degree by 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.
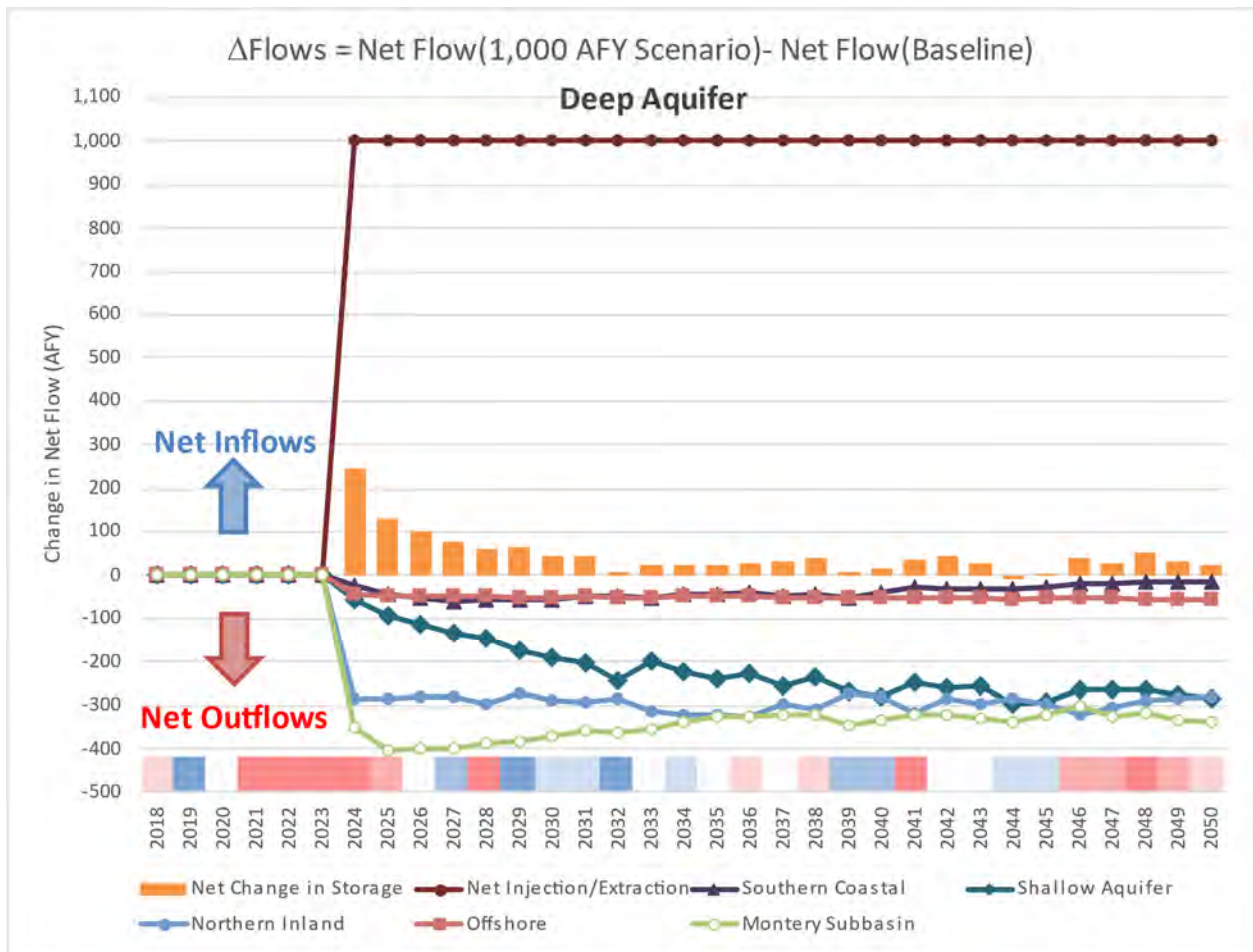
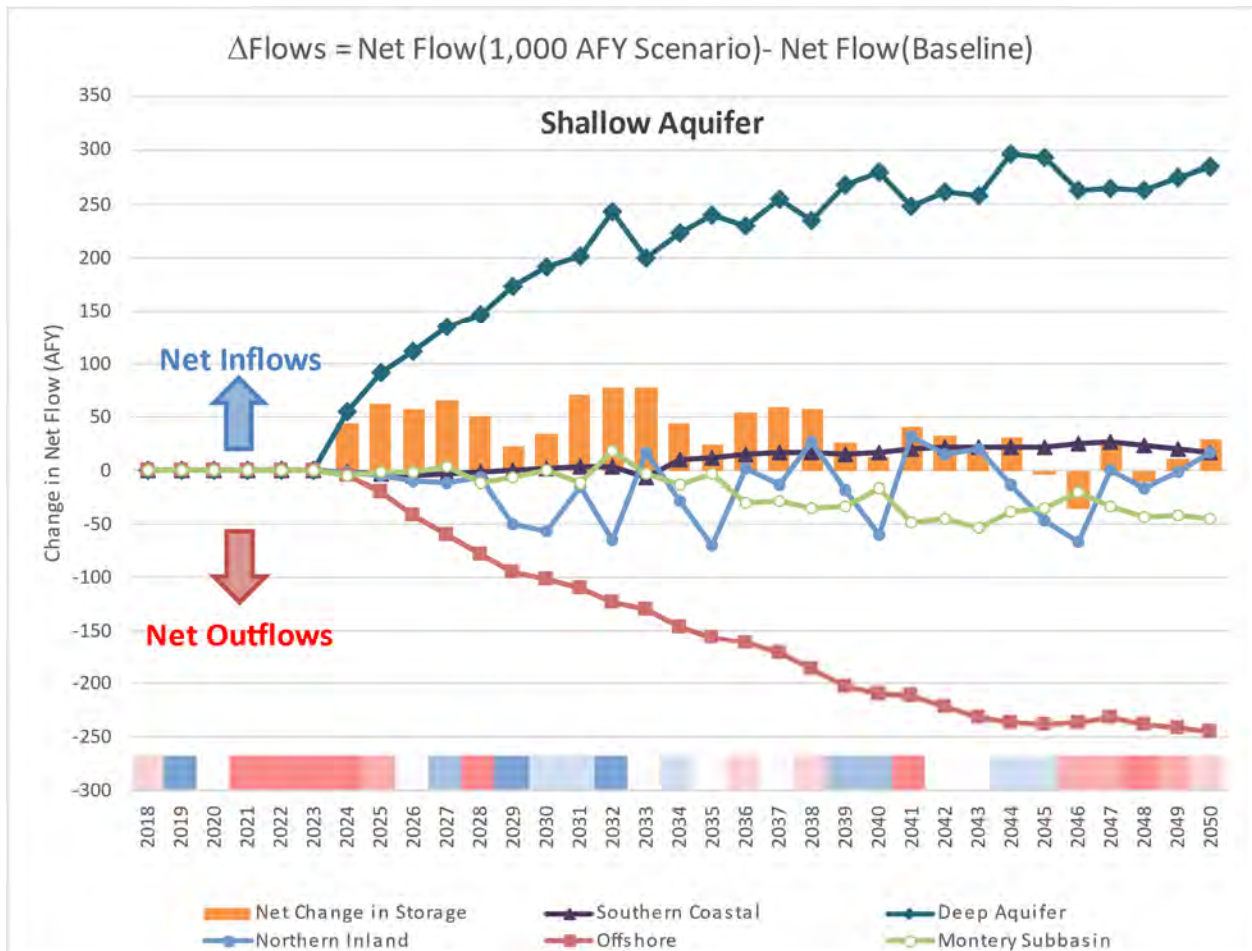Figure 11. Deep Aquifer: Change in Net Flows between Baseline and 1,000 AFY Replenishment Scenarios

Figure 12. 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

Members of the Seaside Technical Advisory Committee (TAC) would like to evaluate the impact of an alternate set of future supply and demand assumptions has on the volume of replenishment water needed to increase groundwater levels at the protective elevations coastal monitoring wells. The alternate demand and supply assumptions are based primarily on Cal-Am's 2020 Urban Water Management Plan (UWMP) (WSC, 2020), 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 TM.

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 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 municipal pumping allocation currently supplied by pumping of Seaside Muni Well #4. So conservatively if the full 514 AFY of SPA 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 hybrid 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, 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. 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

Figure 14 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/7,5700 AF = 81% of the Baseline PWM injection volume. Note that in the Alternative Scnenario1 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 13. 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.
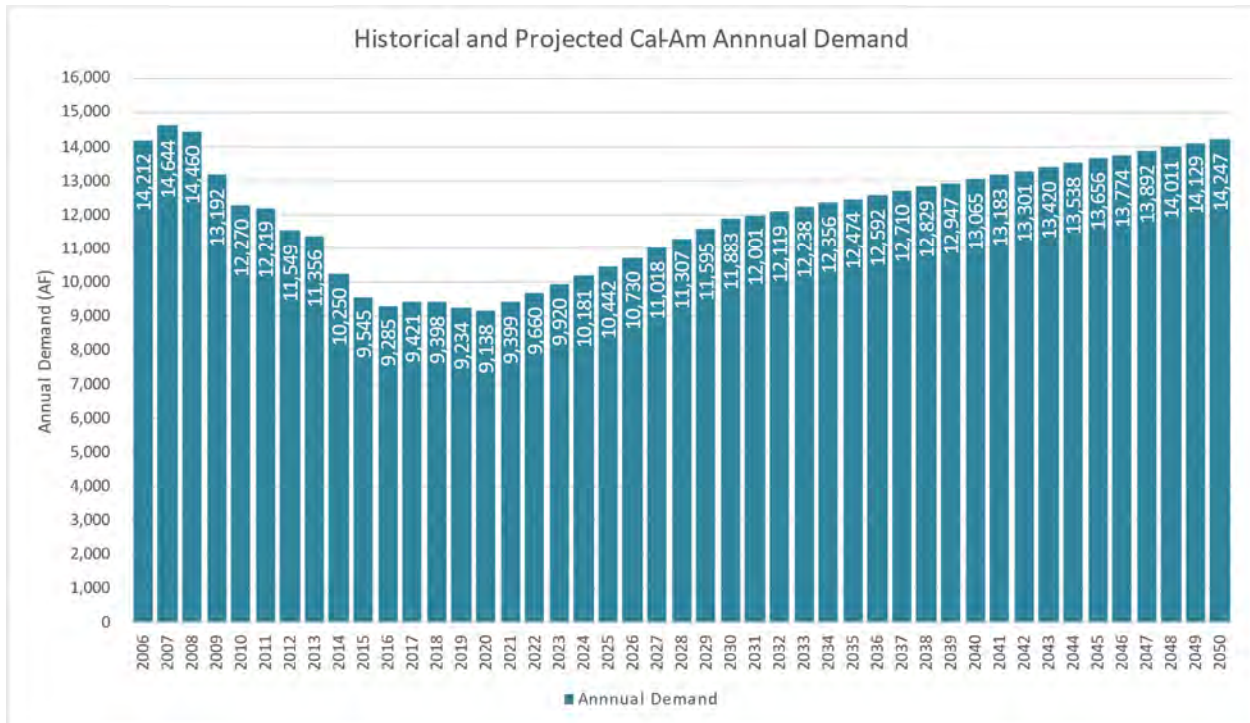

Figure 13. Historical (WY 2006-2020) and Projected (WY 2020-2050) Cal-Am Total System Demand Based on 2020 UWMP Assumption

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 15 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 16 shows the projected annual Seaside 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 till that year. Because of the combination of the assumed higher system demand, and assumptions on reduced volume of ASR and PWM injection during this early simulated drought period, there is a supply shortfall from 2023-2029 until the MPWSP Desal 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 Desal Plant comes online, despite the increased system demand, the average total pumping from the Seaside basin is lower than in the Baseline, because an increasing portion of the higher demand is supplied directly by Desal. This is especially evident during the simulated drought period towards the end of simulation, where a large portion of demand is met by Desal instead of pumping because there is not a built-up bank of ASR water from which to recover water.

Figure 17 shows the annual net injection of PWM and ASR water for both scenarios, defined as the difference between the total annual ASR and PWM injection 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.
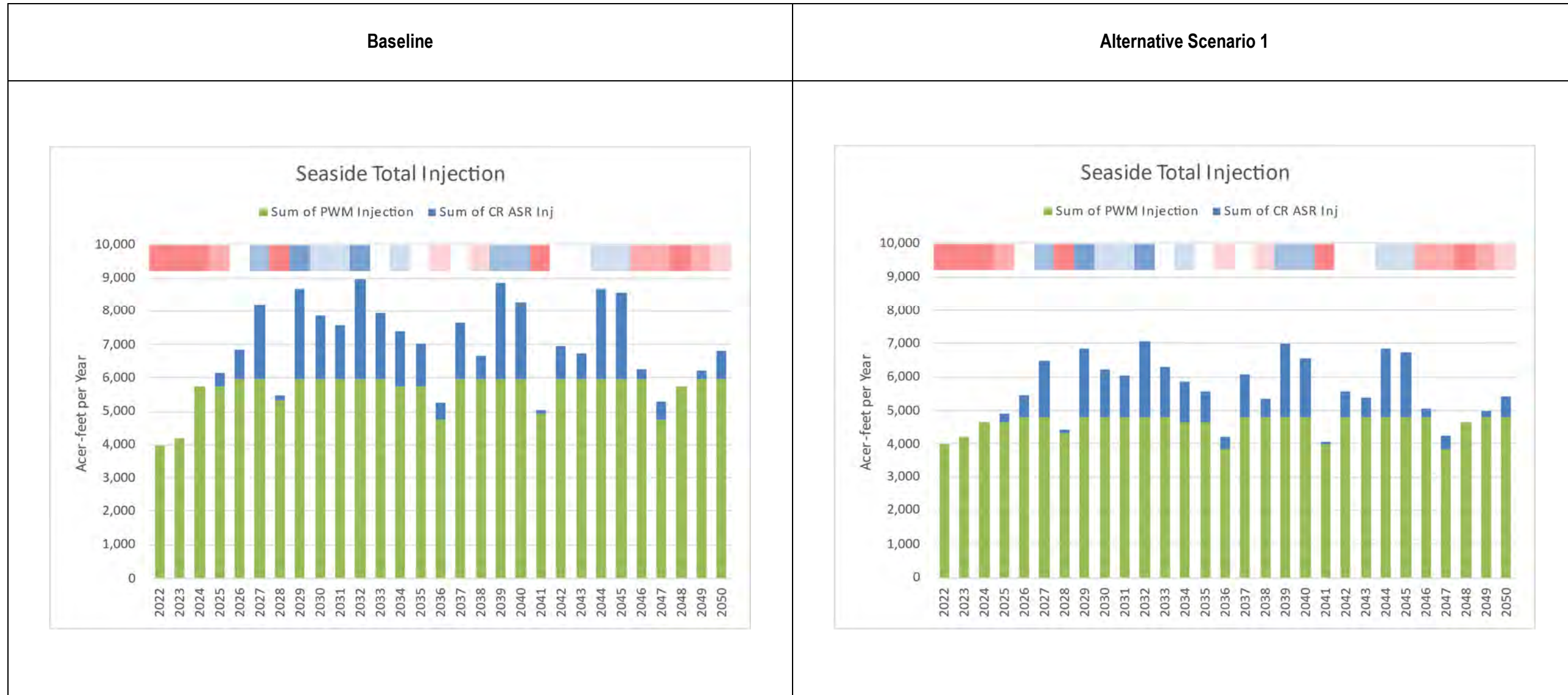
Baseline	Alternative Scenario 1

Figure 14. Projected Total Annual Injection of PWM and Carmel River ASR Water for Baseline and Alternative Scenario 1
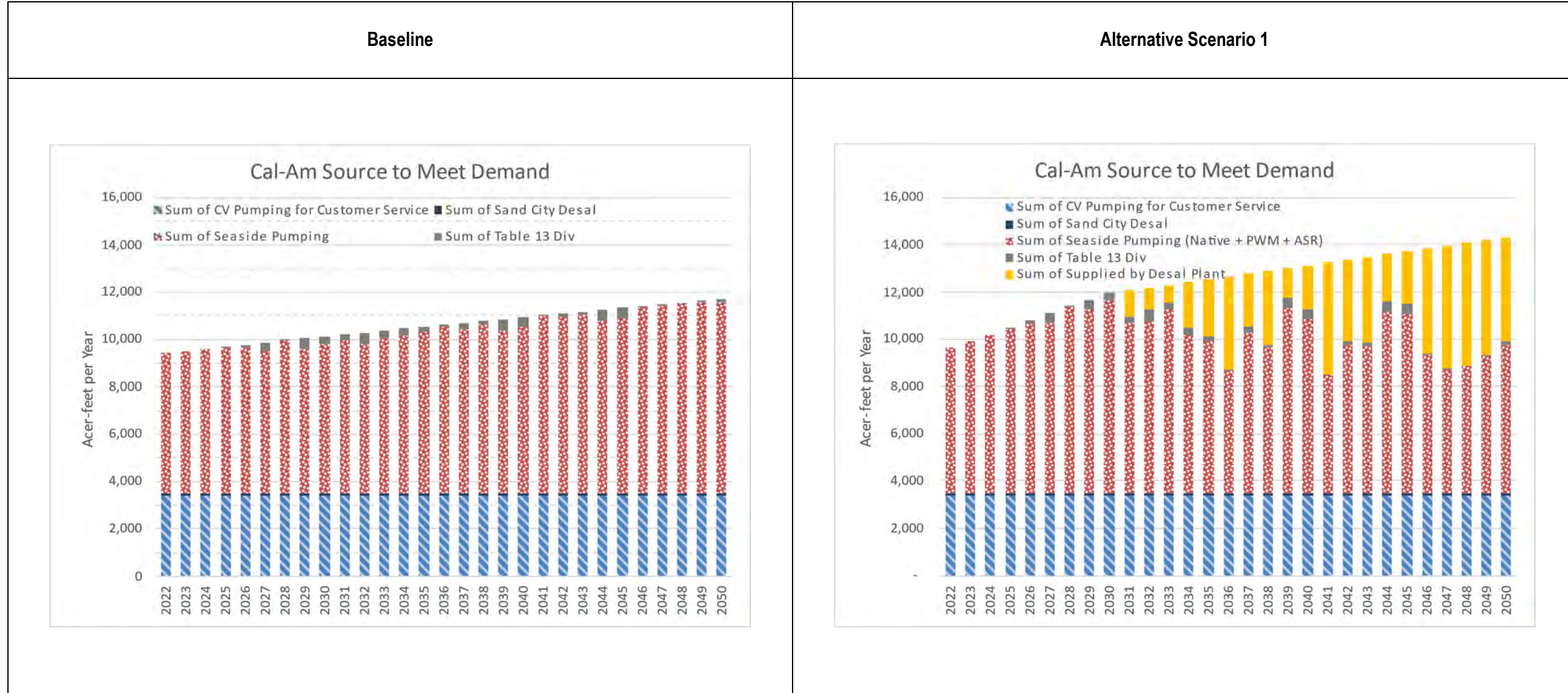
Baseline	Alternative Scenario 1

Figure 15. Projected Cal-Am Total Annual System Demand and Water Supply Source for Baseline and Alternative Scenario 1
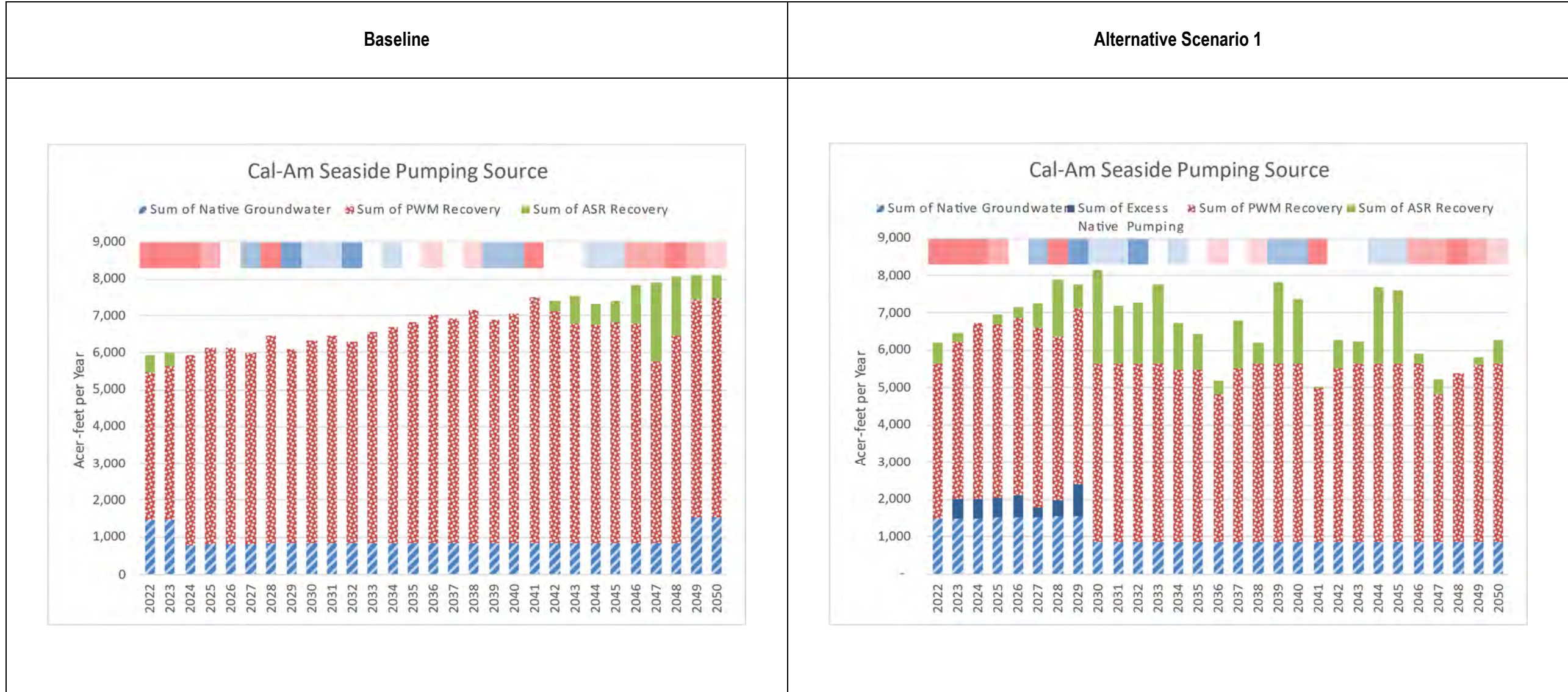
Baseline	Alternative Scenario 1

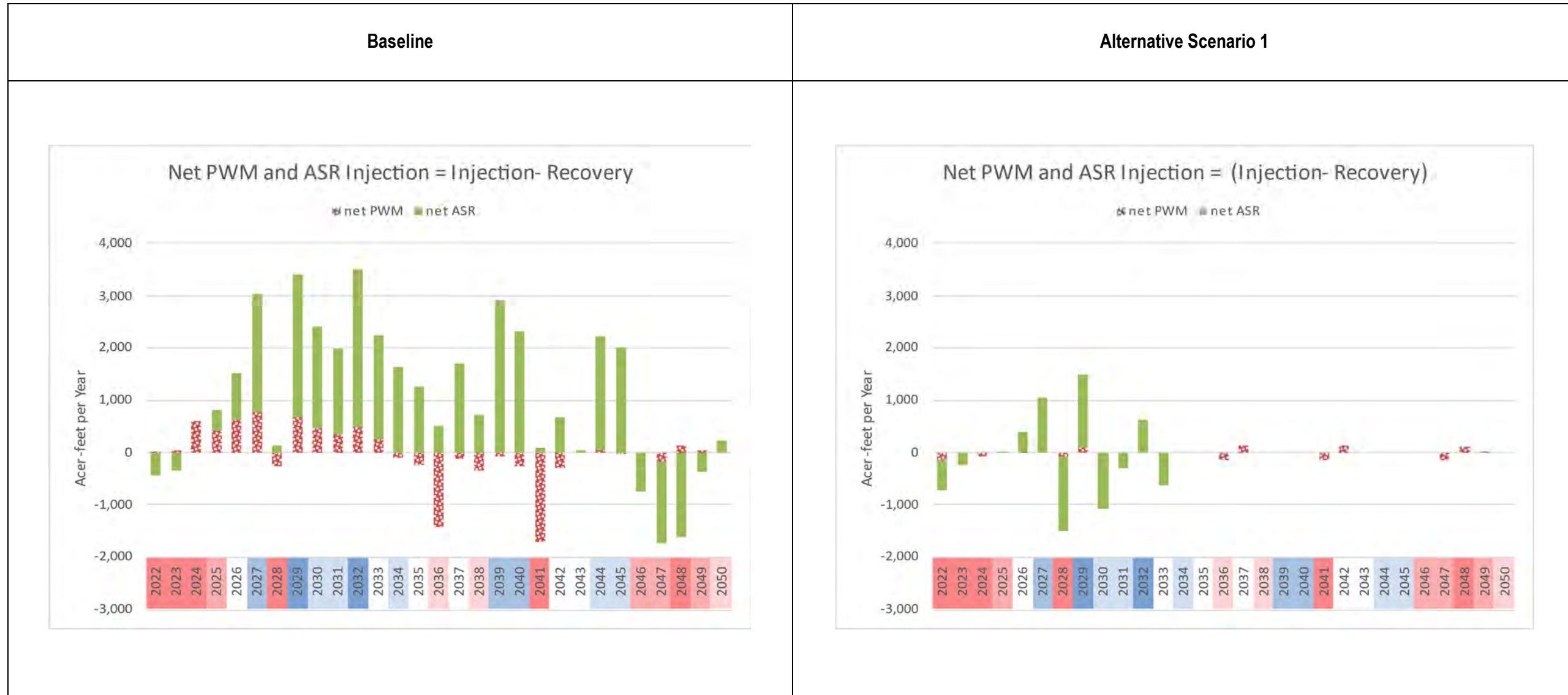Figure 16. Projected Cal-Am Seaside Pumping by Water Source for Baseline and Alternative Scenario 1

Baseline	Alternative Scenario 1

Figure 17. Projected Net PWM and ASR Injection for Baseline and Alternative Scenario 1

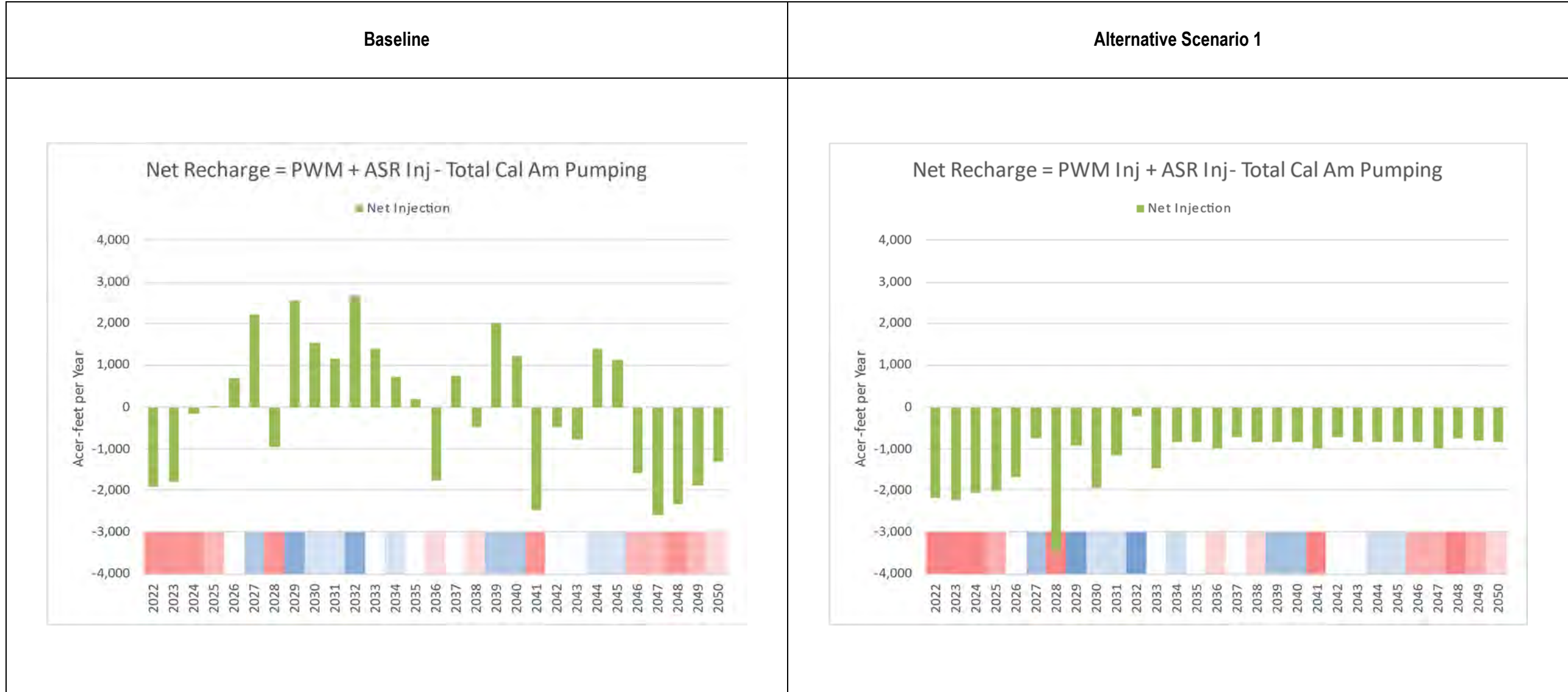|	
Baseline	**Alternative Scenario 1**

Figure 18. Projected Net Recharge for Baseline and Alternative Scenario 1

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

Running additional alternative baseline 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 scenarios is to use a hybrid water-budget-based approach leveraging information available from the already run Baseline simulation and combine 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 order of magnitude estimates for the range of needed annual replenishment volumes 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, we can define the net recharge as follows:

$$Net\ Recharge = \ PWM\ Injection + ASR\ Injection + Replenishment$$
$$- Total\ Cal\text{-}Am\ \&\ Seaside\ Production$$

For the Baseline simulation and Alternative Scenario 1, the Replenishment term is equal to zero. Additional replenishment scenarios can be included by adding in the replenishment amount. 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. We can conceptualize that if future climate conditions cannot provide this amount of ASR injection shown each year in the January 2022 modeling, or if there is increased system demand that requires that 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 how much net recharge is 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 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.

As discussed during the April TAC meeting, 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 TAC 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 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. Additionally, injection wells are all located upgradient of the recovery and extraction wells. This spatial proximity and configuration allow for use of an annual effective injection rate concept at the subarea scale when considering the evolution of groundwater levels downgradient of the extraction wells. If the extraction wells were located very far from the injection wells, in a different aquifer than the injection well, or all in different portions of the basin, or if the recovery wells were upgradient of the injection wells, then it would be less appropriate to use an effective net injection rate approach for this analysis. This approach is still a simplification with 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 18 shows the calculated annual Net Recharge (as defined above) for the Baseline Simulation and Alternative Scenario 1. For the Baseline Simulation, the Net Recharge plot is very similar to the plot of Net Pumping in the Deep Aquifer shown on Figure 9. For 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 needed to be added each year in the Alternative Scenario 1 to have the same Net Recharge as the Baseline Simulation is calculated by the difference in Net Recharge for each scenario:

Additional Replenishment = Net Recharge(Baseline) – Net Recharge(Alternative Scenario 1)

Figure 19 shows a graph of additional replenishment needed each year, incorporating the additional 212 AFY of City of Seaside pumping re-allocation from former golf course pumping not previously included in the Baseline. 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 that occur in the first 20 years of the Baseline Simulation.

Surprisingly, in the later part of the simulation, less additional recharge would be needed, and there would even be years with surplus Net Recharge relative to the Baseline Simulation. 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. 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.
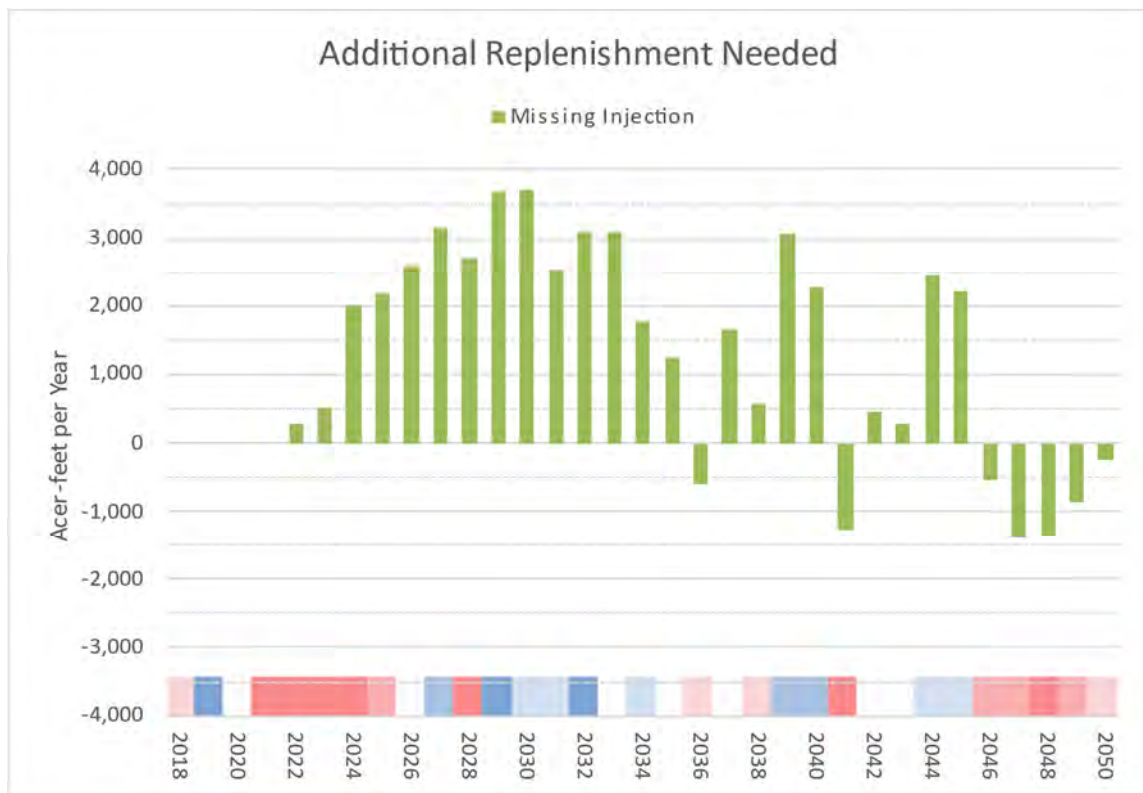

Figure 19. Additional Annual Replenishment Needed for Alternative Scenario 1 to Match Baseline Net Recharge

CONCLUSIONS

Water Budget Analysis

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.

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. 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:

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

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

A net annual volume of between 600 to 1,500 AFY flows out from the Shallow Aquifers 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.

The water budget analysis of the Deep Aquifer shows a similar 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 implications of the strong dependence on rainfall for raising the shallow aquifer levels is that 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).

The results of the water budget analysis also suggest 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, the groundwater level is essentially pinned by sea level, and so outward flows continues as long as inland groundwater levels are greater. In the Monterey Subbasin, however, groundwater levels are not pinned. So as groundwater levels in Monterey Subbasin rise or fall, either in response to the outflows coming from the Seaside Basin or because of water management actions taken in the Monterey Subbasin, the amount of outflow lost from the Seaside Basin will increase or decrease.

Hybrid Water Budget Analysis of Alternative Scenario 1

The hybrid water budget analysis suggests that the large and rapid increases in Deep Aquifer groundwater levels simulated 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 (~1,000 to 3,500 AFY) injected to the basin in the early period of the simulation.

It is unclear exactly what would happen to groundwater levels in the Shallow Aquifer 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. While the hybrid water budget approach could be expanded to consider other climate scenarios, 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 in this way and that this approach is more well suited to evaluating changes in net supply and demand, rather than on climate conditions.

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