APPENDIX 2-I

IMPLEMENTATION AND ANALYSIS OF PROJECTS AND MANAGEMENT ACTIONS IN MODEL SENARIOS AS PART OF GROUNDWATER SUSTAINABILITY PLAN DEVELOPMENT

November 15, 2019

Implementation and Analysis of Projects and Management Actions in Model Scenarios as Part of Groundwater Sustainability Plan Development

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1 INTRODUCTION

A groundwater model (model) of the Santa Cruz Mid-County Groundwater Basin (Basin) has been developed and calibrated as described in the calibration report entitled*: Santa Cruz Mid-County Basin Model Integration and Calibration* (M&A, 2019b). The Santa Cruz Mid-County Groundwater Sustainability Plan (GSP) uses model simulations of future conditions to estimate future water budgets, evaluate the expected benefits of projects and management actions, and estimate sustainable yields. This report documents model simulations of future conditions.

Future water budgets are estimated from model simulation results for both assumed baseline conditions and projects included in the GSP to achieve sustainability. The modeled projects are the two planned projects included in the GSP: Pure Water Soquel (PWS) led by Soquel Creek Water District, and Aquifer Storage and Recovery (ASR) led by the City of Santa Cruz.

The expected benefits of these projects are based on a comparison of groundwater elevations simulated by the model with the projects versus the simulation of baseline conditions. Simulated groundwater elevations are also compared with groundwater elevation proxies for the GSP's sustainable management criteria (SMC) to evaluate whether the projects help prevent or eliminate undesirable results for seawater intrusion and depletion of interconnected surface water.

Sustainable yields by aquifer group are estimated based on testing combinations of pumping and injection rates with the projects that achieve minimum thresholds and therefore sustainability by not causing undesirable results.

2 BASELINE ASSUMPTIONS FOR FUTURE CONDITIONS

Baseline assumptions are implemented into the model simulations of future conditions. The baseline assumptions also represent management actions that Santa Cruz Mid-County Groundwater Agency (MGA) member agencies are already implementing. Except where otherwise noted, these assumptions are consistent for both the simulation of baseline conditions without projects and the simulations of projects.

2.1 Initial Conditions

Initial groundwater elevations for the model are based on simulated groundwater elevations at the end of September 2015 from the calibrated simulation of historical conditions documented in the calibration report. Simulation of Water Year 2016 is based on available data for October 2015 to September 2016. Available data used for Water Year 2016 includes climate data and municipal pumping. Non-municipal pumping and both non-municipal and municipal return flows are estimated following the approaches referenced in the calibration report (HydroMetrics WRI, 2017a and M&A, 2019a).

2.2 Catalog Climate Scenario

Climate for simulated water years representing Water Years 2017-2069 are generated from a catalog of historical climate data from warm years in the Basin's past to simulate warmer temperatures predicted by global climate change (HydroMetrics WRI, 2017b). Specifically, the Catalog Climate uses historical data from the Santa Cruz Co-op and Watsonville Waterworks climate stations as well as corresponding daily temperature values from the DAYMET database of gridded weather parameters (Thornton et al., 2014) for a location near the ridgeline (Figure 1). The model Technical Advisory Committee recommended this approach because it preserves the integrity of the climate data and ensures temperature and precipitation values are associated with real data. The Catalog Climate has an increase of 2.4 °F in temperature at the Santa Cruz Co-op station and decrease of 2.1 - 3.1 inches per year (approximately 10%) in precipitation over the 1985-2015 record at climate stations in Santa Cruz and Watsonville. There is a corresponding increase in potential evapotranspiration of about 6%. Figure 2 shows precipitation and average temperature used for the future simulations at the Santa Cruz Co-op and Figure 3 shows precipitation used at the Watsonville Waterworks climate station. Simulated water years 2-54 shown in these figures represent Water Years 2017-2069.

In comparison to the CMIP5 ensemble of 10 Global Circulation Models (CGM) often applied in California, the simulated Catalog Climate is slightly cooler and drier than most CMIP5 scenarios (M&A, 2018). California Department of Water Resources (DWR) released datasets for climate change projections to use in GSPs, but the use of the data and methods provided by DWR are optional and local data and methods may be more appropriate (DWR, 2018). The datasets provided by DWR result in a 5-8% increase in potential evapotranspiration and a 3-4% increase of precipitation at the closest grid cell to the Santa Cruz-Coop station (Figure 1). Therefore, the Catalog Climate has similar potential evapotranspiration, and has less precipitation than datasets provided by DWR for the Basin area.

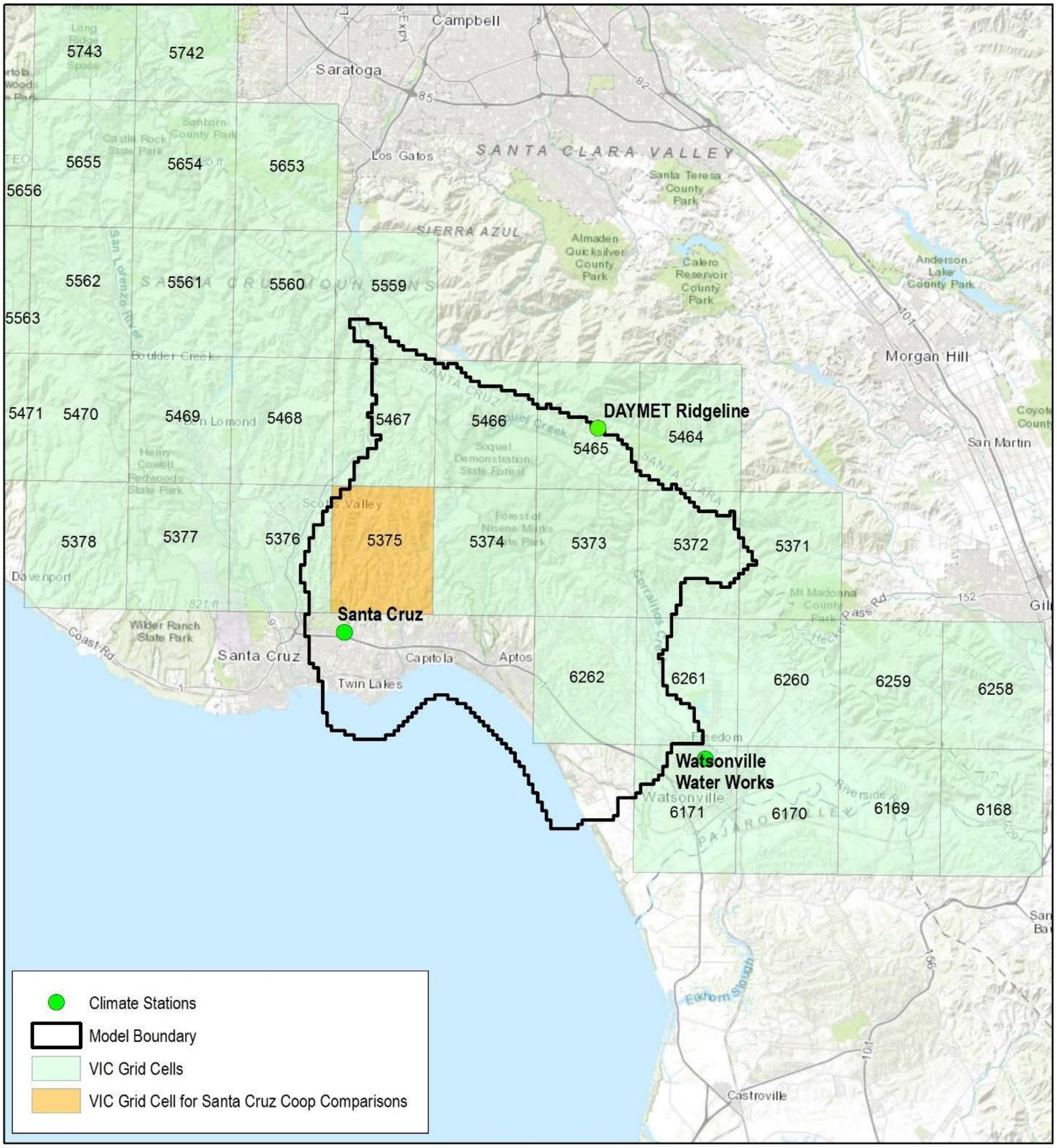

Figure 1. Climate Stations used in Model and Grid Cells for DWR Climate Datasets near Basin

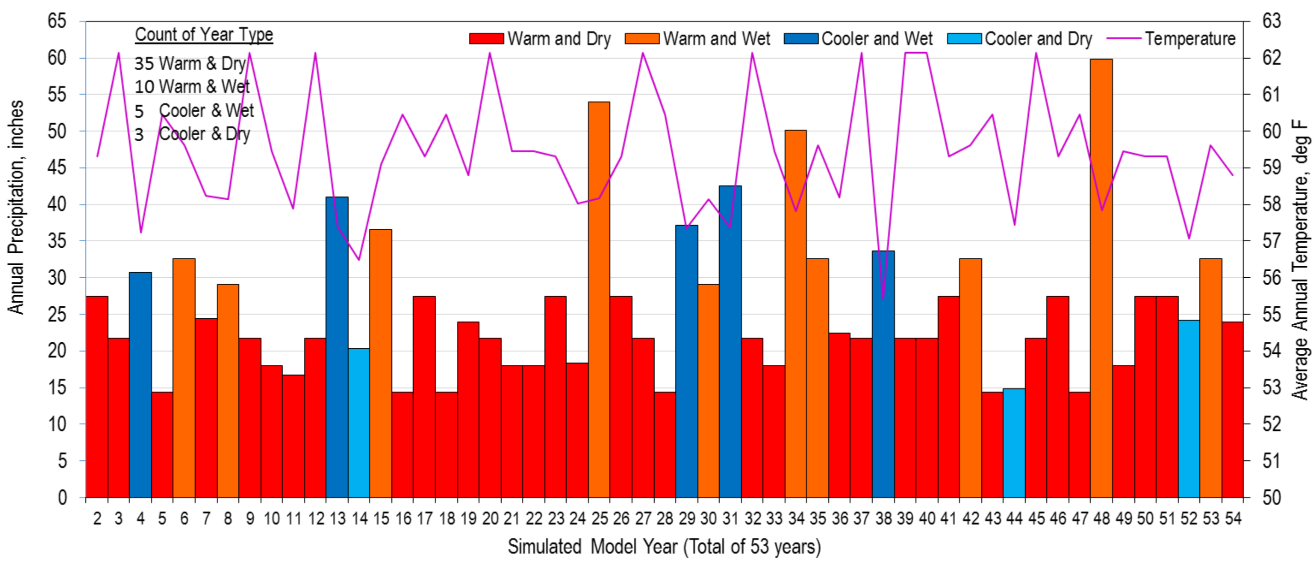

Figure 2. Simulated Future Precipitation and Temperature at Santa Cruz Co-op Station based on Catalog Climate

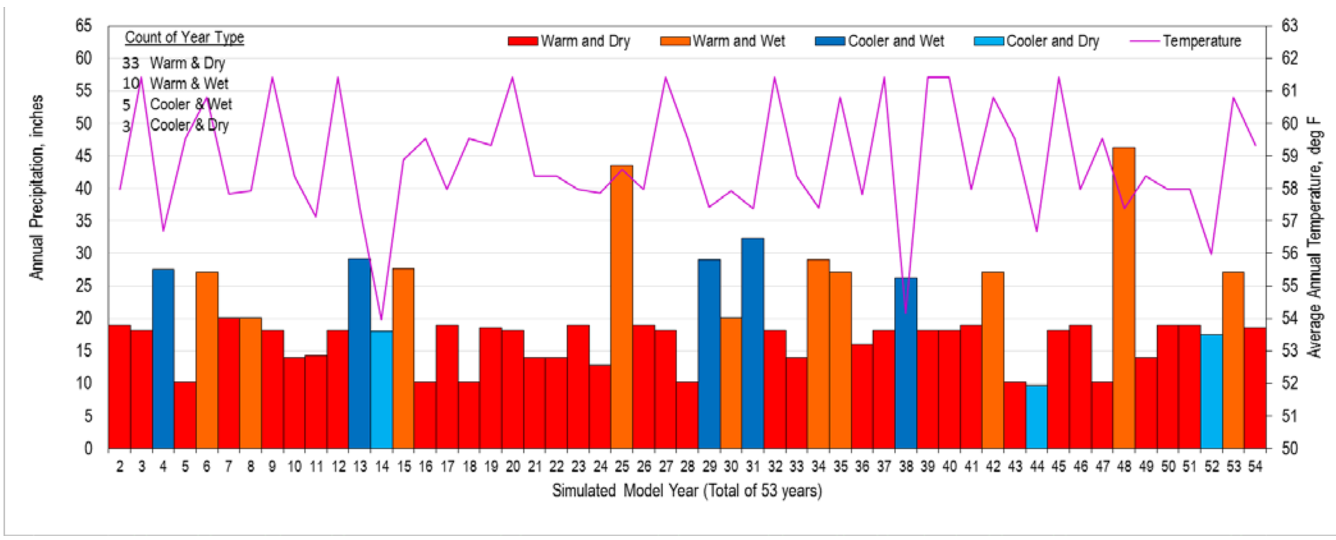

Figure 3. Simulated Future Precipitation at Watsonville Waterworks Station based on Catalog Clima

2.3 Sea Level Rise

Sea level rise is implemented in the model based on projections for Monterey provided by the 2018 update of the *State of California Sea-Level Rise Guidance* (California Natural Resources Agency and California Ocean Protection Council, 2018). The projections used are based on 5% exceedance probability under the high emissions scenario and rise to 2.3 feet by 2070 (Table 1). The increased sea level rise is applied to model general head boundaries with freshwater equivalent heads calculated from sea level.

Table 1. Sea Level Rise Projections Incorporated in Future Simulations

Year	Sea Level Rise (feet)
2030	0.6
2040	0.9
2050	1.3
2060	1.8
2070	2.3

2.4 Land Use

Land use assumed for future simulations are equivalent to land use simulated for historical conditions from Water Years 1985-2015, as documented in the calibration report. Therefore, the distribution of non-municipal pumping and return flows are consistent with the historical simulation. Also consistent are the areal distribution of vegetation type and density and impervious area percentages.

2.5 Baseline Demand

Baseline water demand is assumed to be the same for all future simulations and reflects management actions such as conservation already being implemented, but groundwater pumping to meet that demand changes with implementation of projects.

2.5.1 Municipal Demand

Municipal demand assumed for the future simulations is based on planning projections provided by the three municipal supply water agencies: Central Water District (CWD), City of Santa Cruz Water Department (SCWD), and Soquel Creek Water District (SqCWD).

Assumed future demand for CWD is based on demand from Water Years 2008-2011 prior to the most recent drought. These years are selected as there is anticipated bounce-back in demand from the conservation that occurred during the drought. Annual CWD water demand is assumed to be 550 acre-feet per year in all future simulations with monthly variation based on historical average pumping for Water Years 2005-2014.

Assumed future demand for SCWD is based on demand from 2016-2018 water demand. SCWD has not experienced a rebound in demand from 2014-2015 when SCWD rationed water during the drought (City of Santa Cruz, 2019). SCWD uses the 2016-2018 demand for planning purposes and to evaluate potential future water supply shortages. Therefore, model assumptions for SCWD include the 2016-2018 water demand for all future model simulations.

Assumed future water demand for SqCWD is based on projected demand in its Urban Water Management Plan (WSC, 2016). The SqCWD Urban Water Management Plan (UWMP) projects a demand bounce-back of approximately 65% from the low of Water Year 2016 (3,095 acre-feet per year relative to 2013 (4,279 acre-feet per year) when the drought started. The bounce back is projected in the UWMP to peak around 2020 at 3,900 acre-feet per year. The peak projected bounce-back is based on observed water demand of approximately 3,100 acre-feet per year in Water Year 2016 compared to approximately 3,350 acre-feet per year in Water Year 2018. The UWMP projects SqCWD demand to decline from 3,900 to 3,300 acre-feet per year by 2050 but future simulations do not include a decline in demand and maintain demand at 3,900 acre-feet per year. SqCWD has concluded that its UWMP's demand projections may be underestimated when considering effects such as statewide efforts to address the housing crisis including laws facilitating accessory dwelling uses and is therefore not assuming a long-term decline in demand for planning purposes. Monthly variation in future water demand is based on historical monthly variations in demand data.

2.5.2 Non-Municipal Demand

Non-municipal domestic demand is based on the water use factor used in the historical model simulation for Water Year 2013. Thus, the water use factor is assumed to be 0.35 acre-feet per year per residence in the Basin, the Santa Margarita Basin, and the Purisima Highlands and 0.59 acre-feet per year for the Pajaro Valley Subbasin (HydroMetrics WRI, 2017a). This assumed demand represents slight bounce-back in water demand experienced by small water systems during Water Years 2014 and 2015 during the drought.

Non-municipal domestic demand is assumed to increase over time by projections for population growth rates of 4.2% per year before 2035 and 2.1% per year after 2035. More recent projected growth rates of only 0.2% per year through 2040 as estimated by land use agencies, however, sensitivity runs provided in the calibration report showed a relatively small effect on sustainability by non-municipal pumpers.

Institutional demand and agricultural demand isare estimated based on the approach used for the historical simulation, assuming the same land use and crop type distribution (HydroMetrics WRI, 2017a). Irrigation demand varies with climatic conditions. Since the Catalog Climate is warmer and drier than the historical simulation, institutional and agricultural demand is simulated to be higher in the future simulations than during the historical period.

2.6 Baseline Pumping

Future baseline simulations include assumptions of how much groundwater pumping is needed to meet demand and where pumping occurs. Figure 4 shows the locations of existing and planned municipal pumping wells.

Baseline pumping is simulated in the model via the model's Multi-Node Well 2 (MNW2) MODFLOW package. The package defines the model cell location of the wells and either the screen elevations or model layers of the screens. Monthly time series of well flows for both pumping and injection are assigned to each well in the model.

2.6.1 Central Water District Baseline Pumping

Groundwater pumping at CWD's Rob Roy well field is assumed to meet all of CWD's demand of 550 acre-feet per year. Distribution of pumping between the three Rob Roy wells is based on the 2005-2014 distribution with CWD-12 as the primary pumper and CWD-4 and CWD-10 as secondary pumpers. Any historical pumping occurring at the now inactive Cox well field is assumed to occur at CWD-12 (Table 2). The first chart on Figure 5 shows the groundwater pumping distribution at CWD for future simulations. As CWD pumping is not assumed to change with implementation of projects, the third chart on Figure 5 for the projects simulation is identical to the first chart representing the baseline simulation.

Table 2. Central Water District Pumping Distribution by Wells for Future Simulations

Period	CWD-4	CWD-10	CWD-12	Total
	acre-feet per year			
2017-2069	48	92	410	550

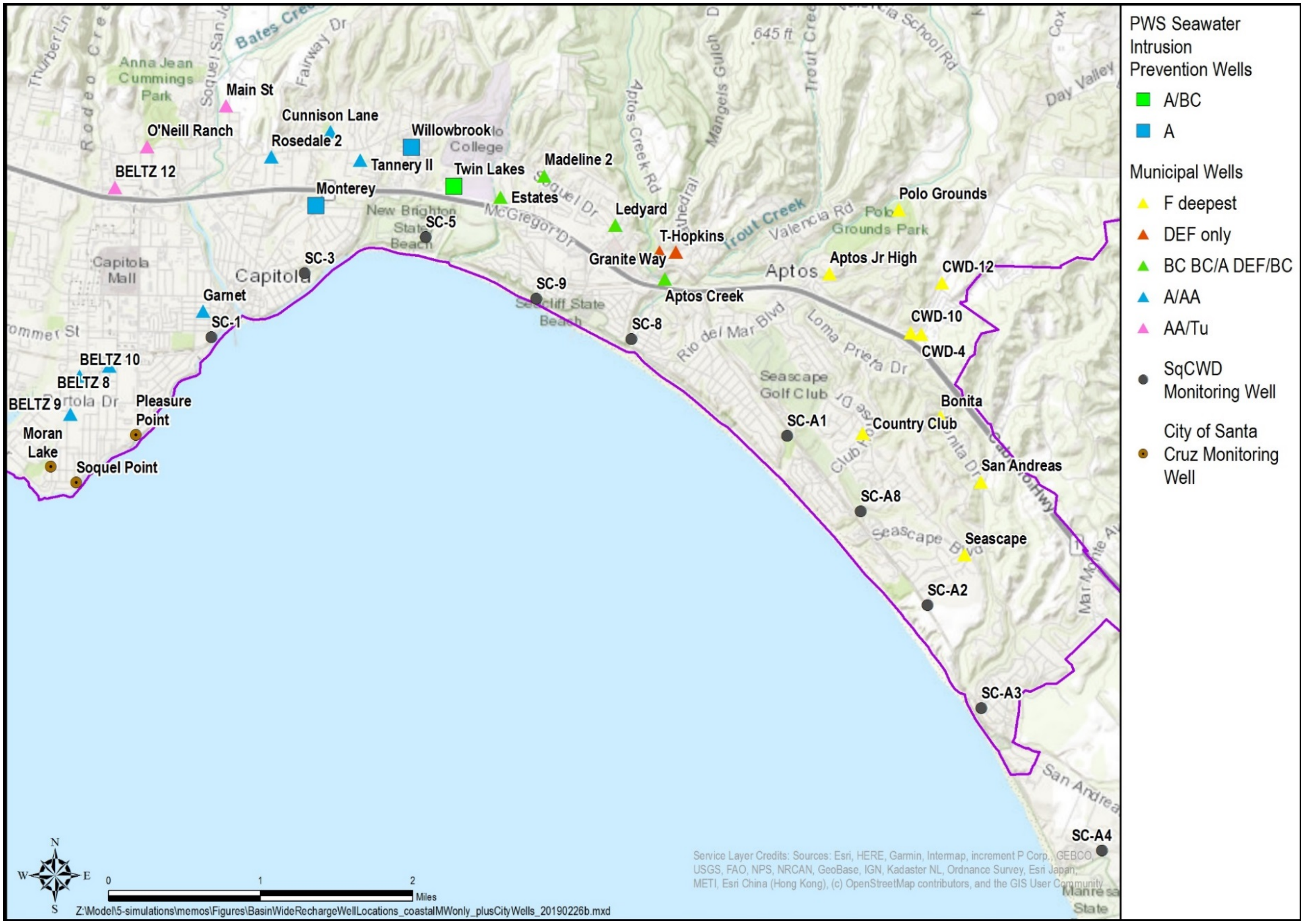

Figure 4. Locations of Existing and Planned Wells for Baseline and Projects Simulation

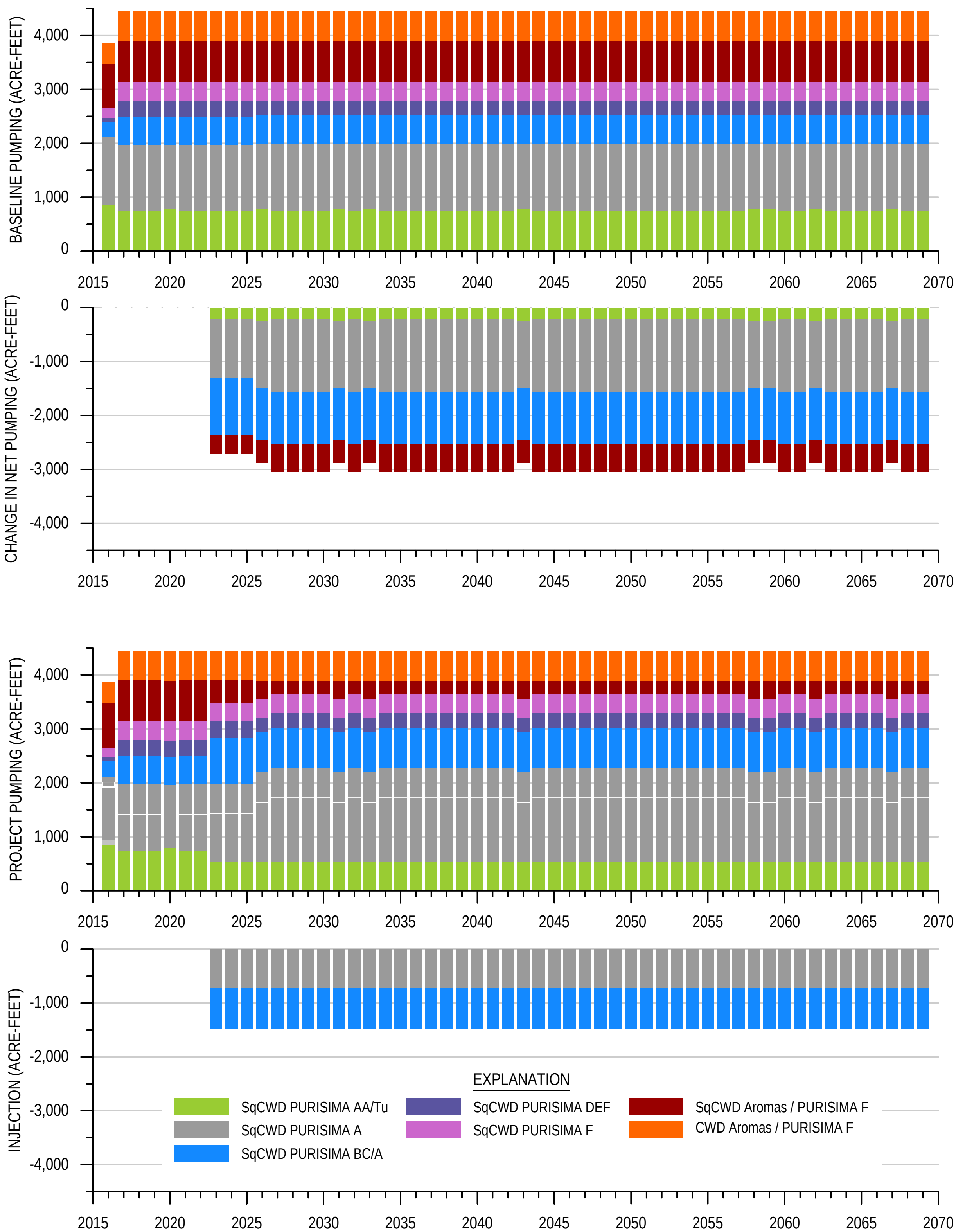

Figure 5. Central Water District and Soquel Creek Water District Pumping Distribution by Aquifer Unit for Baseline and Projects Simulation

2.6.2 City of Santa Cruz Baseline Pumping

Groundwater provides approximately 5% of the City of Santa Cruz's water supply. The City's groundwater pumping varies over time based on the availability of SCWD's surface water supplies. Total SCWD groundwater pumping by month was provided for the baseline simulation by Pueblo Water Resources Inc. based on availability of surface water under the Catalog Climate to meet WY 2016-2018 demands modeled by Gary Fiske & Associates. This work was supported by Balance Hydrologics as part of the SCWD's ASR feasibility evaluation. Groundwater pumping to the four existing Beltz wells was distributed based on historical pumping distributions in those wells during critically and non-critically dry years. Table 3 shows average pumping at the SCWD's Beltz wells for the baseline simulation over different time periods. The first plot of Figure 6 shows the pumping distribution used for the future baseline simulation. Total SCWD pumping averages approximately 350 acre-feet per year for the future baseline simulation.

Table 3. Average Pumping at Beltz Wells for the Baseline Simulation

Period	Beltz 8	Beltz 9	Beltz 10	Beltz 12	Total
	acre-feet per year				
2017-2019	49	127	100	74	350
2020-2025	99	129	96	40	364
2026-2039	100	131	96	42	369
2040-2069	90	119	88	39	337

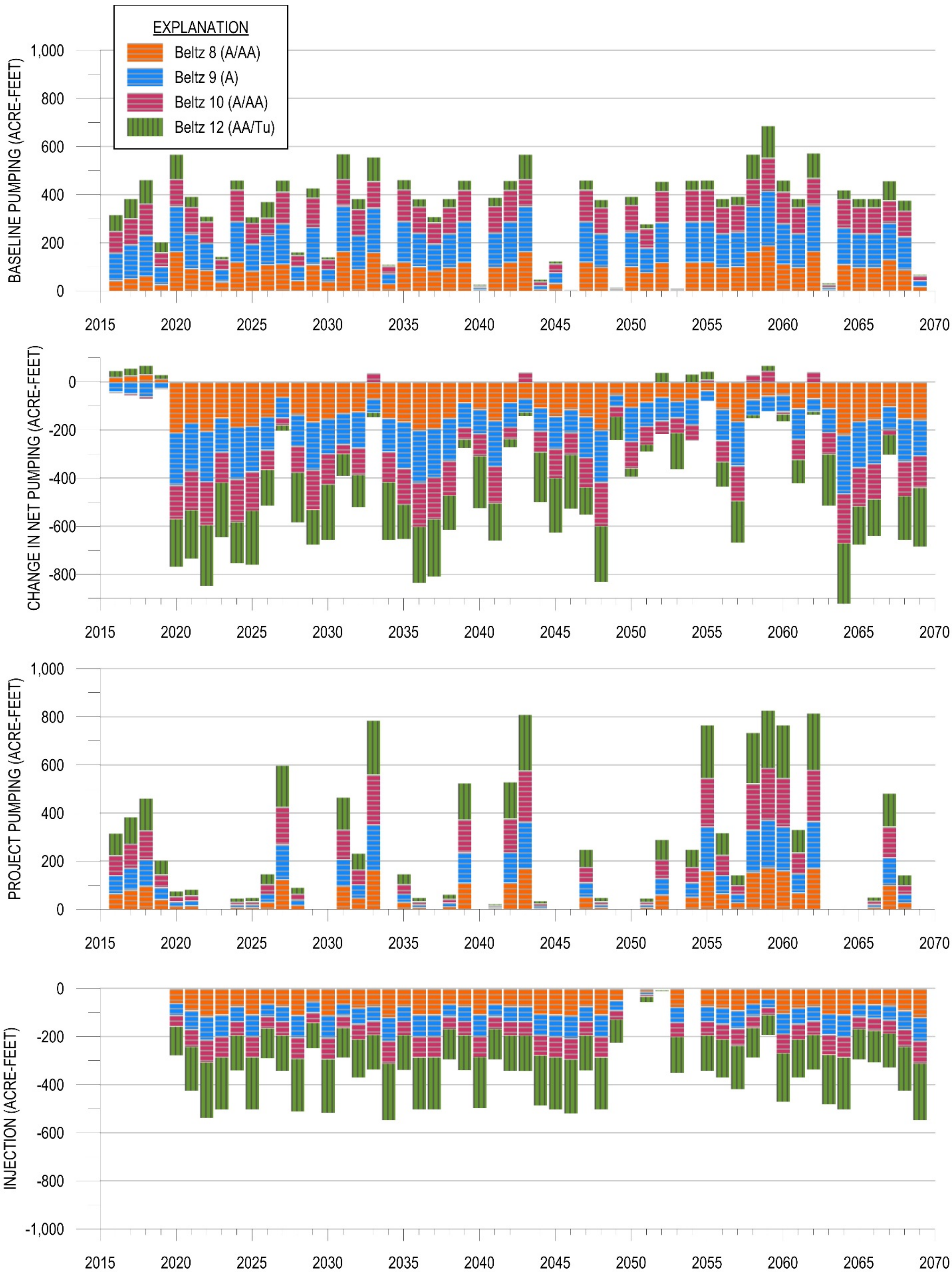

Figure 6. City of Santa Cruz Pumping and Injection for Baseline and Projects Simulations

2.6.3 Soquel Creek Water District Baseline Pumping

Groundwater pumping is assumed to supply 100% of Soquel Creek Water District's demand and thus, as described in Section 2.5.1, 3,900 acre-feet per year is pumped by Soquel Creek Water District in the future simulations. No surface water transfer is assumed and drought curtailment during critically dry years is also not assumed.

The baseline pumping distribution for SqCWD is based on implementing the management action of redistributing pumping to improve Basin sustainability without a project. Production wells used are the same as those included in the simulation of historical conditions, with the addition of the Granite Way well, which will come online in late 2019, and the Cunnison Way well, scheduled to come online in 2026. The pumping distribution is different in critically dry years versus non-critically dry years with the differences applied between April and September. Pumping is shifted inland from the Garnet well in critically dry years when City of Santa Cruz plans increased pumping near the Purisima A unit outcrop area as described in the cooperative monitoring and adaptive management agreement between SqCWD and SCWD. The distribution also changes when the Cunnison Way well comes online. Table 4 shows the pumping distribution. The first chart of Figure 5 shows the pumping distribution by aquifer unit used for the future baseline simulation.

Table 4. Pumping at SqCWD Wells for the Baseline Simulation

Well	Aquifer	2017-2025		2026-2069	
		Non-Critically Dry	Critically Dry	Non-Critically Dry	Critically Dry
		acre-feet per year			
O'Neill Ranch Well	Purisima AA/Tu	222	261	222	261
Main St Well	Purisima AA/Tu	528	532	528	532
Rosedale 2 Well	Purisima A/AA	544	553	544	553
Garnet Well	Purisima A	278	210	278	139
Cunnison Lane	Purisima A	0	0	230	230
Tannery Well II	Purisima A	399	408	196	277
Estates Well	Purisima BC/A	316	316	316	316
Madeline 2 Well	Purisima BC	98	98	98	98
Ledyard Well	Purisima BC	108	108	108	108
Aptos Creek Well	Purisima DEF/BC	0	0	0	0
T-Hopkins Well	Purisima DEF	156	156	137	137
Granite Way	Purisima DEF	145	145	135	135
Polo Grounds Well	Purisima F	100	100	100	100
Aptos Jr High Well	Purisima F	250	250	250	250
Country Club Well	Aromas / Purisima F	70	70	70	70
Bonita Well	Aromas / Purisima F	269	269	269	269
San Andreas Well	Aromas / Purisima F	371	371	371	371
Seascape Well	Aromas / Purisima F	46	46	46	46

Note: Totals do not equal 3,900 acre-feet per year due to rounding error

2.6.4 Non-Municipal Baseline Pumping

Groundwater pumping meets all of the non-municipal demand described in Section 2.5.2. The non-municipal demand averages approximately 1,600 acre-feet per year within the Basin. Figure 7 shows simulated non-municipal demand within the Basin and outside the Basin for categories of private/domestic, institutional, and agricultural. Since land use is not assumed to change, the locations of non-municipal pumping are the same as for simulation of historical conditions documented in the calibration report.

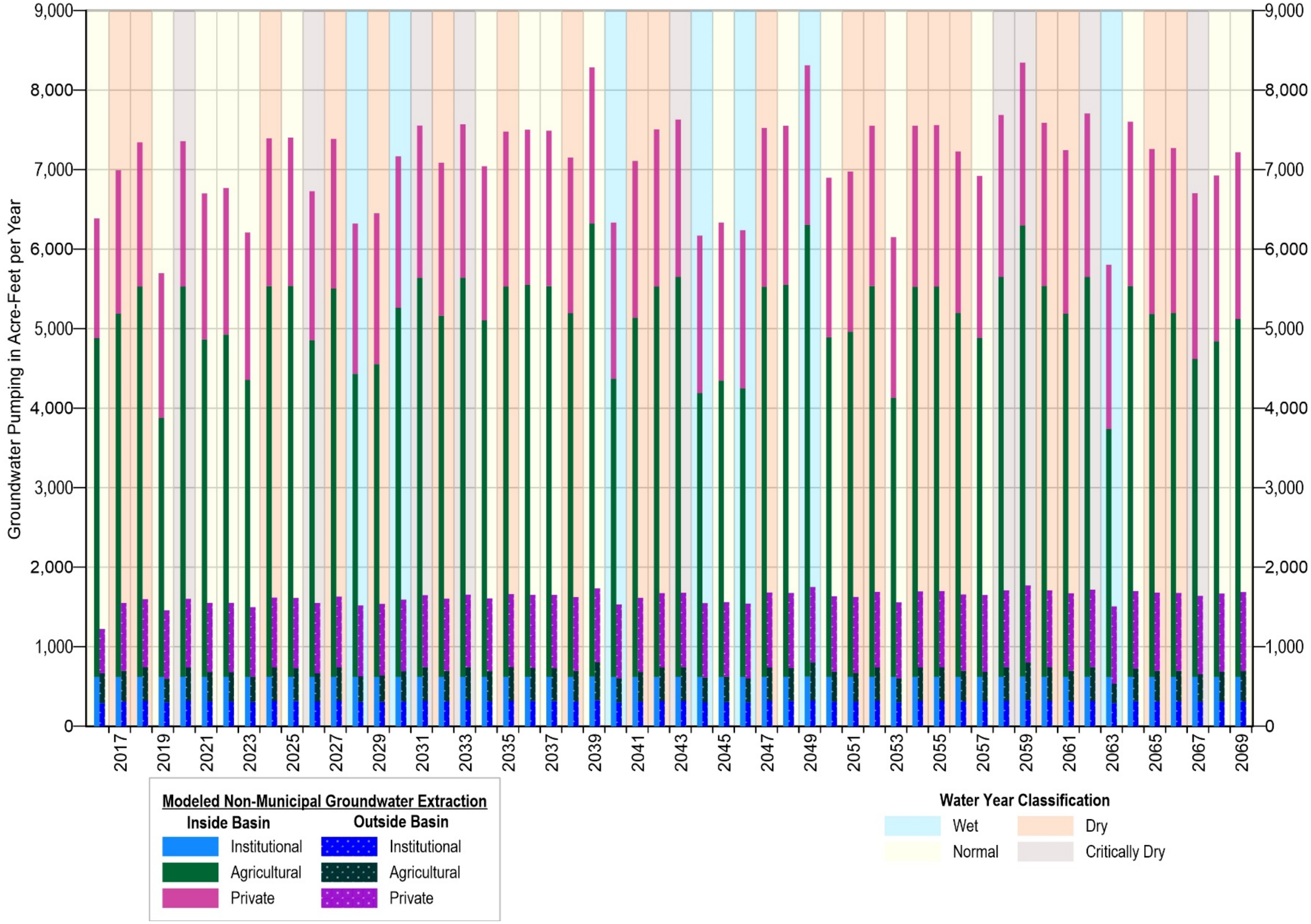

Figure 7. Non-Municipal Pumping for Baseline and Projects Simulation

3 PROJECT ASSUMPTIONS FOR FUTURE SIMULATIONS

The projects simulated by the model are SqCWD Pure Water Soquel (PWS) and the City of Santa Cruz Aquifer Storage and Recovery (ASR). These projects are included in the GSP as projects and management actions evaluated against the sustainable criteria. These are the projects included because they have been developed and thoroughly vetted by their respective proponent MGA member agency and are planned for near-term implementation by that agency.

The simulation of future conditions for the GSP includes both the PWS and ASR projects. This simulation provides information on whether the projects help achieve the sustainability goal and interim milestones. It is also used to estimate the future water budget with projects and management actions implemented as part of the GSP. In order to evaluate expected benefits of each project separately, a simulation of only PWS is performed. The expected benefits of PWS are evaluated by comparing the results of this simulation with the baseline simulation. The expected benefits of ASR are evaluated by comparing the results of the simulation of future conditions with both projects (PWS + ASR) to simulation of PWS only.

3.1 Description of Projects

3.1.1 Pure Water Soquel

SqCWD's Pure Water Soquel (PWS) would provide advanced water purification to existing secondary-treated wastewater that is currently disposed of in the Monterey Bay National Marine Sanctuary. The project would replenish 1,500 acre-feet per year of advanced purified water that meets or exceeds drinking water standards into aquifers within the Basin. Replenishment is currently planned at three locations in the central portion of SqCWD's service area. Purified water would mix with native groundwater and contribute to the restoration of the Basin, provide a barrier against seawater intrusion, and provide a drought proof and sustainable source of water supply. The conveyance infrastructure of PWS is being sized to accommodate the potential for future expansion of the Project's treatment system (if desired at a later time) and to convey up to approximately 3,000 acre-feet per year of purified water.

The PWS Environmental Impact Report (EIR) and project were approved by the lead agency in December 2018. The project is currently in the design and permitting phase and construction is anticipated to be completed in late 2022 with the project to come online in early 2023.

PWS injection is planned into the Basin's Purisima A and BC units. PWS also supports in-lieu recharge in aquifer units and areas where water is not directly injected. In-lieu recharge is facilitated in this simulation of PWS for the GSP by increasing SqCWD pumping from Purisima A and BC aquifer units where PWS injection takes place, which allows for reductions of

SqCWD pumping from the Tu aquifer unit in the western portion of the Basin and from the Purisima F and Aromas Red Sands in the eastern portion of the Basin. Figure 8 shows a map schematic of this strategy for the areas of injection (recharge, down arrows), increased pumping (plus signs), and decreased pumping (minus signs). Therefore, PWS is designed to provide benefits for sustainability throughout the portion of the Basin pumped by SqCWD.

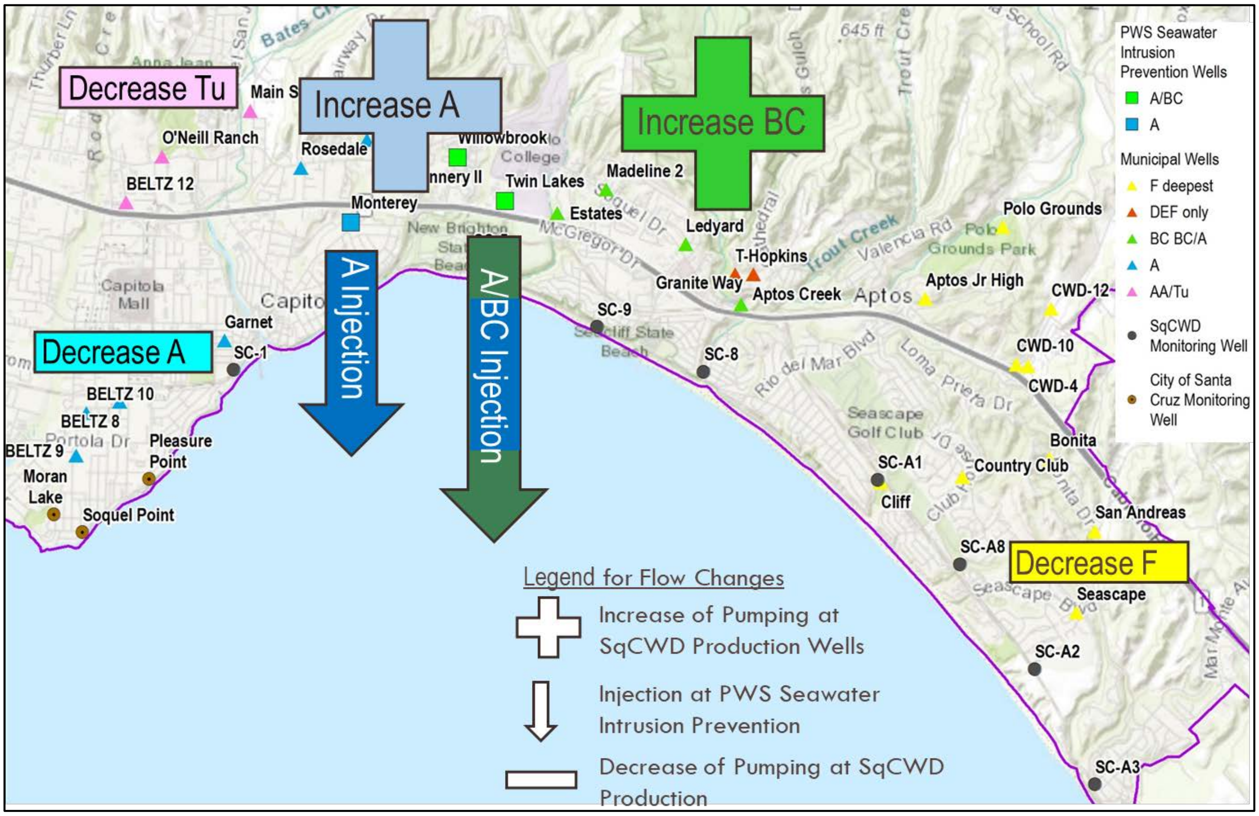

Figure 8 Map Schematic of Changes in Pumping Distribution from Pure Water Soquel Injection

3.1.2 City of Santa Cruz ASR

The ASR project would inject surface water from excess winter flows, treated to drinking water standards, into the natural structure of Basin aquifers which act as an underground storage reservoir. SCWD can treat excess surface water by improving the treatment process at its Graham Hill Water Treatment Plant. Surface water can only be considered excess if it is produced within SCWD's water rights, is above the volume of water required for SCWD operations, and after allowing for fish flows. The primary purpose of the ASR project is to store drinking water in the Basin to provide a drought supply for SCWD's service area. The ASR project is expected to also contribute to Basin sustainability but this may require additional capacity and changes to water rights.

As part of its efforts to update and align its water rights on the San Lorenzo River to incorporate fish flow requirements and provide additional operational flexibility including for ASR, the SCWD has initiated a water rights change process with the State Water Resources Control Board. Compliance with the California Environmental Quality Act (CEQA) for the water rights changes and the ASR project as well additional permitting will need to be completed before full scale ASR is implemented.

ASR pilot tests began at SCWD's Beltz 12 well in 2019. During the winter of 2019/2020, additional pilot testing at Beltz 12 may occur and an additional Beltz well is slated to be retrofitted for pilot testing. Assuming results from the initial pilot testing during 2019 continues to be positive and regulatory requirements are met, full scale phased implementation of ASR would occur beginning in 2021.

The ASR project modeled for the GSP optimizes existing SCWD infrastructure as a more efficient use of available resources to inject excess drinking water into Basin aquifers. However, since SCWD is in the process of developing its plans for the ASR project, eventual implementation of the ASR project may include different strategies and possibly new infrastructure. For evaluation in the GSP, simulations of the ASR project assume that injection and pumping recovery for ASR occurs at the existing Beltz wells: Beltz 8, Beltz 9, Beltz 10, and Beltz 12. These wells are screened in the Purisima A, Purisima AA, and Tu units. The simulation of ASR for the GSP also includes the possibility of in-lieu recharge that reduces groundwater pumping over some periods due to improved treatment and therefore delivers drinking water quality surface water to directly meet demand. Figure 9 shows a map schematic of the strategy for this simulation of ASR for the areas of injection (recharge, down arrows), increased average pumping (plus signs), and decreased average pumping (minus signs). The schematic shows average simulated changes from the assumed baseline, but injection and pumping compared to baseline varies over time based on surface water availability and demand.

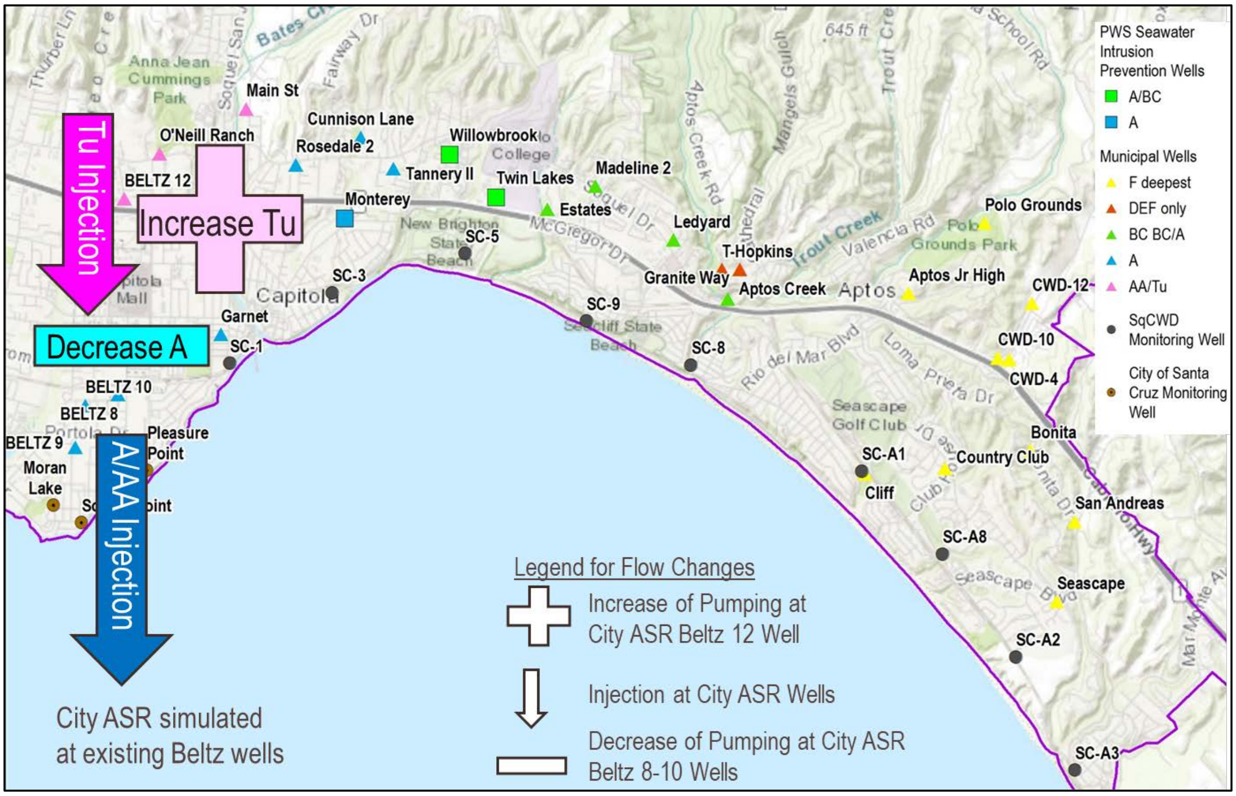

Figure 9 Map Schematic of Changes to ASR Injection and Pumping Distribution

3.2 Implementation of Projects in Model

Projects are simulated in the model by the Multi-Node Well 2 (MNW2) MODFLOW package. The package defines the model cell location of the wells and either the screen elevations or model layers of the screens. Monthly time series of well flows for both pumping and injection are assigned to each well in the model.

3.2.1 Pure Water Soquel

The PWS seawater intrusion prevention (SWIP) wells are added to the wells included in the baseline simulation. The SWIP wells are assigned to model cells based on their planned location and assigned specific model layers for injection. Injection rates are assigned based on estimated injection capacities for the wells and adjusted if model results show simulated groundwater elevations at the SWIP well rising above ground surface elevations. PWS injection at the SWIP wells is simulated to start October 2022 for Water Year 2023 and to continue for the remainder of the future conditions simulation (through Water Year 2069).

Table 5. Simulated SWIP Well Location and Injection Rates

Well	Aquifer	Injection (acre-feet per year) 2023-2069	Capacity Estimate Source	Notes
Monterey SWIP	Purisima A	500	Carollo, 2016	-
Willowbrook SWIP	Purisima A	233	Section 4.1	Screening Purisima BC also to be evaluated
Twin Lakes SWIP	Purisima BC/A	742	Preliminary Estimate from Pilot Testing	-

SqCWD pumping for PWS is redistributed from the baseline simulation to represent the strategy shown in Figure 8. Redistribution commences in Water Year 2023 with the commencement of PWS injection. Redistribution changes starting in Water Year 2026 when the Cunnison Lane well is simulated to come online. As with the baseline, redistributed pumping is different between critically and non-critically dry years. Monthly pumping is redistributed such that total monthly pumping is the same as the baseline simulations while pumping at any well does not exceed the well's monthly pumping capacity based on 50% runtime. The following summarizes the wells with pumping changes for PWS.

- Pumping increases at Tannery, Cunnison Lane (after it comes online in 2026), and Estates wells screened in the Purisima A unit where injection occurs from PWS SWIP wells.
- Pumping increases at the Estates, Madeline, Ledyard, and Aptos Creek wells screened in the Purisima BC unit where injection occurs from PWS SWIP wells.. The Estates well is screened in both the Purisima A and BC units.
- Pumping decreases at the Main Street and O'Neill Ranch wells in the Purisima AA and Tu units in the western portion of the Basin.
- Pumping decreases at the Garnet well in the Purisima A unit in the western portion of the Basin.
- Pumping decreases at the Bonita and San Andreas wells simulated to extract from the Purisima F unit in the eastern portion of the Basin.

Table 6 shows the pumping changes from baseline assumptions and redistributed pumping for simulations of PWS for critically and non-critically dry years. Figure 5 shows the change in pumping from baseline assumptions by aquifer unit over time and the redistributed pumping for the simulations of PWS under future conditions.

Table 6. Soquel Creek Water District Pumping Distribution by Well for Project Simulations in Critically and Non-Critically Dry Years

Well	Aquifer	Non-Critically Dry	Non-Critically Dry	Critically Dry	Average Change From Baseline
		acre-feet per year			
		2023-2025	2026-2069		
O'Neill Ranch Well	Purisima AA/Tu	182	182	181	-47
Main St Well	Purisima AA/Tu	348	348	352	-180
Rosedale 2 Well	Purisima A/AA	544	544	553	0
Garnet Well	Purisima A	222	222	123	-49
Cunnison Lane	Purisima A	0	426	426	184
Tannery Well II	Purisima A	689	563	563	348
Estates Well	Purisima BC/A	466	398	398	86
Madeline 2 Well	Purisima BC	122	122	122	24
Ledyard Well	Purisima BC	120	120	120	12
Aptos Creek Well	Purisima DEF/BC	144	102	102	105
T-Hopkins Well	Purisima DEF	156	137	137	0
Granite Way	Purisima DEF	145	135	135	0
Polo Grounds Well	Purisima F	100	100	100	0
Aptos Jr High Well	Purisima F	250	250	250	0
Country Club Well	Aromas / Purisima F	70	70	70	0
Bonita Well	Aromas / Purisima F	137	68	107	-190
San Andreas Well	Aromas / Purisima F	159	64	106	-293
Seascape Well	Aromas / Purisima F	46	46	46	0

Note: Totals do not equal 3,900 acre-feet per year due to rounding error

3.2.2 City of Santa Cruz ASR

The ASR project simulated for the GSP involves pumping and injection at existing SCWD wells also simulated in the baseline simulation: Beltz wells 8, 9, 10, and 12. Based on this configuration assumed for evaluation in the GSP, SCWD groundwater pumping and injection by month at each well was provided for the projects simulation by Pueblo Water Resources Inc. assuming a combined capacity for the four wells of 1.0 million gallons per day of injection and 1.5 million gallons per day of extraction. This time series input was based on availability of surface water under the Catalog Climate and WY 2016-2018 demands to meet ASR storage objectives as modeled by Gary Fiske & Associates as part of the SCWD's ASR feasibility evaluation. ASR is simulated to commence injection in Water Year 2020 and injection and pumping recovery continues through Water Year 2069 for the remainder of the simulation of future conditions.

The ASR pumping and injection distribution is based on estimated pumping and injection capacities for the wells and prioritization of Beltz 12 use due to less susceptibility to seawater intrusion. Beltz 12 is considered less susceptible to seawater intrusion based on its distance from coast and being screened in the Purisima AA and Tu units that do not outcrop offshore like the Purisima A unit where the other Beltz wells are screened. Therefore, the ASR pumping distribution is different than the pumping distribution assumed under the baseline simulation. As shown in Figure 9, ASR results in an increase in gross pumping from the Tu unit at the Beltz 12 well and a decrease in gross pumping from the Purisima A unit at the Beltz 8, 9, and 10 wells compared to the baseline simulation. Table 7 shows average assumed injection and pumping at the Beltz wells for ASR for different time periods.

Table 7. Average Pumping and Injection at Beltz Wells for Simulation of ASR

Period	Pumping (acre-feet per year)					Injection (acre-feet per year)				
	Beltz 8	Beltz 9	Beltz 10	Beltz 12	Total	Beltz 8	Beltz 9	Beltz 10	Beltz 12	Total
2017-2019	74	84	92	100	350	0	0	0	0	0
2020-2025	9	10	11	12	42	93	77	74	186	430
2026-2039	47	53	58	64	222	84	70	67	167	388
2040-2069	54	61	67	73	255	73	61	58	146	338

Based on the availability of the SCWD's surface water supply, injection and pumping with ASR varies over time as shown on Figure 6. The second chart of Figure 6 shows the annual change in net pumping with ASR compared to the baseline simulation. The third and fourth charts of Figure 6 shows annual pumping and injection respectively. The most significant shortage of surface water supply availability occurs in the two year period of Water Years 2058 and 2059 when pumping recovery is the greatest.

4 MODEL RESULTS

4.1 Evaluation of Well Capacities

The model is used to evaluate well capacities during injection by evaluating simulated heads at the well during injection in comparison to ground surface. Simulated heads substantially above ground surface indicate that the well capacity has been exceeded. Simulated heads at the wells are based on output from the model's MNW2 package that distinguish simulated heads in the well from groundwater elevations for the model grid cell representing aquifer conditions.

4.1.1 Pure Water Soquel

Simulated heads at the Monterey, Willowbrook, and Twin Lakes Church PWS SWIP wells are compared to ground surface elevations. The estimated injection rates of 500 acre-feet per year at the Monterey SWIP well and 742 acre-feet per year at the Twin Lakes Church SWIP well are not simulated to raise heads at the wells to ground surface. The injection rate of 233 acre-feet per year at the Willowbrook SWIP well is the estimated injection capacity based on simulated well heads rising near ground surface. Figure 10 shows the simulated heads at the three SWIP wells for the simulations of PWS with green line labeled PWS+ASR, and without (blue dashes labeled PWS) ASR compared to ground surface (black dashes). The difference between the simulations is negligible.

4.1.2 City of Santa Cruz ASR

Simulated heads at Beltz 8, 9, 10, and 12 wells planned for ASR are compared to ground surface elevations for the project simulation including ASR operations. The estimated total injection rate of 1.0 million gallons per day and distribution are based on groundwater levels at the wells rising to ground surface elevations but not substantially above ground surface. Figure 11 shows the simulated heads at the four Beltz ASR wells for the project's simulation, including ASR shown as a green line and labeled PWS+ASR compared to ground surface (black dashes). Also shown on Figure 11 are simulated heads for the baseline simulation (yellow line) and the simulation of PWS (blue dashes) without ASR. There is negligible effect of PWS at Beltz 8, 9, and 10. Reduction of Tu aquifer pumping planned with implementation of PWS does potentially limit injection capacity at Beltz 12.

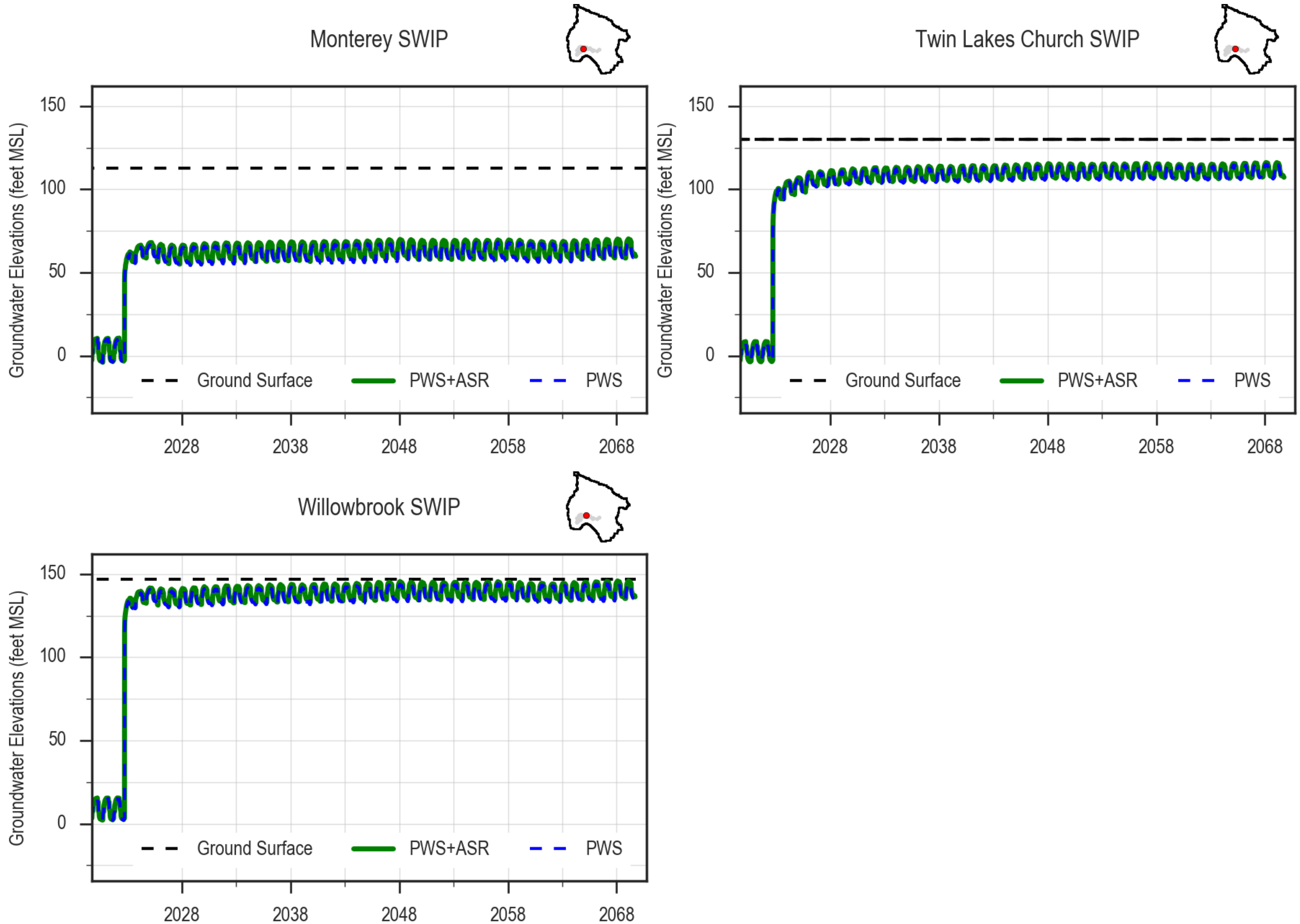

Figure 10. Simulated Well Heads at PWS Seawater Intrusion Prevention Wells versus Ground Surface

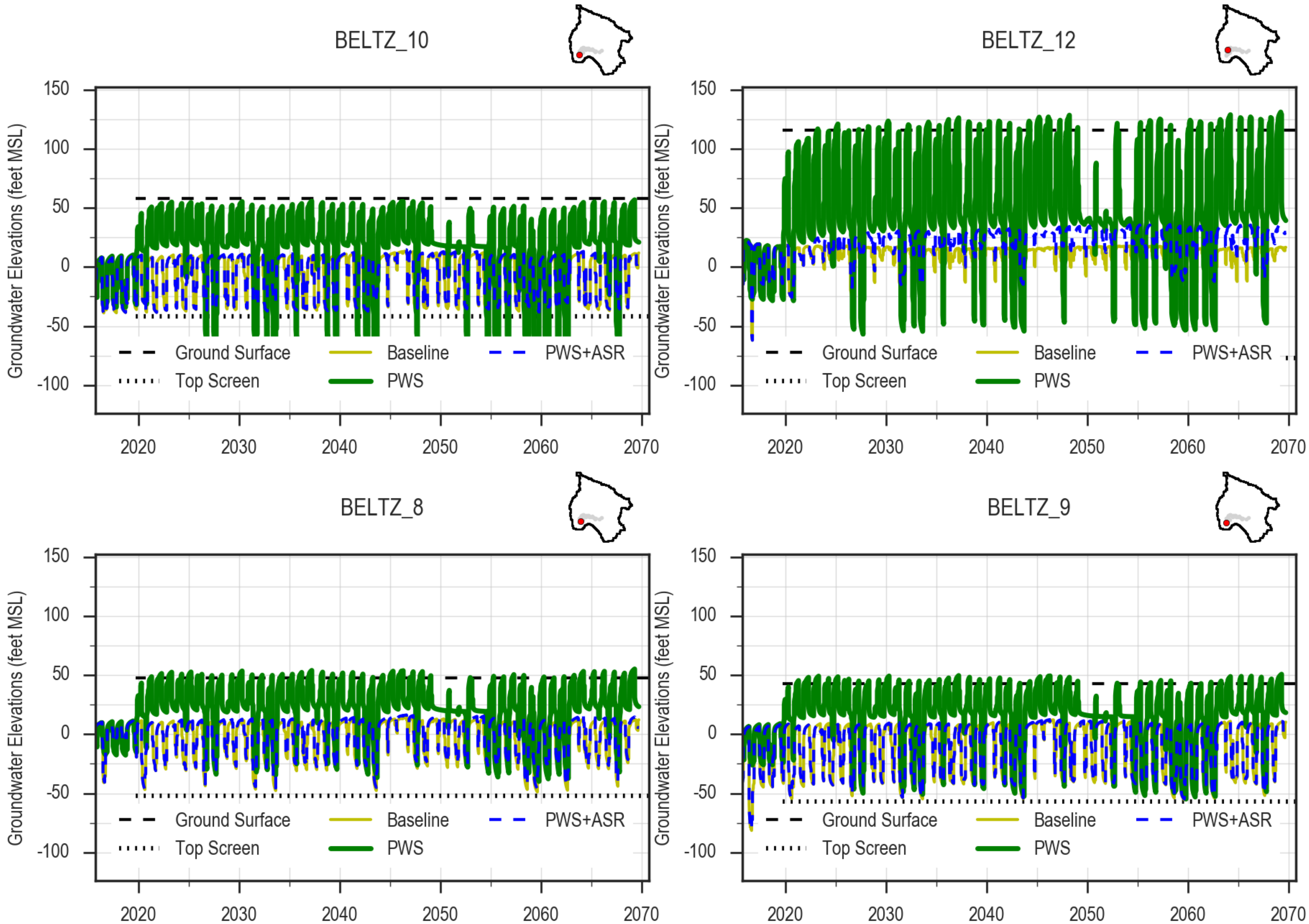

Figure 11. Simulated Well Heads at Beltz ASR Wells vs. Ground Surface

4.2 Expected Seawater Intrusion Benefits of Projects

Expected seawater intrusion benefits of projects are evaluated based on simulated groundwater elevations at the GSP's representative monitoring points with groundwater elevation proxies for protecting the Basin from seawater intrusion (Figure 12). The GSP defines the groundwater elevation proxies based on five-year averages so running five-year averages are calculated from the model's monthly output for comparison with minimum thresholds and measurable objectives. To avoid undesirable results, the running five-year average must achieve the groundwater elevation proxy for the minimum threshold at all of the representative monitoring points by 2040 and be maintained above the minimum threshold thereafter. The goal of the GSP is to achieve measurable objectives to provide operational flexibility, but five-year averages of groundwater elevations below measurable objectives are not considered undesirable results.

The effect of sea level rise is incorporated into the model evaluation of whether projects can raise and maintain groundwater elevations to meet and exceed the groundwater elevation proxies for minimum thresholds. As described in Section 2.3, the model incorporates projected sea level rise up to 2.3 feet in the offshore boundary condition for simulations of future conditions. Since the datum in the model is set at current sea level, simulated future groundwater levels were compared to the groundwater elevation proxies plus the total sea level rise of 2.3 feet. This allows evaluation of whether projects and management actions will raise and maintain groundwater elevations to meet groundwater elevation proxies relative to projections of higher sea levels.

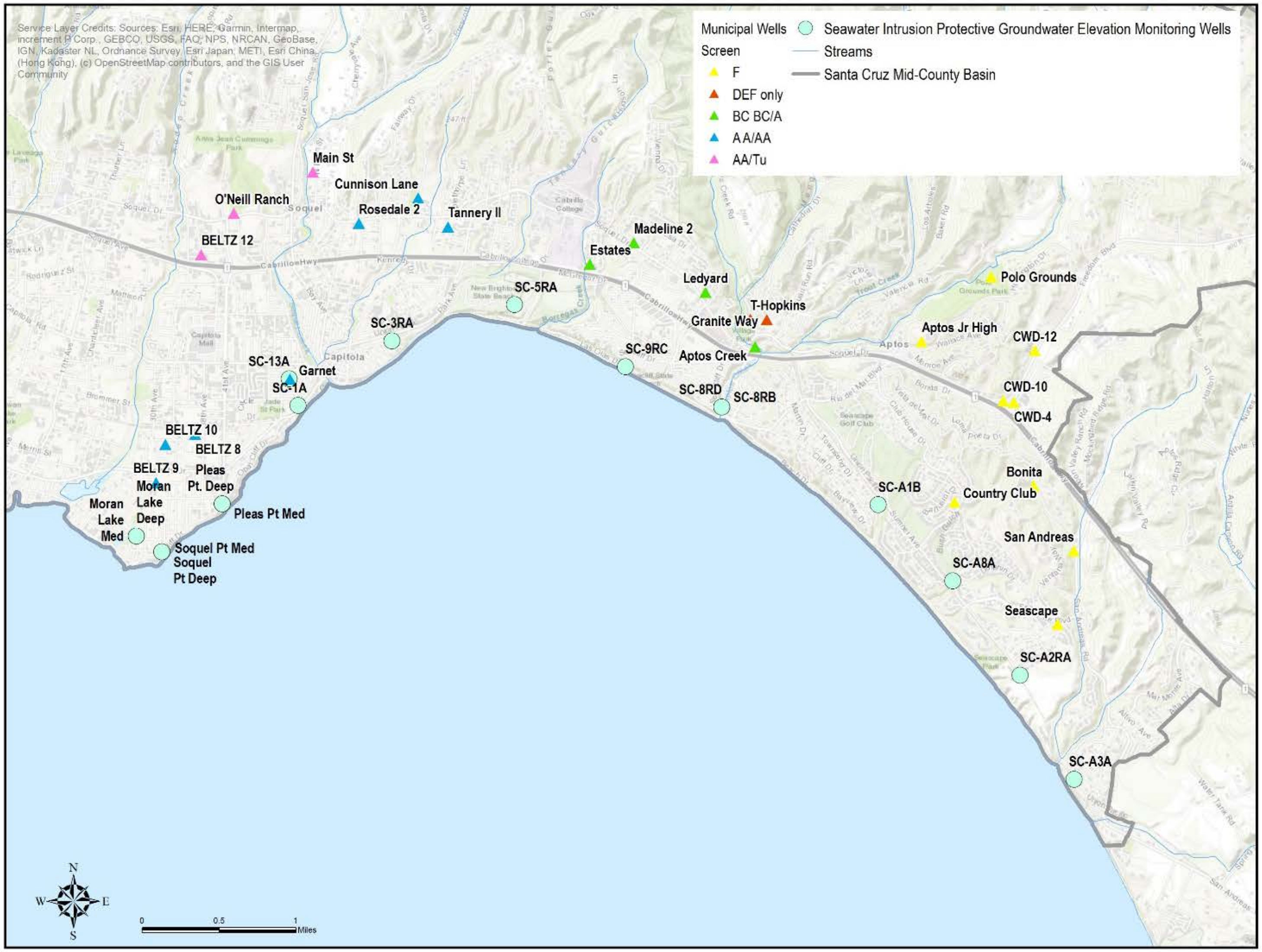

Figure 12. Locations of Representative Monitoring Points with Groundwater Elevation Proxies for Seawater Intrusion in Relation to Municipal Production Wells

4.2.1 Pure Water Soquel

A simulation of the PWS project under projected future climate conditions using the model demonstrates expected Basin sustainability benefits include raising running five-year average groundwater levels at coastal monitoring throughout SqCWD's service area to reduce the risk of seawater intrusion. The figures below show running five-year averages of simulated groundwater levels at representative monitoring points for seawater intrusion in the SqCWD's service area. The simulated groundwater levels are compared to groundwater elevation proxies for minimum thresholds (black dots) and measurable objectives (black dashes) adjusted for sea level rise.

Without the project (yellow line labeled Baseline), undesirable results for seawater intrusion are projected to occur in the Purisima A (Figure 13), Purisima BC (Figure 13), Purisima F (Figure 14) and Tu aquifer units (Figure 15). Running five-year average simulated groundwater levels are projected to be below the minimum threshold at representative monitoring points in these aquifer units pumped by SqCWD.

In the Purisima A and BC aquifer units where PWS injection occurs, groundwater levels are projected to rise to or above measurable objectives (blue dashes labeled PWS) even as pumping is increased from these aquifer units (Figure 13).

In the Purisima F and Aromas Red Sands aquifer units where pumping is reduced under PWS, groundwater levels (blue dashes labeled PWS overlying green line labeled PWS+ASR) are projected to rise above or near measurable objectives by 2040 and to be maintained above minimum thresholds thereafter so that undesirable results for seawater intrusion do not occur (Figure 14).

Figure 15 shows how pumping reduction from the Purisima AA and Tu units under PWS (blue dashes) also is projected to raise groundwater levels above minimum thresholds to prevent undesirable results for seawater intrusion.

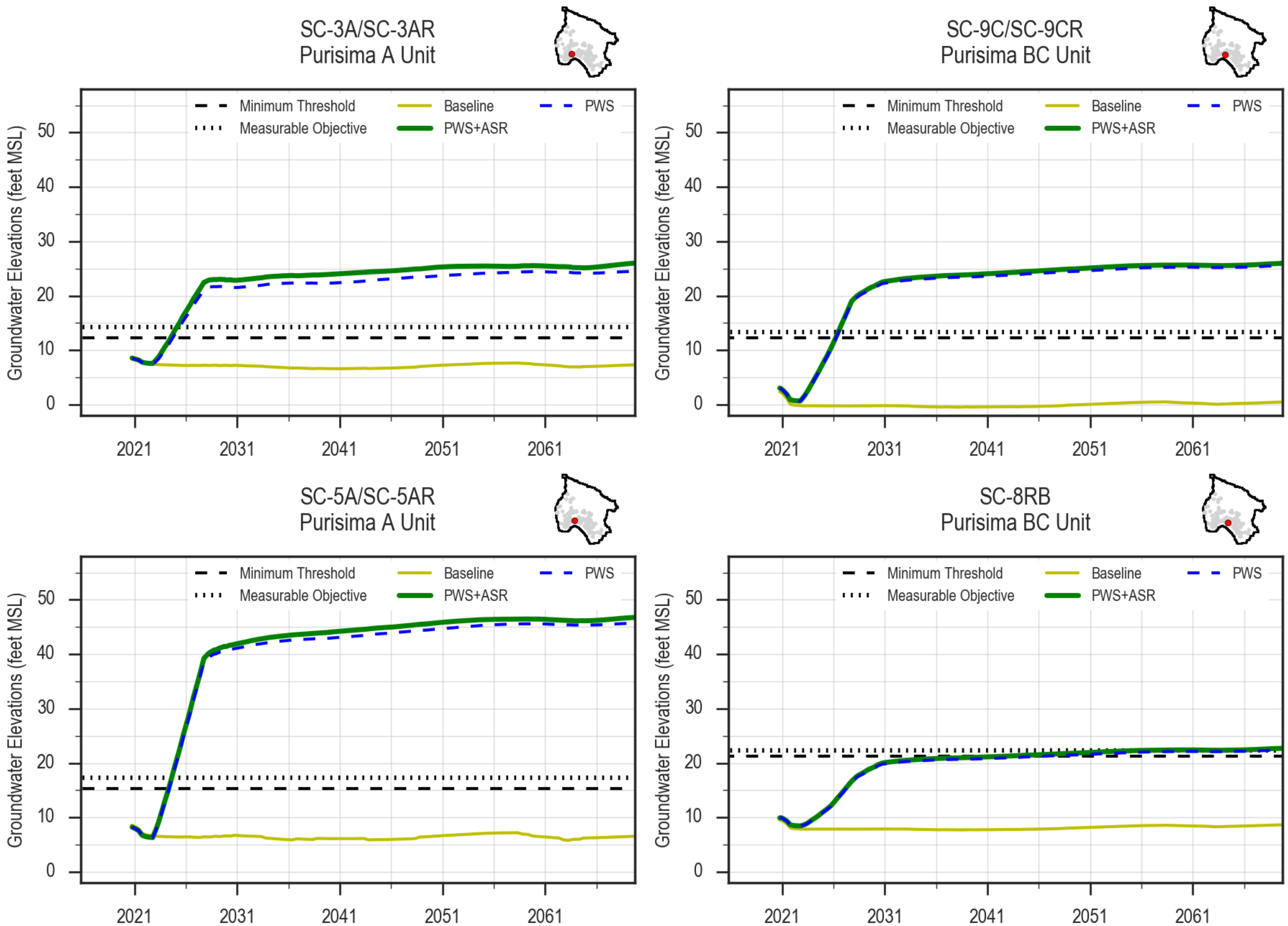

Figure 13. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima A and BC Units

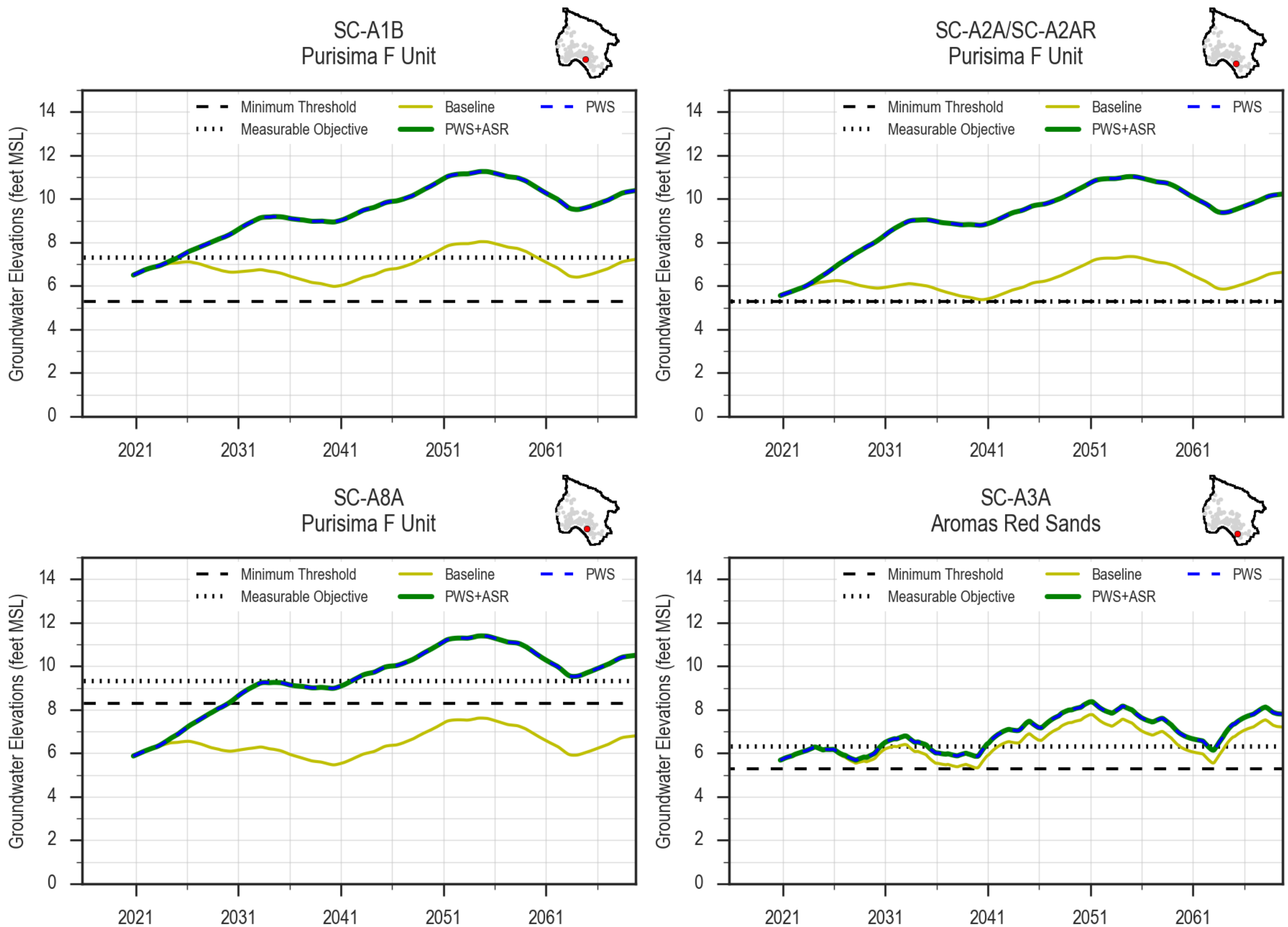

Figure 14. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima F and Aromas Red Sands Units

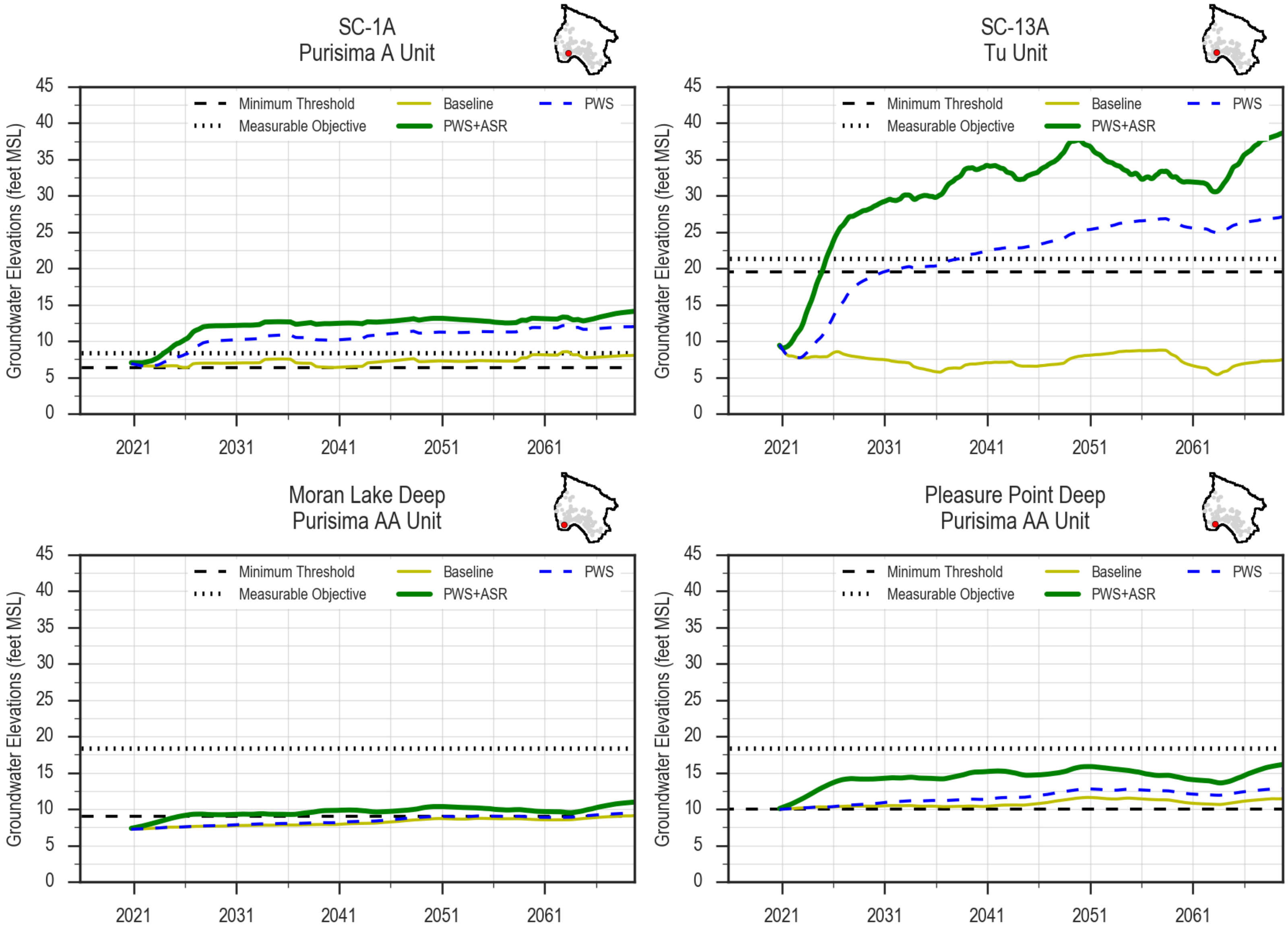

Figure 15. Running Five-Year Average Groundwater Elevations at Coastal Monitoring Wells in Tu and Purisima AA and A Units

4.2.2 City of Santa Cruz ASR

Expected benefits for seawater intrusion sustainability are to raise average groundwater levels at coastal monitoring in SCWD's service area and reduce the risk of seawater intrusion. A simulation of ASR, in combination with the PWS, under projected future climate conditions using the model demonstrates these expected benefits. Figure 15 shows running five-year average simulated groundwater levels at Moran Lake, Soquel Point and Pleasure Point representative monitoring points for seawater intrusion (Figure 12) in SCWD's service area. The simulated groundwater levels are compared to groundwater elevation proxies for minimum thresholds (black dots) and measurable objectives (black dashes) adjusted for sea level rise.

Without ASR, undesirable results are projected to occur as running five-year average simulated groundwater levels are projected to be below the minimum threshold in the Purisima AA unit under the baseline projection. The baseline projection also projects that measurable objectives at the representative monitoring points in the Purisima A unit will not be achieved or maintained. These conditions occur whether or not PWS is implemented (yellow line labeled Baseline vs. blue dashes labeled PWS) as PWS does not substantially raise groundwater levels in much of the SCWD service area.

With ASR that injects water at the existing SCWD Beltz wells and reduces pumping at the Beltz wells (green line labeled PWS+ASR), it is projected that measurable objectives will be achieved and maintained in the Purisima A unit that is the primary source of groundwater supply for SCWD, and minimum thresholds will be achieved and maintained in the Purisima AA unit such that undesirable results for seawater intrusion do not occur. ASR is projected to raise groundwater levels sufficiently such that sustainability is maintained even as SCWD increases recovery pumping to meet drought demand from the 2050s into the early 2060s.

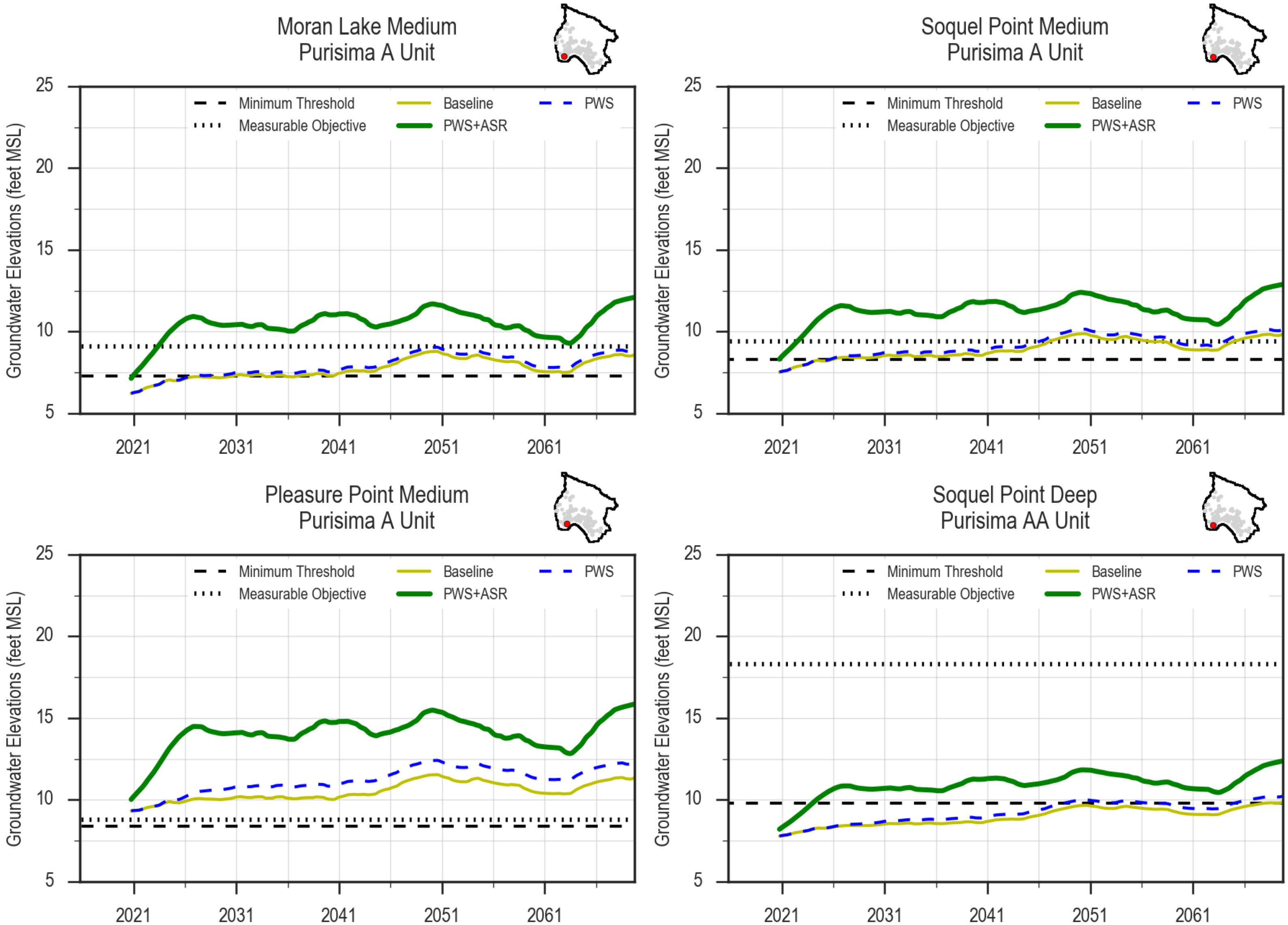

Figure 16. Running Five-Year Average Groundwater Elevations at Coastal Monitoring Wells in Purisima AA and A Units

4.3 Expected Streamflow Depletion Benefits of Projects

Expected streamflow depletion benefits of projects are evaluated based on simulated groundwater elevations at the GSP's representative monitoring points at shallow wells along Soquel Creek with groundwater elevation proxies for preventing increased surface water depletion (Figure 17). The GSP defines the groundwater elevation proxies based on minimum annual groundwater elevations so monthly results from the model are compared to groundwater elevation proxies. To avoid undesirable results, seasonal low groundwater elevations must be above the groundwater elevation proxy for the minimum threshold at all of the representative monitoring points starting in 2040. The goal of the projects is to achieve measurable objectives to provide operational flexibility, but groundwater elevations below measurable objectives are not considered undesirable results.

Figure 17. Locations of Monitoring Wells used as Representative Monitoring Points with Groundwater Elevation Proxies for Streamflow Depletion

4.3.1 Pure Water Soquel

Pure Water Soquel replenishment into the Purisima A unit is also expected to benefit the streamflow depletion sustainability indicator by raising shallow groundwater levels along Soquel Creek. Without PWS (yellow line labeled Baseline), simulated monthly groundwater levels are projected to be below the minimum threshold at most of the shallow wells. With the PWS project, shallow groundwater levels (blue dashes labeled PWS) are projected to rise to measurable objectives and be maintained above minimum thresholds to prevent undesirable results for surface water depletions (Figure 18 and Figure 19).

Figure 18. Simulated Groundwater Elevations at Purisima A Unit along Soquel Creek

4.3.2 City of Santa Cruz ASR

The hydrographs on Figure 19 show that expected benefits are maintained when combining SCWD's ASR project to PWS (green line labeled PWS+ASR). In addition, shallow groundwater levels rise to measurable objectives at the representative monitoring points for surface water depletion.

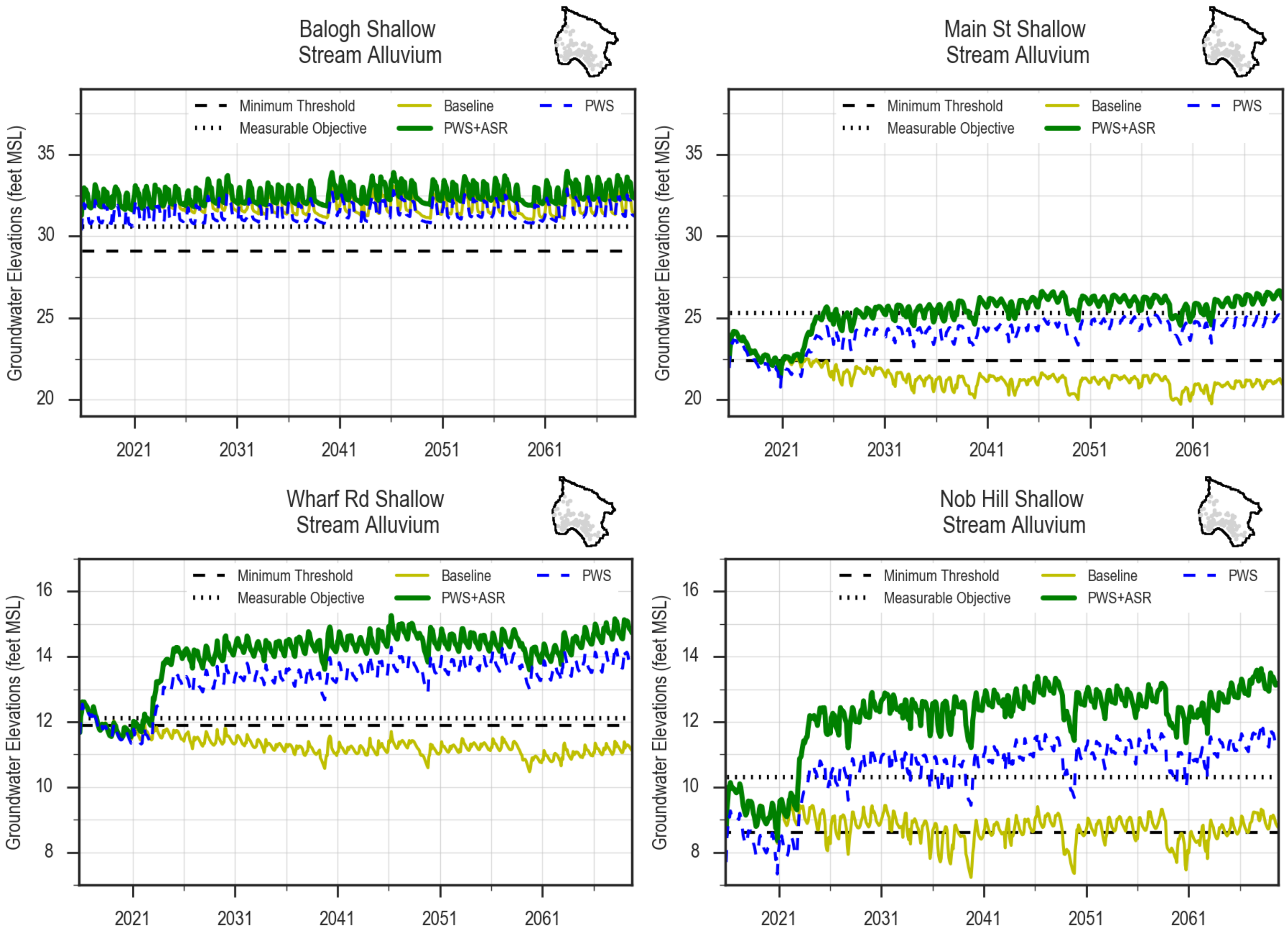

Figure 19. Simulated Groundwater Elevations at Shallow Monitoring Wells along Soquel Creek

4.4 Estimates of Interim Milestones

Interim milestones are interim measurable objectives set at five-year intervals and will be used to measure progress toward the minimum thresholds and measurable objective by 2040. The model is used to estimate groundwater elevation proxies for interim milestones based on the simulation of projects (PWS+ASR) under future conditions at representative monitoring points for seawater intrusion and surface water depletion. The interim milestones are based on modeled groundwater elevation results at representative monitoring points for 2025, 2030, and 2035.

If simulated groundwater elevations in 2025 are above minimum thresholds, the minimum thresholds are used as the interim milestone because there is some uncertainty about when projects would begin. This GSP sets as an interim milestone the elimination of undesirable results by 2025 at locations where model results show it is achievable with project implementation. If modeled groundwater levels in 2030 and 2035 are above measurable objectives, the measurable objectives are used as the interim milestones for those years.

4.4.1 Seawater Intrusion Interim Milestones

Groundwater elevation proxies for seawater intrusion are based on the five-year average of simulated groundwater elevations in Water Years 2025, 2030, and 2035. The simulated groundwater elevations are plotted as the green line labeled PWS+ASR in Figure 13 through Figure 16. Table 8 summarizes the interim milestones for seawater intrusion groundwater elevation proxies.

Table 8. . Interim MIlestones for Seawater Intrusion Groundwater Elevation Proxies

Representative Monitoring Well with Aquifer Unit in Parenthesis	Minimum Threshold	Measurable Objective	Interim Milestone 2025	Interim Milestone 2030	Interim Milestone 2035
	feet above mean sea level				
SC-A3A (Aromas)	3	7	3	3.7	3.7
SC-A1B (F)	3	5	3	5	5
SC-A8RA (F)	6	7	4.5	6.0	6.9
SC-A2RA (F)	3	4	3	4	4
SC-8RD (DEF)	10	11	10	10	10
SC-9RC (BC)	10	11	4.6	11	11
SC-8RB (BC)	19	20	8.4	16.6	18.1
SC-5RA (A)	13	15	13	15	15
SC-3RA (A)	10	12	10	12	12
SC-1A (A)	4	6	4	6	6
Moran Lake Medium (A)	5	6.8	5	6.8	6.8
Soquel Point Medium (A)	6	7.1	6	7.1	7.1
Pleasure Point Medium (A)	6.1	6.5	6.1	6.5	6.5
Moran Lake Deep (AA)	6.7	16	6.7	8.1	7.8
Soquel Point Deep (AA)	7.5	16	7.5	8.3	8.3
Pleasure Point Deep (AA)	7.7	16	7.7	11.8	11.9
SC-13A (Tu)	17.2	19	8.3	16.7	18.1

4.4.2 Surface Water Depletion Interim Milestones

Groundwater elevation proxies for seawater intrusion are based on the annual minimum of simulated groundwater elevations in Water Years 2025, 2030, and 2035. The simulated groundwater elevations are plotted as the green line labeled PWS+ASR in Figure 19. Table 9 summarizes the interim milestones for depletion of interconnected surface water groundwater elevation proxies.

Table 9. Interim Milestones for Deletion of Interconnected Surface Water Groundwater Elevation Proxies

Representative Monitoring Well with Aquifer Unit in Parenthesis	Minimum Threshold	Measurable Objective	Interim Milestone 2025	Interim Milestone 2030	Interim Milestone 2035
	feet above mean sea level				
Balogh	29.1	30.6	29.1	30.6	30.6
Main St. SW 1	22.4	25.3	20.7	22.9	23.2
Wharf Road SW	11.9	12.1	11.3	12.1	12.1
Nob Hill SW 2	8.6	10.3	7.3	9.5	9.9
SC-10RA	68	70	68	70	70

4.5 Basinwide Groundwater Elevation Effects of Projects

Projects are also evaluated based on the area where the projects affect groundwater elevations. Three maps are created for each aquifer unit to evaluate effects of PWS and ASR individually, and the projects in combination.

1. Pure Water Soquel: The effect of PWS is evaluated by mapping the groundwater elevation (head) difference between the PWS simulation and the baseline simulation in September 2039, the approximate seasonal low period before the January 2040 deadline to achieve sustainability.

2. City of Santa Cruz Aquifer Storage and Recovery: The effect of ASR is evaluated by mapping the groundwater elevation (head) difference between the PWS+ASR simulation and the PWS simulation in September 2039, the approximate seasonal low period before the January 2040 deadline to achieve sustainability.

3. Projects in Combination: The effect of the projects in combination is evaluated by mapping the groundwater elevation difference between the PWS+ASR simulation and the baseline simulation in October 2059 at the end of the two year drought over which ASR has its maximum pumping recovery. This will evaluate effects of combined projects when ASR pumping recovery to meet SCWD drought needs is causing groundwater elevations to drop.

The following subsections describe groundwater elevation effects by aquifer unit.

4.5.1 Purisima DEF/F Unit Groundwater Elevation Effects

The simulations of PWS redistribute pumping so that pumping is reduced at the San Andreas and Bonita wells in the Purisima F unit. The PWS and PWS+ASR simulations also increase pumping at the Aptos Creek well that is screened in both the Purisima DEF and BC units. The ASR project does not make any pumping or injection changes to the Purisima DEF or F units.

The upper map of Figure 20 shows the benefits of pumping redistribution with PWS that reduces pumping in the Purisima F unit. Pumping reductions facilitate in-lieu recharge to raise groundwater elevations (green areas) in the Aromas area (southeast portion of the Basin). Increases in groundwater elevations extend to the coastal boundary of the Basin and also across the Basin boundary into the Pajaro Valley Subbasin.

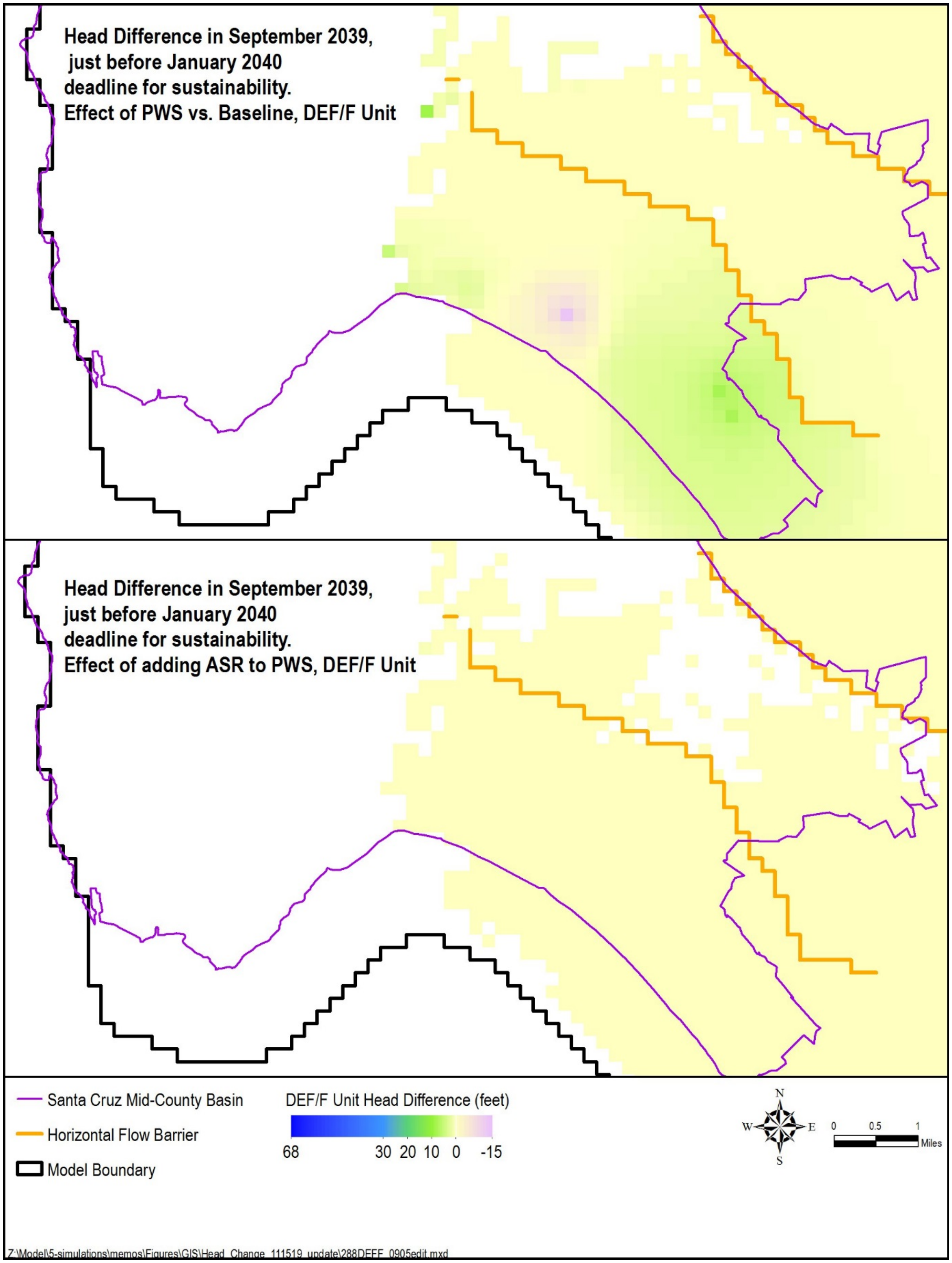

Figure 20. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations, DEF/F Unit

The upper map of Figure 20 shows decreases in groundwater elevations in the Purisima DEF unit (violet area) related to increased pumping at the Aptos Creek well. These simulation results show that the groundwater level decrease in the Purisima DEF unit does not extend to the coast, but the calibration report notes that the model is not calibrated to simulate the confined portion of the Purisima DEF unit. Adjustments to pumping from the Aptos Creek well and other Purisima DEF wells will likely be necessary during implementation to ensure groundwater elevations do not decline at the coast.

The ASR project does not have any effect in these aquifer units as shown on the lower map of Figure 20. Figure 21 that shows the effects of projects in combination is very similar to the upper map of Figure 20 because only PWS affects this area.

4.5.2 Purisima BC Unit Groundwater Elevation Effects

The simulations of PWS include injection into the Purisima BC unit at the Twin Lakes Church SWIP well. The PWS and PWS+ASR simulations also increase pumping at the Aptos Creek, Madeline, Ledyard, and Estates wells screened in the Purisima BC unit. The ASR project does not make any pumping or injection changes to the Purisima BC unit.

The upper map of Figure 22 shows the benefits of PWS injection into the Purisima BC unit. The largest increase (darkest blue area) is at the Twin Lakes Church SWIP well and increases extend to the coastal boundary of the Basin. Groundwater elevation increases are also simulated in the area of the Purisima BC unit where pumping from the unit is increased at SqCWD production wells.

The ASR project does not have any effect in this aquifer unit as shown on the lower map of Figure 22. Figure 23 that shows the effects of projects in combination is similar to the upper map of Figure 22 because only PWS affects this area. Figure 23 shows groundwater elevations are simulated to rise between 2040 and 2059 with nearly 20 years of additional injection into the Purisima BC unit.

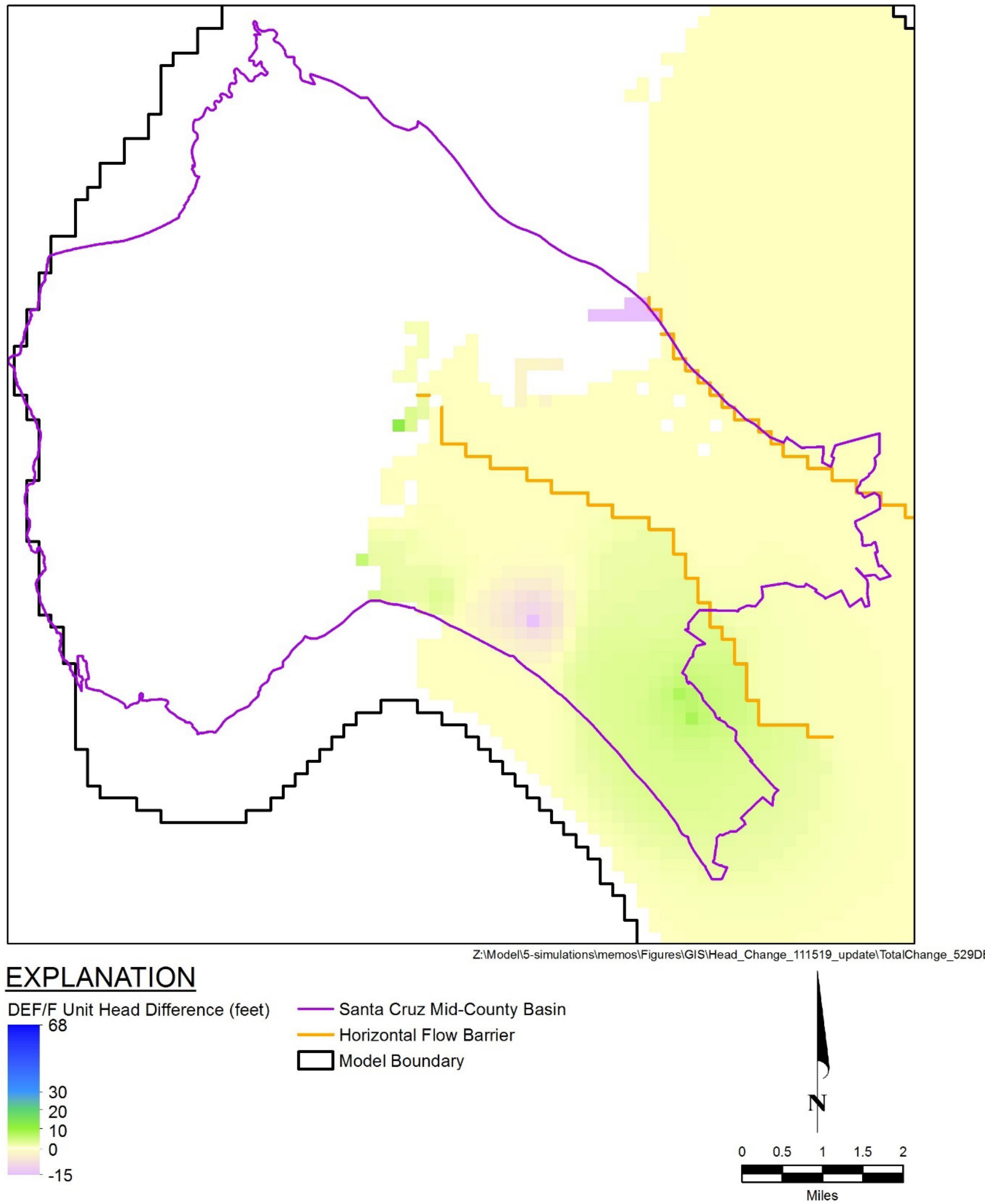

Figure 21. Simulated Effect of ASR and PWS on Groundwater Elevations on October 2059, DEF/F Unit

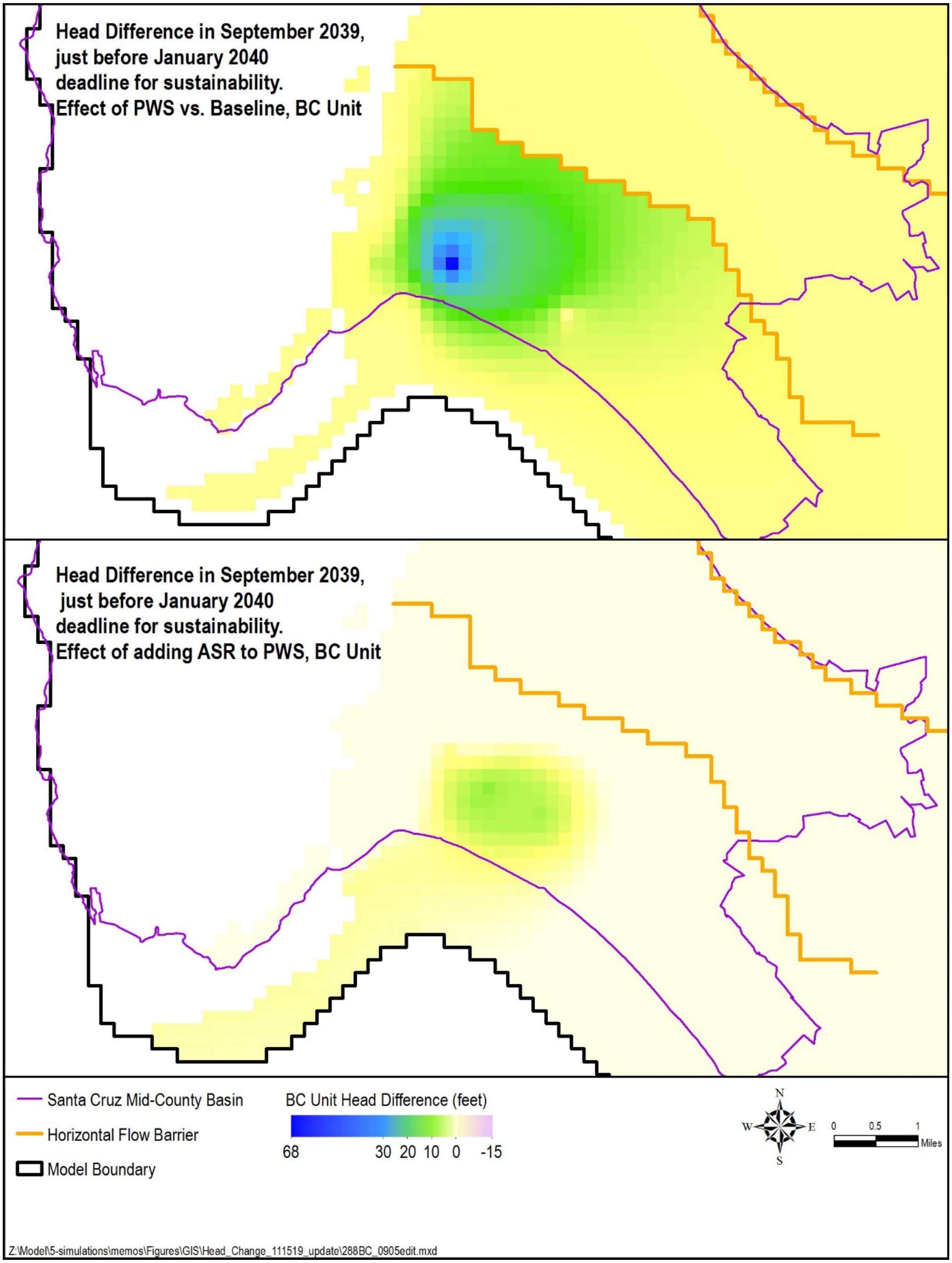

Figure 22. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations , BC Unit

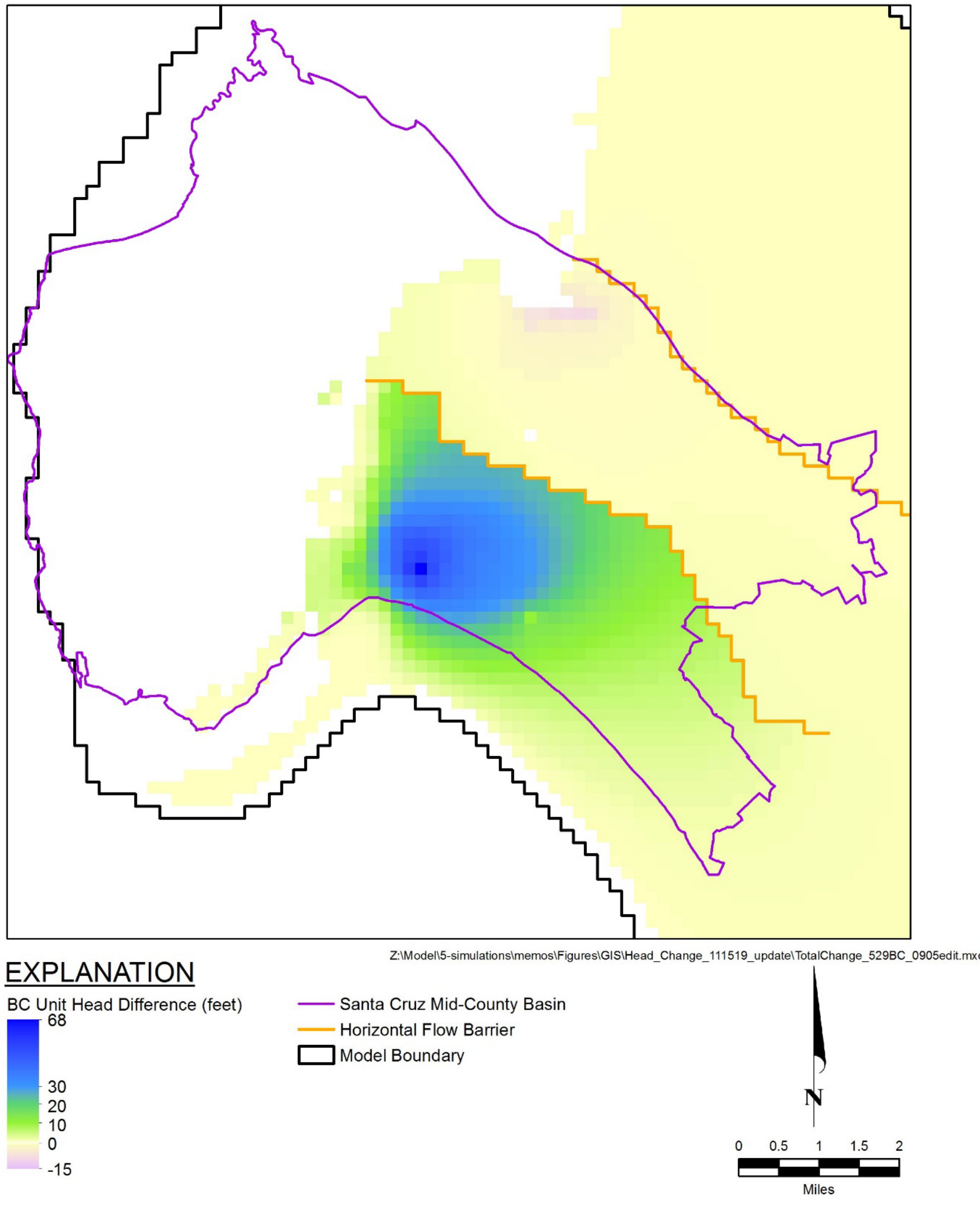

Figure 23. Simulated Effect of ASR and PWS on October 2059 Groundwater Elevations, BC Unit

4.5.3 Purisima A Unit Groundwater Elevation Effects

The simulations of PWS include injection into the Purisima A unit at the Twin Lakes Church, Willowbrook, and Monterey SWIP wells. The PWS and PWS+ASR simulations also increase pumping at the Estates, Tannery II, and Cunnison Lane wells screened in the Purisima A unit. Pumping is decreased at the Garnet well in the Purisima A unit and at the Main Street and O'Neill Ranch wells partially screened in the Purisima AA unit to the west. The simulation (PWS+ASR) incorporating the ASR project includes injection into the Purisima A and AA units at the Beltz 8, 9, and 10 wells. The ASR project also changes pumping at these Purisima A and AA unit wells compared to the baseline simulation. On average, pumping is reduced at the Beltz wells in the Purisima A and AA units, but there are a number of years with lower surface water availability when pumping is increased to meet projected SCWD demand.

The upper map of Figure 24 shows the benefits of PWS injection into the Purisima A unit. The largest increase (darkest blue area) is at the SWIP wells and increases extend to the coastal boundary of the Basin. Groundwater elevation increases are also simulated in the area of the Purisima A unit where pumping from the unit is increased at SqCWD production wells. Groundwater elevation increases are simulated to extend to the west where pumping is decreased in the Purisima A and AA units.

The lower map of Figure 24 shows the benefits of ASR injection and overall pumping reduction in the Purisima A and AA units where groundwater elevations increase (green areas) with the increases extend to the coastal Basin boundary. ASR increases groundwater elevations to the west of most of the groundwater elevation increases caused by PWS. The projects therefore have complementary benefits.

In areas where the PWS SWIP wells are located, groundwater elevation differences in Figure 25 are similar to the upper plot of Figure 24 as ASR has little effect in this area. Figure 21 shows effects of the maximum two-year pumping recovery period under ASR to the west. The model simulates small areas where groundwater elevations fall below baseline groundwater elevations at the Beltz wells (light violet areas) to the west but these declines do not extend to the coastal boundary of the Basin.

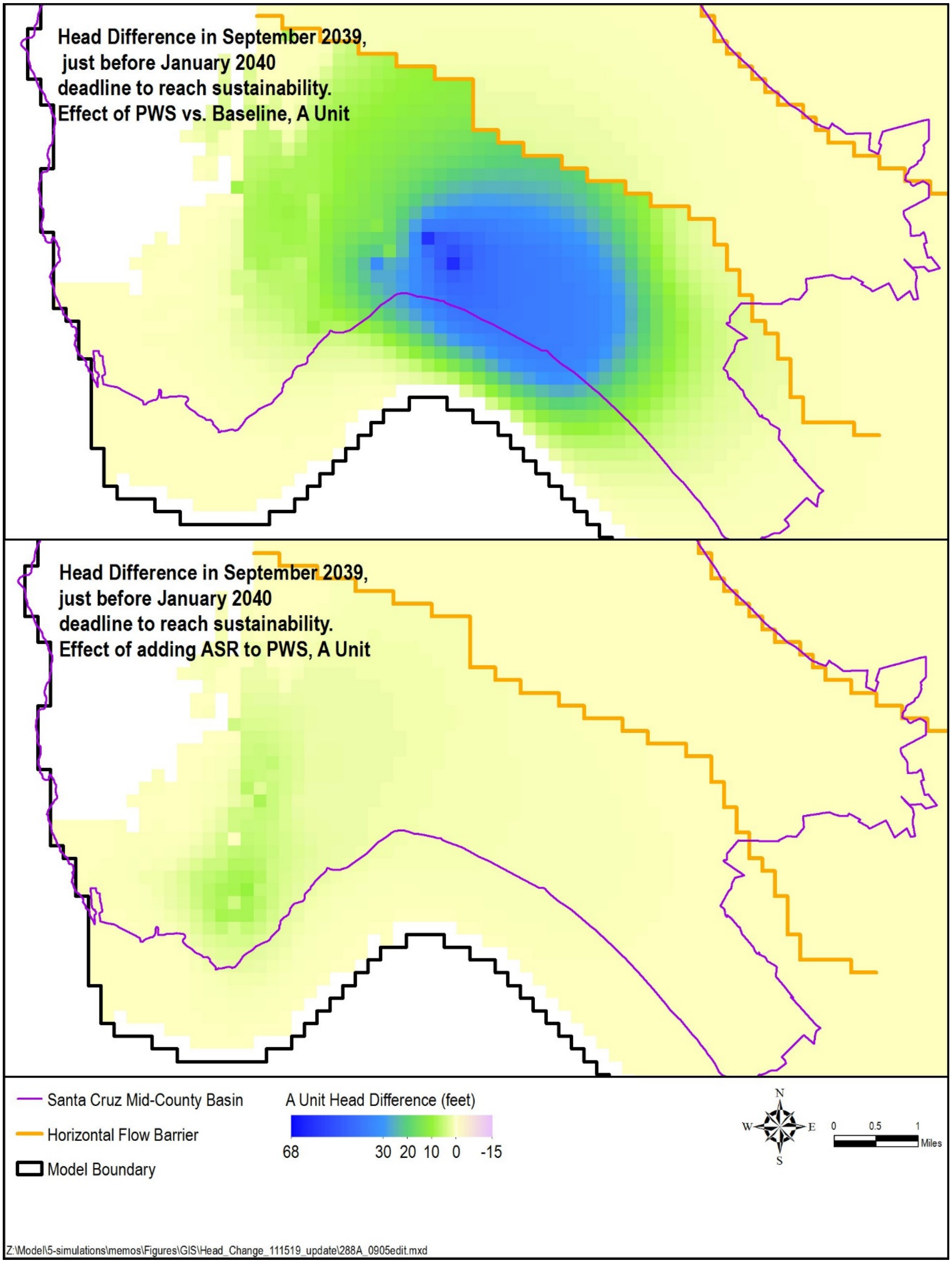

Figure 24. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations, A Unit

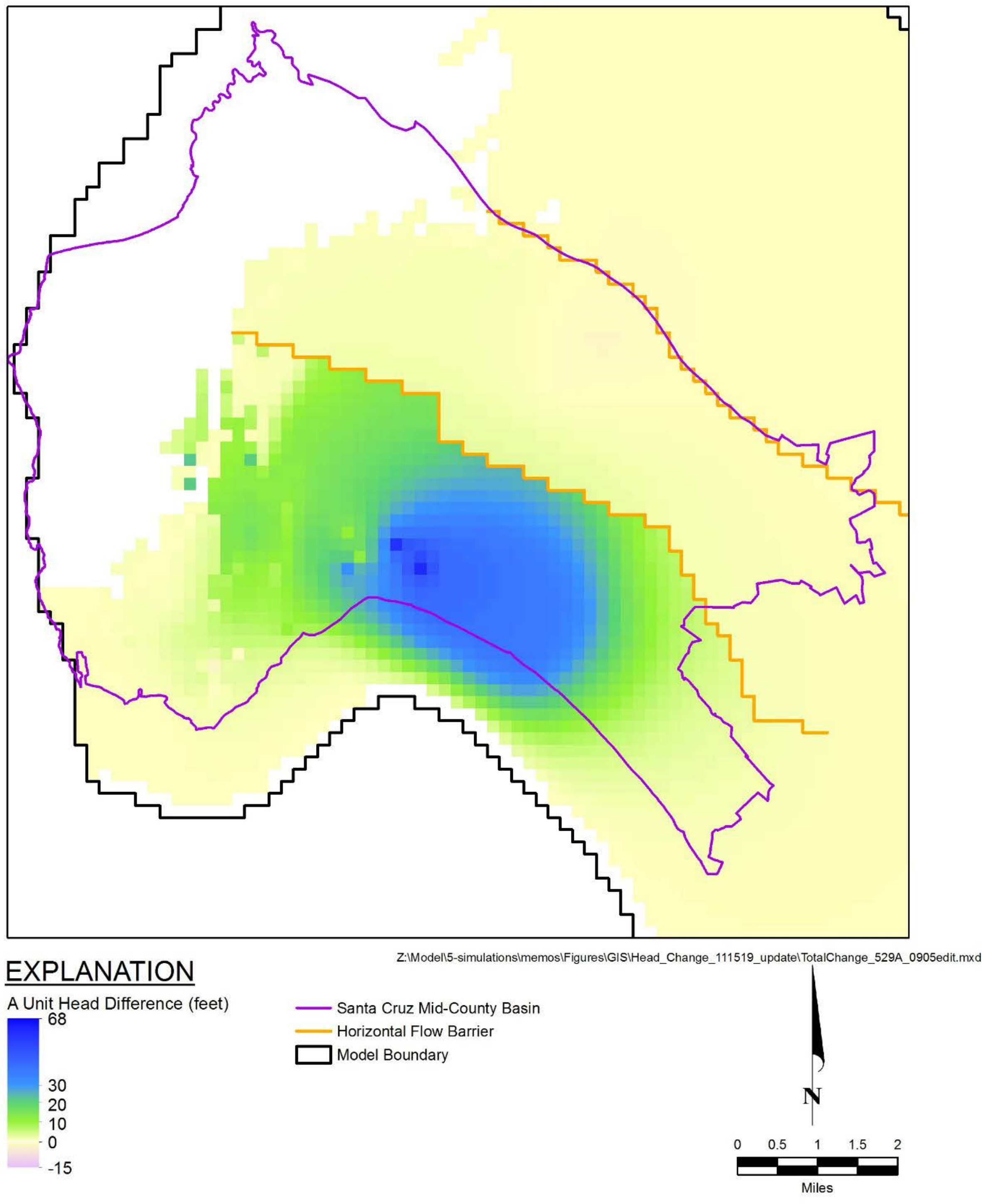

Figure 25. Simulated Effect of ASR and PWS on October 2059 Groundwater Elevations A Unit

4.5.4 Tu Unit Groundwater Elevation Effects

The simulations of PWS include reduction of pumping from the Tu unit at the Main Street and O'Neill Ranch wells. The simulation (PWS+ASR) with the ASR project includes injection into the Tu unit at the Beltz 12 well. The ASR project also changes pumping from the Beltz 12 well from the baseline simulation. On average, pumping is increased at the Beltz 12 well. Both injection and pumping with the ASR project varies over time based on surface water availability.

The upper map of Figure 26 shows the benefits of pumping reduction in the Tu unit that is part of the PWS project. The pumping reduction facilitates in-lieu recharge to raise groundwater elevations with the largest increase (blue area) at the O'Neill Ranch and Main Street wells. The increases extend to the coastal boundary of the Basin.

The lower map of Figure 26 shows a decline in groundwater elevations in the Tu unit at the Beltz 12 well after Water Year 2039 resulting from ASR. ASR has relatively high pumping and low injection in Water Year 2039 due to simulated reduced surface water supply. However, the lower map of Figure 26 shows increases in groundwater elevations resulting from ASR in the Tu unit at the coastal Basin boundary resulting from overall net injection by ASR over the previous twenty years.

Figure 27 shows the effects of projects in combination that raise groundwater elevations throughout the Tu unit compared to the baseline simulation even after ASR's maximum two-year pumping recovery period.

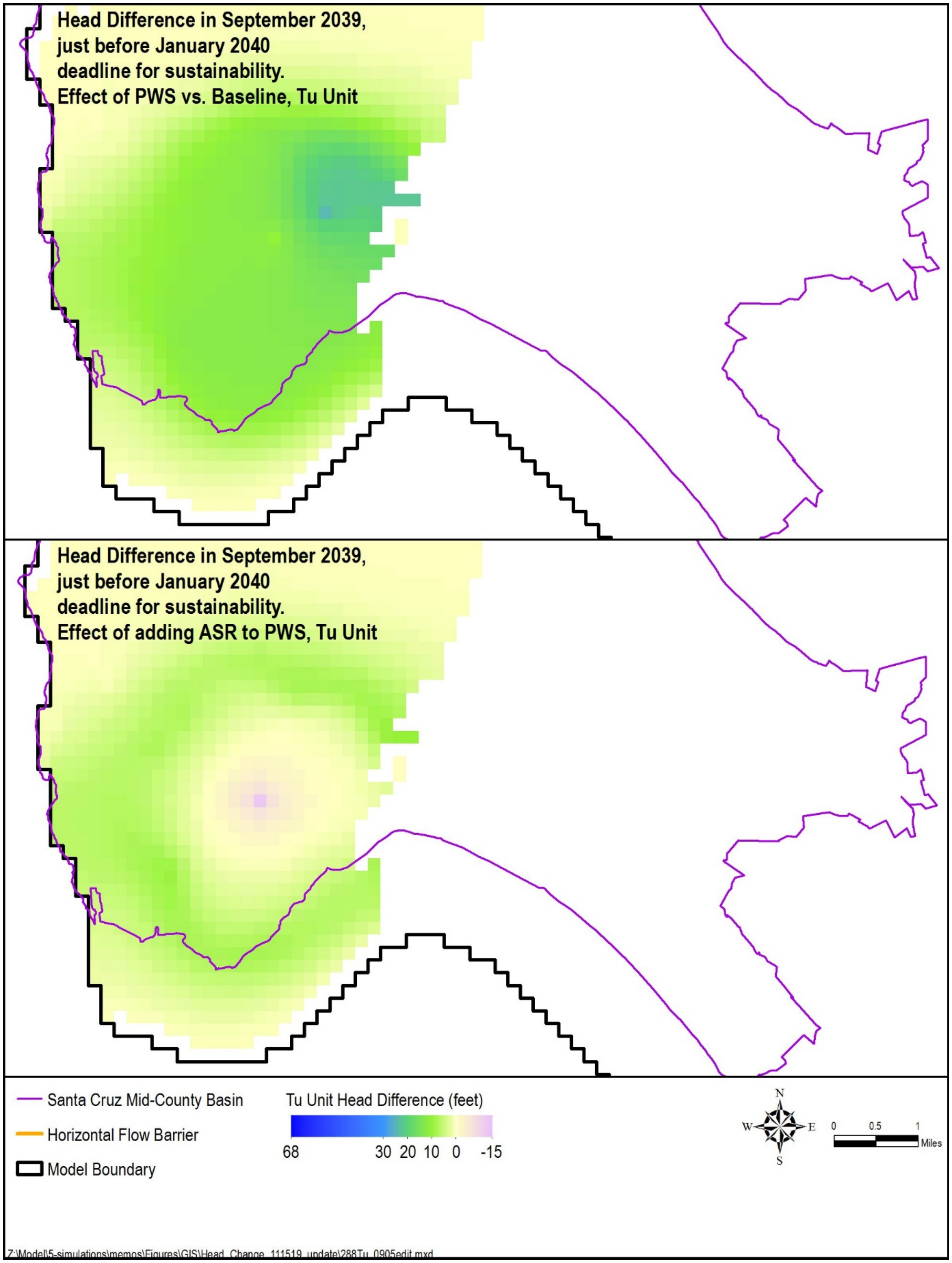

Figure 26. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations, Tu Unit

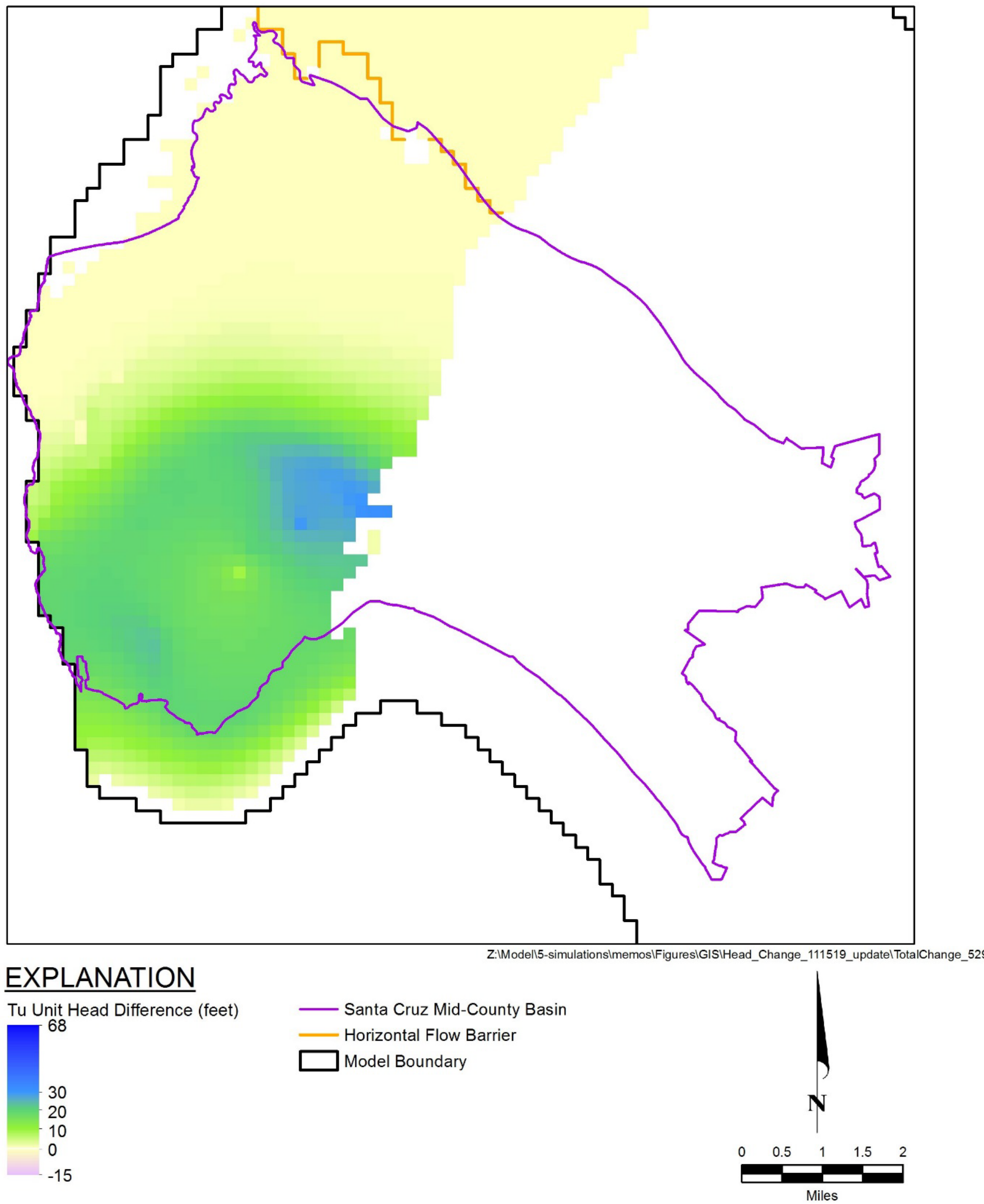

Figure 27. Simulated Effect of ASR and PWS on October 2059 Groundwater Elevations, Tu Unit

4.6 Effect of Projects on Groundwater Budget Components

The combination of PWS and ASR have significant effects on multiple water budget components when simulated over the future time period as shown by a comparison of the PWS+ASR simulation compared to the baseline simulation. The effects of the individual projects can also be evaluated by comparing the PWS simulation to the baseline simulation for the effects of PWS and the PWS+ASR simulation to the PWS simulation for the effects of ASR. These effects are tabulated and presented visually in Table 10 and Figure 28, respectively. The effect of ASR can be seen on Figure 28 starting in 2020, when the City of Santa Cruz begins injection at its Beltz wells. The effects of PWS begins in 2023, the planned start date for injection at the PWS SWIP wells.

Table 10. Groundwater Budget Components, Comparison Between Baseline and Project Scenarios

Groundwater Budget Components	Average (PWS)	Average (ASR)	Average (PWS + ASR)	Difference From Baseline (PWS + ASR)
Inflows	acre-feet per year			percent
UZF Recharge	0	0	0	0%
Net Recharge from Stream Alluvium	-260	-80	-330	- 33%
Recharge from Terrace Deposits	-30	-10	-50	- 3%
Subsurface Inflow from Purisima Highlands	0	0	0	0%
Outflows				
Pumping	-1,280	-460	-1,740	- 28%
Subsurface Outflow to Santa Margarita Basin	0	0	0	0%
Net Subsurface Outflow to Pajaro Valley Subbasin	250	0	250	+ 7%
Offshore	520	320	840	+ 73%
Change in Storage	220	50	280	400%

Note: Differences are normalized so that all decreases indicate a smaller volume of flow, and all increases indicate a greater volume of flow. All values rounded to nearest 10 acre-feet per year

The effects of both projects are most immediately visible in the groundwater pumping budget component, where PWS decreases annual average net pumping by 21%, and ASR causes a further decrease of 7%. Figure 28 shows the decrease in net pumping for PWS is constant while the decrease for ASR varies annually depending on surface water availability. The decreases in net pumping, which includes addition of injection, result in increases of groundwater in storage as plotted by the solid and dashed lines on Figure 28. Groundwater in storage increases an average of approximately 230% with PWS and 60% with ASR. The annual increases of groundwater in storage from PWS decline over the time corresponding with groundwater elevations stabilizing over time, and there are both increase and decreases of groundwater in storage from ASR.

Offshore flows are a key indication of project performance for achieving sustainability, as seawater intrusion is the critical sustainability indicator in the Basin. When compared to baseline, the PWS+ASR simulation displays a 76% higher volume of offshore flow, reflecting higher overall groundwater elevations within the Basin, and a general promotion of conditions that can prevent and possibly reverse seawater intrusion. In an average year, PWS is responsible for about 47% of this increase, while ASR contributes the remaining 29%. These effects are seen over the entire projected period, and are present during both wet and dry climatic conditions (Figure 29).

The PWS+ASR simulation displays a reduction in stream alluvium recharge when compared to baseline, indicating a greater flow of water from groundwater to streams and creeks within the Basin (groundwater flows). In an average year, the majority of the increase in groundwater flows to alluvium is due to PWS injection, while ASR contributes the remaining amount.

Figure 30 specifically examines this relationship in the Soquel Creek watershed, where results highlight the positive effect of both projects on groundwater flows to Soquel Creek during minimum flow months.. As discussed in the calibration report, the magnitude of groundwater flows to streams are not well calibrated so simulation results are only meant to demonstrate that there are expected benefits to streamflow from the projects as opposed to quantifying the benefit.

Higher groundwater elevations resulting from decreases in pumping from the Purisima F unit with PWS in the Aromas area result in a net increase of outflow (or net decrease of inflow) to Pajaro Valley Subbasin so the PWS project should have benefit for sustainability in that neighboring subbasin.

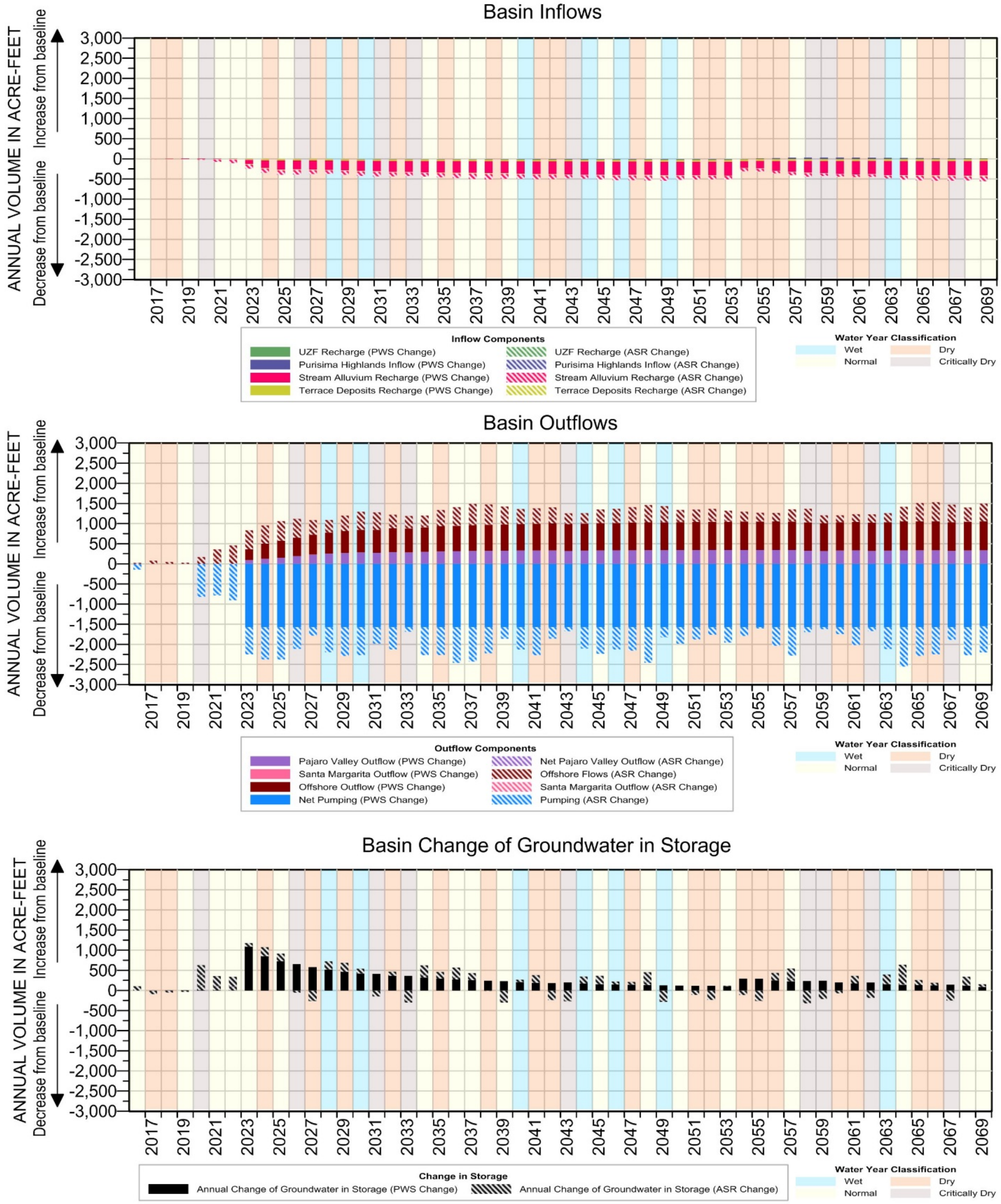

Figure 28. Overall Groundwater Budget, Comparison Between Baseline and Project Scenarios

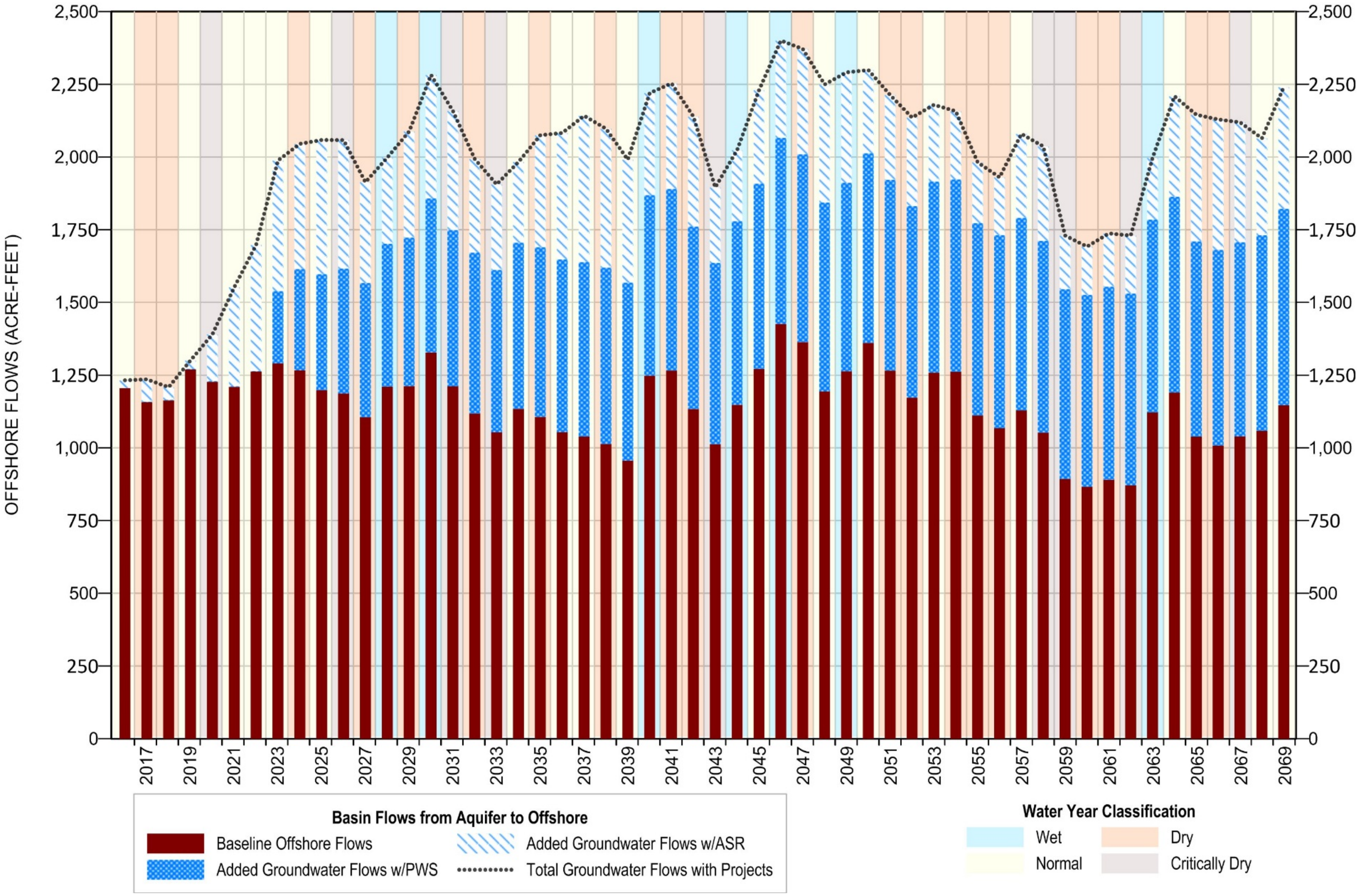

Figure 29. Offshore Flows, Comparison Between Baseline and Project Scenario

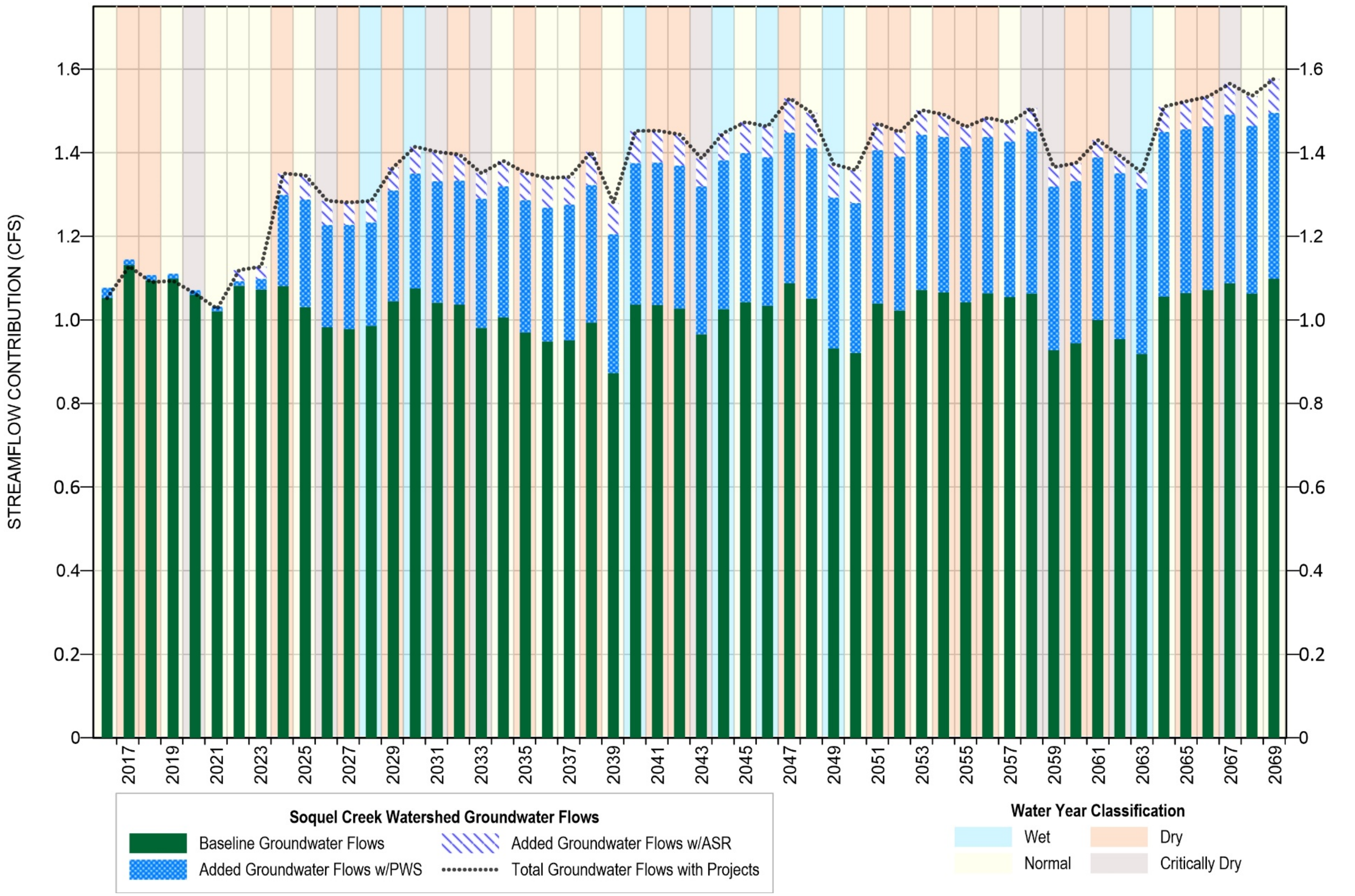

Figure 30. Soquel Creek Watershed Groundwater Flows during Minimum Flow Month Each Year, Comparison between Baseline and Project Scenarios

5 MODELING FOR SUSTAINABLE YIELD ESTIMATES

The GSP requires an estimate of Basin sustainable yield. For the Santa Cruz Mid-County Basin, sustainable yield is defined as the net pumping that avoids undesirable results in the Basin. Net pumping is pumping extraction minus managed recharge such as injection. Sustainable yield is also used as the minimum threshold for the reduction of groundwater in storage sustainability indicator. The Basin GSP sets separate sustainable yields for three aquifer unit groups: Aromas Red Sands/Purisima F, Purisima DEF/BC/A/AA, and Tu. The sustainable yields are based on simulations of future conditions because the Basin has experienced historical and current undesirable results.

5.1 Sustainable Yield Approach

The baseline simulation of future conditions shows undesirable results, but the simulation with projects shows that projects achieve sustainability by meeting minimum thresholds and therefore avoiding undesirable results. In general, projects show groundwater elevations rising higher than minimum thresholds and meeting measurable objectives. As sustainability is defined as avoiding undesirable results by meeting minimum thresholds, the sustainable yield is greater than the net pumping achieved by the projects. The approach for estimating sustainable yield is to use the configuration of the projects but increase net pumping while still meeting minimum thresholds. The estimates of sustainable yield are therefore specific to the configuration of PWS and ASR simulated under future conditions.

5.2 Groundwater Pumping Simulated

Different rates for pumping and injection were tested at SqCWD and SCWD wells included in the configuration of PWS and ASR to test whether minimum thresholds were met. Rates were revised beginning in Water Year 2026 when the final configuration of the projects were set with the Cunnison Lane well coming online. Project rates were used prior to Water Year 2026. CWD and non-municipal rates were not revised from baseline assumptions. Table 11 shows the distribution of pumping rates that achieve minimum thresholds to estimate sustainable yields for each aquifer unit group. There are likely other distributions of pumping rates within each aquifer unit group that also achieve sustainability.

Table 11. Groundwater Pumping and Injection 2026-2069 for Sustainability Estimate

Aquifer Group	Well Name	Average Net Pumping (for Sustainable Yield)	Average Net Pumping (Baseline)	Average Net Pumping (PWS+ASR)
		acre-feet per year		
Aromas Red Sands and Purisima F	Polo Grounds	100	100	100
	Aptos Jr High	250	250	250
	Country Club	0	70	70
	Bonita	75	269	79
	San Andreas	232	371	78
	Seascape	46	46	46
	CWD 4	48	48	48
	CWD 10	92	92	92
	CWD 12	410	410	410
	Domestic	84	84	84
	Institutional	199	199	199
	Agricultural	203	203	203
	Total	1,739	2,142	1,659
Purisima DEF, D, BC, A, and AA	Beltz 8	0	93	-29
	Beltz 9	58	123	-10
	Beltz 10	0	91	-1
	Monterey	-450	0	-500
	Willowbrook	-233	0	-233
	Twin Lakes Church	-742	0	-742
	Rosedale 2	546	545	545
	Garnet	253	254	205
	Cunnison	426	215	399
	Tannery 2	563	223	571
	Estates	398	316	402
	Madeline 2	122	98	122
	Ledyard	120	108	120
	Aptos Creek	102	0	105
	T-Hopkins	137	139	139
	Granite	135	135	135
	Domestic	579	579	579
	Institutional	109	109	109
	Agricultural	162	162	162
	Total	2,285	3,190	2,083

Aquifer Group	Well Name	Average Net Pumping (for Sustainable Yield)	Average Net Pumping (Baseline)	Average Net Pumping (PWS+ASR)
		acre-feet per year		
Tu	Beltz 12	40	39	66
	Main St	349	529	349
	O'Neill	229	229	182
	Domestic	278	278	278
	Institutional	7	7	7
	Agricultural	23	23	23
	Total	927	1,105	905
All Aquifers	**Total**	4,950	6,437	4,502

5.3 Comparison to Minimum Thresholds

Groundwater elevations for future conditions simulated with the pumping rates used to estimate sustainable yield are compared to groundwater elevation proxies at representative monitoring points for seawater intrusion and surface water depletion. Simulated groundwater elevations meeting minimum thresholds demonstrate that the aquifer unit group yields are sustainable.

The following summarizes where pumping rates at specific wells were revised substantially from the projects simulation and which representative monitoring points for seawater intrusion controlled the change.

For the Aromas Red Sands/Purisima F sustainability yield estimate:

- Country Club well pumping is removed to achieve minimum thresholds at SC-A1B and SC-A8A while pumping is increased by greater amounts farther to the east.
- San Andreas well pumping is increased and minimum thresholds are still met at SC-A2A and SC-A3A.

For the Purisima DEF/BC/A/AA sustainability yield estimate:

- The full project net pumping including injection at SWIP wells are needed to achieve minimum thresholds in the Purisima BC unit at representative monitoring points SC-8B and SC-9C.
- Net pumping from Purisima A unit can be increased in SqCWD wells, including increased pumping from the Tannery II, Cunnison Lane, and Garnet wells together with a

decrease in injection at the Monterey SWIP well can still achieve minimum thresholds at representative monitoring points SC-5A, SC-3A, and SC-1A.

- ASR includes net injection on average, but net pumping at the Beltz wells without injection can still achieve minimum thresholds at the Medium (A) and Deep (AA) completions of the Pleasure Point, Soquel Point, and Moran Lake well representative monitoring point.

For the Tu sustainability yield estimate:

- Net pumping from the Tu unit can still achieve minimum thresholds at representative monitoring point SC-13 without ASR injection. The distribution simulated includes no injection, baseline pumping at Beltz 12 and O'Neill Ranch wells, and assumed pumping at the Main Street well under PWS. The simulated distribution achieves sustainability, but other sustainable distributions amongst the three municipal wells in the Tu unit likely also exist.

Figure 34 and

Figure 35 also show that the simulation of net pumping shown in Table 11 also meets minimum thresholds for groundwater elevation proxies for surface water depletion preventing undesirable results for that indicator.

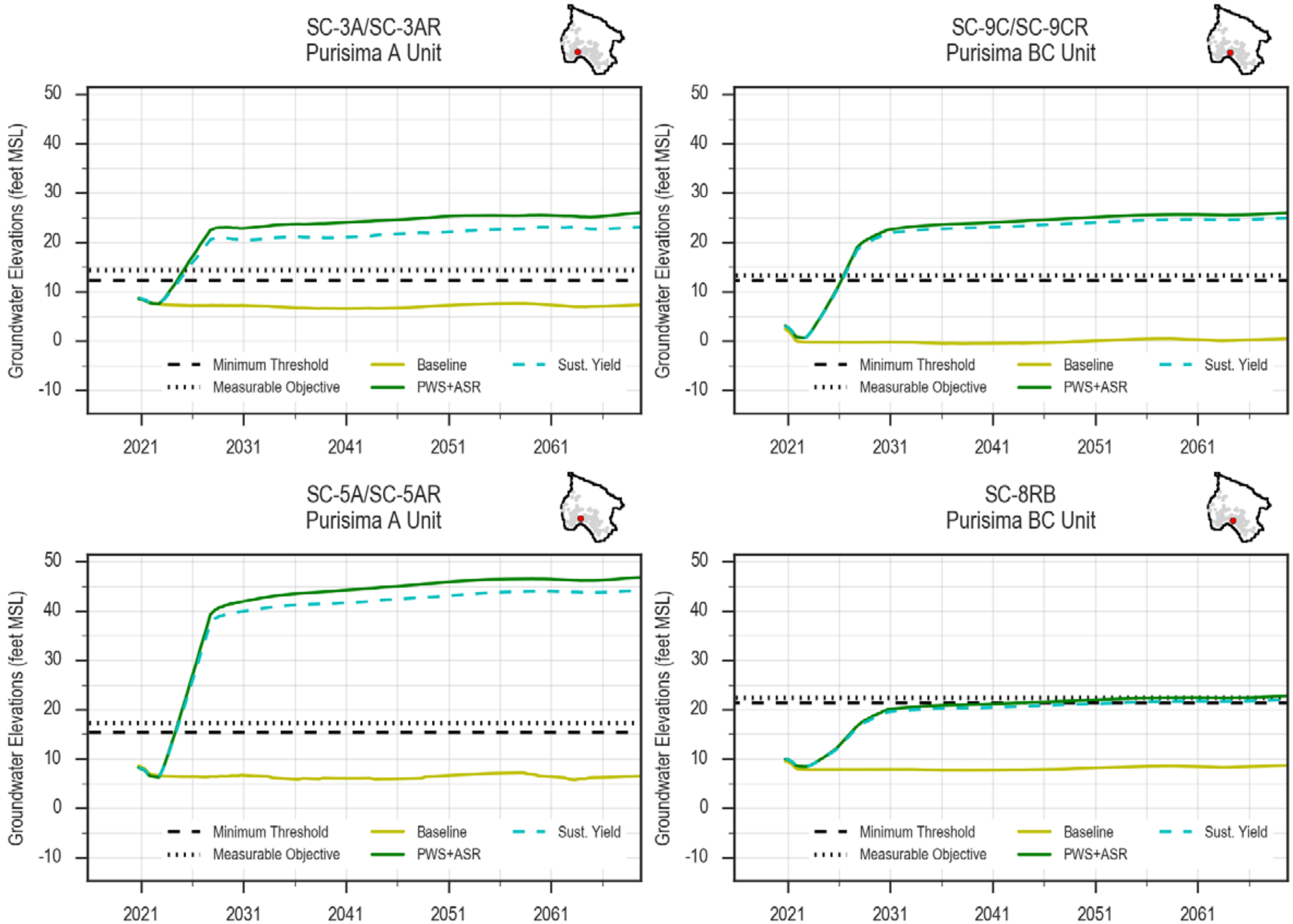

Figure 31. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima A and BC Units for Sustainable Yield Estimate

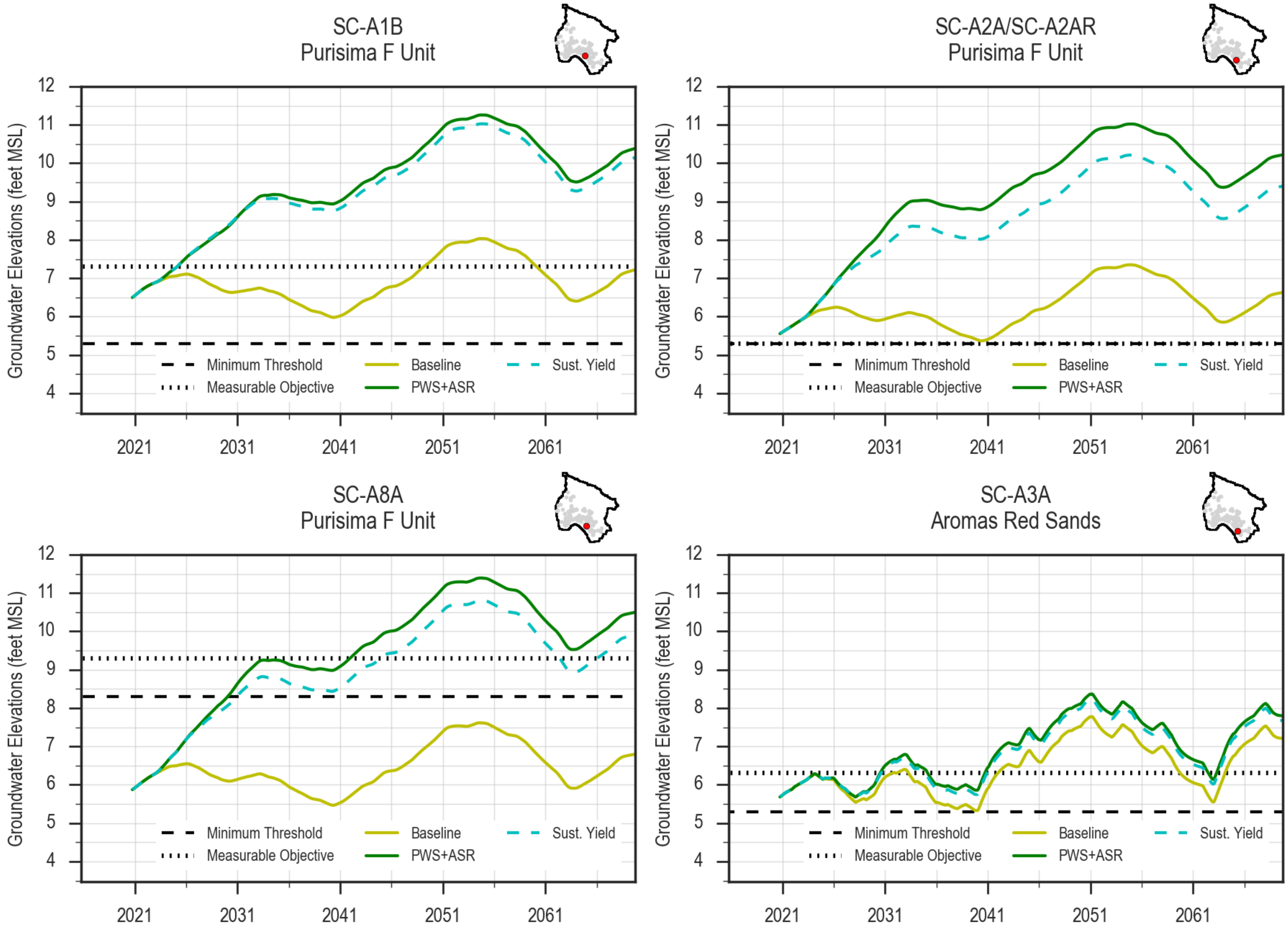

Figure 32. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima F and Aromas Red Sands Units for Sustainable Yield Estimate

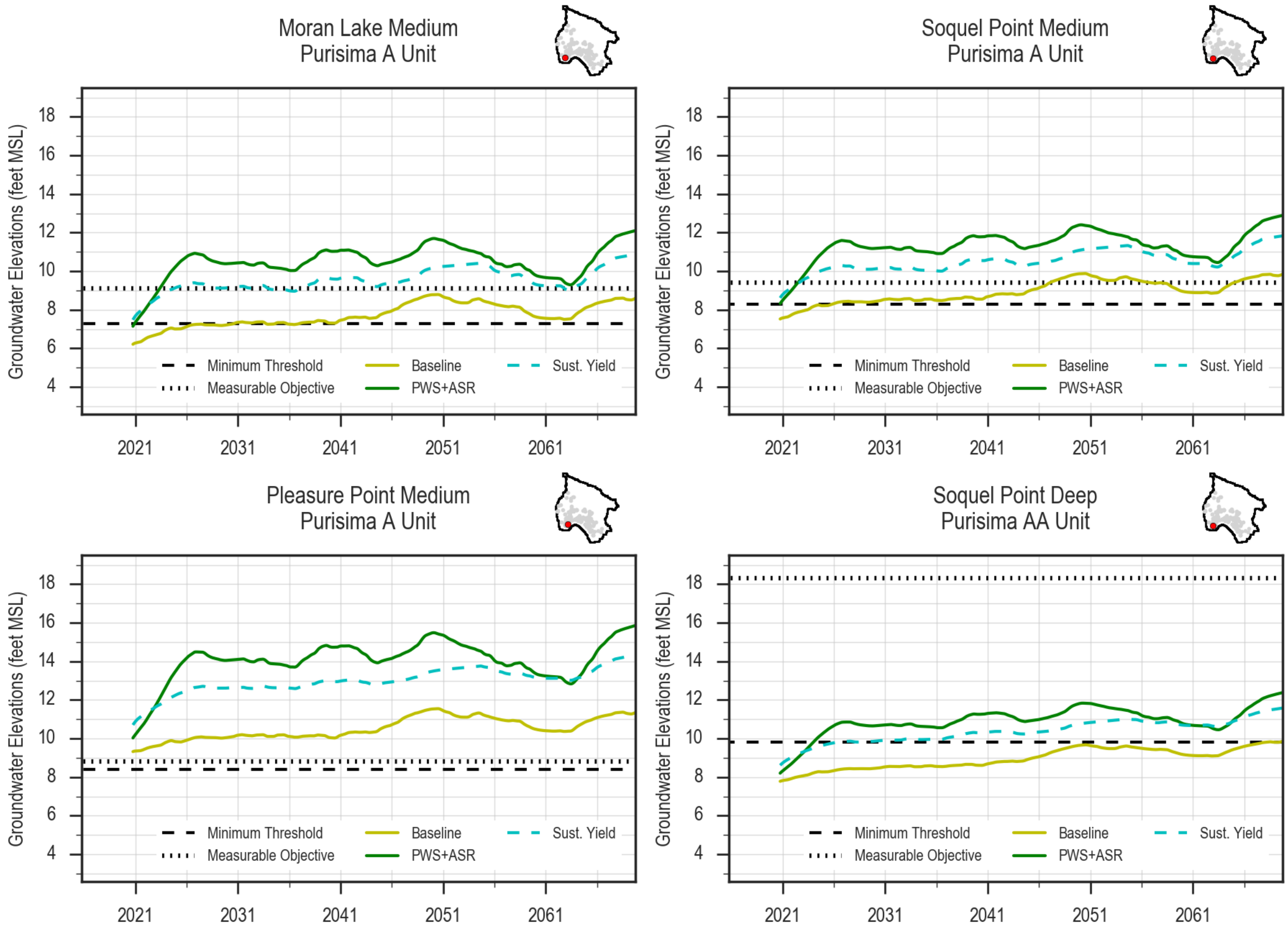

Figure 33. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Tu and Purisima AA and A Units for Sustainable Yield Estimate

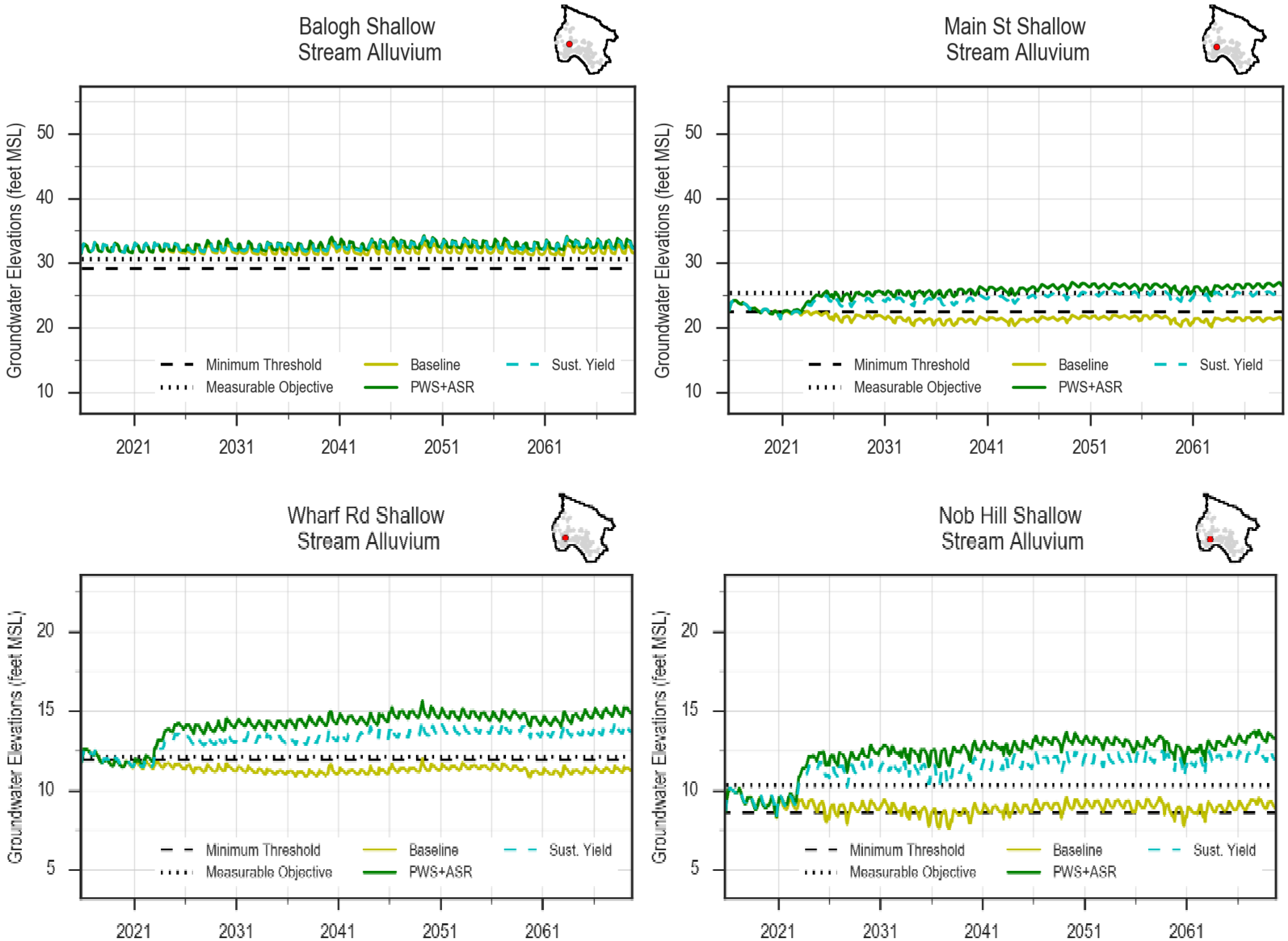

Figure 34. Simulated Groundwater Elevations at Shallow Wells along Soquel Creek for Sustainable Yield Estimate

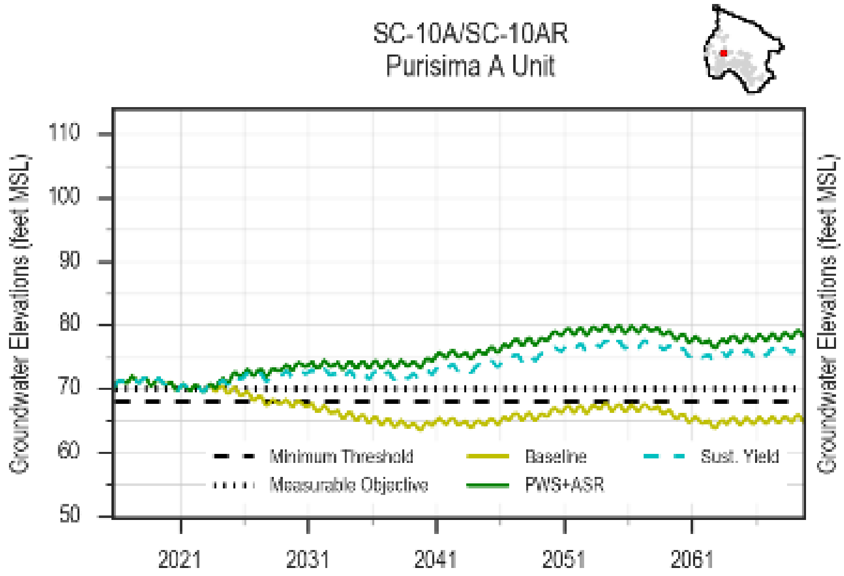

Figure 35. Simulated Groundwater Elevations at Purisima A Unit Well along Soquel Creek for Sustainable Yield Estimate

5.4 Sustainable Yield Estimates

As the simulation of net pumping to estimate sustainable yield shows that minimum thresholds are achieved and undesirable results are eliminated and avoided, Table 12 provides estimates of sustainable yield based on ASR and PWS configuration.

Table 12. Estimates of Sustainable Yield Based on Configuration of Pure Water Soquel and City of Santa Cruz ASR

Aquifer Group	Sustainable Yield (acre-feet per year)
Aromas Red Sands and Purisima F	1,740
Purisima DEF, BC, A, and AA	2,280
Tu	930
Total	4,950

6 CONCLUSIONS

The simulations of future conditions show that implementation of the PWS and ASR projects help the Basin achieve sustainability while the simulation of baseline conditions show continued undesirable results. The simulations show that both PWS and ASR contribute to achieving basin sustainability and are largely complementary in benefiting different areas of the Basin. The model is also used to provide an estimate of sustainable yield based on the configuration of the PWS and ASR projects.

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8 ACRONYMS & ABBREVIATIONS

ASR................Aquifer Storage and Recovery
CWD..............Central Water District
DWR..............California Department of Water Resources
EIR.................Environmental Impact Report
GCM..............Global Circulation Model
GSP ....Groundwater Sustainability Plan
MGA..............Santa Cruz Mid-County Groundwater Agency
MNW2...........Multi-Node Well 2
PWS...............Pure Water Soquel
SCWD............City of Santa Cruz Water Department
SMC...............sustainable management criteria
SqCWD..........Soquel Creek Water District
SWIP..............seawater intrusion prevention
UWMP...........Urban Water Management Plan