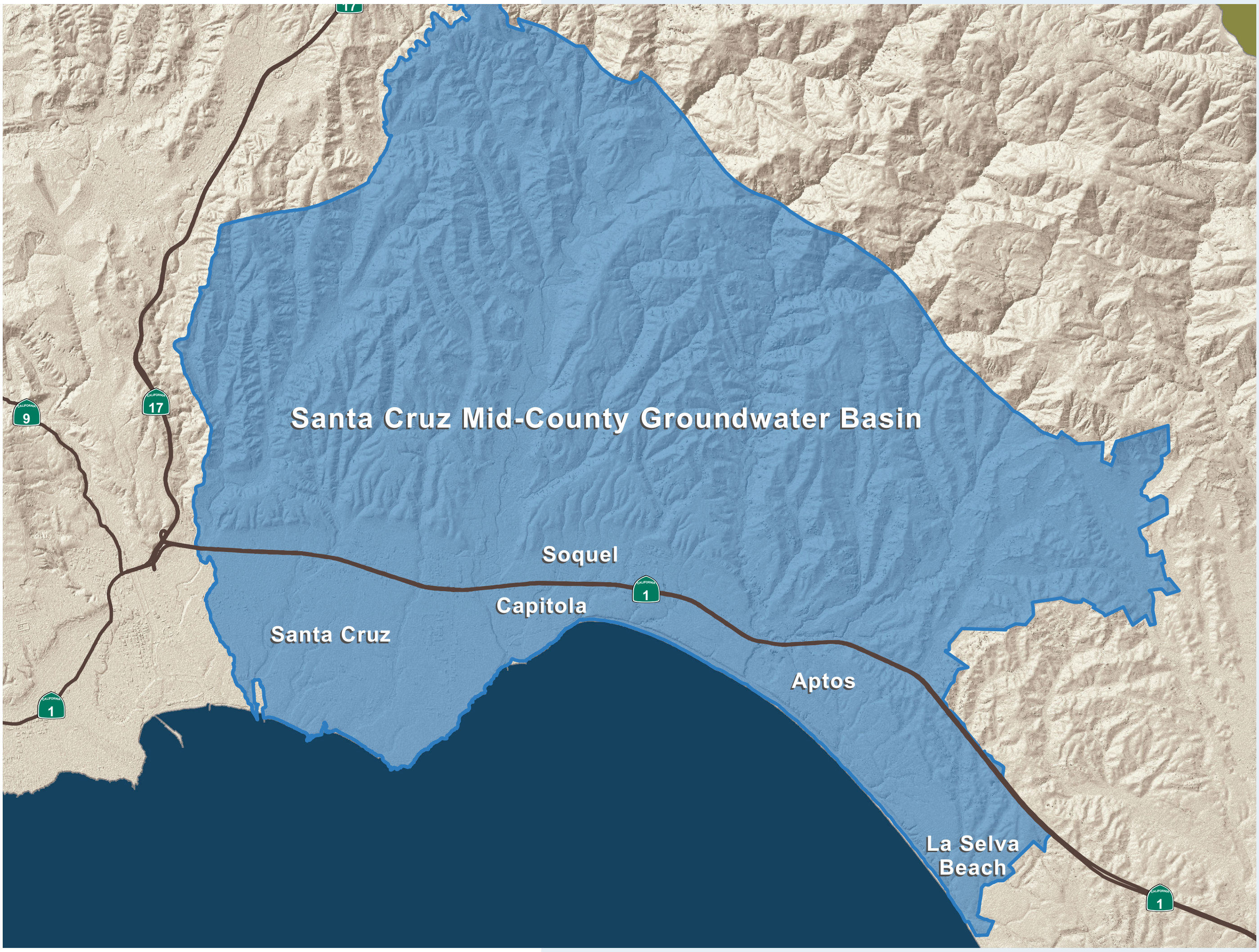
SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY

Santa Cruz Mid-County Groundwater Basin
GROUNDWATER SUSTAINABILITY PLAN

November 2019



ACKNOWLEDGEMENTS

The Santa Cruz Mid-County Groundwater Agency gratefully acknowledges the funding contribution from the California Department of Water Resources. Funding for this project has been provided in part from the Water Quality, Supply, and Infrastructure Improvement Act of 2014 and through an agreement with the Department of Water Resources.

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY BOARD MEMBERS

Curt Abramson, Private Well Owner Rep.
David G. Baskin, Water Commissioner
City of Santa Cruz
Dr. Bruce Daniels, SqCWD Board President
Zach Friend, Supervisor
County of Santa Cruz
Jon Kennedy, Private Well Owner Rep.
James Kerr, Private Well Owner Rep.
Dr. Tom LaHue, SqCWD Director
John Leopold, Supervisor
County of Santa Cruz
Robert Marani, CWD Director
Cynthia Mathews, Council Member
City of Santa Cruz
Marco Romanini, CWD Director

GROUNDWATER SUSTAINABILITY PLAN ADVISORY COMMITTEE MEMBERS

Kate Anderton, Environmental
John Bargetto, Agriculture
David Baskin, City of Santa Cruz
Rich Casale, Small Water System Management
Keith Gudger, At Large
Dr. Bruce Jaffe, SqCWD Director
Dana Katofsky McCarthy, Rate Payer
Jon Kennedy, Private Well
Jonathan Lear, At Large
Marco Romanini, CWD Director
Allyson Violante, County of Santa Cruz
Thomas Wyner for Cabrillo College, Institutional

MEMBER AGENCY STAFF

Soquel Creek Water District	General Manager Ron Duncan and staff
City of Santa Cruz Water Department	Director Rosemary Menard and staff
County of Santa Cruz Water Resources	Director John Ricker, Sierra Ryan and staff
Central Water District	District Manager Ralph Bracamonte

PLANNING, TECHNICAL, & FACILITATION SUPPORT

Regional Water Management Foundation: Tim Carson, Laura Partch, Darcelle Pruitt
Montgomery & Associates: Georgina King, Cameron Tana, Derrik Williams
Kearns & West: Eric Poncelet, Cici Vu

ACKNOWLEDGEMENTS

TECHNICAL ADVISORY COMMITTEE (TAC) MEMBERS AND OTHER PARTICIPANTS

TAC MEMBERSHIP
Bruce Daniels, Ph.D. President, Soquel Creek Water District Board - Hydroclimatology, Climate Change
Andrew Fisher, Ph.D. University of California, Santa Cruz - Professor, Hydrogeology. UC Water Security and Sustainability Research Initiative (UC Water)
Barry Hecht, Balance Hydrologics – Principal Geomorphologist, Hydrogeologist, Surface Water-Groundwater Interactions
Brian Lockwood, PV Water – General Manager, Hydrologist
Robert Marks, Pueblo Water Resources, Inc. - Principal Hydrogeologist, Consultant to City of Santa Cruz

MODELING TEAM
Pascual Benito, Montgomery and Associates - Senior Hydrogeologist
Sean Culkin, formerly Montgomery and Associates - Senior Hydrogeologist
Hanieh Haeri, Montgomery & Associates - Engineering Hydrologist
Justin Huntington, Huntington Hydrologic, Desert Research Institute - PRMS and GSFLOW setup
Georgina King Montgomery and Associates - Senior Hydrogeologist
John Mejia, Montgomery & Associates – Hydrologist, Desert Research Institute, climate downscaling
Cameron Tana, Montgomery and Associates - Principal Hydrologist
Linda Woolfenden, US Geological Survey - GSFLOW experience

TAC MEETING PARTICIPANTS:
Shawn Chartrand, Balance Hydrologics - Principal Geomorphologist, Hydrologist, consultant to City of Santa Cruz
Nick de Sieyes, private well owner at invitation of Central Water District
Jon Kennedy, MGA Board member, private well representative
Eric Poncelet, MGA GSP facilitation team
Joel Smith, subconsultant to City of Santa Cruz on climate futures

MGA PARTICIPANTS:
Ralph Bracamonte, Central Water District – General Manager
Tim Carson, Regional Water Management Foundation, Program Director
Brice Dahlmeier, Soquel Creek Water District – Associate Engineer
Taj Dufour, Soquel Creek Water District - Engineering Manager
Ron Duncan, Soquel Creek Water District - General Manager
Heidi Luckenbach, City of Santa Cruz Water Department - Deputy Water Director/Engineering Manager
Rosemary Menard, City of Santa Cruz Water Department - Water Director

Melanie Mow Schumacher, Soquel Creek Water District - Special Projects, Communication Manager
Darcelle Pruitt, Regional Water Management Foundation - Senior Planner
John Ricker, Santa Cruz County Health Services Agency, Environmental Health – Water Resources Division Director
Sierra Ryan, Santa Cruz County Health Services Agency, Environmental Health – Water Resources Planner
Isidro Rivera, City of Santa Cruz Water Department - Associate Civil Engineer

SURFACE WATER WORKING GROUP PARTICIPATING ORGANIZATIONS

California Department of Fish and Wildlife – Randi Adair, Stephanie Holstege, John Jankowitz, Michelle Leicester, and Monica Oey
California Department of Water Resources (DWR) – Amanda Peisch Derby
City of Santa Cruz – Ezekiel Bean, Chris Berry, and Chris Coburn
Environmental Defense Fund (EDF) – Christina Babbitt, Sarah Fakhreddine, Maurice Hall, and Anthony Saracino.
Friends of Soquel Creek – Carla Christensen
GSP Advisory Committee – Kate Anderton, Keith Gudger, Dr. Bruce Jaffe, Jon Lear, and Allyson Violante
Montgomery & Assoc. (MGA Technical Consultants) – Georgina King and Cameron Tana
The Nature Conservancy (TNC) – Melissa Rohde
National Marine Fisheries Service (NMFS, formerly NOAA Fisheries) – Darren Howe, Rick Rogers, William Stevens, and Andres Ticlavilca
Pajaro Valley Water Management Agency (PV Water) – Brian Lockwood and Casey Meusel
Resource Conservation District SCC (RCD) – Lizzy Eichorn and Lisa Lurie
Santa Cruz County – Kristen Kittleson, John Ricker, and Sierra Ryan
Regional Water Management Foundation – Darcelle Pruitt
US Fish and Wildlife Service – Chad Mitcham

Thank you to all of the community members who participated in public meetings, information sessions, and various MGA events. Your input helped to shape this Plan.

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY

Table of Contents

Figures

Tables

Appendices

EXECUTIVE SUMMARY (ES)

The State of California enacted the Sustainable Groundwater Management Act (SGMA), effective January 1, 2015, as the first legislation in the state's history to mandate comprehensive sustainable groundwater resources management. The Santa Cruz Mid-County Groundwater Agency (MGA or Agency) was formed under SGMA to develop this Groundwater Sustainability Plan (GSP or Plan) for the Santa Cruz Mid-County Groundwater Basin (Basin).

The Basin is classified by the California Department of Water Resources (DWR) as a high priority basin in a state of critical overdraft because of seawater intrusion. Based on this critical overdraft designation, the MGA is required to submit its Board adopted GSP to DWR by January 31, 2020. The MGA initiated development of this GSP in 2017 to guide ongoing management of the Basin with a goal to achieve and maintain groundwater sustainability over a 50-year planning and implementation horizon.

While the SGMA will revolutionize groundwater management in California, MGA member agencies began studying groundwater and managing the Basin long before SGMA was passed into law. The City of Santa Cruz Water Department and Soquel Creek Water District acquired interests in groundwater pumping in the Basin, and together with Santa Cruz County commissioned the first hydrogeologic study of the Basin in the mid-1960's (USGS, 1968). Seawater intrusion identified in the Basin in the 1980s required water managers to develop an extensive monitoring network of wells to monitor the Basin's groundwater and to help improve understanding of the Basin, and to implement water conservation and groundwater management strategies to balance groundwater demand with the Basin's groundwater budget.

This GSP presents detailed information to understand the occurrence of groundwater in the Basin and provides solutions to achieve the Basin's sustainability goals. This GSP and Executive Summary are organized following DWR's guidance documents (DWR, 2016):

- Executive Summary
- Section 1 Introduction to the MGA
- Section 2 Plan and Basin Setting
- Section 3 Sustainable Management Criteria
- Section 4 Projects and Management Actions to Achieve Sustainability
- Section 5 Plan Implementation, Budget and Schedule
- Section 6 References and Technical Studies used to Develop the GSP

Section ES-1: Introduction

The MGA formed in March 2016 as a Joint Powers Authority, with four member agencies: Central Water District, City of Santa Cruz, County of Santa Cruz, and Soquel Creek Water District. The MGA Board of Directors includes two representatives from each member agency and three private well owner representatives. These four agencies have been actively working together and reaching out to private well owners on Basin management since the 1990s, well before SGMA became law in 2015.

Plan development was a collaborative effort among the member agencies and technical consultants, and was informed by input from resource management agencies, community members, and stakeholders. In recognition of the fundamental importance of public engagement, the MGA Board established a GSP Advisory Committee and selected 13 members representing Basin water users and uses including Agricultural, Business, Environmental Uses, Institutional Users, Small Water Systems, and Water Utility Rate Payers. GSP Advisory Committee meetings were open to the public and comments were incorporated into the planning process. Between October 2017 and June 2019, the Advisory Committee convened 20 formal meetings, additional orientation sessions, enrichment sessions, and technical working groups. Based on an open and public process, the Committee provided recommendations on how to address key policy issues required by SGMA.

Section ES-2: Plan and Basin Setting

Section 2 of the Plan describes the Basin setting based on existing studies relating to geology, hydrogeology, climate, historical groundwater conditions, and history of the Basin's groundwater management.

The Basin is located at the northern end of the Central Coast hydrologic region, extending from the Santa Cruz Mountains to the Pacific Ocean, and from Live Oak to La Selva Beach along the Pacific coast. The Plan area and Basin setting are defined by geologic, hydrologic, and jurisdictional boundaries. The Basin includes a portion of the City of Santa Cruz, all of the City of Capitola, and unincorporated areas of Santa Cruz County. Land use is predominantly residential (50%) and open space/parks (34%), with limited commercial (8%) and agriculture (2%). Land use is further divided between urban and rural areas; development densities are greatest in the urban/suburban areas located on the coastal terraces, with much lower densities in the rural areas in the foothills and mountains.

All the major water supply purveyors in Santa Cruz County rely on local sources and import no water from outside the County. Estimated population within the Basin is 92,000 (AMBAG, 2018). Approximately 80,500 residents (88%) receive water from municipal suppliers and 11,600 residents are supplied by private wells or small water systems. Roughly 50,000 Basin residents (54%) rely solely upon groundwater. The remaining 42,000 residents are served by the City of Santa Cruz, with approximately 95% of its supply sourced from surface water from outside the Basin and 5% from groundwater within the Basin (SCWD, 2016).

DWR classified the Basin as in critical overdraft because seawater intrusion is actively occurring (DWR, 2018b). Groundwater extractions in the Basin peaked between the mid-1980s and mid-1990s, causing groundwater overdraft. Over-pumping of Basin aquifers lowered groundwater elevations in the coastal portions of the Basin where the majority of municipal pumping takes place. Lowered groundwater levels allowed seawater intrusion into portions of the aquifer and posed a threat of more widespread seawater intrusion. Since 1995, extensive and effective water conservation efforts have reduced water demand and total Basin groundwater pumping, but modeling conducted as part of GSP development indicates that additional supplemental water is needed to achieve groundwater sustainability.

Groundwater Model

MGA technical consultants developed a computerized numerical model to help understand the hydrogeology of the Basin and to simulate future groundwater conditions for GSP planning purposes. The Basin GSFLOW model is an integrated surface water and groundwater model that combines both Precipitation-Runoff Modeling System (PRMS) and MODFLOW code. It simulates both hydrogeologic and hydrologic conditions within the Basin. The PRMS portion of the model handles watershed flows, MODFLOW simulates subsurface flow, and the MODFLOW Streamflow-Routing (SFR) package simulates streamflow.

Projected Future Basin Conditions, Land Use and Water Use

The Plan includes projects and management actions to stop the advancement of seawater intrusion and to maintain sustainability under future Basin conditions that will be impacted by changes in land use, water use, and climate. The projected climate change effects include 2.3 feet of sea level rise by 2070 and a warmer and drier climate that has an average temperature increase of 2.4° F, a decrease in precipitation of up to 3.1 inches per year, and a 6% increase in evapotranspiration. Land use patterns are assumed to be unchanged while accommodating projected regional population growth of 4.2% pre-2035 and 2.1% post-2035. Projected non-municipal groundwater demand for domestic use assumes pre-drought (2012 – 2015) water demand of 0.35 acre-feet per year per household. Groundwater demand for larger institutions such as camps, retreats, and schools, and agricultural irrigation are assumed to remain the same as historical demands.

Water Budget

Precipitation as rainfall is the primary source of water that becomes either surface water or groundwater in the Basin. Rainfall that falls in the Basin’s watersheds is either evapotransported, flows overland and into streams, percolates into the subsurface and becomes groundwater, or remains in the soil zone as soil moisture. Historically from water years 1985 - 2015, 66% of rainfall that falls in the Basin is evaporated or transpired without reaching a surface water body. Twenty six percent of rainfall (an average of 25,320 acre-feet per year) becomes overland flow that eventually enters streams and creeks within the Basin. Five percent of rainfall percolates beyond the root zone and recharges the Basin. The remaining portion (3%) reflects the net change in soil moisture stored in the soil layers overlying the Basin.

Table ES-1 summarizes the relative distribution of precipitation derived from model simulations for different time periods. During the drier periods (current and projected) when there is less rainfall than the historical period, evapotranspiration takes up a greater proportion of rainfall, with overland flow/streamflow receiving less water. The relative proportion of rainfall that becomes groundwater recharge remains similar for the three different climatic periods.

Table ES-1. Percentage Distribution of Precipitation in Santa Cruz Mid-County Basin

Precipitation Budget Component	Historical (1985 – 2015)	Current (2010 – 2015)	Projected (2016 – 2069)
Precipitation (acre-feet)	96,200	81,600	87,280
Evapotranspiration	66%	72%	69%
Overland Flow	26%	23%	25%
Groundwater Recharge from Precipitation	5%	5%	4%
Soil Moisture	3%	0%	2%

Streamflow occurring in the Basin is fed by a number of sources both within and outside of the Basin. Over the historical period from 1985 – 2015, 55% of streamflow (an average of 25,320 acre-feet per year) is from overland flow generated within the Basin. Flows from upstream of the Basin constitute 43% of flows into the Basin. Groundwater contributions to streamflow are around 3%. Surface water outflows from the Basin are predominantly to the ocean (89%), with the remaining 11% flowing out to neighboring groundwater basins. Relative percentages of surface water inflows and outflows for different time periods are summarized in Table ES-2. In general, the relative percentages of inflow and outflow are similar for the different climatic periods but the volume of inflows is controlled by the amount of precipitation both within and outside the Basin.

Table ES-2. Average Percentage Distribution of Surface Water Budget in Mid-County Basin

Surface Water Budget Component	Historical (1985 – 2015)	Current (2010 – 2015)	Projected (2016 – 2069)
Inflows (acre-feet)	45,800	32,110	37,400
Overland Flow	55%	58%	59%
Flows from Upstream of the Basin	43%	39%	38%
Net Flows From Groundwater	2%	3%	3%
Outflows (acre-feet)	45,800	32,110	37,400
Ocean Outflow	89%	90%	89%
Outflow in Branciforte Creek	9%	8%	9%
Pajaro Valley Subbasin	1%	1%	1%
Santa Margarita Basin	<1%	<1%	<1%

The historical groundwater budget (1985 – 2015) consists of inflows from surface recharge (60% of inflows) and subsurface inflows from the Purisima Highlands Subbasin (40% of inflows). Outflows are primarily by groundwater extraction (59% of outflows) and to the Pajaro Valley (32% of outflows), with only 3% of outflows going to the Santa Margarita Basin. Overall, groundwater flows to and from the ocean are net outflows to the ocean (6% of outflows). However, net flows from offshore occur in the Purisima DEF/F and A-unit aquifers where seawater intrusion is already observed. Relative percentages of groundwater inflows and outflows for different time periods are summarized in Table ES-4. The historical change of groundwater in storage has been an annual increase of 480 acre-feet per year. This reflects recovery from historic low Basin groundwater levels in the 1990s and early 2000s that has been achieved through water conservation efforts and redistributing pumping.

Table ES-3. Average Percentage Distribution of the Groundwater Budget in Santa Cruz Mid-County Basin

Groundwater Budget Component	Historical (1985 – 2015)	Current (2010 – 2015)	Projected (2016 – 2069)	
			Baseline	GSP Implementation
Inflows (acre-feet)	13,070	11,490	11,290	10,920
UZF Recharge	34%	31%	34%	35%
Net Recharge from Stream Alluvium	10%	8%	9%	6%
Recharge from Terrace Deposits	16%	16%	16%	16%
Subsurface Inflow from Purisima Highlands Subbasin	40%	45%	41%	43%
Outflows (acre-feet)	12,590	11,650	11,220	10,570
Pumping	59%	53%	6,190	43%
Subsurface Outflow to Santa Margarita Subbasin	3%	2%	210	2%
Net Subsurface Outflow to Pajaro Valley Subbasin	32%	36%	3,670	37%
Net Outflow Offshore	6%	8%	1,150	19%
Change in Storage (acre-feet per year)	+480	-160	-70	+350

As a result of drier climate, groundwater inflow volumes for current and projected conditions are less than historical inflows (Table ES-3). The current groundwater budget has similar proportions of inflows and outflows to the historical budget. The main changes over this recent period are 1) decreased recharge due to reduced rainfall and 2) decreased municipal pumping due to water conservation. Even though there was decreased recharge, decreases in pumping allowed recovery of groundwater levels. The higher groundwater levels caused slightly more outflow to the ocean and a smaller increase in outflows to the Pajaro Valley Subbasin. The net result was that the Basin experienced only a relatively small decrease of 160 acre-feet per year of groundwater in storage.

Without additional projects and management actions implemented to achieve groundwater sustainability (Baseline scenario), it is projected that the Basin will experience a small loss of 70 acre-feet per year in groundwater storage. Modeled climate change results in a projected average decrease in Baseline groundwater inflows of around 200 acre-feet per year from current inflows. Projected groundwater pumping in the Baseline groundwater budget is expected to be similar to recent pumping. As a result of the projected recharge and pumping conditions, outflow to the ocean remains virtually the same as experienced currently, which will do little to prevent future advancement of seawater intrusion.

With GSP Implementation of projects and management actions to achieve groundwater sustainability, projected average net pumping is reduced by 1,740 acre-feet per year because groundwater demand is offset by supplemental water injected into the Basin. This results in increase of outflows to the ocean that ensures seawater intrusion does not move onshore farther than it is currently, and may potentially even push it back.

Sustainable Yield

The projected sustainable yield is the amount of net Basin pumping that can occur while avoiding undesirable results for the Basin's applicable sustainability indicators. Net pumping is pumping minus volume of managed aquifer recharge. Table ES-4 lists the projected sustainable yields for three aquifer groups that are grouped according to how production wells are typically screened. Section 2.2.3.7 provides details on how the sustainable yield was developed.

Table ES-4. Projected Sustainable Yield

Aquifer Group	Sustainable Yield (acre-feet per year)
Aromas Red Sands and Purisima F	1,650
Purisima DEF, D, BC, A and AA	2,290
Tu	930
Total	**4,870**

Section ES-3: Sustainable Management Criteria

The SGMA's requirement for establishing and maintaining sustainability are based on development of sustainable management criteria (SMC) for six sustainability indicators**.** The MGA developed a Sustainability Goal for the Basin discussed in Sections 1.2, and 3.1 and identified undesirable results, minimum thresholds, measurable objectives, and interim milestones for the sustainability indicators relevant to the Basin as discussed in Sections 3.4 through 3.9. The six sustainability indicators that are required by SGMA are listed below with a general summary of key Basin management objectives for each:

Seawater Intrusion: Prevent seawater from moving farther inland than was observed from 2013 – 2017. Seek to maintain groundwater in coastal monitoring wells at levels that prevent further seawater intrusion with at least 99% modeled probability

Degradation of Groundwater Quality: Maintain groundwater quality so that no state drinking water standard is exceeded in any representative monitoring well as a result of groundwater pumping or managed aquifer recharge.

Chronic Lowering of Groundwater Levels: Do not allow groundwater levels to decline to a level that no longer supports beneficial uses like agricultural, industrial, private and municipal production wells.

Depletion of Interconnected Surface Water: In interconnected streams supporting priority species, ensure there is no more surface water depletion due to groundwater extraction than prior to 2015.

Land Subsidence: The Plan does not include SMCs for the subsidence indicator because the Basin is not geologically susceptible to subsidence.

Reduction of Groundwater in Storage: Maintain net groundwater extraction (pumping minus annual volume of managed aquifer recharge) so other sustainability indicators aren't negatively affected.

The SGMA requires use of monitoring networks to measure the health of the Basin and its progress towards sustainability. An extensive GSP monitoring network of 168 wells will collect data of sufficient quality, frequency, and spatial distribution to characterize groundwater and related surface water conditions in the Basin, and to evaluate changing conditions that occur during implementation of the GSP, particularly relative to the established measurable SMCs.

All of the wells in the GSP monitoring network comprise dedicated monitoring and production wells from MGA member agencies designed to collect information to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions. The GSP monitoring network will be expanded as needed to fully address monitoring needs for GSP implementation. Details on the Basin's GSP monitoring network are provided in Section 3.

As noted in the discussion in Section ES-2 above, seawater intrusion is the primary reason why the Basin is classified as critically overdrafted. Therefore, preventing seawater intrusion is the main focus of sustainability planning. Additionally, the GFLOW model demonstrates that if protective groundwater elevations at the coast are met, undesirable results for other applicable sustainability indicators are also avoided: reduction of groundwater in storage, chronic lowering of groundwater levels, and depletion of interconnected surface water sustainability indicators. This Executive Summary provides the details of the seawater intrusion SMC as it is a highly relevant and representative example of the approach used for all of the SMCs that are fully discussed in Section 3.

SEAWATER INTRUSION SUSTAINABLE MANAGEMENT CRITERIA

SIGNIFICANT AND UNREASONABLE CONDITIONS

Seawater moving farther inland than was observed from 2013 through 2017.

SEAWATER INTRUSION UNDESIRABLE RESULTS

The undesirable results for seawater intrusion are related to the inland movement of chloride. The extent of seawater intrusion currently observed is tracked through chloride concentrations in representative monitoring wells along the coast. Additionally, protective groundwater elevations are used as a proxy for seawater intrusion. Any of the following undesirable results would be considered significant and unreasonable conditions for seawater intrusion.

1. **Undesirable Results for Intruded Coastal Monitoring Wells**
   Any coastal monitoring well with current seawater intrusion that has a chloride concentration above its 2013-2017 maximum chloride concentration. This concentration must be exceeded in 2 or more of the last 4 consecutive quarterly samples.

2. **Undesirable Results for Unintruded Coastal Monitoring Wells, and Inland Monitoring and Production Wells closest to the Coast**
   A. Any unintruded coastal monitoring well that obtains a chloride concentration above 250 mg/L. This concentration must be exceeded in 2 or more of the last 4 consecutive quarterly samples.

   B. Any unintruded inland monitoring well (which includes municipal production wells closest to the coast and other non-coastal monitoring wells) that obtains a chloride concentration above 150 mg/L. This concentration must be exceeded in 2 or more of the last 4 consecutive quarterly samples.

3. **Undesirable Results for Protective Groundwater Elevations**
   Five-year average groundwater elevations identified below protective groundwater elevations for any coastal monitoring well.

Components of Sustainable Management Criteria

Significant and Unreasonable Condition: A qualitative statement regarding conditions that should be avoided.

Undesirable Results: Undesirable results are a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the Basin.

Minimum Thresholds: Minimum thresholds are the quantitative values used to define undesirable results.

Measurable Objectives: Measurable objectives are quantitative goals that reflect the desired groundwater conditions and will guide the MGA to achieve its sustainability goal within 20 years.

SEAWATER INTRUSION MINIMUM THRESHOLDS

Groundwater Elevations as Proxy Minimum Thresholds

Protective groundwater elevations are used as a proxy for seawater intrusion. Since 2009, seawater intrusion in the Basin has been managed by striving to maintain groundwater levels at protective elevations that prevent further seawater intrusion at the coastline. Protective groundwater elevations are also easier to measure and manage than relying solely on chloride concentrations

Chloride Isocontours Minimum Threshold (Aromas and Purisima aquifers)

Separate 250 mg/L chloride isocontours for Aromas and Purisima aquifers (Figure ES-1) have been drawn based on current chloride concentrations in coastal monitoring wells.

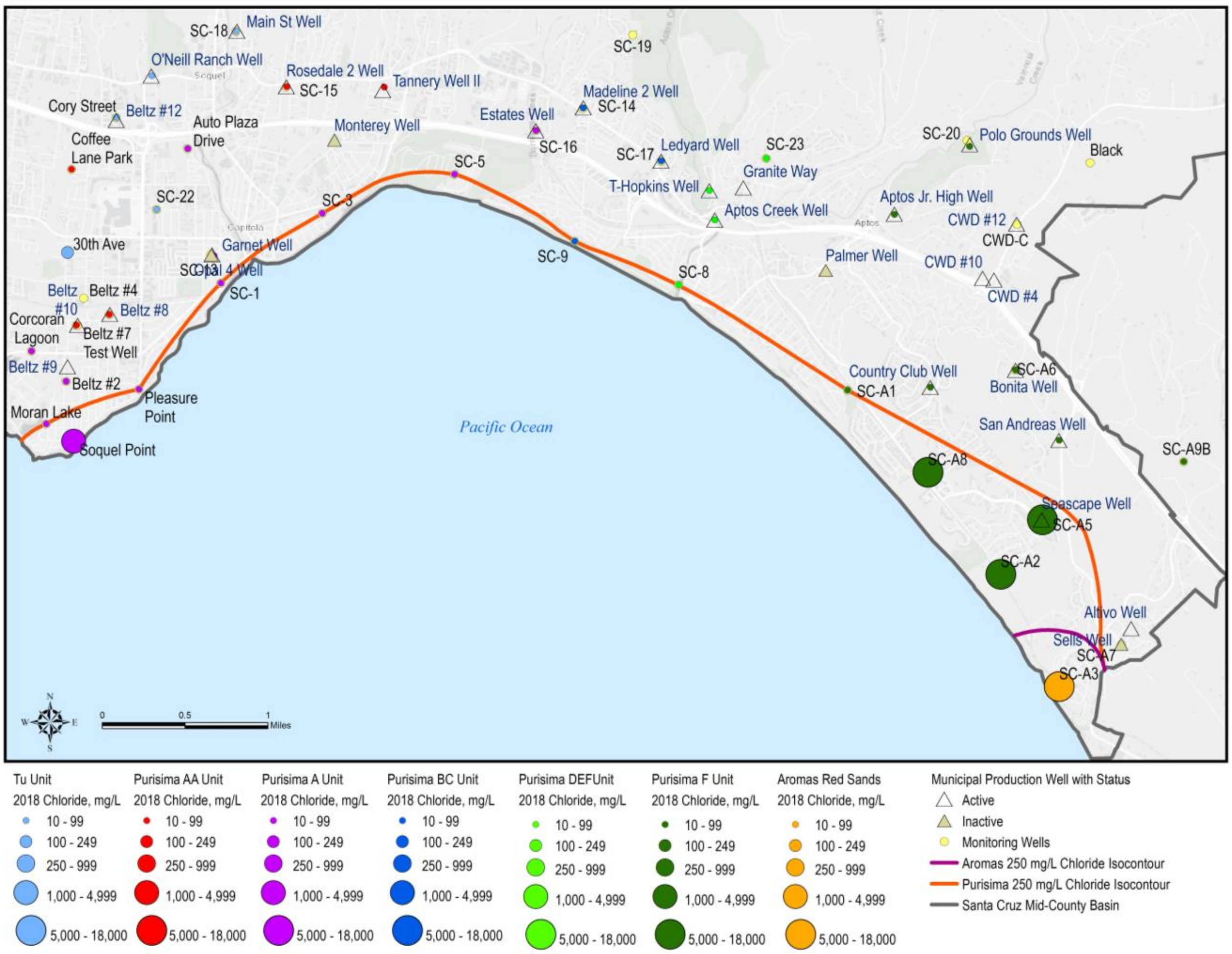


Figure ES-1. 250 mg/L Chloride Isocontours for the Aromas and Purisima Aquifers

SEAWATER INTRUSION MEASURABLE OBJECTIVES

Isocontour Measurable Objective

To reduce the chloride concentration at the same locations as the minimum threshold isocontour shown on Figure ES-1, from 250 mg/L (minimum threshold) to 100 mg/L (measurable objective).

Groundwater Elevations as a Proxy Measurable Objectives

Groundwater elevations as a proxy measurable objectives are determined based on whether the cross-sectional groundwater model is available for the area or not. Measureable objective are:

A. Cross-sectional model available: groundwater elevations for each monitoring well that represent >99% of cross-sectional model simulations as being protective against seawater intrusion. For monitoring wells where seawater intrusion has not been observed, cross-sectional model estimates protective elevations for the entire depth of the aquifer unit of the monitoring wells' lowest screen. For wells where seawater intrusion has been observed, protective elevations to prevent seawater advancement as demonstrated by the cross-sectional model estimate.

B. Cross-sectional model not available: groundwater elevations that represent protective elevations estimated by using the Ghyben-Herzberg method to protect the entire depth of the aquifer unit where the wells are screened.

Section ES-4: Projects and Management Actions to Achieve Sustainability Goal

DWR regulations require each GSP to include a description of projects and management actions necessary to achieve the Basin's sustainability goal.

In November 2018, the MGA Board discussed the agency's role in implementing projects and management actions. It was agreed that the most efficient approach is to have the MGA member agencies perform this function. A major rationale for this decision was the long-standing engagement of member agencies in groundwater management and water supply reliability planning work. In particular, the City of Santa Cruz and Soquel Creek Water District have actively evaluated and pursued supplemental supply options for the last five years.

Projects and management actions have been identified that address sustainability goals, measurable objectives, and undesirable results described for the Basin in Section 3; primarily the avoidance of seawater intrusion, with related benefits to surface water and groundwater dependent ecosystems (GDEs). Because the City of Santa Cruz water system relies heavily on surface water, an additional focus of several of the management actions discussed in this section is creation of a supplemental drought supply to improve reliability for the City's water service area.

Section 4 presents projects and management actions in three groups based on how and when they will be implemented.

Baseline Projects and Management Actions (Group 1)

Group 1 activities represent existing groundwater management commitments by MGA member agencies, including: water conservation and demand management; and installation and redistribution of municipal groundwater pumping. Group 1 activities are currently being implemented and are expected to continue to be implemented to achieve groundwater sustainability within the Basin. Activities in Group 1 are incorporated into the model's baseline when evaluating Group 2 projects and management actions.

Projects and Management Actions Evaluated Against the Sustainable Management Criteria (Group 2)

Activities in Group 2 have been developed and thoroughly vetted by MGA member agencies and are planned for near-term implementation, including: Pure Water Soquel; aquifer storage and recovery (ASR); water transfers / in-lieu groundwater recharge; and distributed storm water managed aquifer recharge.

Identified Projects and Management Actions That May Be Evaluated in the Future (Group 3)

MGA's analysis indicates the ongoing implementation of Group 1 activities and the added implementation of Group 2 projects and management actions will bring the Basin into sustainability. However, if one of the projects and management actions required for sustainability in Group 2 either fails to take place or does not have the expected results, further actions will be required. In that case, appropriate projects and/or management actions will be chosen from Group 3, which include recycled water reuse, desalination, water use curtailment, or other projects that may become possible through emerging technology. The specific activity selected will be based on factors such as size of the water shortage, speed of implementation, and scale of regulatory and political hurdles.

Section ES-5: Plan Implementation

Estimated Cost to Implement the GSP

The estimated total cost to the MGA of GSP Implementation over the 20-year planning horizon is approximately $15.8 million (Section 5, Table 5-1). Costs are based on best estimates available and reflect the MGA's current understanding of Basin conditions and MGA's role and responsibilities under the SGMA. Individual member agencies will continue to fulfill the lead role in funding individual projects and/or management actions.

MGA's major implementation cost categories include: Agency administration and operations, legal services, management and coordination, data collection/analysis/reporting, data management, GSP reporting to DWR, community outreach & education, and financial reserves and contingencies.

Activities of MGA Member Agencies

Monitoring: Individual MGA member agencies conduct groundwater, streamflow and watershed monitoring that informs the management responsibilities of their respective agencies. The MGA does not contribute towards these monitoring efforts and these costs are not included in the MGA's estimated implementation costs. However, the results of these monitoring activities are relevant to the MGA and will inform sustainable Basin management and assessment.

Projects and Management Actions: Individual MGA member agencies are responsible for projects and management actions to achieve groundwater sustainability. These include continuation of existing programs and the implementation of proposed water supply augmentation projects discussed in Section 4, Group 1 and Group 2 respectively. It is largely the projects and management actions implemented by individual MGA member agencies that collectively determine successful achievement of Basin sustainability.

Funding Sources and Mechanisms

Initial GSP Implementation Phase (2020 – 2025): Funding for the initial phase will be obtained from the annual contributions of MGA member agencies. This funding approach will be reevaluated over time. The MGA will also continue to pursue grant funding when available.

Ongoing GSP Implementation (2026 – 2040): As authorized under the SGMA, the MGA may impose fees including, but not limited to, permit fees and fees on groundwater extraction or other regulated activity to fund the costs of a groundwater sustainability program. The MGA had an initial evaluation of funding mechanisms and fee criteria completed to identify alternatives to recover the costs of GSP administration and Basin management. The report is discussed in Section 5.1.4 and attached as Appendix 5-A.Any alternative cost allocation should be equitable to MGA members and basin users. As the GSP implementation proceeds, the MGA may further evaluate funding mechanisms, and possible application of fees to users.

Schedule for Implementation

Figure ES-2 provides an overview of the preliminary schedule of MGA administration, management and coordination activities, GSP reporting and community outreach and education.

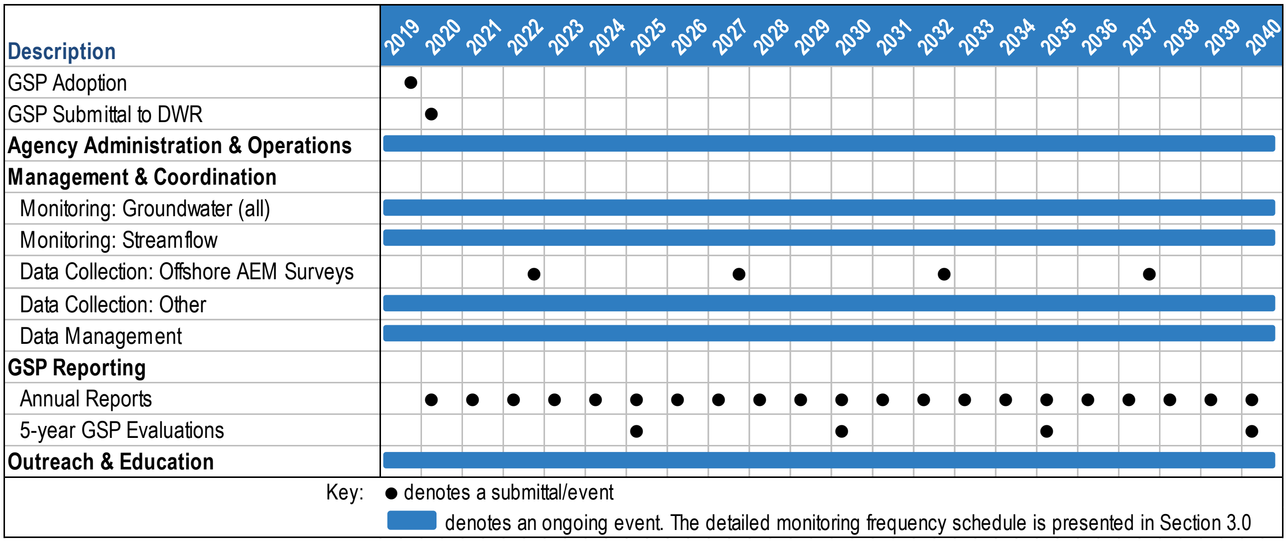


Figure ES-2. GSP Implementation Preliminary Schedule

The estimated schedule for the individual MGA member agency projects and management actions is presented in Figure ES-3. Group 1 Baseline projects are anticipated to be evaluated through the GSP planning and implementation horizon of 50 years. Group 2 estimated schedules for individual member agency projects are based on current estimates. Some projects, such as Distributed Stormwater Managed Aquifer Recharge, include multiple individual projects at separate locations, thus an overlap in development and implementation phases. The timeline for each project is dependent on factors such as permitting, approval, and funding.

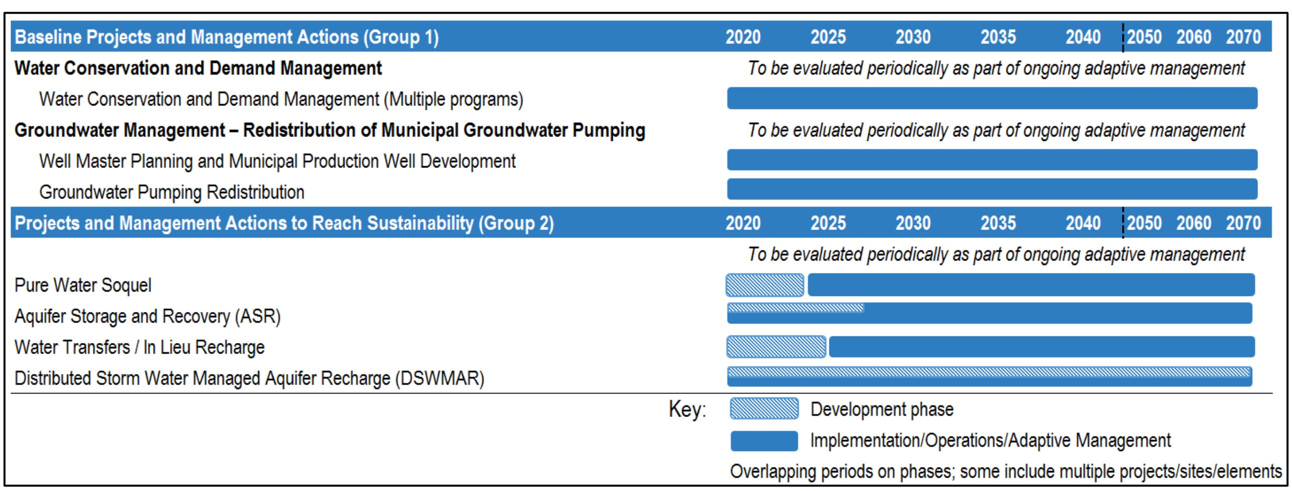


Figure ES-3. GSP Implementation Schedule

Section ES-6: References and Technical Studies

The final section of the GSP includes a complete list of references and technical studies that supported development of this GSP.

Section 1 Contents

Figures

1 INTRODUCTION

1.1 Purpose of the Groundwater Sustainability Plan

In 2014, Governor Edmund G. Brown, Jr. signed three laws that make up the Sustainable Groundwater Management Act (SGMA). SGMA took effect on January 1, 2015 requiring local water agencies to manage groundwater sustainably. This Groundwater Sustainability Plan (GSP or Plan) is a collaborative effort between local water agencies, technical experts, land use agencies, environmental managers, and community members to manage the groundwater basin sustainably. This Plan is prepared by the Santa Cruz Mid-County Groundwater Agency (MGA). Together the people involved in the preparation of this Plan represent water uses and users within the Santa Cruz Mid-County Groundwater Basin (Basin) (Figure 1-1). The intent of the Plan is to guide long-term management of the shared groundwater resource to ensure a reliable water supply for community needs and the natural environment now and into the future.

Statewide, California's groundwater basins support at least one-third of the water used by nearly 39 million people, sustain the nation's most robust agricultural industry, and support hundreds of billions of dollars in economic activity each year (DWR, 2018a).The Basin is located at the northern end of the Central Coast region. This region gets approximately 85% of its water supply from groundwater and is the most groundwater dependent hydrologic region in all of California (DWR, 2013). All the major water supply purveyors in Santa Cruz County rely upon local sources and receive no imported water from outside the County.

The Basin is a high priority groundwater basin in critical overdraft and threatened by seawater intrusion (DWR, 2018b). For many years, the amount of groundwater extracted from the Basin exceeded the amount naturally recharging groundwater through rainfall. Despite extensive water conservation efforts and reductions in groundwater pumping in recent years compared to prior decades, the long-term overdraft of the Basin lowered groundwater elevations along portions of the coast. Lowered groundwater levels have allowed seawater intrusion into coastal portions of the groundwater aquifers and pose the threat of more widespread seawater contamination of groundwater. Once contaminated with seawater, it can be irreversible and can result in either abandoning water supply wells or requiring costly treatment to make the water useable.

While the state's SGMA mandate now requires groundwater sustainability for all high and medium priority groundwater basins, SGMA was not the catalyzing event for sustainable groundwater management in the Santa Cruz Mid-County Groundwater Basin. The water management agencies that share responsibility for our groundwater resources have studied the Basin since the mid-1960s and developed groundwater management strategies to actively manage the Basin since the 1980s in response to the threat of further seawater intrusion impacts to the Basin's freshwater aquifers. Discussion of seawater intrusion is found throughout the GSP, especially in Sections 2.1.4.1; 2.2.4; 3.3.3.3; and 3.6.

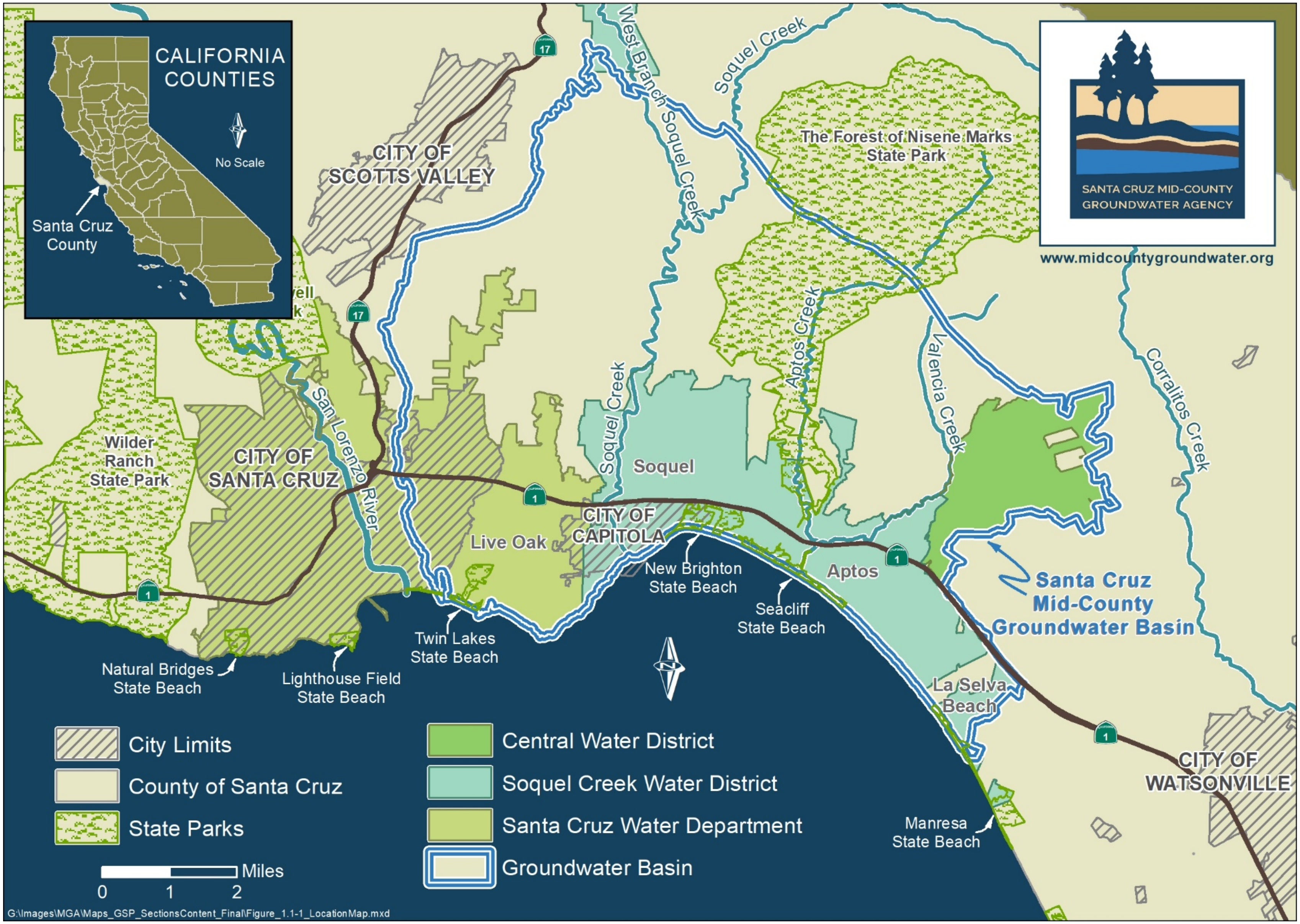


Figure 1-1. Basin Location Map

The Association of Monterey Bay Area Government projects the population within the Basin in 2018 is approximately 92,000 (AMBAG, 2018). Of those, approximately 50,000 Basin residents are primarily served by groundwater wells or municipal suppliers whose only source of water is groundwater. The remaining 42,000 are served by the City of Santa Cruz Water Department, primarily with surface water. In years with average or above average precipitation the City's water supply is approximately 95% surface water from sources outside the Basin and 5% groundwater from the Basin (SCWD, 2016). The amount of groundwater needed from the Basin to fulfill the City of Santa Cruz's water demand goes up in years with below average rainfall.

The goal of SGMA legislation is to avoid undesirable results for the six sustainability indicators identified by the State of California. The six sustainability indicators are: groundwater level declines, groundwater storage reductions, land subsidence, interconnected surface water depletion, seawater intrusion, and water quality degradation.

The two key sustainability indicators in the Basin are seawater intrusion and interconnected surface water depletion. Successful implementation of projects and management actions to effectively protect against adverse impacts for these two regionally significant sustainability indicators should result in groundwater conditions that protect the Basin against undesirable effects for all six state identified sustainability indicators.

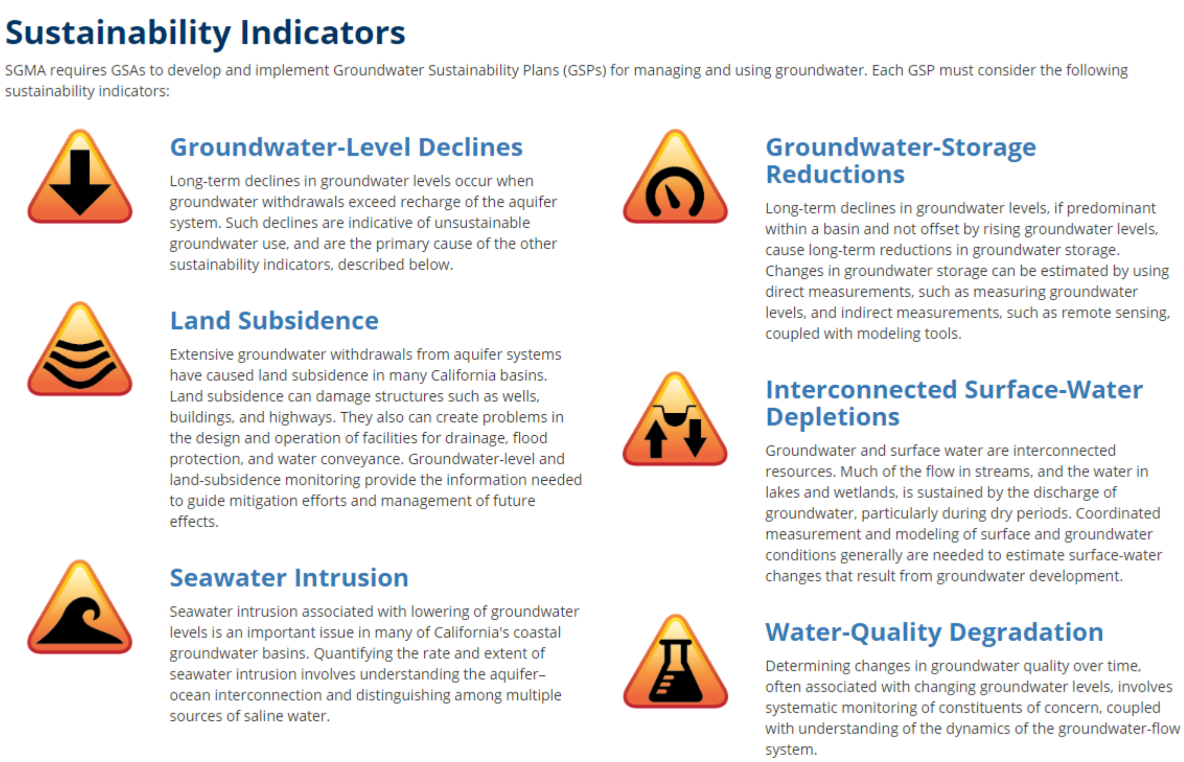


Figure 1-2. Sustainability Indicators[1]

[1] Figure courtesy USGS

1.2 Sustainability Goal

Regulations prepared by the Department of Water Resources (DWR) to implement SGMA require that each Plan develop a sustainability goal that "…culminates in the absence of undesirable results within 20 years…." (23 CCR § 354.24) The Plan must include Basin information used to establish the sustainability goal and a discussion of the measures that will be implemented to ensure that the Basin will be operated to achieve sustainability within the 20-year planning timeframe.

As discussed in Section 2.1.5, the MGA selected a GSP Advisory Committee consisting of representatives of the Basin's groundwater users, interest groups and stakeholders. The Advisory Committee analyzed and provided recommendations to the MGA Board on key policy issues to inform the development of the GSP. Together with MGA staff, technical consultants, and community input, the GSP Advisory Committee developed the Basin sustainability goal and included it among its recommendations to the MGA Board. The MGA Board of Directors adopted the GSP Advisory Committee's recommendations on September 19, 2019.

As required by the SGMA regulations, the MGA developed a sustainability goal for the Basin, which is to:

> Manage the groundwater Basin to ensure beneficial uses and users have access to a safe and reliable groundwater supply that meets current and future Basin demand without causing undesirable results to:
>
> - Ensure groundwater is available for beneficial uses and a diverse population of beneficial users;
> - Protect groundwater supply against seawater intrusion;
> - Prevent groundwater overdraft within the Basin and resolves problems resulting from prior overdraft;
> - Maintain or enhance groundwater levels where groundwater dependent ecosystems exist;
> - Maintain or enhance groundwater contributions to streamflow;
> - Support reliable groundwater supply and quality to promote public health and welfare;
> - Ensure operational flexibility within the Basin by maintaining a drought reserve;
> - Account for changing groundwater conditions related to projected climate change and sea level rise in Basin planning and management;
> - Do no harm to neighboring groundwater basins in regional efforts to achieve groundwater sustainability.

MGA modeling results of the Basin and Projects and Management Actions (presented in Section 4) indicate that maintaining groundwater elevations needed to protect against seawater intrusion will largely prevent undesirable results occurring for all six sustainability indicators. As discussed in Section 2.2.4.5, Basin geology is not susceptible to land subsidence. While subsidence monitoring is recommended in Section 3.8, minimum thresholds and measurable objectives are not identified for this sustainability indicator.

Additional localized groundwater pumping management in the Purisima aquifers where those aquifers are connected to surface water may also be necessary. This additional pumping management may be needed to ensure significant and unreasonable depletion of surface water supporting groundwater dependent ecosystems does not occur from groundwater pumping.

The Basin water budget and water demand forecasts presented in Section 2 indicate that to achieve groundwater sustainability in the Basin will require multiple projects and management actions. These will include the continuation of Group 1 water conservation and demand management, the redistribution of municipal groundwater pumping, and the development of Group 2 water augmentation Projects and Management Actions as presented in Sections 4.1 and 4.2

1.3 Agency Information

In March 2016, the Santa Cruz Mid-County Groundwater Agency (MGA) formed. The four member agencies include: Central Water District, City of Santa Cruz, County of Santa Cruz, and Soquel Creek Water District. These are the principal public agencies that extract groundwater from or regulate groundwater extraction and/or land use activities in the Basin. In May 2016, the MGA submitted an Initial Notice of Intent to DWR to become the Groundwater Sustainability Agency (GSA) for the Santa Cruz Mid-County Groundwater Basin. In August 2017, the MGA filed the initial notification to prepare a GSP for the Santa Cruz Mid-County Groundwater Basin.

The MGA contact information and mailing address is:

Santa Cruz Mid-County Groundwater Agency
c/o Soquel Creek Water District
Attention: Board Secretary
5180 Soquel Drive
Soquel, CA 95073

1.3.1 Organization and Management of the Santa Cruz Mid-County Groundwater Agency

The MGA was created in March 2016 under a Joint Exercise of Powers Agreement. The MGA is governed by an 11-member board of directors consisting of representatives from each member agency and private well representatives within the boundaries of the MGA. The MGA board is comprised of:

- Two representatives from the Central Water District appointed by the Central Water District Board of Directors.

- Two representatives from the City of Santa Cruz appointed by the City of Santa Cruz City Council.
- Two representatives from the County of Santa Cruz appointed by the County of Santa Cruz Board of Supervisors.
- Two representatives from the Soquel Creek Water District appointed by the Soquel Creek Water District Board of Directors.
- Three representatives of private well owners in the Basin appointed by majority vote of the eight public agency MGA directors.
- In addition, an alternate representative for each member agency and for the private well owners is appointed to act in the absence of a representative at Board meetings.

In May 2016, the MGA adopted bylaws establishing provisions relating to how the MGA conducts its affairs, including the duties of its directors and officers, provisions relating to committees and working groups, the framework for the MGA's administration, management and the collaborative staffing approach. The JPA and Bylaws serve as the governing documents for the MGA. The Board is to convene at minimum on a quarterly basis; currently the Board convenes its public meetings every other month (six times per year).

The MGA uses a collaborative staffing model to accomplish its work. Professional and technical staff from MGA member agencies provide staff leadership, management, work products, and administrative support for the MGA. MGA member agency executive staff, comprised of the member agency general managers and directors, provide staff support for MGA officers and Board members. The MGA also contracts with the Regional Water Management Foundation (RWMF) for administrative and planning support.

The development of the GSP was supported by MGA member agency staff, RWMF staff, and consultants providing hydrologic technical support, planning process and facilitation support of the GSP Advisory Committee, and public engagement support.

The contact information for the GSP manager is:

Sierra Ryan, Water Resources Planner
County of Santa Cruz Environmental Health
Health Services Agency
701 Ocean Street | Room 312 | 831.454.3133
Sierra.Ryan@santacruzcounty.us
www.midcountygroundwater.org

1.3.2 Legal Authority of the Santa Cruz Mid-County Groundwater Agency

The MGA has legal authority to perform duties, exercise powers, and accept responsibility for managing groundwater sustainably within the Santa Cruz Mid-County Groundwater Basin. Legal authority comes from the Sustainable Groundwater Management Act, the JPA signed by MGA member agencies and effective on March 17, 2016 and the MGA Bylaws. The JPA is attached as Appendix 1-A to this document. These laws and agreements, taken together, provide the necessary legal authority for the MGA Board to carry out the preparation and implementation of the Basin's Groundwater Sustainability Plan.

1.3.3 Estimated Cost of Implementing the GSP and the MGA's Approach to Meet Costs

MGA is funded by its member agencies through annual contributions based on a cost sharing agreement of estimated impacts to Basin sustainability under SGMA. The member agreed cost sharing allocation has been in place prior to the inception of the agency in March 2016. Costs are allocated 70% to Soquel Creek Water District and 10% each to the County, the City, and Central Water District. This cost allocation may change as the MGA learns more about Basin sustainability impacts through GSP data collection and the beneficial impacts of agency projects and management actions that improve sustainability. Individual member agencies will pay the costs for their projects and management actions as discussed in Sections 4 and 5.

The estimated cost of implementing the GSP is presented by category identified below but also includes maintaining a prudent fiscal reserve and other miscellaneous costs. The major cost categories include:

- Agency Administration and Operations
- Legal
- Management & Coordination
- Data Collection, Analysis, and Reporting
- GSP Reporting (annual and 5-year reports) and
- Outreach and Education
- Contingency (10%)

As presented in Section 5, the estimated cost of implementing the GSP over a twenty-year time horizon is $15.8 million. These are based on the current best estimates with some uncertainties, so the actual costs may vary from those used in making the cost estimate projection. The MGA will not serve as the lead implementing agency for projects in the Basin, this is a role the individual member agencies will continue to fulfill. The various projects, costs and potential funding mechanisms are discussed individually in more detail in Sections 4 and 5.

The MGA's approach to meeting the GSP implementation costs is considered in two phases. In the initial GSP Implementation Phase 1 (2020 – 2025) funding is anticipated to be obtained from the annual contributions of the MGA member agencies. This funding approach has been used since the MGA's formation in 2016. The contribution amounts will be assessed based upon the MGA's annual budget. The MGA will continue to pursue funding from state and federal sources to support GSP planning and implementation activities.

The approach to meeting the GSP implementation costs in Phase 2 (2026 – 2040) will be further evaluated as GSP implementation proceeds. As described in Section 5, the MGA conducted a preliminary evaluation of funding mechanisms and fee criteria to identify opportunities for the MGA to recover costs of GSP administration and Basin management. As authorized under Chapter 8 of SGMA, a GSA may impose fees, including, but not limited to, permit fees and fees on groundwater extraction or other regulated activity, to fund the costs including groundwater sustainability planning and program activities and administration. The MGA will further evaluate the funding mechanisms, the potential application of fees and the fee criteria for non-*de minimis* and *de minimis* users alike.

A key success factor is developing a cost allocation that is equitable to GSA members and Basin users. MGA member agencies agreed early in the SGMA process that the general approach to fund the Plan implementation will be to spread the costs of achieving basin sustainability among groundwater users in a manner that allocates a greater share of costs to users with greater impacts upon groundwater sustainability indicators in the Basin. The findings from the MGA model will support an assessment of impacts to the Basin and will inform the evaluation of funding mechanisms and fee criteria as the GSP implementation proceeds.

1.4 Member Agency Descriptions

1.4.1 Soquel Creek Water District

Soquel Creek Water District (SqCWD) was originally established as a county water district in 1961 to provide flood control and water conservation services. In 1964, SqCWD acquired Monterey Bay Water Company and began delivering water to customers. Today, SqCWD is a public agency that provides potable drinking water and groundwater resource management within its service area in the Santa Cruz Mid-County Groundwater Basin. SqCWD is the largest individual groundwater provider in the Basin and shares the Basin with the City of Santa Cruz Water Department (SCWD), Central Water District (CWD) and a variety of small private wells, small water systems, institutional, and agricultural groundwater pumpers. SqCWD serves a population of approximately 40,400 through 14,438 service connections, of which 94 percent are residential. SqCWD's service area includes portions of the City of Capitola, and the unincorporated communities of Aptos, La Selva Beach, Rio Del Mar, Seascape, Seacliff, and Soquel. As a water district, SqCWD has no land use authority within its service area.

Except for pilot surface water transfers with SCWD during the winter months that began in 2018, the sole water source for SqCWD is groundwater from the Basin. The Basin is currently listed in critical overdraft by DWR. As a result of historic Basin overdraft, portions of the groundwater basin along the coastline have been impacted by seawater intrusion. The Basin is still in long-term overdraft with coastal groundwater elevations below protective levels at five of 13 coastal monitoring well locations (see Section 2.2.4.1.4 for a full discussion of protective elevations and how they are used to evaluate current groundwater levels).

1.4.2 City of Santa Cruz Water Department

The City of Santa Cruz (City), located on the northern shore of Monterey Bay, was established as a Spanish mission in 1791 and incorporated as a town in 1866. The City administers land use within its municipal boundaries and is the county seat of Santa Cruz County. The Santa Cruz Water Department (SCWD) provides water service to an area of approximately 20 square miles, including the entire City, adjoining unincorporated areas of Santa Cruz County, a small part of the City of Capitola, and coastal agricultural lands north of the City. SCWD is responsible for potable water supply in the SCWD's service area to 24,504 connections and a total population of approximately 98,000. The eastern half of the SCWD's service area is within the Basin with an estimated population of approximately 42,000.

The City first acquired an interest in the Basin in 1967 when it purchased its Beltz groundwater wells. SCWD relies on a water supply that is primarily dependent on local surface water runoff, with groundwater contributing only 5 percent of the annual water supply and no connection to an imported water source from outside the region. The strong reliance on local surface water sources and the system's limited ability to store wet season flows for use in the dry season as well as having its groundwater resources in an over-drafted basin that is subject to seawater intrusion are the primary threats to SCWD's water supply reliability. Due to the water system's limited ability to store wet season flows for use in the dry season, SCWD is currently focused on increasing its drought supply and is exploring a number of alternatives, including strategies to store wet season flows in regional aquifers for use during droughts.

1.4.3 Central Water District

Central Water District (CWD) was first organized and approved as Central Santa Cruz County Water District in 1950 by local residents, voters, and the County Board of Supervisors to address the shortage of potable water in the Pleasant Valley area. By December 1953, it had acquired Valencia Water Works and was serving 80 customers. In 1980, the name was shortened to Central Water District. CWD's service area is approximately 3,200 acres or 5 square miles in area and is completely contained within the Basin. Compared to other MGA member agencies, CWD is a relatively small water district serving a rural community that is 98% residential and primarily made up of large residential and agricultural parcels. CWD is solely dependent on groundwater for its water supply and pumps an average of 400 acre-feet per year. Average water use for customers within CWD's service area is approximately 120 gallons per person per day. CWD has participated in groundwater management activities within the Basin since 1995 and has two seats on the MGA board of directors. The total number of CWD's active service connections is 899 providing water to an approximate population of 2,700. As a water district, CWD has no land use authority within its service area.

1.4.4 Santa Cruz County

The County of Santa Cruz (County) was founded in 1850 as one of the 27 original California counties at the time of statehood. The County has a total land area of 445 square miles (US Census Bureau, 2012). The County is the land use jurisdiction for all unincorporated areas outside of city boundaries and is the largest land use jurisdiction within the Basin. The population residing in the unincorporated area of the County within the Basin is approximately 69,500. Of this number, approximately 11,600 people reside in the unincorporated County and do not receive water from a municipal supplier.

The County does not provide water service but does permit and regulate private groundwater wells and small water systems that serve this population. The County's Environmental Health Services Agency (EH) includes the Water Resources Division which participates in countywide planning and management efforts on a variety of water resource programs, including: groundwater management, water quality, stormwater management, water conservation, fish (steelhead) monitoring, watershed and stream habitat protection. The County participated in establishing the groundwater estimates incorporated into the MGA's integrated surface water groundwater model (model) to estimate domestic private well and small water system groundwater pumping at 2,000 acre-feet per year. This estimate was based on groundwater production data from small water systems that are metered. Most private wells within the basin are not metered.

1.5 Private Well Owner Representation

Private well owner representatives participate in Basin groundwater management activities on the MGA Board of Directors. Private well owners, with four (4) or fewer households sharing a private well, have been included in groundwater management activities in the Soquel-Aptos area since at least the mid-1990s. In 2015, the Soquel-Aptos Groundwater Management Committee (SAGMC), a predecessor groundwater agency to the MGA, expanded private well representation to three seats on the SAGMC board. The MGA governance structure continues this engagement approach by including three private well owners on the MGA Board of Directors. MGA private well owner representatives are required to live within the Basin and receive their domestic or agricultural water supply from a private well, shared well, or small water system.

1.6 GSP Organization

1.6.1 Groundwater Sustainability Plan Organization

The MGA's GSP is organized based upon DWR's GSP Annotated Outline with additional information to address content requirements found in the *Preparation Checklist for GSP Submittal* (DWR, 2016).

The GSP is organized as follows:

- **Executive Summary:** This section presents an overview of the GSP, background information on the groundwater conditions in the Basin, an overview the GSP development process, and key information from each GSP sections.
- **Section 1.0 Introduction:** This section presents the purpose of the GSP, the Basin's Sustainably Goal, information about the MGA, and organization of the GSP.
- **Section 2.0 Plan and Basin Setting:** This section describes the Santa Cruz Mid-County Groundwater Basin, existing conditions in the Basin, provides historical data, and uses the data to make prospective estimates for future conditions in the Basin. It is this historic and projected data that set the stage for groundwater planning within the Basin. This section also provides the Basin water budget as context for this long-range groundwater planning effort.
- **Section 3.0 Sustainable Management Criteria:** This section presents the sustainability goal for the Basin and details the criteria for evaluating the SGMA's six sustainable management indicators and the associated undesirable results, minimum thresholds, and measureable objectives. These are the indicator's by which the sustainability of the Basin will be evaluated as GSP implementation occurs.
- **Section 4.0 Projects and Management Actions to Achieve Sustainability Goal:** This section provides a description of projects and management actions necessary to achieve the Basin sustainability goal and to respond to changing conditions in the Basin. These were developed to address sustainability goals, measurable objectives, and undesirable results. The projects and management actions are presented in three groups to provide the clearest description of how and when projects and management actions will be taken to reach sustainability. Group 1 includes projects and management actions that are already implemented and included in the model's baseline. Group 2 includes projects and management actions that are modeled and projected to reach Basin sustainability. Group 3 includes projects and management actions that may be needed if Group 1 & 2 projects fail to achieve Basin sustainability.
- **Section 5.0 Plan Implementation:** This section presents an estimate of GSP implementation costs, the implementation schedule, and outlines the procedural and substantive requirements for the annual and periodic (5-year) evaluations of the GSP.
- **Section 6.0 References and Technical Studies:** This section presents a compiled list of references and technical studies used to prepare this GSP.

Section 2 Contents

TABLES

Figures

2 PLAN AREA AND BASIN SETTING

GSP Section 2 describes the groundwater basin, existing basin conditions, provides historical data, and uses the data to make prospective estimates for future conditions in the Basin. It is this historic and projected data that set the stage for groundwater planning within the Basin.

Section 2 summarizes 50+ years of historic groundwater management within the Basin, it also provides context for local citizens, interested parties, trustee agencies, and state regulatory agencies to understand and participate in this long-range groundwater planning effort.

2.1 Description of Plan Area

Describing the Basin plan area outlines more than just geography. It also summarizes available historical water monitoring information, identifies detailed scientific observations related to water management, documents land use policy over time, and synthesizes groundwater management practices within the Basin.

Agency staff are fortunate to have this wealth of data for the Basin. It provides a deep understanding of the ways in which groundwater has been managed and information on the results of groundwater management over time.

This information is an important lens through which to make Plan decisions going forward. It provides the perspective decision makers need on what has worked in the past, what hasn't worked, and points toward the changes needed to achieve groundwater sustainability as desired on the local level and as required by state law.

The Basin is located between two other groundwater basins that are also required to prepare a GSP under SGMA. To the northwest of the Basin is the Santa Margarita Groundwater Basin, a medium priority basin being managed under SGMA by the Santa Margarita Groundwater Agency. The boundary between these two basins is primarily based on the geology of the region. To the southeast of the Basin is the Pajaro Valley Subbasin, a high priority basin in critical overdraft. The Pajaro Valley Subbasin is managed by the Pajaro Valley Water Management Agency (PV Water). The boundary between the Pajaro Valley Subbasin and the Santa Cruz Mid-County Basin is primarily jurisdictional.

2.1.1 Summary of Jurisdictional Area and Other Features

2.1.1.1 Area Covered by the Plan

2.1.1.1.1 Santa Cruz Mid-County Basin

The Santa Cruz Mid-County Basin is the subject of the Santa Cruz Mid-County Groundwater Agency (MGA)'s Groundwater Sustainability Plan (GSP or Plan). The Plan covers the entire Basin, located entirely within Santa Cruz County (Figure 2-1). The Basin is identified by the California Department of Water Resources (DWR) as Basin 3-001 in *Bulletin 118 Interim Update 2016*.

The Basin was consolidated from all or part of four previously existing basins. The four previous basin and their associated Bulletin 118 basin numbers were the Soquel Valley (3-1), West Santa Cruz Terrace (3-26), Santa Cruz Purisima Formation (3-21), and Pajaro Valley Basins (3-2) (DWR, Bulletin 118 Interim Update 2016).

The consolidated Basin boundary is intended to include all areas where the stacked aquifer system of the Purisima Formation, Aromas Red Sands, and certain other Tertiary-age aquifer units underlying the Purisima Formation constitute the shared groundwater resource to be managed by the MGA. Previous basin boundary definitions were based on surficial alluvium, and did not accurately represent the extent of the deeper aquifer units from which most groundwater is produced. The Basin is defined by both geologic and jurisdictional boundaries (Hydrometrics WRI 2016). Basin boundaries to the west are primarily geologic. Basin boundaries to the east, adjacent to the Pajaro Valley Subbasin managed by PV Water, are primarily jurisdictional.

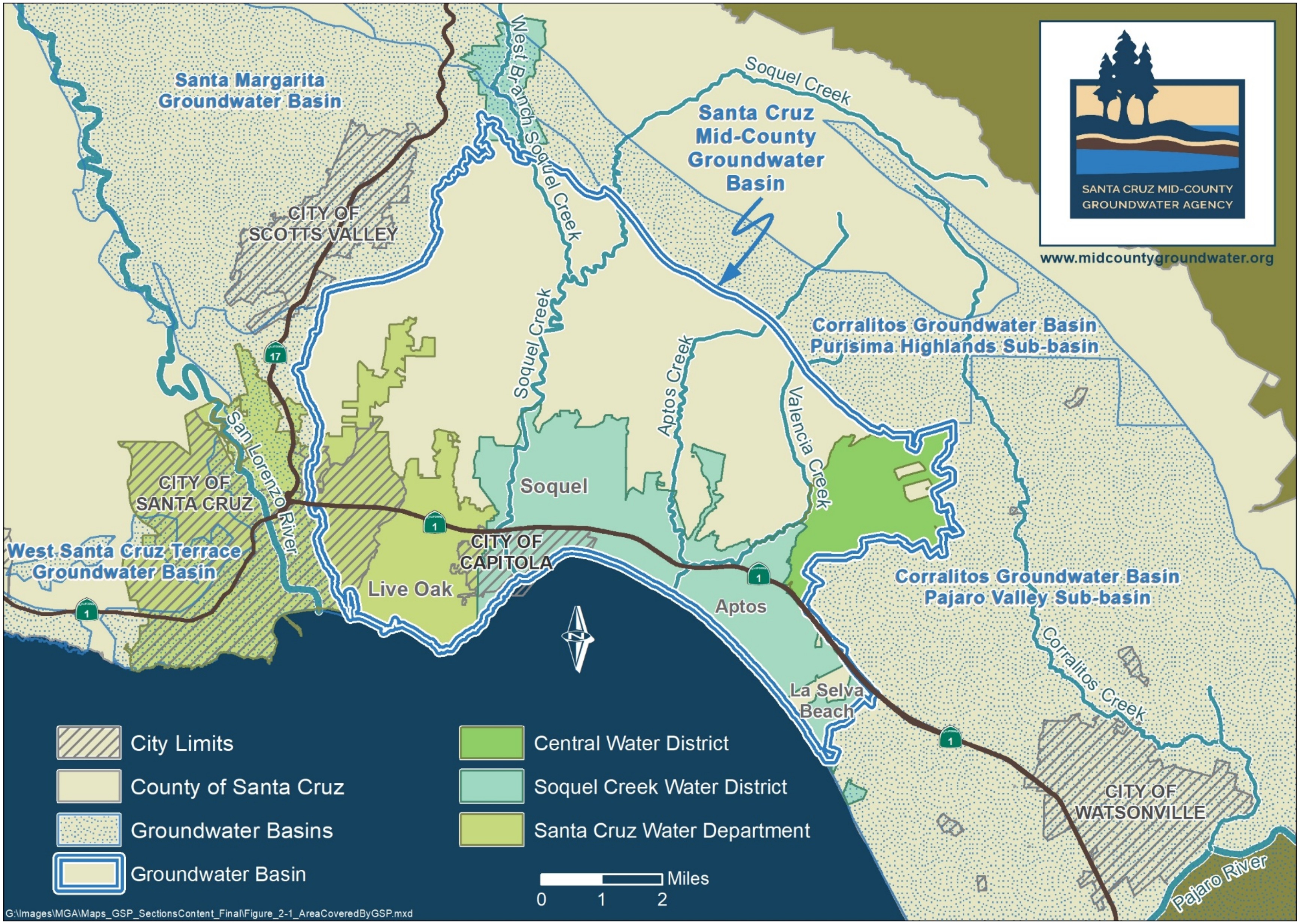


Figure 2-1. Area Covered by the MGA's Groundwater Sustainability Plan

The Basin is adjacent to four neighboring groundwater basins/subbasins: Pajaro Valley Subbasin (3-002.01), Purisima Highlands Subbasin (3-002.02), West Santa Cruz Terrace Groundwater Basin (3-026) and Santa Margarita Groundwater Basin (3-027). All of these basins and subbasins were re-delineated for purposes of SGMA groundwater management in the basin modification process with DWR approval in 2016 (DWR, Bulletin 118 Interim Update 2016). Figure 2-1 shows the location of the neighboring basins in relation to the Santa Cruz Mid-County Basin.

Purisima Highlands (3-002.02) and West Santa Cruz Terrace (3-026) were initially identified as medium priority basins and Santa Cruz County listed as basin manager. However, these are not true groundwater basins and have little groundwater use. DWR re-designated both basins to very low priority and a GSP is not required for SGMA purposes.

Pajaro Valley Water Management Agency (PV Water) manages the Pajaro Valley Subbasin (3-002.01). The Agency was created in 1984 by the Pajaro Valley Water Management Agency Act, legislation developed in response to DWR's 1980 Bulletin 118-80 which identified Pajaro Valley Subbasin as one of 11 groundwater basins in critical overdraft at that time. PV Water has authority to manage groundwater resources in the basin, and its activities typically focus on halting seawater intrusion by balancing overdraft conditions in the basin through promoting water use efficiency and developing and distributing supplemental irrigation water. PV Water's charter specifically prevents the supply of potable water, thus all projects approved in its Basin Management Plan supply non-potable irrigation water. PV Water activities do not include flood control, stream restoration or habitat management (except as mitigations for development projects), which are the responsibility of state and/or county jurisdictions.

The Santa Margarita Groundwater Agency (SMGWA) manages the Santa Margarita Groundwater Basin (3-027) which includes all or parts of three smaller groundwater basins previously identified by DWR as Santa Cruz Purisima Formation Basin (3-21), Scotts Valley Basin (3-27), and Felton Area Basin (3-50). SMGWA is a Groundwater Sustainability Agency (GSA) created in June 2017 by three member agencies: Scotts Valley Water District, San Lorenzo Valley Water District, and the County of Santa Cruz. It is governed by a board of directors with two representatives from each member agency, one representative each from City of Scotts Valley, City of Santa Cruz, Mount Hermon Association, and two private well owner representatives. SMGWA was created in response to SGMA with a mission to sustainably manage its regional groundwater basin. Santa Margarita Groundwater Basin is identified as a medium priority basin not in a state of critical overdraft. As a medium priority basin, SMGWA's GSP is not due until January 31, 2022.

SMGWA and MGA member agencies are in routine communications regarding management of the respective basins. Several MGA member agencies are also members or necessary participants in the groundwater sustainability management efforts of our neighboring basins

2.1.1.2 Adjudicated Areas, Other Agencies within the Basin, and Areas Covered by an Alternative Plan

2.1.1.2.1 Adjudicated Areas

The Basin contains no areas with adjudicated groundwater rights.

Surface water rights were adjudicated in Soquel Creek Watershed by the Santa Cruz County Superior Court in 1977 (SWRCB 1977). At that time, just over 300 users were granted rights to draw from Soquel Creek, its tributaries and stream-feeding springs. First, second, and third priority rights were granted for a variety of uses including domestic, irrigation, recreational, stock watering, agriculture, and fire protection. Limited consideration was given to flows for fish or other environmental users of water, and the adjudication predates the standards expected under the Public Trust Doctrine. During the summer and fall, Soquel Creek regularly has insufficient flow to meet the allocations of all but the first priority right-holders. Most water right holders do not presently exercise their rights.

Soquel Creek has diminished flows late in the dry season (fall), posing limitations on the availability of water for legal diversions and adversely impacting salmonids, amphibians, and other water-dependent organisms and ecosystems. Though the vast majority of the adjudicated allocations are not being used, Santa Cruz County Environmental Health has periodically documented diversions from critical reaches of Soquel Creek. While most identified users have water rights under the adjudication, most have failed to file a Statement of Diversion with the State Water Resources Control Board or secure necessary approvals from the California Department of Fish and Wildlife. The Resource Conservation District of Santa Cruz County is working with state and local agencies and willing landowners with adjudicated water rights, in a non-regulatory context, to identify where winter water storage or other projects could be implemented to reduce diversions during the dry season when the impacts upon salmonids and other aquatic species are greatest.

2.1.1.2.2 Other Agencies within the Basin

Apart from MGA member agencies, no other agencies have direct authority over groundwater within the Basin. The City of Capitola, located entirely within the Basin, has land use authority within its jurisdictional boundaries. Capitola's land use policies can influence the amount of groundwater used. However, Capitola water users must comply with water conservation and other water related resolutions passed by its water providers: City of Santa Cruz Water Department and Soquel Creek Water District.

2.1.1.2.3 Areas Covered by an Alternative

The entire Basin is covered by the MGA and this GSP. No areas within the Basin are covered by an Alternative GSP. PV Water, the neighboring groundwater basin manager to the southeast, has a DWR approved Alternative Plan that covers the entire Pajaro Valley Subbasin (Figure 2-3). Its Alternative Plan was approved on July 17, 2019 and its approval is based on DWR's finding that PV Water's Basin Management Plan is considered a functional equivalent to a GSP for the Pajaro Valley Subbasin to fulfill PV Water's SGMA planning requirements.

2.1.1.3 Jurisdictional Boundaries within the Basin

The Basin extends from the Santa Cruz Mountains to the Pacific Ocean and from the edge of the City of Santa Cruz near Twin Lakes in the west to La Selva Beach in the east (Figure 2-2). The Basin includes portions of the City of Santa Cruz, the entire City of Capitola, Santa Cruz County census designated places of Twin Lakes, Live Oak, Pleasure Point, Soquel, Seacliff, Aptos, and Rio Del Mar. The Basin also includes portions of Santa Cruz County unincorporated census designated places of Day Valley, Corralitos, Aptos Hills-Larkin Valley, and La Selva Beach (DWR, Bulletin 118 Interim Update 2016).

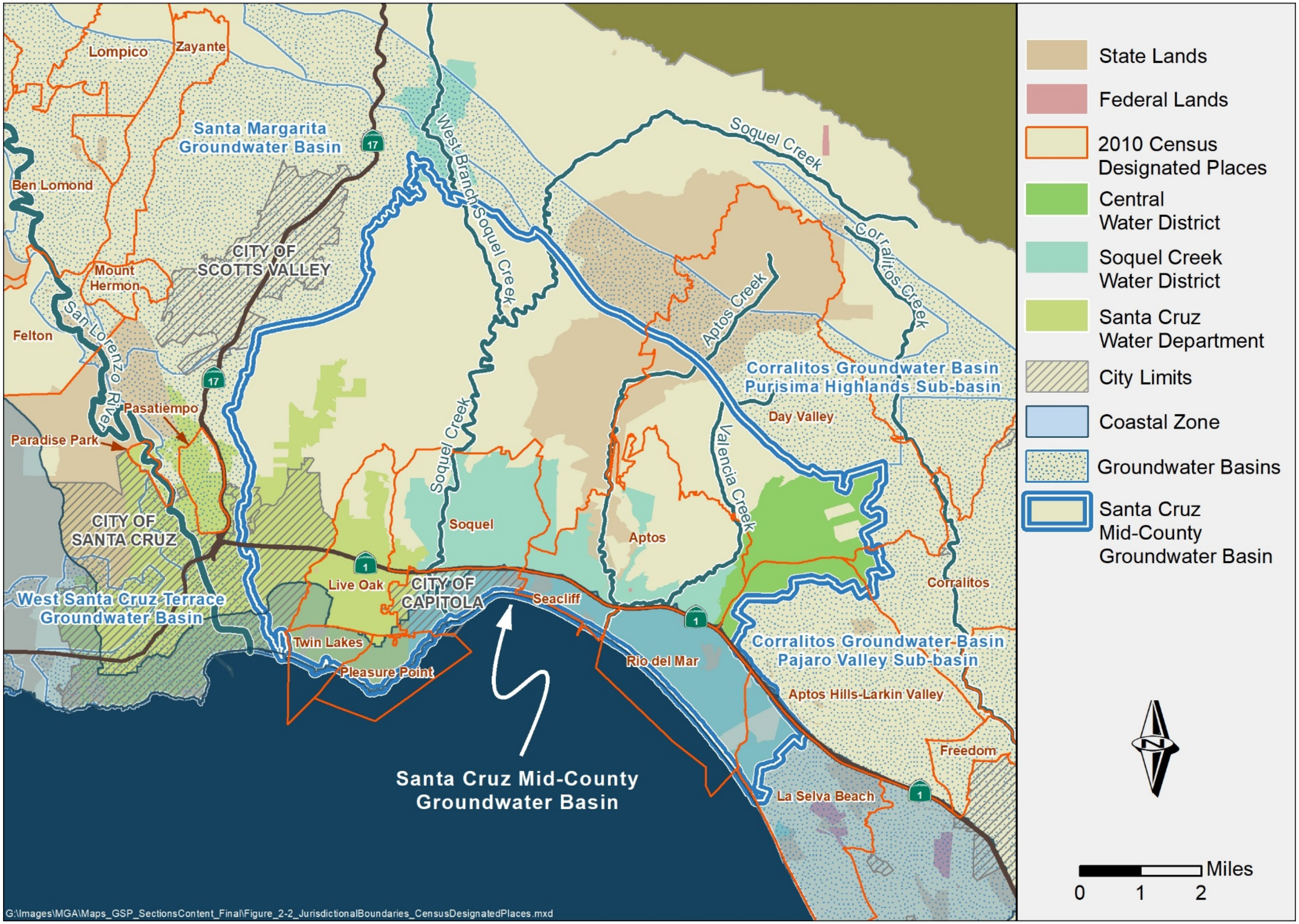


Figure 2-2. Jurisdictional Boundaries and Census Designated Places in or near the Santa Cruz Mid-County Groundwater Basin

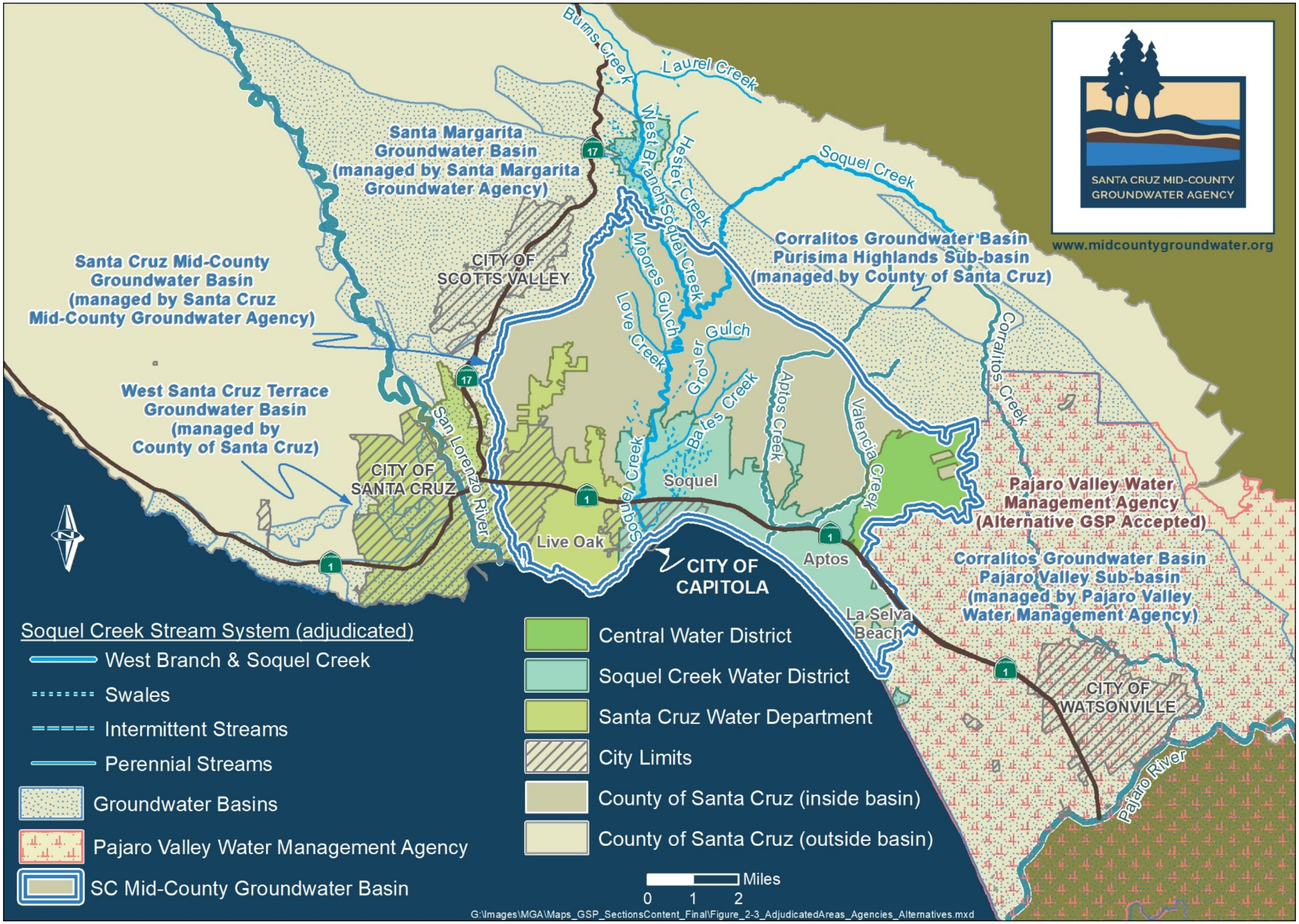


Figure 2-3. Adjudicated Areas, Other Agencies within the Basin, and Areas Covered by an Alternative Plan

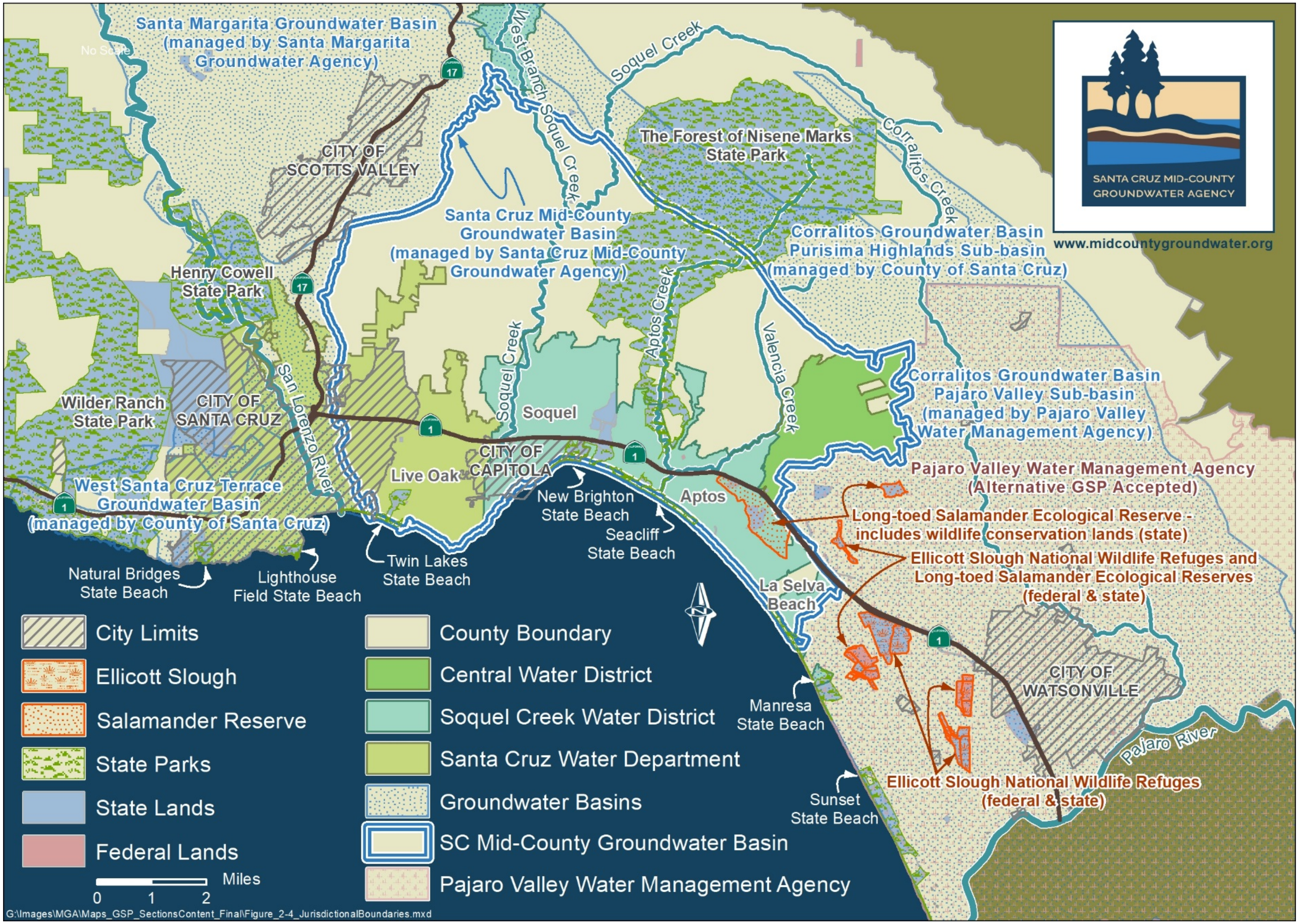


Figure 2-4. Jurisdictional Boundaries of Federal or State Lands

2.1.1.3.1 Federal or State Lands within the Basin

Federal Lands

The Basin contains no federal lands, however, Ellicott Slough National Wildlife Refuge is near the southern Basin boundary. Ellicott Slough is managed by the U.S. Fish and Wildlife Service as part of the San Francisco Bay National Wildlife Refuge Complex (USFWS 2018). Ellicott Slough provides habitat for species federally listed as threatened due to habitat loss, including the Santa Cruz long-toed salamander subspecies, California red-legged frog, California tiger salamander, and robust spineflower. This area of federal land is not included within the Basin and falls outside the Plan area. Groundwater flow from the Basin is in the direction of Ellicott Slough, however, there does not appear to be a connection to the regional aquifer. For this reason, groundwater management consideration is not relevant for this important habitat area outside the Basin.

State Lands

The Basin includes a substantial area of state park lands managed by the California Department of Parks and Recreation (CSP&R 2018). The Basin includes portions of Twin Lakes State Beach and The Forest of Nisene Marks State Park. The Basin also includes the entirety of New Brighton State Beach, Seacliff State Beach, and Rio Del Mar State Beach. The Basin also includes a portion of the Long-toed Salamander Ecological Reserve in the eastern portion of the Basin. This land is managed for resource conservation purposes by the California Department of Fish and Wildlife.

2.1.1.3.2 Tribal Lands

There are no federally designated tribal lands and no federally recognized tribes in the Basin. The Basin is located within a California Tribal and Cultural Area that historically belonged to a division of the Ohlone people known as the Awaswas (DWR 2011). The Awaswas people inhabited the land from present-day Davenport to Aptos. South of the Awaswas, and near the present-day basin boundary with Pajaro, were the Mutsun people, another division of the Ohlone. Decedents of both the Awaswas and Mutsun people are members of the Amah Mutsun Tribal Band. The Tribal Band is petitioning the federal government for tribal recognition and has recently formed the Amah Mutsun Land Trust in an effort to access, protect, and steward lands important to the tribe (AmahMutsun 2019).

2.1.1.3.3 Cities

The Basin contains two municipal city jurisdictions, the City of Capitola and a portion of the City of Santa Cruz. Santa Cruz County unincorporated areas make up the remainder of the Basin.

City of Santa Cruz

The site of the City of Santa Cruz was used by native people before it was discovered by Europeans in 1769. A Spanish mission was established in 1791 and the City of Santa Cruz was incorporated in 1866. The City has land use authority within its municipal boundaries, including those portions that are within the Basin. The Santa Cruz Water Department (SCWD) provides water service to an area of approximately 20 square miles in size, including the entire City, adjoining unincorporated areas of Santa Cruz County, a small part of the City of Capitola, and coastal agricultural lands north of the City. SCWD is responsible for potable water supply in the City's service area to 24,504 connections and a total population of approximately 95,000. The portion of the City's service area within the Basin has an estimated population of approximately 42,000 (AMBAG 2018).

The City also provides wastewater services to City and County residents through its Waste Water Treatment Plant. The City's Public Works Department operates a collection system, treatment plant, and ocean disposal system. The Santa Cruz County Sanitation District, a special district operated to provide service to municipal customers and support to the Santa Cruz County Public Works Department, collects wastewater from the Live Oak, Capitola, Soquel, Aptos, and Seacliff areas. County wastewater is sent to the City's Waste Water Treatment Plant for treatment and disposal through the City's ocean outfall.

City of Capitola

The City of Capitola was incorporated in 1949 after a long history as a native village, as a pier for shipping locally produced resources, and as a resort destination with a train depot. Capitola does not have water management responsibilities. Capitola receives water services from the City of Santa Cruz west of 41st Street and from Soquel Creek Water District to the east. The municipal agencies that provide water to Capitola have regulatory authority to protect the regional water supply. Water users within Capitola are required to comply with the water conservation policies and other programs implemented by their municipal water service providers. Capitola has land use permitting authority over its jurisdictional area. Its municipal land use decisions can impact water demand within the Basin.

2.1.1.3.4 County

The County of Santa Cruz was established in 1850. The County is not a municipal water supplier within the Basin. The County regulates land use in unincorporated areas. The Environmental Health Division of the County Health Services Agency provides watershed management, well permitting oversight, regulatory compliance assistance, and oversight to small water systems and mutual water companies in the unincorporated areas. The Sanitation Division of Santa Cruz County Public Works Department provides staff to the Santa Cruz County Sanitation District, which collects wastewater and provides sewer services to portions of the county and Capitola within the Basin. The County Public Works Department oversees flood control services and storm drain maintenance within Capitola and the unincorporated areas, primarily through Zones 5 and 6 of the County Flood Control and Water Conservation District.

2.1.1.3.5 Water Agencies

Each local water agency with authority over drinking water within the Basin is an MGA member. The member agencies either produce and provide drinking water or regulate drinking water wells. The municipal water agencies have individual authority to pass regulations to protect water resources within their jurisdictional boundaries.

City of Santa Cruz Water Department

The City of Santa Cruz is a public water purveyor that provides water to a population of approximately 42,000 within the Basin (AMBAG 2018). As discussed in Section 2.1.1.3.3, the City's service area within the Basin is a subset of its total service area. The City's primary source of water supply is from surface water sources, including the north coast streams (Majors Creek, Laguna Creek, Liddell Creek, and Reggiardo Creek), the San Lorenzo River, and the Loch Lomond reservoir. The City also owns the Beltz groundwater wells within the Basin which make up approximately 5% of its total water supply in years with normal rainfall. In drought years, the City relies more heavily upon groundwater to meet its needs.

Central Water District

Central Water District (CWD) was established in 1950 and is located at the eastern edge of the Basin. The District was created to provide water service to the Pleasant Valley - Day Valley area east of Aptos. The District covers approximately 3,200 acres or 5 square miles in area. CWD operates groundwater wells within the Basin and is entirely dependent on groundwater for its water supply. It pumps an average of 500 acre-feet per year. CWD is located almost entirely outside of the County's Urban Services Line and most customers utilize individual onsite wastewater treatment systems for wastewater disposal.

Soquel Creek Water District

Soquel Creek Water District was established in 1961 as a flood control and water conservation district. In 1964, it acquired the Monterey Bay Water Company, began delivering water service to customers, and discontinued flood control services. Soquel Creek Water District serves approximately 40,400 customers through 14,438 connections within the Basin (AMBAG 2018). Ninety percent of Soquel Creek Water District's customers are residential and its sole source of water is groundwater. Soquel Creek Water District operates and maintains more than 80 monitoring wells, 15 active production wells, 2 standby production wells, 18 water storage tanks, and delivers water to its customers through more than 166 miles of pipeline. Soquel Creek Water District is working on a range of projects to develop alternative water sources so it is not entirely dependent upon groundwater.

2.1.1.4 Wastewater Management

Wastewater management within the Basin is primarily handled by City of Santa Cruz Public Works Department, the Santa Cruz County Sanitation District, and the Environmental Health Division of the County of Santa Cruz Health Services Agency. The City of Santa Cruz Public Works Department operates and maintains a regional wastewater treatment and disposal facility. Wastewater treatment and ocean outfall disposal are provided for the City of Santa Cruz and the Santa Cruz County Sanitation District, which includes Live Oak, Capitola, Soquel and Aptos. The County of Santa Cruz Health Services Agency permits and oversees all septic systems within Santa Cruz County.

2.1.1.5 Existing Land Use Designations

Land use jurisdictions within the Basin include the County of Santa Cruz, the City of Santa Cruz, and the City of Capitola. Each city has land use authority within its incorporated city boundaries. The County has land use authority within the unincorporated areas of the county. The cities collaborate with the County when planning within their respective spheres of influence to ensure that jurisdictional land use plans compliment the goals of each agency. The cities of Scotts Valley and Watsonville are outside the Basin and are within the neighboring groundwater basins of Santa Margarita and Pajaro Valley respectively.

The three land use jurisdictions with planning authority in the Basin each categorize land use broadly into residential, commercial, agricultural, open space and parks, and utilities and transportation designations. While each jurisdiction defines the specific land uses and development densities allowed in each land use category slightly differently, the general definition of what constitutes these land uses is compatible from jurisdiction to jurisdiction.

Land use within the Basin is further divided between urban and rural land uses. Development densities are greatest on the coastal terraces in the urban and suburban areas within and adjacent to incorporated city boundaries. Development densities are much lower and more rural in the foothills and upland areas of the Santa Cruz Mountains where urban infrastructure is not provided or is less available. A composite general plan map identifying land use designations in and around the Basin is provided to summarize existing land use (Figure 2-5).

2.1.1.5.1 Santa Cruz County

Santa Cruz County is the largest land use jurisdiction in the Basin. The County is the only land use jurisdiction to make a distinction between urban and rural land uses. The County has established urban services lines to focus new development where urban facilities and services already exist. This distinction preserves low densities and limits current levels of development in rural areas where development exists or is already planned, protects rural character by preserving prime agricultural lands, and protects natural and coastal resources from further development that is not compatible with County land use policies. Municipal water service and centralized sewage collection is generally limited to areas within the urban services line.

General plan designations within the county include residential, commercial, agricultural, utilities and transportation, and open space designations. Residential uses are the most prevalent both within the urban and rural services areas. Commercial and industrial uses are located within the urban areas of the Basin and open space and agricultural areas are located in mostly rural areas.

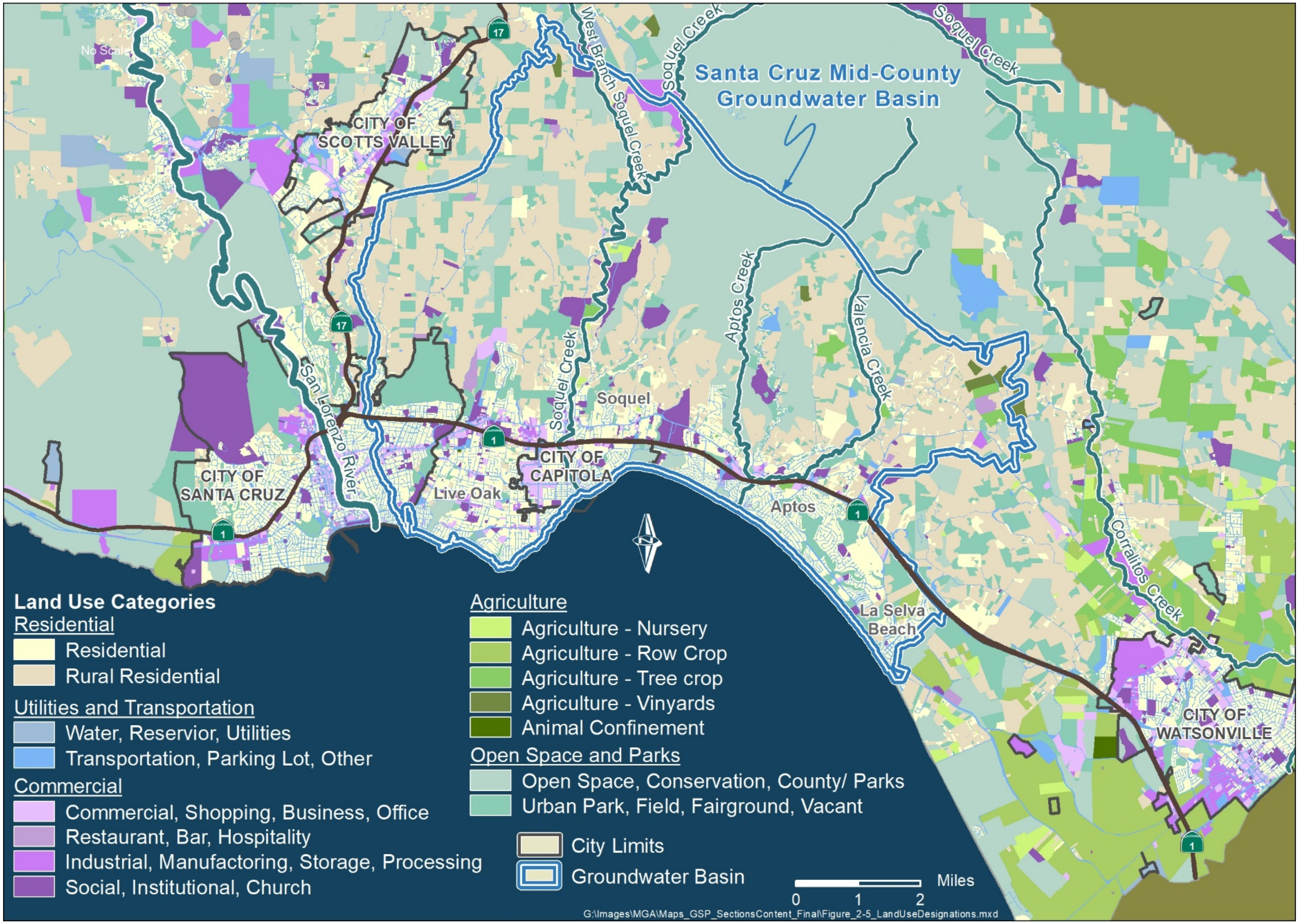


Figure 2-5. Existing Land Use Designations

2.1.1.5.2 City of Santa Cruz

The eastern edge of the City of Santa Cruz is within the Basin. The majority of City land use within the Basin is devoted to residential uses. Parks and open space areas, including large open spaces at Arana Gulch and De Laveaga park and golf course, are the next most abundant land uses, followed by commercial, coastal dependent (Santa Cruz Harbor), and industrial uses.

2.1.1.5.3 City of Capitola

The City of Capitola is the smallest of the land use jurisdictions within the Basin. Approximately 442 acres (53%) of Capitola's total land area in residential use; about 187 acres (21%) is in commercial, industrial, and mixed uses; and 195 acres (23%) is categorized as other uses, such as open space/recreational (118 acres; 14%), public/quasi-public (44 acres; 5%), and vacant parcels (33 acres; 4%) (Capitola 2014).

Each of the three jurisdictions within the Basin has a recently adopted Housing Element that addresses its required regional fair share of the statewide housing needs allocated by the Association of Monterey Bay Area Governments (AMBAG 2014). These documents set forth goals and objectives for housing construction, rehabilitation, and conservation for the period 2015-2023. Water Use and Water Source Type

2.1.1.5.4 Water Use and Water Source Type

Municipal water delivery is one of the primary services that distinguish between urban and rural areas of the Basin. Urban areas within the Basin receive water from municipal suppliers and rural areas, generally, receive water from non-municipal wells, shared wells, small and mutual water systems. The Basin population is approximately 92,100 people (AMBAG 2018). Of this population, approximately 80,500 receive water from municipal suppliers and 11,600 are supplied by non-municipal wells, small and mutual water systems, and other systems.

Groundwater is the primary source of water for residents within the Basin. However, approximately 42,000 Basin residents are supplied by the City of Santa Cruz Water Department (SCWD). These Basin residents receive a mix of surface water and groundwater throughout the year. The SCWD's water source is approximately 95% surface water and 5% groundwater in years with normal rainfall. The remainder of the Basin receives its water supply from groundwater. The Basin receives no imported water from outside Santa Cruz County.

The Basin is highly dependent on groundwater and susceptible to seawater intrusion due to historic overdraft of its productive aquifers. MGA member agencies and other regional partners are working to diversify the regional water supply. An example of this collaboration is the SCWD and Soquel Creek Water District (SqCWD) joint river water transfer pilot project which began in December 2018 under an agreement dated 2016. The parties jointly funded scientific analyses to assess the compatibility and identify potential issues related to supplying treated surface water from the SCWD's system to SqCWD's distribution system, which normally only distributes groundwater. The pilot project supplies surface water treated to drinking water standards to a portion of SqCWD's service area between December and April.

The transfer allows SCWD to divert surface water from its north coast streams when it is available in the winter months that would otherwise flow to the Pacific Ocean and allows SqCWD to rest some of its groundwater wells. The goal is to maximize the use of regional surface water resources when available and leave more water in the aquifer to address the Basin's overdraft condition. Resting SqCWD's groundwater wells also increases groundwater in storage that can be used as a water supply in times of drought. If the pilot is successful (no adverse water quality, health concerns or operational constraints) SCWD and SqCWD plan to negotiate an ongoing agreement to continue the project. SCWD has also applied to amend its water rights to allow the additional diversion of surface water from its other sources to the Basin and neighboring regional groundwater basins.

2.1.1.6 Well Density per Square Mile

In 1971, the County of Santa Cruz began requiring permits for water wells drilled within the County. The County collects data to record location, well depth, and local geology for each well drilled. Over time the County has gathered a significant amount of well data. The County estimates that 20 - 40% of water supply wells in use are unpermitted non-municipal wells drilled prior to 1971.

Because the actual number and location of all non-municipal water supply wells is unknown, the MGA developed a non-municipal well map that uses the best available data to identify where non-municipal domestic, agricultural irrigation, and non-municipal institutional wells are in the Basin. The methodology used is described in Appendix 2-B which is a technical memorandum documenting water use estimates used in the Basin GSFLOW model (model). Estimated non-municipal well locations are used together with known well locations to depict Basin well density. Per GSP regulations, a well density map on Figure 2-6 uses a one-mile square grid to show well density across the Basin. Most non-municipal wells are in inland developed rural areas with relatively fewer non-municipal wells occurring within a mile from the coast. The exception is near the town of Soquel's southwestern border with the City of Capitola, where Soquel SqCWD's service area does not extend more than one half mile from the coast. At this location there are approximately 70 non-municipal water supply wells within a mile of the coast.

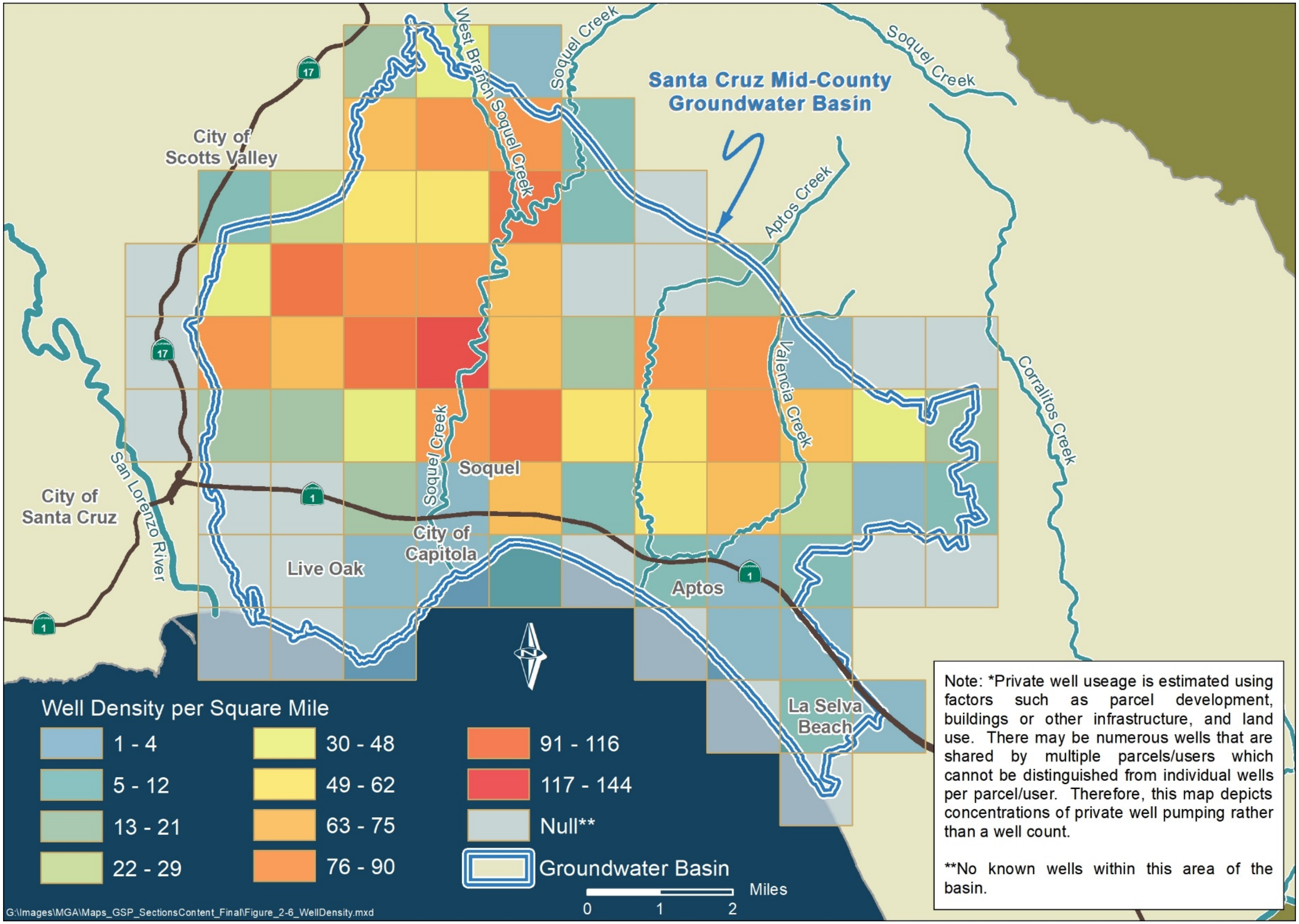


Figure 2-6. Well Density per Square Mile

2.1.2 Water Resources Monitoring and Management Programs

MGA member agencies and other government and regional partners have actively evaluated, monitored, and managed the Basin for over 50 years. In the 1960's, the first studies of local groundwater conditions were initiated to understand regional aquifers and water supply challenges facing this coastal area. In 1967, the United States Geological Survey (USGS) led the first definitive regional groundwater resources study in collaboration with three local water management agencies: Soquel Creek Water District, the City of Santa Cruz, and the County of Santa Cruz (Hickey 1968) shortly after SqCWD and the SCWD began operating groundwater wells inside the Basin.

The 1968 USGS study identified the Purisima Formation as a valuable source of regional water supply, identified the "saltwater wedge" threatening fresh aquifers in the Basin's Purisima and Aromas Red Sands aquifers, and noted that groundwater pumping from the Basin's aquifers had brought saltwater closer to shore. The study also identified seawater intrusion as the primary threat to regional groundwater supplies.

MGA member and regional partner agencies monitor and manage a variety of water resources within Santa Cruz County. There are several monitoring and management programs that MGA member agencies have implemented and use to inform management of municipal pumping in the Basin. These monitoring and management programs cover a variety of Basin water resources including: groundwater, surface water, treated drinking water, wastewater, non-point contaminant sources, and fish habitat.

2.1.2.1 Description of Water Resources Monitoring and Management Programs

<u>Groundwater Management Plan (GMP)</u> – In 1995, Soquel Creek and Central Water Districts partnered to develop a GMP under the provisions of AB 3030 through a Joint Exercise of Powers Agreement (JPA) that established the Basin Implementation Group (BIG). The City of Santa Cruz and County of Santa Cruz joined the GMP team as partner agencies in 2009 when the JPA was amended to expand the BIG. The GMP includes an extensive groundwater monitoring network to monitor productive aquifers together with stream flow and shallow groundwater. The GMP monitoring network extends throughout the Basin and was developed specifically to guide management of aquifers in the Basin. Monitoring is used to assess seawater intrusion, groundwater levels, groundwater quality, municipal production, and surface water interactions. Data collected for the GMP is used to better understand the Basin and to develop adaptive groundwater management strategies that protect the Basin from harm. The GMP will be replaced by the GSP, which will serve as the groundwater management planning document for the Basin.

The GMP monitoring network includes:

- Approximately 80 dedicated groundwater monitoring wells at 30 locations are used to monitor groundwater levels and groundwater quality on a bi-annual basis in spring and fall
  - Coastal Groundwater Monitoring - 13 of these dedicated groundwater monitoring well locations are used as coastal monitoring wells. Because of the high threat of seawater intrusion in the Basin these 13 well locations are monitored much more frequently than wells further from the coast. These coastal wells are manually monitored for groundwater levels and water quality on a quarterly basis to assess the threat of seawater intrusion. Coastal monitoring wells are also equipped with data loggers to record groundwater levels at 15 minute intervals.
- 2 weather stations monitor temperature, humidity, solar radiation, and precipitation in the Basin,
- 4 rain gauges measure rainfall across the Soquel Creek watershed,
- 3 stream gauges monitor streamflow along different reaches of Soquel Creek,
- 5 shallow groundwater wells monitor the relationship between groundwater levels and stream flow [four on Soquel Creek, one on Valencia Creek],
- SCADA groundwater production monitoring system is used to track and manage groundwater production within Soquel Creek Water District's service area and City of Santa Cruz production wells in the Basin,
- WISKI Database is used to manage and analyze groundwater and surface water monitoring and groundwater production data gathered by the monitoring network.

Cooperative Monitoring/Adaptive Groundwater Management Agreement (CGMA) – In April 2015, the City of Santa Cruz Water Department (SCWD) and the Soquel Creek Water District (SqCWD) jointly developed an agreement to ensure the following groundwater management objectives are met:

1. Protect the shared groundwater resource in the Basin from seawater intrusion,
2. Allow for the redistribution of pumping inland away from the Purisima A-unit offshore outcrop area,
3. Maintain inland groundwater levels that promote continued groundwater flow toward coastal wells and the Purisima A offshore outcrop area to maintain coastal groundwater levels that will abate seawater intrusion,
4. Provide both agencies adequate flexibility to respond to changing water demands, changing water supply availability, and infrastructure limitations.

The CGMA identifies monitoring wells from both agency's existing monitoring networks that have been used to monitor the results of management actions taken to protect against seawater intrusion.

Cooperative Monitoring and Mitigation Measures in Response to Soquel Creek Water District's Operation of the Polo Grounds Well – In 2011, CWD and the SqCWD developed a memorandum of agreement to ensure that SqCWD's operation of a new municipal production well, Polo Grounds Well, would not cause excessive drawdown in nearby CWD municipal wells. The agreement is specifically to avoid substantial harm to CWD wells because of an increased risk of physical damage to any of its wells from groundwater levels falling below the well screen or the pump intake as the direct result of increased localized pumping by SqCWD. Monitoring since 2011 indicates that Polo Grounds Well pumping does not have an impact on groundwater levels in CWD municipal wells.

Monitoring and Mitigation Program for Private Wells (MMP) – SqCWD has agreements with private well owners within a 1,000 meter radius of three new municipal wells to monitor their wells for impacts potentially caused by operation of new municipal wells. As part of the program and at SqCWD's expense, private well owner's wells are installed with meters to monitor production and data loggers to record groundwater levels. Well owner participation is voluntary. The ten-year monitoring period is based upon the date each new municipal production well is put into service. Monitoring data from the municipal production well and nearby private wells are analyzed annually. Under these agreements, corrective action is taken to change municipal production operations if municipal pumping causes restrictive effects on private wells.

Soquel Creek Monitoring and Adaptive Management Plan (MAMP) – SqCWD has a monitoring and adaptive management plan for Soquel Creek. This involves monitoring for impacts on stream baseflow related to pumping in the vicinity of the District's O'Neill Ranch well to modify municipal pumping if pumping impacts are detected. As part of the MAMP, SqCWD installed a new shallow monitoring well, weather station, and stream groundwater level gauge (stilling well); and conducts ongoing monitoring of these and other shallow wells and stream level gauges. This monitoring is a requirement from the District's Well Master Plan Environmental Impact Report (EIR) Mitigation Monitoring and Reporting Program (MRMP). The District will have fulfilled its obligations for this monitoring if no impacts have been observed by 2020.

California Statewide Groundwater Elevation Monitoring (CASGEM) Program – The County administers a countywide collaborative groundwater level monitoring and reporting program to fulfill statewide requirements, with biannual groundwater elevation data provided by local water agencies. CASGEM uses monitoring locations throughout the county, including wells within the Basin, to evaluate regional groundwater levels. Statewide groundwater elevation monitoring through CASGEM has provided DWR with data needed to track seasonal and long-term groundwater elevation trends in groundwater basins throughout the state. CASGEM continues to exist as a tool to help achieve the goals set out in SGMA.

Drinking Water Supply Monitoring – MGA member agencies are responsible for monitoring, testing, and reporting drinking water quality to ensure safe drinking water supplies.

- The State Water Resources Control Board, Division of Drinking Water (DDW) – In addition to GMP groundwater monitoring, municipal water utilities collect, test and report on source water quality to DDW as required by federal and state law. This includes testing raw water supply sources, treated drinking water, and water within local distribution systems. Water is tested for 190 parameters to ensure delivered drinking water complies with all federal and state standards.

- County of Santa Cruz Environmental Health (EH) Drinking Water Program – The County is delegated authority by the State DDW to regulate “state small” water systems (5-14 connections) and small public water systems (15-199 connections) to ensure the water provided through these small water systems meets federal and state water quality standards. The County requires sampling, testing, and reporting of chemical and biological parameters and oversees regulatory compliance for these systems. All systems are also required to report their monthly water production at the end of each year.

    - State Small Water Systems with 5-14 connections are regulated under both county and state regulations through the EH Drinking Water Program. State small water systems are required to provide quarterly bacteriologic water quality results to the County, and additional results on a less frequent basis.

    - Public Water Systems located within communities serving 15-199 connections and those that serve more than 25 people for more than 60 days a year through non-community or transient uses (businesses, schools, restaurants, etc.) are regulated by the EH Drinking Water Program acting for the State Department of Health Services through a Local Primacy Agency agreement. Public water systems are required to provide monthly bacteriologic sampling results to the County, with other results provided on an annual or less frequent basis.

County Groundwater Level Monitoring – County Environmental Health has monitored groundwater levels at 20 private wells in the Basin on a biannual basis since May, 2008. The County will also measure groundwater levels at other wells upon request by the property owner.

County Groundwater Quality Testing – As a condition of approval for new development served by an individual well, County Environmental Health requires submission of data on well production and water quality (nitrate, chloride, total dissolved solids, iron and manganese). Since 2010, the County requires submittal of that data for any new well construction.

Wasteload Allocation Attainment Program (WAAP) for Watersheds in Santa Cruz County – the County of Santa Cruz provides countywide watershed water quality monitoring and reporting for all county jurisdictions to fulfill federal Clean Water Act storm water requirements. The County’s WAAP identifies, prioritizes, and makes plans to resolve contaminant issues that could impact the health of the community’s surface water and drinking water. The program monitors surface water quality for nitrate and E. coli, identifies impaired waters by comparing monitoring results to federal water quality standards, identifies the sources of pollution, and prioritizes best management practices to bring impaired surface waters into compliance with federal standards.

Integrated Regional Water Management (IRWM) Program - The Santa Cruz IRWM program provides a countywide framework for local stakeholders to manage the region's water and water-related resources. The region's initial IRWM Plan was completed in 2005 and substantially expanded in 2014. The program promotes an informed, locally-driven, consensus-based approach to water resources management. The Plan includes strategies for developing and implementing policies and projects to ensure sustainable water use, reliable water supply, better water quality, improved flood protection and storm water management, and environmental stewardship. More than 80 projects and technical studies have been funded under this program. Prior projects provide data upon which to evaluate storm water capture and recharge projects.

Urban Water Management Planning (UWMP) - As urban water suppliers with more than 3,000 customers and/or distribution more than 3,000 acre-feet per year, SqCWD and SCWD are required to complete Urban Water Management Plans every 5 years under the UWMP Act administered by DWR. All agencies covered by the UWMP Act must assess their water resources needs and availability over a 20-year planning timeframe. The requirements also include a Water Shortage Contingency Plan (WCSP) which incorporates demand mitigation measures that plan for future water shortages. UWMP is used for the purpose of educating the community, providing information for land use planning agencies, and informing the IRWM Plan. The first UWMPs were completed in 1985/1986, with the most recent plans completed in 2015. The next UWMP update is due on or before July 1, 2021.

Santa Cruz County Juvenile Steelhead and Stream Habitat (JSSH) Monitoring Program - The JSSH Monitoring Program is a partnership between the County of Santa Cruz and local water agencies. The annual monitoring program has been in place since 1989 and measures the density of juvenile steelhead across more than 40 sites throughout the San Lorenzo, Soquel, Aptos, and Pajaro watersheds. The program also assesses habitat conditions for steelhead and coho salmon and helps inform conservation priorities throughout the County. There are 27 JSSH monitoring locations within the Basin and 7 more upstream within the Basin watershed. Additional information on this program can be found at the County of Santa Cruz Environmental Health Steelhead Monitoring Program webpage http://scceh.com/steelhead.aspx.

2.1.2.2 Incorporating Existing Monitoring Programs into the GSP

The MGA will leverage current and historic data on groundwater, surface water, and habitat conditions to sustainably manage the Basin as required by SGMA. As discussed in Section 3, all of the sustainability indicators will be monitored primarily using the existing monitoring network but will also include some additional monitoring features that will be installed as part of GSP implementation.

The existing monitoring network will be used to assess sustainability indicators as follows:

- Chronic Lowering of Groundwater Levels – Representative monitoring wells from the existing network are used to directly monitor groundwater elevations in aquifers throughout the Basin.

- Reduction of Groundwater in Storage - All municipal production wells are included in the existing monitoring network and are used to monitor the extracted volume of groundwater in the Basin. Where small water systems and non-de-minimis users report their production data to Santa Cruz County, this information will be included in extraction calculations. Non-metered production will be estimated based on land use information and extrapolations as discussed in Section 2.1.3.

- Seawater Intrusion – The existing coastal monitoring wells are used as representative monitoring wells to monitor chloride concentrations and groundwater elevations relative to protective elevations designed to keep seawater offshore. Additionally, existing monitoring and production wells are used as representative monitoring wells to monitor chloride concentrations to directly monitor potential seawater intrusion.

- Degraded Groundwater Quality – Groundwater quality information from representative monitoring wells within the existing network are used to directly monitor groundwater quality.

- Depletion of Interconnected Surface Water – Groundwater elevations in representative shallow monitoring wells are used as a proxy to monitor impacts of groundwater management on depletion of interconnected surface water. Existing monitoring network stream flow gauges are also used to evaluate surface water depletion.

- Land Subsidence – this sustainability indicator is not applicable as discussed in Section 3.8.

An important tool used in the development of the GSP is the Basin GSFLOW model (model). The model simulates a simplified version of how climate, geology, surface water, and groundwater interact regionally in a complex natural system. The model is calibrated to match known historic conditions and is used to predict future groundwater conditions based on Basin management strategies using the model's climate catalog and inputs related to groundwater demand. Model calibration relies on data collected from existing monitoring networks. Monitoring data will continue to be incorporated in to the model as the GSP is implemented and the groundwater model is improved with future data. In places where there are no measured data, the groundwater model can be used to simulate groundwater conditions until such time that monitoring features are established in these locations. Model development reports and technical memoranda are included in Appendix 2-B through Appendix 2-I. Information from the model and the existing groundwater monitoring networks provides a framework to understand regional water resources and their connection to groundwater pumping within the Basin.

2.1.2.3 Description of how those Programs may Limit Operational Flexibility in the Basin

As discussed in Sections 2.1.2.1 and 2.1.2.2, the existing groundwater monitoring network, developed for Basin management activities under the prior Groundwater Management Plan, is well suited to assessing groundwater pumping impacts on groundwater levels and groundwater quality related to seawater intrusion. These monitoring data are used to evaluate SGMA sustainability indicators.

The Soquel Creek Monitoring and Adaptive Management Plan (MAMP) was developed to provide data to evaluate potential stream and shallow groundwater level impacts related to deep groundwater pumping near Soquel Creek. The MAMP could limit groundwater pumping if pumping impacts are identified. Stream gauges and shallow monitoring wells were installed as part of this monitoring and mitigation obligation that will sunset in 2020 if no impacts are documented. However, Basin monitoring of surface water depletion at this location would be hindered by loss of data from the MAMP program. MGA plans to maintain this monitoring effort if and when the MAMP program sunsets.

The Monitoring and Mitigation Program for private wells currently applies to two wells in SqCWD's service area within the Basin. Operational flexibility can be hindered at these two municipal production well if monitoring indicates impacts to private wells. When SqCWD developed municipal production wells at the Polo and O'Neill sites, it agreed to limit impacts to surrounding private wells within 1,000 feet of these two municipal wells. If increased production is needed at the O'Neill or Polo production wells as part of a pumping redistribution, they cannot be fully utilized if restrictive effects occur at the nearby private wells. Similar agreements are in place and would take effect at the Granite Way and Cunnison Well sites if and when those municipal wells are developed.

2.1.2.4 Description of Conjunctive Use Programs

Conjunctive use refers to the coordinated use of surface water and groundwater resources to optimize regional water supply and storage management objectives. For the Basin, conjunctive use targets the use of surface water for managed aquifer recharge and/or in lieu recharge. Conjunctive use results in reduced groundwater extraction to leave groundwater in storage for times when excess surface water is not available. Reduced groundwater pumping can lead to increased groundwater levels that can reverse groundwater conditions that have led to overdraft in the Basin. It can also result in groundwater levels that would allow for additional groundwater pumping in times of drought.

The City of Santa Cruz relies upon surface water from outside the Basin (approximately 95% surface water in a typical year), while Soquel Creek and Central Water Districts are dependent upon Basin groundwater for their water supplies. This regional mix in availability of surface water and groundwater resources presents opportunities for future conjunctive use. Interties are in place between the City of Santa Cruz, SqCWD, and CWD but have limited capacity and capabilities. Until December 2018, these interties were historically used only to transfer water between agencies in emergency circumstances. In recent years, as described below, SCWD and SqCWD have initiated efforts towards conjunctive use.

Current conjunctive use projects in the Basin include:

- Cooperative Water Transfer Pilot Project for Groundwater Recharge and Water Resource Management – In 2015, SCWD and SqCWD entered into a Cooperative Water Transfer and Purchase Agreement to collect information to further assess the potential opportunities to reduce groundwater pumping in the Basin through surface water transfers from SCWD to SqCWD. Under this agreement, SqCWD purchases excess surface water from SCWD to meet part of its water demand. This allows SqCWD to reduce groundwater pumping, reduce the potential to accelerate seawater intrusion, and contribute to reversing Basin overdraft conditions that impacts beneficial users of groundwater. SCWD began transferring excess surface water to SqCWD in December 2018. This pilot study transfers surface water using an existing intertie to determine if the introduction of surface water into SqCWD's groundwater only infrastructure could be accomplished without negative impacts to water quality delivered to SqCWD's customers. Operational and health considerations will also be used to evaluate water transfers.

- Aquifer Storage and Recovery (ASR) Pilot Testing – in 2017 SCWD made significant progress assessing the feasibility of ASR in the Basin and neighboring Santa Margarita Groundwater Basin. SCWD began its ASR pilot test in December 2018 at Beltz Well 12 located at the City's Research Park facility within the Basin. SCWD's pilot project injects excess surface water treated to drinking water standards near its service area boundary with SqCWD. The goal of ASR pilot testing is to assess the feasibility and potential impacts of ASR on groundwater levels and groundwater quality. Groundwater will be extracted and sampled for a variety of parameters. Groundwater level changes related to the pilot tests will be monitored by both SCWD and SqCWD. These ASR tests will also assess how much water is lost as outflow from the aquifer and how much water can be recovered for supply during times of drought.

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans

2.1.3.1 Summary of General Plans and Other Land Use Plans

The Basin covers a land area of approximately 56 square miles and includes land areas under the jurisdiction of three municipalities: the County of Santa Cruz, the City of Santa Cruz, and the City of Capitola. Each municipality has an adopted general plan with land use classifications that identify desired development, open space, and conservation purposes. Also included within the Basin are state lands managed by the California Department of Parks and Recreation. The Soquel Creek Demonstration Forest, managed by the Department of Forestry and Fire Protection is located just outside the Basin but occupies much of the upper Soquel Creek Watershed.

All three municipal jurisdictions within the Basin have general plans, local coastal programs, zoning regulations, and development standards that determine the location, type, and density of growth allowed in the region. The general plan serves as the principal policy and planning document guiding long-range land use and conservation decisions in cities and counties. General plans go through rigorous environmental review to understand and mitigate potential adverse impacts related to general plan implementation activities.

The cities of Santa Cruz and Capitola have both completed comprehensive updates to their general plans in the last few years. The Santa Cruz City General Plan timeline extends to 2030, and Capitola's General Plan has a 20 to 30-year planning horizon. The County's current General Plan was adopted in 1994. The County has recently prepared and adopted a Sustainable Santa Cruz County Plan addressing sustainable land use, housing, economic development, and transportation objectives in the urban area of the County (Santa Cruz County, 2015). The time horizon of the County's plan is through 2035. The Housing Element of the County's General Plan was updated in 2015. The County is currently preparing a general plan update to incorporate the Sustainable Santa Cruz Plan into the County General Plan.

The County General Plan contains two additional components that have significant effect on management of water resources in the Basin. In 1978, the voters passed Measure J, which called for a comprehensive growth management system, including population growth limits, the provision of affordable housing, preservation of agricultural lands and natural resources, and the retention of a distinction between urban and rural areas. This has resulted in greatly diminished development density and growth rates in areas outside of the urban services line that do not receive municipal water service. Each year when the Board of Supervisors adopts the growth goal and annual building permit allocation, limitations of water supply are taken into consideration.

The Conservation and Open Space Element of the County General Plan includes many policies and programs for protection and management of groundwater resources, recharge areas, wetlands, streams, riparian corridor, and sensitive habitat areas. Many of these polices are incorporated into the County Municipal Code. These policies, programs, and code requirements were reviewed during development of GSP elements for depletion of surface waters and groundwater dependent ecosystems. The County General Plan maps of recharge areas, sensitive habitats and biotic resources were also utilized. The Conservation and Open Space Element is currently in the process of being updated and wording has been proposed to incorporate references to the GSP into the updated General Plan.

Most growth and development that does happen going forward is expected to be concentrated within the confines of the areas served by MGA's municipal water agencies. Because of the relative scarcity of raw land for urban development, the majority of future growth in these area is likely to be achieved through redevelopment, remodeling, increased density on underutilized land, and infill development in the urban areas and along major transportation corridors, along with new construction on the little amount of vacant land remaining.

Within the Basin, the Coastal Zone extends approximately 1000 yards inland from the coast. Within that zone, many of the major decisions made by local governing bodies about public improvements and private development are also subject to the review and oversight of, or may be appealed to, the California Coastal Commission. Accordingly, land use changes tend to occur slowly, if at all, and only after extensive public review.

State general plan guidance was significantly revised in 2017. Changes to planning laws triggered these revisions, including SGMA's requirement that general plans consider water supply at their next update.[1] Any significant update to a general plan, including to its housing element,[2] will trigger the SGMA mandate to consider development impacts on groundwater supply. MGA staff met with panning staff from Santa Cruz County and the cities of Capitola and Santa Cruz during the public comment period on the Draft GSP. The purpose of these consultations was to discuss the purpose of SGMA, the content of the GSP, to support future comprehensive land use planning and GSP updates, and to facilitate ongoing compliance with SGMA land use planning consultation requirements.

2.1.3.1.1 Existing Land Use Designations

The Basin is dominated by residential land uses, which make up approximately 50% of Basin land acreage (Figure 2-7). Residential uses vary between large rural parcels with few impervious surfaces to suburban and urban residential parcels associated with higher development densities and surrounded by more impervious surfaces, wider roads and more sidewalks. The next most abundant land use in the Basin is open space, which makes up approximately 34% of Basin land area. Open spaces include areas reserved for conservation, or developed as county and state parks, urban parks, fields, and undeveloped lands. The least abundant land use categories serve commercial, utilities and transportation, and agricultural uses.

[1] http://opr.ca.gov/planning/general-plan/

[2] General plans are long range planning documents, however, general plan housing element updates are required on either a five year or eight year planning cycle. This schedule strengthens the connection between housing and transportation planning, to better align the schedules for regional housing needs assessments and local government housing element updates with schedules for adopting regional transportation plans. All Basin municipalities are on an eight year housing element update schedule. The next update is due in 2023.

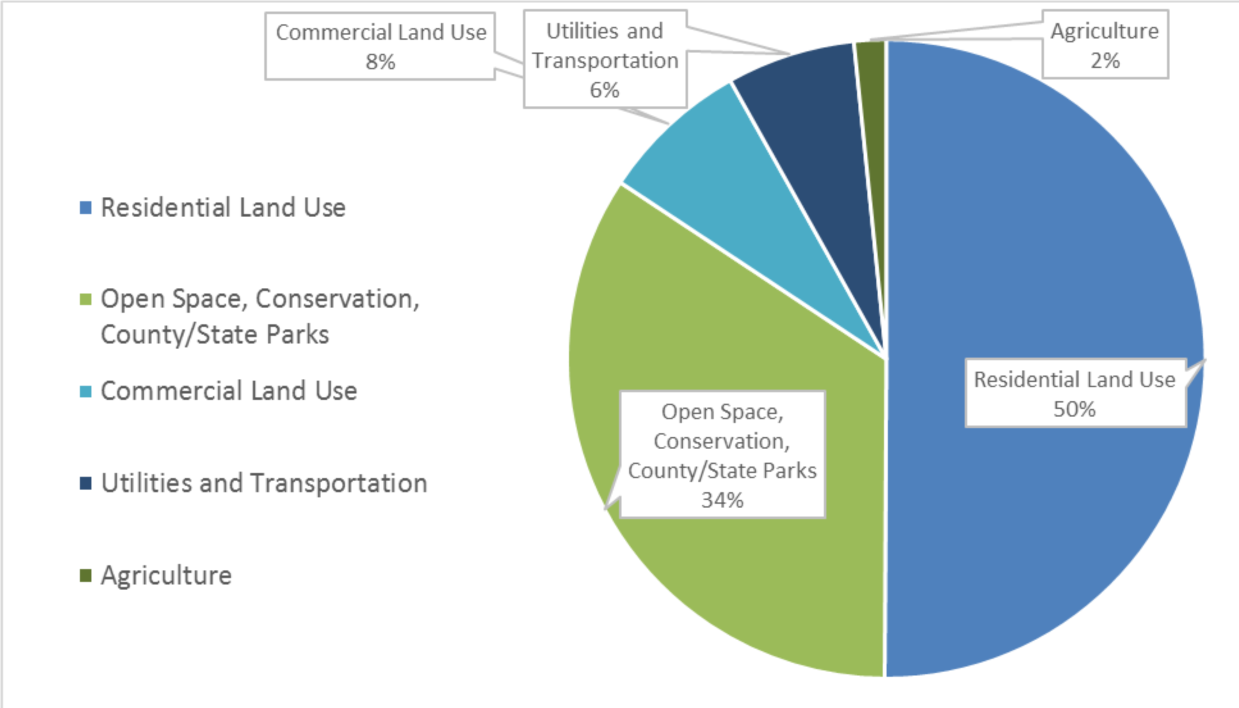


Figure 2-7. Basin Land Uses

2.1.3.1.2 Agricultural Water Demand – Specialized Evaluation

The Assessor's Use Codes that designate land uses on individual parcels based on the actual observed land use are a useful tool to evaluate the generalized land use within a large area. However, because the water demand for different crops varies widely, these land use designations do not necessarily reflect how water is being used on an individual parcel. More detail is particularly important to understand the water use characteristics for agricultural properties or sites with extensive irrigation (Figure 2-8).

Knowing that most large irrigators do not use municipal water, the MGA determined that it would be appropriate to conduct an exercise to improve the understanding of the amount of water used in the Basin by agricultural irrigators. Staff from the County worked with technical consultants to map the location and acreage of irrigated land and nurseries in the Basin using aerial imagery. An initial assumption of crop type and irrigation status was made from the images and then verified in the field by County staff.

Crop-based water use factors – an annualized estimate of the amount of water required for different crops and land uses - were applied to the amount of land in production. According to this exercise, there is approximately 660 acre-feet per year of water being pumped from the Basin for use in agricultural production and large scale irrigation that is not being provided by the Basin's municipal water agencies. The model applies a 20% return flow rate to outdoor irrigation, making the net water impact closer to 528 acre-feet per year.

.

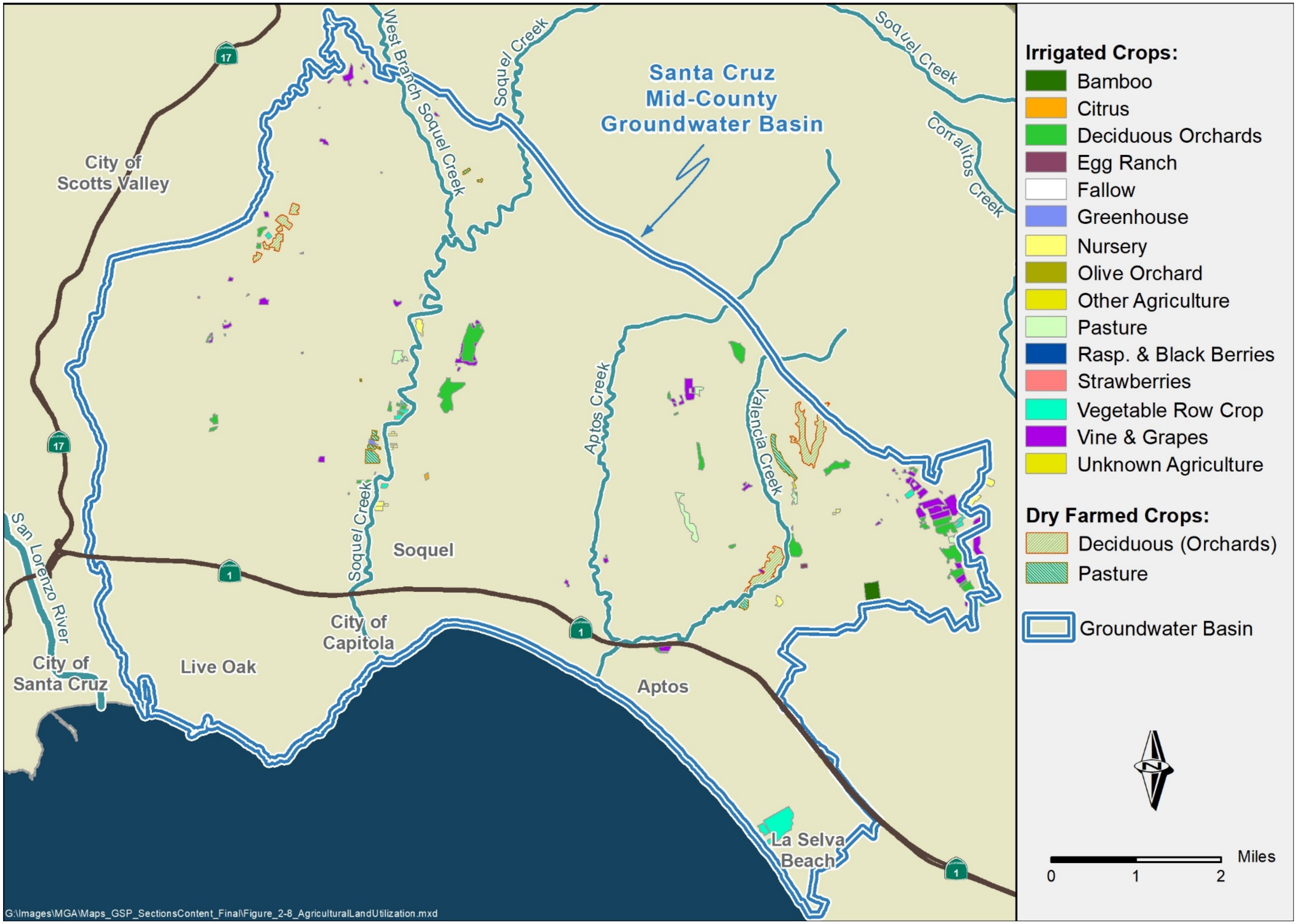


Figure 2-8. Agricultural Land Utilization within the Santa Cruz Mid-County Basin

The MGA acknowledges that there is room for error in this agricultural irrigation water use estimation process. To get a more accurate estimate of the impact of these users on the Basin, the MGA is proposing a metering program which is discussed in Section 5.1.1.4.3. The metering program will be applied to irrigators throughout the Basin estimated to use 5 acre-feet per year or more, or in priority areas using 2 acre-feet per year or more, based on the exercise described above.

2.1.3.1.3 Basin Water Demand

Basin water demand is the amount of water used for an identified time period, typically per person per year for municipal residential uses, per parcel for rural residential land uses, per acre by crop type for acreage in agricultural production, and per acre per year for other land uses. The forecast of future Basin water demand is a complex and foundational component of sustainability planning to account for the water requirements of all Basin water users and uses.

In recent years, historical patterns of water demand have been upended by a variety of factors, including the cumulative effects of tighter efficiency requirements for appliances and plumbing fixtures, greater investments in water conservation, a significant uptick in water rates, an equally significant downturn in economic activity during the Great Recession, and greater awareness of the need for on-going water conservation because of long term droughts in California. These events have resulted in even more uncertainty than usual regarding future water demand and have placed even greater importance on sorting out the effect each has had on demand in recent years as well as how they are likely to affect water demand going forward.

Basin water production is measured by MGA's municipal water producers that supply water to customers. Basin water production by non-municipal wells that are not metered is estimated using data from wells serving similarly situated properties that are metered. Most small water systems and non-municipal institutional users are now metered and report annual use to the County. Agricultural water production is estimated by land area in production and water use by crop type as discussed in Section 2.1.3.1.2. Figure 2-9 shows the amount of Basin groundwater produced by pumper category. Approximately 2% of the non-municipal domestic category includes use for small water systems.

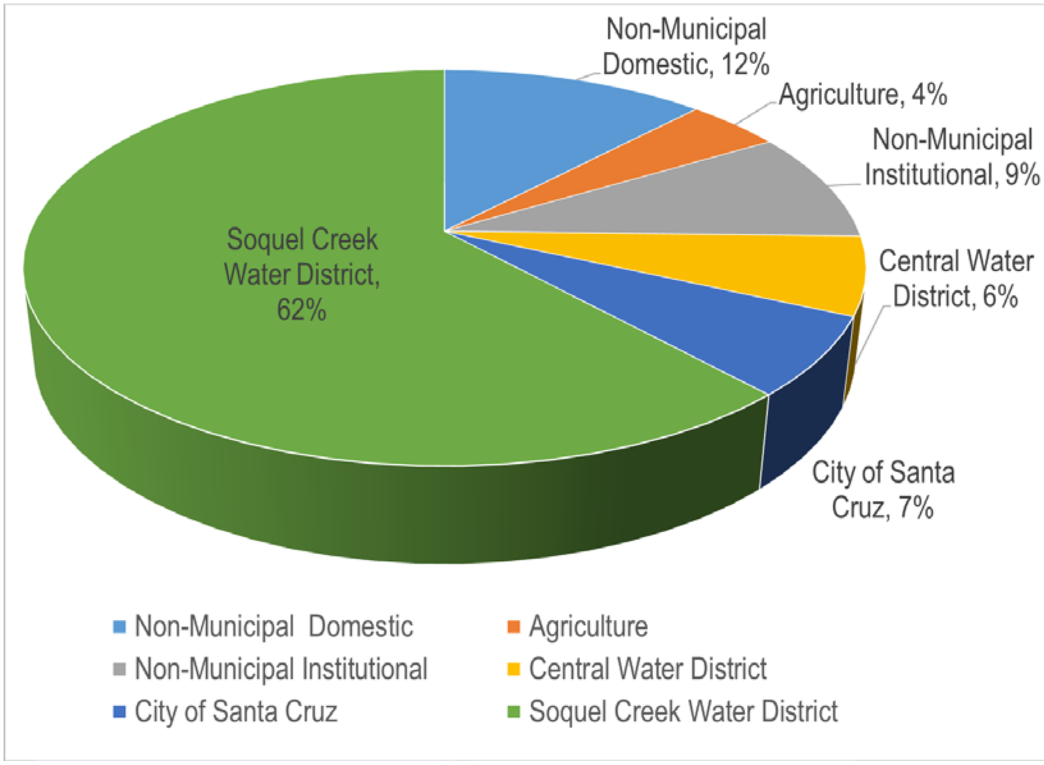


Figure 2-9. Average Annual Basin Groundwater Production by User Type

2.1.3.1.4 Projected Water Demand

Projected non-municipal groundwater demand for domestic use assumes pre-drought (2012 – 2015) water demand of 0.35 acre-feet per year per household. The assumed water demand is applied to projected annual population growths of 4.2% pre-2035 and 2.1% post-2035. Actual growth in non-municipal demand is expected to be much lower, based on current actual growth rates and more recent projected growth rates of only 0.2% per year through 2040 as estimated by the land use agencies. Groundwater demand for larger institutions such as camps, retreats, and schools, and agricultural irrigation remain the same as historical demands. The groundwater model also takes into account the significant amount of return flow from septic systems associated with most rural users.

Projected Baseline municipal groundwater demand (without projects and management actions) is based on several different assumptions:

- Central Water District - pre-drought average groundwater production of 550 acre-feet per year from Water Year 2008 through 2011.
- Soquel Creek Water District - 2015 Urban Water Management Plan (UWMP) projects demand to increase to 3,900 acre-feet per year after historically low pumping achieved from 2010-2015. The 2015 UWMP projects subsequent long-term decline of demand to 3,300 acre-feet per year, but these demands may have been underestimated; for example, new laws facilitating Accessory Dwelling Units have passed since 2015. For

projected water budget, the GSP projects that Soquel Creek Water District groundwater demand remains stable.

- City of Santa Cruz – projections of groundwater pumping in the Basin are based on City of Santa Cruz confluence modeling to meet demand during 2016-2018. The pumping is expected to be between 339 and 369 acre-feet per year. The City considers this demand appropriate for current planning because unlike most other communities in the Bay Area and California, City water demand has not increased much from restricted consumption during the 2012-2015 drought ((SCWD, Water Commission Information Report on Joint Workshop with Former Water Supply Advisory Committee. Attachment 2 (Water Demand) 2019) and (M.Cubed 2019)).

2.1.3.2 Description of How Implementation of the GSP May Change Water Demands or Affect Achievement of Sustainability and How the GSP Addresses Those Effects

As discussed later in Section 2.2, Basin water managers' focus to reduce water demand and redistribute groundwater pumping to protect the Basin against seawater intrusion has resulted in significant progress toward recovering Basin groundwater levels. This progress toward Basin sustainability, that began to show results over the past 25 years, means that the Basin's GSP implementation strategies can focus on technically feasible locally sourced water augmentation strategies that are already well into engineering, permitting, and pilot testing phases by MGA member agencies.

The model was used to evaluate water augmentation projects outlined in Section 4 under climate and sea level rise scenarios. If these water augmentation strategies are implemented and perform as expected, no land use or water demand changes are expected to be required to attain sustainability in the Basin.

2.1.3.3 Description of How Implementation of the GSP May Affect the Water Supply Assumptions of Relevant Land Use Plans

The model calculates that the water supply assumptions of existing land use plans will be supported by ongoing water conservation, groundwater pumping redistribution as described in Section 4, Group 1, and the development of locally sourced water augmentation projects as described in Section 4, Group 2. Additional statewide water conservation legislation is likely to lead to further water use efficiency without requiring significant land use changes or water use curtailment in the Basin. However, should the MGA, its member agencies, or the state determine that the Basin is failing to achieve adequate progress toward sustainability, additional projects from Section 4, Group 3 may also be implemented.

2.1.3.4 Summary of the Process for Permitting New or Replacement Wells in the Basin

Basin well permits are issued by the county and cities within their respective municipal boundaries. These agencies include the cities of Santa Cruz and Capitola within city boundaries and the County of Santa Cruz in the unincorporated areas. Each agency relies on water well standards developed and updated by the California Department of Water Resources. Each agency then specifies any additional requirements in its municipal code that apply to well installation and destruction within its municipal boundaries.

The Water Director is responsible for issuing water well permits within the City of Santa Cruz boundaries. Santa Cruz City water well permit requirements are outlined in the city's municipal code section 16.06 found here: http://www.codepublishing.com/CA/SantaCruz/

The County Environmental Health Division of the Health Services Agency is responsible for issuing water well permits within Capitola city boundaries. City of Capitola water well permit requirements are outlined in the city's municipal code section 8.24 found here: https://www.codepublishing.com/CA/Capitola/#!/Capitola08/Capitola0824.html#8.24

The County Environmental Health Division of the Health Services Agency is responsible for issuing water well permits within the unincorporated areas of Santa Cruz County. Santa Cruz County water well permit requirements are outlined in Chapter 7.70 of the County Code, found here:
http://www.codepublishing.com/CA/SantaCruzCounty/html/SantaCruzCounty07/SantaCruzCounty0770.html

Both Capitola and the County of Santa Cruz have well drilling restrictions that limit issuance of well permits within Soquel Creek Water District's service area due to concerns related to groundwater overdraft and seawater intrusion. These restrictions have been in place since 1981. The County also requires documentation of water efficiency measures as a condition of approval for any well serving any proposed groundwater use expected to use greater than two acre-feet per year.

The County will update its well ordinance to implement elements of this GSP, including metering requirements for non-de minimis users. The County will also address the need to prevent impact on public trust values in surface water from new wells, depending on how this issue evolves in the State. This could include a requirement for increased setbacks from streams and/or deeper seals to reduce the potential to draw from alluvium that is in direct hydraulic contact with a stream.

2.1.3.5 Information Regarding the Implementation of Land Use Plans Outside the Basin that Could Affect the Ability of the Agency to Achieve Sustainable Groundwater Management

Except for the City of Scotts Valley to the northwest Basin boundary, MGA member agencies control land use planning and implementation in the areas outside and contiguous to the Basin boundary. The City of Santa Cruz is the land use planning jurisdiction for the areas outside the western Basin boundary and the County of Santa Cruz has land use jurisdiction over the remainder of the areas adjacent to the Basin.

Santa Cruz County is a relatively small county and MGA member agencies have developed good regional partnerships with neighboring land use jurisdictions, water management agencies, and GSAs. The City of Scotts Valley is a participant in planning for groundwater sustainability in the Santa Margarita Groundwater Agency (SMGWA), as are MGA member agencies the City of Santa Cruz and Santa Cruz County. MGA members will continue to work collaboratively with our regional partners to coordinate groundwater management efforts that ensure groundwater sustainability is achieved throughout Santa Cruz County.

2.1.4 Additional GSP Elements

2.1.4.1 Control of Seawater Intrusion

The 1968 USGS groundwater study identified seawater intrusion as the greatest threat to the Basin's groundwater supplies (Hickey 1968). The report documented a seawater wedge offshore of the Basin's productive aquifers and noted that seawater had likely moved toward the coast in response to groundwater pumping. Subsequent to those findings, saltwater began to appear in wells in the southern quarter of the Basin as well as at the Soquel Point area to the northwest. Coastal groundwater monitoring data in both the Purisima and Aromas Red Sands formations indicate that the seawater wedge has moved further onshore since the 1980s. In response to this and other information, and prior to the passage of the Sustainable Groundwater Management Act in 2014, the agencies that rely upon groundwater from the Basin identified management strategies to prevent further seawater intrusion.

Seawater intrusion management strategies include:

1. Research to understand the regional hydrogeology and groundwater budget, including the development of an Hydrogeologic Conceptual Model;
2. Develop water conservation programs to reduce water demand;
3. Implement tiered water pricing structures to incentivize water conservation;
4. Manage groundwater pumping to more accurately align groundwater extraction rates with groundwater recharge rates;

5. Relocate municipal groundwater pumping inland where extraction is less likely to draw seawater on shore;
6. Establish “protective groundwater elevations” to develop a freshwater “dam” to act as a barrier to prevent drawing seawater further on shore; and
7. Evaluate the effectiveness of the management strategies, conduct coastal groundwater quality and elevation monitoring.

In 2014 SqCWD declared a groundwater emergency and continues to implement provisions of a Stage 3 water shortage emergency and its Water Demand Offset Program requires that new development fund a net reduction in total water use as a pre-condition to receive water service.

As a result of better management and increased water conservation leading up to and during Water Year 2016, municipal pumping in the Basin was the lowest recorded since 1977 and average groundwater levels met established protective elevations at eight of the 13 coastal monitoring wells, the most since the monitoring well system was installed. The decrease in water demand corresponded with increased public awareness about the importance of sustained water conservation in response to the 2011-2015 California drought, curtailment programs instituted by local water agencies, and drought related actions by the state of California. Since the state declared an end to the drought, municipal water demand in the Basin has increased since Water Year 2016 with municipal pumping in Water Year 2018 totaling an estimated 4,360 acre-feet per year, an increase of 9% compared to Water Year 2017 and an increase of 11% compared to Water Year 2016.

The Basin remains vulnerable to seawater intrusion until coastal groundwater levels rise to protective elevations at all coastal monitoring wells. Currently, five coastal monitoring wells have average groundwater levels below their established protective elevations. Full basin recovery has not been achieved, and the Basin is still considered in long-term overdraft due to ongoing seawater intrusion.

In 2017, MGA commissioned an aerial geophysical survey to determine the status of seawater intrusion in the upper aquifers near shore off the coast of the Basin. The survey is documented in Hydrogeological Investigation Salt-Fresh Water Interface – Monterey (Ramboll 2018)) and in a technical memorandum titled Management Implications of SkyTEM Seawater Intrusion Results ((Hydrometrics WRI 2018)). The survey confirmed the existing locations of known seawater intrusion and provided information on the current location of the advance of seawater in regional aquifers below the sea floor. The MGA intends to repeat this survey over time to track the movement of the freshwater-saltwater interface to inform the MGA’s assessment of seawater intrusion.

2.1.4.2 Wellhead Protection Areas

MGA member agencies act to maintain groundwater quality through land use policies and restrictions to protect well production sites, this includes:

- Working with land use agencies to regulate potentially hazardous land uses that could impact productive aquifers; and
- Following well construction and abandonment procedures outlined by the state and overseen by the county to limit the migration of contaminates into groundwater.

The 1996 federal Safe Drinking Water Act amendments require each state to develop and implement a Source Water Assessment Program. In response, California developed the Drinking Water Source Assessment and Protection (DWSAP) Program which includes a source water assessment program and a wellhead protection program. The DWSAP Program addresses both groundwater and surface water sources. The groundwater portion of the DWSAP Program serves as the wellhead protection program. In developing the surface water components of the DWSAP Program, the state integrated the existing requirements for watershed sanitary surveys. MGA member agencies maintain and update their DWSAP reports for each of their production well sites.

MGA member wellhead protection projects include:

- MGA member agencies implement the Santa Cruz County well abandonment requirements (see Section 0 below);
- Santa Cruz County, with funding support in part from a Proposition 50 IRWM grant, implemented a well destruction program in 2012 that destroyed four abandoned wells in the Basin;
- MGA member agencies submitted DWSAPs:
    - Soquel Creek Water District has submitted DWSAP for all its production wells. Access to all SqCWD DWSAP reports (SqCWD, 2019) is at: https://www.soquelcreekwater.org/documents/reports (use Report type "Water Quality", keyword "DWSAP" in search fields).
    - Central Water District submitted DWSAP reports for all its wells in 2009 (Johnson, 2009);
    - City of Santa Cruz has submitted DWSAP reports for all their production wells with the most recent being the Beltz 12 DWSAP in 2015.

2.1.4.3 Migration of Contaminated Groundwater

The County of Santa Cruz Environmental Health Division (EH) administers programs to benefit groundwater and control the migration of contaminants:

Land Use - Sewage Disposal - Waste Water Management
In this role, EH provides guidance and regulatory oversite of onsite sewage disposal for new and existing development outside sewered areas. EH oversees design review of new onsite wastewater treatment and greywater systems as well as repairs and modifications to existing on-site wastewater treatment systems. This work includes the certification of wastewater system operators and siting systems to ensure waste water systems protect against degradation of groundwater wells and drinking water quality.

Hazardous Materials Programs - Certified Unified Program Agency (CUPA)
In 1996 the California Environmental Protection Agency designated EH as the "Certified Unified Program Agency" (CUPA) within the geographic boundaries of the County, including all four Cities. As the CUPA, EH is responsible for enforcing State statutes, regulations, and local ordinances (Chapter 7.100) for the storage, use, and disposal of hazardous materials and hazardous wastes. EH oversees preparation and management of site specific Hazardous Materials Management Plans (Business Plans), Hazardous Waste Generator and Tiered Permitting, Underground Storage Tanks (UST), California Accidental Release Prevention (Cal ARP), and Aboveground Petroleum Storage Tanks.

Site Mitigation
EH oversees the cleanup of property contaminated with toxic chemicals through illegal dumping or disposal, from leaking underground storage tanks, or through accidental release during residential, industrial, or commercial activities. The site mitigation program protects public health and the environment through oversight of cleanup projects to verify that contaminated sites are adequately characterized, remediated, and closed under current cleanup standards.

Water Resources
EH provides collaborative support to other County departments, local agencies, city departments, special districts, and non-governmental organizations to solve water resources and environmental issues through long-range water supply planning, water quality protection, and watershed management. This work is important because Santa Cruz County waters are locally derived through rainfall and provide drinking water for residents and visitors, critical habitat to numerous threatened and endangered species, and opportunities for recreational and commercial activities. The County faces many water resource challenges including impaired water quality, inadequate water supply, overdrafted groundwater basins, depleted streams, and degraded riparian habitat.

2.1.4.4 Well Abandonment and Well Destruction Program

The County of Santa Cruz issues well destruction permits for wells being abandoned within the Basin. The purpose of the County's well abandonment and well destruction policies is to prevent inactive or abandoned wells from acting as vertical pathways for the movement of contaminants into groundwater. Well destruction requirements are found in the County Code, Chapter 7.70.100. A link to Santa Cruz County Code's water well requirements, including well abandonment and destruction is found here: http://www.codepublishing.com/CA/SantaCruzCounty/html/SantaCruzCounty07/SantaCruzCounty0770.html

2.1.4.5 Groundwater Recharge and Replenishment of Groundwater Extractions

The 1980 County General Plan included designation of primary groundwater recharge areas and included policies for the preservation of recharge quantity and quality. Those provisions have been maintained in subsequent general plan and code updates and have recently been strengthened through the adoption of stormwater management policies that require maintenance of pre-project infiltration rates for new development and redevelopment projects.

The Resource Conservation District of Santa Cruz County and the University of California, Santa Cruz - Hydrogeology Group recently completed a joint project funded by the California Coastal Conservancy, entitled "Regional Managed Aquifer Recharge and Runoff Analysis in Santa Cruz County, California" (Fisher et al., 2017). The project studied the possibility for effective groundwater replenishment throughout Santa Cruz County, including within the Basin. It identified surface soils throughout the county where groundwater recharge was most probable as well as compiling a series of subsurface conditions that can impact recharge suitability. A program outline is available at: http://rcdsantacruz.org/managed-aquifer-recharge

Groundwater replenishment projects within the Basin fall in to three general categories:

- In-Lieu Recharge – The practice of using available excess water such as winter surface water, treated to drinking water standards, to supply existing water customers who typically rely on groundwater. This practice passively increasing groundwater stored in the Basin by resting groundwater production wells that would otherwise serve those customers. The City of Santa Cruz and Soquel Creek Water District began piloting an in-lieu recharge project in November 2018. Project planning included scientific water quality and infrastructure studies to determine water compatibility and a determination that adequate surface water was available to supply the pilot study.

- Aquifer Storage and Recovery (ASR) – The process of injecting water treated to state standards into the groundwater basin to actively recharge the Basin to provide storage for subsequent extraction. The City of Santa Cruz is actively pursuing drought storage solutions that include ASR project studies in both the Basin and the Santa Margarita Groundwater Basin to the north. Initial groundwater modeling results for the Basin indicate that a City ASR program can assist groundwater recharge in the Basin, but careful management is needed to balance groundwater withdrawals with ongoing groundwater sustainability requirements.

- Stormwater Recharge – The collection and treatment of stormwater runoff for the purpose of recharging the Basin. Stormwater treatment often relies on natural filter materials including bioswales and native soils to protect the groundwater from infiltration of contaminants present in stormwater. However, other filter materials and pretreatment can be used to address identified source contaminants present in stormwater. A best management practice for stormwater recharge is to allow at least a 10 foot zone of separation between the infiltration area and the seasonally high groundwater elevation, in order to allow for pollutant attenuation through the unsaturated zone.
    - Inside the Basin, the County of Santa Cruz is partnering with the Resource Conservation District of Santa Cruz County (RCD) and Soquel Creek Water District to further assess and develop groundwater recharge sites. The County has developed two stormwater recharge projects inside the Basin at Polo Grounds Park and Brommer Park.
    - Potential stormwater recharge sites identified in the Recharge and Runoff Study have been investigated further by using advanced geophysical techniques. Two of these sites are still in the selection process. Further studies and additional funding sources are needed to develop projects at these sites.

2.1.4.6 Conjunctive Use and Underground Storage

2.1.4.6.1 Conjunctive use

Conjunctive use refers to the coordinated management of surface water and groundwater resources to optimize availability of water supply and is discussed in more detail in Section 2.1.2.4 above. In California's Mediterranean climate, this approach often involves a greater reliance upon surface water sources during the wet winter months and greater reliance upon groundwater during dry periods.

In the Santa Cruz region, MGA member agencies and member agencies of the Santa Margarita Groundwater Agency are actively pursuing conjunctive use strategies. For example, a 2011 study examined diverting surface water from the San Lorenzo River during wet winter months to transfer to neighboring water supply agencies that normally rely entirely upon groundwater (Kennedy/Jenks 2011). The receiving groundwater agencies could then reduce their groundwater pumping during the winter months enabling in-lieu recharge of the aquifers. One objective of surface water transfers would be to use existing underground aquifer storage capacity to recharge regional groundwater basins. Another objective would be to create supplemental supply to augment surface water resources during droughts.

In 2015, the County of Santa Cruz Environmental Health Services developed the Final Report on Conjunctive Use and Water Transfers with Proposition 50 Integrated Regional Water

Management funds (Environmental Health Services 2015). The report outlines the opportunities and challenges of conjunctive use.

During years of normal rainfall, the City of Santa Cruz derives approximately 95% of its water supply from local surface water sources, while SqCWD and Central Water District currently rely solely on local groundwater for their water supplies. The MGA member agencies access to both surface water and groundwater presents opportunities for conjunctive use. Regional conjunctive use has numerous practical, water chemistry, legal, and regulatory hurdles to resolve before full scale conjunctive use can be implemented.

- Practical constraints – The primary practical constraints for sharing surface water between water agencies are water availability and adequate infrastructure to treat and move water within and between neighboring water agency boundaries.
    - Currently, the conjunctive use programs proposed in Santa Cruz County rely on surface water that is fed by local precipitation. The reliance on precipitation in California, with its dramatic swings in annual rainfall, means that water available for transfer is unpredictable from year to year. The City of Santa Cruz has an obligation to provide drinking water to its customers and plans conservatively to ensure this obligation can be met in dry years and during droughts. Thus water available for transfer is constrained by both climate conditions and City's duty to provide a reliable supply of water to its customers.
    - Water demand that can be augmented by in-lieu recharge is more limited during winter months, when supplemental surface water resources are most available, than it is during the dry season. This reduced demand places an upper limit on the amount of surface water that can be taken by the groundwater agencies and thus limits the amount and Basin benefits of potential in-lieu recharge.
    - The City of Santa Cruz, Soquel Creek and Central Water Districts have each made infrastructure improvements in the form of "interties" to enable water transfers between neighboring agencies. These interties have functioned well for water sharing between agencies in emergency situations. While it is feasible to achieve some significant benefits of water sharing using existing infrastructure, full scale water transfers to completely replace winter water in Soquel Creek and Central Water Districts would require additional infrastructure improvements.
    - The City of Santa Cruz has scheduled significant infrastructure to improve the capabilities of its Graham Hill Water Treatment Plant. The City's goals are to increase capability to allow it to treat more turbid (sediment laden) winter water flows. These improvements will increase the availability of excess surface water for transfer and storage in local aquifers. The current treatment facility was built in the 1960s, was last updated in the 1980s, and does not have adequate treatment technology to utilize winter sediment laden waters. For these reasons winter storm flows that are

highly turbid cannot currently be treated at the Graham Hill Treatment Plant so are not available for transfer or storage in the Basin.

- Water chemistry issues – Surface water and groundwater differ in their chemical composition. The water system infrastructure, such as distribution pipelines and water service lines and plumbing on customer properties, can respond to the change in water chemistry with source water changes and may, under certain conditions, adversely impact water quality. The City of Santa Cruz and Soquel Creek Water District conducted multi-year studies to evaluate the potential for water quality degradation associated with the transfer of surface water from the City's system into the District's system which historically has only used groundwater. An additional concern is the difference between surface and groundwater resources related to the formation of disinfection by-products. Disinfection by-products are formed by the chemical interaction of naturally occurring total organic carbon found in many surface water resources and chlorine or ozone based disinfectants. Groundwater resources typically have lower levels of total organic carbon in them and thus disinfectant byproduct levels of these sources will generally be lower than the levels of these chemicals in surface water resources. Disinfectant byproducts are regulated by both federal and state drinking water maximum contaminant level requirements. Even though City water used in in-lieu water transfers complies with all federal and state requirements it contains higher levels of disinfectant byproducts than found in Soquel Creek Water District's groundwater based system. The State Division of Drinking Water is requiring Soquel Creek Water District to monitor distribution system water quality before, during, and after pilot deliveries of surface water to its system to track any changes in water quality that may result from intermittent use of surface water resources if water transfers are implemented as part of a long term Groundwater Sustainability Plan.

- Legal constraints – The City of Santa Cruz water rights have places of use restrictions that limit the areas where water from the San Lorenzo River resources can be utilized. The San Lorenzo River is the City's main source of supply, providing approximately 47% of the total supply annually. The City is currently using excess water from its unrestricted, pre-1914 water rights north coast streams, to support the water transfer pilot study with Soquel Creek Water District. The City has also applied to the California State Water Resources Control Board to expand its places of use for all its San Lorenzo River water rights to include neighboring water agency jurisdictions. If the place of use restrictions are modified, the amount of surface water available for transfer to both the Basin and the Santa Margarita Basin will be less constrained.

- Regulatory constraints – Transfer of surface water also includes regulatory program compliance for the City and Soquel Creek Water District. The City must address fish flow requirements to preserve special-status species protected under state and federal Endangered Species Acts before it can determine the amount of water available for transfer. The City is in the process of preparing a Habitat Conservation Plan for its water diversions and has worked with federal and state fish and wildlife regulatory agencies to establish new bypass requirements to support all stages of the salmonid life cycle. The new fish flow requirements for migration, spawning, and rearing have significantly reduced the amount of water available for water supply and transfer.

2.1.4.6.2 Underground Storage

As discussed in Section 2.1.4.5: Groundwater Recharge and Replenishment of Groundwater Extractions above, MGA member agencies, City of Santa Cruz and Soquel Creek Water District, are pursuing conjunctive use underground storage projects. Both in-lieu and ASR projects use excess surface water treated to drinking water standards as their water source. The County of Santa Cruz and Soquel Creek Water District are also pursuing underground storage projects using storm water and advanced purified wastewater respectively as water sources. The County and Soquel Creek Water District are partnering in the Basin on storm water recharge projects and Soquel Creek Water District's Pure Water Soquel project would use advanced purified wastewater as its water source. All of these projects would store water underground as either a seawater intrusion barrier, as a future water supply source, or both.

2.1.4.7 Well Construction Policies

As discussed above in Section 2.1.3.4, Santa Cruz County permits water wells within the unincorporated areas of the Basin and within the City of Capitola. The Santa Cruz City Water Department permits wells within the Santa Cruz City limits. Well construction standards are found in the County Code, Chapter 7.70. The purpose of the County's well construction standards is to record and manage the location, construction, repair, and reconstruction of all wells to prevent groundwater contamination. County standards also ensure that water obtained from groundwater wells is suitable for the purpose for which it is used and will not jeopardize the health, safety, or welfare of the people of Santa Cruz County. The County implements the State Bulletin 74 Well standards by reference in the County Code. The County Code also prohibits new wells within the service area for the Soquel Creek Water District unless the well serves an agricultural use or is a replacement well.

2.1.4.8 Groundwater Contamination Cleanup, Recharge, Diversions to Storage, Conservation, Water Recycling, Conveyance and Extraction Projects

2.1.4.8.1 Groundwater Contamination Cleanup

As discussed above in Section 2.1.4.3, Santa Cruz County Environmental Health Services is the Certified Unified Program Agency (CUPA) for the entire County. As CUPA, the County is responsible to enforce laws regulating the storage, use, and disposal of hazardous materials and hazardous wastes. The County also oversees all hazardous materials cleanups. Where hazardous materials have contaminated groundwater, the clean-up is also overseen by the Central Coast Regional Water Quality Control Board or the State Department of Toxic Substances Control.

The State Water Resources Control Board's Geotracker database is an online data management system for sites that impact, or have the potential to impact water quality in

California, with an emphasis on groundwater. Geotracker can be used to identify contamination sites under regulatory action. It is available at: https://geotracker.waterboards.ca.gov/

2.1.4.8.2 Groundwater Recharge

MGA member agencies have developed two storm water recharge projects within the Basin and are in the process of piloting ASR and In-Lieu recharge projects and Soquel Creek Water District is in the process of permitting its Pure Water Soquel projects as discussed in Sections 2.1.4.5 and 2.1.4.6 above. MGA member agencies are in the process of evaluating additional storm water recharge projects that could improve groundwater recharge and storage within the Basin and neighboring groundwater basins. County development and storm water management policies protect recharge areas and infiltration capacities as discussed in Section 2.1.4.5.

2.1.4.8.3 Diversions to Storage

There are presently no significant diversions to storage within the Basin. Outside the Basin the City of Santa Cruz created the Loch Lomond reservoir in 1960 by impounding Newell Creek with construction of the Newell Creek Dam. The reservoir is supplied by runoff from the Newell Creek watershed as well as by flows diverted from San Lorenzo River which is pumped from the Felton Diversion Dam to Loch Lomond. It is the City's only reservoir and is an integral part of the water system as it provides water supply for peak season demands and as a drought reserve.

Both the City of Santa Cruz and Soquel Creek Water District are evaluating and/or permitting water supply augmentation alternatives that would put more local water into storage in the Basin for future use and to prevent further seawater intrusion. The primary focus of these water augmentation alternatives is to recharge groundwater supplies in the Basin and neighboring basins. These water augmentation alternatives include in-lieu recharge through the treatment and use of excess surface water, aquifer storage and recovery (ASR), stormwater recharge, and the injection of advanced purified wastewater into the Basin.

2.1.4.9 Efficient Water Management Practices

MGA's member agencies have a full range of water conservation programs in place and have actively and successfully implemented policies and programs promoting and incentivizing water conservation and efficient water use. The City's and SqCWD's residential water usage are among the lowest in the state.

The City's and SqCWD's Urban Water Management Plans provide more detail on the various programs and policies of the specific agencies. The range of strategies in place to promote efficient water use includes:

- Water Waste Prevention Ordinances,
- Metering (widespread use of Automated Meter Reading (AMR) technology),
- Tiered Rate Structures to Promote Efficient Use,

- Programs to Assess and Manage Distribution System Losses,

- Water Conservation Programs with dedicated staff to conduct:
    - Public Awareness and Education
    - Water Demand Monitoring
    - Long-Term Water Conservation Programs:
    - Water Shortage Contingency Planning

- Residential and Commercial Demand Management Measures, including: Home Water Survey Program; High Efficiency Clothes Washer Rebate Program; Toilet Rebate Program, Laundry to Landscape Rebate Programs; Rain Barrel Program; and, Plumbing Fixture Retrofit Ordinance.

- Demand Management Measures for Commercial Customers, including: Smart Business Rebate Program (for installing water efficient fixtures including toilets, urinals and clothes washers) and the Monterey Bay Green Business Program.

- Demand Management Measures for Water Efficient Landscapes

All MGA member agencies participate in the Water Conservation Coalition of Santa Cruz County. The Water Conservation Coalition of Santa Cruz County has created a regional source for county-wide water reduction measures, rebates, and resources at: https://watersavingtips.org/

The County and the Resource Conservation District of Santa Cruz (RCD) provide outreach to rural landowners on recommendations for greater water use efficiency and methods to promote more groundwater recharge on their properties. The County requires implementation of water use efficiency measures for new wells serving agricultural uses and other non-de minimis uses. The RCD also provides outreach and technical services specifically for agricultural users.

Additional conservation program information is described at the water agency's individual websites:

- Central Water District: https://sites.google.com/view/centralwaterdistrict/conservation

- City of Santa Cruz Water Department: http://www.cityofsantacruz.com/government/city-departments/water/conservation

- County of Santa Cruz: http://scceh.com/Home/Programs/WaterResources/WaterConservationProgram.aspx

- Soquel Creek Water District: http://www.soquelcreekwater.org/conserving-water

2.1.4.10 Relationships with State and Federal Regulatory Agencies

Section 2.1.2 includes a description of monitoring and management programs that involve coordination with state and federal agencies. The MGA coordinated with representatives from the DWR throughout the GSP development. The following state and federal agencies were consulted during the preparation of this GSP [provisional list]:

- California Department of Fish and Wildlife
- California Department of Water Resources
- Central Coast Regional Water Quality Control Board
- National Marine Fisheries Service (NMFS, formerly NOAA Fisheries)
- State Water Resources Control Board
- US Fish and Wildlife Service

As discussed in Sections 2.1.4.12 and 2.1.5.2.2 below, the MGA, through its GSP Advisory Committee, established a Surface Water Working Group sub-committee that included five committee members, local issue area experts, non-governmental organizations with extensive resource management and protection experience, and state and federal resource and regulatory agencies. The purpose of this sub-committee was to gather issue area experts together to discuss the resources, agency mandates, and best available science to develop groundwater driven sustainability recommendations for the entire GSP Advisory Committee to consider when developing its recommendations for surface water depletion related to groundwater pumping.

In addition to working with various resource management agencies during the development of the GSP, MGA member agencies including the County of Santa Cruz, the City of Santa Cruz, and the Soquel Creek Water District have all established long-term working relationships with the resource management agencies identified above. Ongoing coordination and collaboration with these agencies focus on planning for and managing utility and resource protection programs and projects, utility operations, and development and construction of capital improvement projects.

2.1.4.11 Land Use Plans and Efforts to Coordinate with Land Use Planning Agencies to Assess Activities that Potentially Create Risks to Groundwater Quality or Quantity

MGA planners reviewed existing planning documents and consulted with land use planners from agencies with jurisdictional responsibilities for land use decisions within the Basin. The land use agencies within Basin are Santa Cruz County, California State Parks, City of Santa Cruz, and the City of Capitola.

Elected officials from the County of Santa Cruz and the City of Santa Cruz are on the MGA Board of Directors. These elected County and City representatives, whose responsibilities include oversight of land use policy decisions for their jurisdictions, are participants in groundwater sustainability policy making within the Basin.

During development of this GSP, the MGA conferred with governmental and non-governmental entities with regional land use interests and expertise in the Basin. This collaborative effort to address regional land use interests is intended to create a continuing dialog to heighten regional awareness of groundwater sustainability management as it relates to land use decisions.

Partners consulted include:

- City of Capitola
- City of Scotts Valley
- Pajaro Valley Water Management Agency (PV Water)
- Santa Margarita Groundwater Agency (SMGWA)
- Resource Conservation District of Santa Cruz County (RCD)
- National Marine Fisheries Service (NMFS, formerly NOAA Fisheries)
- The Nature Conservancy
- Environmental Defense Fund
- California Department of Fish and Wildlife
- State Water Resources Control Board
- Central Coast Regional Water Quality Control Board
- US Fish and Wildlife Service
- Friends of Soquel Creek
- Regional Water Management Foundation
- Managers and operators of small public water systems

Planning documents reviewed during the preparation of this GSP include:

- Santa Cruz County General Plan
- Santa Cruz County Housing Element
- Santa Cruz County Town/Community Plans for:
    - Aptos Village
    - Pleasure Point
    - Seacliff Village
    - Soquel Village
- Sustainable Santa Cruz County Plan
- City of Capitola General Plan
- City of Santa Cruz General Plan and General Plan EIR
- City of Santa Cruz Housing Element
- City of Santa Cruz 2015 Urban Water Management Plan
- Soquel Creek Water District 2015 Urban Water Management Plan
- Scotts Valley General Plan
- Scotts Valley 2015 Urban Water Management Plan
- Soquel Aptos Area Groundwater Management Plan
- Santa Cruz Integrated Regional Water Management Plan

2.1.4.12 Impacts on Groundwater Dependent Ecosystems

The County of Santa Cruz assessed and identified Groundwater Dependent Ecosystems (GDE) where interconnected surface and groundwater exist within the Basin. As a first step to identify GDEs, where data were available MGA compared surface water and groundwater elevations to determine interconnections between surface water and groundwater. Where groundwater level data were unavailable, the surface water-groundwater model developed for the Basin is used to identify where surface water and groundwater are connected (Figure 2-10). County staff utilized available information from the California Natural Diversity Database (CDFW, 2019) and The Nature Conservancy (2019) to identify important species present in areas where groundwater and surface water are interconnected. The only areas within the Basin where surface water and groundwater connections were identified were in riparian zones. No interconnected lakes or ponds were identified and no areas of shallow groundwater away from streams were noted within the Basin.

Technical staff presented and discussed the information with the Surface Water Working Group comprised of GSP Advisory Committee participants, resource agencies, local planning agencies, and environmental partners to confirm the habitats, plants, and animals dependent on groundwater within and adjacent to Basin boundaries. The groundwater dependent species identified for priority management are found in Table 2-1.

Table 2-1. Groundwater Dependent Species Identified for Priority Management

Species Common Name	Priority for GDE management	Needs Covered by Prioritized Species
Steelhead	X	
Coho Salmon	X	
California Giant Salamander		X
Foothill Yellow-Legged Frog		X
Western Pond Turtle		X
Riparian forest including willow and sycamore	X	

The GSP Advisory Committee and the Surface Water Working Group found that:

- Maintaining groundwater contribution to support adequate stream flow for salmonids during the late summer and fall will support the needs of other identified critical species in Table 2-1,
- Fish habitat and streamflow are greatly influenced by many factors other than groundwater contribution. Maintaining groundwater levels to minimize depletion of flow during the dry season will help critical species, but will not resolve other stream flow impacts created by lack of precipitation, evapotranspiration, and surface water withdrawals during the dry season,

- Groundwater management criteria for GDE linked to priority species' basic aquatic needs is a reasonable proxy for monitoring management success in coordination with existing direct species monitoring, and
- Groundwater level monitoring for GDEs will focus on:
  - Areas of highest groundwater extraction, and
  - Where streams are interconnected with groundwater.

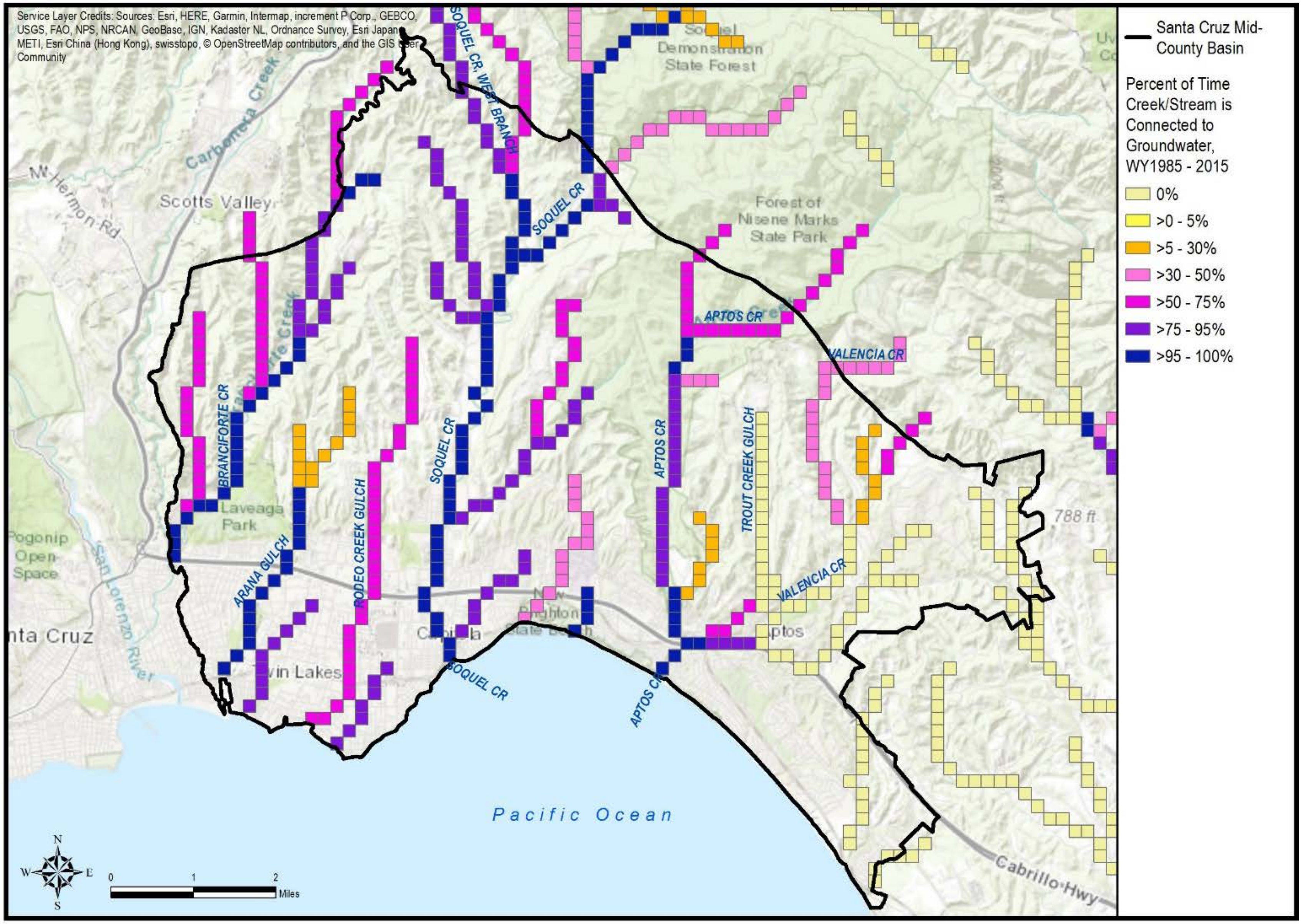


Figure 2-10. Percentage of Time Surface Water and Groundwater are Connected (Water Years 1985-2015)

2.1.5 Notice and Communication

SGMA requires the MGA develop an open public process to consider the interests of beneficial uses and users of basin groundwater and the land uses and property interests required to achieve groundwater sustainability. MGA has developed a variety of open meeting formats and uses many forms of public outreach to inform and engage the Basin public about the importance of groundwater sustainability.

MGA outreach efforts focus on educating the public about groundwater, the Basin, and SGMA sustainability requirements. The Basin community must know the challenges to our water supply security, the need to address these challenges to protect our water supply, and agree to implement regional solutions to protect fresh water supplies for current and future human and environmental uses to achieve sustainability.

MGA general outreach methods include: postcard mailers, news articles, informational handouts, stakeholder presentations, email newsletters, website content, signs posted on major driving corridors, community outreach events, and other opportunities to discuss groundwater resource management in public settings.

MGA also acknowledges that the public participation requirements of SGMA demand a high level of well-informed community input to represent the beneficial uses and users of groundwater within the Basin. For this reason the MGA created in-depth technical orientation materials, presented in person and recorded for later viewing, to educate groundwater users and other stakeholders to allow them to make highly informed comments on the Plan's contents.

MGA's detailed materials are specifically directed at the engaged members of the public who want to dive deeper into the subject matter. These materials include GSP Advisory Committee orientation session and meeting materials, groundwater management information and enrichment sessions, MGA Board meetings materials, and the basin-wide agency and project information provided during our publicly noticed GSP Advisory Committee field trip. Most of these detailed meeting materials (and their recorded presentations) are openly available on the MGA website.

2.1.5.1 Description of Beneficial Uses and Beneficial Users of the Basin

The MGA Board established a GSP Working Group to provide advice on how to achieve optimum SGMA compliance during the GSP planning process. The GSP Working Group was a limited duration temporary committee of the MGA Board made up of Board members and supported by MGA staff.

The charge of the GSP Working Group was to examine SGMA requirements and make compliance recommendations to the MGA Board. Based on the GSP Working Group's advice, the MGA Board recommended creation of a GSP Advisory Committee to represent the interests of Basin water users and uses. The GSP Advisory Committee would then accomplish the detailed public policy analysis required by SGMA to make detailed GSP sustainable management criteria recommendations to the MGA Board.

In Water Code Section 10723.2, SGMA requires the MGA consider the interests of all beneficial uses and users of groundwater within the Basin. These interests include, but are not limited to, the following:

- Holders of overlying groundwater rights, including:
  - Agricultural users
  - Domestic well owners
- Municipal well operators
- Public water systems
- Local land use planning agencies
- Environmental users of groundwater
- Surface water users, if there is a hydraulic connection between surface and groundwater bodies
- The federal government, if there is a hydraulic connection between surface water and groundwater bodies
- California Native American tribes
- Disadvantaged communities, including but not limited to, those served by non-municipal domestic wells or small community water systems
- Protected Lands, including recreational areas
- Public Trust Uses, including wildlife, aquatic habitat, fisheries, recreation, and navigation
- Entities listed in Section 10927 that are monitoring and reporting groundwater elevations in all or a part of a groundwater basin

2.1.5.1.1 Interest Groups Representation

The GSP Working Group considered each of the interest groups named by SGMA to determine if they were present within the Basin and considered their current representation on the MGA Board.

Agricultural users: There is limited farming within the Basin that only uses approximately four percent of total Basin groundwater extracted. The majority of agriculture is by a few large operators. The agricultural sector is primarily served by private wells that support vineyards, vegetables, orchards, and berries. One of the private well owner representatives on the MGA Board includes a private agricultural well owner, and the GSP Advisory Committee includes an agricultural representative to ensure that the agricultural community is represented and informed about groundwater sustainability planning within the Basin.

Non-Municipal Domestic Well Users: Private residential well owners are estimated to pump approximately 10% of the water used from the Basin. To ensure private well owners are represented, the MGA Board includes three private well owner representatives, and one of those representatives also serves on the GSP Advisory Committee. Private well owner water use extends primarily to residential, landscape, and some small-scale farming and livestock usage up to one half acre of land. Up to four service connections can be on one well for that well to be considered domestic. These wells are also considered de minimis users.

Small Water Systems: There are two categories for small water systems which are regulated by the County: State Smalls have between 5-14 service connections, and Small Public Water Systems are between 15-199 connections or serve at least 25 people for at least 60 days a year. These systems serve both individual domestic properties, commercial uses such as camps, and institutional uses such as schools. In total, small water systems use approximately 2% of the water pumped every year from the Basin. Figure 2-11 shows the location of small water systems within the Basin.

Small public water systems in the Basin are represented by the County of Santa Cruz and private well owner representatives on the MGA Board. MGA staff is in regular communication with this group. The president of Trout Gulch Mutual, the largest small public water system in the Basin, is a private well owner alternate to the MGA Board. The County offers quarterly forums to small water system operators to promote compliance with state water quality and other applicable regulations. SGMA has been a recurring topic at these quarterly forums. MGA staff has presented information to public water system operators and all receive the MGA email newsletter.

Large Public and Municipal Well Operators: As discussed more specifically in Section 2.1.1.3.5, there are three large Public Water Systems, each serving over 800 connections in the Basin, the City of Santa Cruz Water Department (a municipal well operator), Central Water District, and Soquel Creek Water District (Figure 2-11). Together, these three systems supply approximately 90% of the water users within the Basin, however, most of the water supplied to City of Santa Cruz water customers is surface water derived from outside of the Basin. In total, these systems extract approximately 75% of all groundwater pumped from the Basin. The MGA Board includes two elected representatives from each of these systems. Together these large water systems provide water for residential, commercial, industrial, institutional, and landscape uses.

Local Land Use Agencies: Three land use agencies are located within the Basin. These are Santa Cruz County, the City of Santa Cruz, and the City of Capitola. Two of the three agencies are represented on the MGA Board and planners with the City of Capitola were invited to participate in the GSP Advisory Committee. The City of Capitola declined a seat on the Committee and instead will participate as GSP document reviewer.

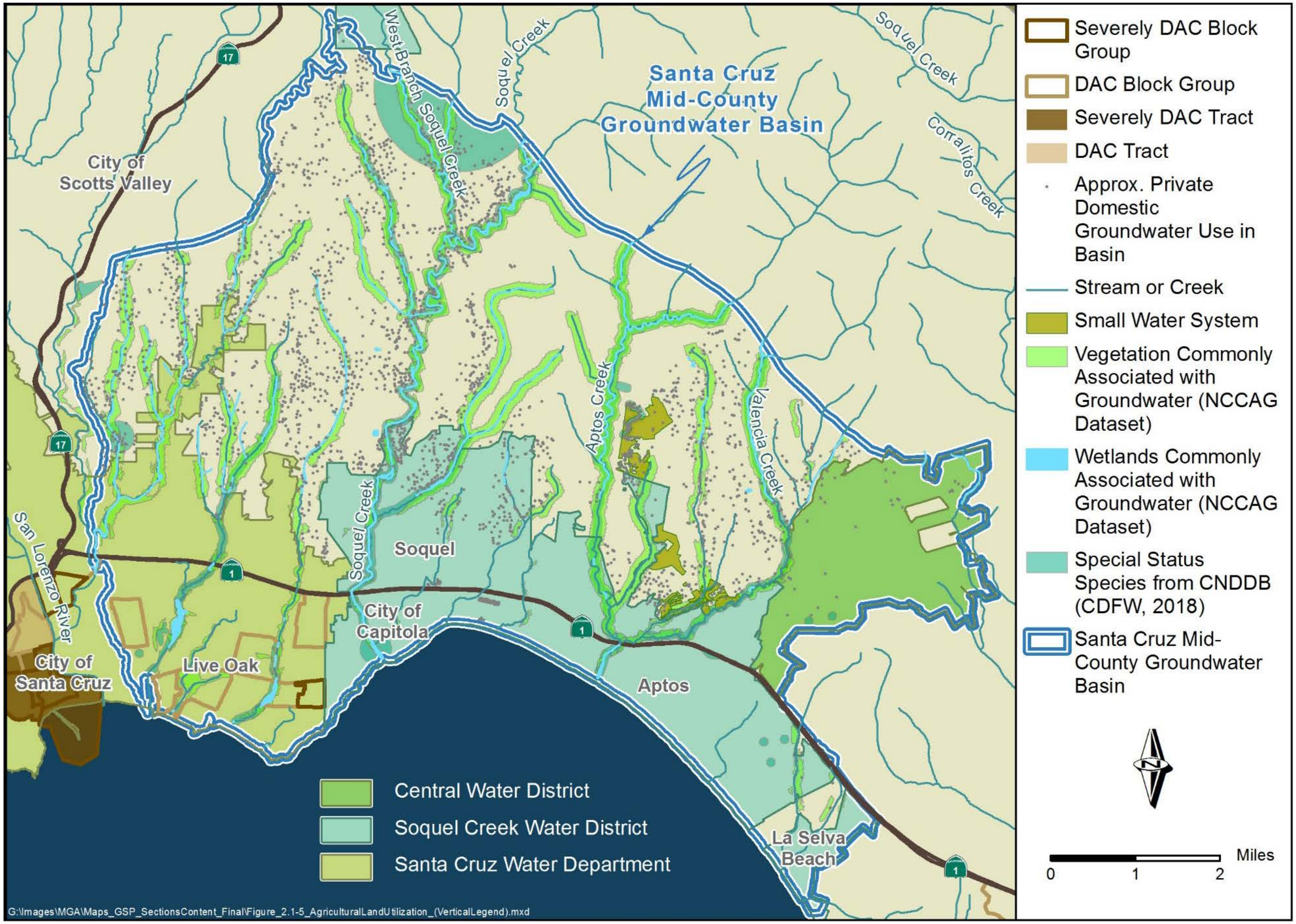


Figure 2-11. Locations of Beneficial Users in the Santa Cruz Mid-County Basin

Environmental Users of Groundwater: The Basin includes creeks, streams, ponds and marshes, some of which are partially supplied by groundwater during the dry seasons when surface water from rain is not available. Some of the plants and animals found in Basin habitats supported by groundwater are unique to the region and are state and federally listed as sensitive species. Many government agencies, individuals, and private groups are interested in environmental restoration of habitats and species within the Basin. These groups collaborated in the Surface Water Working Group, a subcommittee of the GSP Advisory Committee, to develop recommendations on groundwater dependent ecosystems and sustainability criteria to avoid surface water depletion from groundwater extractions.

Surface Water Users with a Connection to Groundwater: The Basin includes several streams that are connected to groundwater in some of their reaches.

- *Branciforte Creek*, is connected to groundwater, but surface and groundwater use is limited to individual private users along the creek. Many of these properties are served by the City of Santa Cruz Water Department.

- *Soquel Creek*, is connected to groundwater in much of its watershed within the Basin. Surface water rights on Soquel Creek are limited by a 1977 adjudication of surface water rights. The Resource Conservation District of Santa Cruz County (RCD) is studying the creek to better understand surface water use and its impacts on stream flow. The RCD's study includes a technical advisory committee of local experts, some of whom are also involved with the MGA's work. A data gap that the MGA and RCD are working to fill is understanding how shallow wells drawing water from alluvial deposits near Soquel Creek may impact surface water flows. The MGA is planning additional monitoring to help refine the understanding of this relationship on sustainability.

- *Aptos Creek,* is connected to groundwater in some of its lower reaches. It runs through the Forest of Nisene Marks, a state park, and there are no significant surface water diversions and few groundwater wells to impact surface water flows in the upper reaches of Aptos Creek. There are at least two riparian users of surface water from Aptos Creek west of Soquel Drive where groundwater is connected to surface water.

- *Valencia Creek*, is not connected to groundwater currently and groundwater levels from the 1950's indicate that an historic connection to groundwater is unlikely.

Federal Government: there are no federal lands within the Basin (see Section 2.1.1.3.1). However, there are federally listed species dependent on groundwater in the Basin. Federal resource agencies including the National Oceanic and Atmospheric Administration National Marine Fisheries and US Fish and Wildlife Service participated in the MGA's Surface Water Working Group, a subcommittee of the GSP Advisory Committee. This group developed recommendations that were considered and incorporated into the Basin's groundwater dependent ecosystems and sustainability criteria to avoid surface water depletion that could impact federally listed species.

California Native American tribes: there are no tribal lands within the Basin (see Section 2.1.1.3.2). The Amah Mutsun Tribal Band were historically present in the region. County staff is in contact with representatives of the Amah Mutsun Tribal Band on Basin water issues.

Disadvantaged Communities (DAC) – Data from DWR's DAC mapping tool identifies seven DACs, including one severely disadvantaged community within the Basin; all seven DACs are located within the City of Santa Cruz water supply service area (Figure 2-11). The total DAC population in the Basin is approximately 8,375. The DAC designation is based upon median household income from the US Census American Community Survey 5-Year Data (2012 – 2016). Disadvantaged communities were identified with DWR's mapping tool using census tracts, blocks, and places. An assessment of the water related needs of DACs is occurring through a Proposition 1 IRWM Disadvantaged Community Involvement Grant. MGA staff are in coordination with IRWM program to coordinate efforts in these communities.

As stated above, all disadvantaged communities identified within the Basin are served with municipal water from either SCWD or SqCWD. As discussed in section 2.2.4.4, water delivered to municipal customers is regularly sampled and tested to ensure it meets or exceeds all state and federal drinking water standards. No DAC within the Basin receives water from small community drinking water systems or domestic wells.

Entities Monitoring and Reporting Groundwater Levels: MGA member agencies are the only entities that monitor and report groundwater levels within the Basin.

2.1.5.1.2 GSP Advisory Committee Composition

The GSP Working Group was established on November 17, 2016 as a temporary Board committee composed entirely of board members and supported by MGA staff. MGA Board members included: John Benich, Bruce Jaffe, and Jon Kennedy. The GSP Working Group was charged with examining the state's adopted GSP emergency regulations, developing a scope of work, strategy, and schedule for preparing the GSP.

Among other things, the GSP Working Group identified six categories of groundwater uses and users, land uses, and property interests within the Basin, in addition to those already represented on the MGA Board, that needed a sustained voice throughout the GSP planning process. These were:

- Agricultural Users
- Business Users
- Environmental Uses
- Institutional Users
- Small Water System Management
- Water Utility Rate Payers

The GSP Working Group recommended the creation of a GSP Advisory Committee to provide the sustained public input required by GSP regulations. MGA created a GSP Nominating Committee to advertise GSP Advisory Committee openings, accept and review applications, interview candidates, and recommend GSP Advisory Committee representatives to the MGA Board for each identified category. The MGA Board approved these and other recommendations on September 21, 2017. GSP Advisory Committee representatives included eight (8) members of the general public and five (5) MGA Board members*:

- Agricultural Representative (1)
- At Large Representatives (3) – 1 resigned during orientation and was replaced
- Business Representative (1) – 1 resigned after partial participation and was not replaced
- Central Water District Representative (1)*
- City of Santa Cruz Representative (1)*
- County of Santa Cruz Representative (1)*
- Environmental Representative (1)
- Institutional Representative (1) - 1 resigned during orientation and was replaced
- Private Well Representative (1)*
- Small Water System Management (1)
- Water Utility Rate Payer (1)
- Soquel Creek Water District (1)*

Over its 21 month commitment, three GSP Advisory Committee members resigned for various personal reasons. Two members resigned during orientation (one at-large representative and the institutional representative) and were replaced by engaged members of the public. The business representative resigned later in the planning process and was not replaced.

The eight general public GSP Advisory Committee members were: Agriculture - John Bargetto; At Large - Keith Gudger, Jonathan Lear, and Charlie Rous; Business - Douglas P. Ley (resigned 9/25/2018); Environmental - Kate Anderton; Institutional - Thomas Wyner for Cabrillo College; Small Water System Management - Richard Casale; Water Utility Rate Payer - Dana Katofsky McCarthy. The MGA Board approved all general public committee members and their replacements.

Private well owner representatives to the MGA Board and member agency governing bodies selected MGA representatives to serve on the GSP Advisory Committee. The MGA representatives were: Private Well Owner - Jon Kennedy; Central Water District - Marco Romanini; City of Santa Cruz - David Green Baskin; County of Santa Cruz - Allyson Violante, and Soquel Creek Water District - Bruce Jaffe.

2.1.5.2 Decision Making Process

2.1.5.2.1 MGA Board of Directors

The JPA that created the MGA requires the regional GSA to hold public meetings at least quarterly that are noticed and meet all of the requirements of the Ralph M. Brown Act for transparency in California government. To hold a valid meeting the MGA must have a quorum of the Board of Directors, which consists of an absolute majority of directors plus one director. With these requirements in mind, the MGA:

- Holds board meetings on a regular schedule (once every other month);
- Provides written notice of meetings with meeting agenda and meeting materials available at least 72-hours prior to the meeting time;
- Sends email meeting reminders to MGA's contact list that includes approximately 700 unique email addresses; and
- Posts meeting agenda at the meeting location prior to the meeting as required.

Under SGMA, the MGA Board of Directors is responsible to approve a GSP and submit it to DWR on or before January 31, 2020. Once a quorum is present, most MGA decisions require a simple majority of all appointed directors participating in the vote. If a director is disqualified from voting on a matter before the board because of a conflict of interest, that director shall be excluded from the calculation of the total number of directors that constitute a majority.

There are certain matters that come before the MGA Board of Directors that require a unanimous vote of all water agency member directors participating in the vote. These include approval of any of the following:

- Capital expenditures estimated to cost $100,000 or more;
- Annual budget;
- GSP for the Basin or any amendment thereto;
- Levying of assessments or fees;
- Issuance of indebtedness; or
- Stipulations to resolve litigation concerning groundwater rights within or groundwater management for the Basin.

MGA agendas include general public comments at the beginning of each board meeting. General comments allow community members to raise any groundwater related issue that is not on the agenda. Public comment time is also given prior to a vote on all agenda items to ensure public opinion can be incorporated into MGA Board of Director decisions. The public may also make submissions to the board for inclusion in the meeting packet.

The MGA accepts requests from the public for additional presentation time and is responsive to requests for items to be added to the agenda. Examples of public items added to the MGA agenda are: in depth presentations on water supply alternatives that focus on different water sources (river water transfers, recycled water, and excess storm water). In response to a public request, the MGA held a joint session of the Board of Directors and GSP Advisory Committee on water supply alternatives in July 2018 at which members of the public and MGA member agencies made presentations to the joint assembly.

The MGA Board directs agency staff to fulfill the various requirements of SGMA. To do this, MGA staff provides the board with research and recommendation memos, work plans, technical summaries, budgets, and other work products as required to support board decision making.

2.1.5.2.2 GSP Advisory Committee

As discussed above in Section 2.1.5.1.2, the GSP Advisory Committee was created to provide sustained GSP public policy input from beneficial groundwater users and uses and to represent land uses and property interests within the Basin. The GSP Advisory Committee was directed to work with staff and technical consultants to support development of the GSP.

The Committee's responsibilities included:

- Evaluate scientific information and recommendations from staff on the impacts to the Basin, and assess various management approaches to reach sustainability;
- Consider the effect of changing climate and sea level on groundwater conditions;
- Establish measurable objectives and minimum thresholds for state mandated sustainability indicators; and
- Promote public education about GSP decisions and Basin sustainability.

Committee members agreed to deliberate based on scientific data regarding current and projected Basin conditions. The Committee also agreed to work collaboratively in an open and public process to ensure community concerns were addressed within the GSP.

Between October 2017 and June 2019, the GSP Advisory Committee met 20 times, on average, once per month. Three of these meetings were joint meetings with the MGA Board. The GSP Advisory Committee also hosted and participated in four (4) Surface Water Working Group sub-committee meetings, one (1) optional field trip, and two (2) enrichment sessions (one each on understanding the model and Water Demand). All GSP Advisory Committee meetings, enrichment sessions, and the field trip were open to the public and included opportunities for public participation.

The Surface Water Working Group meetings represented a collaboration of GSP Advisory Committee members, MGA staff and technical consultants, resource agencies and non-governmental organizations deeply involved with local, regional, national, and international habitat protection.

As a temporary subcommittee of the GSP Advisory Committee, Surface Water Working Group meetings were not open to the public. Meeting materials were posted on the MGA website and meeting summaries were reported back to the full GSP Advisory Committee during its open meetings. The GSP Advisory Committee discussed and developed its recommendations regarding surface water sustainability in its open meeting format.

Subcommittee participants included:

- California Department of Fish and Wildlife
- California Department of Water Resources (DWR)
- City of Santa Cruz Water Department
- Environmental Defense Fund (EDF)
- Friends of Soquel Creek

- GSP Advisory Committee
- The Nature Conservancy (TNC)
- National Marine Fisheries Service (NMFS, formerly NOAA Fisheries)
- Pajaro Valley Water Management Agency (PV Water)
- Resource Conservation District SCC (RCD)
- Santa Cruz County
- Regional Water Management Foundation
- US Fish and Wildlife Service

On May 16, 2019 the MGA Board of Directors and GSP Advisory Committee held a joint meeting to discuss the committee's provisional recommendations for Basin sustainability goals and draft GSP Sustainable Management Criteria. The GSP Advisory Committee held its final meeting on June 19, 2019 where it deliberated and voted on revisions to its final GSP recommendations and the draft conveyance memorandum to submit its recommendations to the MGA Board of Directors.

On July 18, 2019 MGA staff presented the GSP Advisory Committee's final GSP recommendations to the MGA Board and staff presented the Draft GSP based on those recommendations. The MGA Board accepted the Committee's recommendations, the Draft GSP, and opened the public comment period on the Draft GSP. The public comment period on the Draft GSP was open from July 18, 2019 through September 19, 2019.

2.1.5.3 Public Engagement Opportunities

The MGA uses a variety of ways to actively encourage public participation, as outlined in its *Communication and Engagement Plan* (Appendix 2-A). MGA's Communication and Engagement Plan was approved by the MGA Board at its September 21, 2017 meeting and posted to the MGA website shortly thereafter. Table 2-2 provides a summary of public engagement opportunities.

<u>MGA Website:</u> provides SGMA and agency information. Includes a calendar with upcoming events, meeting information, meeting materials, and links to meeting agendas and packets. The website provides links to agency resource materials, maps, FAQs, newsletters, presentation materials, and meeting recordings.

<u>MGA Monthly E-Newsletter</u>: provides information on regional developments in groundwater sustainability, MGA updates, and announces upcoming groundwater events to approximately 650 people.

<u>MGA Road Signs:</u> reaches private well owners living in the Santa Cruz Mountains, the MGA uses four road signs to advertise its meetings and events.

<u>Bi-Monthly Board Meetings:</u> MGA business meetings where public can present information to the Board on agenda items and introduce items of concern for future deliberation.

Bi-Monthly Drop in Sessions: MGA open forum for public to meet informally with MGA Board members and staff to discuss groundwater policy and other topics.

GSP Orientation and Enrichment Sessions: Public learning sessions to present technical background [recorded and available on the MGA Website].

GSP Advisory Committee Meetings: MGA committee selected by the MGA Board to represents Basin water uses and users. Public meetings are held to provide detailed GSP policy input for staff and GSP recommendations [recorded and available on the MGA Website].

Stakeholder Meetings: Informational meetings to introduce the public to the SGMA sustainability process and to keep the public informed about the GSP planning process.

Public Outreach on the Draft GSP: MGA held a public comment period on the Draft GSP from July 18 through September 19, 2019. The public comment period included two open houses in July and a Q&A session in August. The purpose of each open house was to orient people to the information contained in the Draft GSP soon after it was available for review. The Q&A session was scheduled to answer public questions after the public had an opportunity to review the Draft GSP.

Postcard Mailers: Three rounds of postcards to approximately 1,600 private well owners to engage this group (2016 – 2018). Draft GSP notice of release on a large format informational postcard to every household and landowner within the Basin (June 2019).

Surveys: The first survey was targeted to Private Well Owners at the outset of GSP development to help understand the needs and concerns of this stakeholder group. Sixty-four people responded. A second survey was issued near the release of the draft GSP. This is to inform staff of the level of public knowledge about the Basin and inform the MGA's Draft GSP rollout and implementation outreach efforts.

Existing Outreach Venues: The MGA also used the member agencies existing outreach networks to provide regular updates about the GSP Development. This includes information via email newsletters, bill inserts, social media, and presentations to their decision-making bodies. The MGA presented groundwater information and GSP outreach to cities at their council meetings and participated in local and regional festivals to teach the general public about SGMA. Example events include: Connecting the Drops, Water Harvest Festival, Wharf to Wharf, Earth Day and others.

Table 2-2. Summary of Public Outreach and Engagment Opportunities

Topic	Detail
Public Meetings	• 12 private well owner/stakeholder meetings between May 2014 and June 2018 • 6 informational sessions between October 2017 and April 2019 • 2-hour community drop-in sessions every other month since 2016 • 20 GSP Advisory committee meetings between October 2017 and June 2019 • 2 GSP Workshops and 1 GSP Q&A Session planned between July 2019 and August 2019 • 37 MGA, SAGMC, BIG, GSA FC meetings between February 2014 and November 2019
Postcard Mailings and letters	• June 2019 – GSP Survey and Plan update to all Basin residents and owners • March 2018 – GSP update to private well owners and small water systems • June 2017 – GSP update meeting to private well owners and small water systems • January 2017 - GSP update meeting to Basin agricultural and commercial pumpers • December 2015 – GSP update meeting to private well owners
Survey	• June 2019 - GSP outreach mechanism and to inform future MGA outreach efforts • Nov 2017 to May 2018 - Private well owner outreach to inform GSP planning process
Email List-Serve	• Monthly E-newsletter to approximately 650 unique email addresses, including interested parties
Brochure	Targeted at rural users mailed to all private well owners and small water systems
Open House	3 GSP Open House events during Draft GSP public comment period
Road Signs	4 message boards placed at prominent thoroughfares before meetings and events
Public MGA Board Meetings	37 public Board meetings between February 2014 and November 2019 for MGA, and predecessor agencies
GSP Advisory Committee	Total of 20 monthly public meetings from October 2017 through June 2019
Surface Water-Groundwater Working Group	4 Surface Water Working Group meetings consisting of GSP Advisory Committee participants, resource agencies, local planning agencies, and environmental groups.
Tabling and Presentations	Connecting the Drops, Water Harvest Festival, presentations and conferences
Website	midcountygroundwater.org
Miscellaneous	Newspaper articles/editorials, social media through partner agencies, handouts, tour, tabling events

2.1.5.4 Encouraging Active Involvement

As discussed in Section 2.1.5.3, MGA gathers public input in many ways. GSP Advisory Committee meetings and MGA Board meetings provide multiple opportunities for public comment at each meeting. Notes from GSP Advisory Committee meetings are kept by facilitation consultants, reviewed by committee members, and submitted to the MGA Board. MGA meeting minutes are recorded by agency staff, reviewed, and approved by the MGA Board. All meeting minutes and notes are collected on the MGA website along with supporting agendas, packets, and presentation materials. The MGA Board of Directors is both interested in public opinion and regularly incorporates committee input and public suggestions into its deliberations and the decisions it makes during MGA Board meetings.

A partial list of examples when the MGA Board incorporated public input into its decision-making and recommendations include directing staff to:

- Record and post MGA Board of Director meetings;
- Obtain and use MGA road signs to advertise MGA events;
- Record and post GSP Advisory Committee meetings;
- Organize and hold a Basin field trip open to public participants;
- Consider MGA email policy to establish MGA email addresses to serve private well owner board representative and other non-agency GSP Advisory Committee members;
- Develop and publish MGA public participation guidelines;
- Hold regular drop-in meetings with staff and board members; and
- Hold a joint MGA Board of Director and GSP Advisory Committee meeting for the public to present water augmentation recommendations to the MGA Board.

2.1.5.5 Informing the Public on GSP Implementation Progress

The Draft GSP was presented to the public on the July 12, 2019 as part of the MGA Board of Director's July 18th meeting packet. The MGA held two public outreach meetings on July 20th and 22nd to introduce and summarize the Plan. An additional Q&A session was held on August 28, 2019. The Board of Directors accepted comments on the Draft GSP during the MGA public comment period from July 18-September 19, 2019. The MGA Board of Directors established a temporary GSP Comment Committee on September 19, 2019 to provide MGA staff with oversight and direction when responding to Draft GSP comments.

The MGA Board of Directors will adopt the Plan and submit it to DWR prior to the GSP deadline for critically overdrafted basins on January 31, 2020. The MGA will implemented the GSP through ongoing Basin monitoring and management. While the GSP Advisory Committee sunset at its final meeting on June 19, 2019, the MGA Board will continue to meet to guide the GSP implementation process. The MGA will continue to follow the adopted MGA Communication and Engagement Plan to guide future outreach during the GSP implementation process.

2.2 Basin Setting

This section describes the Basin setting based on existing studies relating to geology, climate, historical groundwater and surface water conditions and Basin management that predates SGMA. The purpose of this section is to provide an overview of what is known about the Basin and how the Basin has responded to groundwater management over time.

SGMA guidelines require a significant amount of scientific hydrogeological detail. The purpose of this detail is to describe how the Basin's physical components interact with the dynamic elements of climate to understand groundwater movement and groundwater and surface water interactions. A good conceptual understanding of the complex interaction between physical Basin structure and changing climate is needed to adapt Basin management strategies to achieve and maintain sustainability.

2.2.1 Basin Boundaries

The lateral boundaries of the Basin generally follow the definable limits of the stacked Purisima Formation aquifer system, as well as the Aromas Red Sands, plus some other Tertiary-aged units that occur between the base of the Purisima Formation and the granitic basement of the Basin (Johnson et. al., 2004). Figure 2-12 provides a map showing the rationale used in the basin modification request to DWR. These features are discussed in more detail below.

The western boundary of the Basin follows the watershed boundary between Carbonera Creek and Branciforte Creek where the Purisima Formation is eroded to the granitic basement so is considered a barrier to groundwater flow (Figure 2-12). The watershed boundary runs north from the Pacific Ocean separating the Basin from the West Santa Cruz Terrace Basin to the west. The watershed continues 1,300 feet north of the West Santa Cruz Terrace Basin thereby forming part of the shared boundary with the Santa Margarita Basin. The shared boundary between the Basin and the Santa Margarita Basin mostly follows a structural granitic high separating westward-dipping stacked aquifer units of the Santa Margarita Basin from the eastward-dipping stacked aquifer units of the Santa Cruz Mid-County Basin (Figure 2-12). The structural granitic high boundary continues to Blackburn Gulch where the shared basin boundary changes to coincide with the eastern boundary of the Lompico Formation outcrop and southern edge of the Butano Formation until it reaches the Zayante-Vergeles fault.

The Zayante-Vergeles fault forms the northern boundary of the Basin and extends from the shared Santa Margarita Basin boundary to CWD's jurisdictional boundary (Figure 2-12). The Zayante-Vergeles fault is considered a barrier to groundwater flow that separates stacked aquifer units of the Purisima Formation in the Basin south of the fault and undifferentiated sediments of the Purisima Formation of the Purisima Highlands Subbasin north of the fault. Where the Zayante-Vergeles fault crosses CWD's western jurisdictional boundary, the Basin boundary then continues along CWD's boundary, extending north of the Zayante-Vergeles fault (Figure 2-12).

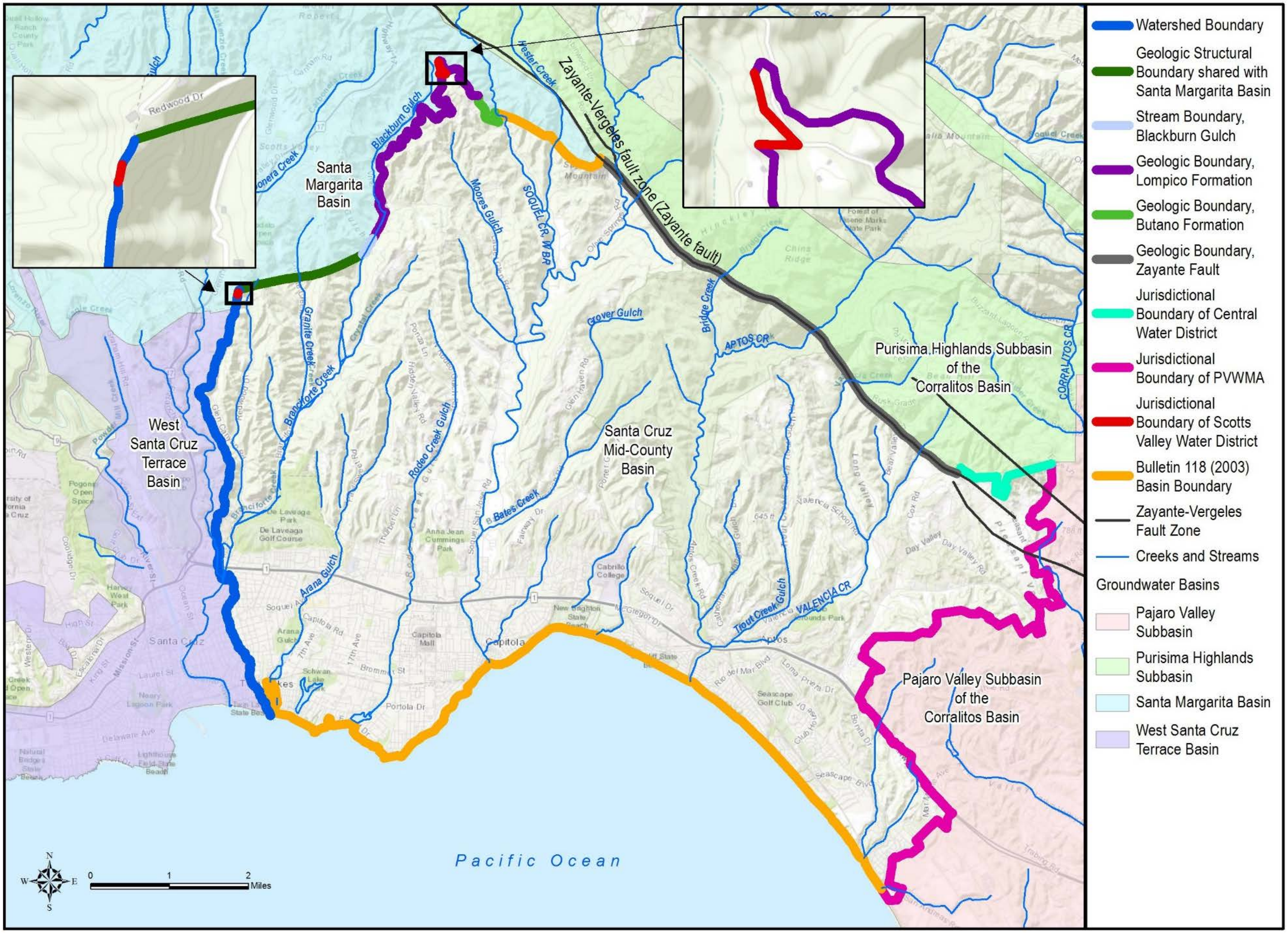


Figure 2-12. Santa Cruz Mid-County Basin Modification Rationale

The Basin's eastern boundary coincides with CWD's eastern boundary and PV Water's western boundary until it meets the Pacific Ocean (Figure 2-12). Even though the Basin's productive aquifer units outcrop offshore, the coastline constitutes the southern boundary of the Basin. This has implications for seawater intrusion as the offshore outcrop is an important boundary condition across which groundwater and seawater mix and area exchanged within the aquifer system.

Granitic basement rock constitutes the definable bottom of the Basin. Granitic rock is observable in boreholes and outcrops, and underlies the stacked aquifer system over the full Basin extent. There is also a limited area of the Basin where Lompico and/or Butano Formations that primarily occur in the Santa Margarita Basin are presumed to lie between the granitic rock and outcropping Purisima Formation aquifer unit.

2.2.2 Climate

The Basin has a Mediterranean climate characterized by warm, mostly dry summers and mild, wet winters. Due to its proximity to Monterey Bay, fog and low overcast are common during the night and morning hours, especially in the summer when warmer weather inland draws in the cool coastal marine layer (SCWD 2015). Annual rainfall recorded at the Santa Cruz Co-op station within the Basin averages 29.3 inches. In the Santa Cruz Mountains, rainfall averages nearly 50 inches per year. The majority of seasonal rainfall occurs between November and March. However, of all 50 states, California has the greatest climatic variability and rainfall can vary greatly from year to year. Monthly and annual climate data for the Santa Cruz Co-op station are summarized in Table 2-3.

Table 2-3. Average Santa Cruz Co-op Temperature and Precipitation

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temp. (ºF)	60.4	62.4	64.6	67.9	70.5	74.0	74.6	75.1	76.1	73.0	66.7	61.2	68.9
Average Min. Temp. (ºF)	38.8	40.9	41.9	43.3	46.1	48.8	51.1	51.4	49.9	46.7	42.2	39.1	45.0
Average Total Precipitation (inch)	6.14	5.42	4.33	1.92	0.80	0.22	0.06	0.07	0.42	1.39	3.31	5.24	29.33
Average Total Snowfall (inch)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Western Regional Climate Center - Period of Record: 01/01/1893 to 06/09/2016 Percent of possible observations for period of record.

Future average temperatures in the Basin are expected to increase and global climate models differ regarding whether rainfall will increase, decrease, remain the same, or shift both temporally in amount and intensity. The Climate Adaptation Study indicates changing temperatures and precipitation will impact ecosystems, fire risk, water quality and quantity, human and environmental health (City of Santa Cruz 2011).The USGS projected specific climate changes and impacts on water resources for the Santa Cruz Mountains (Flint and Flint, 2012). Municipalities in the region recognize the significance of climate change to the region's economic well-being, public health, and environment, and have begun taking steps to respond.

Simulated precipitation and temperatures used under projected conditions are discussed in greater detail in Section 2.2.5.6.1, with supporting documentation included in Appendix 2-G and 2-H.

2.2.3 Hydrogeologic Conceptual Model

2.2.3.1 Overview

GSP regulations require a descriptive hydrogeologic conceptual model (HCM) of the Basin based on technical studies and qualified maps. The HCM's purpose is to characterize the physical components of the basin and describe occurrence of groundwater and its movement in and out of the Basin. The HCM is also the conceptual model for developing the numerical integrated surface water-groundwater GSFLOW model used to simulate future Basin conditions based on changing climate and future groundwater projects and management actions.

Hydrogeologic studies of the Basin date back to 1968, when Soquel Creek Water District, the County of Santa Cruz, and the City of Santa Cruz collaborated to commission a USGS study of the groundwater characteristics of the Soquel Aptos Area. Until the mid-1960s, groundwater pumping in the Basin was limited to small water service providers and private wells. These water systems were dependent on groundwater and little was known hydrogeologically about the Basin. The USGS hydrogeologic study focused on groundwater conditions in the Soquel-Aptos area (Hickey, 1968). Hickey identified the regional aquifers that support groundwater production, described how groundwater pumping created conditions to draw the saltwater wedge closer to shore, and noted seawater intrusion as the greatest threat to regional groundwater production but that it had not yet come onshore. The natural groundwater discharge from the major Purisima aquifers was estimated to be 10,000 acre-feet per year (Hickey, 1968). In 1980, in response to observed seawater intrusion in the Purisima aquifers, the USGS produced a report on seawater intrusion and potential yield of aquifers in the Soquel-Aptos area (Muir, 1980). This report concluded the potential yields of the two principal aquifers in the Soquel-Aptos area were 4,400 acre-feet per year from the Purisima Formation and 1,500 acre-feet per year from the Aromas Red Sands (Muir, 1980).

A Basin HCM was first developed as part of a groundwater assessment of alternative conjunctive use scenarios (Johnson, et al. 2004). That report provided a comprehensive synthesis of information available at the time to characterize groundwater flow, evaluate the potential for seawater intrusion and diminished stream baseflow, and provide a foundation for subsequent analysis. The HCM in this GSP is primarily based on that report but has been updated for implementation in the numerical groundwater model developed for the Basin, including defining hydrostratigraphy of aquifer and aquitard units as well as model boundary conditions (HydroMetrics WRI, 2015).

Figure 2-13 provides a schematic basin conceptual model to describe general inflows and outflows within the Basin, including those to the Pacific Ocean and neighboring basins.

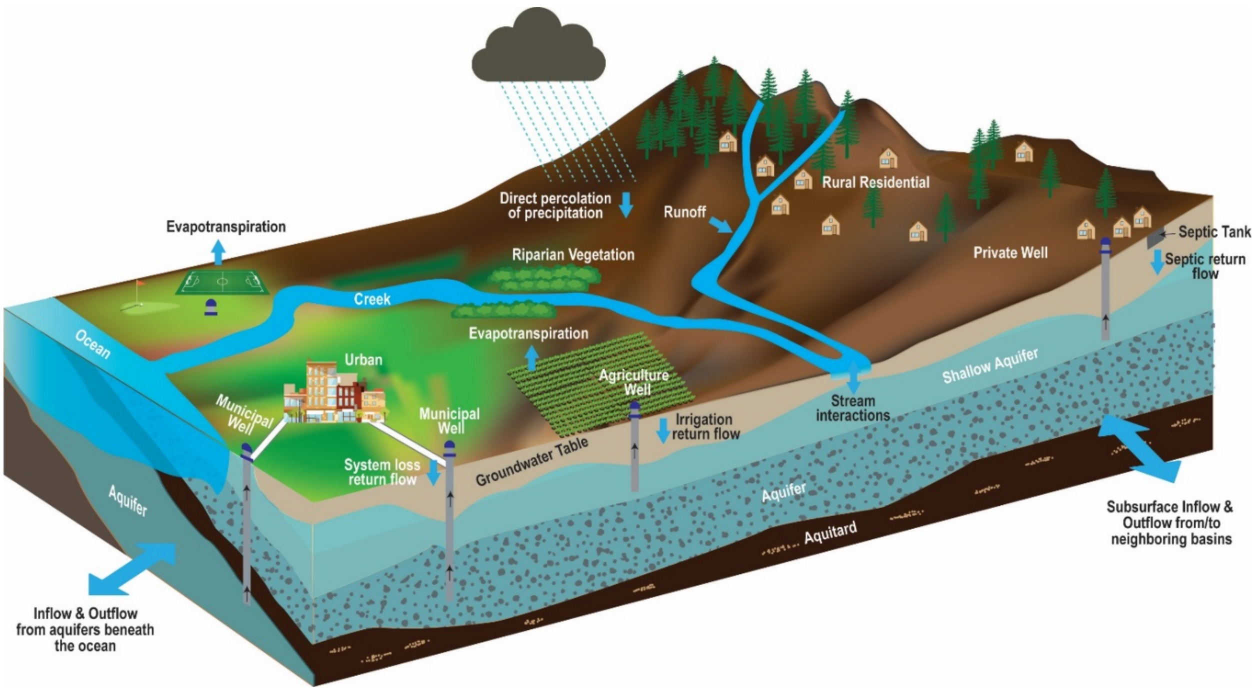


Figure 2-13. Santa Cruz Mid-County Basin Conceptual Model

The Basin extends ten miles from the Santa Cruz Mountains to the Pacific coastline and Monterey Bay. Elevations in the Basin range from sea level at the coast to approximately 1,200 feet above sea level in the coastal mountains (Figure 2-14).

The Basin has a narrow, relatively densely populated, coastal plain along the Pacific Ocean. The coastal plain is bounded landward by the Santa Cruz Mountains that rise to elevations of over 2,600 feet outside of the Basin. The most populated areas of the Basin lie on relatively flat topographic benches formed by marine wave erosion at a time when the land was lower relative to sea level than at present. The benches, referred to as marine terraces, were preserved by gradual uplift of the region. These terraces are separated from successively higher (older) terraces by steep slopes that mark ancient sea cliffs. The older terraces ascend stair-step like up the mountain front.

The lowermost of these terraces forms a broad, gently seaward sloping surface that terminates in a sea cliff at the modern shoreline. This modern sea cliff, or coastal bluff, is a result of wave erosion that is cutting a new marine terrace offshore. The marine terrace surfaces are cut by a series of south flowing creeks and seasonal streams that occupy smaller stream valleys.

Branciforte Creek is at the western edge of the Basin flowing southward from the Santa Cruz Mountains to the ocean. Soquel Creek has the largest watershed drainage and is centrally located within the Basin. Aptos and Valencia Creeks are located further east and merge together near State Route 1 before discharging into the Pacific Ocean at Rio Del Mar. The headwaters of all of these creeks originate in the Santa Cruz Mountains outside of the Basin.

Figure 2-14. Basin Topography

2.2.3.2 Soil Characteristics

The soils of the Basin are derived from exposed geologic formations, and influenced by other factors such as climate, vegetation, and local relief. Soil and vegetation affect how much precipitation can infiltrate into the soil to recharge the regional groundwater aquifers.

Saturated hydraulic conductivity of surficial soils is a good indicator of the soil's infiltration potential. Soil data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) (USDA NRCS, 2007) is shown by the four hydrologic groups on Figure 2-15. The soil hydrologic group is an assessment of soil infiltration rates that is determined by the water transmitting properties of the soil, which includes hydraulic conductivity and percentage of clays in the soil, relative to sands and gravels. The groups are defined as:

- Group A – High Infiltration Rate: water is transmitted freely through the soil; soils typically less than 10 percent clay and more than 90 percent sand or gravel.
- Group B – Moderate Infiltration Rate: water transmission through the soil is unimpeded; soils typically have between 10 and 20 percent clay and 50 to 90 percent sand.
- Group C – Slow Infiltration Rate: water transmission through the soil is somewhat restricted; soils typically have between 20 and 40 percent clay and less than 50 percent sand
- Group D – Very Slow Infiltration Rate: water movement through the soil is restricted or very restricted; soils typically have greater than 40 percent clay, less than 50 percent sand

The hydrologic group of the soil generally correlates with the hydraulic conductivity of underlying geologic units, with higher soil hydraulic conductivity zones, such as the Aromas Red Sands having higher infiltration capacities. Soils overlying many of the terrace deposits have a well-developed clay subsoil, with much lower hydraulic conductivity than the underlying deposits.

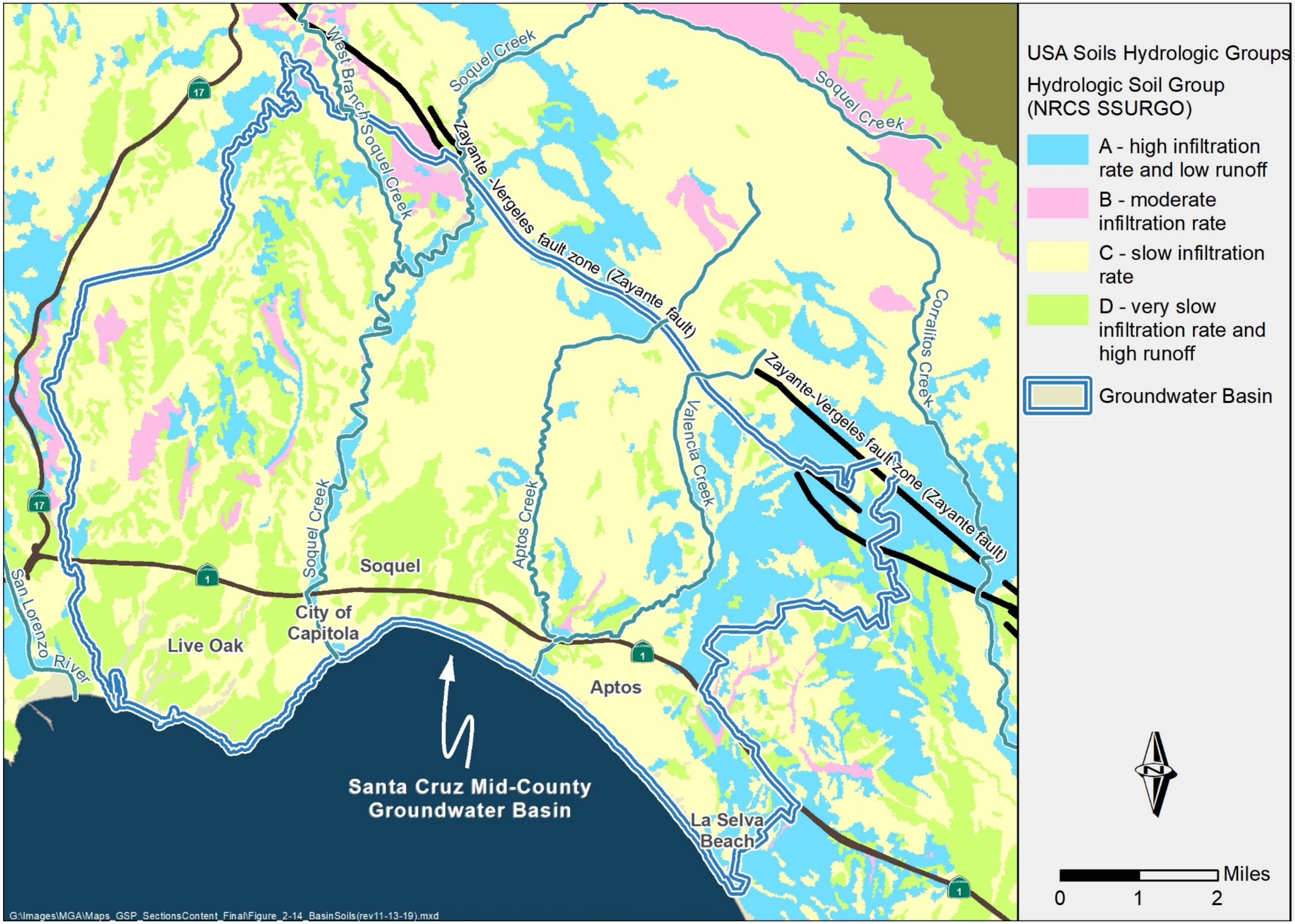


Figure 2-15. Basin Soils

2.2.3.3 Surface Geology

As discussed above, two main geologic formations occur across the Basin: the Purisima Formation and the Aromas Red Sands. Other surficial deposits include Quaternary colluvium, alluvium, flood plain deposits, beach sands, and terrace deposits. USGS mapped surface geology is provided on Figure 2-16.

2.2.3.3.1 Purisima Formation

The Pliocene to late Miocene age Purisima Formation (Tp) is a sequence of grey, sometimes described as blue, moderately consolidated, silty to clean, fine- to medium-grained sandstones containing siltstone and claystone interbeds. It underlies the entire Basin; however, it is blanketed by the Aromas Red Sands in the eastern third of the Basin, and by relatively shallow intermittent alluvial and terrace deposits elsewhere (Figure 2-16).

2.2.3.3.2 Aromas Red Sands

The Pleistocene age Aromas Red Sands (Qar) overlie the Purisima Formation in the hills and coastal terraces east of Valencia Creek (Figure 2-16). Aromas Red Sands comprises interbedded fluvial (Qaf) and aeolian (Qae) sediments that are generally brown to red, poorly consolidated, fine- to coarse-grained sands containing lenses of silt and clay. Consistent with this varied depositional history, there are significant heterogeneities within the Aromas Red Sands. They are assumed to be flat lying as no extensive structures have been identified that could be used to determine strike and dip.

2.2.3.3.3 Surficial Deposits

Quaternary surficial deposits overlying the Purisima Formation include colluvium, alluvium, flood plain deposits, beach sands, and terrace deposits.

Colluvium (Qtl) occurs primarily over parts of the Aromas Red Sands and western portion of the Purisima Formation (Figure 2-16). It comprises unconsolidated, heterogeneous deposits of moderately to poorly sorted silt, sand, and gravel. It was deposited by slope wash and mass movement, and has some minor fluvial reworking. Locally includes numerous landslide deposits and small alluvial fans. Its contacts with other deposits are generally gradational.

Alluvium (Qal) is generally associated with existing rivers and creeks (Figure 2-16). It is heterogeneous, with moderately sorted silt and sand containing discontinuous lenses of clay and silty clay. These deposits are generally relatively shallow. Older unconsolidated flood plain deposits (Qof) consisting of fine-grained sand, silt, and clay occur adjacent to the mainstem of Soquel Creek.

Since the Basin is bound on one side by the Pacific Ocean, there is a ribbon of beach sands (Qbs) that extend almost the length of the coastal boundary. These sediments are an unconsolidated and well-sorted sand that locally may contain layers of pebbles and cobbles. Thin discontinuous lenses of silt are relatively common in back-beach areas. Its thickness is variable, in part due to seasonal changes in wave energy, but is usually less than 20 feet thick.

The Basin's terrace deposits are both fluvial and coastal. Fluvial terrace deposits (Qt) are weakly consolidated to semi-consolidated heterogeneous deposits of moderately to poorly sorted silt, silty clay, sand, and gravel. Their thickness is highly variable but can reach a thickness of 60 feet. Some of the deposits are relatively well indurated in the upper 10 feet of weathered zone.

There are two different mapped types of coastal terrace deposits. The lowest emergent coastal terrace deposit (Qcl) is a semi-consolidated, generally well-sorted sand with a few thin, relatively continuous layers of gravel. It was deposited in nearshore high-energy marine environment. Its thickness is variable but only reaches a maximum of approximately 40 feet. It thins northwards where it ranges from 5 to 20 feet thick. Undifferentiated coastal terrace deposits (Qcu), are semi-consolidated, moderately well sorted marine sands with thin, discontinuous gravel-rich layers. It also has a variable thickness and is generally less than 20 feet thick.

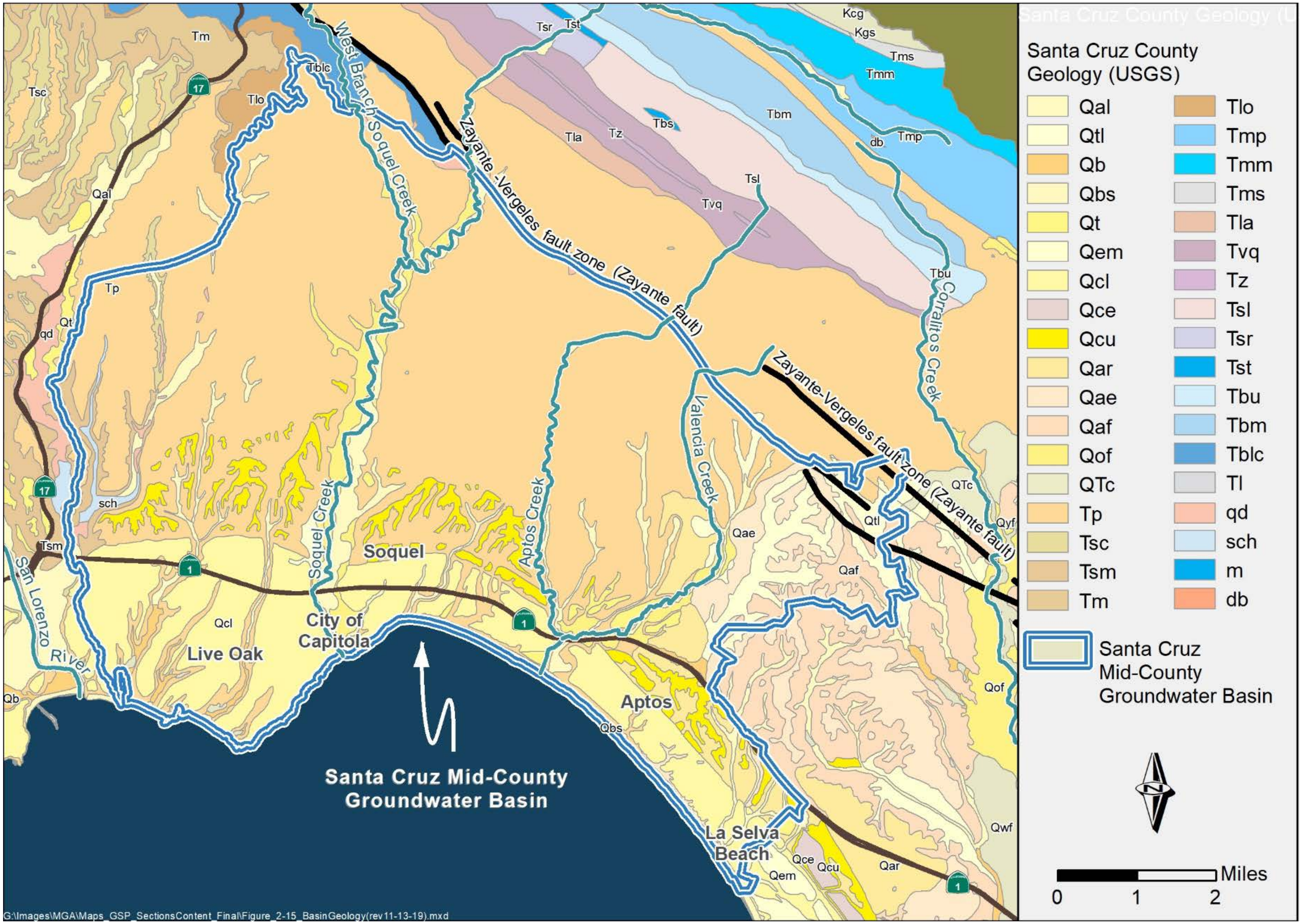


Figure 2-16. Basin Surface Geology

2.2.3.4 Regional Geologic Structures

The Zayante-Vergeles fault zone, which forms the northern Basin boundary, is a major northwest-striking structural element of the Santa Cruz Mountains restraining bend of the larger San Andreas fault zone. It is a major dextral reverse-oblique-slip fault with late Pleistocene and possible Holocene displacement with an estimated vertical slip rate of 0.2 mm per year (Bryant, 2000). The Zayante-Vergeles fault is considered a barrier to groundwater flow due to Purisima Formation being impacted by faulting and folding north of the fault such that sediments are not expressed as stacked aquifer units as in the Basin south of the fault zone.

Although not a documented fault, during development of the MGA integrated groundwater-surface water model (model) a fault-like feature was added to the model to achieve the hydraulic gradients observed in monitoring wells in the central portion of the Basin. Additional evidence supporting the possibility of a fault in this location are 1) a U.S. Geological Survey report of earthquakes and faults within the greater San Francisco Bay Area, including Santa Cruz County (Sleeter, et al., 2004) indicates that, based on seismic activity in the area, there is evidence of some faulting south of the Zayante-Vergeles fault zone, and 2) Alexander (1953) observed deformation of the marine terraces near Capitola between Aptos and Rio del Mar; the axis of deformation appears to have an east-west alignment similar to faulting found in the USGS report and inferred from regional groundwater elevation gradients. A technical memorandum describing hydrogeological conceptual model changes incorporated in to the model is provided in Appendix 2-E. The model calibration report (Appendix 2-F) and model simulations report (Appendix 2-I) refer to this feature as the Aptos area faulting.

As described in Section 2.2.1, the definable bottom of the Basin is the granitic basement rock that is observed in boreholes and in outcrops throughout the Basin. The granitic basement structure has been defined by U.S. Geological Survey (USGS) gravity anomaly data (Roberts et al., 2004) and refined by use of borehole log and e-log data supporting development of the Basin model (Appendix 2-D). During the Paleocene (between 95 and 61 million years ago) regional uplift led to “unroofing” of the metasedimentary and granitic rock. “Unroofing” occurred where this overlying rock was removed by erosion (McLaughlin and Clark, 2004). After this “unroofing” event, the granitic rock formed the surface where subsequent deposition occurred.

Both the Purisima Formation and Aromas Red Sands are relatively undeformed in the Basin. Locally, the Purisima Formation dips to the southeast at approximately 4 degrees (Figure 2-19). This dip results in remnants of the lower-most strata occurring only along ridge tops west of the study area. The Purisima Formation also occurs within a tightly folded syncline north of the Zayante-Vergeles fault zone outside the Basin, and along the upper portions of the Soquel and Aptos Creek watersheds.

2.2.3.5 Principal Aquifers and Aquitards

2.2.3.5.1 Aquifer and Aquitard Descriptions

There are two primary water-bearing geologic formations within the Basin: the Purisima Formation and the Aromas Red Sands. The Basin is dominated by the Purisima Formation which extends throughout the Basin and overlies granitic basement rock that outcrops in the west of the Basin. In the southeast of the Basin, east of Valencia Creek, the Purisima Formation is overlain by unconfined Aromas Red Sands.

Since the Purisima Formation dips to the southeast and the Aromas Red Sands are assumed to be flat lying, groundwater flows by gravity following the local topography but also follows the orientation of local geologic stratigraphy. Essentially, groundwater flows from the local mountains toward the ocean, but where present, also follows preferred pathway through the subsurface based on the local geology.

Both the Purisima and Aromas aquifers are hydrologically connected to the Pacific Ocean. This connection creates a seawater intrusion threat to the freshwater aquifers when groundwater pumping from the Basin exceeds natural and artificial groundwater recharge into the Basin.

Hydrographs on Figure 2-17 showing groundwater levels in the Basins' aquifers display relatively large variations in groundwater levels in the deeper highly-confined aquifers, for example in the Purisima BC unit. This variation suggests that groundwater levels are highly influenced by pumping and less so by annual recharge. The hydrographs also show large vertical gradients between the different hydrostratigraphic units.

The Purisima Formation is composed of named aquifer and aquitard layers, where the Aromas Red Sands is considered a single aquifer unit, but has significant heterogeneities. Each of the principal aquifers and aquitards that occur in the Basin are discussed below.

Aromas Red Sands Formation (Qa ~400 feet thick): The southeastern portion of the Basin, generally beginning east of Valencia Creek, is identified as the Aromas Red Sands aquifer. The poorly consolidated Aromas Red Sands consist of interbedded fluvial, marine, and eolian sands with lenses of silt and clay. Consistent with this varied depositional history, the Formation contains significant heterogeneities. The Aromas Red Sands overlie the Purisima Formation in the hills and coastal terraces east and southeast of Aptos. LSCE (1987) subdivided the Aromas Red Sands into an upper and a lower unit within Pajaro Valley. A large portion of the upper zone may be unsaturated, especially where the water table is drawn down to near sea level. Johnson et al. (2004) estimates that the hydraulic conductivity of the Lower Aromas Red Sands ranges between 6 and 50 feet per day, and the hydraulic conductivity of the Upper Aromas Red Sands ranges between 3 and 40 feet per day. There is no identifiable stratigraphy and no continuous aquitard between the Aromas Red Sands and uppermost Purisima unit (the Purisima F-unit).

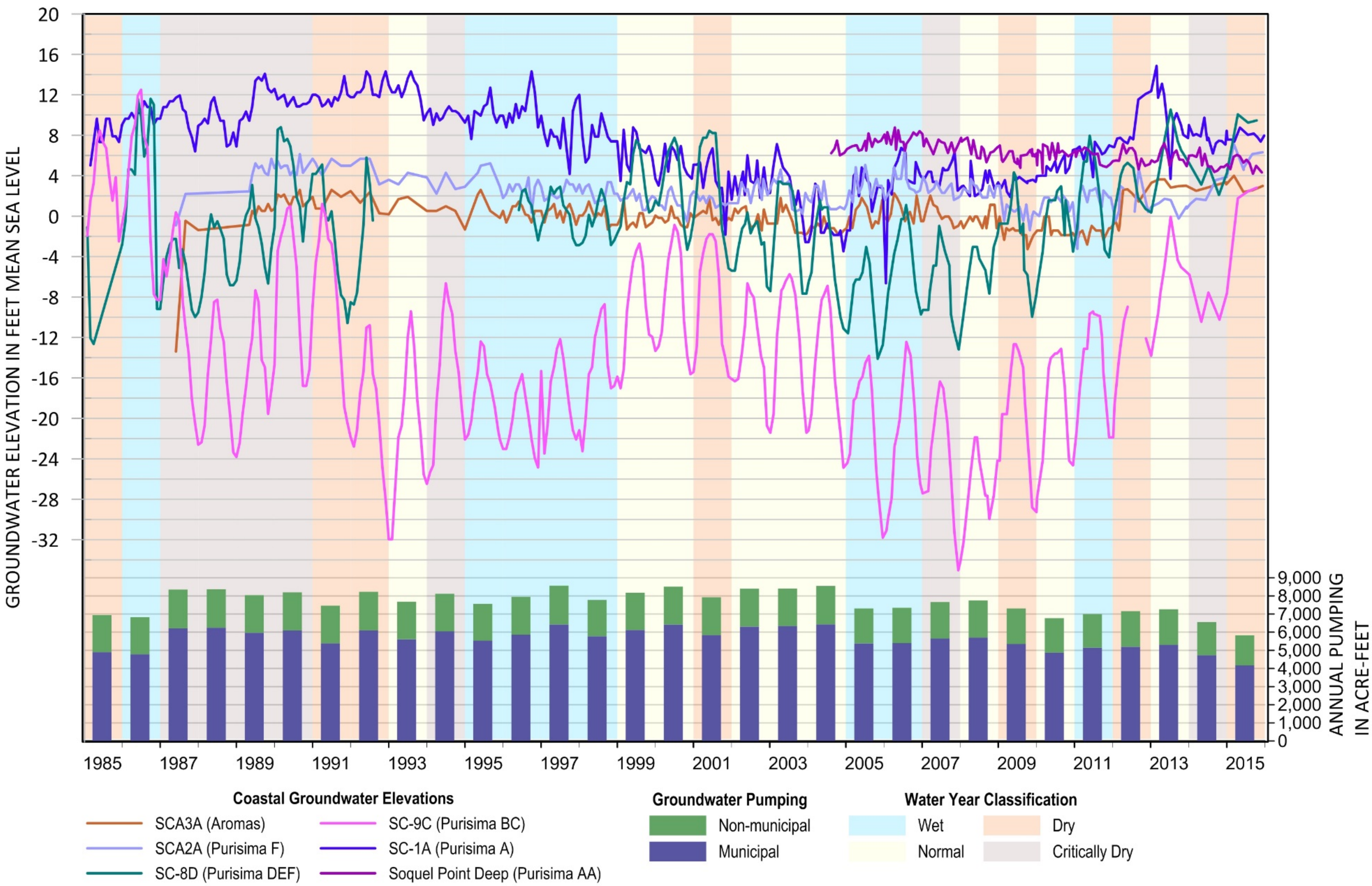


Figure 2-17. Coastal Groundwater Elevations Compared with Historical Basin Pumping (1985-2015)

Purisima Formation (Tp): The Purisima Formation has an uneroded total thickness of up to 2,000 feet (Hickey, 1968). The 1968 USGS Hydrogeologic Study subdivided the Purisima Formation into three hydrostratigraphic units in the Soquel-Aptos area, designated from oldest to youngest as A, B, and C (Hickey, 1968). In 2004, the current hydrostratigraphic model was developed by Johnson et al. reviewing additional geologic investigations by Luhdorff and Scalmanini Consulting Engineers (LSCE, 1984). Johnson et al. accepted the general layered aspect of the Purisima Formation, and by combining the AA through F units into hydrostratigraphic units that define regional aquifers and aquitards. These Purisima Formation hydrostratigraphic units are defined from oldest to youngest as follows:

Purisima-AA Aquifer Unit (150 to 300 feet thick). This unit comprises a sequence of interbedded, moderately coarse- and fine-grained zones underlying the well-defined A-unit. A fine-grained zone 20 to 70 feet thick divides the AA unit from the overlying A unit. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 1 and 10 feet per day.

Purisima-A Aquifer Unit (~250 feet thick). This distinct aquifer is the most consistently coarse-grained aquifer within the Purisima Formation. It is sometimes divided into an upper and lower zone, with the lower zone being more coarse-grained. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 7 and 65 feet per day.

Purisima-B Aquitard Unit (~150 feet thick). This aquitard consists of the lower portion of the LSCE unit B. This portion of unit B is consistently fine-grained, with the lower 25 to 45 feet being the most highly correlated feature across the Soquel-Aptos Area Basin. A coarse-grained bed is often encountered in the middle of this otherwise fine-grained unit. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 0.005 and 1 foot per day.

Purisima-BC Aquifer Unit (~200 feet thick). The LSCE unit C is grouped with the upper portion of the LSCE unit B to form Aquifer BC. This is a moderately coarse-grained unit with a distinct 15 to 20 foot thick coarse-grained unit at the top of the unit. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 1 and 3 feet per day.

Purisima-D Aquitard Unit (~80 feet thick). The lower 60 to 80 feet of LSCE unit D is predominantly fine-grained, with one or two minor coarse-grained intervals. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 0.005 and 1 foot per day.

Purisima-DEF Aquifer Unit (~330 feet thick). This moderately coarse aquifer includes intermittent fine-grained zones. The top of this aquifer seems poorly defined; Johnson et al. (2004) does not identify a distinct marker or aquitard separating this aquifer from the overlying Aquifer F. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 2 and 6 feet per day.

Purisima-F Aquifer Unit (500+ feet thick). This unit consists of alternating moderately coarse- and fine-grained zones. Johnson et al. (2004) identifies this aquifer as the upper portion of the Purisima F-unit that is often screened in conjunction with the lower Aromas Red Sands. Johnson et al. (2004) estimates that the hydraulic conductivity of this hydrostratigraphic unit ranges between 2 and 6 feet per day.

Because of the interlayering of aquifers with aquitards, groundwater is confined in some of the Purisima aquifers. Groundwater within confined aquifers can be under pressure, creating artesian conditions when wells are installed such that groundwater flows toward the surface without a pump. This is the case currently at a coastal monitoring well that is screened in the Purisima DEF-unit. Confining layers in an aquifer can also act as a barrier to the spread of contamination and can contribute to delay or prevent the spread of contamination between layered aquifers.

Purisima Formation hydrostratigraphic units shown on Figure 2-18 are based on Johnson et al. (2004) and coastal terrace deposits mapped by Brabb et al. (1997). The hydrostratigraphic units do not always outcrop at the surface as they are often covered by alluvium or coastal terrace deposits (Figure 2-16). Hydrostratigraphic cross-sections on Figure 2-19 and Figure 2-20 illustrate the Basin’s aquifers and significant structural features.

Undifferentiated Sandstone of Tertiary Age (Tu, between 10 and 3,000 feet thick): The Tu unit is not a formal formation mapped by the USGS but it is a localized productive aquifer that includes all non-Purisima water-bearing units between the poorly defined base of the Purisima AA aquifer unit and the top of granitic basement. This unit is generally found in the western portion of the Basin and pinches out where the base of the Purisima Formation intersects the granitic basement.

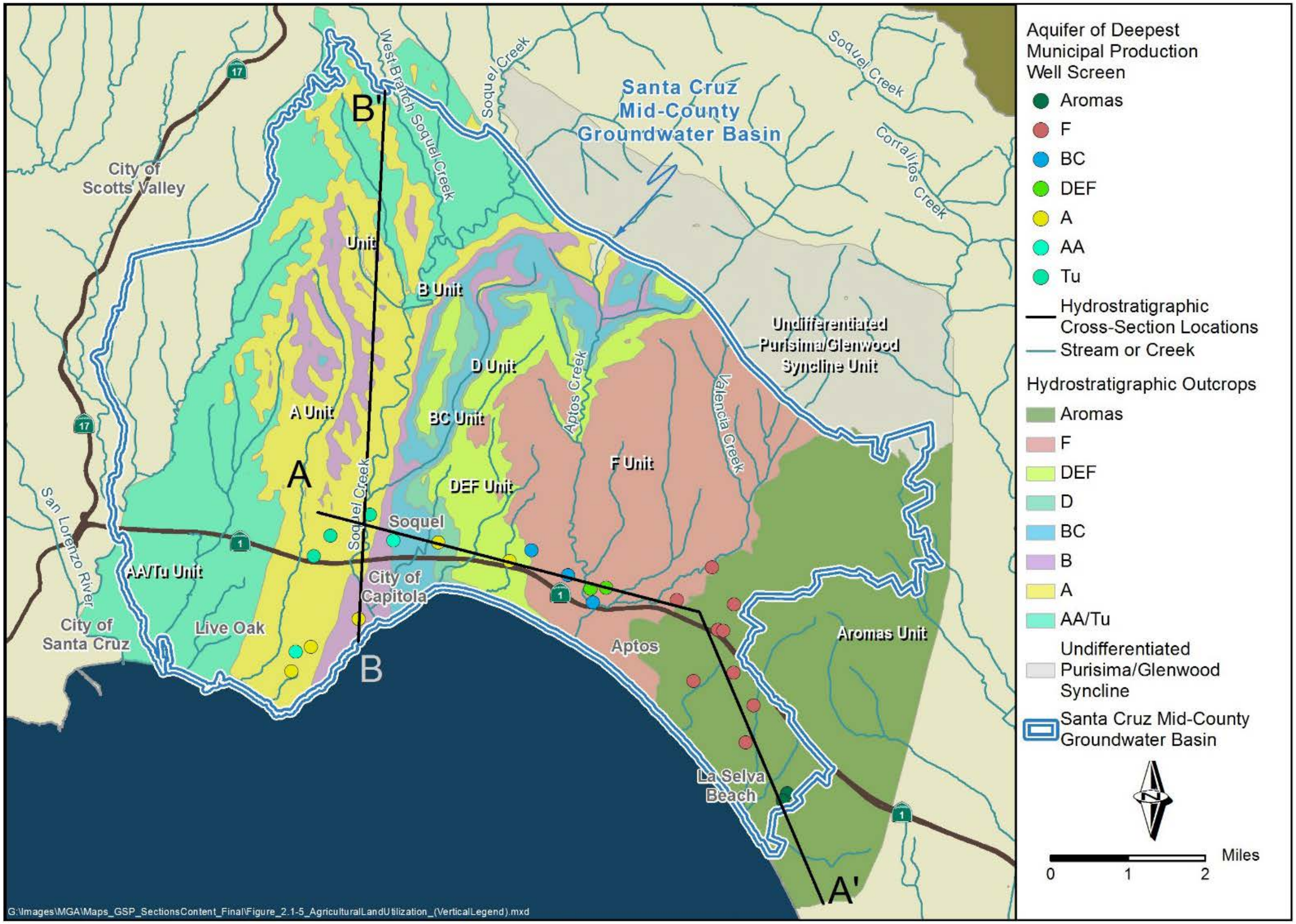


Figure 2-18. Aquifer and Aquitard Distribution Across the Basin

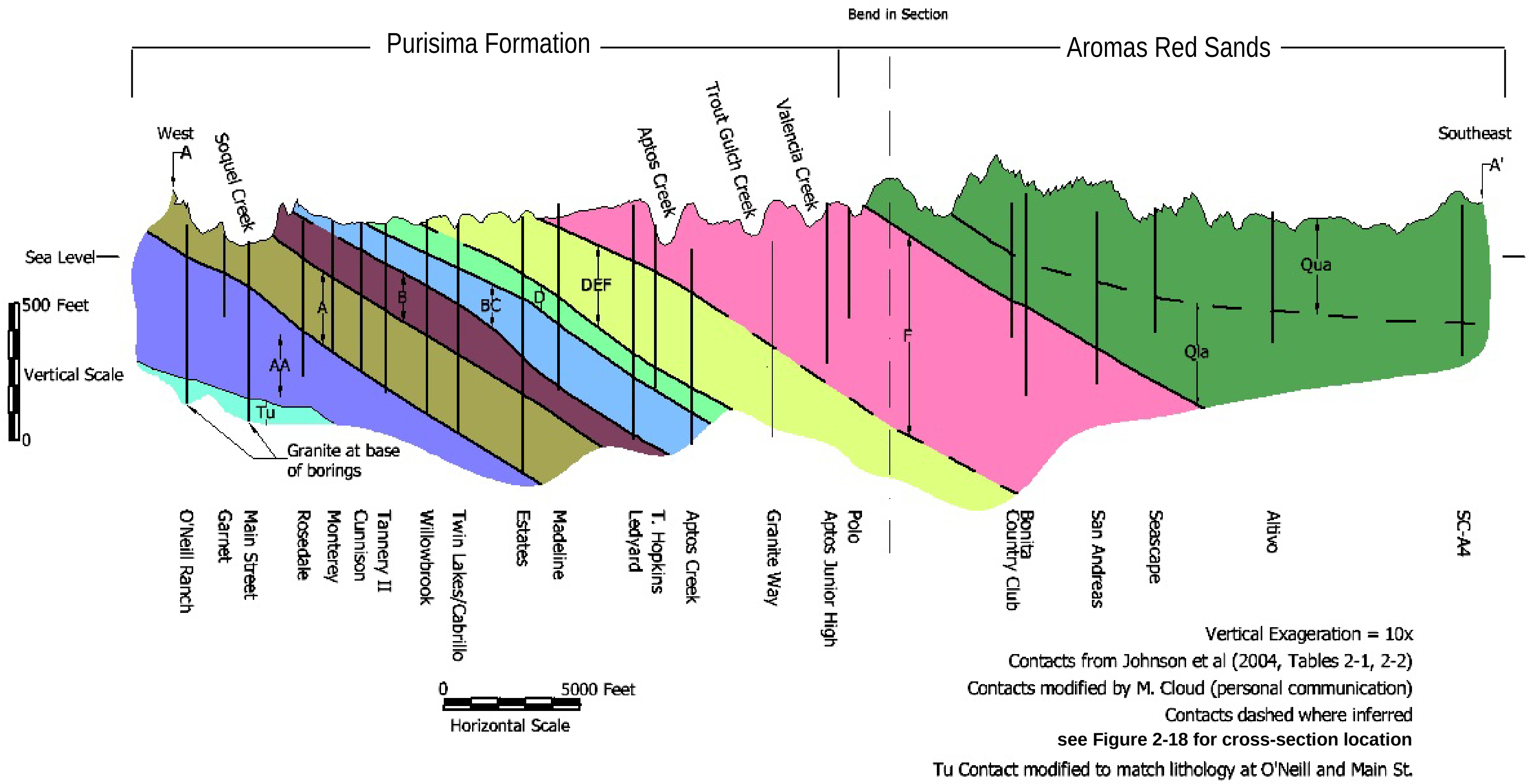


Figure 2-19. Hydrostratigraphic Cross-Section, A – A’

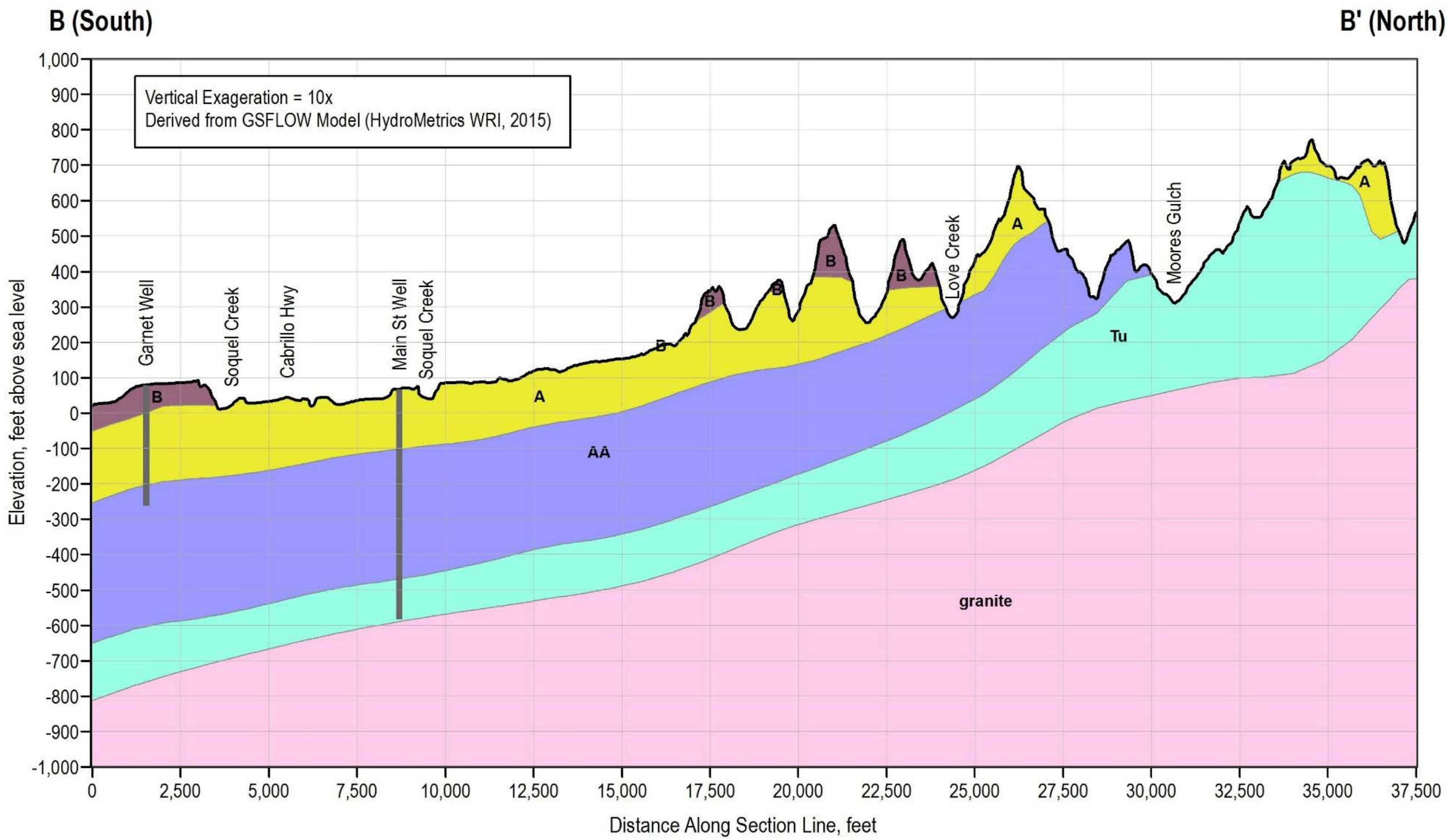


Figure 2-20. Hydrostratigraphic Cross-Section, B – B'

2.2.3.5.2 Primary Aquifer Use

The Purisima Formation aquifer units and the Aromas Red Sands aquifer are the primary aquifers pumped throughout the Basin by all extractors (Table 2-4). Non-municipal domestic and small scale agriculture users of groundwater generally complete their wells in the shallowest productive aquifers, while municipal extractors complete their wells in specific aquifer units that may be much deeper than domestic wells. For example, in the western portion of the Basin, most domestic wells pump from the Purisima A-unit which is the shallowest aquifer, while the City of Santa Cruz and SqCWD pump from the deeper Purisima AA-unit or Tu aquifer in addition to the overlying Purisima A-unit. Many municipal wells are screened through multiple Purisima aquifers to maximize well yield. Residential, agricultural, and municipal wells are often screened through both the Aromas Red Sands and Purisima F-unit aquifers when the Purisima F-unit is relatively shallow. The average proportion of pumping by aquifer and user type from 1985 through 2016 is summarized in Table 2-4.

Table 2-4. Proportion of Total Basin Extractions by Aquifer and Use Type

Aquifer	Non-Municipal Domestic	Non-Municipal Institutions	Agriculture	Municipal	All Pumpers
	Percent of Total Groundwater Extractions				
Aromas Red Sands	1%	<1%	2%	29%	34%
All Purisima Aquifer Units	12%	8%	2%	46%	66%
Total	13%	9%	4%	75%	100%

Data Source: metered pumping for municipal extractions and estimated extractions for non-municipal extractions. See Appendix 2-B for details on methodology for non-municipal extractions.

Municipal pumpers, SqCWD and CWD, have over the past few years been pumping less from the Aromas Red Sands than what they pumped historically because of naturally occurring Chromium-VI and elevated nitrate concentrations associated with septic systems and possibility fertilizer use. These groundwater quality issues are discussed in more detail in Section 2.2.4.4.

2.2.3.6 Surface Water Bodies Significant to Basin Management

DWR regulations requires the HCM describe surface water bodies significant to the management of the Basin. In the Basin, significant water bodies fall into four categories:

a) Surface water bodies that impact Basin water quality
b) Surface water bodies that supply water to Basin residents
c) Surface water bodies connected to Basin groundwater
d) Surface water supporting Groundwater Dependent Ecosystems (GDE)

The first three categories are outlined in this subsection while the fourth category, surface water that supports GDE, is identified and discussed in detail in Sections 2.1.4.12; 2.2.4.6; and 2.2.4.7. Figure 2-21 shows the location of significant surface water bodies in the Basin.

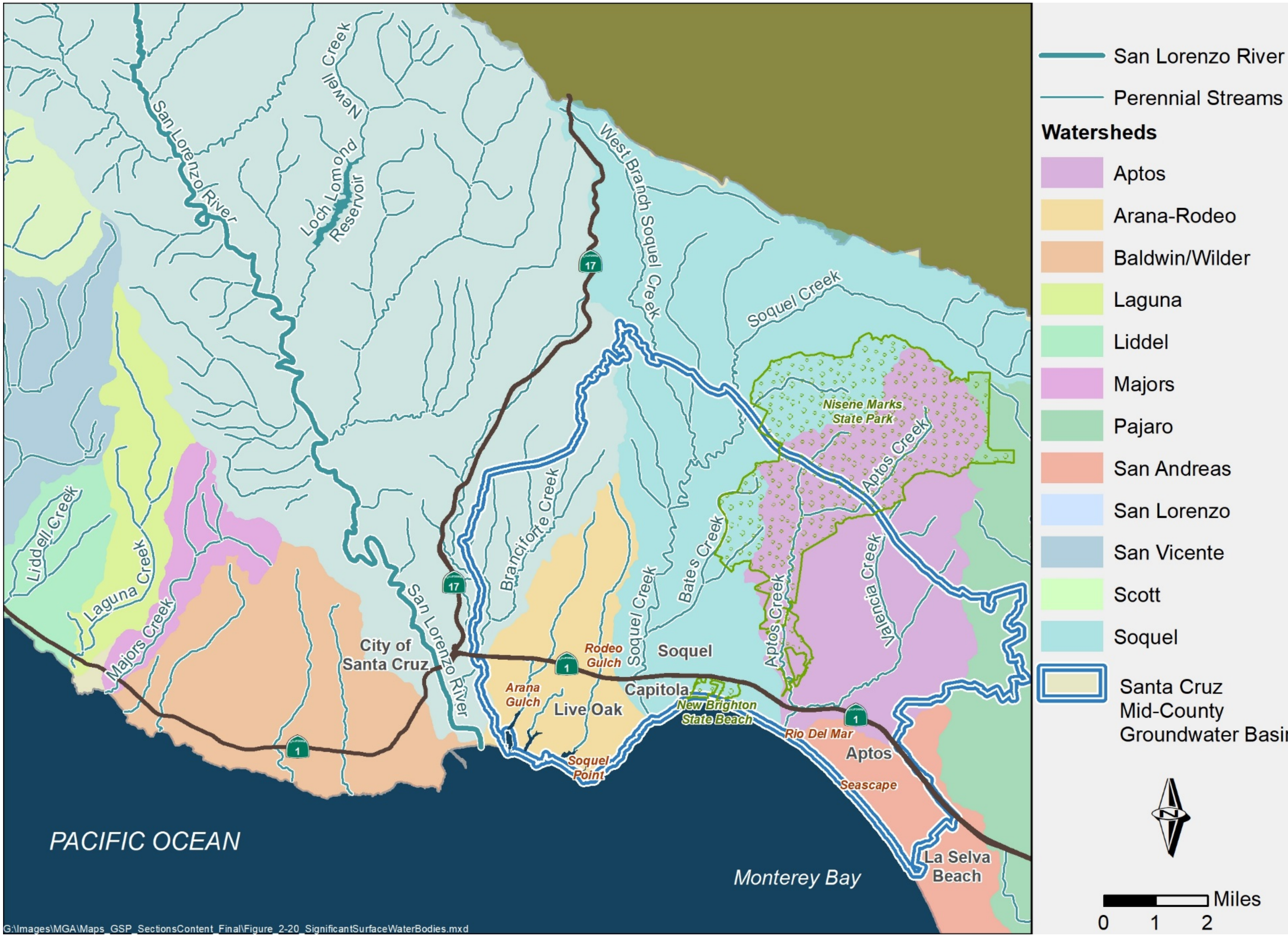


Figure 2-21. Significant Surface Water Bodies

2.2.3.6.1 Surface Water Bodies that Impact Basin Water Quality

The Basin includes 10 miles of coastline along the Pacific Ocean inside of Monterey Bay. The Purisima and Aromas Red Sands groundwater aquifers used for water supply by Basin residents are hydrologically connected to the Pacific Ocean. This connection creates a threat of seawater intrusion into Basin freshwater supply aquifers. Because of this threat, the Pacific Ocean is the largest surface water body that impacts groundwater management practices in the Basin.

Both the Purisima and Aromas Red Sands have been impacted by seawater intrusion. The Purisima A-unit aquifer has experienced seawater intrusion at Soquel Point and the Aromas Red Sands aquifer has ongoing seawater intrusion in the Seascape and La Selva Beach areas. MGA sponsored geophysical research indicates that seawater intrusion is an active threat all along the Basin’s coastal margin (Ramboll, 2018). Groundwater elevations and groundwater modeling indicate a high risk of additional seawater intrusion in the New Brighton and Seascape areas and the advance of seawater intrusion at Soquel Point and in La Selva Beach (Hydrometrics, 2018).

Basin management has and will continue to focus on controlling seawater intrusion. MGA member agencies have successfully developed water conservation and pumping management plans optimized to keep groundwater elevations high enough at the coast to prevent further onshore movement of seawater into the Basin’s freshwater aquifers. These management efforts have resulted in some the lowest per capita municipal water demand in the state and reduced municipal groundwater pumping from approximately 7,000 acre-feet per year in the late 1980s to approximately 4,000 acre-feet per year in Water Year 2017. However, model simulations indicate that supplemental water supplies or groundwater use curtailment is needed to reach and maintain protective groundwater elevations and achieve groundwater sustainability in the face of climate change as modeled and discussed in Sections 4.2 and 4.3.

2.2.3.6.2 Surface Water Bodies that Supply Water to Basin Residents

The City of Santa Cruz Water Department supplies approximately 45% of Basin residents with water that is primarily sourced from surface water. The surface waters used by the City to serve its Basin customers are: San Lorenzo River, Majors Creek, Liddell Creek, Laguna Creek, Reggiardo Creek, and Loch Lomond Reservoir on Newell Creek. All of the City’s surface water supply sources are located outside of the Basin.

In addition to the surface water supplied to its own customers within the Basin, SCWD also has supplied SqCWD with treated drinking water when SCWD has excess surface water available. This water transfer from SCWD to SqCWD is part of a conjunctive use pilot project. The pilot project is an in-lieu water transfer that began delivering treated surface water to SqCWD customers in December 2018 to fulfill an agreement negotiated in 2016. This in-lieu water transfer allows less groundwater pumping from the wells that typically serve SqCWD customers. Reduced pumping allows natural recharge to occur.

2.2.3.6.3 Surface Water Bodies Connected to Basin Groundwater

Groundwater elevation monitoring, stream elevations, stream gauging data, and integrated surface water-groundwater modeling (Figure 2-10) have all been used to identify streams that are connected to groundwater within the Basin. These data have also been used to determine the amount of time throughout the year that each surface water body within the Basin is connected to groundwater.

Soquel Creek has the largest watershed in the Basin and its complete catchment measures approximately 42 square miles (Figure 2-21). Soquel Creek's main upper tributary is the West Branch of Soquel Creek. Bates Creek is a lower tributary. Soquel Creek is connected to shallow groundwater during most of the year at most of its reaches within the Basin (Figure 2-10). Where data are available on lower Soquel Creek only, there are both gaining and losing reaches.

Two smaller streams within the Basin, Aptos Creek and Valencia Creek, are also connected to groundwater in their lower reaches for at least part of the year (Figure 2-10). In their upper reaches, groundwater elevation monitoring and stream elevations indicate that both Aptos Creek and Valencia Creek are not connected to groundwater. Current and historic groundwater elevations (dating to the 1950s) are significantly below stream elevations. This historic information, especially given that Aptos Creek is mostly within Nisene Marks State Park where few wells are located, indicates that these streams were unlikely to have been connected to groundwater in the historic past. However, both Aptos and Valencia Creeks become connected to groundwater near their confluence one half mile before Aptos Creek enters the Pacific Ocean at Rio Del Mar.

In the western portion of the Basin, Arana Gulch and Rodeo Gulch may be connected to groundwater in their lower reaches. Branciforte Creek is the westernmost creek in the Basin, but much of the stream channel flows directly over the underlying granitic basement and has little influence on the Basin's aquifers. Maps and additional detailed recommendations for improved monitoring and management of surface water bodies connected to groundwater are found in Section 3.9.

2.2.3.6.4 Surface Water Supporting Basin Groundwater Dependent Ecosystems (GDE)

Significant surface water bodies supporting GDEs are mapped and discussed in detail in Section 2.1.4.12; 2.2.4.6; and 2.2.4.7.

2.2.3.7 Recharge Areas and Water Deliveries

2.2.3.7.1 Basin Recharge Areas

Recharge to the Basin occurs through natural processes, groundwater recharge projects developed or permitted by MGA member agencies, or by percolation directly from water-related infrastructure, such as from leaks in water, wastewater, storm water delivery systems, and from septic systems in unsewered portions of the Basin. Natural recharge zones have been mapped by the County of Santa Cruz and managed aquifer recharge suitability has been evaluated by Russo et al. (2014). The Basin's recharge zones and relative managed aquifer recharge surface suitability are shown on Figure 2-22. Figure 2-18 shows the "outcrop" of the Basin's aquifers, however, the hydrostratigraphic units do not always outcrop at the surface as they are often covered by alluvium or coastal terrace deposits (Figure 2-16).

2.2.3.7.2 Water Deliveries

A limited amount of water is imported from Santa Clara County to small water systems in the Summit Area of the Santa Cruz Mountains. This area is outside the Basin but within the Upper Soquel Creek watershed, which drains into the Basin.

Some Basin residents do receive water from outside the Basin, either as direct municipal customers who receive treated surface water supplied to them from the SCWD or as part of the in-lieu water transfer pilot project between SCWD and SqCWD (Figure 2-23).

Planned and emergency water transfers into the Basin take place between MGA member municipal water providers using interties that connect the individually owned and maintained agency water systems to each other. These interties were originally developed as emergency connections between water agencies to improve water supply reliability. Conjunctive use water transfers are expected to expand with increased water availability if water rights place of use changes are approved in the future. Conjunctive use is discussed in greater detail in Sections 2.1.4.5, 2.1.4.6, and 4.2.3.

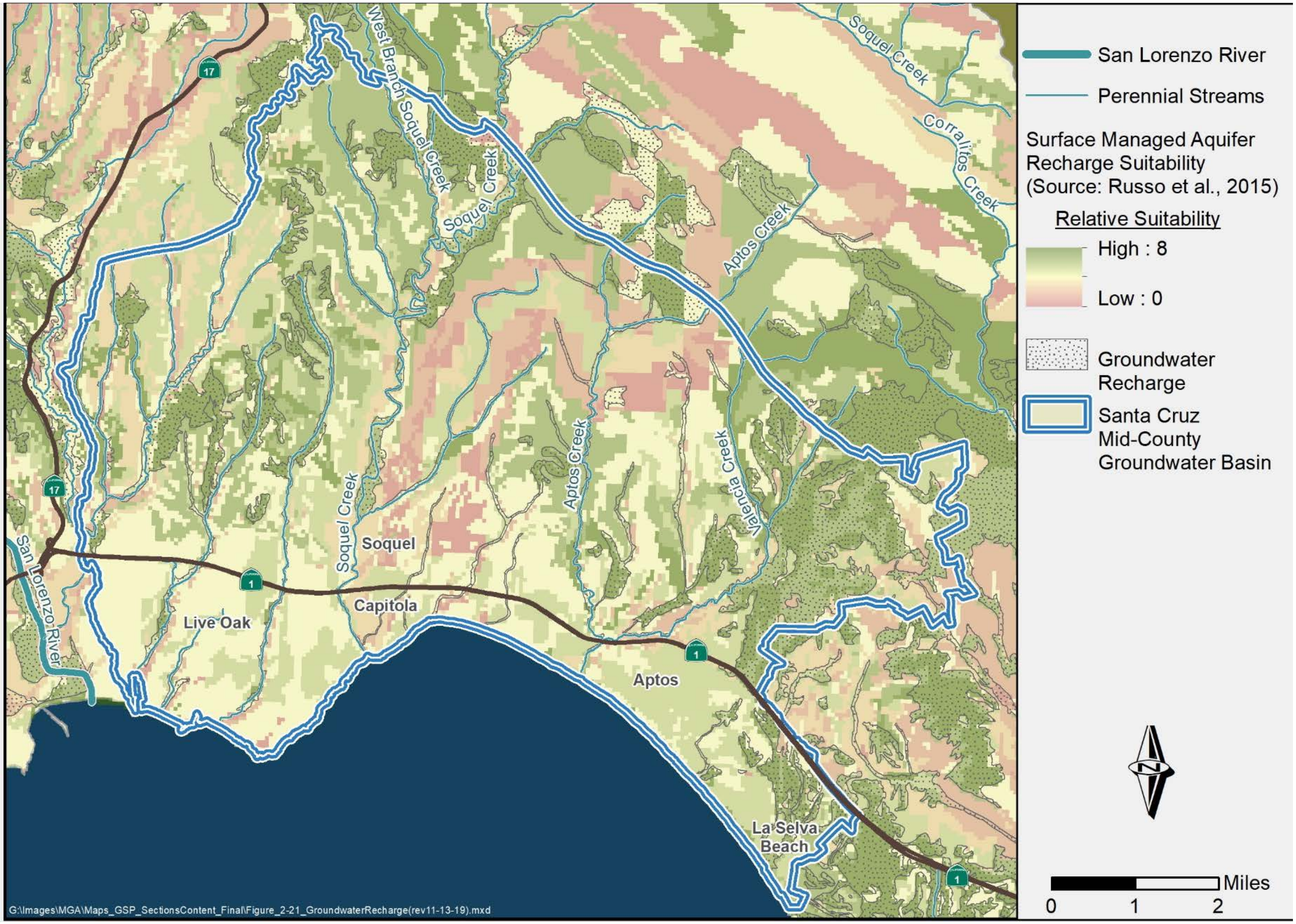


Figure 2-22. Groundwater Recharge Zones

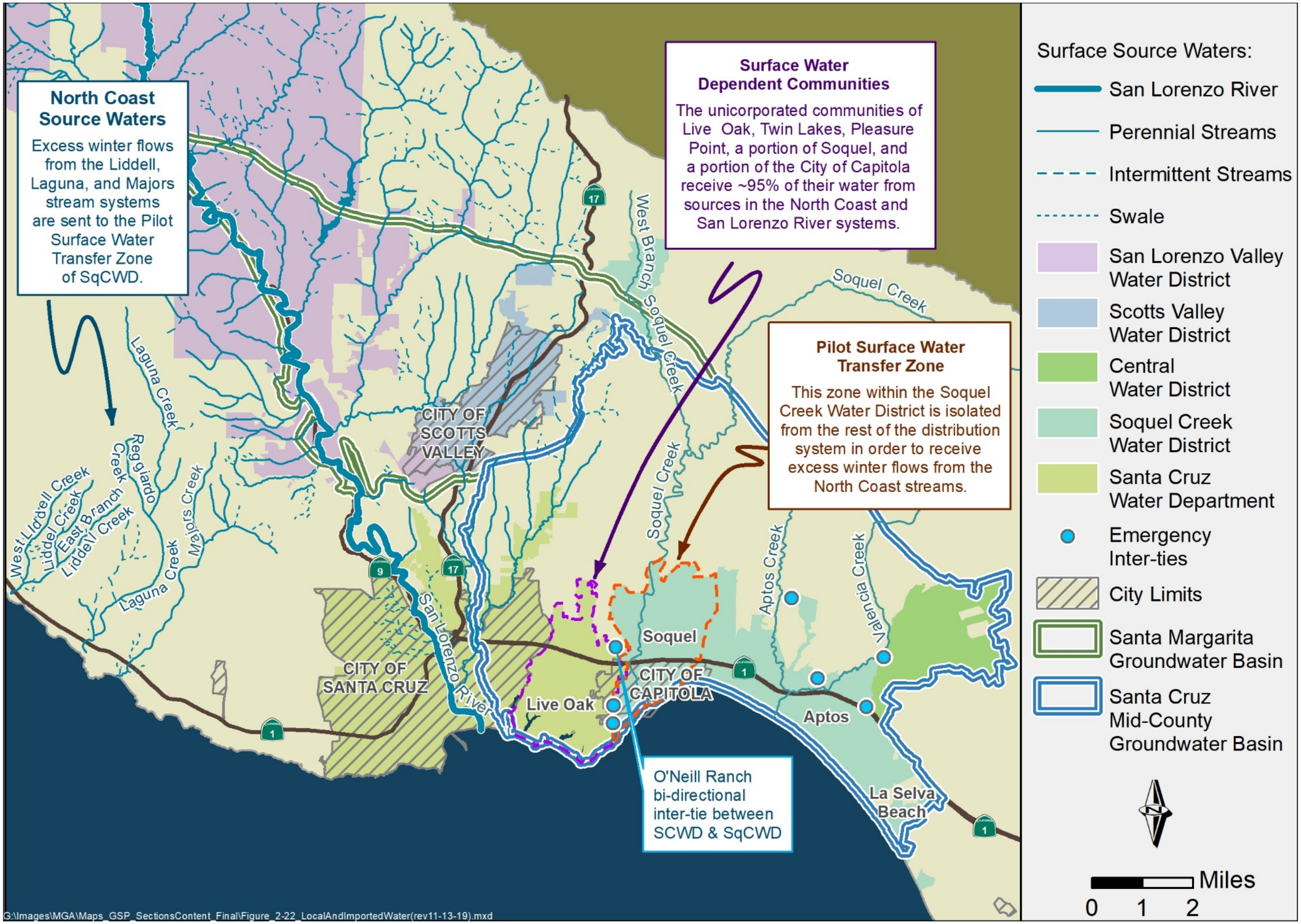


Figure 2-23. Local and Imported Water

2.2.3.8 Hydrogeologic Conceptual Model Data Gaps and Uncertainty

There is a good general hydrogeological conceptual understanding in the coastal portions of the Basin because this is where the municipal production and monitoring wells are located that have been drilled under the supervision of professional geologists. The stratigraphic detail obtained from wells logged by geologists is generally greater than those obtained from well driller's logs submitted to DWR or the County. There are specific areas that have data gaps due to a lack of deep wells to characterize parts of the Basin:

1. The lateral extent of the Tu unit beneath the lowermost Purisima AA-unit is uncertain due to limited wells that extend to the deeper depths where the Tu unit occurs. A few municipal wells in the western portion of the Basin are screened in the Tu unit, but no known private wells are screened in the Tu unit.

2. Recharge sources to the Tu unit are not well understood because of a lack of wells completed to the west of production wells in the Tu unit and lack of definitive correlation between Tu unit sediments and mapping of geologic outcrops.

3. The area north of the Aptos area faulting is poorly understood because there are only non-municipal domestic, agricultural, and non-municipal institutional wells that are relatively shallow and generally extend only to the shallowest water-bearing formation. The data from well driller's logs associated with these private wells generally do not allow for stratigraphy to be determined.

4. The Purisima units beneath the Aromas and Purisima F-unit in the eastern portion of the Basin are not well understood because wells are not drilled deeper than the Purisima F-unit.

5. The hydrogeology along the Basin's boundary with the Santa Margarita Basin is poorly understood because of limited good quality stratigraphy data.

6. The offshore outcrops of aquifer units are based on the intersection of seafloor elevations and offshore projections of hydrostratigraphic surfaces (described in Appendix 2-D). Due to the submarine nature of these outcrops, there is a high level of uncertainty as to the exact location and extent of the outcrops.

2.2.4 Current and Historical Groundwater Conditions

Under SGMA, the Basin is defined as a high priority basin in critical overdraft principally because active seawater intrusion impacts its productive aquifers. Between 1964 and 1967, the City of Santa Cruz and Soquel Creek Water District began serving Basin water customers along the coast.[3] Each water agency had either been recently formed, acquired small groundwater-dependent water companies to serve its customers, or both. However, at that time neither agency had adequate information on the Basin's groundwater conditions nor its safe yield to serve customer's needs and manage the Basin to prevent seawater intrusion.

As discussed in Section 2.2.2, the first hydrogeological study (Hickey, 1968) in the Soquel-Aptos area identified that there was no seawater intrusion at that time but that it may be close to coming onshore. A follow up study by the USGS in 1980 in response to observed seawater intrusion, found that pumping from the Purisima Formation, averaging about 5,400 acre-feet per year since 1970, had caused groundwater levels along the coast to decline below sea level and allowed seawater to enter the aquifer (Muir, 1980). The report concluded that the potential yields of the two principal aquifers in the Soquel-Aptos area were 4,400 acre-feet per year from the Purisima Formation and 1,500 acre-feet per year from the Aromas Red Sands (Muir, 1980).

Prior to 1980, the water agencies that now make up the MGA believed they were operating within the Basin's safe yield. Since 1980, they have expanded the groundwater monitoring well network to better understand groundwater in the Basin, managed the Basin to prevent seawater intrusion by groundwater pumping redistribution and reducing pumping through water conservation programs, and implemented water pricing and other strategies to promote more efficient water use.

2.2.4.1 Groundwater Elevation Data

2.2.4.1.1 Historical Groundwater Elevations

Long-term overdraft of the Basin has led to ongoing seawater intrusion. The Basin's greatest groundwater level declines were measured in the Purisima BC-unit in 1984 where declines on the order of 140 feet occurred. In 1988, both the Purisima A and DEF-units reached their greatest groundwater level declines of 80 feet and 100 feet respectively.

By 2005, Basin groundwater levels in the Purisima aquifers had recovered somewhat, but were still characterized by a broad and persistent pumping trough surrounding municipal production wells that was below sea level. Groundwater elevation contours in the most productive Purisima aquifer units in fall 2005 showed depressed groundwater levels from 10 to 80 feet below sea level (Figure 2-24 and Figure 2-25). This was a significant improvement over groundwater levels in the 1980s but groundwater levels at the coast still ranged from sea level to 30 feet below sea level. Figure 2-26 shows fall 2005 groundwater contours combined for the Aromas Red Sands and Purisima F-unit aquifers. Only a small area south of the Country Club production well had

[3] Central Water District formed in 1950 to serve the inland areas.

groundwater elevations below sea level. Hydrographs of Aromas and Purisima F-unit wells on Figure 2-17 show that groundwater elevations along the coast were very close to sea level thereby continuing to increase the threat of seawater intrusion in this area.

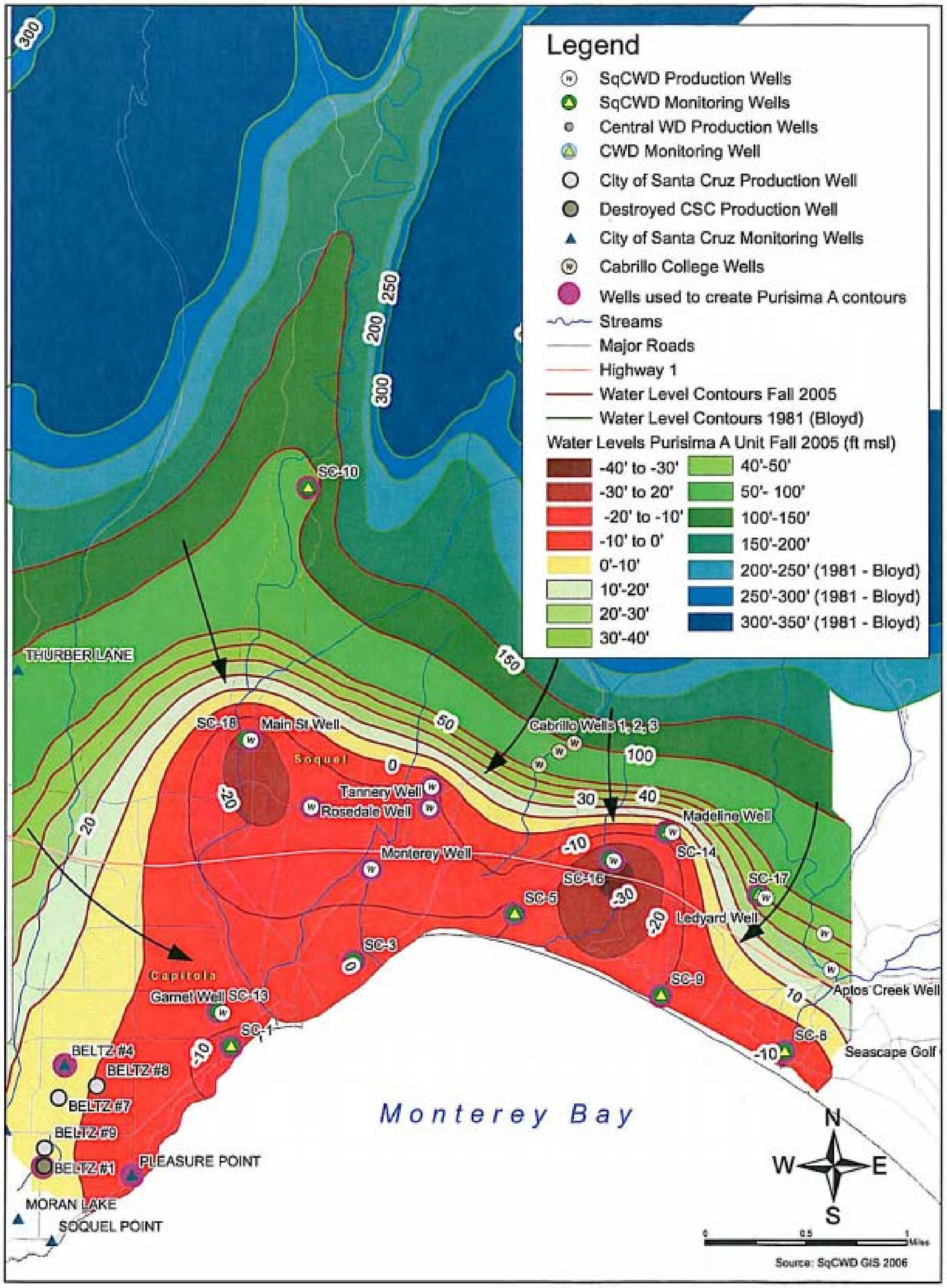


Figure 2-24. Groundwater Elevation Contours in Purisima A-Unit, Fall 2005

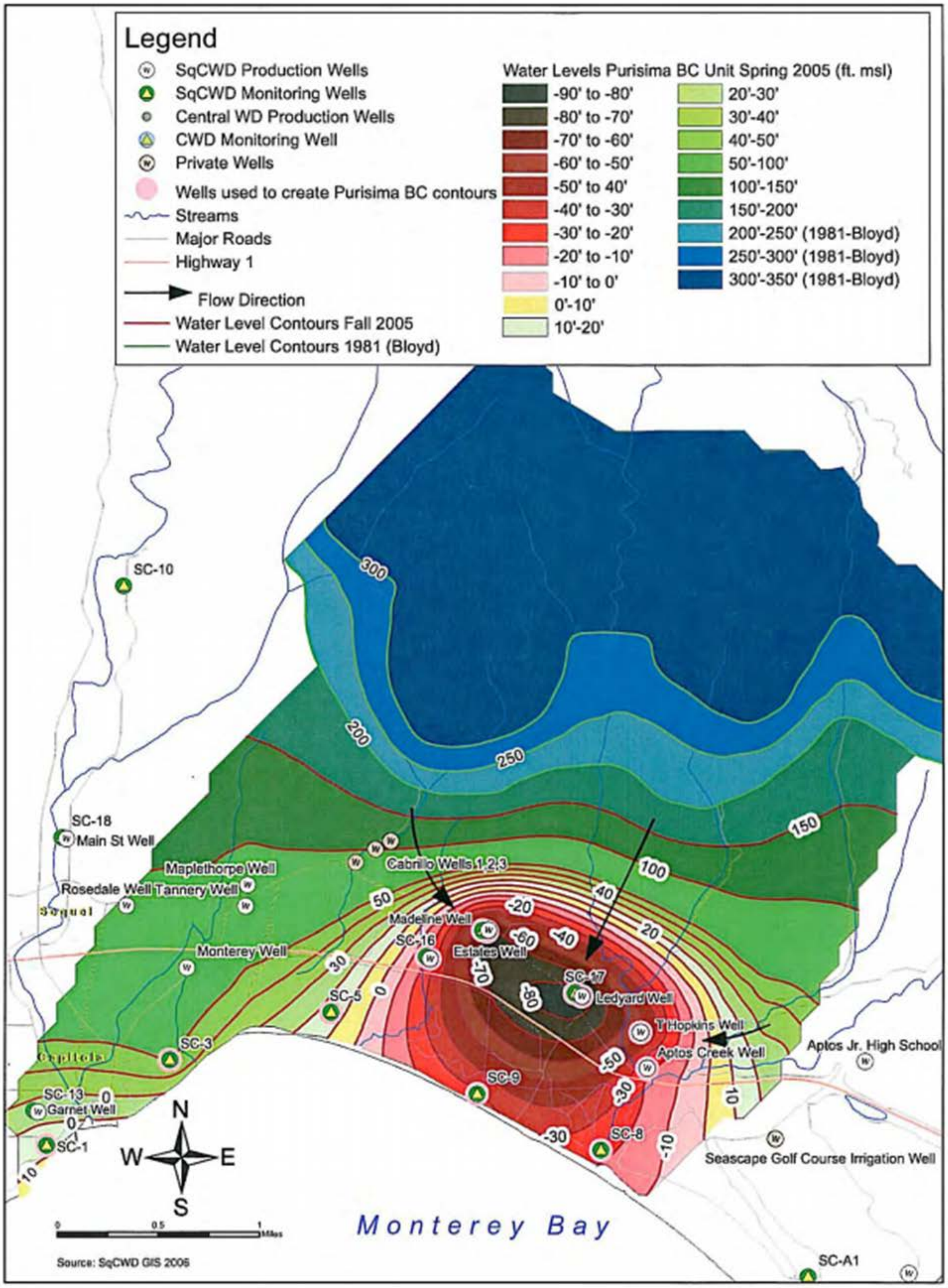


Figure 2-25. Groundwater Elevation Contours in Purisima BC- Unit, Fall 2005

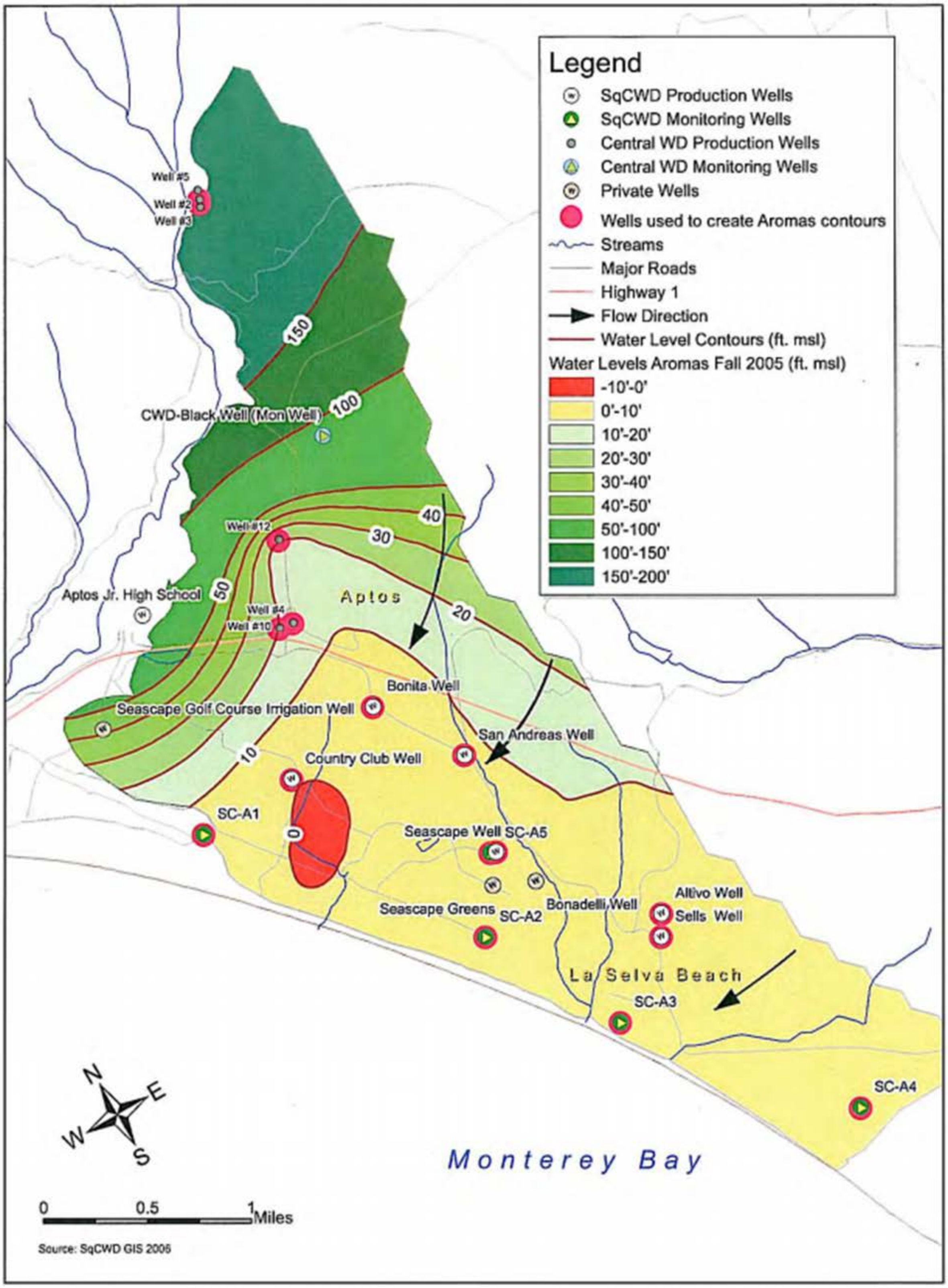


Figure 2-26. Groundwater Elevation Contours in Aromas Red Sands and Pursima F-Unit, Fall 2005

2.2.4.1.2 Current Groundwater Elevations

Tu-Unit

Figure 2-27 shows fall 2016 groundwater elevations in the Tu-unit below the Purisima Formation as a snapshot of groundwater conditions after SqCWD's O'Neill Ranch and the City's Beltz 12 well came online in 2015. Flow tests at these wells indicate that significant flow in these wells comes from the Tu unit (also called the SM unit as it may be Santa Margarita Formation), but pumping tests at these wells showed slow recovery so monitoring groundwater levels in the Tu-unit will be important for assessing the reliability of supply from these wells. Fall groundwater levels were lower than spring groundwater levels in the Tu-unit for Water Year 2016 with Beltz 12 pumping primarily in summer and fall (HydroMetrics WRI, 2017).

Purisima A and AA-Units

Contour maps of groundwater elevations in fall 2016 for the Purisima A and AA-units are shown in Figure 2-28. The contours show that fall coastal groundwater levels in the A-unit are lower than protective elevations in much of the area, with defined pumping depressions inland of the coast around SqCWD production wells. The area of pumping depressions below sea level is limited to the Tannery II well when as recently as Fall 2013, the area of groundwater elevations below sea level extended to the coast at SC-5A and SC-9A.

As inferred from the contour map, groundwater flows towards SqCWD's production wells but flows offshore also occur that reduce risk of seawater intrusion. Groundwater flows from inland toward the coast are intercepted by the City of Santa Cruz's production wells in the most western portion of the Purisima area. The contour map indicates significant flow from the northwest consistent with outcrop areas for the A and AA- units being towards the north and west (Johnson et al., 2004).

Purisima BC-Unit

Contour maps of groundwater elevations in fall 2016 for the Purisima BC-unit are shown in Figure 2-29. Fall 2016 coastal groundwater levels in the Purisima BC-unit were at protective elevations due to recovery in early 2016. Pumping depressions around production wells are shown but are much smaller than previous years. The figures show groundwater flows from all directions including from the coastal area towards the pumping depression in the Purisima BC-unit.

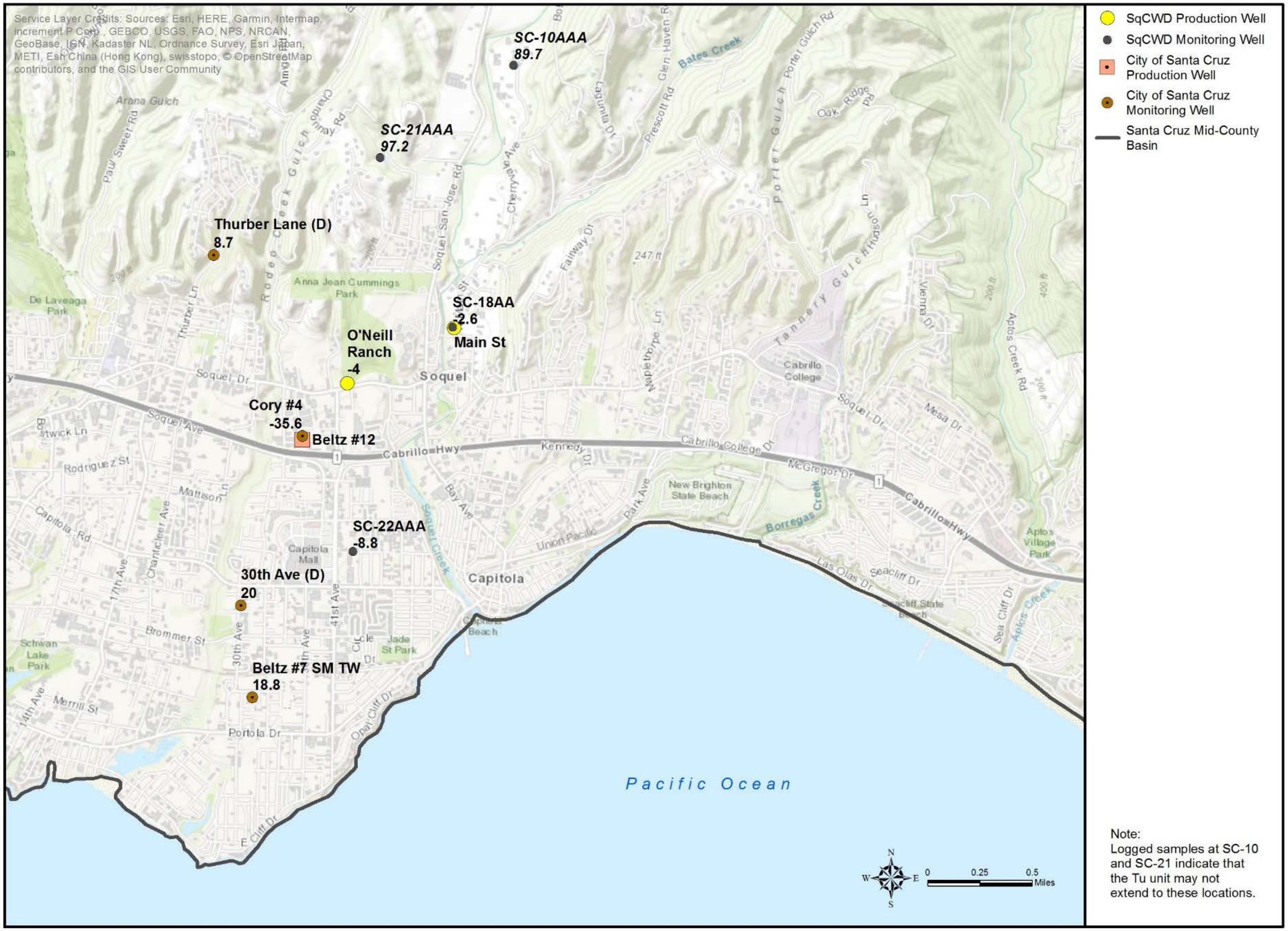


Figure 2-27. Groundwater Elevations in Tu-Unit, Fall 2016

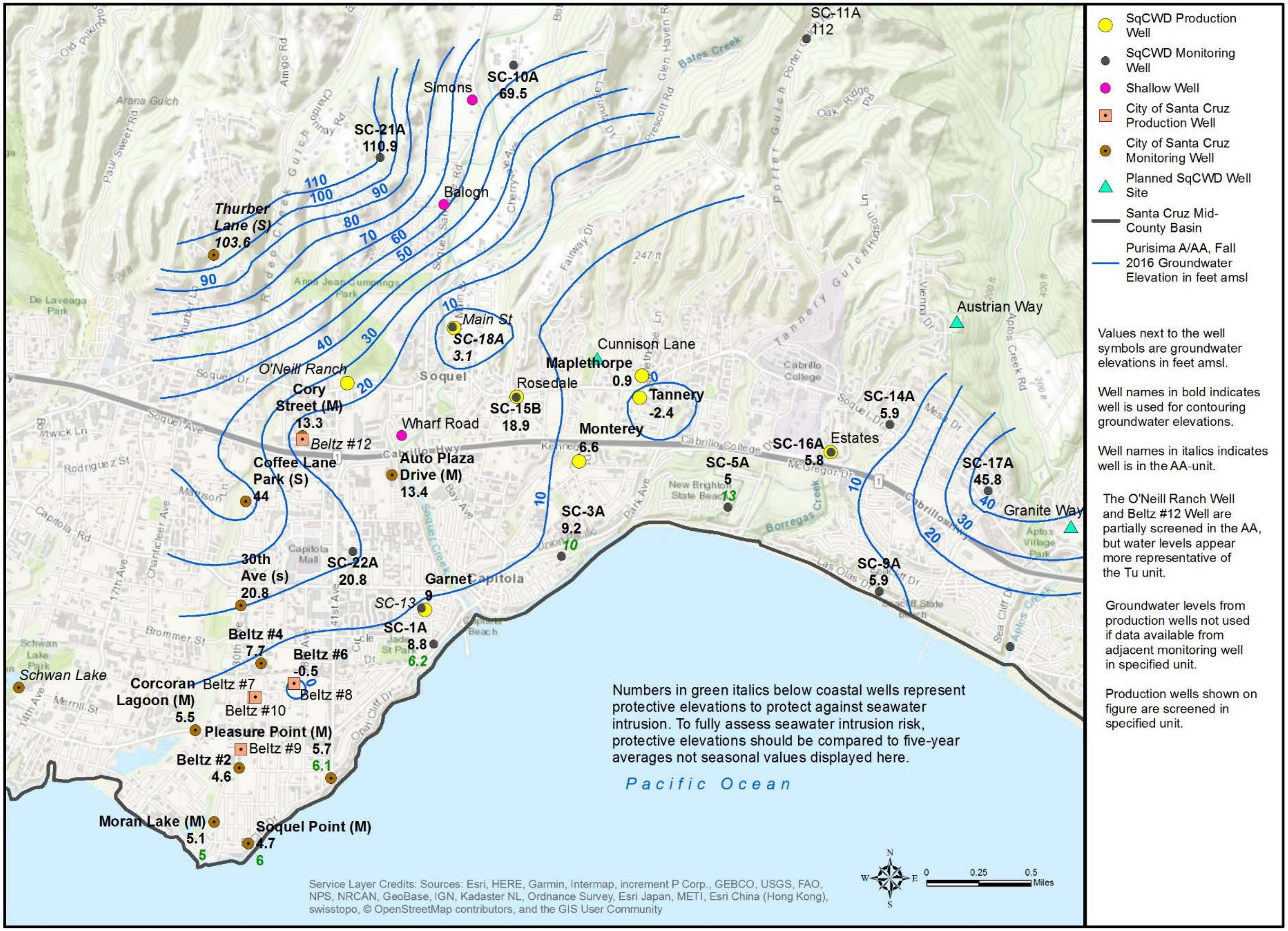


Figure 2-28. Groundwater Elevation Contours in Purisima A and AA-Unit, Fall 2016

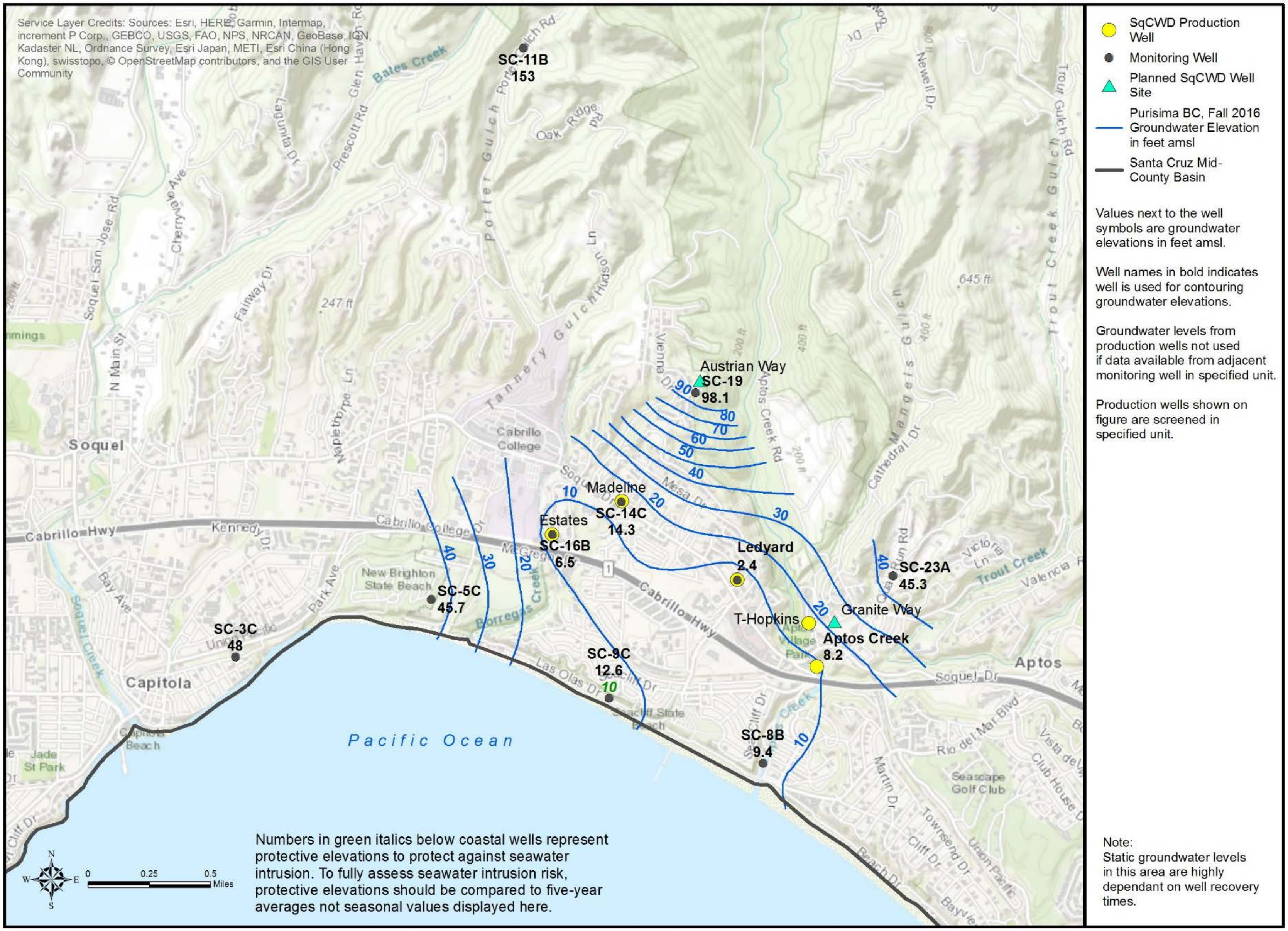


Figure 2-29. Groundwater Elevation Contours in Purisima BC-Unit, Fall 2016

Purisima DEF/F-Units

Contour maps of Purisima DEF/F-units groundwater elevations in fall 2016 are shown in Figure 2-30. The western area with SC-9, SC-8, T. Hopkins, and SC-23 wells represent the deeper Purisima DEF-unit groundwater levels. Figure 2-30 shows that the fall 2016 coastal groundwater levels in the Purisima DEF-unit were above protective elevations due to recovery in early 2016. Groundwater flows towards a pumping depression at the T. Hopkins well but flows offshore are also shown that reduce risk of seawater intrusion.

The contour map of groundwater elevations of the Purisima DEF and F-units (Figure 2-30) overlaps somewhat with the groundwater elevations shown on Figure 2-31 for the Aromas Red Sands. Figure 2-30's eastern area that includes SqCWD's Service Area 3 and Service Area 4 production wells and CWD's production wells represent the shallower Purisima F-unit groundwater levels. SqCWD's Aptos Jr. High and Polo Grounds wells and CWD's Cox well field (#3 and #5) are completed in the Purisima F-unit but do not underlie the Aromas Red Sands and a pumping depression at the Polo Grounds well is evident on Figure 2-30. East of this area, the Purisima F-unit mostly underlies Aromas Red Sands. Pumping depressions are evident at CWD #12 as well as between Country Club and San Andreas wells where production wells are screened in both the F unit and Aromas Red Sands. Groundwater flows towards production wells but also toward the coast that helps reduce risk of further seawater intrusion into the Purisima F-unit.

Groundwater generally flows from the hills to the ocean with some of the flow pattern altered by pumping. There also appears to be a groundwater flow divide south and east of SqCWD and CWD. South and east of this divide, groundwater flows to Pajaro Valley. There is also a surface watershed divide in this area.

Aromas Red Sands

A contour map of groundwater elevations in fall 2016 for the Aromas Red Sands are shown in Figure 2-31. The contour map shows that groundwater levels were mostly above sea level, with coastal groundwater levels below protective elevations for some of the coast. Groundwater flows toward the coast where it is partially intercepted by SqCWD's Country Club and San Andreas production wells. These flows may not be sufficient to prevent seawater intrusion as coastal groundwater levels are sometimes below protective elevations.

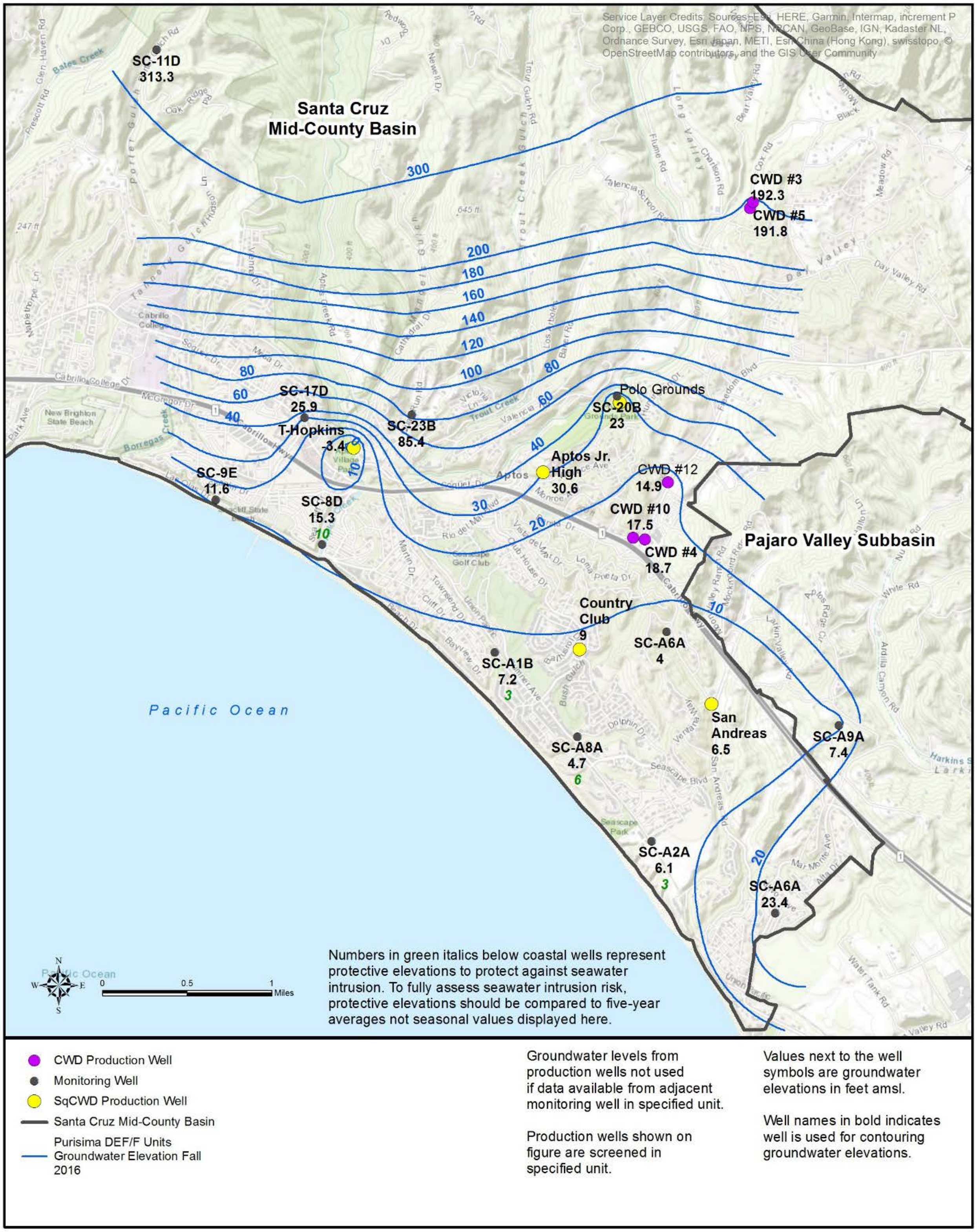


Figure 2-30. Groundwater Elevation Contours in Purisima DEF/F-Unit, Fall 2016

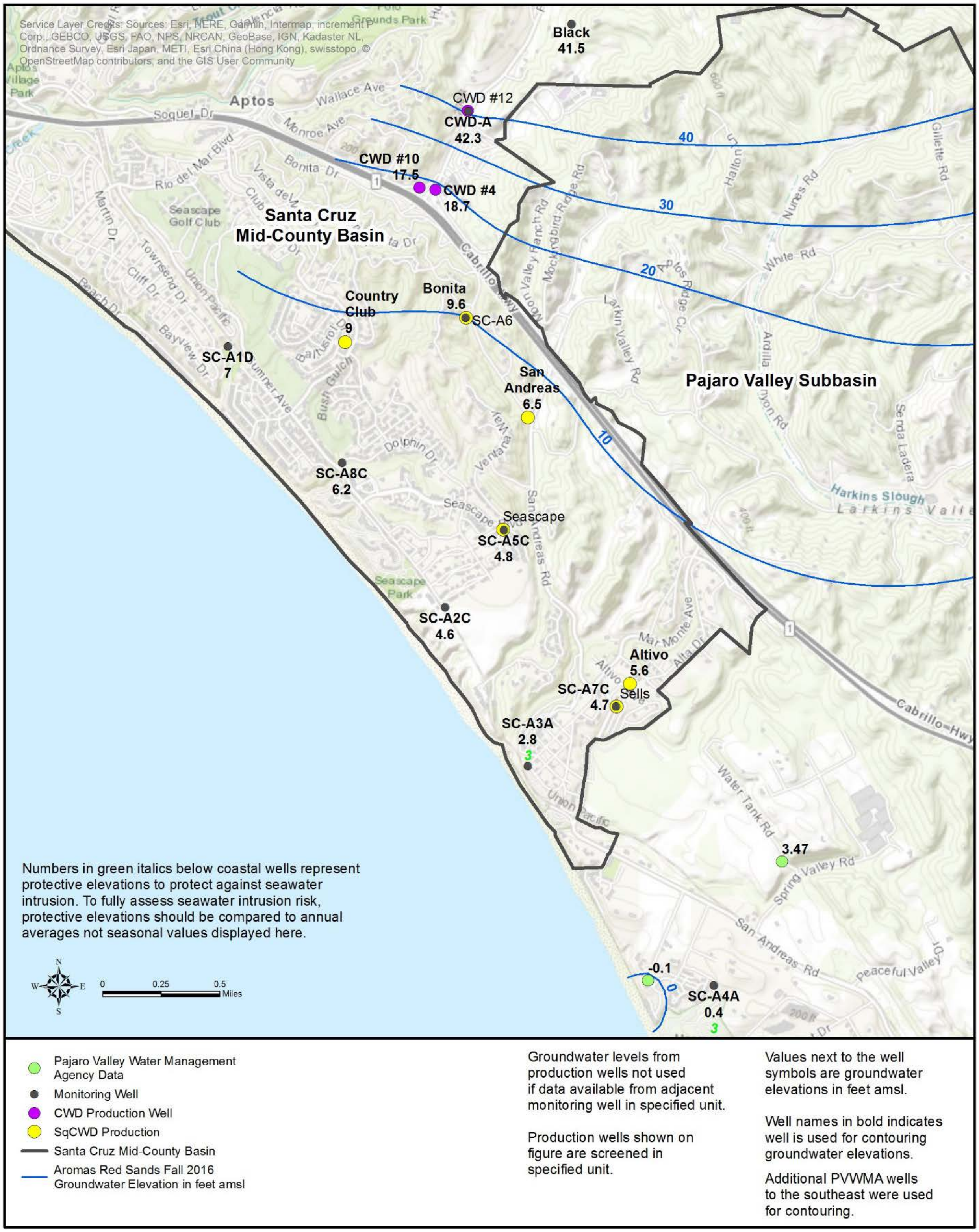


Figure 2-31. Groundwater Elevation Contours in the Aromas Area, Fall 2016

2.2.4.1.3 Groundwater Level Trends

Long-Term Groundwater Level Trends

Over the past 30 years, and especially in the past ten years, groundwater levels in the Basin have recovered from dramatically low levels in the 1980s to the highest measured groundwater conditions in Water Year 2017. The hydrographs on Figure 2-17 describe a history of over-production followed by sustained recovery:

- Declining groundwater levels as groundwater demand increased through 1988.
- Municipal groundwater demand peaked during the period from 1989 - 2004. Also during this period, there was a drought from 1984 through 1992. Together, high demand and drought caused groundwater levels to decline to historic lows measured in 1992/1993.
- In 2005, groundwater demand dropped and stayed fairly constant until 2009. Groundwater recovery started with two consecutive years of above average rainfall in 2005/2006. The economic recession starting around 2008 and further reduced water demand, possibly contributing to recovering groundwater levels during the period of below average rainfall from 2007-2009.
- A further drop in groundwater demand took place in 2010. Since 2010, groundwater demand has been less than previous years. Interestingly, the first two years of the recent drought (2012 and 2013) had increased demand, which is typical when there is below average rainfall. More recently there has been recovery of groundwater levels from 2014 through 2017. The 2014/2015 drop in demand and associated increase in groundwater levels corresponds with increased statewide water restrictions due to the 2012-2015 drought.

Operational changes in the Basin show that the most influential factor in changing coastal groundwater levels is changing the amount of groundwater pumping in high yielding municipal supply wells. Recharge from rainfall generally has a less immediate effect on coastal groundwater levels because most aquifers are confined by less permeable layers, and areas where the aquifers are exposed at the surface and can be directly recharged are limited.

Short-Term Groundwater Level Trends

As a result of ongoing long-term recovery starting in 2005 and an acceleration of recovery in Water Years 2015-2016[4], by 2016 groundwater levels in the Purisima Formation were at their highest elevations since the groundwater monitoring network was installed. In the same locations where the 2005 pumping depression was previously located, groundwater levels had risen to between 2.4 feet below sea level to 6 feet above sea level, and 2016 groundwater elevations were above sea level in all coastal monitoring wells. Figure 2-32 shows five-year average groundwater level trends between 2012 and 2016. The round symbols indicate recovery continued in much of the Basin, particularly along the coast, during the 2011-2015 drought.

[4] California Water Years run from October 1 to September 30 of each year.

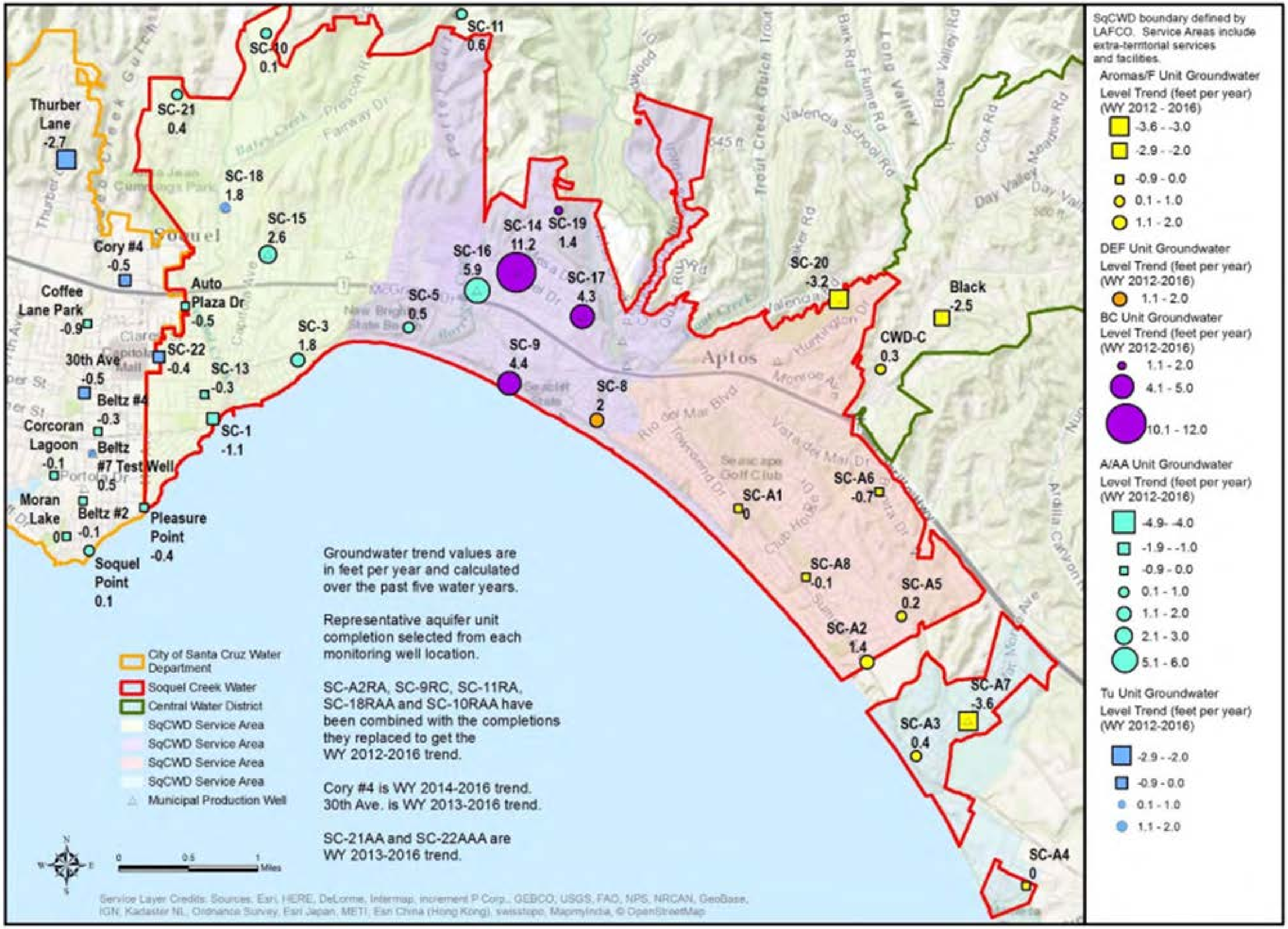


Figure 2-32. 2012-2016 Groundwater Level Trends

Much of this accelerated recovery is attributed to longstanding water conservation by Basin residents and by increasingly severe water use curtailment within the Basin, especially during the 2011-2015 drought. In Water Year 2015, Soquel Creek Water District and the City of Santa Cruz continued Stage 3 water shortage emergency with a drought curtailment target of 25% and Central Water District continued a Stage 2 water shortage alert with a drought curtailment target of 20%.

In Water Year 2016, the lower than average rainfall over the preceding five years led Soquel Creek Water District and Central Water District to maintain these curtailment targets. On-going water use curtailments in Water Years 2015 and 2016, resulted in municipal production of 4,121 and 3,928 acre-feet respectively which were the lowest municipal pumping totals since 1977.

Water Year 2017 was a very wet year, with the highest groundwater elevations seen within the Basin since coastal groundwater monitoring began. However, Water Year 2018, was a dry year with some increases in pumping since the State declared an end to the 2011-2015 drought. Drought restriction were lifted at the state level and within the City of Santa Cruz, however, SqCWD has remained at Stage 3 water usage curtailment because of risk of seawater intrusion. Since coastal groundwater elevations peaked in 2017, Basin groundwater levels have declined between 0.4 to 4.0 feet in the coastal monitoring wells.

2.2.4.1.4 Protective Elevations and How They Are Used to Evaluate Current Groundwater Levels

Prior to SGMA, local water agencies focused their Basin management activities on raising groundwater levels at the coast to control seawater intrusion. Seawater intrusion is the primary threat to Basin water supply. In response to the 1980 USGS study (Muir, 1980) an extensive groundwater monitoring well network was developed throughout the Basin during the 1980s to better assess groundwater conditions, especially at the coast.

Figure 2-33 shows the 13 key coastal monitoring well locations used to assess the risk of seawater intrusion and the status of groundwater recovery in the Basin. These keys wells include three City of Santa Cruz wells in the Purisima Formation (Moran Lake Medium, Soquel Point Medium, and Pleasure Point Medium), five Soquel Creek Water District wells in the Purisima Formation (SC-1A, SC-3A, SC-5A, SC-9C and SC-8D), and five Soquel Creek Water District well clusters in the Aromas area (SC-A1A and B, SC-A8A and B, SC-A2A and B, SC-A3A and B, and SC-A4A and B).

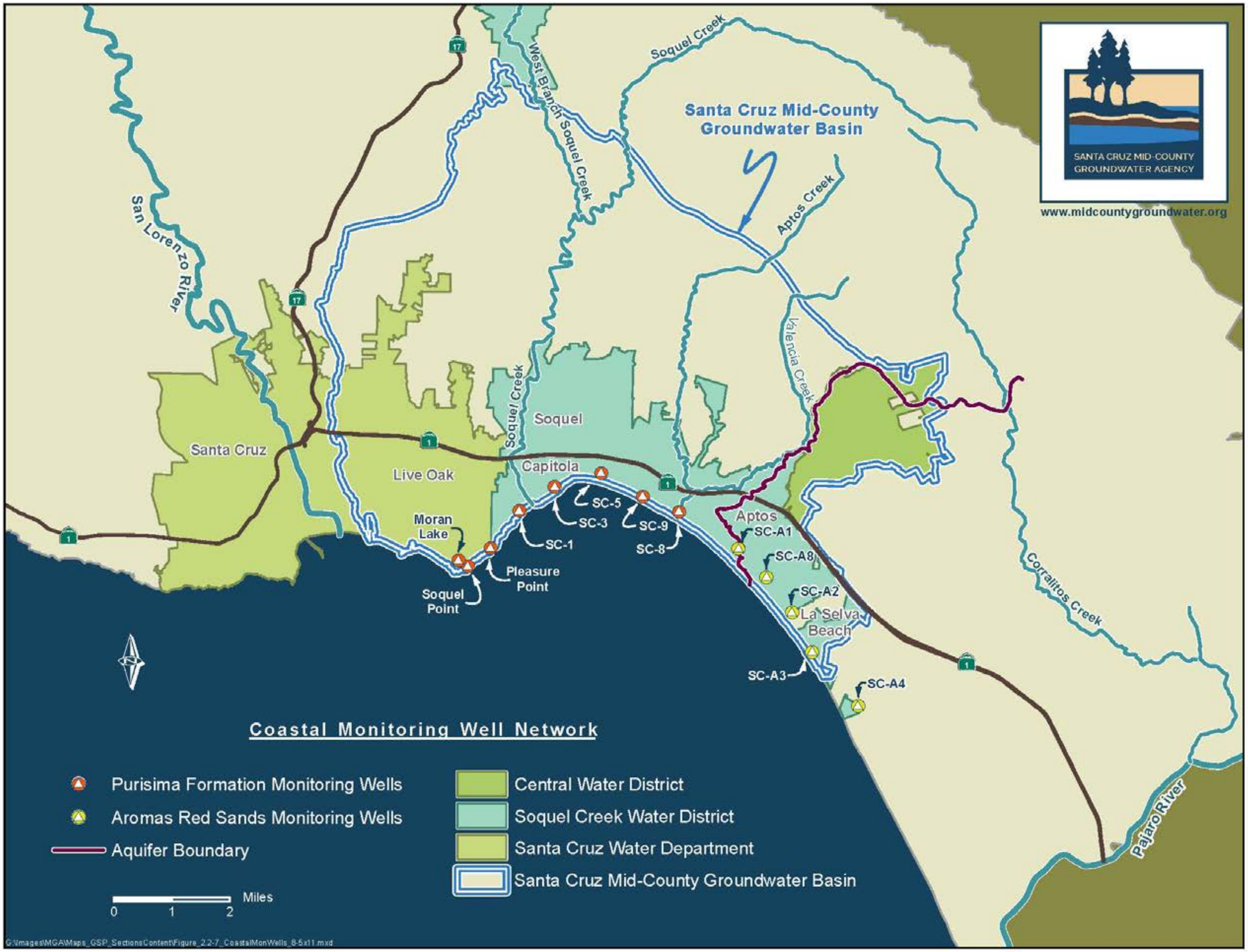


Figure 2-33. Location of Coastal Monitoring Wells

Soquel Creek Water District and the City of Santa Cruz have established protective groundwater elevations[5] for each coastal monitoring well. Groundwater levels are used to measure progress in preventing seawater intrusion. Because salt water is heavier than fresh water, groundwater elevations must be above sea level to have sufficient hydraulic head to keep seawater off shore and out of the Basin's productive aquifers.

Protective groundwater elevations are set for each individual coastal monitoring well completion[6] as determined to be feasible to protect the aquifer at that location against seawater intrusion. Groundwater elevations persistently below protective elevations are expected to lead to seawater intrusion over time and indicate overdraft conditions. Table 2-5 compares annual average 2018 groundwater elevations with protective groundwater elevations.

Table 2-5. Groundwater Level Averages Calculated from Logger Data at Coastal Monitoring Wells

Well	Data Through	365 Day Average (ft amsl)	Protective Elevation (ft amsl)	Percent Runs Protective
Moran Lake Medium	9/30/2018	6.0	5.0	>GH[7]
Soquel Point Medium	9/30/2018	5.4	6.0	<GH
Pleasure Point Medium	9/30/2018	8.6	6.1	>GH
SC-1A	9/30/2018	10.2	6.2 (4*)	>99
SC-3A	9/30/2018	10.6	10	>70
SC-5A	9/30/2018	9.5	13	<50
SC-9C	9/30/2018	9.5	10	<70
SC-8D	6/5/2018	13.3	10	>99
SC-A1B	9/30/2018	7.9	3	>99
SC-A8A	9/30/2018	4.9	6	<50
SC-A2A	9/30/2018	6.6	3	>99
SC-A3A	9/30/2018	2.8	3	<60
SC-A4A**	9/30/2018	1.4	3	<50

* The protective elevation based on 70th percentile of cross-sectional models at SC-1A is 4 feet above mean sea level.
** SC-A4A is in the Pajaro Valley Subbasin, not the Santa Cruz Mid-County Basin.
ft amsl = feet above mean sea level

[5] The freshwater elevation set at a particular monitoring well location necessary to prevent seawater intrusion with a certain level of certainty at that location. Protective elevations are set in response to geologic conditions and depend on scientific estimates and policy decisions related to feasibility.
[6] Monitoring wells clusters in the Aromas have completions at multiple depths to allow sample collection and evaluation of water from different elevations within this unconfined coastal aquifer.
[7] Protective elevations at City of Santa Cruz wells based on Ghyben-Herzberg (GH) relationship as opposed to 100 sets of cross-sectional model runs so percentage runs protective are not calculated. Instead, it is noted whether 365 day average is greater or less than Ghyben-Herzberg calculation.

Through September 30, 2018, coastal monitoring wells in the Purisima with annual averages above the protective elevations are: Moran Lake, Pleasure Point, SC-1A, SC-3A, and SC-8D. Coastal monitoring wells in the Aromas with yearly averages above protective elevations are SC-A1 and SC-A2. Annual averages for the same time period are below protective elevations in the Purisima at Soquel Point, SC-5A, and SC-9C. Coastal monitoring wells in the Aromas with groundwater elevations below protective levels are: SC-A8A, and SC-A3A. Until all wells meet or exceed protective elevations the Basin will continue to be in critical overdraft due to seawater intrusion.

2.2.4.2 Change in Groundwater in Storage

The amount of groundwater in storage in the Basin generally reflects changes in groundwater elevations over time as described in Section 0. Figure 2-34 shows the model simulated change in storage from Water Year 1985 through 2015. Groundwater elevations were at their lowest between the 1980s and 1997 when municipal groundwater pumping was between 5,000 and 7,000 acre-feet per year and overall Basin groundwater pumping was estimated at between 7,000 and 9,000 acre-feet per year. Figure 2-34 shows how groundwater was consistently lost from storage each year from 1985 to 1992. Three years of fairly balanced conditions marked the start of ten significant years of groundwater storage recovery of the Basin from 1995 through 2006. In 1997 municipal pumping declined to approximately 5,000 acre-feet per year.

Over the period from 2009 through 2011, although there were both loses and gains in storage due to below average rainfall, there was no overall cumulative change. Despite slight overall Basin storage declines over the drought period from 2012 through 2015, groundwater elevations at the coast increased due to water conservation efforts and redistribution of pumping.

2.2.4.3 Seawater Intrusion

Historically, seawater intrusion has been documented at Soquel Point in the Purisima A- and has been consistently detected at deep monitoring wells in all coastal monitoring clusters in the Aromas area (in both Purisima F-unit and Aromas Red Sands aquifers). With the exception of monitoring well cluster SC-A1, coastal monitoring clusters in the Aromas area were installed with their deepest completion intentionally located below the freshwater-saltwater interface to monitor increases in chloride concentrations. Chloride data from Water Year 2018 shows that the extent of seawater intrusion has remained the same over the past few years (Figure 2-35). Coastal well locations where seawater intrusion has not been observed continue to show no indication of seawater intrusion. Groundwater quality where seawater intrusion has been observed is either stable or improving with the exception of one well. At SC-A2B, an increasing trend has been observed over the last two years and the latest sample exceeded the minimum threshold that is set for this well as part of the Basin's sustainable management criteria in Section 3. If any of the following three samples at SC-A2B exceed the minimum threshold, this would be considered an undesirable result based on the sustainable management criteria proposal contained in this GSP.

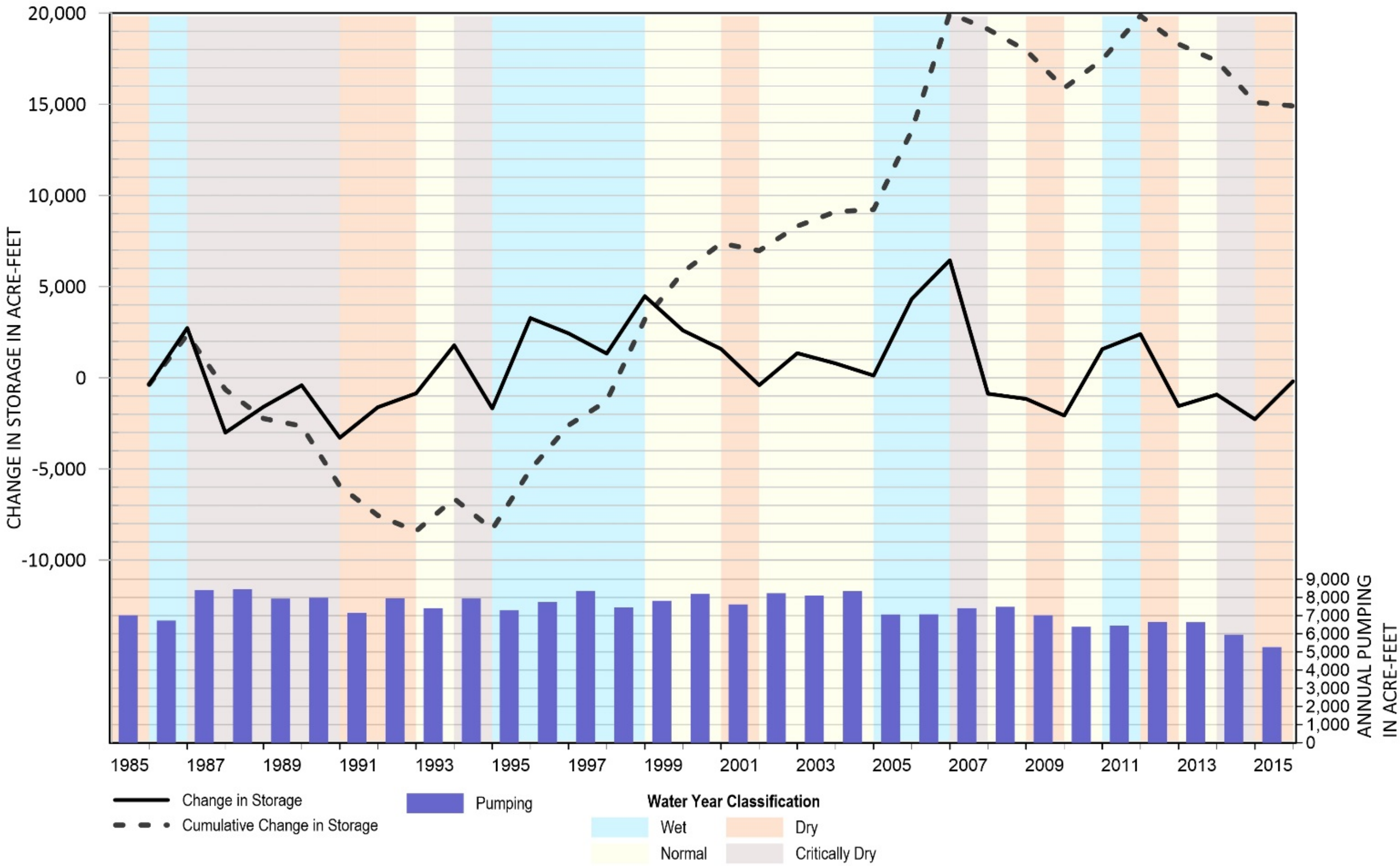


Figure 2-34. Cumulative Change in Groundwater in Storage

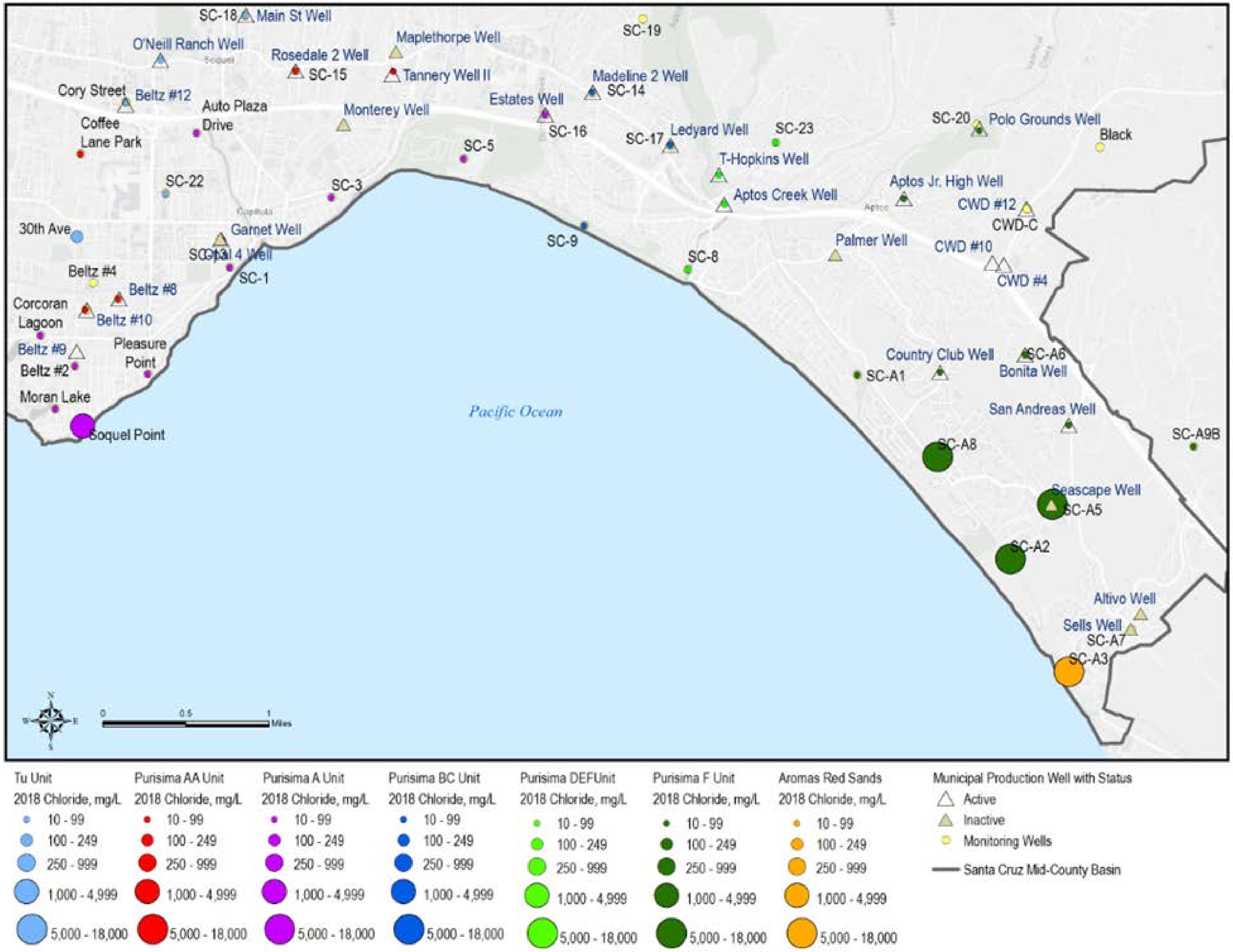


Figure 2-35. Water Year 2018 Chloride Concentrations

The Basin has one instance of seawater intrusion reversal. When the City of Santa Cruz's Moran Lake monitoring well was installed in 2005, the Medium well depth completion in the Purisima-A unit had chloride concentrations at levels indicating seawater intrusion (700 mg/L) Since 2005, average groundwater levels in the well have been at or above the protective elevation calculated for the well, and chloride concentrations have consistently dropped to concentrations now at 78 mg/L (Figure 2-36). This indicates that groundwater levels meeting protective elevations can reverse seawater intrusion. Although, groundwater levels were already above protective elevations at the time of the well's installation, there are data from nearby Beltz #2 well showing how low groundwater levels in 1995 correspond with a period of increased City of Santa Cruz pumping. The lower than normal groundwater levels associated with increased pumping are thought to have resulted in an increase of chloride concentrations over at least a five-year period. As groundwater levels rose with a reduction in City pumping by more than 50%, chloride concentrations at Beltz #2 declined after 1994 showing the beginning of seawater intrusion reversal that continues to be observed at the Moran Lake monitoring well (inset and overlay on Figure 2-36).

In May of 2017, when groundwater elevations were at historic highs, the MGA contracted the firms SkyTEM and Ramboll to fill seawater intrusion data gaps offshore of and between coastal monitoring network locations. SkyTEM used a helicopter to carry electronic geophysical equipment to survey the resistivity of subsurface geology over the coast and a mile off shore to look for areas of salty water in the land beneath the ocean. The survey identified seawater intrusion just offshore of the Basin's unintruded coastal aquifers and confirmed the location and extent of known seawater intrusion in the productive aquifer units at the Basin's coastal margins. Further review by MGA consultant's, HydroMetrics WRI, of the information provided in the Ramboll report identified areas near Soquel Point, New Brighton, Rio Del Mar and La Selva as facing the greatest potential for future seawater intrusion in the Basin (Figure 2-37).

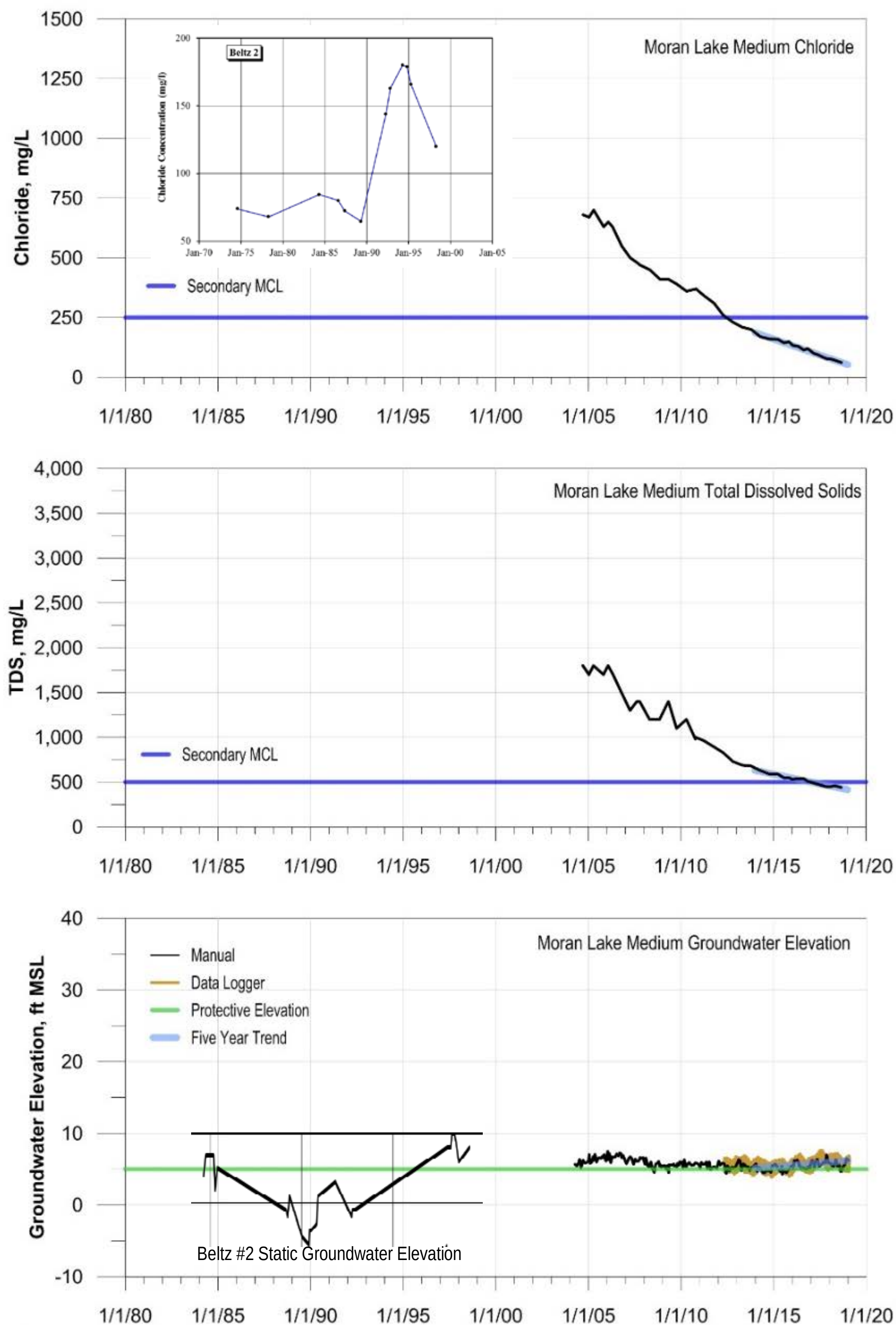


Figure 2-36. Hydrograph and Chemograph of Moran Lake Medium Well (Montgomery & Associates, 2019) Overlain by Hydrograph and Inset Chemograph of Beltz #2 Well (Johnson et al., 2004)

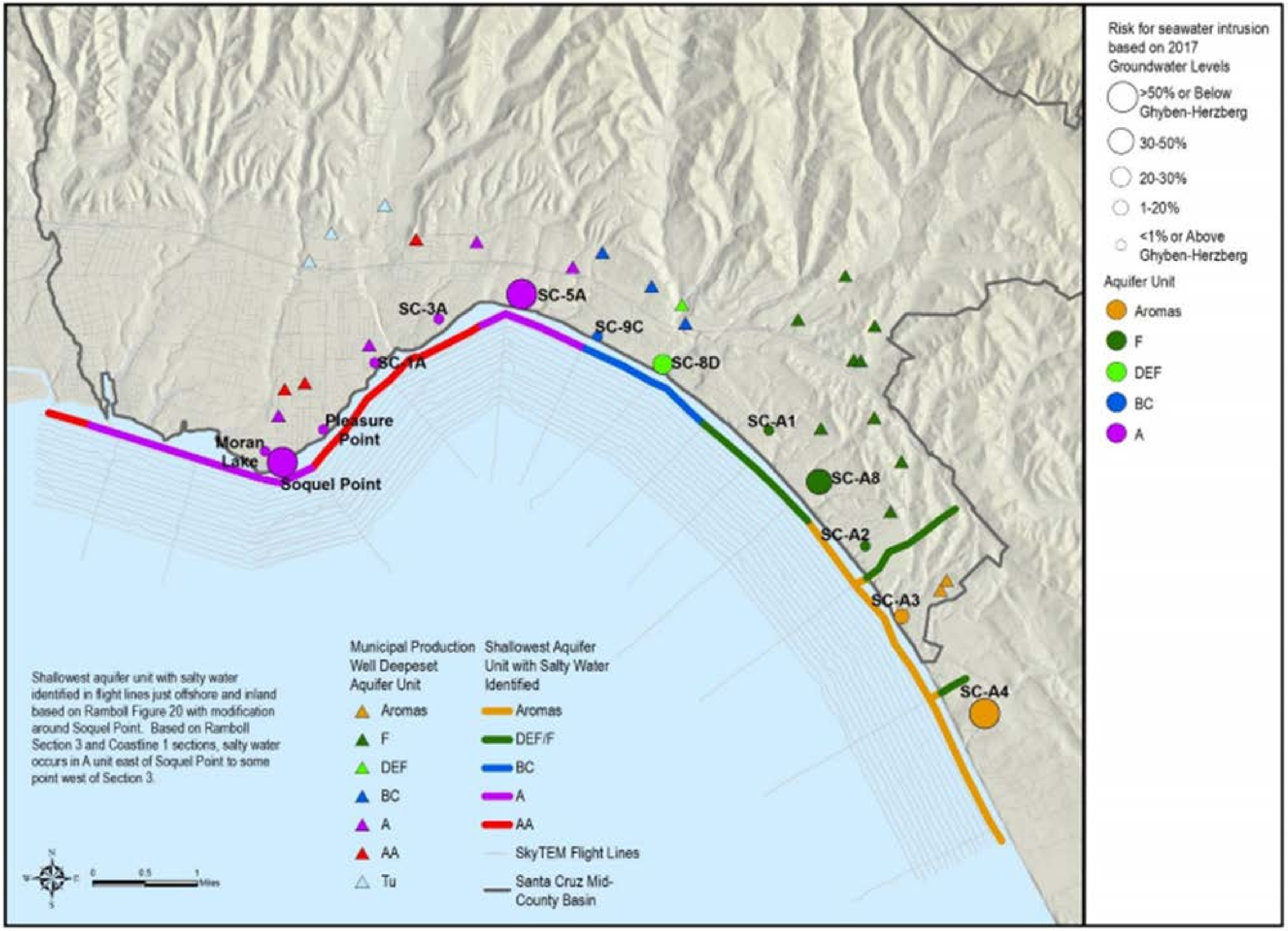


Figure 2-37. Water Year 2017 Risk of Seawater Intrusion into Pumped Aquifer Units Based on Groundwater Levels and SkyTEM Data on Shallowest Aquifer Unit with Salty Water Just Offshore

2.2.4.4 Groundwater Quality

Groundwater produced in the Basin is generally of good quality and does not regularly exceed primary drinking water standards. A few naturally occurring constituents, including iron and manganese exceed drinking water standards in parts of the Basin. As previously mentioned, some coastal monitoring wells have elevated chloride and TDS concentrations associated with seawater intrusion.

Treated groundwater delivered by MGA member municipal water agencies meets or exceeds all state and federal drinking water parameters. The municipal water agencies routinely analyze their untreated groundwater to determine the groundwater quality of the Basin and to comply with state water quality reporting requirements. Groundwater quality parameters analyzed include general minerals, general physical parameters, and organic/inorganic compounds. Analyses for these constituents are conducted in accordance with requirements of the California Code of Regulations, Title 22. Groundwater quality results are compared to primary and secondary drinking water standards, established by the U.S. Environmental Protection Agency (USEPA), and water quality standards established by the California State Water Resources Control Board's Division of Drinking Water (DDW).

Primary drinking water standards are concentrations that, in the judgment of the State Water Resources Control Board (SWRCB), may have an adverse effect on human health. Secondary standards are set for aesthetic concerns for constituents that are not health threatening, but public water systems still test and treat their water for these constituents to meet secondary standards, unless they obtain a waiver. Exceeding secondary standards may cause effects which do not damage the body but are still undesirable. These undesirable effects may include water tastes or odors, damage to water equipment, or reduced effectiveness of treatment for other constituents.

Private domestic use wells are not subject to DDW drinking water regulations. However, the County of Santa Cruz requires one-time testing of nitrate, total dissolved solids (TDS), chloride, iron and manganese for any new non-municipal well. Small water systems that supply groundwater to 15 – 199 service connections also report water quality to the County and the Public Utilities Commission (PUC) for PUC regulated systems. These water quality constituents include: inorganics, nitrates, arsenic, perchlorate, chromium, radiation, synthetic organic compounds, and volatile organic compounds (including methyl tertiary-butyl ether (MTBE)). The frequency of reporting ranges between one year and nine years depending on the constituents. Smaller water systems of between 5 – 14 service connections have limited one-time testing requirements for inorganics.

2.2.4.4.1 Natural Groundwater Quality

Total Dissolved Solids (TDS) and Chloride Concentrations

TDS concentrations measured in production wells in the Purisima aquifers have historically ranged between 270 and 740 mg/L. TDS concentrations measured in municipal production wells in the Aromas Red Sands aquifer have historically ranged between 95 and 470 mg/L. Inland non-municipal wells typically have TDS concentrations between 210 and 480 mg/L. The secondary maximum contaminant level for TDS is 1,000 mg/L. There is a small water system well near Pot Belly Beach Club, east of New Brighton State Beach, that historically had TDS concentrations close to 1,000 mg/L since at least 1994, but there is no increasing trend.

Chloride concentrations measured in production wells in the Purisima Formation have typically ranged between 10 and 100 mg/L. Chloride concentrations measured in production wells in the Aromas aquifer have historically ranged between 8 and 58 mg/L. Inland private wells generally do not have chloride concentrations greater than 20 mg/L. The secondary maximum contaminant level for chloride is 250 mg/L. The private well at Pot Belly Beach Club has historically had chloride concentrations no higher than 140 mg/L.

TDS and chloride concentrations in municipal production wells do not indicate any impacts from seawater intrusion. Chloride in groundwater that is associated with seawater intrusion is addressed separately from overall water quality by the seawater intrusion sustainability indicator. The only changes in TDS and chloride trends that have been observed in the Basin are associated with seawater intrusion discussed in Sections 2.2.4.3 and 3.6.

Iron and Manganese

Groundwater in the Purisima Formation regularly has iron and/or manganese concentrations above secondary drinking water standards of 300 *µg*/L and 50 *µg*/L, respectively. Production wells with elevated iron concentrations can reach 3,000 *µg*/L, and manganese can reach up to 600 µg/L. Both iron and manganese occur naturally in the Purisima Formation as a result of the dissolution of metals within the aquifer. Concentrations within a well can fluctuate greatly and may range by two orders of magnitude. The secondary drinking standards are based on aesthetics so iron and manganese at the concentrations found in the Basin can result in discoloration of the water. Neither constituent poses a major health concern at the levels found within the Basin, however, manganese has a DDW health-based Notification Level of 500 *µg*/L based on neurotoxic risk.. Because iron and manganese are naturally occurring, there have been no increasing trends in their concentrations. Groundwater pumped from the Purisima Formation for municipal purposes is treated to reduce iron and manganese levels prior to distribution.

The Aromas Red Sands aquifer does not have iron and manganese concentrations above secondary drinking water standards.

Arsenic

Arsenic concentrations of up to 5.5 *µg*/L are regularly detected at two municipal water supply wells that produce groundwater from the Purisima Formation, near Aptos Village. All concentrations are below the state drinking water standard of 10 *µg*/L.

Soquel Creek Water District conducted a special investigation of the low concentrations of arsenic in 2003 and concluded that the arsenic detections are most likely associated with the natural occurrence of arsenic resulting from the depositional and geochemical conditions in the coastal environment. Desorption or dissolution of arsenic oxyanions from iron oxide appears to be the most common cause of arsenic in groundwater. Managed aquifer recharge projects can cause dissolution and mobilization of arsenic in the aquifer that may increase the arsenic concentrations above drinking water standards.

There have been no increasing arsenic concentration trends in affected wells because the source of arsenic occurs naturally within the sediments and is not being added from a contamination point source.

Chromium VI

Chromium is a naturally occurring metallic element that can be found naturally in water, soil, and rocks, but it may also occur in groundwater due to industrial contamination. In water, chromium exists either in its more reduced form, trivalent chromium (chromium III), or its more oxidized form, hexavalent chromium (chromium VI). Chromium III is an essential nutrient; however, chromium VI may pose a potential public health risk, even when present at low levels. Inhalation of chromium VI is known to cause cancer in humans and is likely to be more toxic when inhaled than when ingested. Studies indicate that most of the total chromium in the Basin comprises chromium VI.

Chromium VI, from natural sources, has been detected at concentrations ranging between 5 and 40 µg/L in the coastal Aromas aquifer where both SqCWD and Central Water District (CWD) have production wells. These concentrations are below the current state drinking water standard of 50 µg/L for total chromium. A lower chromium VI standard of 10 µg/L, set by the SWRCB regulations in July 2014 was deleted by a Sacramento trial court in May 2017 because the SWRCB failed to address the economic concerns of small water systems before setting the chromium VI standard. However, the state may adopt a drinking water standard lower than 50 µg/L in the near future. There have been no increasing chromium VI concentration trends in affected wells.

Where the overlying Aromas aquifer has elevated chromium VI concentrations, the underlying Purisima F unit sometimes has very low detections of chromium VI. Groundwater in other Purisima Formation units does not have detectable chromium VI.

2.2.4.4.2 Contaminated Groundwater Quality

The locations of known contaminant sites in 2018 are identified on Figure 2-38. Basin groundwater is primarily pumped from confined aquifer units deeper than the contamination at these sites. Thus, the likelihood that groundwater pumping induces contaminant plume movement towards water supply wells is relatively small. Several constituents of concern are discussed further below.

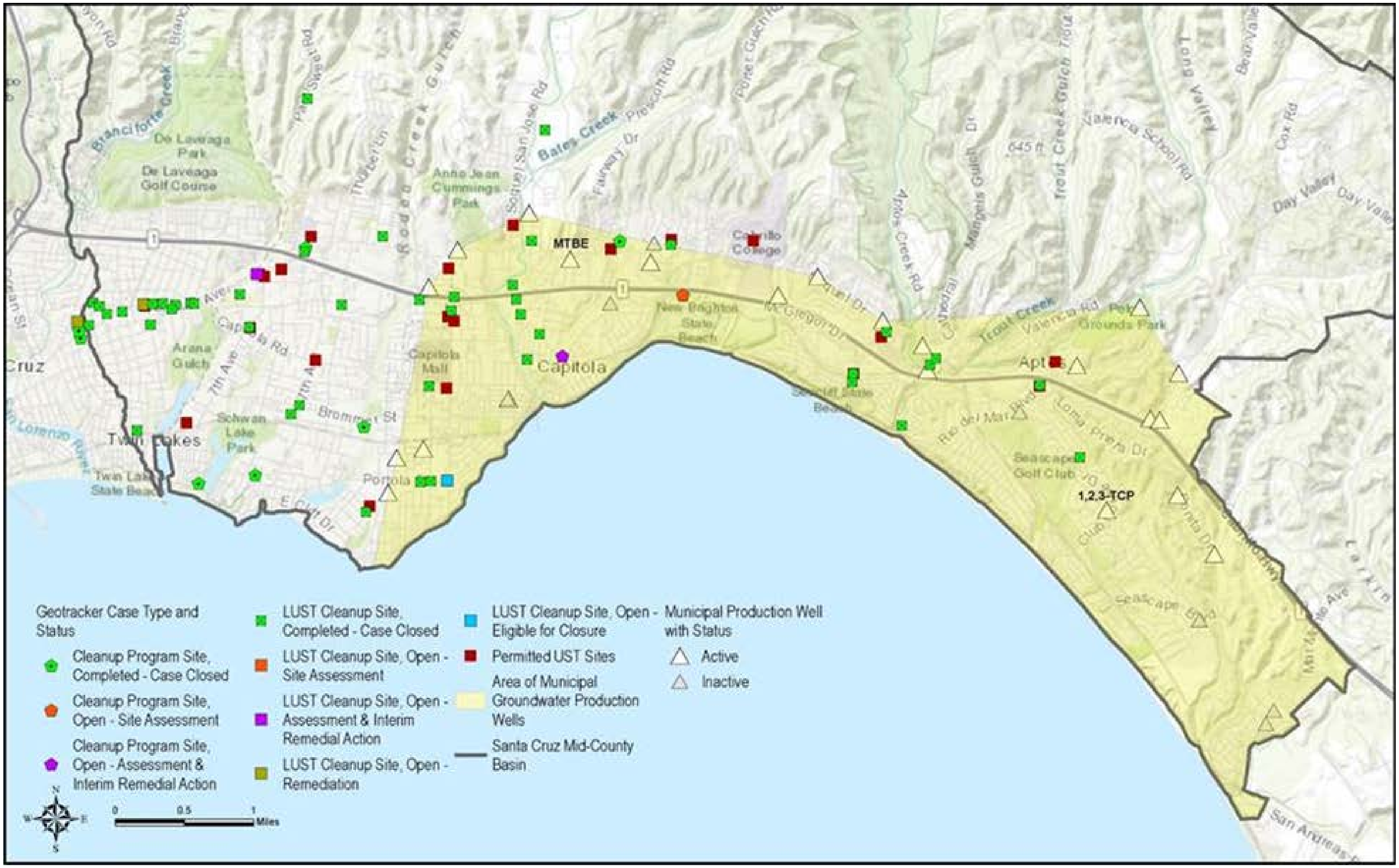


Figure 2-38. Known Contaminant Locations

Nitrates

Nitrate is a naturally occurring compound that is formed in the soil when nitrogen and oxygen combine. Elevated nitrate concentrations are most likely due to runoff and leaching from fertilizer use, leaching from septic tanks and sewage, and erosion of natural deposits. Infiltration of nitrate through the unsaturated zone and into groundwater is a greater concern in areas with highly permeable sandy soils. A large area of the Basin is on septic systems because of the rural, low residential density, but only limited areas have highly permeable soils. High nitrate concentrations can cause health problems for infants that results in a dangerous condition called methaemoglobinaemia, also known as “blue baby syndrome”. State primary drinking water standards are 10 mg/L for nitrate as nitrogen (N); 10 mg/L for nitrate plus nitrite as N; and 1 mg/L for nitrite as N.

The Basin has historical nitrate as N concentrations in production wells that range from mostly non-detectable to a maximum of 11 mg/L. The highest nitrate as N concentrations are at shallowest depths. All recent nitrate as N concentrations are below the state drinking water standards and have not impacted the municipal water supplies that currently produce groundwater from depths greater than 200 feet. However, SqCWD had to inactivate the Sells production well in the Aromas Red Sands aquifer in 2009 because nitrate as N concentrations were above state drinking water standards.

In areas with sandy soils where septic systems are used, nitrate contamination can be an issue. However, groundwater quality data from private wells in the Basin, which generally produce groundwater from shallower depths than municipal production wells, suggests that septic systems have not adversely increased nitrate concentrations in private wells.

Organic Compounds

Organic compounds are those that include Volatile Organic Chemicals (VOCs) and pesticides. VOCs are chemicals that are carbon-containing and evaporate, or vaporize, easily into air at normal air temperatures. VOCs are found in a variety of commercial, industrial, and residential products, including gasoline, solvents, cleaners and degreasers, paints, inks and dyes, and pesticides. VOCs in the environment are typically the result of human activity, such as a spill or inappropriate disposal where the chemical has been allowed to soak into the ground. Once released into the environment, VOCs may infiltrate into the ground and migrate into the underlying production aquifers.

The SWRCB’s Geotracker database was used to provide the status and location of contamination sites within the Basin (Figure 2-38). Geotracker tracks regulatory data about leaking underground fuel tanks (LUFT), Department of Defense (DoD) cleanup sites, Spills-Leaks-Investigations-Cleanups (SLIC), and landfill sites. Figure 2-38 shows that just less than half of contaminant sites in the Basin are located within the area of municipal production, with none occurring in the inland portions of the Basin where non-municipal wells are used for water supply. The proximity of contaminated sites to municipal wells poses a greater risk to the municipal wells; however, most released contaminants remain shallow and rarely migrate down to the aquifers used by municipal production wells. Regulation and oversight of the remediation of contaminated sites in the Basin is overseen by the Regional Water Quality Control Board (RWQCB) and Santa Cruz County Environmental Health.

SqCWD has identified 1,2,3-trichloropropane (TCP) at its Country Club production well, which is drilled within the Aromas Red Sands and Purisima F unit aquifers. The source of the 1,2,3-TCP in groundwater at this location is believed to be past use of fumigants that contained 1,2,3-TCP as an impurity, based on past agricultural land uses near the well. The state drinking water standard for 1,2,3-TCP is 5 parts per trillion (ppt). The recent average concentration in the Country Club well for 1,2,3-TCP is approximately 6 ppt. SqCWD is currently not pumping from this well, but has plans to use the Country Club well once a treatment plant for 1,2,3-TCP has been constructed and water from this well again meets or exceeds state drinking water quality standards.

Contaminants of Emerging Concern

Contaminants of emerging concern (CECs), including pharmaceuticals and personal care products (PPCPs), are increasingly being detected at low levels in surface water and water infiltrating to groundwater from septic systems. Groundwater may be impacted by recharge of treated wastewater, surface water, and from septic systems. New and emerging contaminants are currently unregulated but may be subject to future regulation. Examples of new and emerging contaminants are N-Nitrosodimethylamine, a semi-volatile organic compound (NDMA and other nitrosamines), and 1,4-dioxane, per- and polyfluoroalkyl substances (PFAS) etc.

The Unregulated Contaminant Monitoring Rule (UCMR) was part of the federal Safe Drinking Water Act Amendments of 1996 and is administered by the USEPA. The UCMR has required additional water quality testing within the Basin every five years since 2001. SqCWD conducts the UCMR testing within the Basin. Additionally, in 2007 and 2011 SqCWD participated in two phases of a joint USGS – USEPA study on CECs in drinking water. This joint USGS-USEPA study tested for additional CECs that are not included in standard UCMR tests.

The production wells that have had detections of CECs are Sells, Altivo, and Bonita. Sells is the La Selva area well with elevated nitrates as N that is currently inactive in the Aromas Red Sands aquifer. The CEC detected in Sells and Altivo is PPCPs, a pharmaceutical found during the USGS-USEPA joint test. SqCWD also identified 1,4-dioxane and 1,1-dichloroethane in its Bonita well during standard five yearly UCMR testing.

2.2.4.5 Land Subsidence Conditions

Land subsidence is the gradual or sudden lowering of the land surface. For land subsidence to occur certain conditions are needed:

- Drainage and decomposition of organic soils,
- Underground mining, oil and gas extraction, hydrocompaction, natural compaction, sinkholes, and thawing permafrost, or
- Aquifer-system compaction

None of these conditions are known to be present within the Basin and there is no known or anecdotal evidence of subsidence related to groundwater extraction in the Basin. According to the County of Santa Cruz, there have been no formal studies on subsidence in this region. There are also no known organic soils in the Basin. The depositional environments of the sediments comprising the Basin's aquifers are not conducive to deposition of organics. Neither is there is underground mining, oil and gas extraction, hydrocompaction, natural compaction, sinkholes, nor thawing permafrost occurring in the Basin.

Because there have been historical declines in groundwater levels greater than 50 feet, the possibility of aquifer-system compaction does exist. Susceptibility to land subsidence from groundwater level declines requires aquitards (fine-grained silts and clays) above- or within-which preconsolidation-stress thresholds are exceeded. Preconsolidation-stress is the maximum amount of *past effective stress the soil has ever experienced.*

There are aquitards in the Basin between the aquifer units. However, in areas with pumping, the bottom elevations of aquitards are generally more than 100 feet below sea level, which is deeper than typical groundwater levels. This means that the aquitards do not get dewatered, but may still be subjected to changes in preconsolidation stresses.

2.2.4.5.1 Land Subsidence Relationship to Groundwater Elevations

The greatest groundwater level declines since recording levels started in 1984 are in the Purisima BC units where declines in the order of 140 feet historically occurred. The Purisima A and DEF units have also had significant historical declines that led to historic low levels, which have since recovered. Table 2-6 summarizes the maximum declines for each aquifer and the year in which it occurred.

Table 2-6. Representative Aquifer Historic Groundwater Level Declines

Aquifer Unit	Maximum Decline in Feet (Monitoring Well)	Year of Historic Low
Aromas/Purisima F	5 (SC-A2A)	2000
Purisima DEF	100 (SC-17C)	1988
Purisima BC	140 (SC-14B)	1986
Purisima A	80 (SC-16A)	1988
Purisima AA/Tu	35 (SC-22AAA)	2017

Even during these periods of significant groundwater level declines, no subsidence has been documented in the Basin. This lack of evidence of subsidence linked to substantial groundwater level declines, the lack of susceptibility of Basin geology to subsidence, and existing regional subsidence monitoring near the Basin shows no evidence of subsidence indicates the inapplicability of the subsidence sustainability indicator in the Basin.

2.2.4.5.2 Historical Land Subsidence Monitoring

No subsidence monitoring takes place in the Basin because subsidence has not occurred and is not a concern. There are, however, two continuous global positioning system (CGPS) stations in the vicinity of the Basin in the Aromas area (Figure 2-39). These CGPS stations are part of the UNAVCO Plate Boundary Observatory network of CGPS stations (UNAVCO Community, 2006; UNAVCO Community, 2007).

Both CGPS stations are located in areas underlain by the Aromas aquifer where groundwater levels have not experienced any significant declines. One of the stations, the Larkin Valley CGPS station (P212), is within 0.5 miles of some of the Soquel Creek Water District's production well pumping from the Aromas Red Sands and Purisima F-unit aquifers. Even though the station is outside of the Basin, it still hydraulically connected and has the same aquifers as the Santa Cruz Mid-County Basin and is representative of the Basin. Unfortunately, no CGPS stations are located in areas of the Basin where the main Purisima aquifers are being pumped and where historic long-term declines in groundwater have occurred.

Horizontal (North and East) and vertical displacement charts are shown on Figure 2-40 for the Larkin Valley CGPS station (P212) and Figure 2-41 for the Corralitos CGPS station (P214). Both stations show small amounts of elastic subsidence in the vertical dimension (height charts at the bottom) that appear to be annual shifts of up to 2 inches, and are possibly related to seasonal changes in groundwater levels. Although 2 inches appears to be quite a bit of subsidence, the movement is not noticeable in buildings and other structures because it is not differential subsidence but occurs more or less uniformly over a very large area.

2.2.4.5.3 Inapplicability of Land Subsidence in the Basin

The consolidated nature of the Purisima Formation, where groundwater level declines have historically occurred, is the main reason why land subsidence related to lowered groundwater levels has not occurred in the Basin, and why subsidence is unlikely to occur in the future. Implementation of the GSP and avoiding undesirable results in the other five sustainability indicators will ensure that historic low groundwater levels are not repeated. This argument supports the assertion that land subsidence due to lowered groundwater levels will not occur in the future.

With no subsidence occurring in the Basin, past, present or future, it is not an effective indicator of sustainability, and is not included in the GSP. In the highly unlikely event that land subsidence caused by lowered groundwater levels does occur in the Basin and is identified as such by observational monitoring, the MGA will immediately regulate groundwater pumping in the area of land subsidence. The identification of active land subsidence will trigger the need for dedicated subsidence monitoring and an amendment to the GSP that includes development of Sustainable Management Criteria for the land subsidence sustainability indicator.

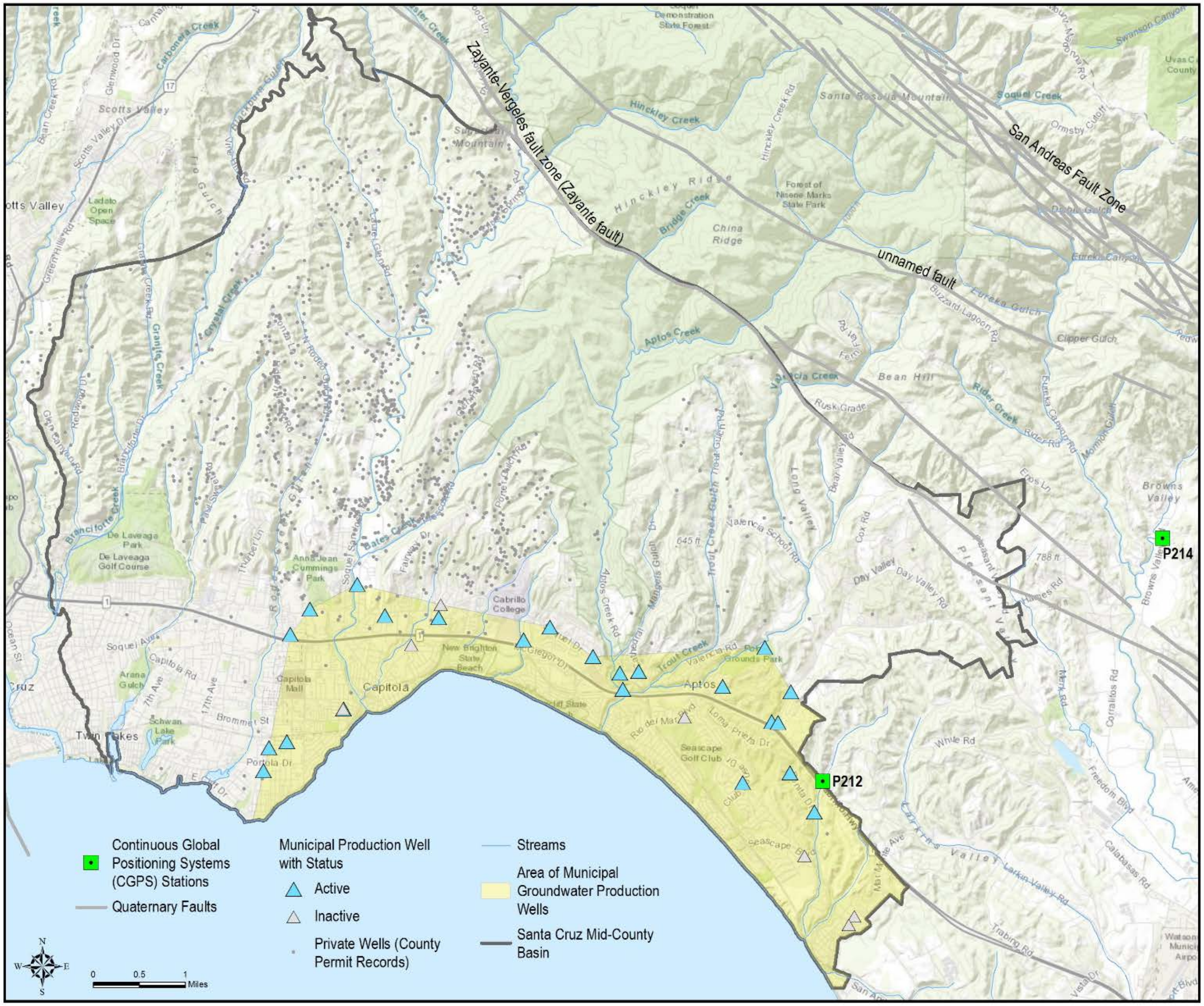


Figure 2-39. Location of Continuous GPS Stations near the Santa Cruz Mid-County Basin

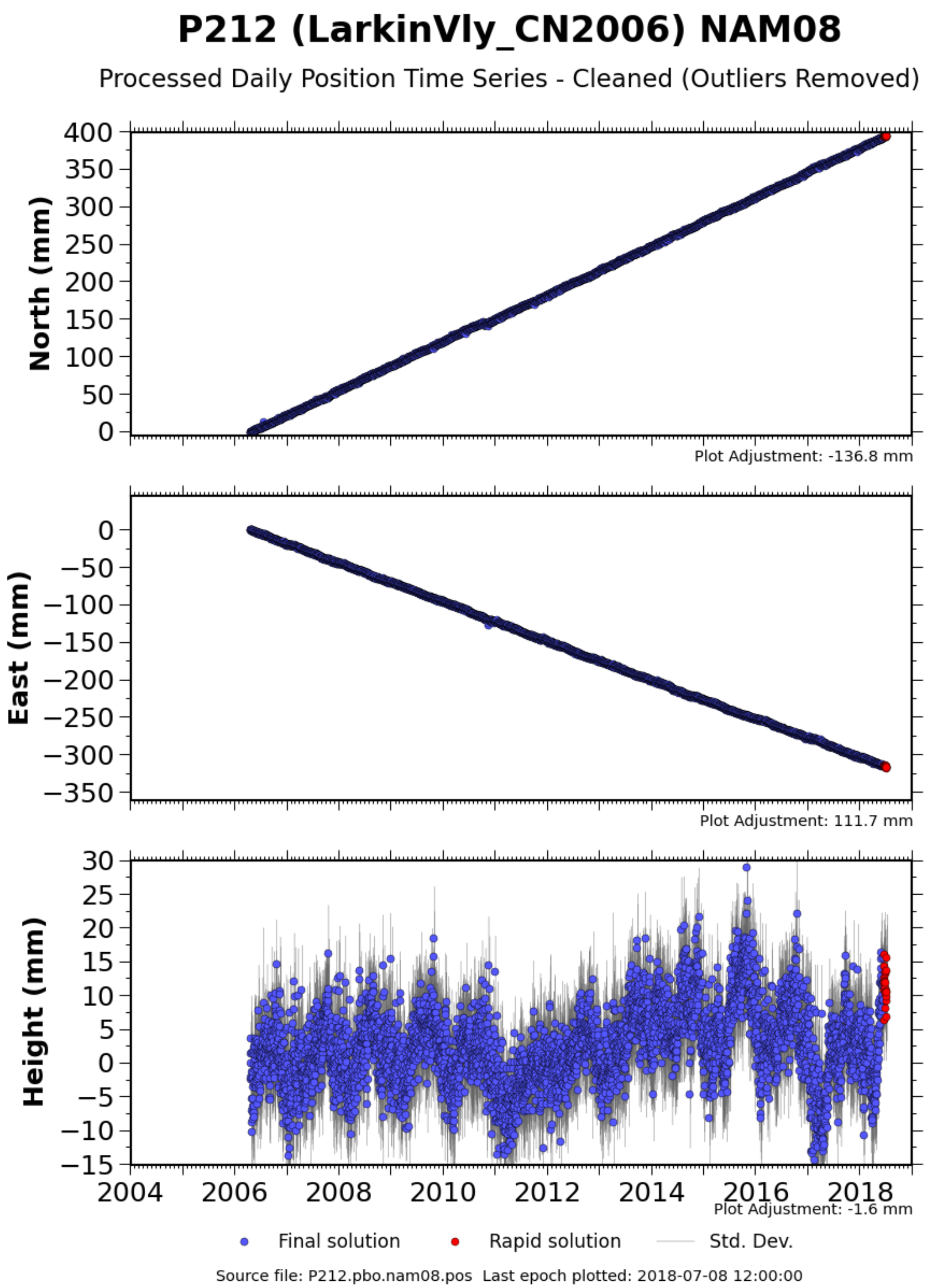


Figure 2-40. P212 Larkin Valley CGSP Station Daily Position

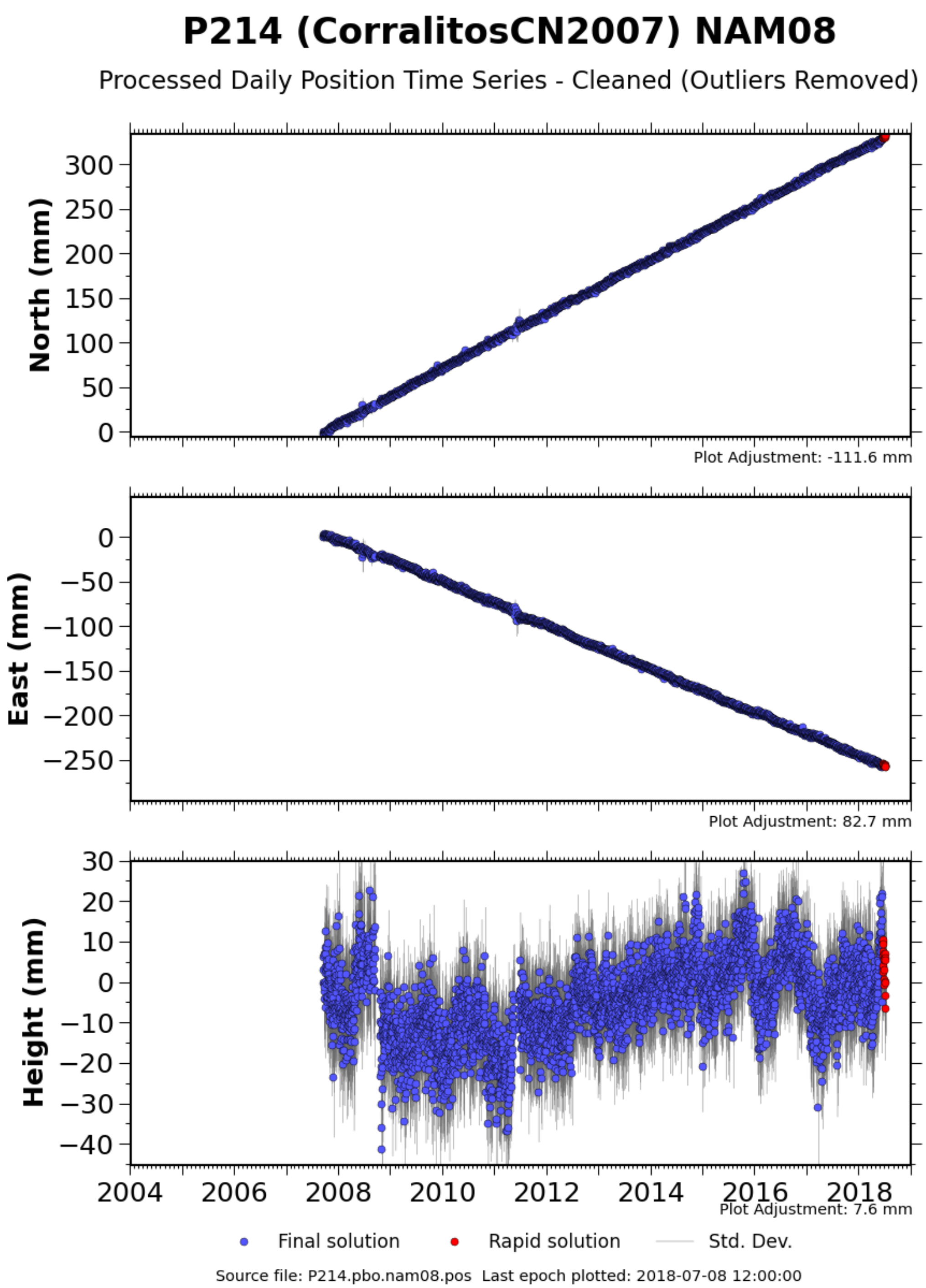


Figure 2-41. P214 Corralitos CGSP Station Daily Position

2.2.4.6 Identification of Interconnected Surface Water Systems

In general, the relationship between surface water and groundwater can be described in the following ways: 1) a gaining stream that receives water from groundwater, 2) a losing stream that recharges the Basin from surface water, 3) a stream that may be separated from groundwater by a hydrogeologic formation, such as an aquitard that prevents interaction between surface water and groundwater completely.

Interconnected surface water is hydraulically connected to by a continuous saturated zone to the underlying aquifer. Interconnected streams can be both gaining and losing streams where the gradient between surface water and groundwater is what determines the extent to which water is gained or lost from the streams. In some cases, even relatively small changes in gradient can convert a gaining stream to a losing stream and vice versa. Some losing streams are defined as "disconnected" meaning the groundwater is so far below the surface water that recharge occurs through an unsaturated zone to the water table. In these cases, although water is typically percolating out of the stream down to the underlying groundwater, the rate of loss is not affected by the elevation of the groundwater.

The MGA's current understanding of surface water and groundwater interactions are informed by both direct monitoring of streamflow and groundwater levels where those data are available, and by simulating surface and groundwater flow using the integrated surface water groundwater model (model). The interactions are simulated through several components of flow using both the surface water portion of the model, called the Precipitation-Runoff Modeling System (PRMS), and the groundwater portion of the model (MODFLOW). In particular, interactions with surface water (streams) occur through surface runoff, interflow, and groundwater (see Figure 2-42).

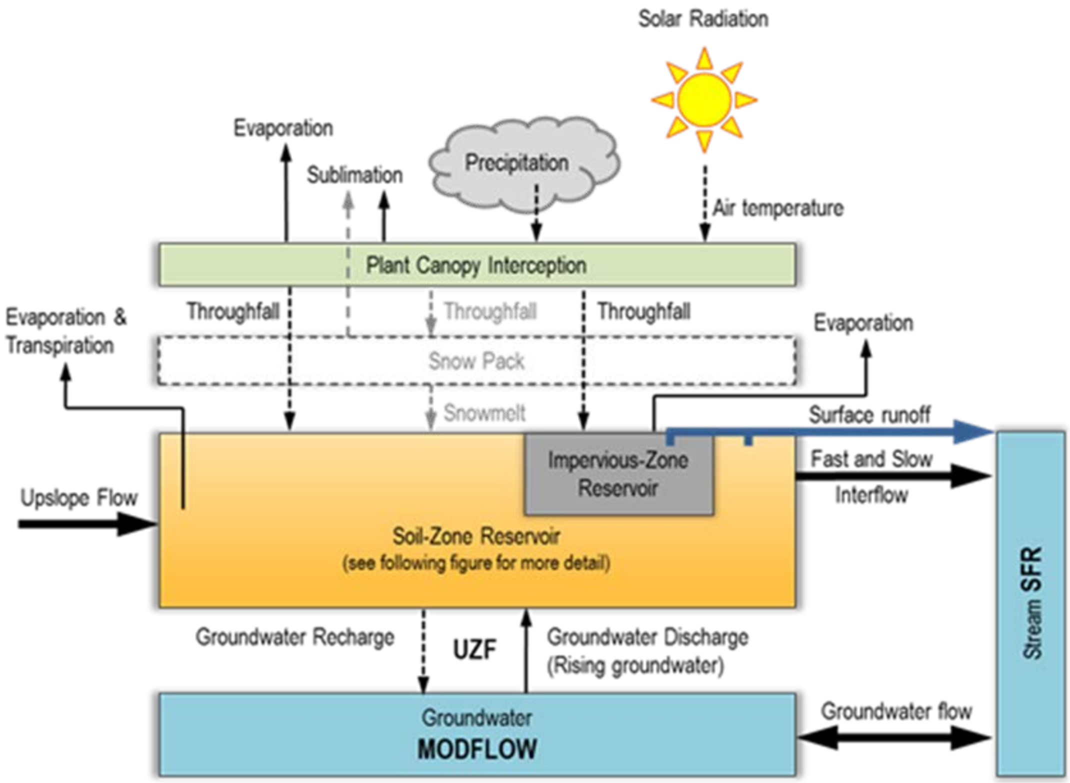


Figure 2-42. Hydrologic Process Simulated by the Precipitation-Runoff Modeling Systems (PRMS)

Throughout the Basin there is spatial variation in the percent of time surface waters are connected to groundwater (Figure 2-10). As described in the model calibration report provided in Appendix 2-F, the model was used to simulate the percent of time surface water was connected to groundwater between Water Year 1985 and 2015. This information is generally supported by observations of groundwater levels where the MGA currently has monitoring wells. As the MGA proceeds with GSP implementation, additional data will be collected and the model refined to improve understanding of the location and nature of the groundwater-surface water connections on priority streams. The following are findings from model simulations:

- Where streams are disconnected, groundwater levels are well below the bottom of the stream, thus, even substantial groundwater level changes do not impact streamflow.
- The Eastern side of the Basin, specifically upper Valencia Creek, Trout Creek Gulch, and a number of ponds, are connected to groundwater less than 5% of the time. This may be a geologic condition of the highly permeable underlying Aromas and Purisima F units, and/or may be influenced by lowered groundwater levels in the adjacent Pajaro Valley Subbasin (Figure 2-43).
- Soquel and Branciforte Creeks have the most connection to groundwater. Some reaches in those streams are connected to groundwater more than 95% of the time (Figure 2-10).

- Most other Basin streams are connected to groundwater between 30-95% of the time (Figure 2-10).

- Results for two modeled stream segments on Soquel Creek, 1) Simons to Balogh, and 2) Main Street to Nob Hill, where there are shallow groundwater data from which to calibrate, show strong stream-aquifer interactions relative to the model as a whole, and are near municipal pumping. In the months with lowest flows, groundwater flow to surface water contributes more than surface/near-surface runoff flows for these segments, but the groundwater contribution (< 0.5 cubic foot per second [cfs]) is small compared to the overall flow in each of these segments of Soquel Creek (Figure 2-44 and Figure 2-45). Most of the streamflow in those segments comes from higher up in the watershed (Figure 2-44 and Figure 2-45). As data quantifying flows between the stream and shallow groundwater are not available for calibration, there is high uncertainty of the magnitude of simulated flows between stream and aquifer calculated by the model. The groundwater contribution to streamflow along these stretches of less than 0.5 cfs is consistent with estimates from previous studies that streamflow depletion has not been observed because depletion of up to 0.5 cfs cannot be observed from the data (Johnson et al., 2004).

- The model simulates the relative contribution of surface/near-surface flows for the entire watershed in minimum streamflow months is greater than groundwater contribution and drives the inter-annual variability in streamflow. The groundwater contribution is simulated as approximately 1 cfs.

- Measured streamflow is highly affected by evapotranspiration from streamside vegetation, which is not taken into account in the model. This creates a challenge for calibrating the model to measured flow.

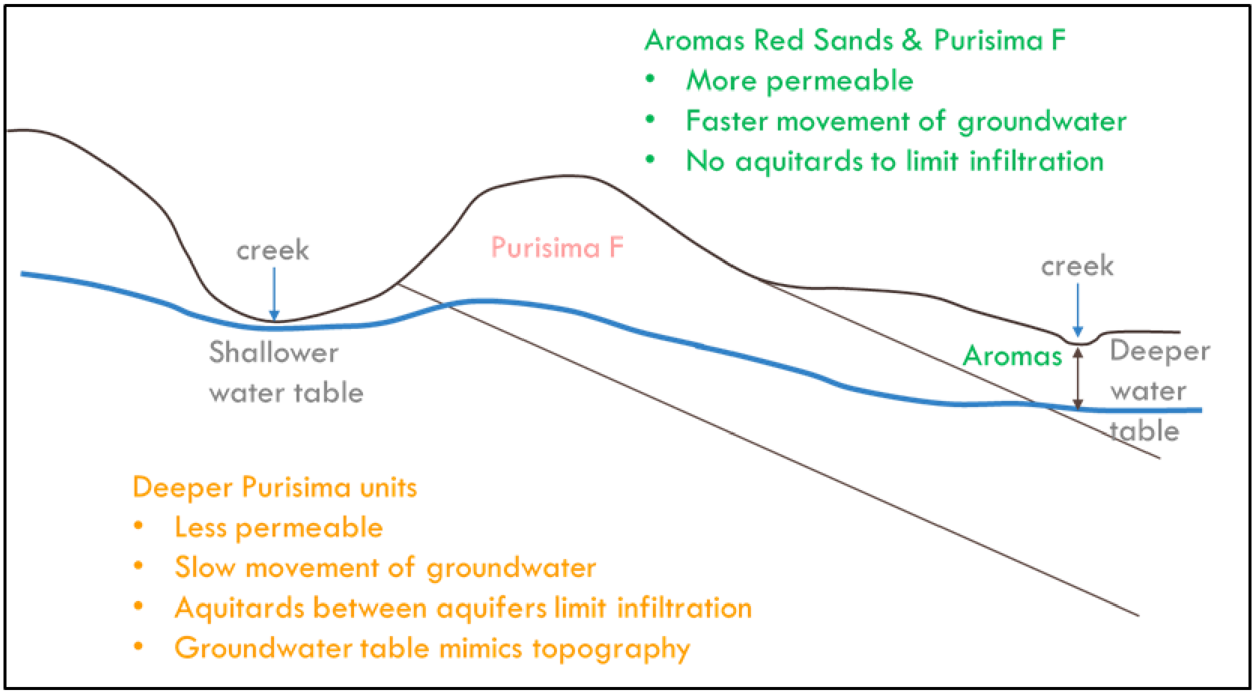


Figure 2-43. Differences Between Purisima and Aromas Connection to Groundwater

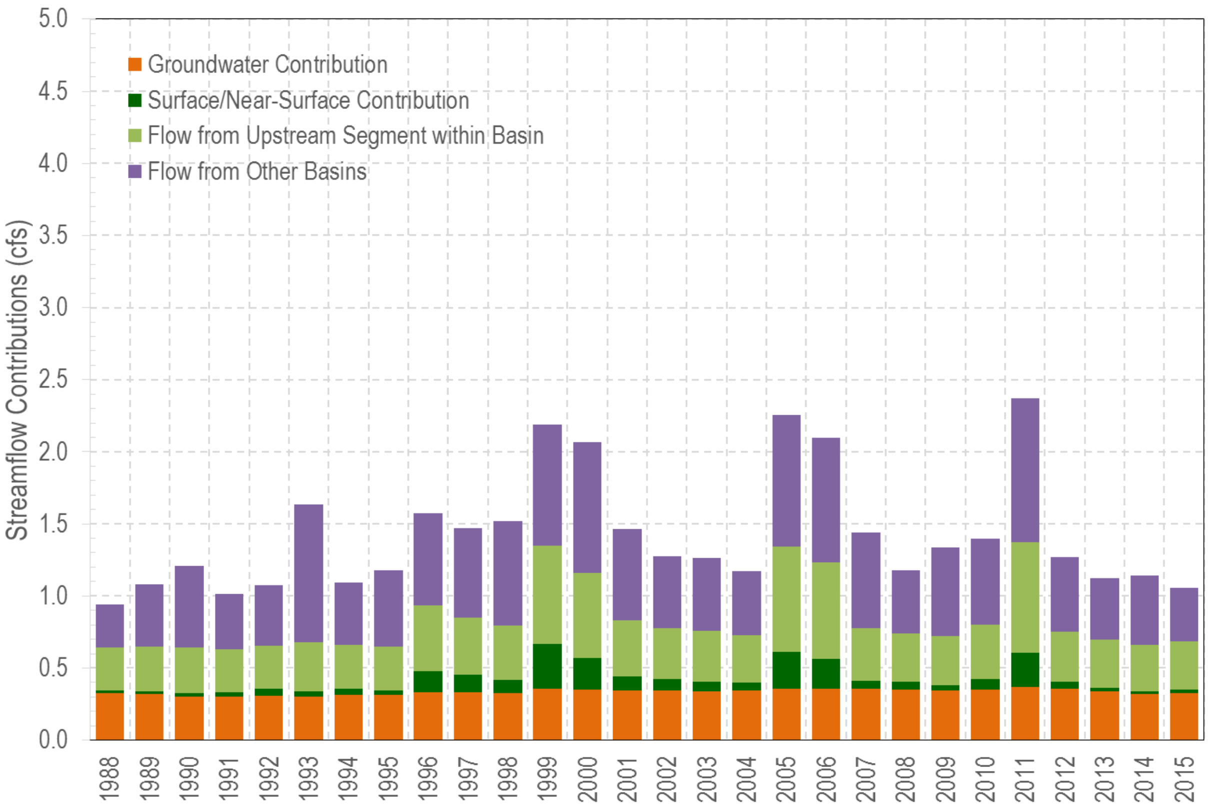


Figure 2-44. Simulated Minimum Monthly Flows from Moores Gulch to Bates Creek

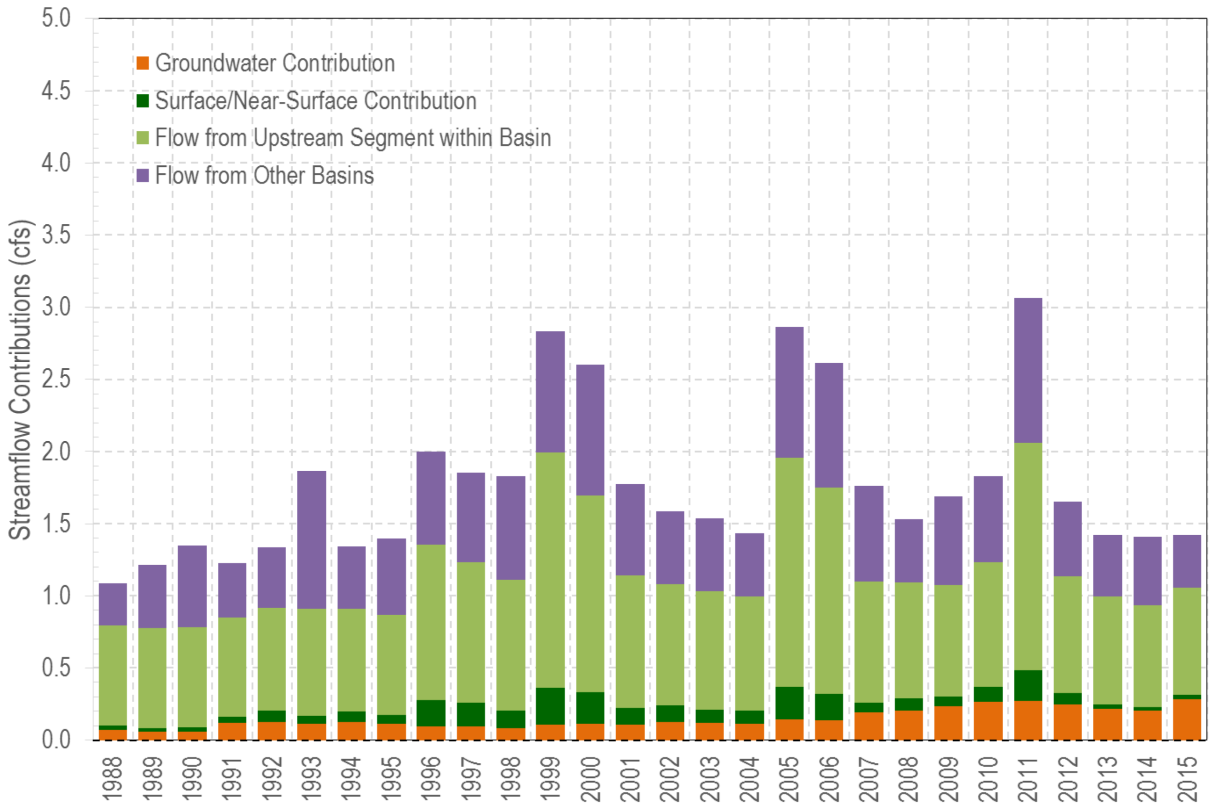


Figure 2-45. Simulated Minimum Monthly Flows Downstream from Bates Creek

Given the uncertainty in the groundwater modeling, the limited data available to assess surface water-groundwater interactions, and recognizing the possible importance of even small amounts of groundwater flow contributions or additional flow depletions during low flow periods, the MGA intends to improve Basin monitoring to better understand surface water-groundwater interactions over time, and revisit these estimates as new information is developed. This relationship and improvements to monitoring are discussed in more detail in Section 3.9.

Developing sustainable management criteria for depletion of interconnected surface water needs to consider not only how often there is connection with groundwater, but also how much that connection influences streamflow, and the location of groundwater pumping that may affect groundwater levels and streamflow. Soquel Creek is the primary stream in the Basin where there are major pumping centers and a connection between surface and groundwater (Figure 2-46).

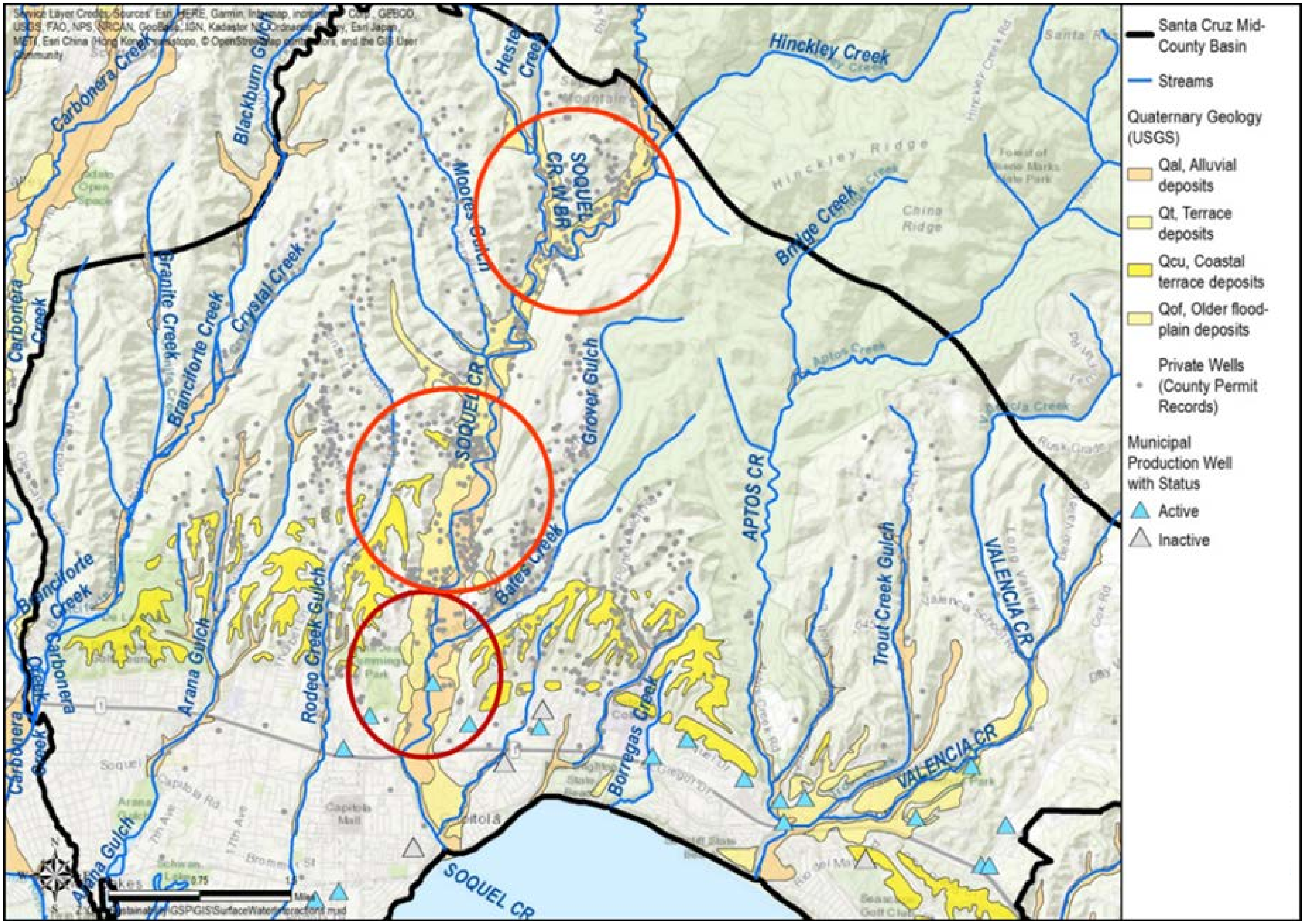


Figure 2-46. Areas of Concentrated Groundwater Pumping along Soquel Creek

Soquel Creek Water District has been monitoring surface water interactions near its Main Street municipal well with its monitoring well network for almost 20 years. Annual reports evaluating the connection between Main Street and other nearby municipal wells to Soquel Creek have been prepared since 2015 (HydroMetrics, 2015; HydroMetrics, 2016; HydroMetrics, 2017). These reports have shown no direct measurable connection to creek flow or stage in response to pumping starting and stopping in the Main Street municipal well, which is screened in the Purisima AA-unit and Tu-unit (as shown in Figure 2-47). But there is an expected indirect influence of pumping on streamflow resulting from general lowering of groundwater levels and reduction of groundwater contribution to the stream. This is also indicated by the groundwater model.

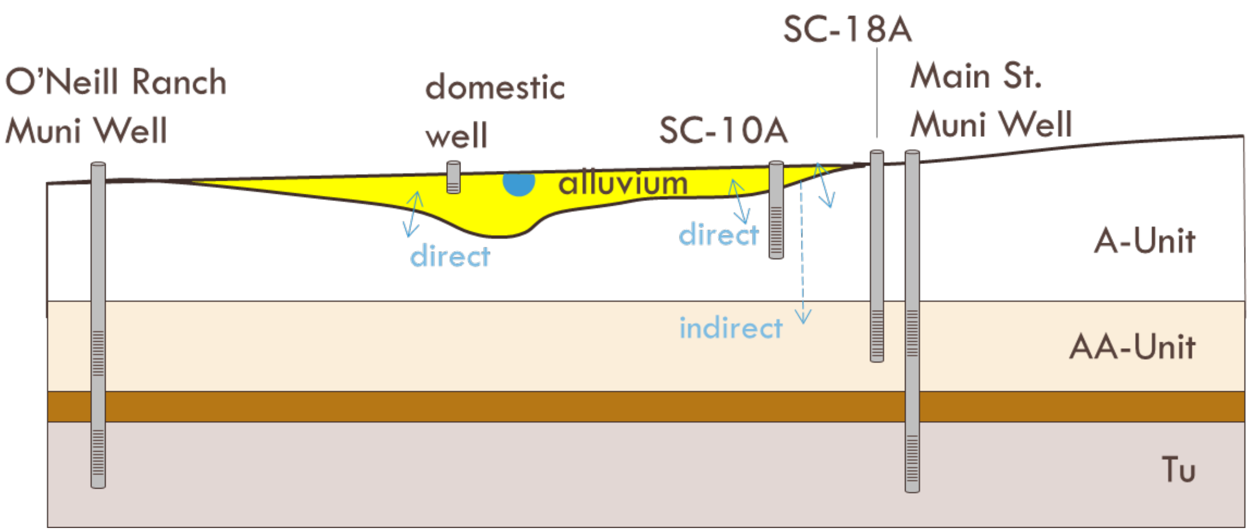


Figure 2-47. Conceptual Connections between Soquel Creek, Alluvium, and Underlying Aquifers

Figure 2-48 shows hydrographs for monitoring well SC-18A (screened in Purisima AA-unit) and the Main Street shallow monitoring well (screened in alluvium and top of the Purisima A-unit) plotted with: (1) streamflow at the USGS Soquel Creek at Soquel gauge located adjacent to the Main Street wells, (2) precipitation recorded at the Main Street site (since January 2012), and (3) monthly pumping at the Main Street municipal well.

Evaluation of the relationships between measurements shown on Figure 2-48 indicate:

- Shallow groundwater levels fluctuate in response to both pumping and rainfall.
- Shallow groundwater levels rose during the period between April 2014 and April 2015 when the Main Street municipal well was offline. The increase occurred even though it was the middle of the 2011-2015 drought and groundwater levels were below average.
- There is a 1-2 foot increase in shallow groundwater levels in the Main Street shallow well that corresponds to the increase in Purisima AA-unit groundwater levels in SC-18A (it also corresponds to rainfall). However, record high groundwater levels in SC-18A are not matched by record high shallow groundwater levels.

The above information suggests that the alluvium, and hence the creek, is connected to underlying aquifers. That connection appears to be more direct with the Purisima A-unit, and indirect with aquifers below the Purisima A-unit.

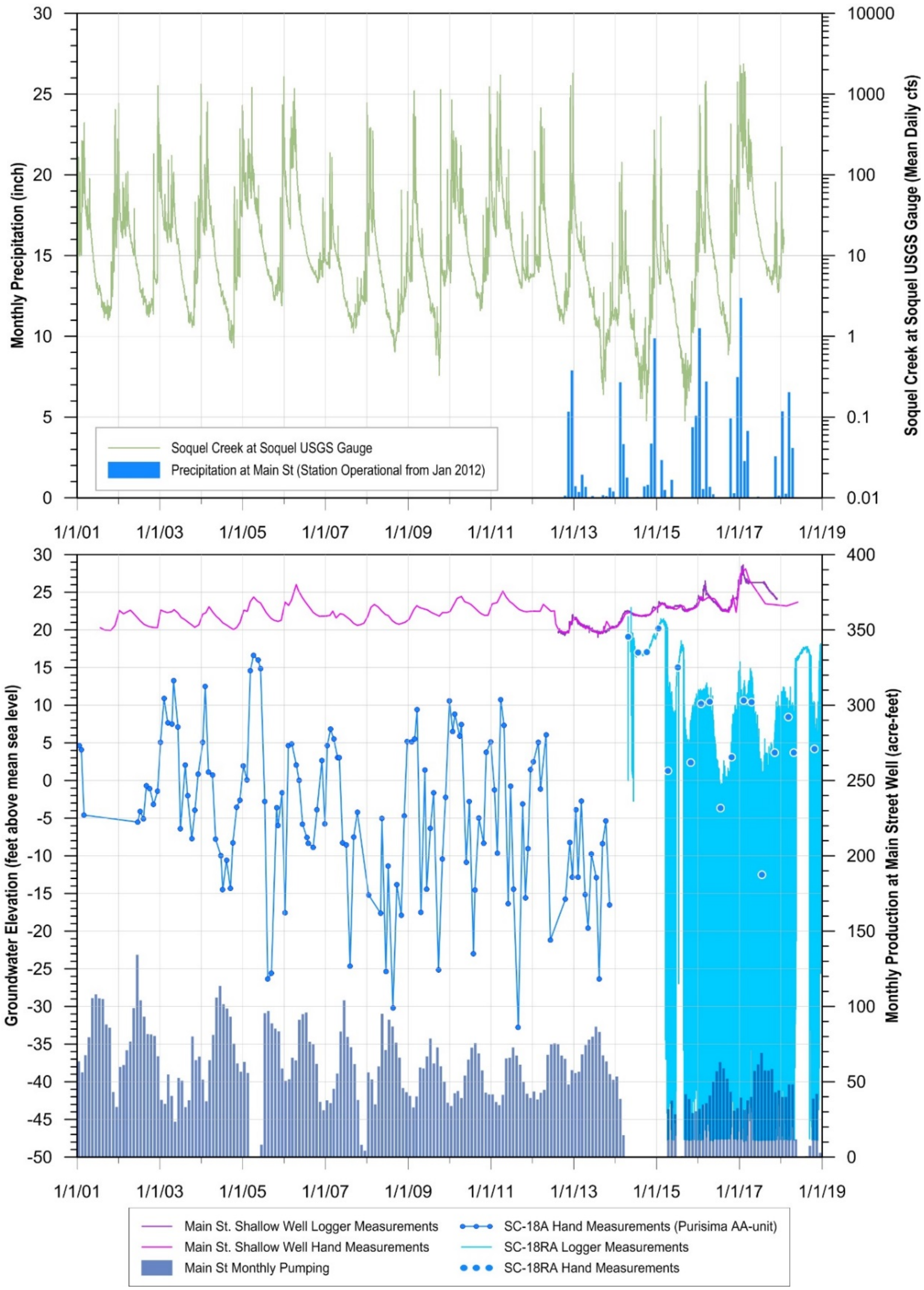


Figure 2-48. Hydrographs for Main Street Monitoring Wells Compared to Monthly Main Street Pumping, Creek Flow and Precipitation

2.2.4.7 Identification of Groundwater-Dependent Ecosystems

SGMA defines an undesirable result as “depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.” In order to address this issue, it is necessary to identify the aquatic species and habitats that could be adversely affected by lowered groundwater levels in principle aquifers and interconnected surface water depletion. Because of the critical nature of this work, the MGA established the Surface Water Working Group to bring additional expertise to this important conversation and provide information to the GSP Advisory Committee. The Surface Water Working Group included staff and representatives from the following groups:

- GSP Advisory Committee
- California Department of Fish and Wildlife
- California Department of Water Resources
- City of Santa Cruz
- County of Santa Cruz
- Friends of Soquel Creek
- National Marine Fisheries Service (NMFS, formerly NOAA Fisheries)
- Pajaro Valley Water Management Agency (PV Water)
- Regional Water Management Foundation/MGA
- Resource Conservation District of Santa Cruz County
- The Nature Conservancy
- Environmental Defense Fund
- US Fish and Wildlife Service

The Surface Water Working Group began by identifying where ecosystems are connected to groundwater that could be impacted by groundwater pumping. Figure 2-10 in Section 2.1.4.12 identifies where surface water is connected to groundwater within the Basin and the percentage of time that that connection exists. Due to the stacked nature of the geology and the fact that pumping is typically happening in some of the lower aquifers, the focus of the group was narrowed to the habitats supported by surface water systems like streams (Figure 2-49).

Numerous habitats (Figure 2-50) and species (Figure 2-51) are supported by surface water systems within the Basin. During the first meeting of the Working Group, staff led a discussion about these species and the best way to address them through the GSP. The Working Group requested an evaluation of the requirements for specific plant and animal species in relation to dependence on water for some or all of their life stages. Based on that evaluation, staff proposed that the highest water need was for steelhead trout, coho salmon, and several riparian trees including willow and sycamore. These were labelled “priority species.” The remaining species evaluated either 1) were in an area sensitive to groundwater management, however their aquatic needs were less than those of the priority species, or 2) were not in an area sensitive to groundwater management due to either a lack of groundwater pumping or disconnected surface water.

MGA staff used the California Natural Diversity Database and National Wetlands Inventory to identify species whose ranges potentially overlap the Basin boundaries. Table 2-7 outlines all of the species evaluated from these databases. Table 2-8 lists species actually observed within the Basin through various monitoring programs discussed in Section 2.1.2.1.

The salamander ponds that were identified inside and outside of the eastern portion of the Basin (see Figure 2-4) were found to be generally supported by the interflow in perched groundwater and surface water runoff which were both considered beyond the scope of GSP management. The group also considered the issue of possible marine ecosystems dependent on freshwater outflow of groundwater into the marine environment. However, after discussions with experts in the field Dr. Charles Paull, MBARI; Dr. Willard Moore, University of South Carolina Distinguished Faculty Emeritus; and Dr. Adina Paytan, UCSC Research Scientist/Lecturer and further consideration, the group determined that any possible ecosystem effects in the marine environment would be challenging to evaluate, are likely quite small if they exist at all, and will benefit from the management policies put in place to protect priority aquatic species.

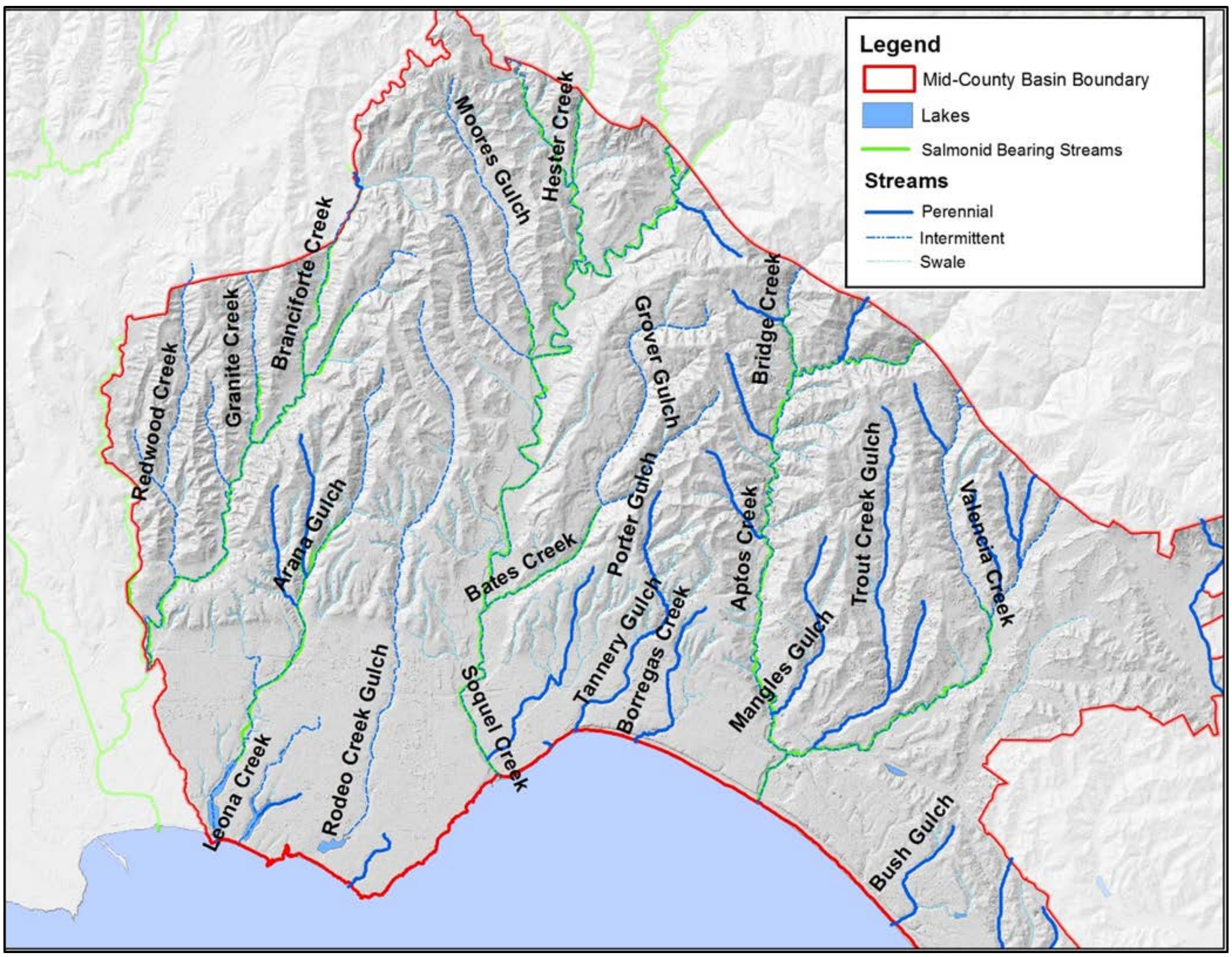


Figure 2-49. Stream Habitat in the Santa Cruz Mid-County Basin

Using guidance developed by TNC (https://groundwaterresourcehub.org/), and input from MGA technical staff, the Surface Water Working Group reviewed information on the distribution of aquatic species throughout the Basin and the habitat requirements for those species (Figure 2-50). Where applicable, the potential effect groundwater management could have on habitat was also discussed with the Surface Water Working Group.

The Working Group agreed to the following:

- The GSP should only address impacts to surface water that are directly related to groundwater management. There are many factors that affect streamflow including rainfall, evapotranspiration, and surface water diversions, that are beyond the scope of the GSP. These factors were considered when developing depletion of interconnected surface water sustainable management criteria..
- The Basin supports numerous aquatic species of concern. Steelhead and coho salmon are priority species for evaluating the effects of groundwater management. By managing for their specific habitat requirements in Basin streams, the needs of other aquatic species of concern will also be met (see Table 2-8 for occurrences of non-salmonid aquatic species found through the County's monitoring program).
- Maintaining flow for fish will also support other beneficial uses of streams and downstream lagoons, including recreational use and domestic supply, among others. Note that while coho do not appear in the California Natural Diversity Database (Figure 2-51) they have been seen in the Basin through the County's monitoring program (Table 2-7). Branciforte, Soquel, and Aptos Creeks are designated as coho recovery streams.
- Similarly, riparian forest that includes native trees like cottonwood, willow and sycamore were identified as a habitat type that should be prioritized for management. For those species, if groundwater levels are maintained at a level to support streamflow for fish, the groundwater levels will also be high enough to supply the roots of the riparian vegetation.
- Modeling and management should focus on areas of highest groundwater extraction where streams are interconnected with groundwater as identified in Figure 2-46 along Soquel Creek.
- Linking the basic water needs of the species and habitats of concern, relative to groundwater elevations, is an appropriate way to move forward with the assessment and development of sustainable management criteria to benefit those species.

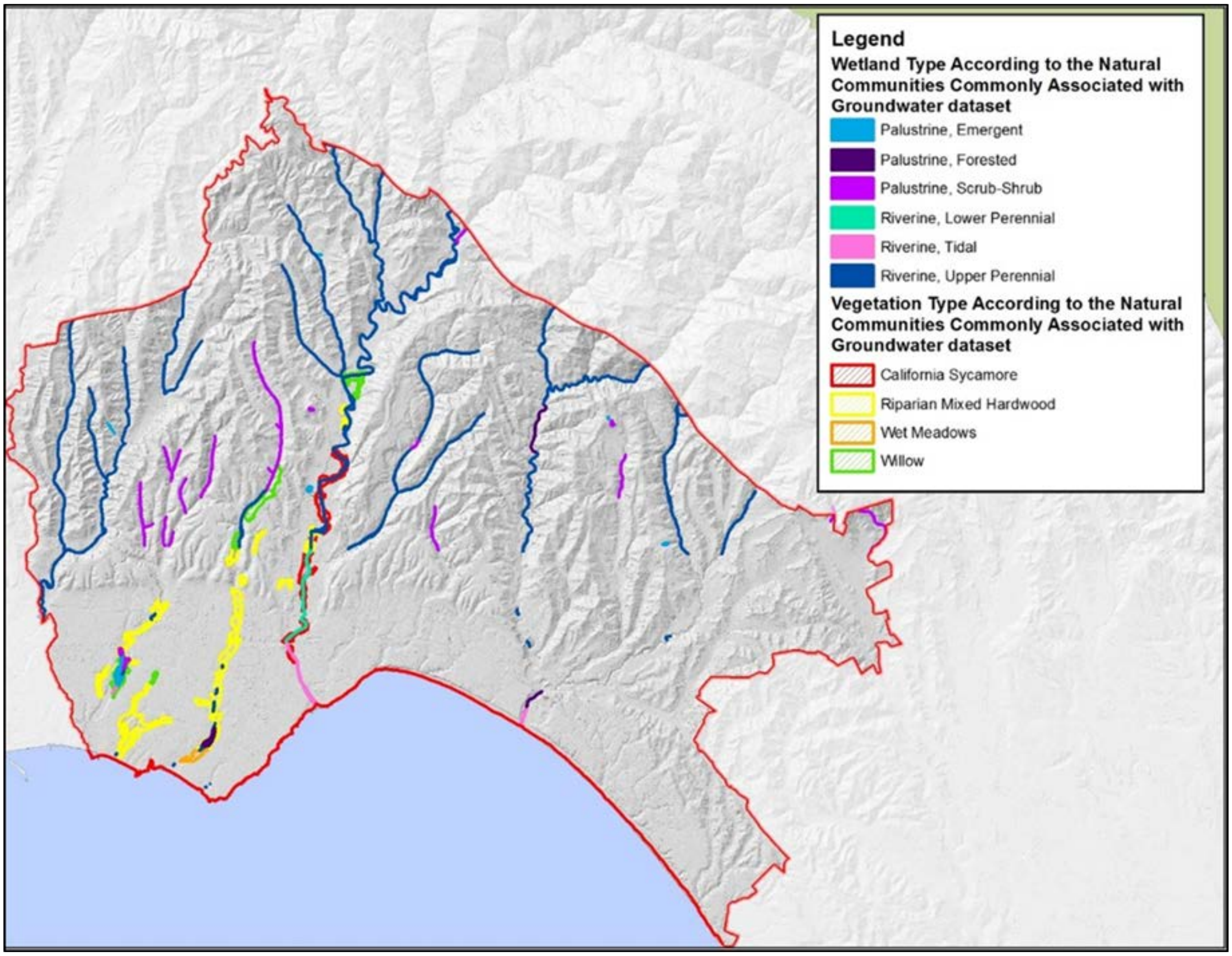


Figure 2-50. Wetland and Vegetation Types according to the Natural Communities Commonly Associated with Groundwater Dataset

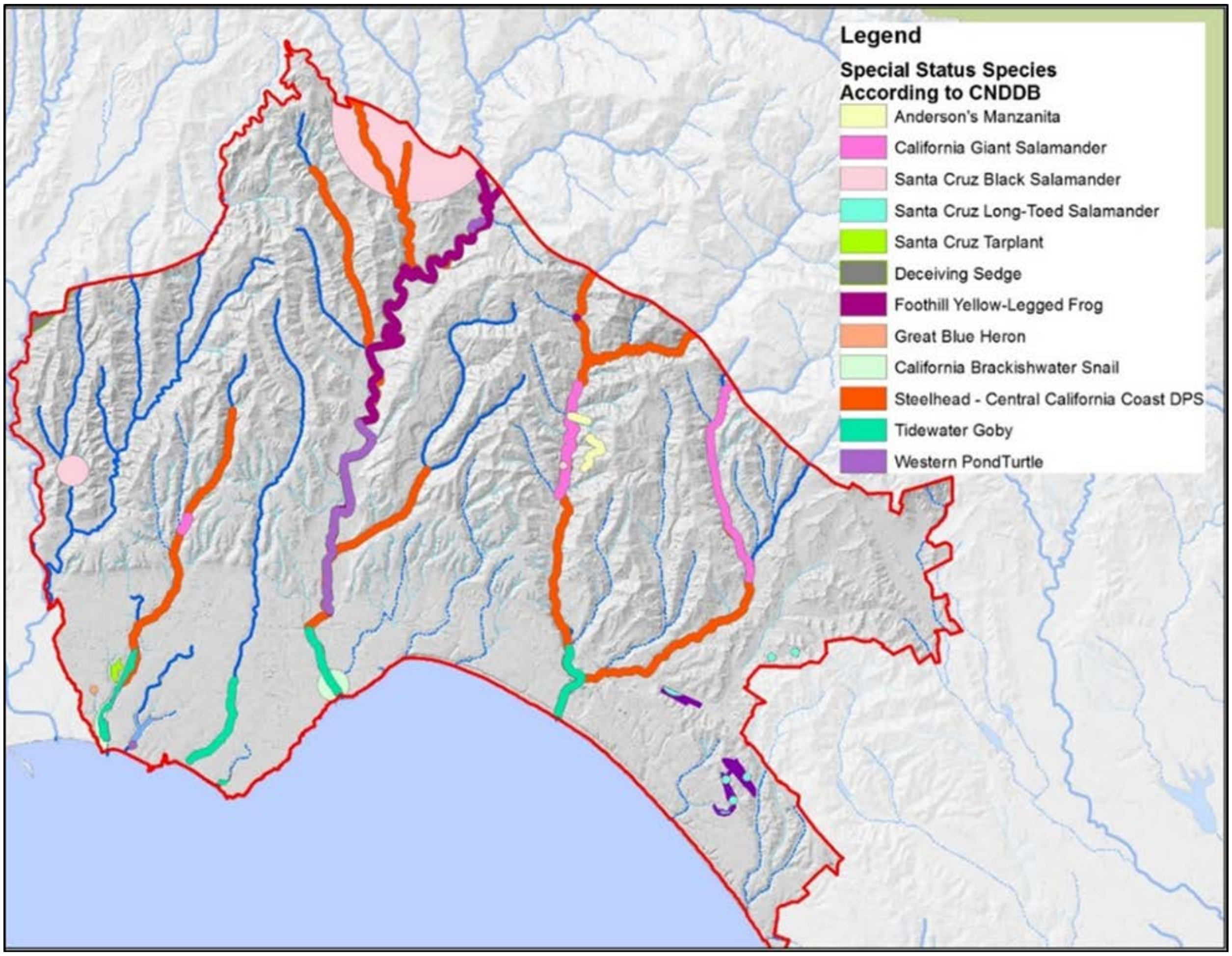


Figure 2-51. Distribution of Species throughout the Santa Cruz Mid-County Basin according to the California Natural Diversity Database [8]

[8] Several streams support multiple species. Note that due to the layering of species on the map, some species that use the entire stream reach.

Table 2-7. All Species Identified using California Natural Diversity Database and National Wetlands Inventory and Considered for Management with Potential for Range inside Basin Boundaries

Species common name	Priority for GDE management	Needs Covered by Priority Species (*), or Not Impacted by Groundwater Management
Steelhead	X	
Coho Salmon	X	
Riparian forest including willow and sycamore	X	
California Brackishwater Snail		X
Tidewater Goby		X
Wet Meadows		X
amprey		X*
Santa Cruz Long-Toed Salamander		X
Santa Cruz Black Salamander		X
Foothill Yellow-Legged Frog		X*
California Red-Legged Frog		X*
Western Pond Turtle		X*
Anderson's Manzanita		X
Santa Cruz tarplant		X
Deceiving sedge/Santa Cruz Sedge		X

Table 2-8. Non-Salmonid Aquatic Species Identified in Mid-County Streams during Field Sampling Program, 1996-2017

Site	Sample Count	Lamp-Rey	Giant Salamander	Yellow-Legged Frog	Tide-Water Goby	Red-Legged Frog	Western Turtle
SLR-bran-21a1	2	0	0	0	0	0	0
SLR-bran-21a2	15	10	0	0	0	0	0
SLR-bran-21b	10	2	0	0	0	0	0
SLR-bran-21c	5	0	0	0	0	0	0
SOQ-east-13b	4	0	0	1	0	0	0
SOQ-main-1	20	8	0	1	0	0	0
SOQ-main-2	9	1	0	0	0	0	0
SOQ-main-3	7	1	0	1	0	0	0
SOQ-main-4	21	8	1	14	0	0	0
SOQ-main-5	6	0	0	3	0	0	0
SOQ-main-6	9	1	0	3	0	0	0
SOQ-main-7	6	1	0	2	0	0	0
SOQ-main-8	7	1	0	5	0	0	0
SOQ-main-9	10	2	0	3	0	0	0
SOQ-main-10	22	6	2	10	0	0	0
SOQ-main-11	5	1	0	1	0	0	0
SOQ-main-12	21	10	2	11	0	0	0
SOQ-east-13a	22	5	3	9	0	0	0
SOQ-west-19	17	4	3	1	0	0	0
SOQ-west-20	9	0	3	0	0	0	0
SOQ-east-14	10	3	0	5	0	0	0
SOQ-west-21	13	2	9	0	0	0	0
APT-apto-3	13	1	1	0	1	0	0
APT-apto-4	13	1	3	0	0	0	0
APT-vale-2	9	0	0	0	0	0	0
APT-vale-3	9	0	1	0	0	0	0

Note: The Sample Count column indicates the number of times over the sampling period that the site was visited. The other Columns show the number of times

2.2.5 Water Budget

This section summarizes estimated water budgets for the Santa Cruz Mid-County Basin and contains information required by SGMA regulations in addition to other important information required in an effective GSP. According to SGMA Regulations (§354.18), the GSP must include basin-wide water budgets which include an assessment of total annual volume of surface water and groundwater entering and leaving the Basin during historical, current, and future conditions. These water budgets account for the change in the total volume of water stored in the Basin under these conditions.

2.2.5.1 Water Budget Data Sources

All water budgets in this section are developed using outputs from the Basin GSFLOW model (model) which simulates basin-wide hydrogeologic and hydrologic conditions. The model is an integrated surface water and groundwater model, utilizing both PRMS and MODFLOW code. PRMS handles watershed flows, MODFLOW simulates subsurface flow, and the MODFLOW Streamflow-Routing (SFR) package simulates streamflow. These components inform the integrated model which simulates both surface water and groundwater hydrology in order to obtain water budgets for the Basin.

The model domain covers the entire Basin area plus portions of the adjacent Santa Margarita Basin, Purisima Highlands Subbasin, and Pajaro Valley Subbasin (Figure 2-52). The model domain is bound by the Carbonera Creek and Branciforte Creek watersheds in the west and by the Corralitos Creek watershed in the east. The northern model boundary approximately follows Summit Road and Loma Prieta Avenue for about 17 miles along a northwest to southwest alignment that represents the watershed boundary, while the southern model boundary parallels the coastline approximately one mile offshore. The nine model layers simulate major hydrostratigraphic units in the Basin that include both aquifers and aquitards.

The model was calibrated using measured groundwater level data from 121 individual monitoring locations, streamflow data from 11 stream gauges, and potential ET and solar radiation data from two weather stations. Appendix 2-F contains the full model calibration report. Water budget components and an indication of if the component is a model input or output are summarized in Table 2-9. If the component is an input, Table 2-9 describes its data source.

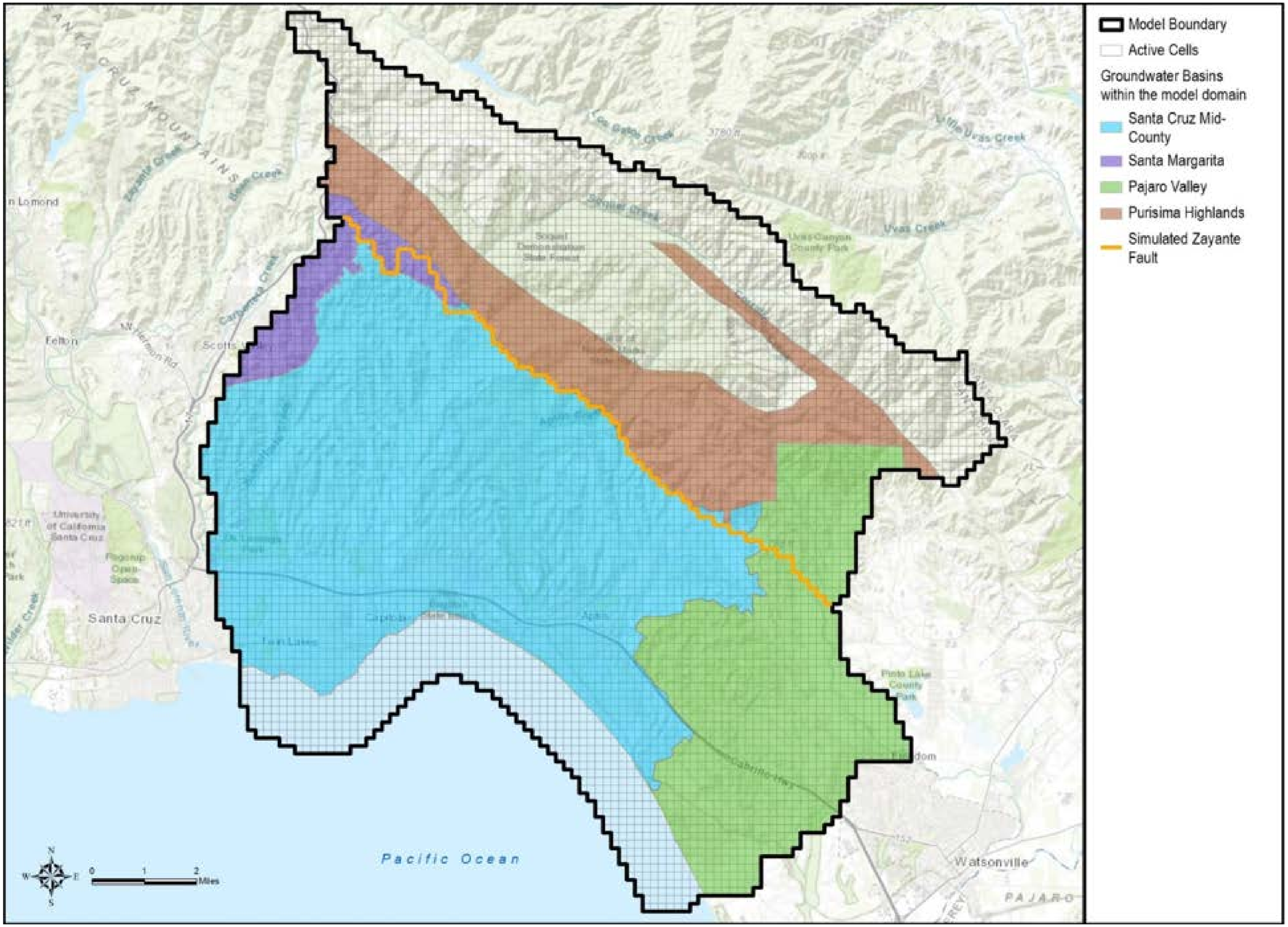


Figure 2-52. GSFLOW Model Domain

Table 2-9. Summary of Water Budget Component Data Sources

Water Budget Component	Source of Model Input Data	Limitations
Precipitation	Measured precipitation spatially distributed for historical simulations; climate catalog precipitation uses same spatial distribution as historical simulations	Spatial precipitation distribution may change with changing climate
Evapotranspiration	Measured and estimated temperature spatially distributed for historical simulations; climate catalog temperature uses same spatial distribution as historical simulations. Simulated from calibration to potential evapotranspiration. Simulated ET includes ET from shallow groundwater lumped together with surface ET	Not simulated from surface water bodies or streamside vegetation
Soil Moisture	Simulated from calibrated model	Not measured but based on calibration of streamflow to available data from gauged creeks
Surface Water Inflows		
Flow from Area Upstream of Basin	Simulated from calibrated model for all creeks	Not all creeks have data for calibration
Groundwater Discharge to Creeks	Simulated from calibrated model	For overall Basin, calibration to streamflow indicated groundwater interactions less significant than watershed characteristics
Overland Runoff	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks
Interflow from Unsaturated Zone	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks
Surface Water Outflows		
Groundwater Discharge	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks
Streambed Recharge to Groundwater	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks
Diversions	Not modeled	Diversions known to exist, but are currently limited in number and small in magnitude
Discharge to Ocean	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks
Groundwater Inflows		
Direct Percolation of Precipitation	Measured precipitation spatially distributed for historical simulations and percolation simulated by watershed component of calibrated model	Assumes percolation applies directly as recharge to water table without delay through unsaturated zone

Water Budget Component	Source of Model Input Data	Limitations
Groundwater Inflows cont.		
Streambed Recharge to Groundwater	Simulated from calibrated model	Shallow groundwater level data are only available for the lower Soquel Creek, therefore only area calibrated for surface water-groundwater interactions. For overall Basin, calibration to streamflow indicated groundwater interactions less significant than watershed characteristics controlling overland/near surface flow to creeks.
Irrigation Return Flows	Estimated from demands based on crop, acreage and temperature	Assumes return flow locations remain the same historically and in the future
Septic System Return Flows	Estimated based on percentage of indoor water use for non-sewered parcels	Assumes return flow locations remain the same historically and in the future
Subsurface Inflow (includes onshore flows)	Simulated from calibrated model	Assumes conditions in Santa Margarita Basin and Pajaro Valley Subbasin do not change in the future. Assumes specific amount of sea level rise in the future.
Managed Aquifer Recharge (MAR)	No MAR in historical water budget Used in projected water budget only based on assumed MAR implementation	Based on current plans for MAR that could be revised in future
Groundwater Outflows		
Groundwater Pumping	• Metered for historical municipal pumping and some small water systems • Estimated for non-municipal domestic pumping • Estimated for agricultural and large-scale turf irrigation • All future pumping is estimated	Future pumping based on current estimates for municipal demand. Future non-municipal domestic pumping based on estimated growth rates higher than latest estimates
Groundwater Discharge to Creeks	Simulated from calibrated model	Groundwater level data from which to calibrated is only available for the lower Soquel Creek, therefore only area calibrated for surface water-groundwater interactions. For overall Basin, calibration to streamflow indicated groundwater interactions less significant than watershed characteristics
Subsurface Outflow to Adjacent Basins	Simulated from calibrated model	Assumes conditions in Santa Margarita Basin and Pajaro Valley Subbasin do not change in the future
Subsurface Outflow to Ocean	Simulated from calibrated model	Assumes specific amount of sea level rise

2.2.5.2 Model Assumptions and Uncertainty Related to the Water Budget

All groundwater models contain assumptions and some level of uncertainty, particularly when predicting future conditions. Model uncertainty stems from heterogeneity in Basin geology, hydrology, and climate. However, inputs to the model are carefully selected using best available data, resulting in a model well suited to predict Basin hydrogeologic conditions. As GSP implementation proceeds, the model will be updated and recalibrated with new data to better inform model simulations of current and projected water budgets. Specific assumptions implemented when modeling future conditions are discussed in Section 2.2.5.6.1.

The model calibration report (Appendix 2-F) discusses all model assumptions and uncertainty. The assumptions that cause the greatest uncertainty with respect to the water budget are:

- Shallow monitoring wells are only available along one stretch of lower Soquel Creek. Calibration of the interaction of Soquel Creek with alluvium and the underlying Purisima A aquifer unit is based on the groundwater level data from a few wells. The remainder of the model area does not have the benefit of measured data from which to calibrate the model and therefore the simulation of shallow groundwater and stream-aquifer interaction is much more uncertain than in areas with shallow monitoring wells.

- Even where shallow groundwater level data are available, data quantifying flows between the stream and shallow groundwater are not available for calibration so there is high uncertainty of the magnitude of simulated flows between stream and aquifer calculated by the model.

- There is much less data for calibration north of the Aptos area faulting than south of it where the vast majority of wells with groundwater level data are. As a result there is greater uncertainty in the water budget north of the Aptos area faulting than south of it.

- Model construction combines the Purisima F and DEF aquifer units into one model layer so there is greater uncertainty for estimates of changes of groundwater in storage where the Purisima DEF aquifer unit is pumped. Pumping in this area is from the confined Purisima DEF aquifer unit but the model simulates combined Purisima DEF/F units as unconfined so inaccurately uses higher specific yield values for change in storage instead of specific storage.

2.2.5.3 Water Budget Components

This subsection describes the different components of the Basin water budget inflows and outflows for both surface water and groundwater. Sustainable management criteria described in Section 3 are sometimes aquifer specific and so for management purposes it is important to break up the water budget by aquifer. Most of the different aquifer units within the Basin are modeled as separate layers in the model and therefore the water budget can be broken down by model layer/aquifer. This additional functionality provides MGA with increased knowledge and operation flexibility for managing aquifers separately in order to achieve sustainability.

The groundwater budgets account for all flows entering and leaving the primary aquifers in the Basin. This includes subsurface inflows and outflows, pumping, and all forms of natural and managed aquifer recharge. Similarly the surface water budgets account for surface flows entering and leaving the Basin, precipitation and evapotranspiration, and groundwater recharge through stream alluvium. For both surface water and groundwater, the change in storage is simply the difference between all inflows and outflows.

While basin-wide water budgets are required per SGMA regulations, subarea water budgets are also provided for areas north and south of the Aptos area faulting (Figure 2-53). South of the Aptos area faulting is where the majority of groundwater extraction, including all municipal extraction, takes place. A water budget south of the Aptos area faulting is also more instructive for evaluating seawater intrusion, which is the sustainability indicator that has driven designation of the Basin as being critical overdrafted. The area north of the Aptos area faulting only has non-municipal domestic and agricultural groundwater pumping and has a water budget more influenced by inter-basin flow.

Rainfall is the source of almost all water that becomes either surface water or groundwater in the Basin. The PRMS portion of the GSFLOW model distributes rainfall across the Basin's watersheds based on DAYMET mean annual rainfall distribution. Appendix 2-F provides details of the approach used to input rainfall into the model. Rainfall that falls in the Basin's watersheds is either evapotransported, flows overland and into streams, percolates into the subsurface and becomes groundwater recharge, or remains in the soil zone as soil moisture. Within the surface water inflow budget subsections below, an accounting of how rainfall is apportioned within the Basin is provided in the beginning of the discussion.

Evapotranspiration is calculated by the GSFLOW model based on calibration to potential evapotranspiration. Evapotranspiration includes water that never percolates to groundwater and groundwater that rises into the unsaturated soil zone. A small amount of water that is not used by evapotranspiration, and has not yet become surface water or groundwater is stored in the unsaturated soil zone as soil moisture.

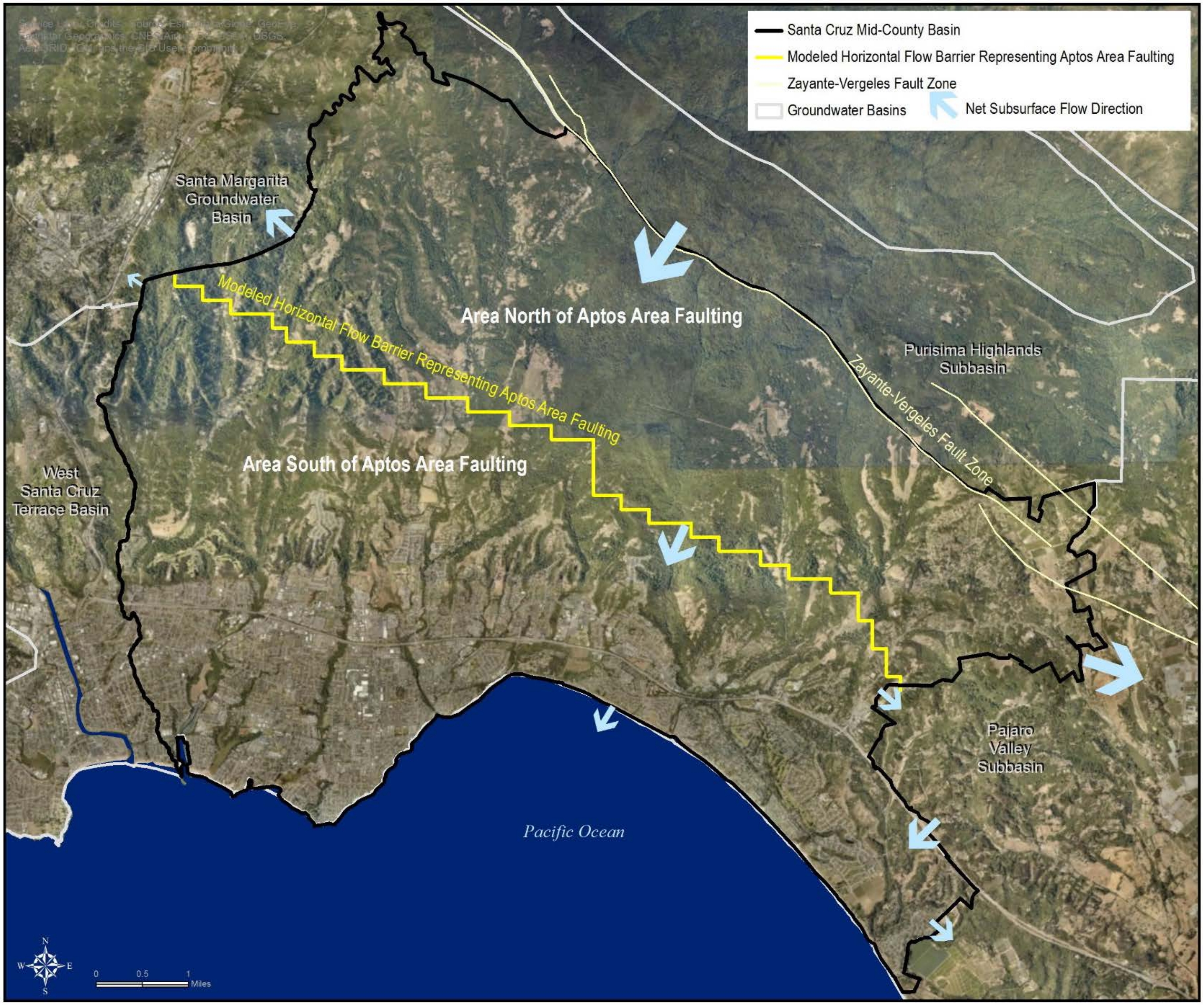


Figure 2-53. Groundwater Budget Subareas

2.2.5.3.1 Surface Water Inflows

Surface water flows enter from across the northern Basin boundary. Creeks that have their headwaters upstream of the Basin include: Granite Creek, Branciforte Creek, West Branch of Soquel Creek, Soquel Creek, Hester Creek, Hinkley Creek, Bridge Creek, Aptos Creek, and Valencia Creek. There are no gauges at the Basin boundary and therefore inflows are simulated using the model, which encompasses the entire watershed of the Basin and is calibrated to measured flows at gauges within the Basin.

Apart from creek flows from outside the Basin, overland runoff into the creeks and groundwater discharge are additional sources of surface water inflows. These are simulated by the model using surface processes that are calibrated to measured flows at USGS gauges within the model domain.

2.2.5.3.2 Groundwater Inflows

Groundwater enters the Basin's aquifers by: subsurface inflow, direct percolation of precipitation, streambed recharge, irrigation return flows, septic system return flows, and managed aquifer recharge in simulations of future Basin conditions.

Substantial subsurface inflow enters the Basin from the Purisima Highlands Subbasin along the northern Basin boundary and from the Pajaro Valley Subbasin, south of the Aptos area faulting (Figure 2-53). There are lesser subsurface inflows across the Basin boundary from the Santa Margarita Basin, however, the net flow is an outflow to the Santa Margarita Basin (Figure 2-53). There are places along the coast where subsurface flows moving onshore from beneath the ocean occur, however over the entire coastal boundary net flows are outflows (Figure 2-53).

Aquifer recharge occurs from precipitation percolating directly into outcropping aquifers, streambed recharge, and recharge from precipitation percolating through stream alluvium and terrace deposits to underlying aquifers. Recharge also occurs due to percolation of irrigation and septic system return flows. In the model, areal recharge from direct percolation of precipitation is calculated using PRMS code for watershed processes while return flows from irrigation and septic systems are input using the MODFLOW Unsaturated Zone Flow (UZF) modeling package. The recharge from direct percolation of precipitation and return flows are then grouped together by MODFLOW using the UZF package. Therefore, the water budget groups these groundwater budget components together and refers to it as UZF recharge.

2.2.5.3.3 Surface Water Outflows

Surface water outflows from the Basin are primarily to the ocean and through streambeds to underlying aquifers. There are some surface water diversions that take place for domestic use, irrigation, or stock watering but these are not included in the model and water budget because records are poor and there are likely some illegal diversions that are difficult to account for. The number of current observed diversions is relatively low. For modeling purposes, all rural water use in the Basin is assumed to come from groundwater extraction, even though a very small portion may actually be supplied by surface water diversions. A small amount of Basin surface flows out of the Basin in Branciforte Creek and then out to the Pacific Ocean.

2.2.5.3.4 Groundwater Outflows

Groundwater leaves the Basin by: subsurface outflows, groundwater pumping, and discharge to creeks. Relatively large subsurface outflows occur to the Pajaro Valley Subbasin north of the Aptos area faulting, while lesser outflows into the Santa Margarita Basin occur depending on hydrologic conditions (Figure 2-53). Outflows offshore, which are necessary to prevent seawater intrusion, occur along the coastal Basin boundary (Figure 2-53). Additional groundwater leaves the Basin when extracted by municipal, domestic, industrial, and agricultural users.

2.2.5.3.5 Change in Groundwater in Storage

The change in groundwater in storage is the difference between groundwater inflows and outflows. Because the model is used to estimate change in storage, estimates can be made for each aquifer. Unconfined aquifers have volumetric changes in storage orders of magnitude greater than confined aquifers because they have much greater specific yields and are not under pressure as confined aquifers are. The water budgets provided below include inflows, outflows, and changes in storage by aquifer and for the Basin as a whole.

2.2.5.4 Historical Water Budget

According to the SGMA regulations (§354.18), the historical water budget included in the GSP must be created based on at least 10 years of recent historical data. The 31-year historical time period from 1985 - 2015 used for the historical water budget corresponds with the period selected for the model. The model period started in 1985 because groundwater extraction and groundwater levels data are available for the majority of the Basin from 1985 onwards. The average rainfall from 1985 – 2015 of 29 inches per year is almost the same as the long-term 1894 – 2015 average rainfall of 29.1 inches per year, and thus is a good representation of long-term historical climate.

2.2.5.4.1 Santa Cruz Mid-County Basin Historical Surface Water Budget

Over the historical period, annual precipitation at the Santa Cruz Co-op station was between approximately 16 inches and 65 inches (1990 and 1998, respectively). On average in the historical model simulation, 66% of precipitation that falls in the Basin is evaporated or transpired without reaching a surface water body. Evapotranspiration includes water that never percolates to groundwater and groundwater that rises to the soil zone. Twenty six percent becomes overland flow that eventually enters streams and creeks within the Basin. Five percent of precipitation is simulated to percolate beyond the root zone and enter the underlying aquifer as UZF recharge, terrace deposits recharge, or stream alluvium recharge. The remaining portion (3%) reflects the net change in soil moisture stored in the soil layers overlying the Basin. In most years the soil moisture value is negative, reflecting gaining soil moisture conditions. However, in some years this value is positive, reflecting a loss of moisture in the soil zone. Typically, this occurs during relatively dry years following a wet period, as evapotranspiration (ET) occurs from the soil zone during the drier year. The model simulated apportionment of precipitation in the Basin is tabulated in Table 2-10, and presented graphically on Figure 2-54.

Table 2-10. Percentage Distribution of Historical Precipitation in Santa Cruz Mid-County Basin

Precipitation Budget Component	Average Annual (acre-feet)	Average Percent of Precipitation
Precipitation	96,200	100%
Evapotranspiration	63,650	66%
Overland Flow	25,320	26%
Groundwater Recharge from Precipitation	4,810	5%
Soil Moisture	2,420	3%

Approximately 55% of inflow to the Basin's surface water system occurs due to overland flow entering streams and rivers within the Basin. Another relatively large portion (43%) enters the Basin from areas upstream of the Basin. Primary surface water features which have this inflow include Soquel Creek, Hester Creek, Hinckley Creek, and Aptos Creek. The remaining 2% of inflow to the Basin's surface water system is net inflow from groundwater to streams.

Surface water outflows from the Basin are dominated by flows to ocean (89%). Nine percent leaves the Basin via Carbonera Creek, which flows into Branciforte Creek after it leaves the Basin and then flows into the Pacific Ocean. The remaining 11% of surface water outflows comprises flows to areas downstream of the Basin. The historical surface water system water budget is summarized in Table 2-11 and shown on an annual bar chart as Figure 2-55.

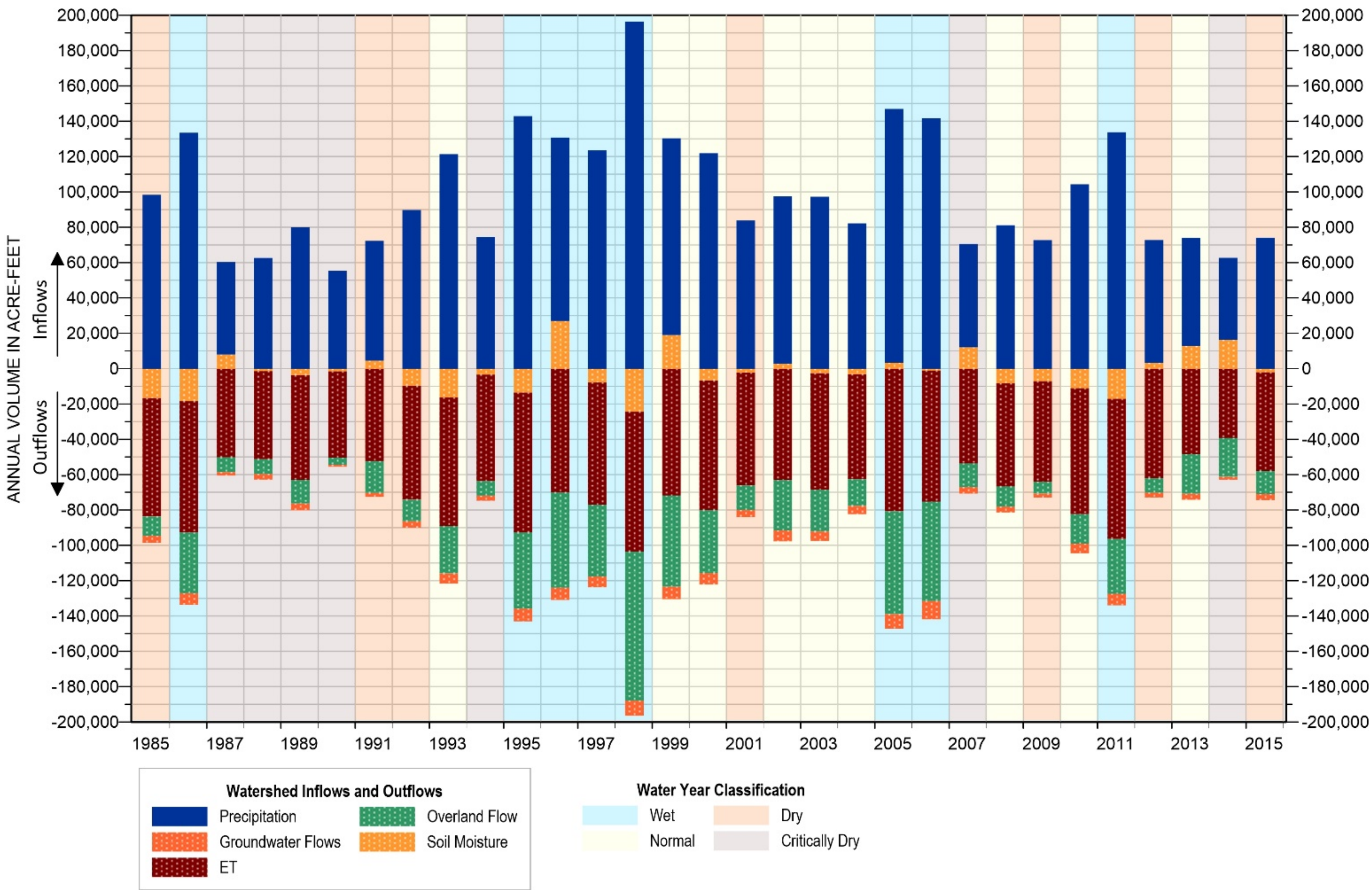


Figure 2-54. Apportionment of Precipitation in Santa Cruz Mid-County Basin Over the Historical Period

Table 2-11. Santa Cruz Mid-County Basin Historical Surface Water Budget

Surface Water Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
Overland Flow	4,080	84,280	25,320	55%
Flows from Upstream of the Basin	2,540	59,920	19,690	43%
Net Flows From Groundwater	680	900	790	2%
		Total Inflow	**45,800**	100%
Outflows (acre-feet per year)				
Ocean Outflow	6,840	119,890	41,000	89%
Outflow in Branciforte Creek	400	16,840	4,120	9%
Pajaro Valley Subbasin	10	2,860	460	1%
Outflow to Carbonera Creek	20	970	220	<1%
		Total Outflow	**45,800**	100%

Note: ‘Groundwater Flows’ refers to flow between streams and underlying alluvium, and is distinct from ‘Stream Alluvium Recharge’ seen in groundwater budgets.

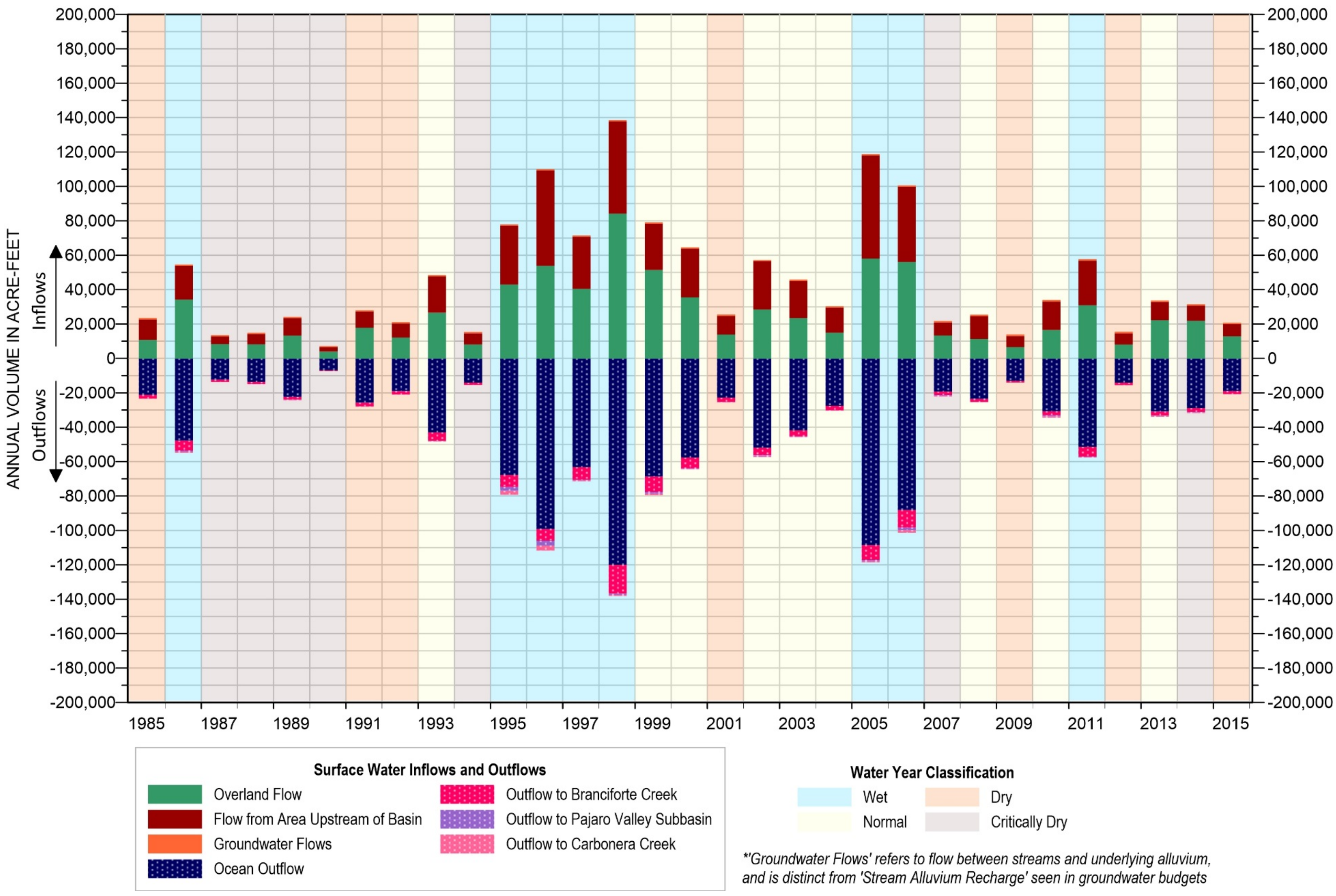


Figure 2-55. Santa Cruz Mid-County Basin Historical Surface Water Budget

During an average year, approximately 45,800 acre-feet of water flows into the Basin's surface water system. An example of the range in surface water inflows is shown on Figure 2-55 where in 1998, at the height of a four-year wet period, almost 140,000 acre-feet flowed into the Basin; while during the peak of the dry period from 1987-1990, surface water inflow was only 6,570 acre-feet .

Surface water within the Basin is not used extensively for water supply purposes. There are surface water diversions for minor domestic use, irrigation, or stock watering but these are not always reported. The most important aspect of the surface water budget from a water management perspective is its connection to groundwater, as groundwater dependent ecosystems that could be impacted by surface water depletion by groundwater use do occur in the Basin. Net groundwater flows into surface water are estimated to be a small component of the overall surface water budget but those flows could still be critical to groundwater dependent ecosystems. The magnitude of estimated flows between surface water and groundwater is highly uncertain due to the limited shallow groundwater data available and lack of data quantifying interconnected flows. Therefore, sustainability management criteria should not be based on the estimated flow values.

The Basin is divided by three watersheds. In the east, the Soquel Creek watershed stretches over half of the Basin, from just east of Cabrillo College to the Basin's western boundary. This watershed includes the Rodeo Gulch, Arana and Branciforte Creek sub-watersheds, even though they do not actually drain into Soquel Creek. The Aptos Creek watershed covers the majority of the remaining portion of the Basin, while the Corralitos watershed overlies a relatively small area in the east (Figure 2-56). Surface water budgets for the Basin's three watersheds are provided on Figure 2-57, Figure 2-58, and Figure 2-59.

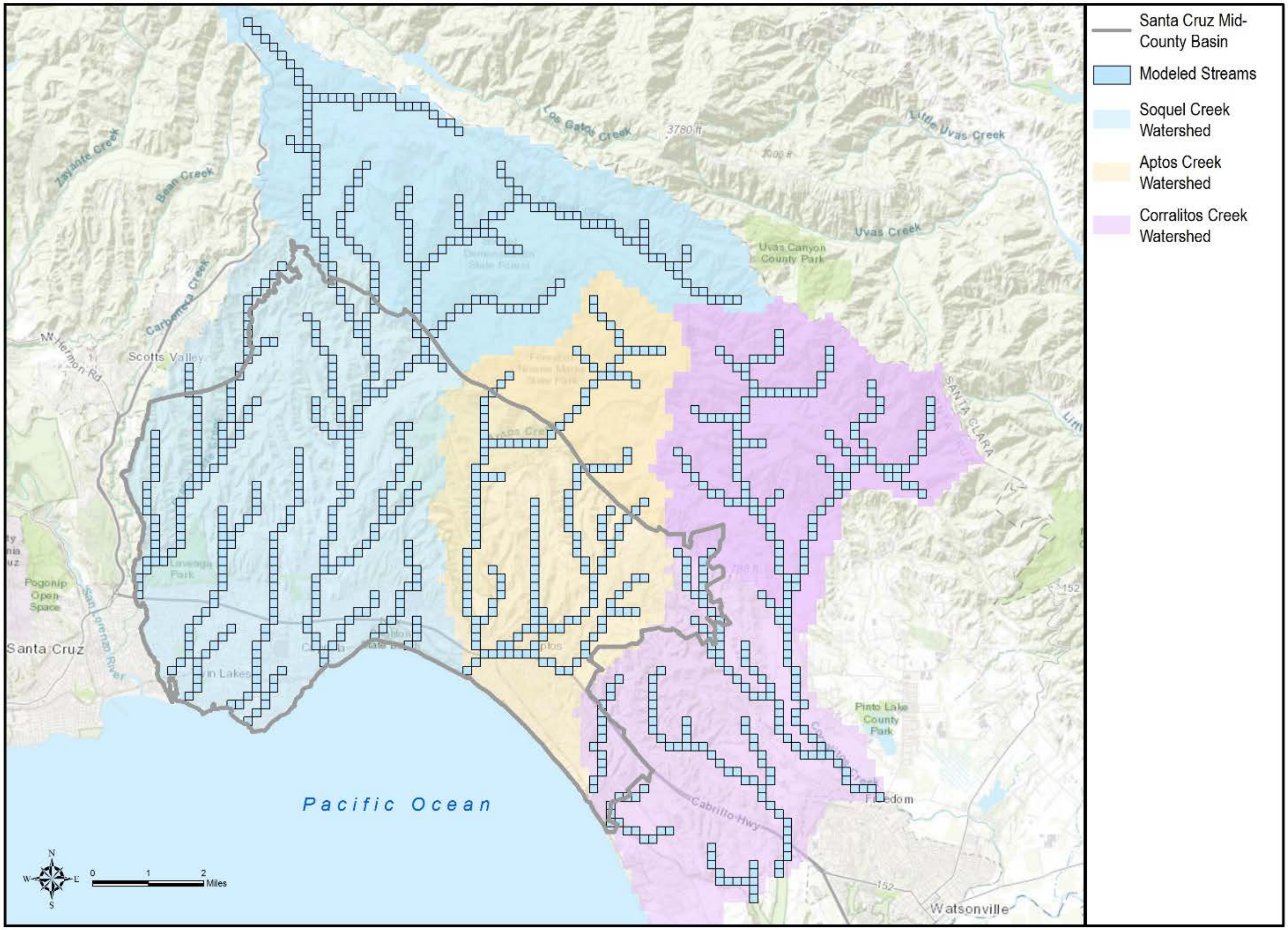


Figure 2-56. Santa Cruz Mid-County Basin Watersheds

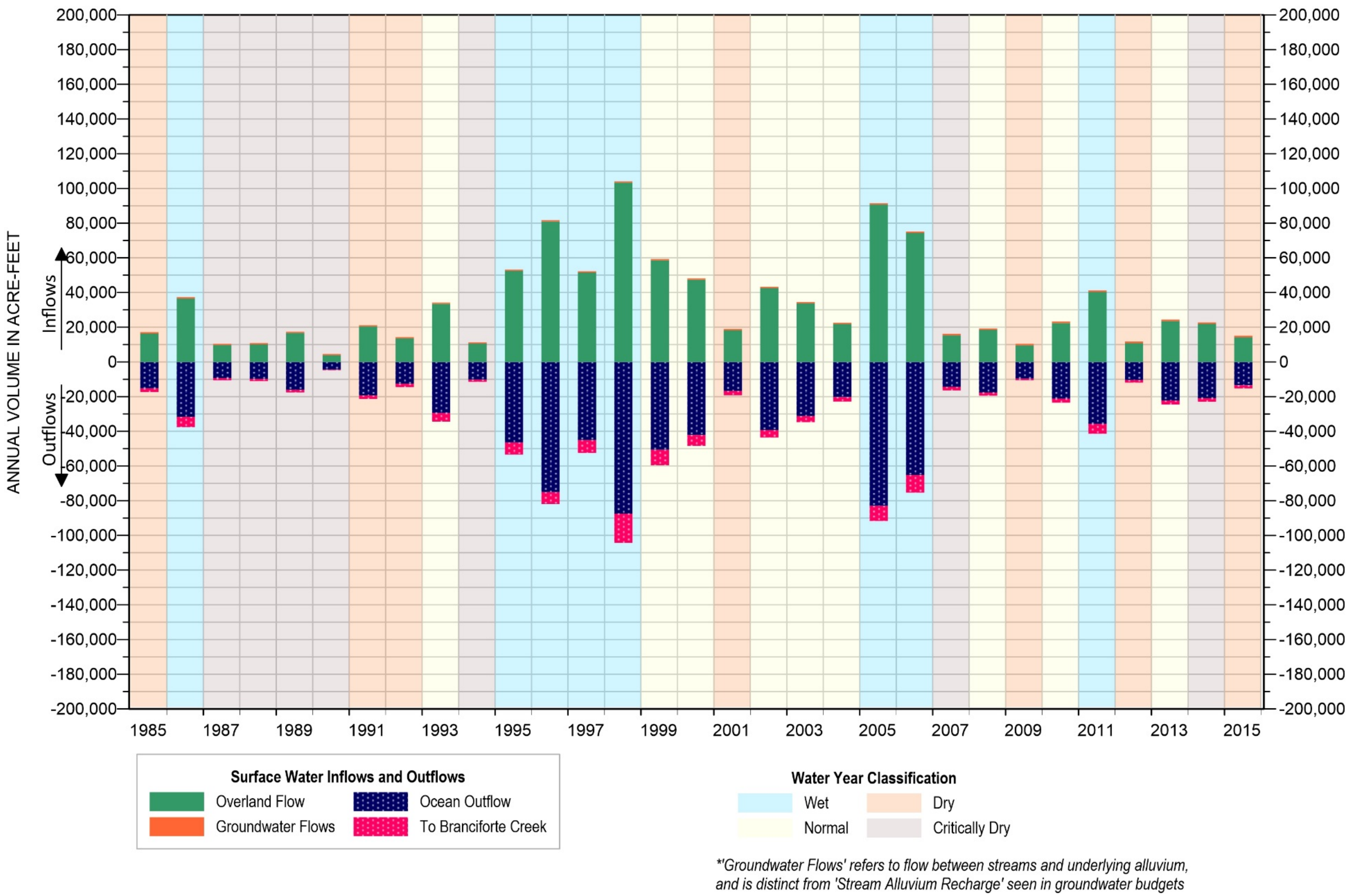


Figure 2-57. Soquel Creek Watershed Historical Budget

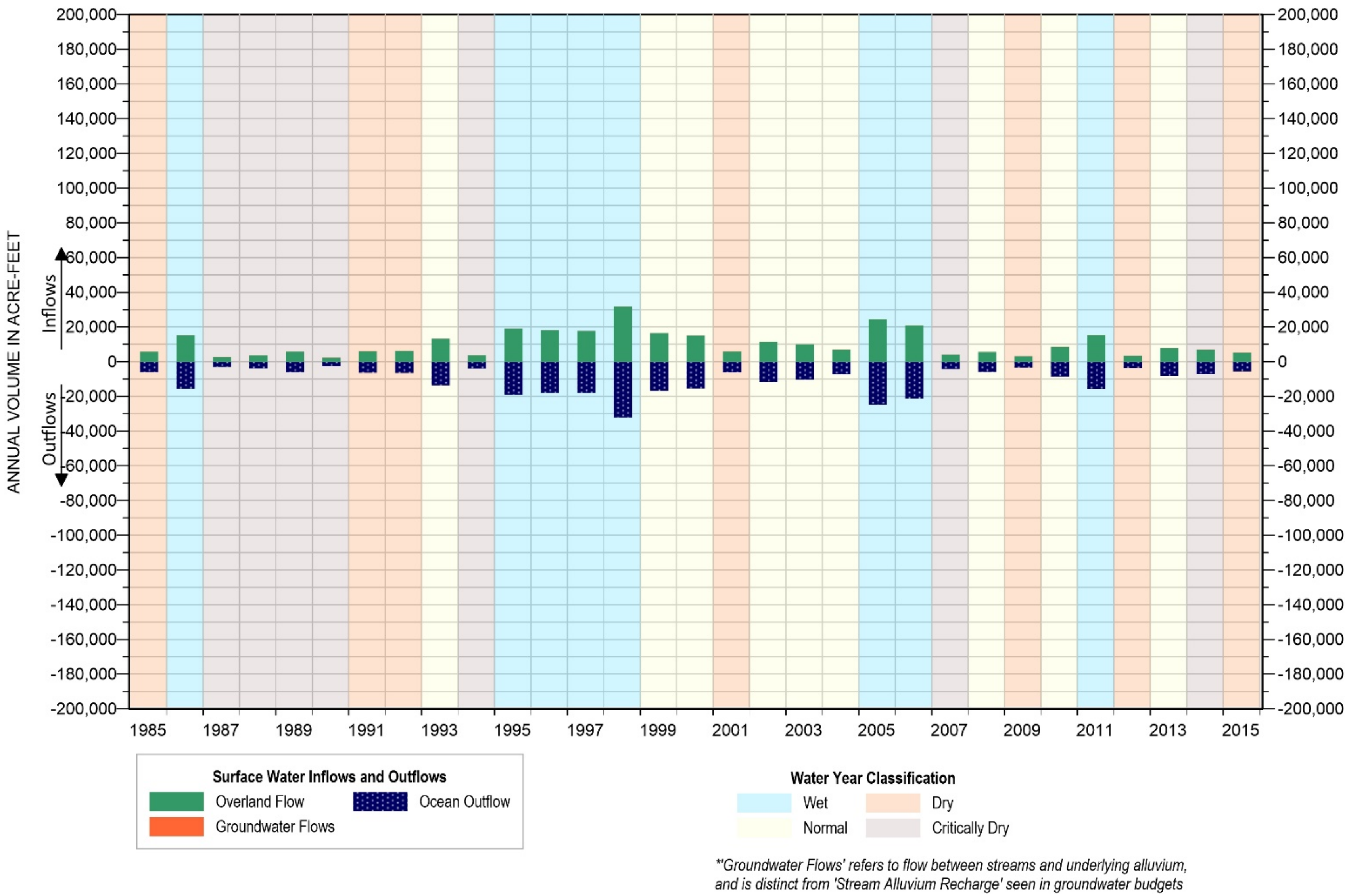


Figure 2-58. Aptos Creek Watershed Historical Budget

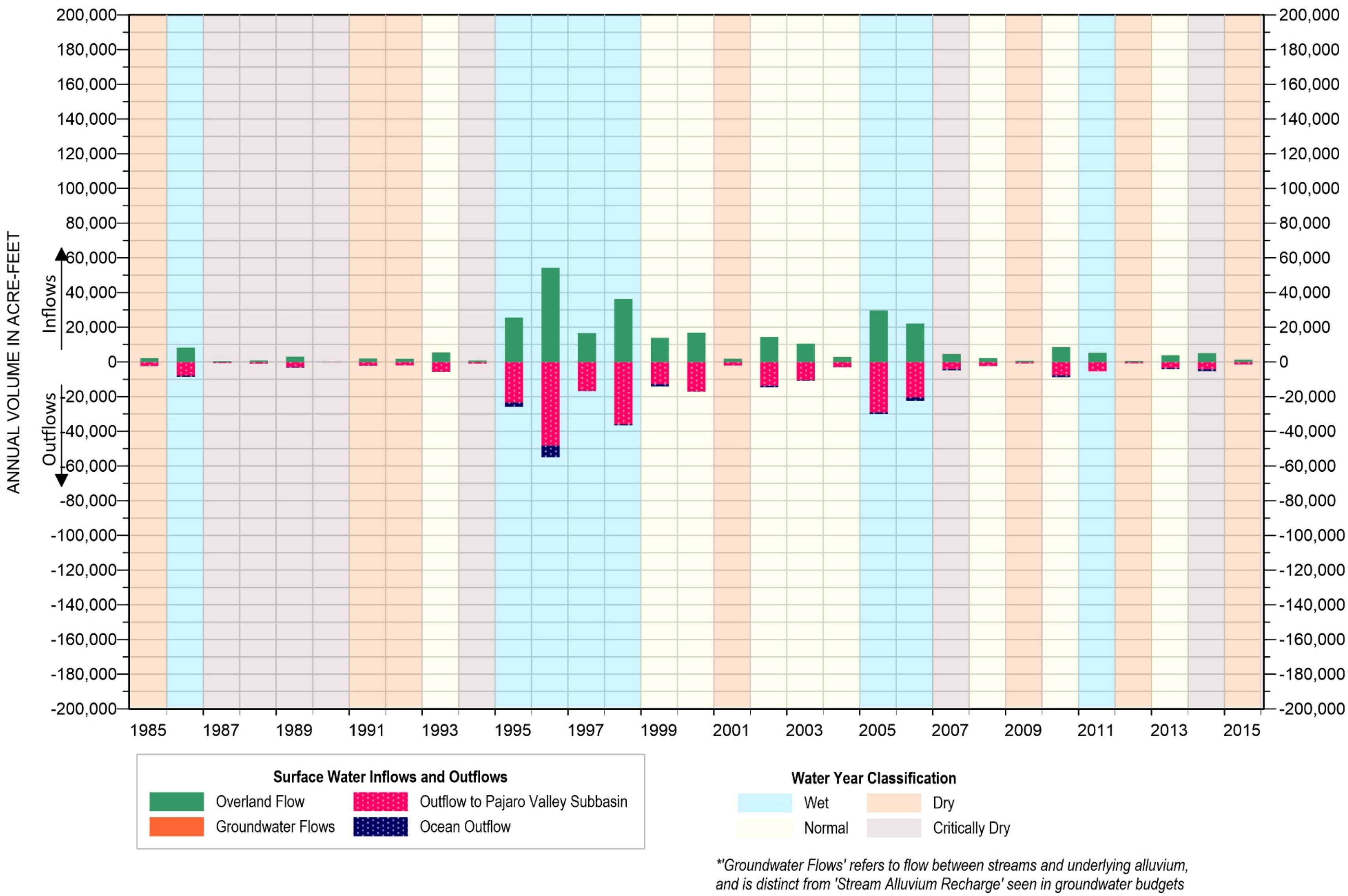


Figure 2-59. Corralitos Creek Watershed Historical Budget

2.2.5.4.2 Santa Cruz Mid-County Basin Historical Groundwater Water Budget

Approximately 60% of Basin groundwater inflow during the historical period comes from surface recharge: UZF recharge (direct percolation of precipitation and return flows) constitutes 34%, while recharge from stream alluvium and terrace deposits contribute 10% and 16%, respectively (Table 2-12). The rest of Basin inflows are fairly consistent subsurface flows across the northern Basin boundary from the Purisima Highlands Subbasin (40% of inflows). Those inflow components that rely on rainfall (UZF recharge and recharge from stream alluvium and terrace deposits) are the most variable due to prolonged wet or dry climatic cycles, as described below.

Table 2-12. Santa Cruz Mid-County Basin Historical Groundwater Budget Summary (1985 – 2015)

Groundwater Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
UZF Recharge	1,550	7,840	4,460	34%
Net Recharge from Stream Alluvium	780	2,130	1,260	10%
Recharge from Terrace Deposits	1,490	3,340	2,080	16%
Subsurface Inflow from Purisima Highlands Basin	4,940	5,570	5,270	40%
		Total Inflow	**13,070**	**100%**
Outflows (acre-feet per year)				
Pumping	5,260	8,460	7,410	59%
Subsurface Outflow to Santa Margarita Subbasin	260	390	310	3%
Net Subsurface Outflow to Pajaro Valley Subbasin	3,770	4,370	4,080	32%
Net Outflow to Offshore	150	1,060	790	6%
		Total Outflow	**12,590**	**100%**
	Cumulative		**Average**	
Change in Storage (acre-feet per year)	+14,910 acre-feet		+480	

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

Primary groundwater outflows during the historical period are groundwater pumping and subsurface flow to Pajaro Valley Subbasin, which are 59% and 33% of total outflows, respectively (Table 2-12). The remaining 9% of Basin outflow consists of flows offshore (6%) and subsurface flows to Santa Margarita Subbasin (3%).

Historically, the Basin experienced net recharge from stream alluvium to the primary aquifers and aquitards of the Basin (Table 2-12). There are locations where groundwater in stream alluvium discharges to streams but overall there is also net recharge from stream alluvium to the primary aquifers of the Basin. Net recharge from stream alluvium occurs even where the stream alluvium discharges groundwater to streams because groundwater levels in the stream alluvium are generally higher than groundwater levels in underlying aquifers. Therefore net recharge from stream alluvium does not necessarily mean the stream is recharging groundwater in that area.

Over the historical period, there is a Basin-wide average increase in groundwater in storage of approximately 480 acre-feet per year, or 14,910 acre-feet cumulatively (Table 2-12). The cumulative change in storage line (dashed) on Figure 2-60 shows three distinct cumulative change in storage trends:

- From 1985 to 1994 (10 years) basin-wide pumping in excess of 7,930 acre-feet per year and an extended dry climate which limited recharge contributed to a cumulative decline in groundwater in storage of about 8,000 acre-feet (an average decrease of 800 acre-feet per year) which corresponds to declining groundwater levels in the area of municipal production.

- The years from 1995 through 2006 had a cumulative increase of groundwater in storage of approximately 28,000 acre-feet (an average increase of 2,300 acre-feet per year). This 12-year period only has one year classified as a dry water year, with all the other years being either normal or wet. Notably, the period starts and ends with wet years: four consecutive wet years from 1995 through 1998 and two wet years in 2005 and 2006 (Figure 2-60). Because of the normal to wet climatic conditions, surface recharge increased thereby causing an increase in groundwater in storage.

- From 2007 through 2015 (nine years), there are only three years of normal or wet water years, which resulted in less groundwater recharge than occurred in the prior 12 years (Figure 2-60). Even though this period has below normal rainfall, there has only been a cumulative loss of 4,000 acre-feet (or an average of 440 acre-feet per year) in groundwater in storage because from 2005 onwards, municipal groundwater pumping is on average 10% less compared to the average pumping from 1985 – 1994. Reduction in groundwater pumping was achieved through focused water conservation measures and responsive groundwater management.

Overall, the Basin's historical groundwater budget consists of inflows from surface recharge and subsurface inflows from the Purisima Highlands Subbasin. Outflows are primarily from groundwater extraction and outflow to the Pajaro Valley. Over the 31 years of the historical water budget period, there has been an overall increase in groundwater in storage. This overview does not reflect the groundwater budgets of specific aquifers, some of which may still have overall losses of groundwater in storage and therefore cause undesirable results such as seawater intrusion. Table 2-13 provides a summary of the historical groundwater budget by aquifer and annual groundwater budgets for individual aquifers are contained in Appendix 2-F.

Flows between the Basin and the ocean (offshore) are an important component of the water budget for evaluating groundwater sustainability because seawater intrusion is the sustainability indicator that is the basis for the Basin's overdraft condition. Figure 2-61 plots each aquifer's offshore inflows and outflows. Net outflows (negative on the water budget chart on Figure 2-61) of some magnitude is required to prevent seawater intrusion. Net inflows (positive on the water budget chart on Figure 2-61) are indicative of flow conditions that will eventually result in seawater intrusion. Inflows from offshore consistently occur in the Purisima DEF/F and Purisima A aquifer units. These are the aquifers where seawater intrusion is occurring. The Tu aquifer has small volumes of inflow from offshore, which reverses to offshore flow in wet years.

Although inflows to the Basin from the ocean have decreased since 2005, corresponding with reduced municipal pumping (Figure 2-61), inflows from offshore still indicate seawater intrusion risk. However, groundwater budget results should not be the primary method for evaluating seawater intrusion because freshwater outflow offshore may not be enough to prevent denser seawater from intruding. In addition, net flows representing flows across the entire coastal boundary may not represent the localized risk near pumping centers. The primary model results for evaluating seawater intrusion should be simulated groundwater levels at coastal monitoring wells compared to established protective elevations as discussed in more detail in Section 3.

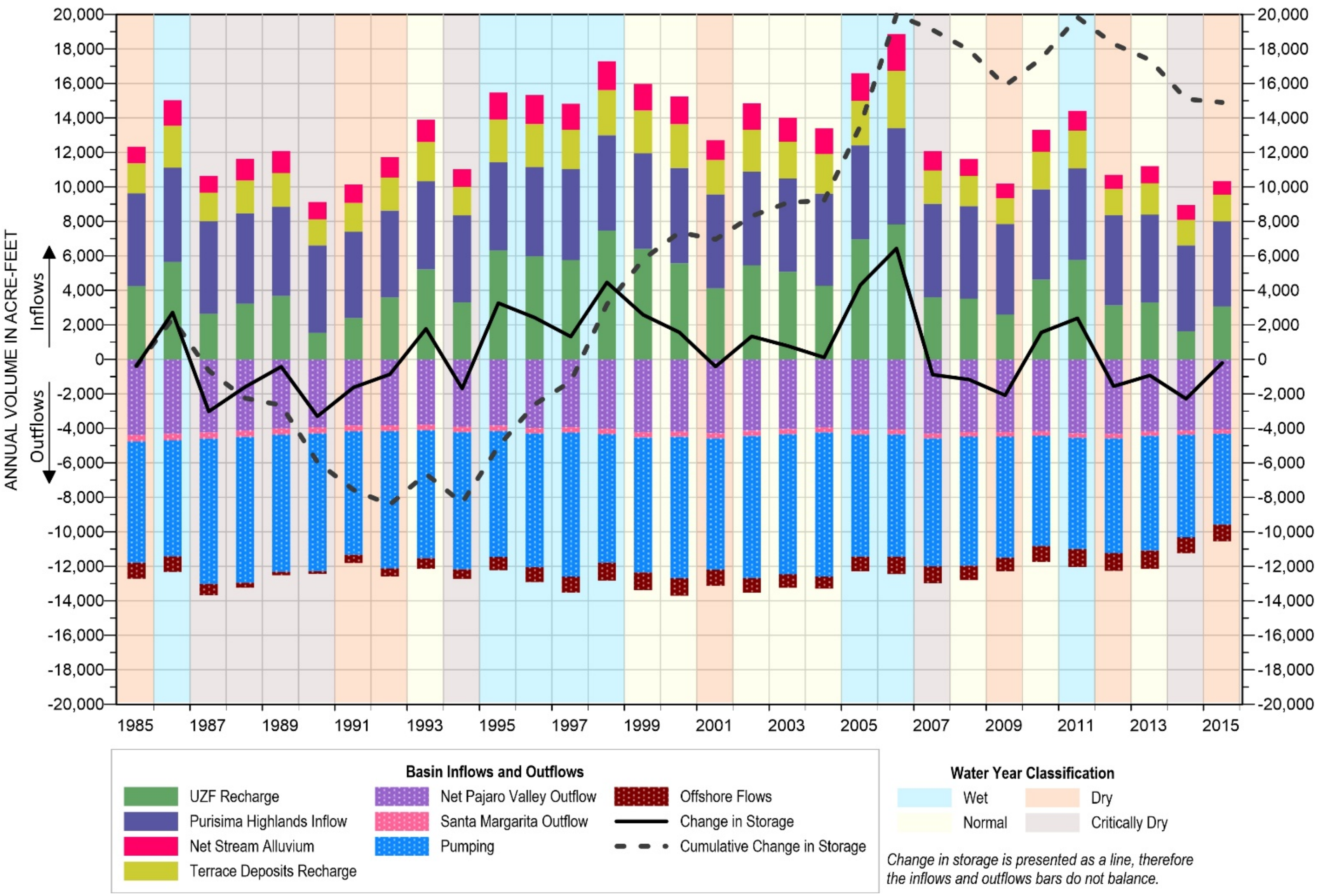


Figure 2-60. Santa Cruz Mid-County Basin Historical Annual Groundwater Budget (1985 – 2015)

Table 2-13. Santa Cruz Mid-County Basin Historical Groundwater Budget by Aquifer Summary (1985 – 2015)

Groundwater Budget Component	Aromas Red Sands (L2)	Purisima DEF/F (L3)	Purisima D (L4)	Purisima BC (L5)	Purisima B (L6)	Purisima A (L7)	Purisima AA (L8)	Tu (L9)	Total
Annual Average Inflows (acre-feet per year)									
UZF Recharge	770	780	200	190	220	570	540	1,190	4,460
Recharge from Stream Alluvium	530	130	_	280	_	380	190	10	1,520
Recharge from Terrace Deposits	1,050	170	_	290	100	230	240	_	2,080
Subsurface Inflow from Purisima Highlands Subbasin	_	2,870	330	320	360	590	780	20	5,270
Offshore Inflow	_	80	_	_	_	30	_	10	120
Inter-Layer Flow	_	740 (L2) 50 (L4)	_	100 (L4)	40 (L5)	140 (L6)	20 (L7)	_	1,090
Total Inflow	**2,350**	**4,820**	**530**	**1,180**	**720**	**1,940**	**1,770**	**1,230**	**14,540**
Annual Average Outflows (acre-feet per year)									
Pumping	980	2,130	<10	900	150	1,590	1,110	550	7,410
Discharge to Stream Alluvium	_	_	80	_	180	_	_	_	260
Subsurface Outflow to Santa Margarita Basin	_	_	_	_	_	_	_	310	310
Subsurface Outflow to Pajaro Valley Subbasin	420	2,590	300	100	150	330	190	_	4,080
Outflow Offshore	210	_	10	140	100	_	450	_	910
Inter-Layer Flow	740 (L3)	_	50 (L3) 100 (L5)	40 (L6)	140 (L7)	20 (L8)	_	_	1,090
Total Outflow	2,350	4,720	540	1,180	720	1,940	1,750	860	14,060
Change in Storage (acre-feet per year)	**0**	**100**	**-10**	**0**	**0**	**0**	**20**	**370**	**480**

Notes: The abbreviation L is for model layer, e.g., L2 is model layer 2

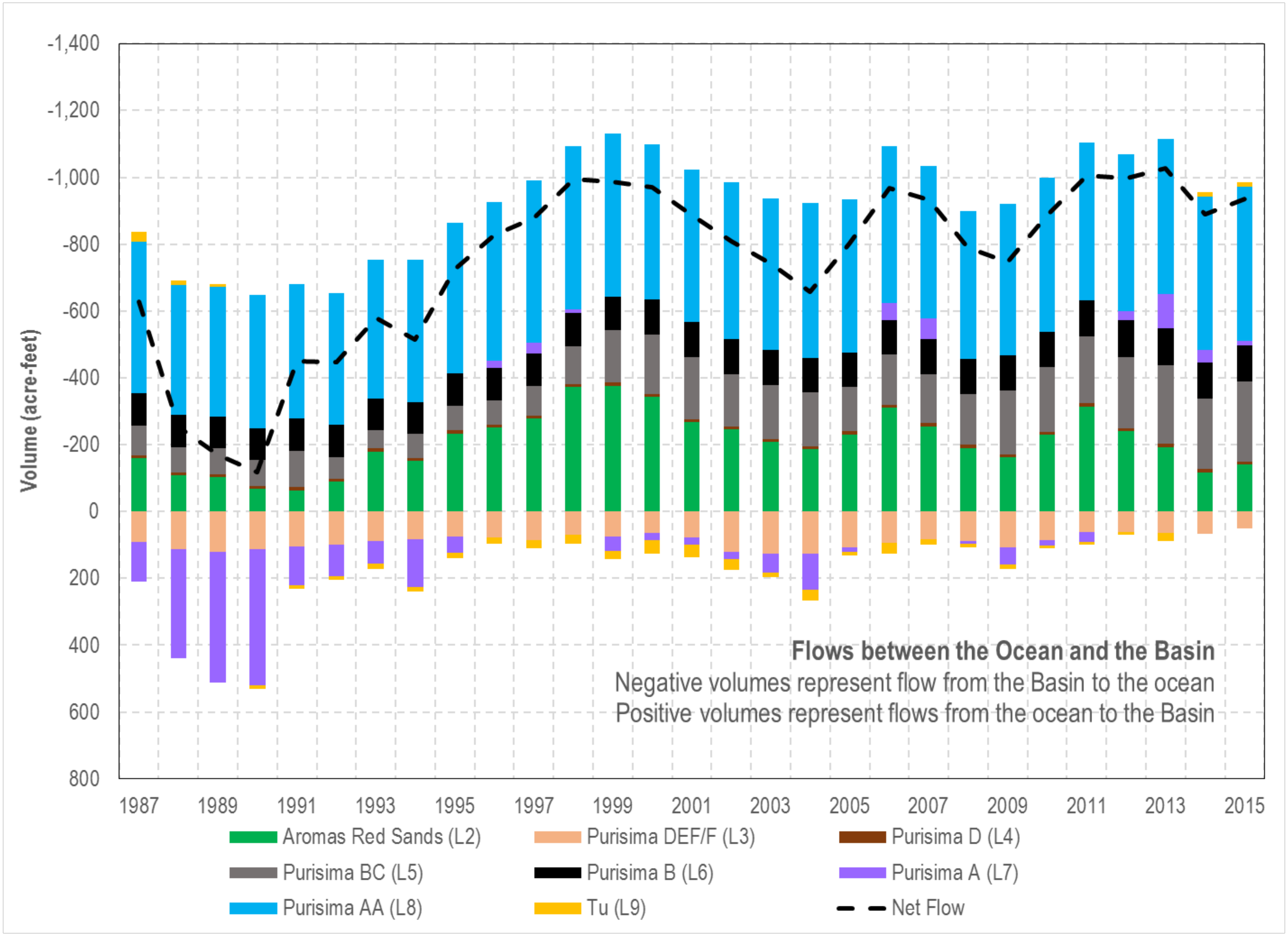


Figure 2-61. Offshore Groundwater Flow to Santa Cruz Mid-County Basin by Model Layer

2.2.5.4.3 North of Aptos Area Faulting Historical Groundwater Budget

Historical groundwater inflows into the area north of the Aptos area faulting consist of inflows from the Purisima Highlands Subbasin (66%) and UZF recharge (34%) (Table 2-14).

As the area north of the Aptos area faulting does not support a large population like the more urban area south of the Aptos area faulting, groundwater pumping is not the primary outflow. Instead 64% of the outflow is by means of subsurface outflow to Pajaro Valley. Nineteen percent of outflows are to the area south of the Aptos area faulting. The remainder of outflows are from groundwater pumping (8%), subsurface outflow to the Santa Margarita Basin (4%), and groundwater discharge to streams (4%). The balance of inflows and outflows results in a slight increase in groundwater in storage of approximately 30 acre-feet per year. This indicates that the historical water budget north of the Aptos area faulting is well balanced. A graphical representation of the historical annual water budget is provided in Table 2-14.

Cumulative change in storage trends for the area north of the Aptos area faulting are similar to the basin-wide change in storage trends: an extended dry period during the 1980's through to the mid-1990's contributing to storage losses, followed by a period of recovery and storage gain starting in 1995, and stabilizing from 2007 through 2015. The recent drought from 2012-2105 appears to have impacted the area north of the Aptos area faulting with cumulative storage declining 3,000 acre-feet from 2012 - 2015. The range in UZF recharge (maximum less minimum), which predominantly includes direct percolation of rainfall, is greater in the area north of the Aptos area faulting (Table 2-14) compared to the area south of the Aptos area faulting (Table 2-15). This may be due to the greater area that has impermeable surfaces in the more urban area south of the fault that limits areal recharge.

Table 2-14. North of Aptos Area Faulting Historical Groundwater Water Budget Summary (1985 – 2015)

Groundwater Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
UZF Recharge	750	5,410	2,730	34%
Subsurface Inflow from Purisima Highlands Subbasin	4,940	5,570	5,270	66%
		Total Inflow	**8,000**	**100%**
Outflows (acre-feet per year)				
Pumping	440	850	690	8%
Discharge to Streams	170	560	360	4%
Subsurface Outflow to Santa Margarita Subbasin	240	380	300	4%
Subsurface Outflow to Pajaro Valley Subbasin	4,810	5,360	5,110	64%
Subsurface Outflow to South of Aptos Area Faulting	1,470	1,530	1,510	19%
		Total Outflow	**7,970**	100%
	Cumulative		Average	
Change in Storage (acre-feet per year)	+910 acre-feet		+30	

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

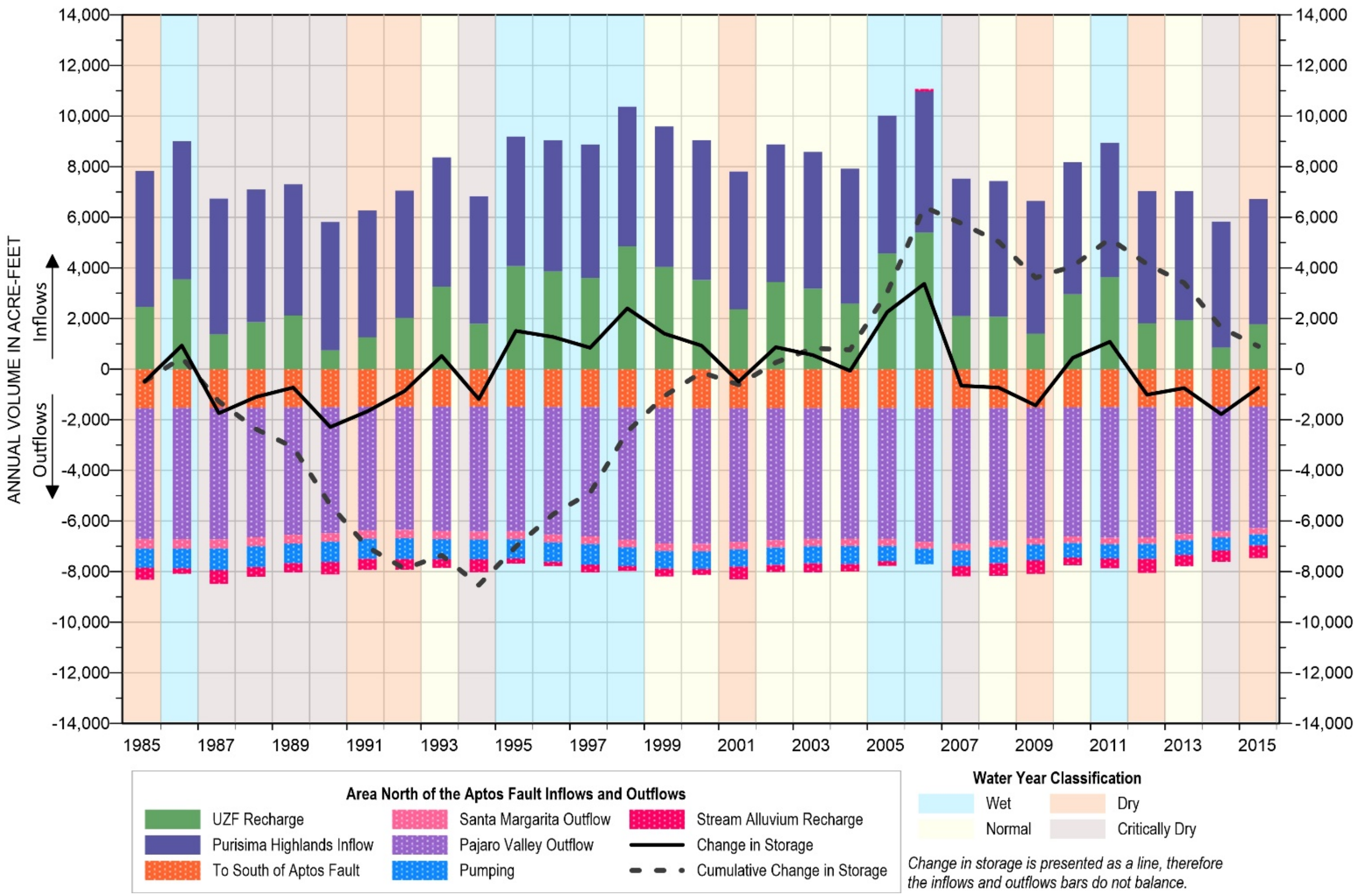


Figure 2-62. North of Aptos Area Faulting Historical Annual Groundwater Budget (1985 – 2015)

2.2.5.4.4 South of Aptos Area Faulting Historical Groundwater Budget

Historical groundwater inflows to the portion of the Basin south of the Aptos area faulting are summarized in Table 2-15. Primarily inflows are from terrace deposits (26%), UZF recharge (22%), and recharge from stream alluvium (20%). Slightly lesser inflows are from subsurface sources: the area north of the Aptos area faulting (19%) and Pajaro Valley (12%). On average, combined natural recharge constitutes around 68% of groundwater inflow with subsurface inflow from the north and Pajaro Valley comprising the remaining 32%.

Groundwater outflows in the area south of the Aptos area faulting are primarily from groundwater pumping, which comprises 89% of average outflows (Table 2-15). The remaining 11% comprised almost completely of flows offshore, with a very minor amount of 10 acre-feet flowing into the Santa Margarita Basin. For the area south of the Aptos area faulting, the average change in storage over the 31-year historical period is an increase of approximately 470 acre-feet per year. A graphical representation of the historical groundwater budget over the historical period is provided in Figure 2-62.

Cumulative change in storage trends for the area south of the Aptos area faulting are similar to the whole Basin change in storage trends: an extended dry period during the 1980's through to the mid-1990's contributing to storage losses, followed by a period of recovery and storage gain starting in 1995, and stabilizing from 2007 through 2015. The storage loss in the area south of the Aptos area faulting (Figure 2-63) from 1985-1994 is less pronounced than in the area north of the Aptos area faulting (Figure 2-62) due in part to the presence of flows from offshore and seawater intrusion. As surface sources of recharge decrease during this period, flow offshore also decreases substantially, indicating conditions supporting seawater intrusion. From 1995 onward, cumulative storage is gained and flows offshore are consistent. Even though there is overall offshore flow, seawater intrusion and risk of further seawater intrusion is still present and MGA activities such as MAR will be necessary to prevent further seawater intrusion.

Table 2-15. South of Aptos Area Faulting Historical Groundwater Water Budget Summary (1985 – 2015)

Groundwater Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
UZF Recharge	790	2,620	1,730	22%
Recharge from Stream Alluvium	1,280	2,030	1,630	20%
Recharge from Terrace Deposits	1,490	3,340	2,080	26%
Subsurface Inflow from Pajaro Valley Subbasin	760	1,230	1,030	13%
Subsurface Inflow from North of Aptos Area Faulting	1,470	1,530	1,510	19%
		Total Inflow	**7,980**	**100%**
Outflows (acre-feet per year)				
Pumping	4,830	7,640	6,710	89%
Subsurface Outflow to Santa Margarita Subbasin	<10	20	10	<1%
Net Outflow Offshore	150	1,060	790	11%
		Total Outflow	**7,510**	**100%**
	Cumulative		**Average**	
Change in Storage (acre-feet per year)	+13,980 acre-feet		+470	

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

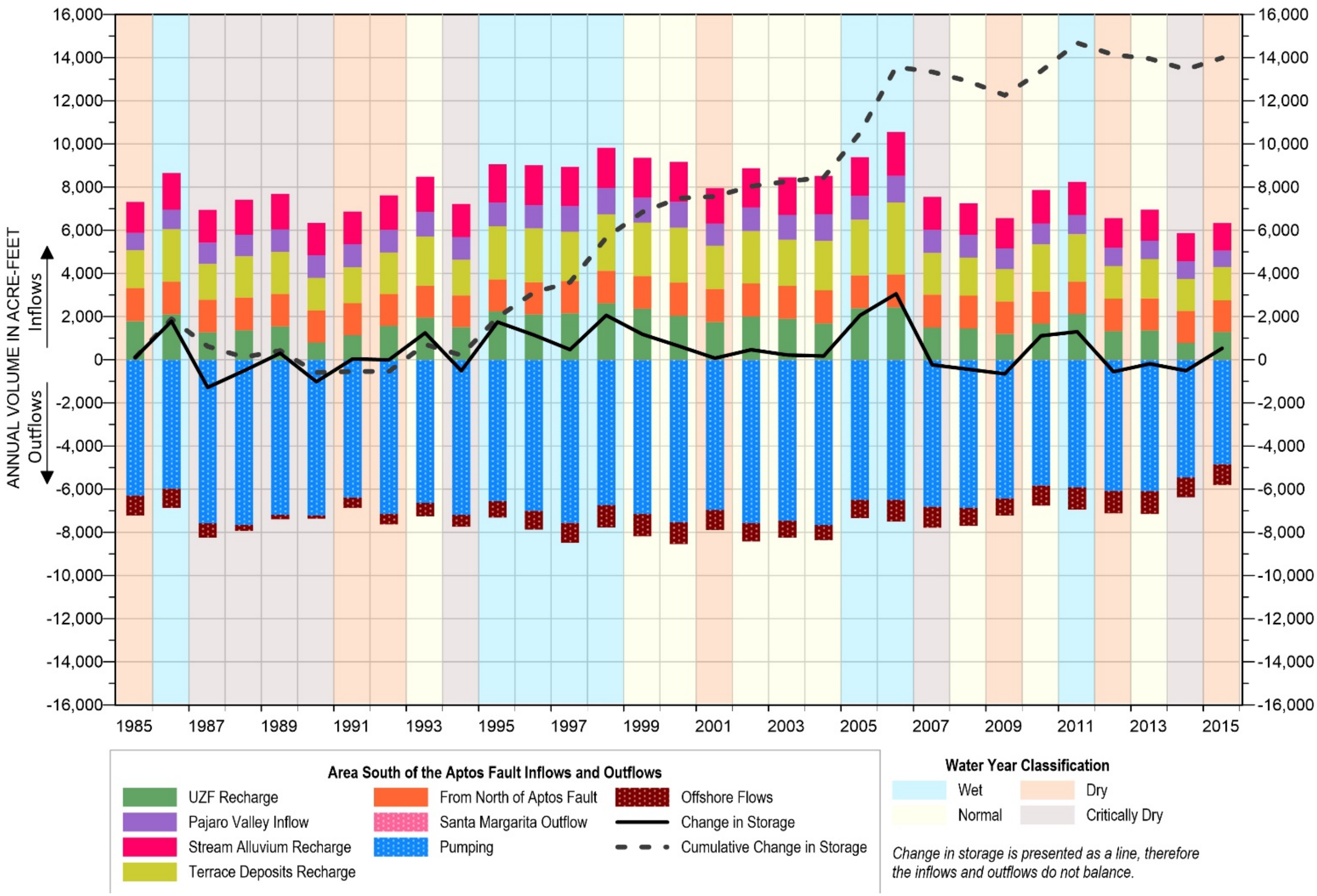


Figure 2-63. South of Aptos Area Faulting Historical Annual Groundwater Budget (1985 – 2015)

2.2.5.5 Current Water Budget

The current water budget for the Basin includes the most recent information available, and covers the period from Water Year 2010-2015. This period was selected as it encompasses both the recent 2012 – 2015 drought and two relatively wet years resulting in an average rainfall of 24.3 inches per year at the Santa Cruz Co-op station. The current water budget period represents overall drier conditions with 5.7 inches less rainfall than the 1985 - 2015 average of 29 inches per year.

2.2.5.5.1 Santa Cruz Mid-County Basin Current Surface Water Budget

From Water Year 2010 through 2015, 5.7 inches less rainfall than historical conditions at the Santa Cruz Co-op station translates to an average of approximately 14,600 acre-feet per year less water available for evapotranspiration, overland flow, groundwater recharge and soil moisture (Table 2-10 and Table 2-16). Evapotranspiration during these drier years declined by approximately 4,350 acre-feet per year, but it used up relatively more of the available water in the Basin (72% compared to 66% in the historical period). Water available for overland flow was on average 6,750 acre-feet per year less than over the historical period. Groundwater recharge was on average 910 acre-feet less per year while the relative percentage of recharge remained the same. Conditions during the current period were so dry, water from soil moisture occurred, likely to evapotranspiration, which is why its value is negative in Table 2-16.

Table 2-16. Percentage Distribution of Current Precipitation in Santa Cruz Mid-County Basin

Precipitation Budget Component	Average Annual (acre-feet)	Average Percent of Precipitation
Precipitation	81,600	100%
Evapotranspiration	59,300	72%
Overland Flow	18,660	23%
Groundwater Recharge from Precipitation	3,910	5%
Soil Moisture	-270*	0%

Note: * a negative soil moisture value indicates soil moisture was lost and not gained

The lower rainfall results in the current surface water budget having 13,740 acre-feet less surface water flowing into the Basin and 11,940 acre-feet less flowing out to the ocean compared to the historical period (Table 2-11 and Table 2-17). Despite the overall inflow decrease, relative volumetric proportions between groundwater components are consistent with the historical budget. The surface water budget is shown graphically on Figure 2-64.

Table 2-17. Santa Cruz Mid-County Basin Current Surface Water Budget

Surface Water Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
Overland Flow	8,060	30,580	18,670	58%
Flows from Upstream of the Basin	6,520	25,930	12,570	39%
Net Flows from Groundwater	810	900	870	3%
		Total Inflow	**32,110**	**100%**
Outflows (acre-feet per year)				
Ocean Outflow	14,000	51,310	29,070	91%
Outflow in Branciforte Creek	1,420	5,730	2,630	8%
Pajaro Valley Subbasin	10	690	280	<1%
Outflow to Carbonera Creek	70	350	130	<1%
		Total Outflow	**32,110**	**100%**

Note: ‘Groundwater Flows’ refers to flow between streams and underlying alluvium, and is distinct from ‘Stream Alluvium Recharge’ seen in groundwater budgets.

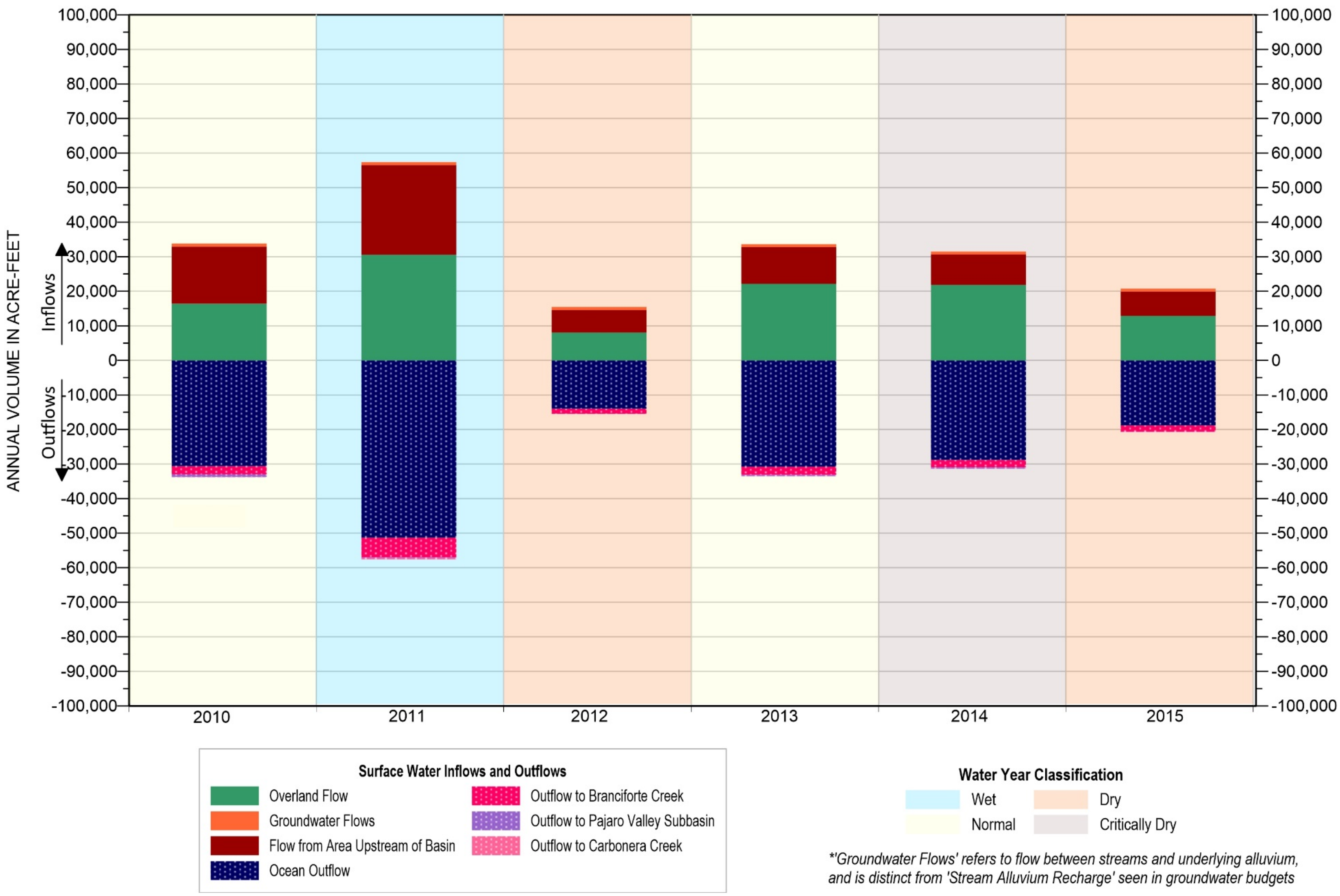


Figure 2-64. Santa Cruz Mid-County Basin Current Annual Surface Water Budget

2.2.5.5.2 Santa Cruz Mid-County Basin Current Groundwater Budget

The inflow and outflow components for the current groundwater budget are the same components as the historical budget, and their relative contributions are similar. Table 2-18 summarizes the minimum, maximum, and average annual inflows and outflows, and average annual change in groundwater in storage. A graphical representation of the current annual groundwater budget over the current period is provided in Figure 2-65.

On average, combined surface recharge sources constitute approximately 55% of Basin inflows, with inflow from subsurface flow from the Purisima Highlands Subbasin comprising the remaining 45%. Current inflows are about 1,580 acre-feet per year less than during the historical period due to below normal rainfall which occurred over most of this period.

For the current water budget period, Basin outflow from groundwater pumping is on average 1,190 acre-feet less than during the historical period. This reflects the reduction in pumping that occurred across the Basin through conservation in response to the 2012-2015 drought and the groundwater emergency declaration by Soquel Creek Water District. Subsurface outflow offshore is greater during the current period than the historical period because of higher groundwater elevations in the area of municipal production. Increased groundwater elevations are a direct result of historically low pumping in the Basin. The MGA anticipates a bounceback in groundwater demand so the GSP does not rely on historically low pumping continuing into the future to help achieve sustainability. Management actions employed also have included redistributing municipal pumping to increase groundwater levels along the coast to protective elevations.

The average loss of groundwater in storage for the Basin was 160 acre-feet per year (Table 2-18) which is approximately 320 acre-feet per year less than the historical period (Table 2-12). During the normal and wet years of 2010 and 2011, the Basin gained almost 2,000 acre-feet of cumulative groundwater in storage. By 2015, four consecutive dry years contributed to a loss of all the groundwater gained in 2010 and 2011, plus additional losses for an overall cumulative groundwater in storage loss of approximately 1,000 acre-feet over the six-year period. A comparison of Basin inflows and outflows between the current and historical periods is provided on Figure 2-66.

Table 2-18. Santa Cruz Mid-County Basin Current Groundwater Budget Summary (2010-2015)

Groundwater Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
UZF Recharge	1,640	5,770	3,600	31%
Net Recharge from Stream Alluvium	780	1,260	970	8%
Recharge from Terrace Deposits	1,490	2,200	1,790	16%
Subsurface Inflow from Purisima Highlands Basin	4,940	5,310	5,130	45%
		Total Inflow	**11,490**	**100%**
Outflows (acre-feet per year)				
Pumping	5,260	6,650	6,220	53%
Subsurface Outflow to Santa Margarita Basin	250	270	270	2%
Net Subsurface Outflow to Pajaro Valley Subbasin	4,050	4,300	4,170	36%
Net Outflow Offshore	920	1,060	990	9%
		Total Outflow	**11,650**	**100%**
	Cumulative		**Average**	
Change in Storage (acre-feet per year)	-970 acre-feet		-160	

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage.

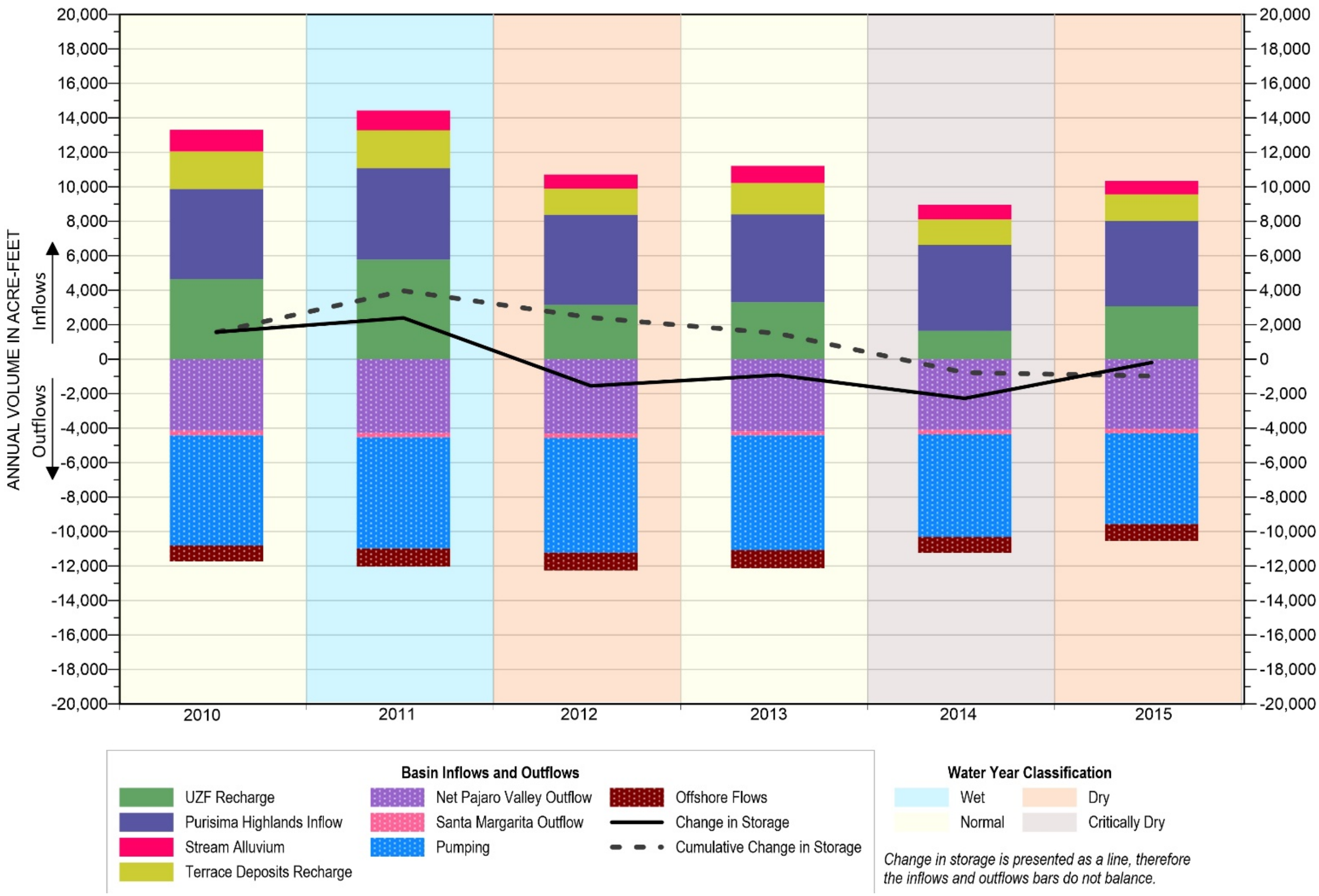


Figure 2-65. Santa Cruz Mid-County Basin Current Annual Groundwater Budget (2010 – 2015)

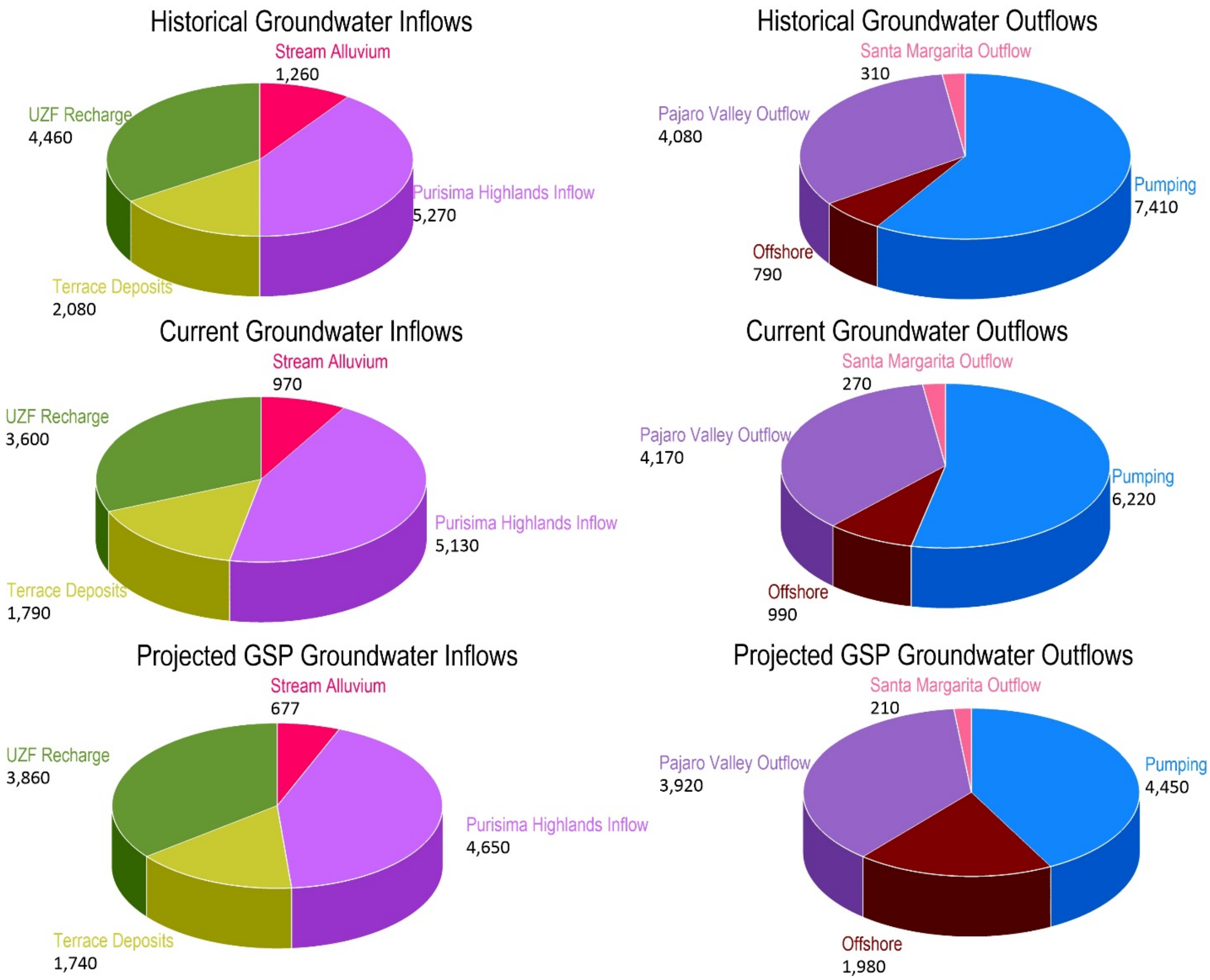


Figure 2-66. Comparison of Historical, Current, and Projected GSP Groundwater Inflows and Outlflows (acre-feet per year)

Table 2-19. Santa Cruz Mid-County Basin Current Groundwater Budget by Aquifer Summary (1985 – 2015)

Groundwater Flow Component	Aromas Red Sands (L2)	Purisima DEF/F (L3)	Purisima D (L4)	Purisima BC (L5)	Purisima B (L6)	Purisima A (L7)	Purisima AA (L8)	Tu (L9)	Total
Annual Average Inflows (acre-feet per year)									
UZF Recharge	614	550	160	148	179	485	460	1,004	3,600
Recharge from Stream Alluvium	393	119	_	274	_	267	157	_	1,200
Recharge from Terrace Deposits	827	136	_	274	69	246	241	_	1,793
Inflow from Purisima Highlands	_	2,813	326	323	361	549	734	23	5,129
Offshore Inflow	_	54	_	_	_	_	_	4	58
Inter-Layer Flow	_	544 (L3) 50(L4)	_	79 (L4)	27 (L5)	112 (L6)	33 (L7)	_	1,214
Total Inflow	**1,834**	**4,256**	**486**	**1,098**	**636**	**1,659**	**1,625**	**1,031**	**12,994**
Annual Average Outflows (acre-feet per year)									
Pumping	788	1,770	1	766	123	1,1284	1,019	482	6223
Discharge to Stream Alluvium	_	_	64	_	164	_	_	_	228
Outflow to Santa Margarita	_	_	_	_	_	_	_	267	267
Outflow to Pajaro Valley	515	2,597	302	100	143	328	188	_	4,173
Offshore Outflow	211	_	10	217	108	41	464	_	1,051
Inter-Layer Flow	544 (L3)	_	50 (L3) 79(L5)	27 (L6)	112 (L7)	33 (L8)	_	_	1,213
Total Outflow	**2,058**	**4,367**	**506**	**1,110**	**650**	**1,686**	**1,661**	**749**	**13,155**
Change in Storage	**-224**	**-111**	**-21**	**-12**	**-13**	**-26**	**-36**	**281**	**-162**

Notes: The abbreviation L is for model layer, e.g., L2 is model layer 2

2.2.5.5.3 North of Aptos Area Faulting Current Groundwater Budget

Similar to the historical period, groundwater inflows in the area north of the Aptos area faulting comprise inflow from Purisima Highlands (70%) and UZF recharge (30%) during the current period (Table 2-20). Outflows are primarily flows to Pajaro Valley (65%), with minor flows to Santa Margarita (3%) and discharge to streams (6%) (Table 2-20). During the current period, the average change in groundwater in storage represented a loss in storage of around 450 acre-feet per year. A graphical representation of the historical annual groundwater budget north of the Aptos area faulting over the current period is provided on Figure 2-67.

The change from an average groundwater in storage gain during the historical period to an average storage loss for the current period is influenced by a decline in both average inflows from the Purisima Highlands Subbasin and UZF recharge. The recharge reductions are due to limited surface recharge during the 2012-2015 drought that is included in the current water budget period. Overall, the area north of the Aptos area faulting lost about 2,710 acre-feet in cumulative storage over the six years included in the current water budget period (Table 2-20).

Table 2-20. North of Aptos Area Faulting Current Groundwater Budget Summary (2010 – 2015)

Groundwater Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
UZF Recharge	860	3,640	2,170	30%
Subsurface Inflow from Purisima Highlands	4,940	5,310	5,130	70%
		Total Inflow	**7,300**	**100%**
Outflows (acre-feet per year)				
Pumping	440	590	540	7%
Discharge to Streams	300	560	440	6%
Subsurface Outflow to Santa Margarita Subbasin	240	260	250	3%
Subsurface Outflow to Pajaro Valley Subbasin	4,940	5,310	5,030	65%
Subsurface Outflow to South of Aptos Area Faulting	1,470	1,500	1,490	19%
		Total Outflow	**7,750**	**100%**
	Cumulative		**Average**	
Change in Storage (acre-Feet per year)	-2,710 acre-feet		-450	

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

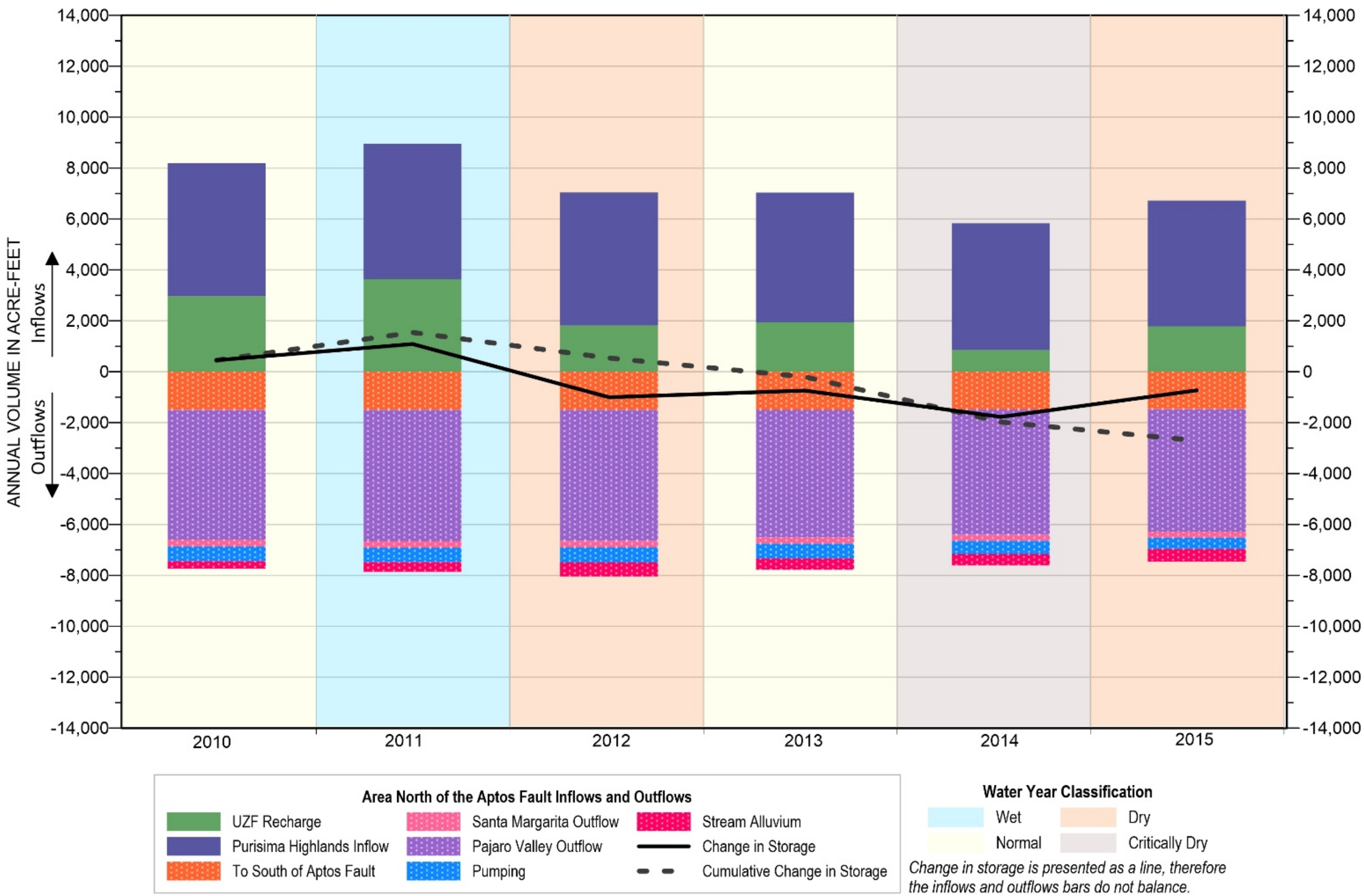


Figure 2-67. North of Aptos Area Faulting Current Annual Groundwater Budget (2010 – 2015)

2.2.5.5.4 South of Aptos Area Faulting Current Groundwater Budget

Similar to the distribution of groundwater inflows during the historical period, current groundwater inflows in the area south of the Aptos area faulting are comprised of inflow from recharge through alluvium and terrace deposits (combined 46%), inflow from the area north of the Aptos area faulting (21%), UZF recharge (22%), and from Pajaro Valley (12%) (Table 2-21). Outflows are primarily by groundwater pumping (85%) and offshore (14%) (Table 2-21). A graphical representation of the historical annual groundwater budget north of the Aptos area faulting over the current period is provided on Figure 2-68.

During the current water budget period, there is an increase in groundwater storage of approximately 290 acre-feet per year. Due to a reduction in overall groundwater inflow during the 2012-2015 drought, average change in groundwater in storage was 180 acre-feet per year lower than during the historical period, yet still gaining. Overall, the area south of the Aptos area faulting gained approximately 1,730 acre-feet in cumulative storage over the current water budget period (Table 2-21). Increased groundwater levels in the area of municipal pumping is the reason for this unexpected gain in storage during a drought period. As mentioned previously, increased groundwater elevations are a direct result of specific management actions focused on controlling seawater intrusion. Management actions include redistributing municipal pumping to increase groundwater levels along the coast to protective elevations and water conservation.

Table 2-21. South of Aptos Area Faulting Current Groundwater Budget Summary (2010 – 2015)

Groundwater Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
UZF Recharge	790	2,130	1,430	21%
Recharge from Stream Alluvium	1,280	1,560	1,410	20%
Recharge from Terrace Deposits	1,490	2,200	1,790	26%
Subsurface Inflow from Pajaro Valley Subbasin	760	920	850	12%
Subsurface Inflow from North of Aptos Area Faulting	1,470	1,500	1,490	21%
		Total Inflow	**6,980**	**100%**
Outflows (acre-feet per year)				
Pumping	4,830	6,060	5,680	85%
Subsurface Outflow to Santa Margarita Subbasin	<10	20	10	<1%
Net Outflow Offshore	920	1,060	990	15%
		Total Outflow	**6,690**	**100%**
Change in Storage (acre-feet per year)	**Cumulative**		**Average**	
	+1,730 acre-feet		+290	

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

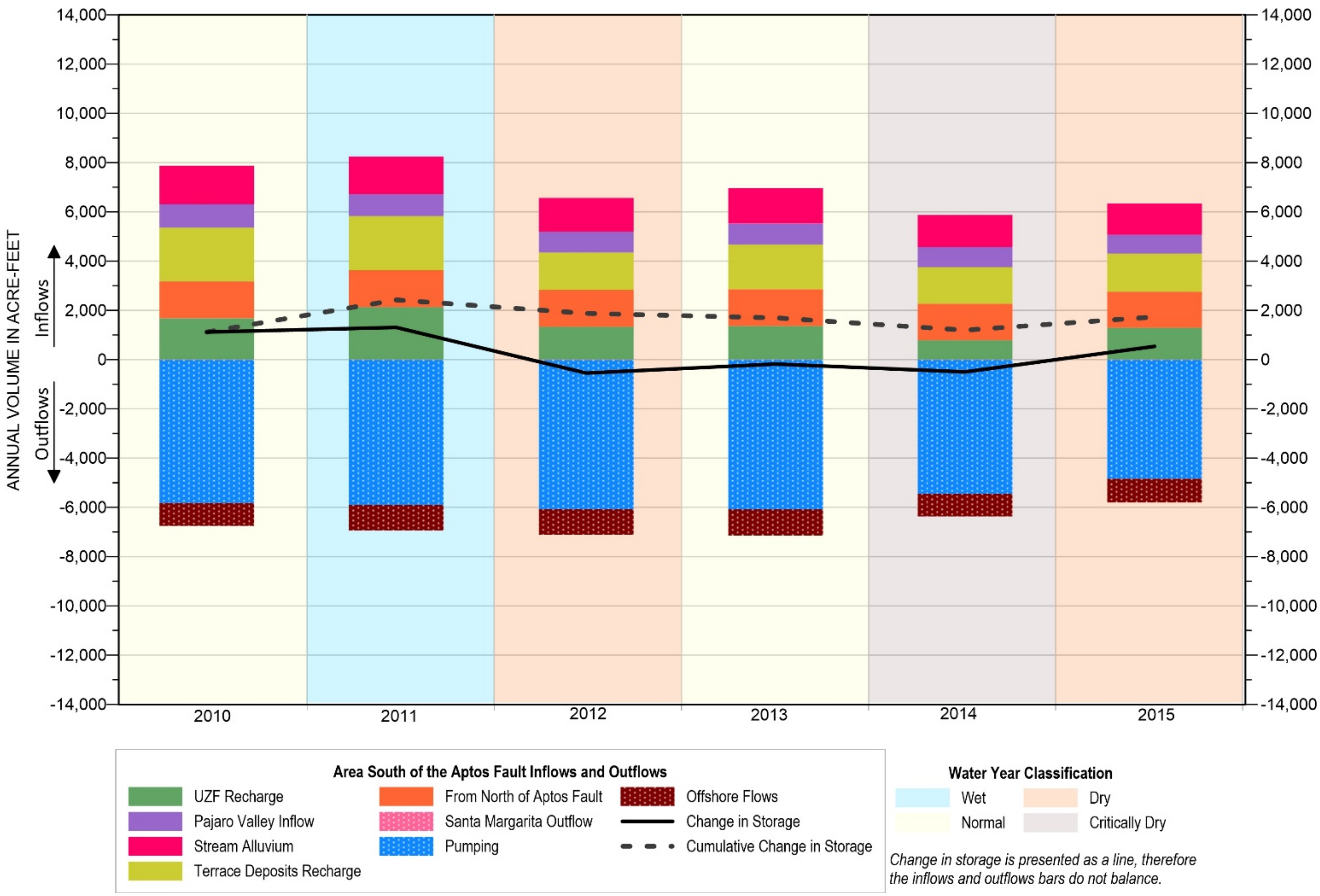


Figure 2-68. South of Aptos Area Faulting Current Annual Groundwater Budget (2010 – 2015)

2.2.5.6 Projected Water Budget

SGMA regulations require the development of a projected water budget based on at least 50 years of historical data. The projected water budget is used to estimate changes in water supply, demand, and aquifer conditions in response to GSP implementation. The projected water budget covers a 54-year period from Water Years 2016 through 2069, and includes a predictive period of 53 years that starts in 2017. This projection provides a baseline that is used in the GSP to evaluate Basin impacts from GSP implementation. The water budgets included in this subsection are (1) a projected baseline water budget that does not include projects and management actions as part of GSP implementation (Baseline) and (2) a projected water budget with projects and management actions implemented as part of the GSP (GSP Implementation).

2.2.5.6.1 Assumptions Used in Projected Water Budget Development

Assumptions included in the model used to estimate the projected water budget are made based on best available data to account for predicted changes in Basin climate, sea-level, projected groundwater demand, supplemental water sources, and management actions. More documentation on the projected simulations and assumptions are included in Appendix 2-I. Model assumptions for predictive simulations are summarized briefly below.

Climate

The projected water budgets account for future climate generated from a catalog of historical climate data from warm years in the Basin's past to simulate the warmer temperatures predicted by global climate change. Specifically, the Catalog Climate uses historical data from the Santa Cruz Co-op and Watsonville Waterworks climate stations. This approach was recommended by the model Technical Advisory Committee (TAC) to address the uncertainty regarding precipitation forecasts in coastal California in a variety of global climate models. The catalog approach 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 and decrease of 1.3 - 3.1 inches per year in precipitation over the long-term record at climate stations in Santa Cruz and Watsonville. There is a corresponding increase in evapotranspiration of about 6%. Appendix 2-G is a technical memorandum that describes the development of the Catalog Climate data in more detail.

In comparison to the CMIP5 ensemble of 10 Global Circulation Models (GCM) often applied in California, the modeled catalog climate is slightly cooler and drier than most CMIP5 scenarios. A panel of local experts recommended the Catalog Climate approach as appropriate for Basin planning. More technical information on a comparison of climate change scenarios is contained in Appendix 2-H.

Sea-Level

Global sea-level rise is incorporated in projected water budgets because changes in sea-level impact the location of the saltwater/freshwater interface and can alter the volume and direction of flows offshore. The model includes projections from the California Ocean Protection Council and California Natural Resources Agency sea-level rise guidance (California Natural Resources Agency, 2018), which gives a range of sea-level rise predictions for Monterey based on possible greenhouse gas emission scenarios. Based on that data source, the model from which the water budgets are derived assumes around 2.3 feet of sea-level rise between 2000 and 2070.

Land Use

Future land use is assumed to remain the same as historical land use.

Projected Groundwater Demand

Historically, almost all water supply to the Basin is pumped from aquifers within the Basin. The Soquel Creek Water District and Central Water District rely solely on groundwater. The City of Santa Cruz water system relies predominantly on surface water supplies sourced from outside of the Basin, only 5% of its supply is from groundwater. Although a small component of its water supply, groundwater is a crucial component of the Santa Cruz water system for meeting peak season demands, maintaining pressure in the eastern portion of the distribution system, and for weathering periods of drought. Projected Basin water demand assumes groundwater will remain the main source of water supply, and that surface water sources within the Basin will not be used.

Projected non-municipal groundwater demand for domestic use assumes pre-drought (2012 – 2015) water demand of 0.35 acre-feet per year per household. The assumed water demand is applied to projected annual population growths of 4.2% pre-2035 and 2.1% post-2035. Groundwater demand for larger institutions such as camps, retreats, and schools, and agricultural irrigation remain the same as historical demands.

Municipal groundwater demand from the Basin is different for the projected Baseline (no projects) water budget and projected with projects and management actions water budget. This is because projects afford the MGA agencies the ability to operate wells differently.

Projected Baseline municipal groundwater demand (without projects and management actions) is based on several different assumptions:

- Central Water District - pre-drought average groundwater production from Water Year 2008 through 2011of 550 acre-feet per year.

- Soquel Creek Water District - 2015 Urban Water Management Plan (UWMP) projects demand to increase to 3,900 acre-feet per year after historically low pumping achieved from 2010-2015. The 2015 UWMP projects subsequent long-term decline of demand to 3,300 acre-feet per year, but SqCWD has concluded that its 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. For projected water budget, the GSP projects that Soquel Creek Water District groundwater demand will be stable at 3,900 acre-feet per year.

- City of Santa Cruz – projections of groundwater pumping based on City of Santa Cruz Confluence modeling to meet demand during 2016-2018. The City considers this demand appropriate for current planning because unlike most other communities in the Bay Area and California, City water demand has not increased much from restricted consumption during the 2012-2015 drought (SCWD, 2019, and M.Cubed, 2019). The GSP projects that City of Santa Cruz groundwater pumping will average approximately 350 acre-feet per year without any projects, but is assumed to vary annually based on surface water supplies.

Groundwater Management Activities

The projected water budget with projects and management actions accounts for activities to be conducted by MGA member agencies during GSP implementation. The general project types include in-lieu recharge, injection, and ASR. Projects included in the future simulations are:

- Pure Water Soquel to replenish the Basin and protect against further seawater intrusion using advanced water purification methods to purify recycled water, and

- City of Santa Cruz ASR of excess San Lorenzo River flows to meet City water shortfall (modeled as part of project feasibility study).

Management actions included are enhancements to municipal pumping distribution that are possible in combination with Pure Water Soquel.

Bar charts showing the projected net groundwater pumping for both the Baseline (transparent bars) and the scenario incorporating projects and management actions (non-transparent bars) are shown on Figure 2-69 for Water Years 2016 – 2039 and Figure 2-70 for Water Years 2040 – 2069. There are no projects or management actions which would reduce demand from Baseline for Central Water District, domestic pumping, or agricultural pumping. Projected groundwater demand for the City of Santa Cruz is reduced by City of Santa Cruz ASR activities which store surplus surface water during wet years. Projected net groundwater pumping for Soquel Creek Water District is reduced significantly after the year 2023 by operation of Pure Water Soquel, which will inject approximately 1,500 acre-feet into the Purisima A and BC-unit aquifers annually. Overall, the average annual projected net pumping with projects and management actions (4,910 acre-feet) is 1,430 acre-feet less than what is projected in the Baseline scenario (6,340 acre-feet).

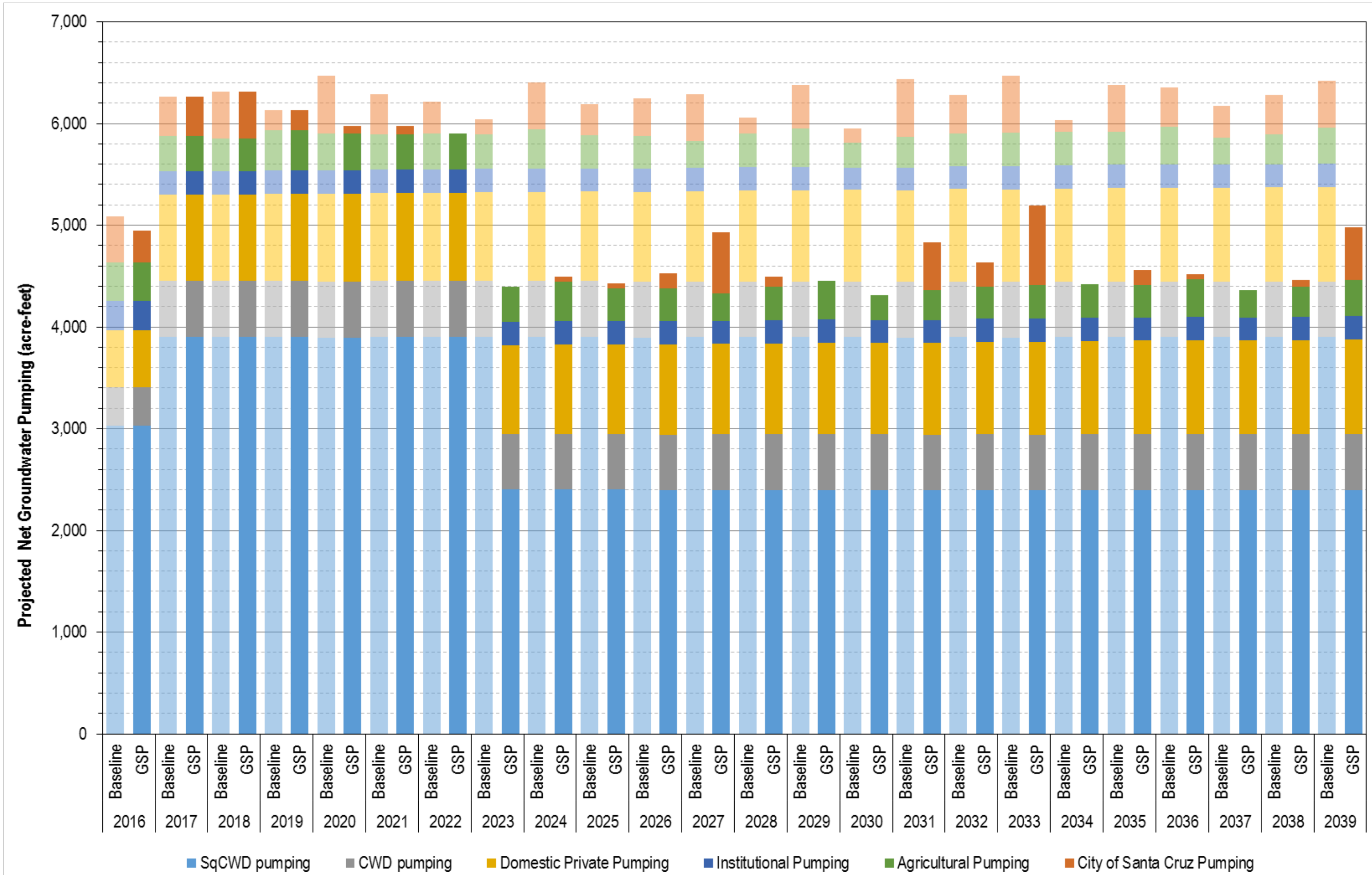


Figure 2-69. Projected Baseline vs. Projected GSP Implementation Net Groundwater Pumping in the Santa Cruz Mid-County Basin (2016-2039)

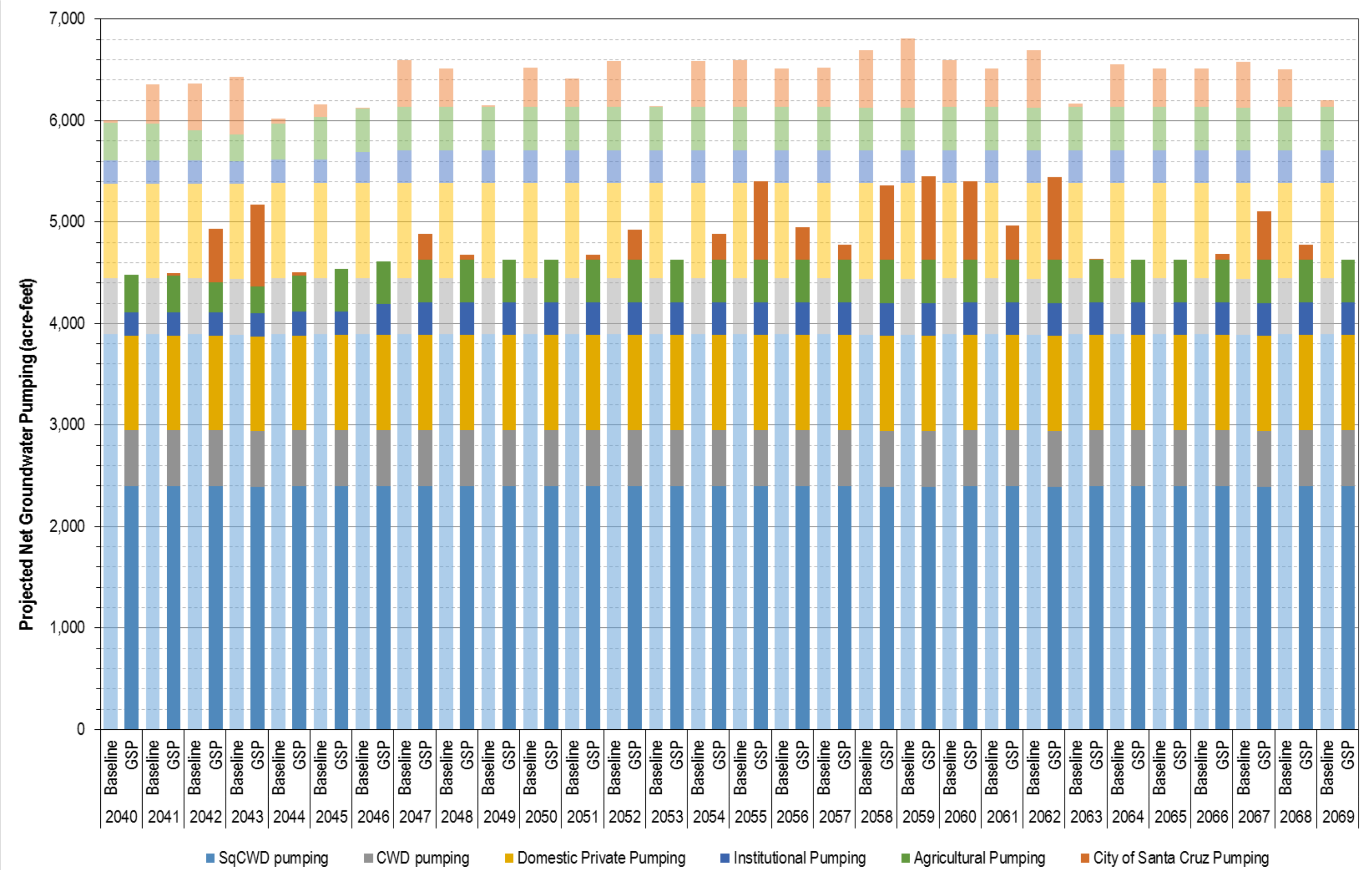


Figure 2-70. Projected Baseline vs. Projected GSP Implementation Net Groundwater Pumping in the Santa Cruz Mid-County Basin (2040-2069)

2.2.5.6.2 Santa Cruz Mid-County Basin Projected Surface Water Budget

Projected precipitation in the Basin is on average about 15% lower compared to the historical period. This translates to an average decrease in precipitation of just under 8,930 acre-feet annually (Table 2-10 and Table 2-22). Evapotranspiration, relative to other components, is simulated to increase by 3% (Table 2-10 and Table 2-22), which reflects higher average temperatures in the Basin over the projected period. With the decrease in precipitation and relative increase in evapotranspiration, overland flow and groundwater recharge are simulated to decrease on average by 2% and 1%, respectively. In terms of volume, it is projected that there will be 3,570 acre-feet less surface water and 2,330 acre-feet less groundwater recharge from precipitation available within the Basin (Table 2-10 and Table 2-22).

Table 2-22. Percentage Distribution of Projected Precipitation in Santa Cruz Mid-County Basin

Precipitation Budget Component	Average Annual (acre-feet)	Average Percent of Precipitation
Precipitation	87,280	100%
Evapotranspiration	60,000	69%
Overland Flow	22,030	25%
Groundwater Recharge from Precipitation	3,140	4%
Soil Moisture	2,110	2%

The relative percentages of projected surface water budget components mirror the historical budget. However, the projected surface water budget is characterized by a decrease in average surface water inflows of approximately 8,450 acre-feet per year compared with historical averages (Table 2-11 and Table 2-23). Over the projected period, total surface water inflows and outflows decrease by about 18% each, which reflects the drier climatic conditions predicted in the future. The amount of water flowing through the Basin's stream system ranges from 156,660 acre-feet to 6,270 acre-feet annually (Figure 2-71).

Despite the predicted drier conditions in the projected simulation, the average annual amount of groundwater contributing to surface water inflows will be slightly higher (280 acre-feet per year) than during the historical period due to overall higher groundwater levels predicted in response to projects and management actions.

As mentioned previously, surface water is not a significant agricultural, municipal, or domestic water source within the Basin, and is therefore not included in the projected model simulations since it is not expected that more surface water will be diverted for use in the future.

On a Basin-wide scale, the difference in average inflow and outflow surface water budget components between the projected Baseline condition and GSP Implementation with projects and management actions is only 350 acre-feet per year. However, slight decreases (<1%) in the inflow to surface water from groundwater is projected to result in relatively large increases in groundwater contribution to Soquel Creek. Starting around 2024, PWS and City ASR projects are simulated to increase groundwater inflow to Soquel Creek over the Baseline condition (Figure 2-72). This increase in baseflow reflects higher groundwater elevations throughout the Basin that supports increased creek baseflow that would not occur without those projects. As discussed in the calibration report in Appendix 2-F, 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.

Table 2-23. Santa Cruz Mid-County Basin Projected GSP Implementation Surface Water Budget

Surface Water Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
Overland Flow	3,750	89,840	22,040	59%
Flows from Upstream of the Basin	2,520	66,780	14,280	38%
Net Flows from Groundwater	850	1,190	1,080	3%
		Total Inflow	**37,400**	**100%**
Outflows (acre-feet per year)				
Ocean Outflow	6,870	141,570	33,580	89%
Outflow in Branciforte Creek	397	15,900	3,340	9%
Pajaro Valley Subbasin	<10	2,310	320	1%
Outflow to Carbonera Creek	20	890	160	<1%
		Total Outflow	**37,400**	**100%**

Note: ‘Groundwater Flows’ refers to flow between streams and underlying alluvium, and is distinct from ‘Stream Alluvium Recharge’ seen in groundwater budgets.

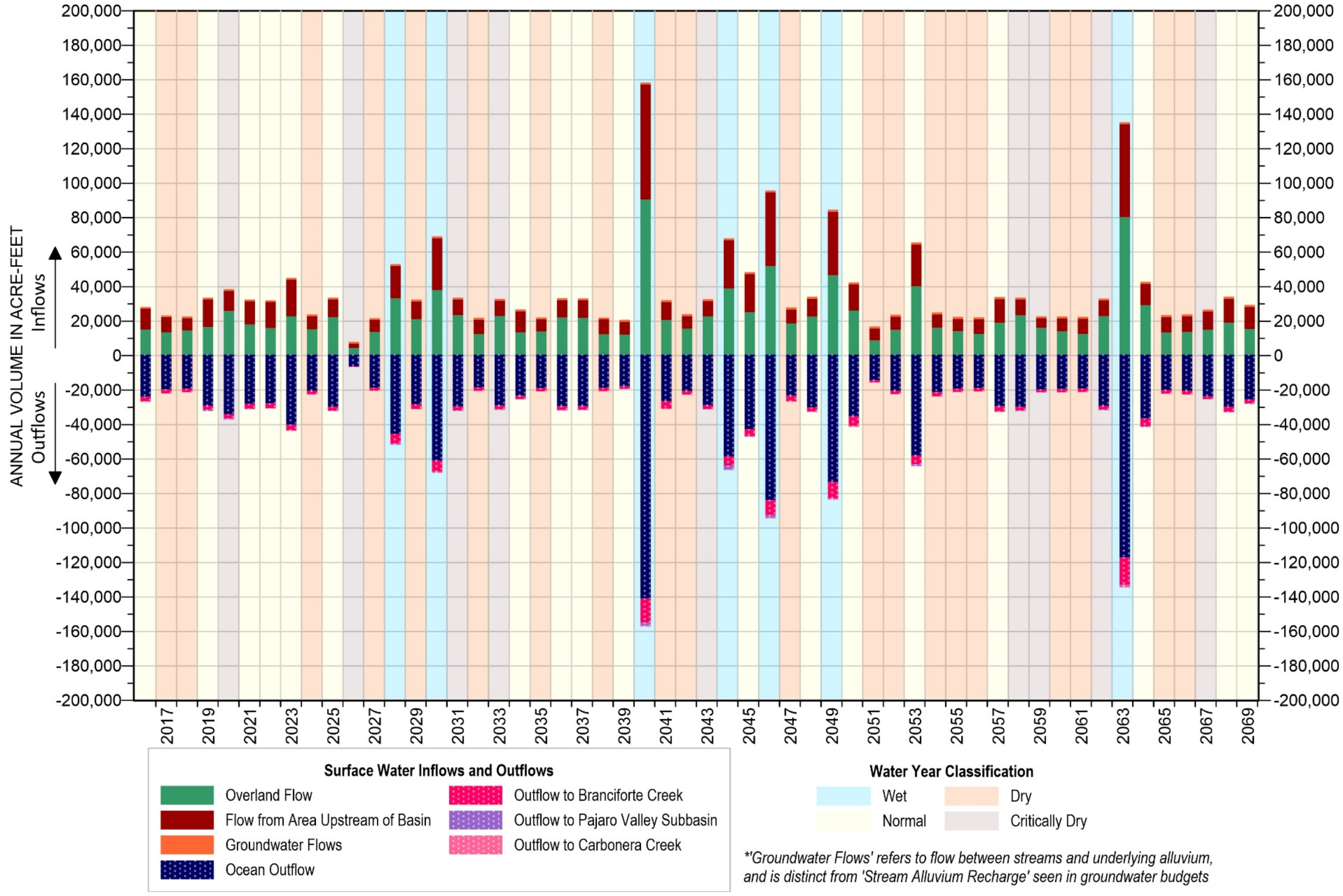


Figure 2-71. Santa Cruz Mid-County Basin Projected Annual Surface Water Budget (2016 – 2069)

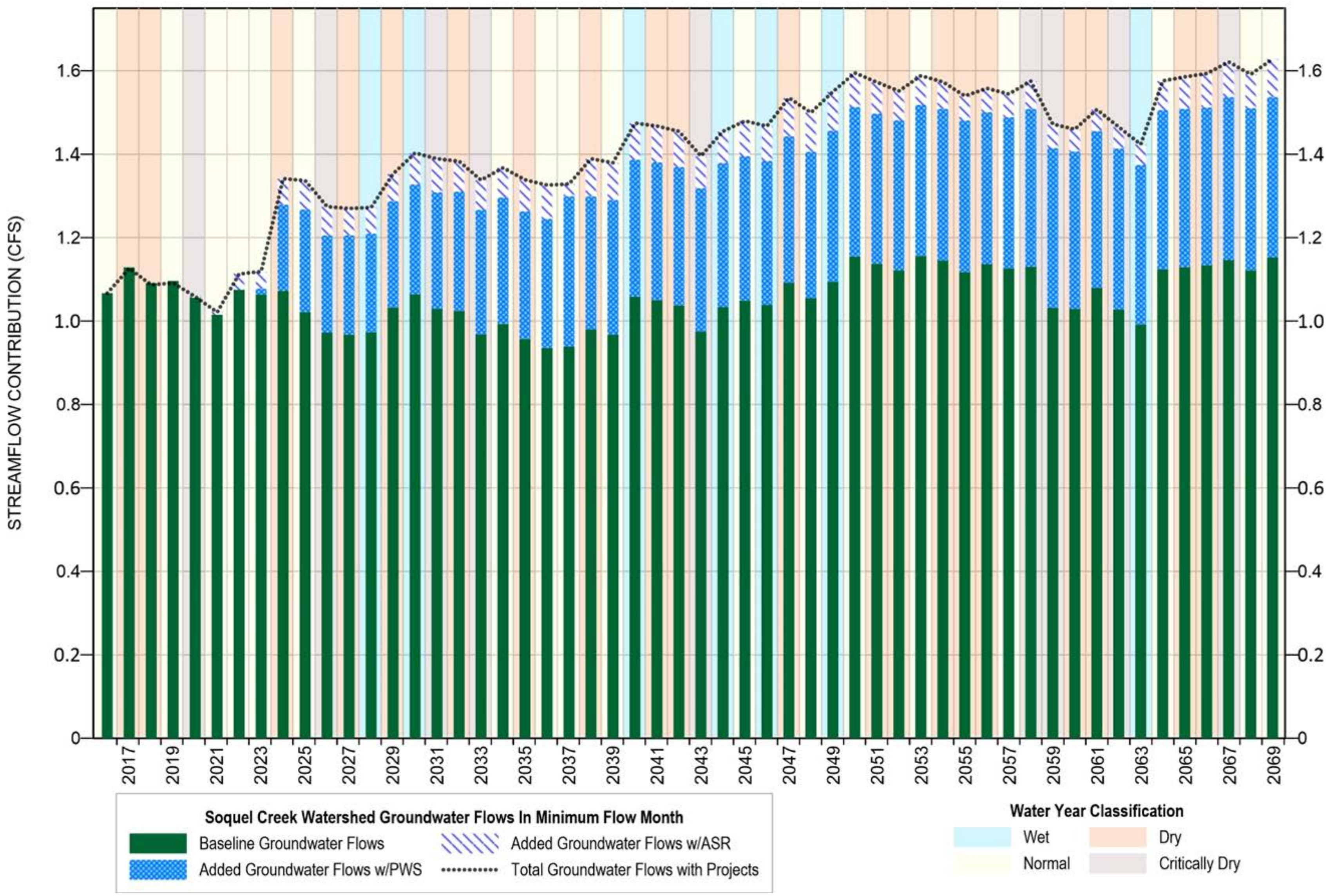


Figure 2-72. Effect of Projects and Management Actions on Soquel Creek Watershed Groundwater Contribution (2016 – 2069)

2.2.5.6.3 Santa Cruz Mid-County Basin Projected Groundwater Budget

The projected inflow and outflow components for the projected groundwater budget are the same as the historical and current budgets, and their relative contributions are similar (Figure 2-66). For both projected water budgets, the catalog climate implemented to represent climate change only has three wet years over the 54-year period; reflecting overall warmer and drier conditions. This results in less natural recharge in both projected scenarios.

For the Baseline projection with no projects and management actions, groundwater inflows to the Basin are reduced by around 200 acre-feet per year compared to current conditions and 1,780 acre-feet per year compared to historical conditions. Projected groundwater pumping in the Baseline groundwater budget is almost the same as recent pumping. As a result of the projected recharge and pumping conditions, outflow to the ocean under Baseline conditions remains similar to current outflows which are not sufficient to prevent seawater intrusion. Without projects and management actions implemented to achieve groundwater sustainability (Baseline scenario), it is projected the Basin will experience a loss of groundwater in storage of 3,240 acre-feet cumulatively over the fifty-four-year period.

With projects and management actions implemented to achieve groundwater sustainability (GSP Implementation), projected net pumping is reduced by 1,740 acre-feet per year because groundwater demand is offset by supplemental water injected into the Basin. This results in an increase in average groundwater outflow of 840 acre-feet per year (an increase of 73%) to the ocean that will ensure seawater intrusion does not move onshore farther than it is currently, could potentially even push seawater intrusion back. It is projected that with projects and management actions, there will be an average annual increase in groundwater in storage of 280 acre-feet, which equates to a cumulative gain over 54 years of 18,530 acre-feet.

Table 2-24. Santa Cruz Mid-County Basin Projected Groundwater Budget Summary (2016 – 2069)

Groundwater Budget Component	Projected Baseline		Projected GSP Implementation		Difference between GSP Implementation and Baseline
	Annual Average	Average % (rounded)	Annual Average	Average % (rounded)	
Inflows (acre-feet per year)					
UZF Recharge	3,860	34%	3,860	35%	0
Net Recharge from Stream Alluvium	1,000	9%	670	6%	-330
Recharge from Terrace Deposits	1,780	16%	1,740	16%	-40
Subsurface Inflow from Purisima Highlands Subbasin	4,650	41%	4,650	43%	0
Total Inflow	**11,290**	**100%**	**10,920**	**100%**	**-370**
Outflows (acre-feet per year)					
Pumping	6,190	55%	4,450	43%	-1,740
Subsurface Outflow to Santa Margarita Subbasin	210	2%	210	2%	0
Net Subsurface Outflow to Pajaro Valley Subbasin	3,670	33%	3,920	37%	250
Net Outflow Offshore	1,150	10%	1,990	19%	840
Total Outflow	**11,220**	**100%**	**10,570**	**100%**	**-650**
	Average	**Cumulative**	**Average**	**Cumulative**	**Average**
Change in Storage (acre-feet per year)	+70	-3,240 acre-feet	+350	+18,530 acre-feet	+280

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

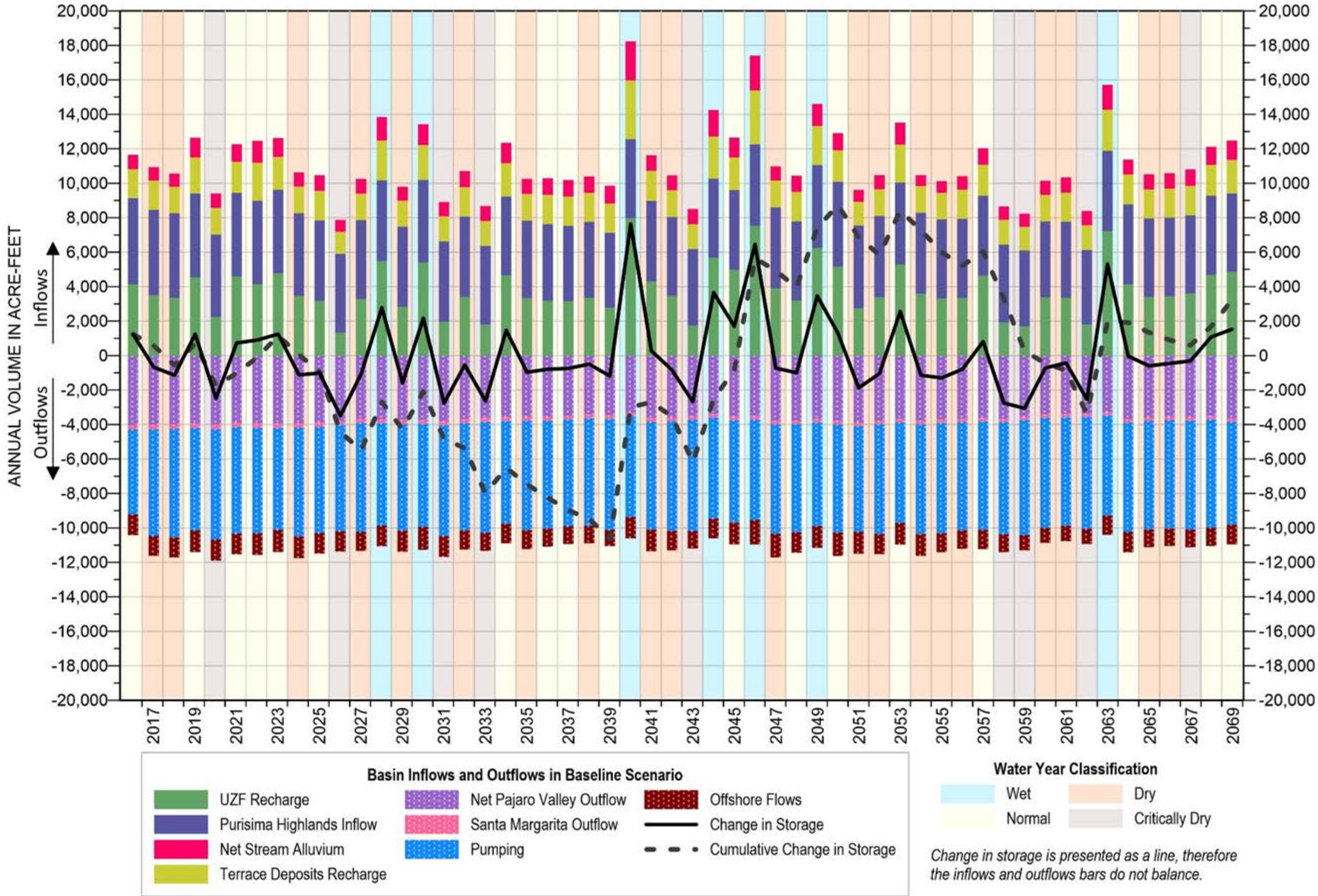


Figure 2-73. Santa Cruz Mid-County Basin Projected Baseline Annual Groundwater Budget (2016 – 2069)

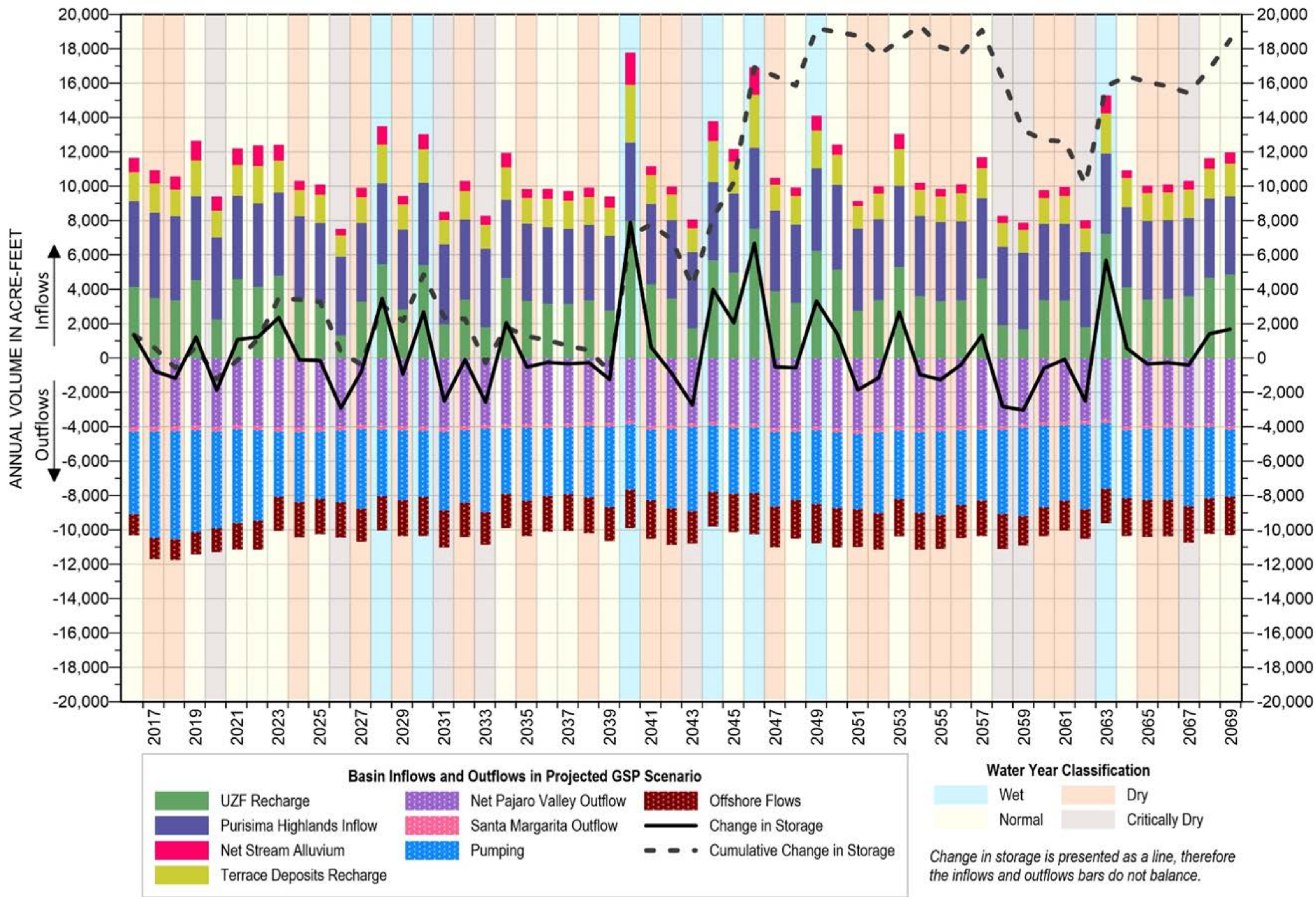


Figure 2-74. Santa Cruz Mid-County Basin Projected GSP Implementation Annual Groundwater Budget (2016 – 2069)

2.2.5.6.4 North of Aptos Area Faulting Projected Groundwater Budget

In both the projected groundwater budgets for the area north of the Aptos area faulting, the inflow and outflow components occur in relatively similar proportions to the historical period (Table 2-14). Both inflows (UZF recharge and inflow from Purisima Highlands) decrease due to the drier climate, amounting to 970 acre-feet less in average annual inflow. Similarly, outflows also decrease by about 970 acre-feet when compared to the historical average. While all groundwater outflows decrease slightly, subsurface outflow to Pajaro Valley decreases by almost 660 acre-feet annually (Table 2-14).

In the Baseline projection, an average loss of groundwater in storage of 20 acre-feet annually culminates in a total loss of nearly 1,140 acre-feet over the 54-year projected period. With projects and management actions, the area North of the Aptos area faulting experiences an average increase in groundwater in storage of 30 acre-feet annually, culminating in a total gain of 1,710 acre-feet by 2069. The difference may be attributable to overall increases in groundwater elevations in the area south of the Aptos area faulting where GSP projects are implemented. The increase groundwater elevations may reduce the hydraulic gradient across the Aptos area faulting thereby resulting in less outflow to the area south of the fault (Table 2-14).

Table 2-25. North of Aptos Area Faulting Projected Groundwater Water Budget Summary (2016 – 2069)

Groundwater Budget Component	Projected Baseline		Projected GSP Implementation		Difference between GSP Implementation and Baseline
	Annual Average	Average % (rounded)	Annual Average	Average % (rounded)	
Inflows (acre-feet per year)					
UZF Recharge	2,380	33%	2,380	33%	0
Subsurface Inflow from Purisima Highlands	4,650	67%	4,650	67%	0
Total Inflow	**7,030**	**100%**	**7,030**	**100%**	**0**
Outflows (acre-feet per year)					
Pumping	610	9%	610	9%	0
Discharge to Streams	360	5%	350	5%	-10
Subsurface Outflow to Santa Margarita Subbasin	190	3%	190	3%	0
Net Subsurface Outflow to Pajaro Valley Subbasin	4,450	63%	4,450	63%	2
Subsurface Outflow to South of Aptos Area Faulting	1,440	20%	1,400	20%	-40
Total Outflow	**7,050**	**100%**	**7,000**	**100%**	**-30**
	Average	**Cumulative**	**Average**	**Cumulative**	**Average**
Change in Storage (acre-feet per year)	-20	-1,140 acre-feet	30	+1,710 acre-feet	+50

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

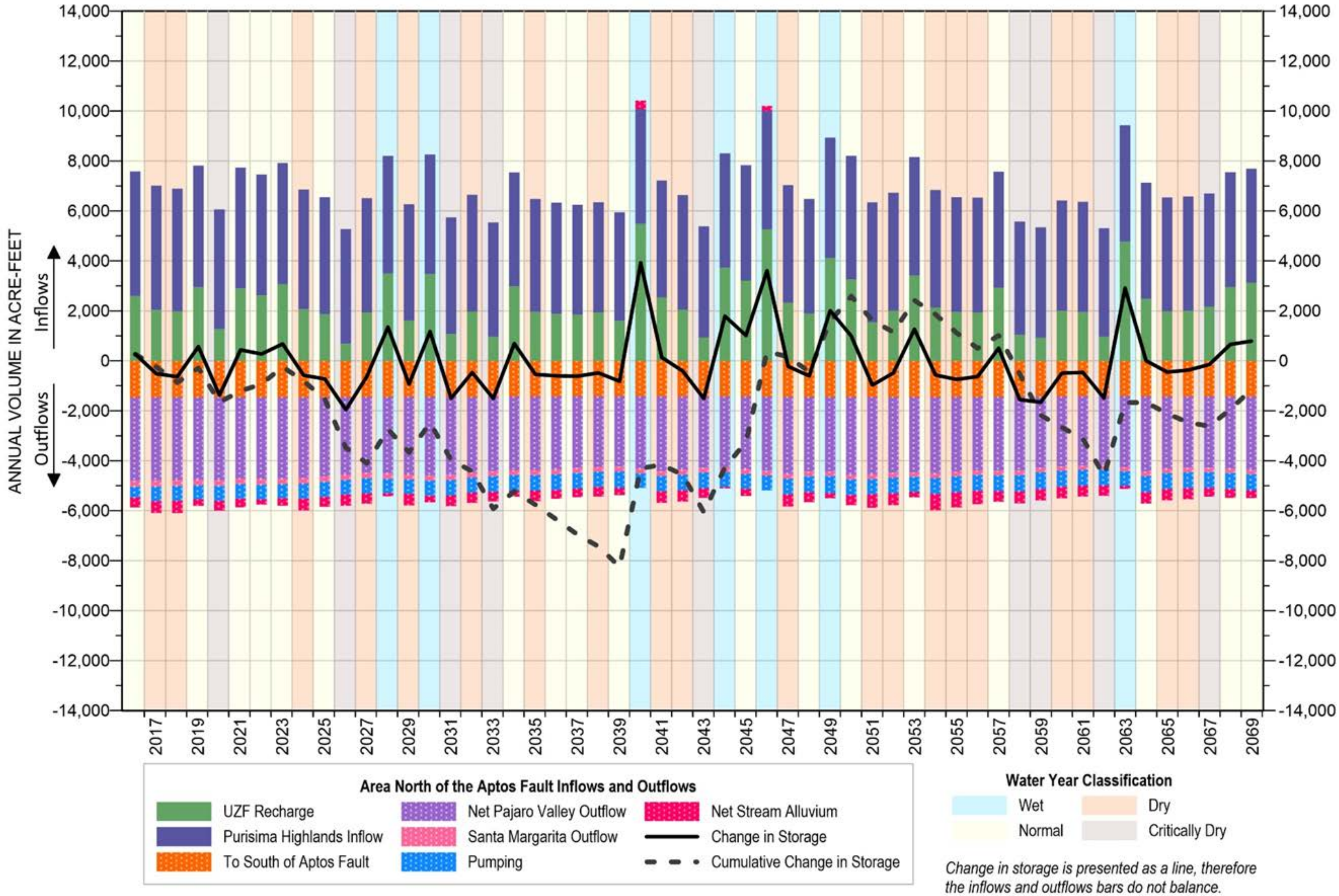


Figure 2-75. North of Aptos Area Faulting Projected Baseline Annual Groundwater Budget (2016 – 2069)

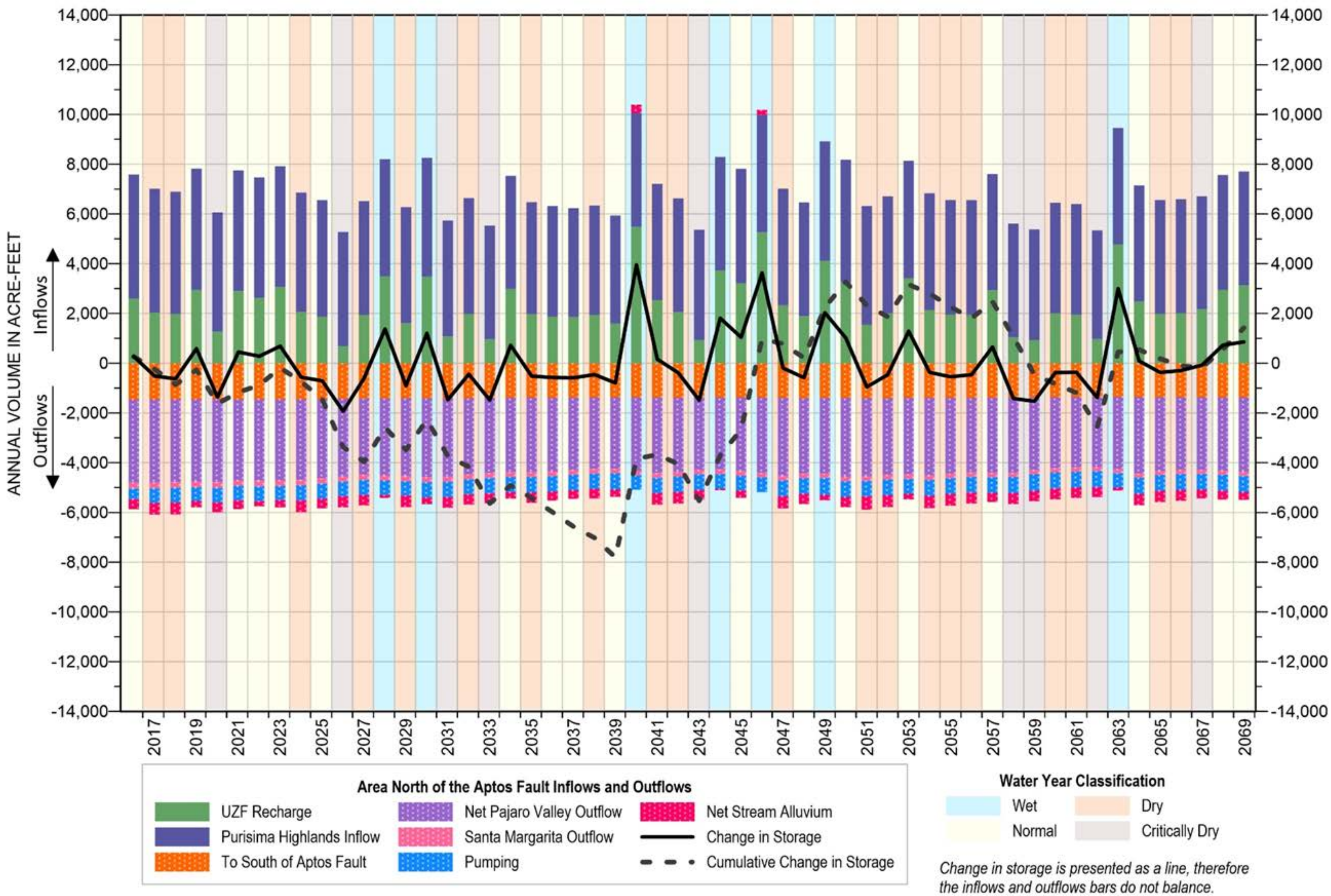


Figure 2-76. North of Aptos Area Faulting Projected GSP Implementation Annual Groundwater Budget (2016 – 2069)

2.2.5.6.5 South of Aptos Area Faulting Projected Groundwater Budget

The relative proportions of projected groundwater inflow and outflow components for the area south of the Aptos area faulting are very similar to the historical and current periods. All inflows decrease slightly due to the drier and warmer climate (Table 2-15 and Table 2-26). Groundwater pumping is decreased by about 1,130 acre-feet annually in the Baseline projection when compared to the historical time period because of improved groundwater management practices and water conservation.

In the projected GSP Implementation scenario, pumping is further decreased by 1,740 acre-feet per year from Baseline pumping because of projects that provide supplemental water as a supply source (Table 2-26). With GSP Implementation, offshore flows are increased when compared to the historical, current, and Baseline budgets. These increased offshore flows reflects higher groundwater elevations within the Basin as a result of projects and management actions.

Under both Baseline and GSP Implementation projections, the area south of the Aptos area faulting is simulated to have increases in groundwater in storage (Table 2-26). In the Baseline scenario, an average annual gain in storage of 70 acre-feet per year creates 4,380 acre-feet of cumulative storage by 2069. In the projected GSP Implementation scenario, an average annual gain in storage of 320 acre-feet per year creates about 17,100 acre-feet of cumulative storage by 2069.

Table 2-26. South of Aptos Area Faulting Projected Groundwater Water Budget Summary (2016 – 2069)

Groundwater Budget Component	Projected Baseline		Projected GSP Implementation		Difference between GSP Implementation and Baseline
	Annual Average	Average % (rounded)	Annual Average	Average % (rounded)	
Inflows (acre-feet per year)					
UZF Recharge	1,480	22%	1,480	24%	0
Net Recharge from Stream Alluvium	1,360	20%	1,030	17%	-330
Recharge from Terrace Deposits	1,780	25%	1,740	27%	-40
Subsurface Inflow from Pajaro Valley Subbasin	780	11%	530	9%	-250
Subsurface Flow from North of Aptos Area Faulting	1,430	22%	1,390	23%	-40
Total Inflow	**6,830**	**100%**	**6,170**	**100%**	**-660**
Outflows (acre-feet per year)					
Pumping	5,580	83%	3,840	66%	-1,740
Net Subsurface Outflow to Pajaro Valley Subbasin	10	<1%	10	<1%	0
Net Outflow Offshore	1,150	17%	2,000	34%	850
Total Outflow	**6,740**	**100%**	**5,850**	**100%**	**-890**
Change in Storage (acre-feet per year)	**Average**	**Cumulative**	**Average**	**Cumulative**	**Average**
	+70	+4,380 acre-feet	+320	+17,100 acre-feet	+390

Note: all values are rounded to the nearest foot. This causes slight discrepancies between average and cumulative change in groundwater in storage

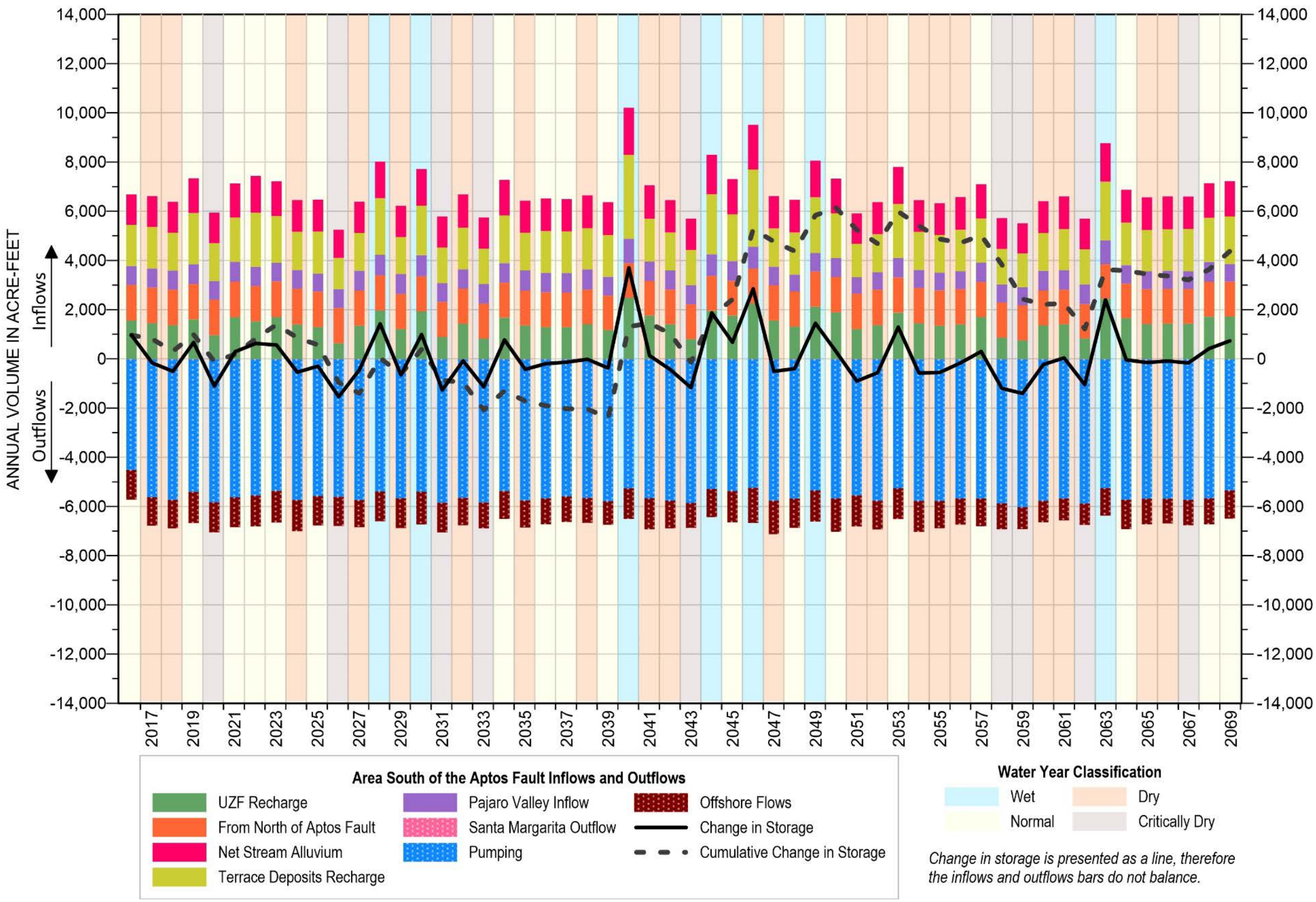


Figure 2-77. South of Aptos Area Faulting Projected Baseline Annual Groundwater Budget (2016 – 2069)

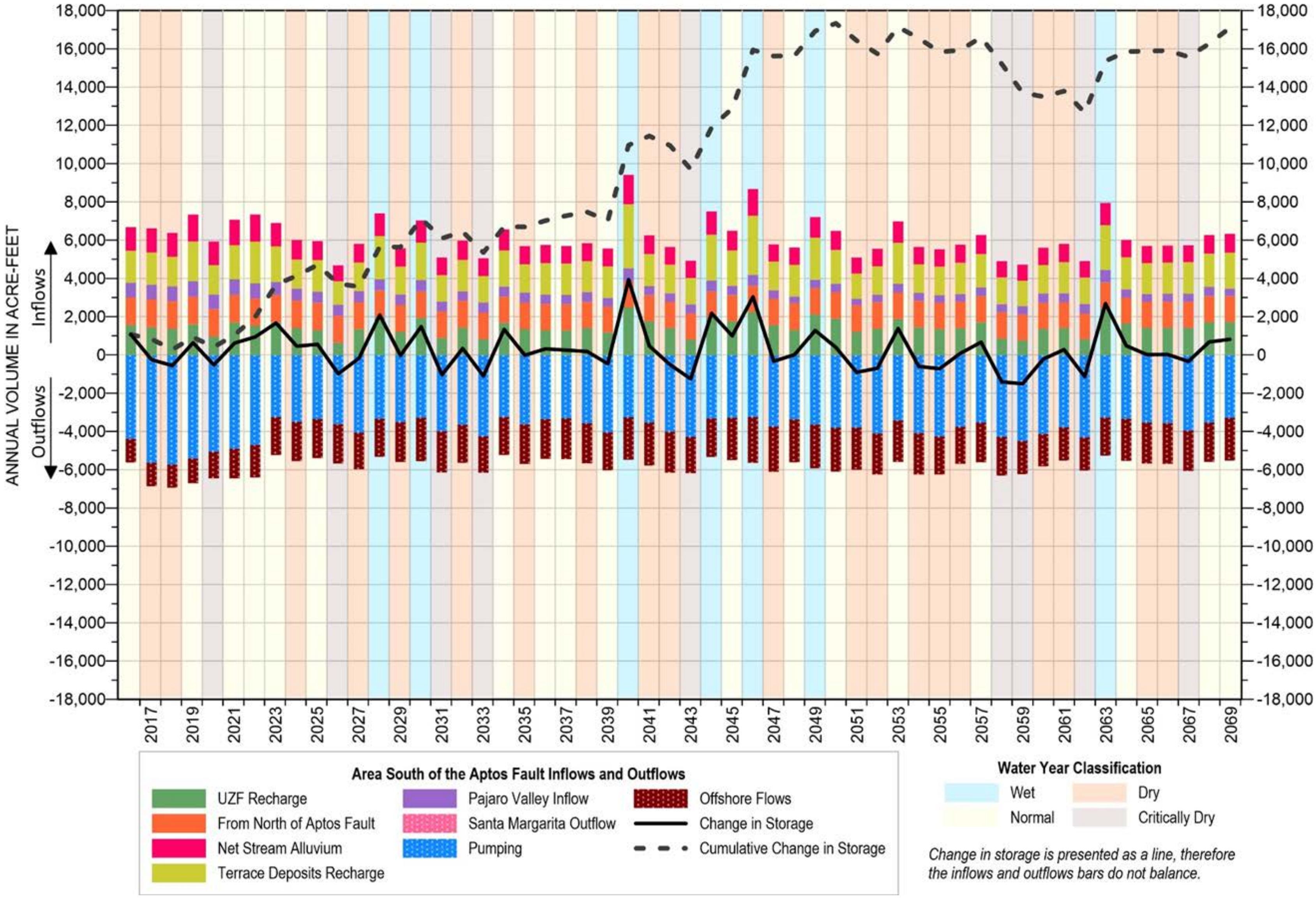


Figure 2-78. South of Aptos Area Faulting Projected GSP Implementation Annual Groundwater Budget (2016 – 2069)

2.2.5.7 Projected Sustainable Yield

The projected sustainable yield is the amount of net Basin pumping that can occur while being able to avoid undesirable results for the applicable sustainability indicators described in Section 3. Section 4 describes the expected benefits of Soquel Creek Water District's Pure Water Soquel project and the City of Santa Cruz's Aquifer Storage and Recovery project as preventing undesirable results in the Basin. Therefore, once the projects are implemented, net Basin pumping is planned to be within the sustainable yield.

The sustainable yield is higher than the net Basin pumping planned with project implementation because the projects have goals beyond achieving minimum thresholds that define undesirable results. Section 4 shows that the projects have expected benefits of achieving or approaching measurable objectives beyond the minimum thresholds that define undesirable results.

To estimate the sustainable yield that is higher than planned net Basin pumping but still avoids undesirable results, sensitivity model runs were conducted to test whether undesirable results would still be avoided if injection was reduced and/or pumping increased at municipal wells. The following summarizes the conclusions of the sensitivity model runs that inform the estimated sustainable yield.

- Long term net injection by City ASR develops a drought supply, but is not necessary for avoiding undesirable results. Reducing pumping at the City's Beltz wells can avoid undesirable results.
- Pumping reductions at Soquel Creek Water District's Garnet and O'Neill Ranch wells planned as part of the Pure Water Soquel project to meet measurable objectives are not necessary to meet minimum thresholds and avoid undesirable results.
- Planned injection at Pure Water Soquel seawater intrusion prevention wells help meet measurable objectives, but lower injection amounts can raise groundwater levels to avoid undesirable results.

Based on the sensitivity model runs, average pumping and injection at municipal pumping that avoid undesirable results is estimated and combined with projected non-municipal pumping to estimate sustainable yield for each of the following aquifer groups:

- Aromas Red Sands aquifer and Purisima F aquifer units,
- Purisima DEF, BC, A, and AA aquifer units, and
- Tu aquifer.

The aquifer groupings are based on how production wells are typically screened through multiple aquifers. The full rationale for the aquifer grouping is provided in Section 3.5.1: Undesirable Results - Reduction of Groundwater Storage.

There may be other combinations of injection and pumping using planned infrastructure or other combinations of projects that can avoid undesirable results. Other combinations would likely result in different estimates of sustainable yield for the aquifer groupings. The estimates of sustainable yield presented here are appropriate for use as minimum thresholds for the reduction in groundwater storage indicator in this GSP because they are estimated to avoid undesirable results and are achievable with the planned projects.

The sustainable yield for each of the aquifer groups and the entire Basin is presented in Table 2-27. The overall projected Basin sustainable yield is 4,870 acre-feet per year, which is just over 1,000 acre-feet less than what was pumped from 2010 to 2015.

Table 2-27. Projected Sustainable Yield

Aquifer Group	Sustainable Yield (acre-feet per year)
Aromas Red Sands and Purisima F	1,650
Purisima DEF, D, BC, A and AA	2,290
Tu	930
Total	**4,870**

2.2.6 Management Areas

SGMA allows groundwater sustainability agencies to define one or more management areas within a groundwater basin if the agency determines that the creation of management areas will facilitate implementation of its GSP. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin.

The GSP Advisory Committee and MGA technical staff considered whether or not to recommend the creation of management areas within the Basin during its meeting #12 on December 12, 2018. MGA technical staff outlined four potential management areas for the committee to consider within the Basin and the reasoning associated with each potential management area.

The GSP Advisory Committee considered the following management areas, and chose to recommend against management areas at this time.

1. **Inland Private Well Area**: Management area could be warranted in inland areas where less frequent monitoring is required because non-municipal domestic groundwater use has less influence on Basin sustainability, most notably seawater intrusion. The Committee discussed the potential impacts of non-municipal domestic groundwater use impacting nearby inland surface waters. Additional monitoring of sustainable management criteria for interconnected surface-water depletion specified in Section 3.9

will likely indicate if further management actions are needed, thus creation of a management area is not required at this time.

2. **Aromas Red Sands Area**: Management area could be warranted where seawater intrusion currently occurs and different sustainable management criteria are set for this area. The Committee discussed that the Aromas Red Sands Area is hydraulically linked to the Pajaro Valley Subbasin and the MGA does not have sole influence over groundwater levels through its management actions. Ongoing monitoring in this area may require additional management actions and inter-basin coordination to address seawater intrusion in this area, but the Committee agreed that creation of a management area is not required at this time.

3. **Area of Municipal Groundwater Production**: Management area could extend one to two miles inland along the majority of the coastline of the Basin where all municipal wells are located that influence coastal groundwater levels. This area also includes larger institutional groundwater users: Cabrillo College and Seascape Golf Course. The Committee was asked to consider extending a management area inland to 50 feet above mean sea level groundwater elevation because this area is the most vulnerable to seawater intrusion and pumping in this area has the greatest impact on coastal groundwater levels. It is also the area where supplemental water supply projects are most likely to be implemented. While the Committee agreed that ongoing groundwater monitoring was necessary the Committee agreed that creation of a management area is not required at this time.

4. **Alluvial Channels of Major Creeks**: Management area could be warranted if pumping wells connected to shallow alluvium require the future installation of meters to monitor groundwater extractions that may influence creek baseflows. While the Committee agreed that this is an example of how a certain area may require a specific management approach, the Committee agreed that creation of a management area is not required at this time.

Management areas were not recommended because the overall sustainability goals (minimum thresholds and measurable objectives) apply to the entire MGA Basin. These goals are specifically defined for each sustainability indicator and each representative monitoring location. Because representative monitoring locations and monitoring requirements are set specifically for each sustainability indicator, the technical staff and the GSP Advisory Committee found no additional benefit to establishing separate management areas within the Basin.

Section 3 Contents

Tables

Figures

3 SUSTAINABILITY MANAGEMENT CRITERIA

This section defines the conditions that direct sustainable groundwater management in the Santa Cruz Mid-County Basin, discusses the process by which the MGA characterizes undesirable results, and establishes minimum thresholds and measurable objectives for each sustainability indicator. The undesirable results, minimum thresholds, and measurable objectives define the Basin's future conditions and commits the MGA to meet these objectives. Defining Sustainable Management Criteria (SMC) requires a significant level of analysis and scrutiny, and this section includes explanation of how SMC were developed and how they influence all beneficial uses and users of groundwater.

3.1 Sustainability Goal

As required by the SGMA regulations, the MGA developed a sustainability goal for the Basin, which is to:

> Manage the groundwater Basin to ensure beneficial uses and users have access to a safe and reliable groundwater supply that meets current and future Basin demand without causing undesirable results to:

- Ensure groundwater is available for beneficial uses and a diverse population of beneficial users;
- Protect groundwater supply against seawater intrusion;
- Prevent groundwater overdraft within the Basin and resolves problems resulting from prior overdraft;
- Maintain or enhance groundwater levels where groundwater dependent ecosystems exist;
- Maintain or enhance groundwater contributions to streamflow;
- Ensure operational flexibility within the Basin by maintaining a drought reserve;
- Support reliable groundwater supply and quality to promote public health and welfare;
- Account for changing groundwater conditions related to projected climate change and sea level rise in Basin planning and management;
- Do no harm to neighboring groundwater basins in regional efforts to achieve groundwater sustainability.

3.2 Sustainable Management Criteria

This section defines the groundwater conditions that constitute sustainable groundwater management, discusses the process by which the MGA characterizes undesirable results, and establishes minimum thresholds and measurable objectives for each applicable sustainability indicator. Undesirable results, minimum thresholds, and measurable objectives together define sustainable conditions in the Basin and commit the MGA to actions that will achieve those conditions. These SGMA specific terms and others are defined in the Glossary.

Defining Sustainable Management Criteria (SMC) requires significant analysis and scrutiny. This section presents the data and methods used to develop SMC and demonstrates how they influence beneficial uses and users. The SMC are based on currently available data and the application of best available science. As noted in this GSP, data gaps exist in the hydrogeologic conceptual model related to the interconnection of surface water and groundwater. Uncertainty caused by these data gaps was considered when developing the SMC. Due to uncertainty in the hydrogeologic conceptual model, the SMC are considered initial criteria that will be reevaluated and potentially modified in the future as new data becomes available.

This section is organized to address all of the SGMA regulations regarding SMC. To retain an organized approach that focuses on SMC for each individual sustainability indicators, the SMC are grouped by sustainability indicator. Each subsection follows a consistent format that contains the information required by Section §354.22 *et. seq* of the SGMA regulations and outlined in the Sustainable Management Criteria BMP (DWR, 2017). Each Sustainable Management Criteria section includes a description of:

- How locally defined significant and unreasonable conditions were developed.
- How undesirable results were developed, including:
  - The criteria defining when and where the effects of the groundwater conditions cause undesirable results based on a quantitative description of the combination of minimum threshold exceedances (§354.26 (b)(2)).
  - The potential causes of undesirable results (§354.26 (b)(1)).
  - The effects of these undesirable results on the beneficial users and uses (§354.26 (b)(3)).
- How minimum thresholds were developed, including:
  - The information and methodology used to develop minimum thresholds (§354.28 (b)(1)).
  - The relationship between minimum thresholds and the relationship of these minimum thresholds to other sustainability indicators (§354.28 (b)(2)).
  - The effect of minimum thresholds on neighboring basins (§354.28 (b)(3)).
  - The effect of minimum thresholds on beneficial uses and users (§354.28 (b)(4))
  - How minimum thresholds relate to relevant Federal, State, or local standards (§354.28 (b)(5)).
  - The method for quantitatively measuring minimum thresholds (§354.28 (b)(6)).
- How measurable objectives were developed, including:
  - The methodology for setting measurable objectives (§354.30).
  - Interim milestones (§354.30 (a), §354.30 (e), §354.34 (g)(3)).

3.2.1 Process of Developing Sustainable Management Criteria

Development of SMC involved initial proposals by staff, followed by discussion and refinement by the GSP Advisory Committee over multiple meetings. Prior to discussing SMCs for a particular sustainability indicator with the GSP Advisory Committee, the members were provided background information on the status of the indicator in the Basin and a brief on the groundwater conditions pertaining to the indicator. This information was provided both in written materials included in the meeting agenda packet and a presentation that was made during the meeting. Discussion during the meeting facilitated additional information sharing and clarity. Once there was comfort in understanding Basin conditions related to the sustainability indicator, the technical consultant described possible options or proposals for indicator specific significant and unreasonable groundwater conditions that indicate the Basin was unsustainable.

Based on the qualitative statement of significant and unreasonable conditions that was formed by the Committee, the same approach of providing several options for the quantitative criteria: undesirable results and minimum thresholds, were provided to the GSP Advisory Committee for consideration. This approach was taken so that it could be understood that within the various options, there are relative levels of protectiveness. Meeting summaries posted on the MGA website reflect the discussions that took place for each sustainability indicator.

Farther along in the SMC development process when minimum thresholds were generally agreed upon, options for measurable objectives were presented and discussed by the Committee. Several iterations of providing options were afforded each sustainability indicator which allowed for continual improvements to the criteria. Additionally, opportunities for public comment on the topics being discussed at the GSP Advisory Committee meetings were provided and taken into consideration during development of the SMCs.

Interim milestones were developed based on current conditions and modeled groundwater levels and did not have direct GSP Advisory Committee input.

3.3 Monitoring Network

This subsection describes the monitoring networks that currently exist in the Basin to monitor Basin conditions and that will continue to be used during GSP implementation, Representative Monitoring Points (RMPs) for which sustainable management criteria are set, and improvements to the monitoring networks that will be made as part of GSP implementation. It also includes a description of monitoring objectives, monitoring protocols, and data requirements. The monitoring network subsection is before the sustainability management criteria (SMC) subsection because it is important to describe the representative monitoring networks that measure Basin sustainability before SMC associated with the RMPs in the networks are provided.

The monitoring networks included in this subsection are based on existing monitoring networks described generally in Section 2.1.2: Water Resources Monitoring and Management Programs. To be able to relate monitoring features to sustainability indicators, monitoring networks are described below for each of the information types that are needed to evaluate the applicable sustainability indicators.

3.3.1 Description of Monitoring Networks

The SGMA regulations require monitoring networks be developed to promote the collection of data of sufficient quality, frequency, and spatial distribution to characterize groundwater and related surface water conditions in the Basin, and to evaluate changing conditions that occur during implementation of the GSP. Monitoring networks should accomplish the following:

- Demonstrate progress toward achieving measurable objectives described in the GSP.
- Monitor impacts to the beneficial uses and users of groundwater.
- Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.
- Quantify annual changes in water budget components.

The Santa Cruz Mid-County Basin’s existing monitoring networks have been used for several decades to collect information to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions. The monitoring networks include features for the collection of data to monitor the five groundwater sustainability indicators that are applicable to the Basin: chronic lowering of groundwater levels, seawater intrusion, depletion of interconnected surface water, reduction of groundwater in storage, and degraded groundwater quality (Table 3-1). As discussed in Section 2: Basin Setting, land subsidence is not an applicable sustainability indictor in the Basin and therefore monitoring of land surface elevations is not included in the current monitoring network. Section 3.3.1.5 does however include a source of monitoring data for land surface elevations in the Basin that is provided by public agencies not part of the MGA.

Table 3-1. Applicable Sustainability Indicators in the Santa Cruz Mid-County Basin

Sustainability Indicator	Metric	Proxy
Chronic Lowering of Groundwater Levels	Groundwater elevation	-
Reduction of Groundwater in Storage	Volume of groundwater extracted	-
Seawater Intrusion	Chloride concentration	Groundwater elevation
Degraded Groundwater Quality	Concentration	-
Depletion of Interconnected Surface Water	Volume or rate of streamflow	Groundwater elevation

3.3.1.1 Groundwater Level Monitoring Network

Each MGA member agency has its own network of dedicated monitoring wells and production wells that monitor groundwater elevations in its own service area or area of jurisdiction. Many of these monitoring sites have been used to manage the Basin since the 1980's which was prior to completion of the 1995 Groundwater Management Plan (GMP) that covered the Soquel-Aptos area. These individual networks are combined into the GMP monitoring network, as described in Section 2.1.2: Water Resources Monitoring and Management Programs. The GMP monitoring network has been added to and maintenance of the network has included replacing monitoring wells when they are damaged. Almost all monitoring wells and all production wells have data loggers to continuously monitor groundwater levels. Shallow monitoring wells used to monitor surface water / groundwater interactions are also included in this extensive GMP monitoring network.

Table 3-2 summarizes the number of wells included in the existing GMP monitoring network across the Basin to monitor groundwater levels. Figure 3-1 is a map showing the basin-wide distribution of groundwater level monitoring wells. The aquifers monitored by each well with their frequency of monitoring are listed in Table 3-3. With 170 wells in the Basin monitored at least twice a year, the network is demonstrably extensive and sufficient to evaluate short-term, seasonal, and long-term trends in groundwater for groundwater management purposes. Groundwater level data from many of the wells have been used since 2006 to generate fall and spring groundwater elevation contours for all of the Basin's aquifers. As there are multiple well clusters with monitoring wells completed in different aquifers at the same location included throughout the Basin, these are used to understand changes in vertical gradients between aquifers.

Table 3-2. Summary of MGA Member Agency Monitoring Well Network for Groundwater Levels

Member Agency	Number of Wells			
	Monitoring Wells	Production Wells	Total in Network	Representative Monitoring Wells
City of Santa Cruz	34	4	38	7
Soquel Creek Water District	78	17	95	26
Central Water District	6	3	9	2
Santa Cruz County	0	27	27	2
Total	*118*	*51*	*169*	*37*

Note: each well in a cluster of multi-depth wells is counted as a separate well

The groundwater level monitoring network accomplishes the following for each sustainability indicator that relies on groundwater levels either directly or using groundwater levels as a proxy to determine Basin sustainability:

- Chronic Lowering of Groundwater Levels: Monitoring wells are distributed throughout the Basin in all the aquifers used for groundwater production, and the distribution of wells is sufficient to develop groundwater elevation contours for each aquifer.

- Seawater Intrusion: The monitoring network includes coastal monitoring wells that are used to monitor seawater intrusion through groundwater quality and groundwater levels as a proxy. Each location has multiple monitoring wells completed at different depths within the productive aquifers. Protective groundwater elevations are established at each of these locations to prevent seawater intrusion. Two additional monitoring wells, one in the Tu-unit and one in the Purisima AA-unit, are needed to complete the monitoring network as described in Section 3.3.4.1: Groundwater Level Monitoring Data Gaps.

- Depletion of Interconnected Surface Water: The current shallow monitoring wells used to monitor and evaluate interactions between surface water and groundwater are focused on the lower stretch of Soquel Creek where there are several municipal production wells. In addition, there are multiple depth monitoring well clusters near Soquel Creek that are included in the evaluation of surface water and groundwater interactions. Eight new shallow monitoring wells will be added to complete the monitoring network to better evaluate the effects of groundwater extractions on streamflow in interconnected surface waters (see Section 3.3.4.1: Groundwater Level Monitoring Data Gaps.)

Each agency will use its own resources to continue to monitor these wells as the GSP is implemented. Groundwater level data collected, both hand soundings and recorded by data loggers, for each well will be stored in the WISKI DMS.

The only data gaps that exist for the groundwater level monitoring network are two deep coastal monitoring wells to monitor seawater intrusion in the Tu and Purisima AA aquifers, and eight shallow monitoring wells to monitor depletion of interconnected surface water. These are discussed in more detail in Section 3.3.4.1: Groundwater Level Monitoring Data Gaps.

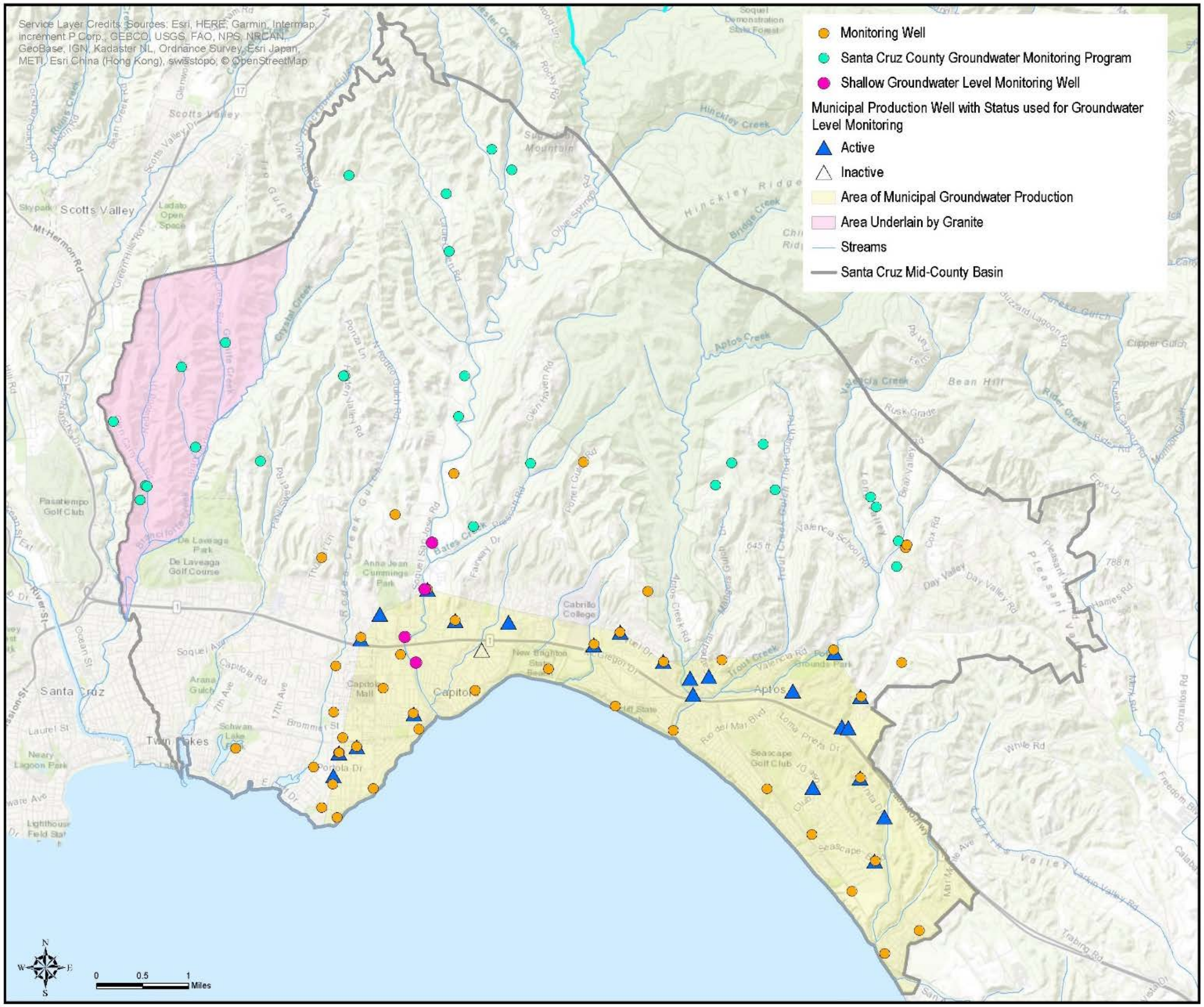


Figure 3-1. Location of Existing Basin-Wide Wells Used for Groundwater Level Monitoring

Table 3-3. Monitoring Wells for Groundwater Levels in the Santa Cruz Mid-County Basin

Aquifer Unit	Well Name	Monitoring Agency	Sounding Frequency	Data Logger
Shallow Well for Surface Water Interactions	**Balogh** [1]	SqCWD	Quarterly	y
	Main St SW 1 [1]	SqCWD	Quarterly	y
	Wharf Road SW [1]	SqCWD	Quarterly	y
	Nob Hill SW 2[1]	SqCWD	Quarterly	y
Various	27 Private Domestic Wells Unnamed for Privacy Reasons **(2 wells used as RMPs)** [3]	Santa Cruz County	Semi- Annually	n
Aromas	SC-A1C	SqCWD	Quarterly	y
	SC-A1D	SqCWD	Quarterly	y
	SC-A2RC	SqCWD	Quarterly	y
	SC-A3A [2]	**SqCWD**	**Quarterly**	**y**
	SC-A3B	SqCWD	Quarterly	y
	SC-A3C	SqCWD	Quarterly	y
	SC-A5C	SqCWD	Quarterly	y
	SC-A5D	SqCWD	Quarterly	y
	SC-A6C	SqCWD	Monthly	n
	SC-A7C [3]	**SqCWD**	**Monthly**	**n**
	SC-A7D	SqCWD	Monthly	n
	SC-A8B	SqCWD	Quarterly	y
	SC-A8C	SqCWD	Quarterly	y
	CWD-12A	CWD	Quarterly	n
	CWD-12B	CWD	Quarterly	n
	CWD-10 PW	CWD	Monthly	n
Aromas/ Purisima F	Polo Grounds PW	SqCWD	Annually	y
	Aptos Jr. High 2 PW	SqCWD	Annually	y
	Country Club PW	SqCWD	Annually	y
	Bonita PW	SqCWD	Annually	y
	San Andreas PW	SqCWD	Annually	y
	Seascape PW	SqCWD	Annually	y
	CWD-4 PW	CWD	Monthly	y
	CWD-12 PW	CWD	Monthly	y
Purisima F	SC-20A	SqCWD	Quarterly	y
	SC-20B	SqCWD	Quarterly	y
	SC-20C	SqCWD	Quarterly	y

Aquifer Unit	Well Name	Monitoring Agency	Sounding Frequency	Data Logger
	SC-23C [3]	**SqCWD**	**Quarterly**	**y**
	SC-8RF	SqCWD	Quarterly	y
	SC-A1B [2]	**SqCWD**	**Quarterly**	**y**
	SC-A2RA [2]	**SqCWD**	**Quarterly**	**y**
	SC-A2RB	SqCWD	Quarterly	y
	SC-A5A	SqCWD	Quarterly	y
	SC-A5B	SqCWD	Quarterly	y
	SC-A6A	SqCWD	Quarterly	n
	SC-A6B	SqCWD	Quarterly	n
	SC-A7A	SqCWD	Monthly	n
	SC-A7B	SqCWD	Monthly	n
	SC-A8A [2]	**SqCWD**	**Quarterly**	**y**
	CWD-12C	CWD	Quarterly	n
	Black [3]	**CWD**	**Monthly**	**n**
	CWD-3	CWD	Monthly	n
	CWD-5 [3]	**CWD**	**Monthly**	**y**
Purisima DEF	**SC-8RD** [2]	**SqCWD**	**Quarterly**	**y**
	SC-8RE	SqCWD	Quarterly	y
	SC-9RE	SqCWD	Quarterly	y
	SC-11RD [3]	**SqCWD**	**Quarterly**	**y**
	SC-17C	SqCWD	Monthly	n
	SC-17D	SqCWD	Monthly	n
	SC-23B [3]	**SqCWD**	**Quarterly**	**y**
	SC-A1A	SqCWD	Quarterly	y
	T. Hopkins PW	SqCWD	Annually	y
	Granite Way PW	SqCWD	Annually	y
Purisima BC	SC-1B	SqCWD	Monthly April – Nov, otherwise Quarterly	y
	SC-3RC	SqCWD	Quarterly	y
	SC-5RC	SqCWD	Quarterly	y
	SC-8RB [2]	**SqCWD**	**Quarterly**	**y**
	SC-8RC	SqCWD	Quarterly	y
	SC-9RC [2]	**SqCWD**	**Quarterly**	**y**
	SC-11RB [3]	**SqCWD**	**Quarterly**	**y**
	SC-14B	SqCWD	Monthly	n

Aquifer Unit	Well Name	Monitoring Agency	Sounding Frequency	Data Logger
	SC-14C	SqCWD	Monthly	n
	SC-16B	SqCWD	Monthly	n
	SC-17B	SqCWD	Monthly	n
	SC-19 [3]	**SqCWD**	**Monthly**	**n**
	SC-23A [3]	**SqCWD**	**Quarterly**	**y**
	Madeline 2 PW	SqCWD	Annually	y
	Ledyard PW	SqCWD	Twice monthly	n
	Aptos Creek PW	SqCWD	Annually	y
Purisima B	SC-3RB	SqCWD	Quarterly	y
	SC-5RB	SqCWD	Quarterly	y
Purisima A	**SC-1A** [2]	**SqCWD**	**Monthly April – Nov, otherwise Quarterly**	**y**
	SC-5RA [2]	**SqCWD**	**Quarterly**	**y**
	SC-8RA	SqCWD	Quarterly	y
	SC-9RA	SqCWD	Quarterly	y
	SC-10RA [1]	SqCWD	Quarterly	y
	SC-15B	SqCWD	Quarterly	y
	SC-17A	SqCWD	Monthly	n
	SC-21A	SqCWD	Quarterly	y
	SC-22A [3]	**SqCWD**	**Monthly April – Nov, otherwise Quarterly**	**y**
	Tannery 2 PW	SqCWD	Annually	y
	Estates PW	SqCWD	Annually	y
	Garnet PW	SqCWD	Annually	y
	Main St. PW	SqCWD	Annually	y
	Rosedale PW	SqCWD	Annually	y
	Corcoran Lagoon Med.	City	Monthly	y
	Corcoran Lagoon S.	City	Monthly	n
	Moran Lake Medium [2]	**City**	**Monthly**	**y**
	Moran Lake Shallow	City	Monthly	n
	Beltz #2	City	Monthly	y
	Beltz #4 Deep	City	Monthly	y
	Beltz #4 Shallow	City	Monthly	n
	Soquel Point Shallow	City	Monthly	n
	Soquel Point Medium [2]	**City**	**Monthly**	**y**

Aquifer Unit	Well Name	Monitoring Agency	Sounding Frequency	Data Logger
	Pleasure Point Medium [2]	**City**	**Monthly**	**y**
	Pleasure Point Shallow	City	Monthly	n
	Coffee Lane Shallow [3]	**City**	**Monthly**	**y**
	Auto Plaza Med	City	Monthly	y
	Auto Plaza Shallow	City	Monthly	n
	Cory Street Medium	City	Monthly	y
	Cory Street Shallow	City	Monthly	n
	30th Ave Shallow (3)	City	Monthly	y
	Beltz #8 PW	City	Annually	y
	Beltz #9 PW	City	Annually	y
	Beltz #7 Shallow	City	Monthly	n
	Beltz #6	City	Monthly	n
Purisima A/AA	SC-11RA	SqCWD	Quarterly	y
	SC-14A	SqCWD	Monthly	n
	SC-16A	SqCWD	Quarterly	y
	SC-3RA [2]	**SqCWD**	**Quarterly**	**y**
	Beltz #10 PW	City	Annually	y
	Beltz #7 Deep	City	Monthly	n
Purisima AA	**SC-10RAA [3]**	**SqCWD**	**Quarterly**	**y**
	SC-15A	SqCWD	Quarterly	y
	SC-18RA	SqCWD	Quarterly	y
	SC-21AA	SqCWD	Quarterly	y
	SC-21AAA	SqCWD	Quarterly	y
	SC-22AA [3]	**SqCWD**	**Monthly April – Nov, otherwise Quarterly**	**y**
	SC-22AAA	SqCWD	Quarterly, with Monthly visits April - Nov	y
	Corcoran Lagoon Deep	City	Monthly	y
	Moran Lake Deep [2]	**City**	**Monthly**	**y**
	Soquel Point Deep [2]	**City**	**Monthly**	**y**
	Pleasure Point Deep [2]	**City**	**Monthly**	**y**
	Schwan Lake	City	Monthly	y
	Coffee Lane Deep	City	Monthly	y
	Auto Plaza Deep	City	Monthly	y
	Cory Street Deep	City	Monthly	y

Aquifer Unit	Well Name	Monitoring Agency	Sounding Frequency	Data Logger
	30th Ave Medium (2)	City	Monthly	y
	Thurber Lane Shallow	City	Monthly	y
Purisima AA/Tu	Beltz #12 PW	City	Annually	y
	O’Neill Ranch PW	SqCWD	Annually	y
Tu	SC-10AAA	SqCWD	Quarterly	y
	SC-13A [2]	**SqCWD**	**Quarterly**	**y**
	SC-18RAA	SqCWD	Quarterly	y
	Cory Street-4	City	Monthly	y
	30th Ave Deep (1)	City	Monthly	y
	Beltz #7 SM Test	City	Monthly	y
	Thurber Lane Deep	City	Monthly	y

PW = production well; City = City of Santa Cruz, SqCWD = Soquel Creek Water District; CWD = Central Water District; monitoring wells in bold are representative monitoring points (RMP) for groundwater elevations; [1] = RMP for depletion of interconnected surface water; [2 =] RMP for seawater intrusion; [3 =] RMP for chronic lowering of groundwater levels

3.3.1.2 Groundwater Quality Monitoring Network

Each MGA member agency monitors a network of dedicated monitoring wells and production wells for groundwater quality in its service area or area of jurisdiction. These monitoring sites have been used to manage the Basin and added to since the 1980's which was prior to completion of the 1995 Groundwater Management Plan that covered the Soquel-Aptos area. Table 3-4 summarizes the wells included in the existing monitoring network across the Basin. A map showing the distribution of monitoring wells used to sample groundwater quality is shown on Figure 3-2, and the aquifers monitored by each well with their frequency of sampling are listed in Table 3-5. There is no established inland groundwater quality monitoring network within the areas outside of the MGA member water supply agency sphere of influence where predominantly private domestic and agricultural extractions take place. As described in Section 2: Basin Setting, groundwater quality in the inland Purisima aquifer areas of the Basin is very good, with the exception of occasional low concentrations of native arsenic, and elevated naturally occurring iron and manganese. The Aromas area of the Basin is more susceptible to surface sources of contamination because the underlying aquifers are unconfined and highly permeable. The distribution and sampling frequency of monitoring and production wells used for sampling groundwater quality reflects locational and aquifer depth susceptibility to contamination, including from seawater. Iron and manganese are sampled more frequently in municipal production wells as a necessary step in the iron and manganese treatment process.

Table 3-4. Summary of MGA Member Agency Monitoring Well Network for Groundwater Quality

Member Agency	Number of Wells			
	Monitoring Wells	Production Wells	Total in Network	Representative Monitoring Wells
City of Santa Cruz	28	4	32	18
Soquel Creek Water District	51	17	68	47
Central Water District	0	3	3	3
Total	*79*	*24*	*103*	*68*

Note: each well in a cluster of multi-depth wells is counted as a separate well

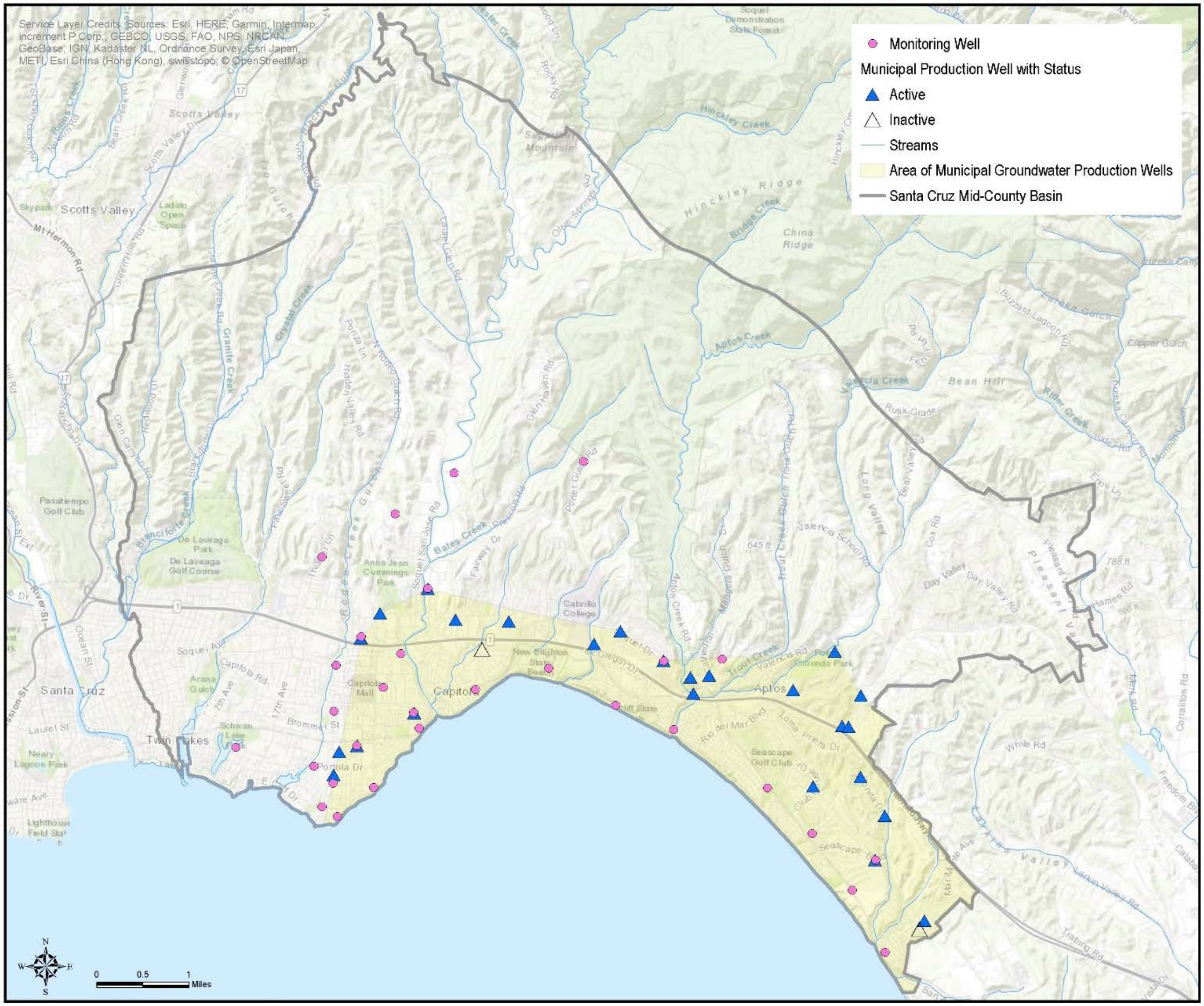


Figure 3-2. Location of Basin-Wide Wells Used for Groundwater Quality Monitoring

Table 3-5. Monitoring Wells for Groundwater Quality in the Santa Cruz Mid-County Basin

Aquifer Unit	Well Name	General Mineral Sampling Frequency	Chloride and TDS Sampling Frequency
Aromas	Altivo PW	Semi-Annually	Quarterly
	CWD-10 PW [1]	**Triennial, nitrate as (N) Annually**	**Triennial**
	SC-A1C [1]	**Annually**	**Quarterly**
	SC-A1D	Semi-Annually	Quarterly
	SC-A2RC [1]	**Semi-Annually**	**Quarterly**
	SC-A3A [1 2]	**Annually**	**Quarterly**
	SC-A3B [2]	**Annually**	**Quarterly**
	SC-A3C [1]	**Annually**	**Quarterly**
	SC-A5C	Semi-Annually	Quarterly
	SC-A5D	Annually	Quarterly
	SC-A8B [1 2]	**Semi-Annually**	**Quarterly**
	SC-A8C [1]	**Annually**	**Quarterly**
Aromas/ Purisima F	**Polo Grounds PW [1]**	**Semi-Annually, nitrate (as N) Annually**	**Quarterly**
	Aptos Jr. High 2 PW [1]	**Semi-Annually, nitrate (as N) Annually**	**Quarterly**
	Country Club PW [1]	**Semi-Annually, nitrate (as N) Annually**	**Quarterly**
	Bonita PW [1]	**Semi-Annually, nitrate (as N) Annually**	**Quarterly**
	San Andreas PW [1 2]	**Semi-Annually, nitrate (as N) Annually**	**Quarterly**
	Seascape PW [1 2]	**Semi-Annually, nitrate (as N) Annually**	**Quarterly**
Purisima F	**CWD-4 PW [1]**	**Triennial, nitrate as (N) Annually**	**Triennial**
	CWD-12 PW [1]	**Triennial, nitrate as (N) Annually**	**Triennial**
	SC-23C	Annually	Semi-Annually
	SC-8RF	Annually	Semi-Annually
	SC-A1B [2]	**Annually**	**Semi-Annually**
	SC-A2RA [1 2]	**Annually**	**Quarterly**
	SC-A2RB [2]	**Semi-Annually**	**Quarterly**
	SC-A5A [2]	**Annually**	**Quarterly**
	SC-A5B [2]	**Annually**	**Quarterly**
	SC-A8A [1 2]	**Annually**	**Quarterly**
Purisima DEF	**T-Hopkins PW [1 2]**	**Annually**	**Annually**
	Granite Way PW [1]	**Annually**	**Annually**

Aquifer Unit	Well Name	General Mineral Sampling Frequency	Chloride and TDS Sampling Frequency
	SC-8RD [1] [2]	**Annually**	**Semi-Annually**
	SC-8RE	Annually	Semi-Annually
	SC-9RE [1]	**Annually**	**Semi-Annually**
	SC-11RD	Semi-Annually	Semi-Annually
	SC-23B	Annually	Annually
	SC-A1A [1] [2]	**Semi-Annually**	**Quarterly**
Purisima BC	**Ledyard PW [1] [2]**	**Annually**	**Annually**
	Madeline 2 PW [1]	**Annually**	**Annually**
	Aptos Creek PW [1]	**Annually**	**Annually**
	SC-3RC [1]	**Annually**	**Semi-Annually**
	SC-23A [1]	**Annually**	**Annually**
	SC-8RB [1] [2]	**Semi-Annually**	**Semi-Annually**
	SC-8RC	Semi-Annually	Semi-Annually
	SC-9RC [1] [2]	**Annually**	**Semi-Annually**
	SC-11RB	Annually	Semi-Annually
	SC-17B	Annually	Semi-Annually
Purisima B (Aquitard)	SC-3RB	Annually	Annually
	SC-5RB	Annually	Annually
Purisima A	**30th Ave Shallow (3) [1]**	**Semi-Annually**	**Semi-Annually**
	Auto Plaza Medium	Semi-Annually	Semi-Annually
	Auto Plaza Shallow	Semi-Annually	Semi-Annually
	Corcoran Lagoon Med.	Semi-Annually	Semi-Annually
	Corcoran Lagoon S.	Semi-Annually	Semi-Annually
	Cory Street Medium	Semi-Annually	Semi-Annually
	Cory Street Shallow	Semi-Annually	Semi-Annually
	Pleasure Point Medium [2]	**Quarterly**	**Quarterly**
	Pleasure Point Shallow [1]	**Quarterly**	**Quarterly**
	Beltz #2 [2]	**Semi-Annually**	**Semi-Annually**
	Moran Lake Medium [2]	**Quarterly**	**Quarterly**
	Moran Lake Shallow	Quarterly	Quarterly
	Soquel Point Medium [2]	**Quarterly**	**Quarterly**
	Soquel Point Shallow	Quarterly	Quarterly
	Tannery II PW [1]	**Annually**	**Annually**
	Estates PW [1] [2]	**Annually**	**Annually**

Aquifer Unit	Well Name	General Mineral Sampling Frequency	Chloride and TDS Sampling Frequency
	Main Street PW [1]	**Annually**	**Annually**
	Rosedale 2 PW [1]	**Annually**	**Annually**
	Garnet PW [1,2]	**Annually**	**Annually**
	Beltz #6	Semi-Annually	Semi-Annually
	Beltz #8 PW [1,2]	**Triennial, iron & manganese quarterly, nitrate (as N) Annually**	**Triennial**
	Beltz #9 PW [1]	**Triennial, iron & manganese quarterly, nitrate (as N) Annually**	**Triennial**
	SC-1A [2]	**Annually**	**Annually**
	SC-3RA [2]	**Annually**	**Annually**
	SC-5RA [1,2]	**Semi-Annually**	**Semi-Annually**
	SC-8RA	Quarterly	Quarterly
	SC-9RA [1]	**Quarterly**	**Quarterly**
	SC-10RA [1]	**Annually**	**Annually**
	SC-21A	Annually	Annually
	SC-22A [1]	**Annually**	**Annually**
Purisima A/AA	**Beltz #10 PW [1]**	**Triennial, iron & manganese quarterly, nitrate (as N) Annually**	**Triennial**
	SC-11RA	Annually	Annually
Purisima AA	**SC-10RAA [1]**	**Annually**	**Annually**
	SC-18RA	Annually	Annually
	SC-21AA	Annually	Annually
	SC-21AAA	Quarterly	Quarterly
	SC-22AA [2]	**Semi-Annually**	**Quarterly**
	SC-22AAA [1]	**Semi-Annually**	**Quarterly**
	30th Ave Medium (2)	Semi-Annually	Semi-Annually
	Auto Plaza Deep	Semi-Annually	Semi-Annually
	Coffee Lane Deep [1]	**Semi-Annually**	**Semi-Annually**
	Corcoran Lagoon Deep [2]	**Semi-Annually**	**Semi-Annually**
	Cory Street Deep	Semi-Annually	Semi-Annually
	Pleasure Point Deep [1,2]	**Quarterly**	**Quarterly**
	Moran Lake Deep [2]	**Quarterly**	**Quarterly**
	Soquel Point Deep [2]	**Quarterly**	**Quarterly**
	Thurber Lane Shallow [1]	**Annually**	**Annually**

Aquifer Unit	Well Name	General Mineral Sampling Frequency	Chloride and TDS Sampling Frequency
	Schwan Lake [1] [2]	**Semi-Annually**	**Semi-Annually**
Purisima AA/Tu	**O'Neill Ranch PW [1]**	**Annually**	**Annually**
	Beltz #12 PW [1]	**Triennial, iron & manganese quarterly, nitrate (as N) Annually**	**Triennial**
Tu	30th Ave Deep (1)	Semi-Annually	Semi-Annually
	Cory Street-4	Semi-Annually	Semi-Annually
	Thurber Lane Deep [1]	**Annually**	**Annually**
	SC-10RAAA	Semi-Annually	Semi-Annually
	SC-13A [2]	**Quarterly**	**Quarterly**
	SC-18RAA [1]	**Semi-Annually**	**Quarterly**

PW = production well; monitoring wells in bold are representative monitoring points (RMP) for groundwater quality; [1] = RMP for degraded groundwater quality; [2] = RMP for seawater intrusion

The groundwater quality monitoring network accomplishes the following for the sustainability indicators relying on groundwater quality to determine Basin sustainability:

- Degraded Groundwater Quality: Monitoring wells are distributed throughout the Basin in all the aquifers used for groundwater production, and the distribution of wells and their sampling frequency is sufficient to determine groundwater quality trends over time for each aquifer. No additional monitoring wells for degraded groundwater quality are needed until projects are implemented.

- Seawater Intrusion: The monitoring network includes coastal monitoring wells that are used to monitor groundwater quality related to seawater intrusion. Most locations have multiple monitoring wells completed at different depths within the productive aquifers. All coastal monitoring wells are sampled for chloride and TDS quarterly to ensure increases in salinity are identified quickly. The two deep monitoring wells to be added for monitoring groundwater levels as a proxy for seawater intrusion will also be part of the network to monitor groundwater quality related to seawater intrusion. Like other coastal monitoring wells, these two deep monitoring wells will be monitored quarterly once constructed and equipped.

Each agency will use its own resources to continue to sample these wells as the GSP is implemented. Groundwater quality data collected for each well will be stored in the WISKI DMS.

3.3.1.3 Groundwater Extraction Monitoring

3.3.1.3.1 Metered Groundwater Extraction

Each MGA member agency that supplies water meters its own groundwater extraction in its service area by individual well. All municipal production wells have SCADA systems to automatically record groundwater extraction. Manual meter readings are also recorded. Monthly extraction data by well is stored in the WISKI DMS.

Small water systems (SWS) having between 5 and 199 connections are required to meter their groundwater production with monthly meter readings that are reported annually to Santa Cruz County. Monthly metered production is also required by the State Water Resources Control Board Division of Drinking Water (DDW) under California Code of Regulations §64561. This requirement also includes businesses or other operations that extract groundwater and that serve more than 25 people for more than 60 days a year. Annual extractions for reporting SWSs will be stored in the WISKI DMS.

3.3.1.3.2 Unmetered Groundwater Extraction

In areas outside of the municipal service areas, there are over one thousand private wells that each extract less than 2 acre-feet per year of groundwater for domestic purposes. These are called *de minimis* users and their wells are typically unmetered. Estimates of pumping for private domestic use are made based on the number of parcels with a residence and typical water use factor per connection derived from metered SWS water use per connection. To keep a current estimate of *de minimis* pumping, records of the number of rural parcels with residences and estimates of water use per connection from SWSs need to be updated annually.

Groundwater extraction for agricultural use (irrigation and livestock) is currently unmetered in the Basin. Annual agricultural demand is estimated based on the crop irrigated, monthly reference evapotranspiration that is measured at a nearby CIMIS station, and irrigated crop acreage. The MGA will need to monitor the acreage of irrigated lands in the Basin annually, and include cannabis which was not included in the agricultural use estimates in the historical groundwater model. As part of GPS implementation, the MGA will be implementing a metering plan that will require some of the larger agricultural and other non-de minimis users to meter their wells and provide the MGA with extraction data.

Estimated groundwater extractions will not be included in the WISKI DMS as the data are not measured. Spreadsheets and GIS containing the data used to estimate groundwater extractions for unmetered wells will be used to store estimated extraction data. These data will be included in annual reporting and to update the model periodically.

3.3.1.4 Streamflow Monitoring

The USGS streamflow gauge No. 11160000 (Soquel Creek at Soquel) is one of five streamflow gauges currently active in the Basin. The USGS gauge has been operational since 1951 and is part of the USGS's National Water Information System.

Other streamflow monitoring in the Basin is focused on Soquel Creek (Figure 3-3 and Table 3-6). This is because SqCWD recognized the potential of stream impacts from pumping their municipal supply wells close to Soquel Creek. As part of SqCWD's Soquel Creek Monitoring and Adaptive Management Plan (MAMP) described in Section 2.1.2.1: Description of Water Resources Monitoring and Management Programs, SqCWD has stream water level loggers in Soquel Creek alongside the shallow monitoring wells shown on Figure 3-3. Since changes in stream levels from groundwater pumping of nearby municipal wells have not been measurable at the monitoring locations since monitoring started, stream water level monitoring may be terminated after five years of monitoring (after 2019).

Trout Unlimited is working in conjunction with the Resource Conservation District of Santa Cruz County (RCD) to monitor dry season flows at four locations on Soquel Creek (Figure 3-3) to help measure the impact of stream diversions and evaluate opportunities for streamflow enhancement. The current effort is funded through 2019 under a Proposition 1 Grant from the Wildlife Conservation Board for streamflow enhancement. After 2019, ongoing monitoring of the streamflow gauges will be continued by the MGA.

All streamflow data will be stored in the WISKI DMS.

Table 3-6. Streamflow Gauges in the Santa Cruz Mid-County Basin

Monitoring Entity	Streamflow Gauge Name
USGS	USGS 11160000 Soquel Creek at Soquel
Trout Unlimited / Santa Cruz Resource Conservation District	Soquel Creek West Branch
	Soquel Creek near Olive Springs
	Soquel Creek above West Branch Confluence
	Soquel Creek above Bates Creek

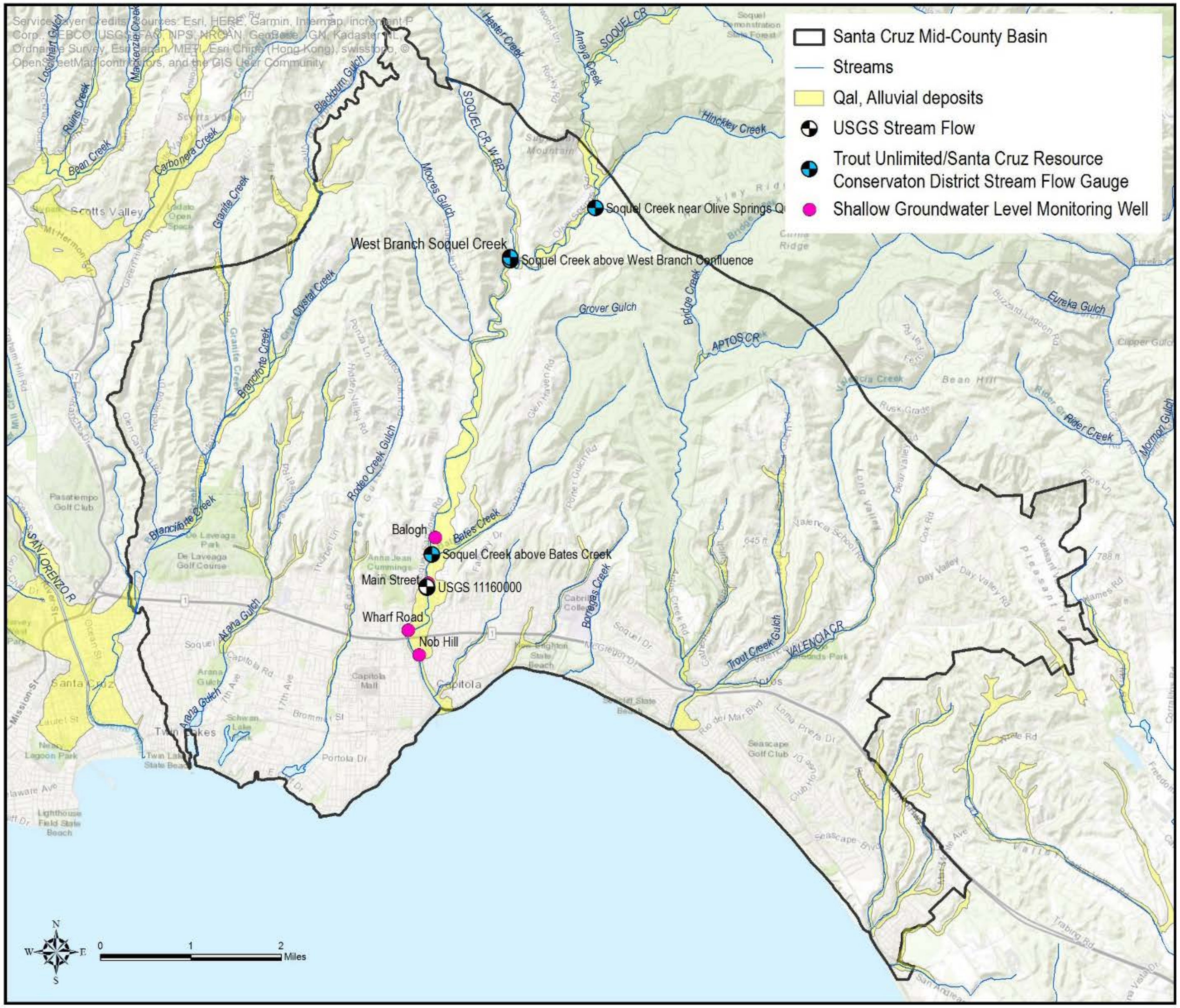


Figure 3-3. Location of Basin Streamflow Gauges

3.3.1.5 Land Elevation Monitoring

Land subsidence is not an applicable indicator of sustainability in the Basin and land surface elevations within the Basin have not been monitored historically, nor are there plans to monitor it in the future. There are however two land subsidence monitoring networks that are publicly available: (1) Continuous Global Positioning System (CGPS) stations in the vicinity of the Basin that are part of the UNAVCO Plate Boundary Observatory network of CGPS stations, and (2) Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. (TRE).

1. The CGPS data are a subset of Plate Boundary Observatory GPS with near real-time data streams made available by UNAVCO. The data is provided as elevation (Z) and longitude (X) and latitude (Y). There is one CGPS stations (Larkin Valley CGPS station (P212)) just outside of the Aromas area of the Basin that can be used to assess subsidence at the basin boundary (Figure 3-4).

2. Through a contract with TRE ALTAMIRA Inc. (TRE) and as part of DWR’s SGMA technical assistance for GSP development and implementation, DWR has made available measurements of vertical ground surface displacement in more than 200 of the high-use and populated groundwater basins across California, including for the Santa Cruz Mid-County Basin. Vertical displacement estimates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by TRE. The InSAR dataset has also been ground-truthed to best available independent data. The current data covers the months between January 2015 and June 2018, and DWR is planning on supporting updating the dataset on an annual basis through 2022.

The CGPS data and TRE ALTAMIRA InSAR subsidence dataset can be used by the MGA annually to compare against groundwater elevations to confirm that subsidence is not occurring in the Basin.

3.3.1.6 Climate Monitoring

Climate conditions are collected by MGA member agencies and partners at various locations in the Basin. Monitored information includes precipitation and temperature to help provide information on recharge, soil moisture, and evapotranspiration. This information is also important to consider influences on streamflow. Consideration will be given to expanding this network and providing for more direct measurement of evapotranspiration and occurrence of fog cover.

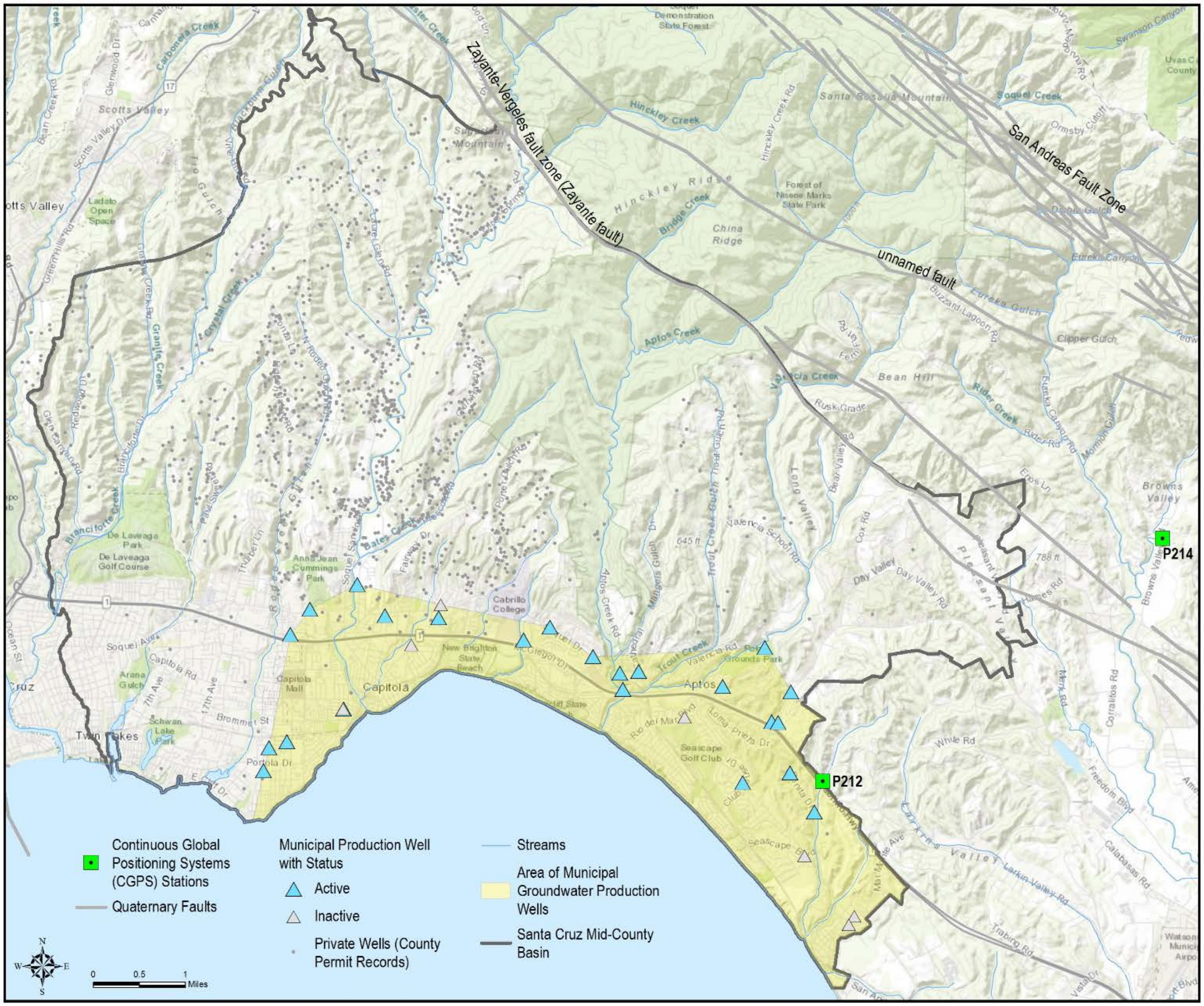


Figure 3-4. Location of Continuous GPS Stations near the Santa Cruz Mid-County Basin

3.3.2 Monitoring Protocols for Data Collection and Monitoring

Pursuant to the goals of SGMA, MGA member agencies use robust and reliable data collection protocols to monitor groundwater conditions in the Basin. Use of the monitoring protocols contained within this GSP ensure data is consistently collected by all member agencies, thereby increasing the reliability of data used to evaluate GSP implementation. Overall there are five types of data collected by MGA member agencies: groundwater elevations, groundwater quality, streamflow, volume of groundwater extracted, and climate conditions.

3.3.2.1 Groundwater Elevation Monitoring Protocols

Groundwater elevation monitoring is conducted to evaluate Basin conditions relative to the sustainable management criteria for chronic lowering of groundwater levels, seawater intrusion (proxy), and depletion of interconnected surface water (proxy), as shown in Table 3-1. Most groundwater levels in the Basin are measured and recorded at least daily using data loggers and measurements at most wells without loggers occur at least monthly. This allows the evaluation of a 'snapshot' of groundwater conditions for any given month.

All groundwater elevation measurements are referenced to a consistent elevation datum, known as the Reference Point (RP). For monitoring wells, the RP consists of a mark on the top of the well casing. For most production wells, the RP is the top of the well's concrete pedestal. The elevation of the (RP) of each well is surveyed to the National Geodetic Vertical Datum of 1929 (NGVD 29). The elevation of the RP is accurate to at least 0.5 foot, and most MGA well RPs are accurate to 0.1 foot or less.

Groundwater level measurements are taken to the nearest 0.01 foot relative to the RP using procedures appropriate for the measuring device. Equipment is operated and maintained in accordance with manufacturer's instructions, and all measurements are in consistent units of feet, tenths of feet, and hundredths of feet.

Groundwater elevation is calculated using the following equation:

$$GWE = RPE - DTW$$

where:

GWE = groundwater elevation

RPE = reference point elevation

DTW = depth to water

In cases where the official RPE is a concrete pedestal but the hand soundings are referenced off the top of a sounding tube, the measured DTW is adjusted by subtracting the sounding tube offset from the top of the pedestal.

All groundwater level measurements include a record of the date, well identifier, time (in 24-hour format), RPE, DTW, GWE, and comments regarding factors which may influence the recorded measurement such as nearby production wells pumping, weather, flooding, or well condition.

3.3.2.1.1 Manual Groundwater Level Measurement

Manual groundwater level measurements are made with electronic sounders or steel tape. All manual groundwater level measurements taken by MGA member agencies abide by the following protocols:

- Equipment usage follows manufacturer specifications for procedure and maintenance.
- Measurements are taken in wells that have not been subject to recent pumping. At least two hours of recovery must be allowed before a hand sounding is taken.
- For each well, multiple measurements are collected to ensure the well has reached equilibrium such that no significant changes in groundwater level are observed.
- Equipment is sanitized between well locations in order to prevent contamination and maintain the accuracy of concurrent groundwater quality sampling.

The majority of manual groundwater level measurements taken by MGA member agency utilize electric sounders. These consist of a long, graduated wire equipped with a weighted electric sensor. When the sensor is lowered into water, a circuit is completed and an audible beep is produced, at which point the sampler will record the depth to water. Some production wells may have lubricating oil floating on the top of the water column, in which case electric sounders will be ineffective. In this circumstance steel tape may be used. Steel tape instruments consist of simple graduated lines where the end of the line is chalked so as to indicate depth to water without interference from floating oil.

3.3.2.1.2 Groundwater Level Measurement with Continuous Recording Devices

In addition to manual groundwater level measurements, most municipal production wells, most monitoring wells, and the full subset of monitoring wells used as representative monitoring points are equipped with pressure transducers to collect more frequent data than manual measurements. Installation and use of pressure transducers abide by the following protocols:

- Prior to installation the sampler uses an electronic sounder or steel tape to measure and calculate the current groundwater level in order to properly install and calibrate the transducer. This is done following the protocols listed above.
- All transducer installations follow manufacturer specifications for installation, calibration, data logging intervals, battery life, and anticipated life expectancy.
- Transducers are set to record only measured groundwater level in order to conserve data capacity; groundwater elevation is calculated later after downloading.

- In any log or recorded datasheet, the well ID, transducer ID, transducer range, transducer accuracy, and cable serial number are all recorded.
- The sampler notes whether the pressure transducer uses a vented or non-vented cable for barometric compensation. If non-vented units are used, data are properly corrected for natural barometric pressure changes.
- All transducer cables are secured to the well head with a well dock or another reliable method. This cable is marked at the elevation of the reference point to allow estimates of future cable slippage.
- Transducer data is periodically checked against hand measured groundwater levels to monitor electronic drift, highlight cable movement, and ensure the transducer is operating correctly. This check occurs at least annually, typically during routine site visits.
- For wells not connected to SCADA, transducer data is downloaded as necessary to ensure no data is overwritten or lost. Data is entered into the data management system as soon as possible. When the transducer data is successfully downloaded and stored, the data is deleted or overwritten to ensure adequate data logger memory.

3.3.2.2 Groundwater Quality Monitoring Protocols

Groundwater quality samples are required to monitor the effect of GSP implementation on the degraded groundwater quality and seawater intrusion sustainability indicators (Table 3-1). All groundwater quality analyses are performed by laboratories certified under the State Environmental Laboratory Accreditation Program.

While specific groundwater sampling protocols vary depending on the constituent and the hydrogeologic context, the protocols contained here provide guidance which is applied to all groundwater quality sampling. Prior to sampling, the sampler contacts the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements. Laboratories must be able to provide a calibration curve for the desired analyte and are instructed to use reporting limits that are equal to or less than the applicable data quality objectives, regional water quality objectives/screening levels, or state Detection Limit for Purposes of Reporting.

- Each well used for groundwater quality monitoring has a unique identifier (ID). This ID is written on the well housing or the well casing to avoid confusion.
- Sample containers are labeled prior to sample collection. The sample label includes: sample ID, sample date and time, sample personnel, sample location, preservative used, analyte, and analytical method.

- In the case of wells with dedicated pumps, samples are collected at or near the wellhead. Samples are not collected from storage tanks, at the end of long pipe runs, or after any water treatment.

- Prior to any sampling, the sampler cleans the sampling port and/or sampling equipment so that it is free of any contaminants, and also decontaminates sampling equipment between sampling locations to avoid cross-contamination between samples.

- At the time of sampling, groundwater elevation in the well is also measured following appropriate protocols described above in the groundwater level measuring protocols.

- For any well not equipped with low-flow or passive sampling equipment, at least three well casing volumes are purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. If pumping causes a well to be go dry, the condition is documented and the well is allowed to recover to within 90% of original level prior to sampling.

- In addition to the constituent of interest, field parameters of dissolved oxygen, electrical conductivity, temperature, oxidation reduction potential and pH are collected for each sample during well purging, with dissolved oxygen and conductivity being the most critical parameters. Samples are not collected until these parameters stabilize. Parameters are considered stabilized at the following ranges: dissolved oxygen and oxidation reduction potential, ±10%; temperature and electrical conductivity, ±3%; and pH ±0.2%.

- All field instruments are calibrated each day of use, cleaned between samples, evaluated for drift throughout the day of use.

- Samples are collected exclusively under laminar flow conditions. This may require reducing pumping rates prior to sample collection.

- Samples are collected according to the appropriate standards listed in the Standard Methods for the Examination of Water and Wastewater and the USGS National Field Manual for the Collection of Water Quality Data. The specific sample collection procedures reflect the type of analysis to be performed and characteristics of the constituent.

- All samples requiring preservation are preserved as soon as practically possible and filtered appropriately as recommended for the specific constituent.

- Samples are chilled and maintained at 4 °C to prevent degradation of the sample.

- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.

3.3.2.3 Streamflow Monitoring Protocols

Streamflow discharge measurements are collected by MGA member agencies and partners to monitor streamflow interaction related to groundwater extractions, monitor stream conditions related to fish habitat, and help preserve other beneficial uses of surface water. There is one USGS gauge that is operated and monitored by the USGS according to procedures outlined by USGS (1982).

Surface water is most easily measured using a stream gauge and stilling well system, which requires development of rating curves between stream stage and total discharge. Several measurements of discharge at a variety of stream stages are taken to develop an accurate ratings curve.

3.3.2.4 Measuring Groundwater Extraction Protocols

Groundwater extraction volumes are collected to provide data for well field management and for assessment of the Basin's water budget. Additionally, the volume of groundwater extraction is the metric for the reduction of groundwater in storage sustainability indicator. Municipal MGA member agencies measure discharge from all their production wells with calibrated flow meters. Supervisory Control and Data Acquisition (SCADA) for individual wells are used to monitor and control production in close to real-time.

Small water systems (SWS) report their annual extractions to Santa Cruz County. Meters are typically read monthly.

3.3.3 Representative Monitoring Points

Representative Monitoring Points (RMPs) are a subset of the Basin's overall monitoring network. Designation of an RMP is supported by adequate evidence demonstrating that the site reflects general conditions in the area. Representative monitoring points are where numeric values for minimum thresholds, measurable objectives, and interim milestones are defined. Avoiding undesirable results based on data collected at RMPs demonstrates the Basin's sustainability.

Groundwater levels may be used as a proxy for sustainability indicators whose metric is not groundwater levels if the following can be demonstrated:

1. Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.

2. Measurable objectives established for groundwater elevation include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.

Table 3-1 lists the metrics for each of the Basin's applicable sustainability indicators. The sustainability indicators for *seawater intrusion* and *depletion of interconnected surface water* use groundwater levels as a proxy.

3.3.3.1 Chronic Lowering of Groundwater Level Representative Monitoring Points

The objective of the chronic lowering of groundwater levels representative monitoring network is to monitor areas where there is a concentration of groundwater extraction, but not immediately adjacent to municipal production wells. This is to avoid the dynamic drawdown caused by high-capacity wells. Use of dedicated monitoring wells in the network is preferable over wells actively used for groundwater extraction. Clustered multi-depth monitoring wells are included to evaluate groundwater elevations in different aquifers at the same location and to evaluate vertical gradients between aquifers. Because groundwater elevations to protect against seawater intrusion are higher (or more stringent) than groundwater elevations to prevent chronic lowering of groundwater levels, RMPs along the coast are not included in the chronic lowering of groundwater levels monitoring network. Groundwater elevations along the coast are instead controlled by the seawater intrusion sustainable management criteria in coastal monitoring wells. Figure 3-5 includes all wells in the representative monitoring network used for monitoring chronic lowering of groundwater levels.

Table 3-7. Representative Monitoring Points for Chronic Lowering of Groundwater Levels

Aquifer Unit	Well Name	Rationale
Aromas	SC-A7C	Located near boundary with Pajaro Valley Subbasin
Purisima F	Private Well 2	Located in an inland area with a high concentration of private domestic wells
	Black	Located near boundary with Pajaro Valley Subbasin in an area with a high concentration of private domestic wells, and is a dedicated monitoring well
	CWD-5	Located in an area with a high concentration of private domestic wells and is a dedicated monitoring well
	SC-23C	Just inside the area of municipal production but close to municipal production wells pumping from the Purisima F-unit and a high concentration of private domestic wells
Purisima DEF	SC-11RD	Located in an area with a high concentration of private domestic wells
	SC-23B	Just inside the area of municipal production but close to municipal production wells pumping from the Purisima DEF-unit and a high concentration of private domestic wells
Purisima BC	SC-11RB	Located in an area with a high concentration of private domestic wells
	SC-19	Outside the area of municipal production but close to municipal production wells pumping from the Purisima BC-unit and in an area between private domestic well pumping centers
	SC-23A	Just inside the area of municipal production but close to municipal production wells pumping from the Purisima BC-unit and a high concentration of private domestic wells
Purisima A	Coffee Lane Shallow	Outside the area of municipal production but close to municipal production wells pumping from the Purisima A-unit
	SC-22A	Inside the area of municipal production but close to municipal production wells pumping from the Purisima A-unit
Purisima AA	SC-22AA	Inside the area of municipal production but close to municipal production wells pumping from the Purisima AA-unit
	SC-10RAA	Located in an area with a high concentration of private domestic wells
Purisima AA/Tu	Private Well 1	Located in an inland area with a high concentration of private domestic wells
Tu	30th Ave Deep (1)	One of the few monitoring wells screened in the Tu aquifer located outside of the area of municipal production
	Thurber Lane Deep	One of the few monitoring wells screened in the Tu aquifer located outside of the area of municipal production

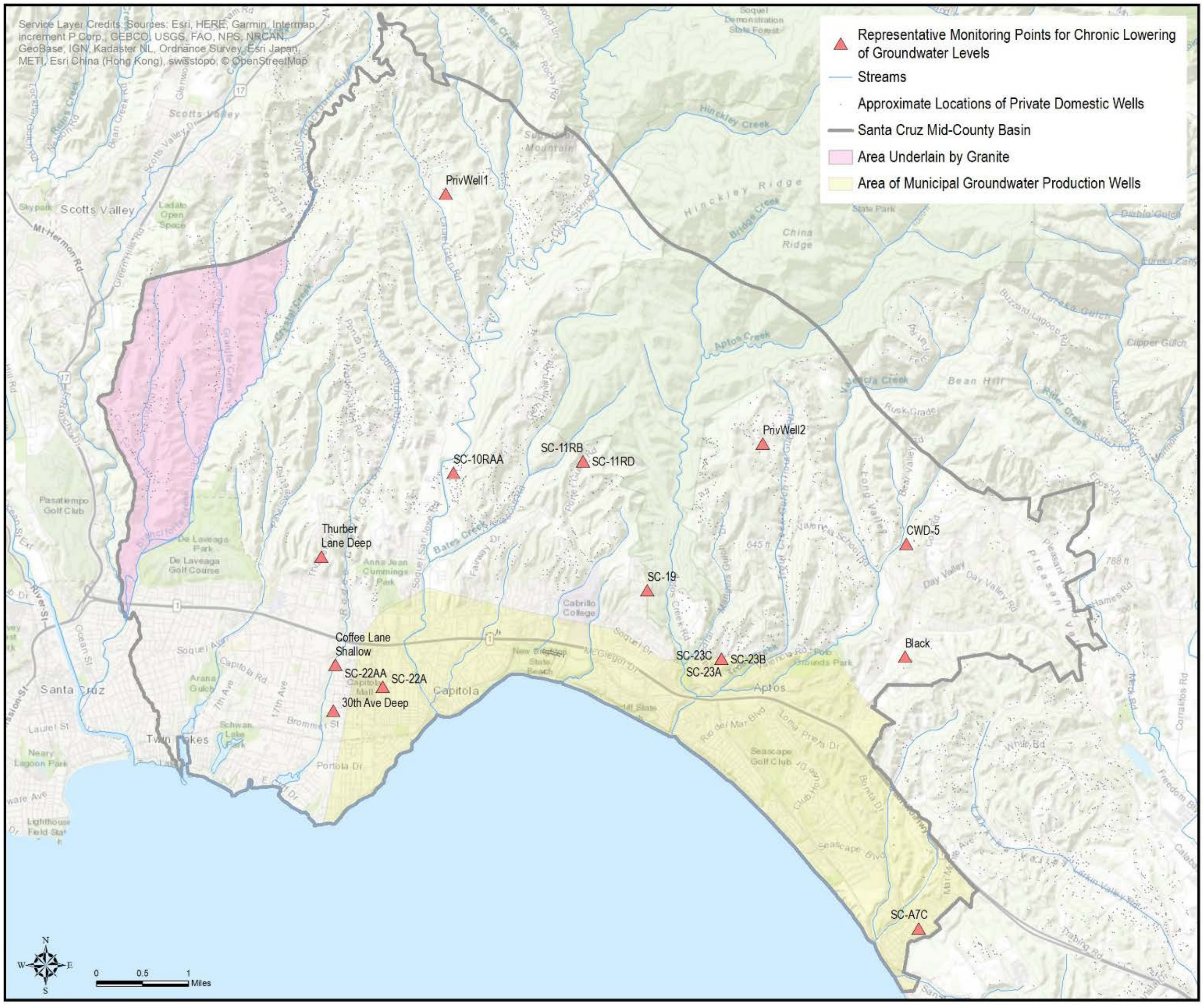


Figure 3-5. Chronic Lowering of Groundwater Level Representative Monitoring Network

3.3.3.2 Reduction of Groundwater in Storage Representative Monitoring Points

The physical well locations for the reduction of groundwater in storage representative monitoring network are all metered wells in the Basin (Figure 3-6). These are the only points where measured extraction data are available to evaluate the sustainability of the Basin with respect to reduction of groundwater in storage. All other groundwater extraction in the Basin will be estimated. Section 3.3.1.3 (Groundwater Extraction Monitoring) describes how small water systems, de minimis private pumping, and agricultural irrigation pumping will be estimated.

Wells that are metered as part of GSP implementation will be added as RMPs to the reduction of groundwater in storage representative monitoring network.

3.3.3.3 Seawater Intrusion Representative Monitoring Points

The seawater intrusion monitoring network monitors both chloride concentration and groundwater elevations as a proxy for seawater intrusion. Chloride concentrations are monitored in wells which are at least 0.5 mile away from the coast and either side of the chloride isocontour representing a minimum threshold for seawater intrusion. The City of Santa Cruz and SqCWD have been using protective groundwater elevations in coastal monitoring wells since 2009 to monitor and manage seawater intrusion in the Basin, and these same wells plus some additional wells to monitor the very deepest aquifers will be included in the representative monitoring network for proxy monitoring of seawater intrusion. Groundwater levels are continuously monitored with data loggers in all coastal monitoring wells where protective elevations are set. Hand soundings are taken at least quarterly in these RMP coastal monitoring wells.

In the event of data logger failure, monthly soundings measured during the data gap should be used to replace missing data in calculating averages used to determine if undesirable results have occurred. If no sounding measurement occurred during the data gap, the average of available hourly readings in the 7 days before and the 7 days after the data gap (up to 336 total hourly readings) should be used to replace the missing data in calculating averages. If data logger groundwater level data are shown to be inconsistent with a sounding measurement, the sounding measurement should be used to replace the inconsistent logger data in the calculation of averages. Inconsistent logger data is considered a variation of 0.5-feet between data logger and manual well soundings.

Figure 3-7 shows the locations of all RMPs in the seawater intrusion monitoring network used for both chloride concentrations and groundwater elevation proxies. The wells used to measure chloride concentrations have a different symbol than those used to monitor protective groundwater elevations. Table 3-8 lists the wells in the representative monitoring network and provides a brief rationale why each well was selected as an RMP.

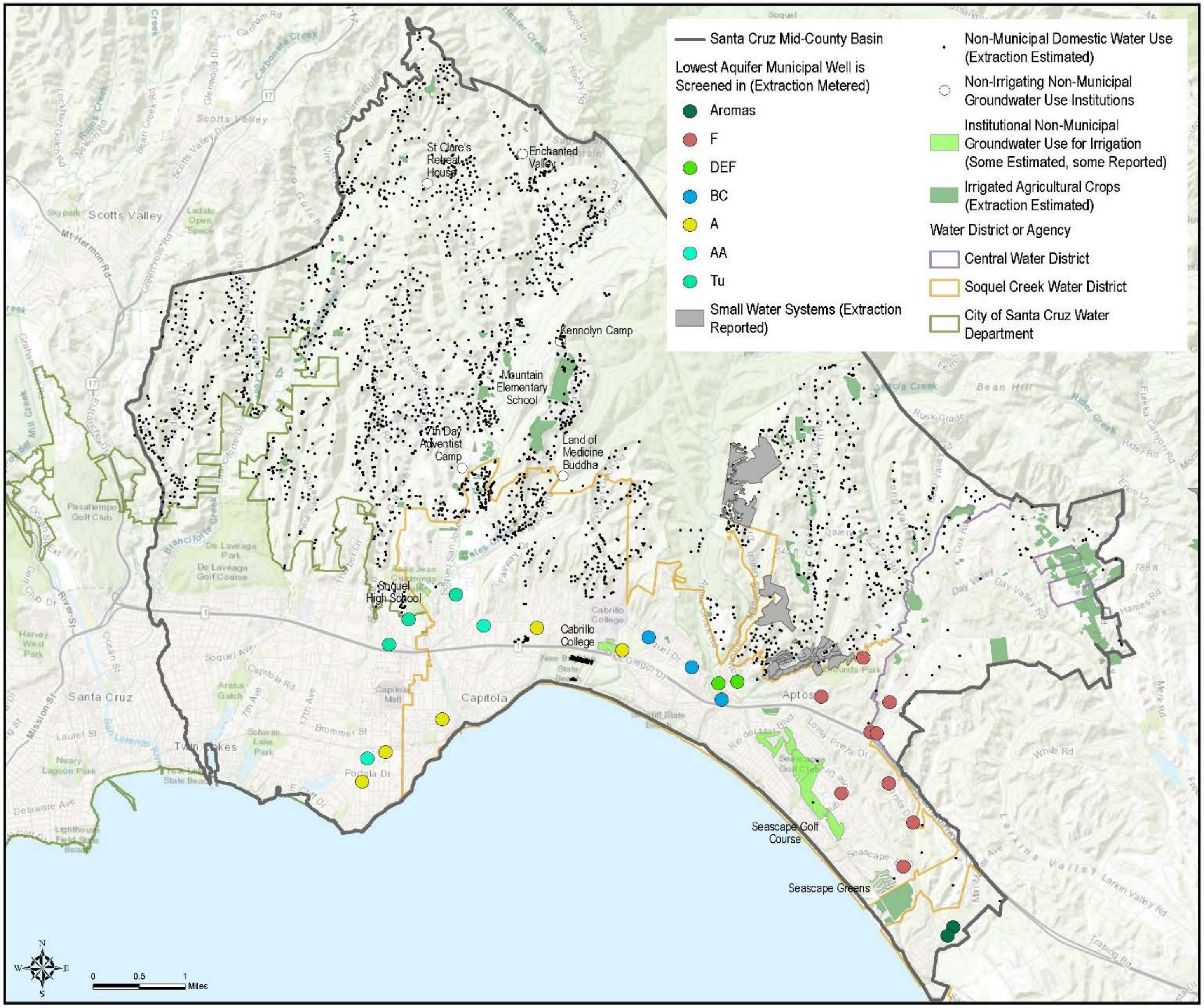


Figure 3-6. Reduction of Groundwater in Storage Representative Monitoring Network

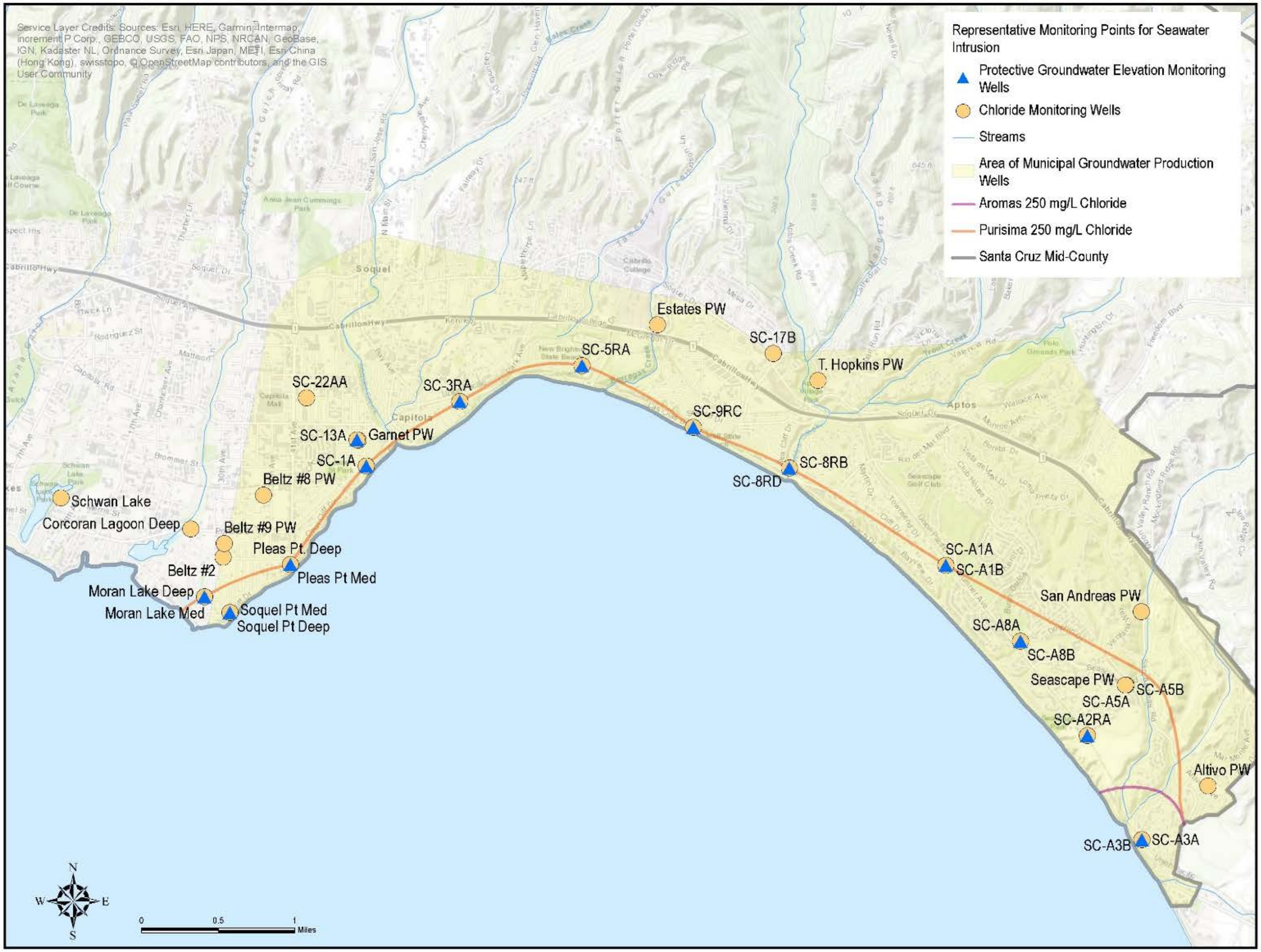


Figure 3-7. Seawater Intrusion Representative Monitoring Network

Table 3-8. Representative Monitoring Points for Seawater Intrusion

Aquifer Unit	Well Name	Rationale	Metric
Aromas	SC-A3B	Coastal monitoring well within the area intruded by seawater	Chloride
	SC-A3A	Coastal monitoring well within the area intruded by seawater	Chloride and GWL
	SC-A8B	Coastal monitoring well within the area intruded by seawater but at a depth above saltwater interface	Chloride
Aromas / Purisima F	Seascape PW	Municipal production well within the area intruded by seawater but at a depth above saltwater interface	Chloride
	San Andreas PW	Municipal production well closest inland of the chloride isocontour	Chloride
Purisima F	SC-A1B	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	SC-A2RA	Coastal monitoring well within the area intruded by seawater	Chloride and GWL
	SC-A2RB	Coastal monitoring well within the area intruded by seawater	Chloride and GWL
	SC-A8A	Coastal monitoring well within the area intruded by seawater	Chloride and GWL
	SC-A5A	Inland monitoring well with seawater intrusion; screened ~100 ft below Seascape PW	Chloride
	SC-A5B	Inland monitoring well at a depth above saltwater interface; screened ~20 ft below Seascape PW	Chloride
Purisima DEF	SC-8RD	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	SC-A1A	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride
	T. Hopkins PW	Municipal production well closest inland of the chloride isocontour	Chloride
Purisima BC	SC-9RC	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	SC-8RB	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL

Aquifer Unit	Well Name	Rationale	Metric
	Ledyard PW	Municipal production well between the Estates and T-Hopkins production wells	Chloride
Purisima A/BC	Estates PW	Municipal production well closest inland of the chloride isocontour	Chloride
Purisima A	Moran Lake Medium	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	Soquel Point Medium	Coastal monitoring well within the area intruded by seawater	Chloride and GWL
	Pleasure Point Medium	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	SC-1A	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	SC-3RA	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	SC-5RA	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	Beltz #2	Inland monitoring well that monitors inland of the chloride isocontour	Chloride
	Beltz #8 PW	Municipal production well closest inland of the chloride isocontour	Chloride
	Garnet PW	Municipal production well closest inland of the chloride isocontour	Chloride
Purisima AA	Moran Lake Deep	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	Pleasure Point Deep	Coastal monitoring well through which the 250 mg/L chloride isocontour runs through	Chloride and GWL
	Soquel Point Deep	Coastal monitoring well within the area intruded by seawater but at a depth below intrusion	Chloride and GWL
	SC-22AA	Inland monitoring well that monitors inland of the chloride isocontour	Chloride
	Corcoran Lagoon Deep	Inland monitoring well that monitors inland of the chloride isocontour	Chloride

Aquifer Unit	Well Name	Rationale	Metric
	Schwan Lake	Westernmost monitoring well	Chloride
Tu	SC-13A	Coastal monitoring well	Chloride and GWL

PW = production well; GWL = groundwater level

3.3.3.4 Degraded Groundwater Quality Representative Monitoring Points

Figure 3-8 shows the distribution of wells selected as RMPs for the degraded groundwater quality monitoring network. Since the sustainability of the degraded groundwater quality indicator is related to quality impacts caused by projects and management actions implemented as part of the GSP, its RMPs are located in areas where projects and management actions are most likely to be located in the future, i.e., within the water districts' and City service areas.

The majority of municipal production wells in the Basin are included as RMPs for degraded groundwater quality since they are the wells that provide groundwater to the largest beneficial user group. Municipal production wells are only excluded as RMPs if there is another nearby municipal production well screened in the same aquifer that is an RMP. In the area of municipal production (yellow shaded area on Figure 3-8), monitoring wells are added as RMPs in areas where there are no municipal production wells.

Future projects implemented as part of the GSP to achieve sustainability will have designated monitoring wells, some existing and some new, as part of their permit conditions. Additional monitoring wells not currently identified as RMPs for degraded groundwater quality will be included as needed to monitor future projects under the GSP. The constituents monitored for each new RMP will comply with permit conditions for these future projects, will become constituents of concern for these new RMPs, and will be incorporated into monitoring and reporting requirements under this GSP.

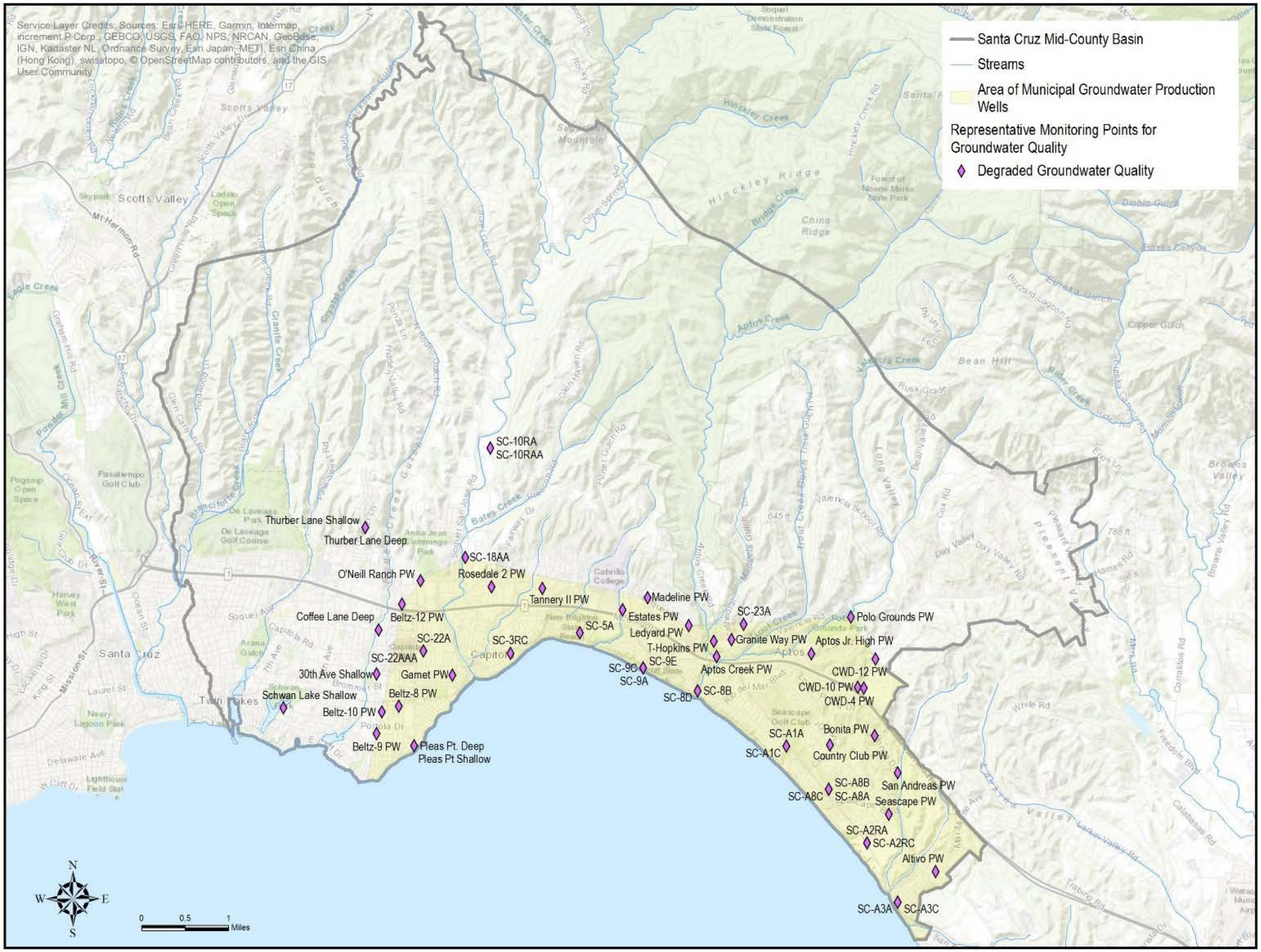


Figure 3-8. Degraded Groundwater Quality Representative Monitoring Network

Table 3-9. Representative Monitoring Points for Degraded Groundwater Quality

Aquifer Unit	Well Name	General Water Quality Sampling Frequency	Rationale
Aromas	Altivo PW*	Semi-Annual	Production well and area impacted by nitrate
	CWD-10 PW	Triennial, nitrate as (N) annual	Production well
	SC-A1C	Annual	Coastal monitoring well in area with spare monitoring wells
	SC-A2RC	Semi-Annual	Coastal monitoring well, and located between an area of private well domestic and agricultural users
	SC-A3A	Annual	Southernmost coastal monitoring well
	SC-A3C	Semi-Annual	Southernmost coastal monitoring well
	SC-A8B	Semi-Annual	Coastal monitoring well
	SC-A8C	Annual	Coastal monitoring well
Aromas/ Purisima F	Polo Grounds PW	Semi-Annual, nitrate (as N) annual	Production well
	Country Club PW*	Semi-Annual, nitrate (as N) annual	Production well
	Bonita PW	Semi-Annual, nitrate (as N) annual	Production well
	San Andreas PW	Semi-Annual, nitrate (as N) annual	Production well
	Seascape PW	Semi-Annual, nitrate (as N) annual	Production well
Purisima F	CWD-4 PW	Triennial, nitrate as (N) annual	Production well
	CWD-12 PW	Triennial, nitrate as (N) annual	Production well, inland
	Aptos Jr. High 2 PW	Semi-Annual, nitrate (as N) annual	Production well
	SC-A2RA	Annual	Coastal monitoring well, and located between an area of private well domestic and agricultural users
	SC-A8A	Annual	Coastal monitoring well
Purisima DEF	SC-8RD	Annual	Coastal monitoring well
	SC-9RE	Annual	Coastal monitoring well
	SC-A1A	Semi-Annual	Coastal monitoring well in area with few monitoring wells
	Granite Way PW	Annual	Production well
	T-Hopkins PW	Annual	Production well
Purisima BC	Ledyard PW	Annual	Production well
	Madeline 2 PW	Annual	Production well

Aquifer Unit	Well Name	General Water Quality Sampling Frequency	Rationale
	Aptos Creek PW	Annual	Production well
	SC-23A	Annual	Inland of a production wellfield
	SC-3RC	Annual	Coastal monitoring well
	SC-8RB	Annual	Coastal monitoring well
	SC-9RC	Annual	Coastal monitoring well
Purisima A	30th Ave Shallow (3)	Semi-Annual	Just outside of area of municipal production
	Pleasure Point Shallow	Quarterly	Coastal monitoring well
	Estates PW	Annual	Production well
	Garnet PW	Annual	Production well
	Tannery II PW	Annual	Production well
	Rosedale 2 PW	Annual	Production well
	Beltz #8 PW	Triennial, iron & manganese quarterly, nitrate (as N) annual	Production well
	Beltz #9 PW	Triennial, iron & manganese quarterly, nitrate (as N) annual	Production well
	SC-5RA	Annual	Coastal monitoring well
	SC-9RA	Annual	Coastal monitoring well
	SC-10RA	Annual	Inland monitoring well
	SC-22A	Quarterly	Between several municipal production wells
Purisima A/AA	Beltz #10 PW	Triennial, iron & manganese quarterly, nitrate (as N) annual	Production well
Purisima AA	SC-10RAA	Annual	Inland monitoring well
	SC-22AAA	Semi-Annual	Between several municipal production wells
	Coffee Lane Deep	Semi-Annual	Just outside of area of municipal production
	Pleasure Point Deep	Quarterly	Coastal monitoring well
	Thurber Lane Shallow	Semi-Annual	Inland monitoring well
	Schwan Lake	Semi-Annual	Westernmost monitoring well
Purisima AA/Tu	O'Neill Ranch PW	Annual	Production well
	Beltz #12 PW	Triennial, iron & manganese quarterly, nitrate (as N) annual	Production well
Tu	SC-18RAA	Semi-Annual	Next to production well
	Thurber Lane Deep	Semi-Annual	Inland monitoring well and one of the few Tu unit wells

3.3.3.5 Depletion of Interconnected Surface Water Monitoring Representative Monitoring Points

The depletion of interconnected surface water representative monitoring network monitors shallow groundwater elevations adjacent to creeks that both support priority species and are interconnected with groundwater. Groundwater elevations as a proxy for surface water depletion are needed as a measure of sustainability because no direct measurable change in streamflow from deep groundwater extraction has been detected in over 18 years of monitoring shallow groundwater levels adjacent to lower Soquel Creek. Even though there is no measurable direct change in streamflow from groundwater extraction, there is a demonstrable indirect influence on shallow groundwater connected to the creek from deeper aquifers pumped by municipal and private wells. This is discussed in Section 2.2.4.6: Identification of Interconnected Surface Water Systems.

Figure 3-9 shows the location of four shallow monitoring wells currently used to monitor depletion of interconnected surface water. These four wells are designated as RMPs for groundwater level proxy measurements. One other monitoring well, SC-10RA, is also included as an RMP because it is located within 730 feet of Soquel Creek, is screened from 110-170 feet below ground in the Purisima A-unit aquifer underlying alluvium, and has groundwater levels that correspond to changes in creek flows. Table 3-10 lists the RMPs and summarizes rationale for selection.

Since these wells only monitor the lower reach of Soquel Creek, the MGA recognizes that other shallow wells are needed to better characterize the surface water / groundwater interaction for other reaches of Soquel Creek and for other creeks that are connected to groundwater. Section 3.3.4 discusses the monitoring data gaps for this sustainability indicator.

Table 3-10. Representative Monitoring Points for Depletion of Interconnected Surface Water

Monitoring Type	Well Name	Rationale
Shallow Groundwater Levels	Balogh	Dedicated shallow groundwater / surface water monitoring well
	Main St. SW 1	Dedicated shallow groundwater / surface water monitoring well
	Wharf Road SW	Dedicated shallow groundwater / surface water monitoring well
	Nob Hill SW 2	Dedicated shallow groundwater / surface water monitoring well
Purisima A	SC-10RA	Shallow monitoring well 730 feet from Soquel Creek, screened in Purisima A-unit below alluvium. Groundwater levels show response to creek flows and rainfall

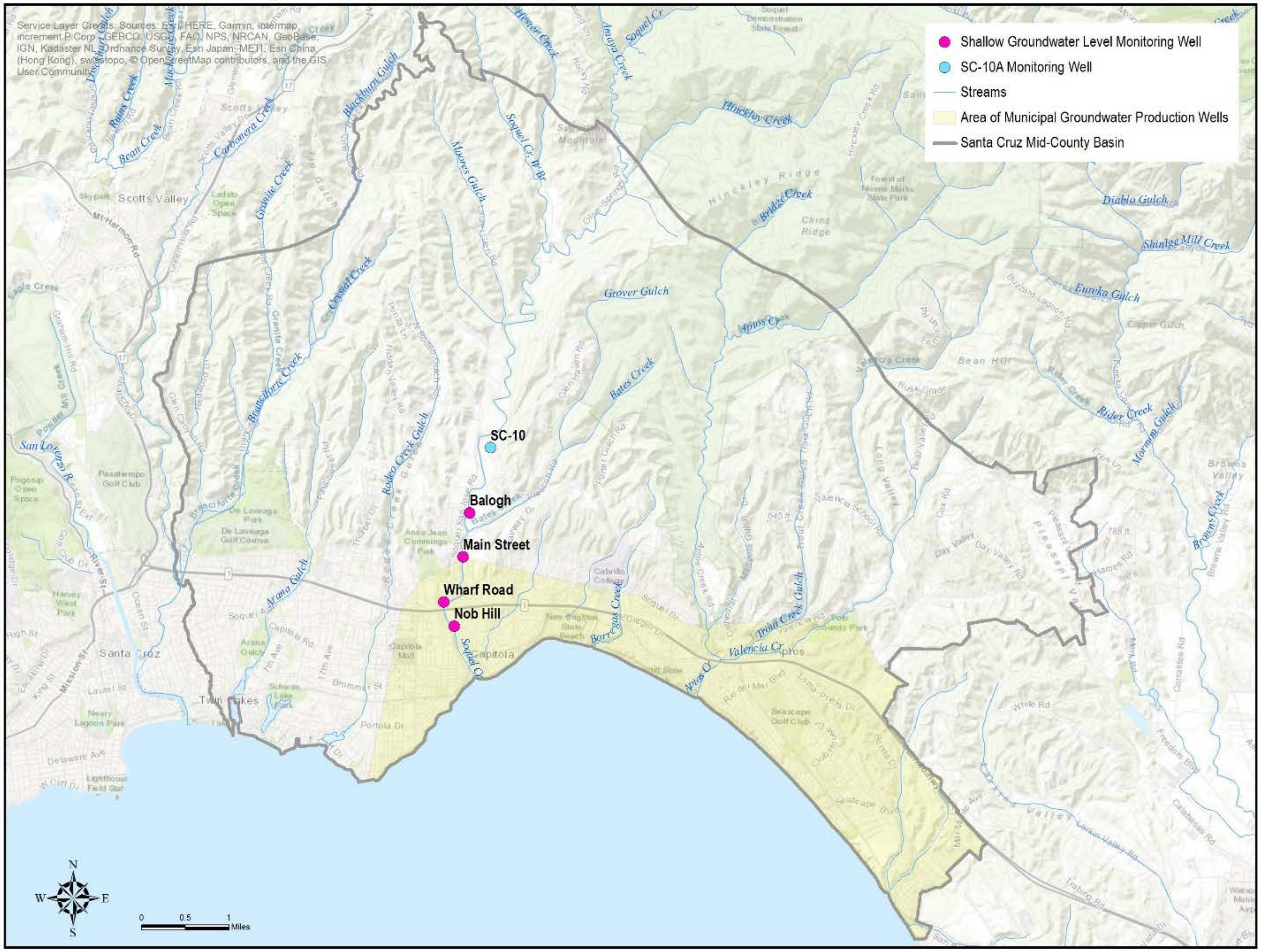


Figure 3-9. Depletion of Interconnected Surface Water Existing Representative Monitoring Network

3.3.4 Assessment and Improvement of Monitoring Network

3.3.4.1 Groundwater Level Monitoring Data Gaps

The existing groundwater level monitoring network described in Section 3.3.1.1 is extensive laterally both across the Basin and vertically through all of the Basin's aquifers. There are however some locations where new monitoring wells are required to evaluate groundwater levels for improved Basin characterization and to potentially include as RMPs once they have been constructed.

Seawater Intrusion monitoring: Additional deeper wells are needed in two locations along the coast. Existing monitoring wells at these locations do not extend down far enough to establish protective groundwater elevations for the deepest producing aquifers that are being used for production and in the near future potentially used for storage. Figure 3-10 shows the locations of the two proposed deep monitoring wells. One of the locations, SC-3 (AA), will involve adding a deeper monitoring well adjacent to an existing SqCWD monitoring well screened in the Purisima A-unit. The second location, will be a deep Tu monitoring well located between the City of Santa Cruz's Soquel Point and Pleasure Point monitoring cluster. The exact location is still to be determined.

Depletion of interconnected surface water monitoring: To more fully characterize interconnections between surface water and groundwater, additional monitoring of shallow groundwater levels is needed in the upper reaches of Soquel Creek and on other creeks that both support priority species and have a connection to groundwater. The locations for additional shallow wells are selected based on whether groundwater is connected to surface water, it is in an area of concentrated groundwater extraction, has a suitable nearby location for a streamflow gauge, and has potential site access. There is a fair degree of uncertainty regarding access at some of the proposed locations. The actual locations of future shallow wells will be determined based on a site suitability study that will include the ability to obtain easements or an access agreement. Figure 3-10 shows the locations of eight proposed shallow monitoring wells that fill monitoring gaps in the Basin. To indicate areas of concentrated groundwater extraction, Figure 3-10 shows the area of municipal pumping and the small dots are approximate locations of private domestic wells. The proposed shallow well on Lower Aptos is an example of a well site that may be moved, based on findings from the site suitability study, to a better location that may be on Valencia Creek above Aptos Creek. The shallow well on Rodeo Gulch is a lower priority site which may require synoptic measurements to establish where it is gaining and losing before finalizing a new shallow monitoring well site. Section 5 on Plan Implementation outlines how the MGA plans to finance and construct the eight shallow monitoring wells.

Table 3-11. Summary of Additional Monitoring Wells to Fill Groundwater Level Data Gaps

Sustainability Indicator being Monitored	General Location	Rationale
Seawater Intrusion	Deep well near Soquel Point	No existing coastal monitoring in the Tu unit in the SCWD area
	Deep well at the SC-3 well site	No existing coastal monitoring exclusively in the AA unit in the SqCWD area
Depletion of interconnected surface water	Shallow well on lower Aptos Creek	The majority of Aptos Creek flows through The Forest of Nisene Marks State Park and has no groundwater extractions. The lower reach of Aptos Creek is where private domestic and municipal extraction occurs
	Shallow well on Aptos Creel above Valencia Creek	
	Shallow well on the East Branch of Soquel Creek	In areas of concentrated private domestic pumping
	Shallow well on Soquel Creek below Moores Gulch	
	Shallow well near the existing SC-10 well cluster	Add a shallow well to the cluster of monitoring wells at SC-10 which already monitor the Purisima A and AA-units, and Tu Unit
	Shallow well near the Balogh stream gauge	Add two wells to supplement the existing shallow well. If feasible, wells are to be completed perpendicular to the creek to determine groundwater gradient
	Shallow well near the Balogh stream gauge	
	Shallow well on Rodeo Gulch	Near concentrated private domestic pumping

The locations of additional monitoring wells, and additional streamflow gauges discussed below in Section 3.3.4.2, have been selected to identify the location, quantity, and timing of surface water depletion caused specifically by groundwater use in areas where no monitoring features currently exist. Section 5.2 describes the timeline for completing installation of these new monitoring features.

Data obtained from these monitoring features will inform the validity of groundwater levels as a proxy for depletion of interconnected surface water, and better inform if changes are needed to minimum thresholds to avoid undesirable results. Groundwater level data collected will be evaluated annually with respect to streamflow, climate, groundwater usage, and noted biological responses. Biological responses will include information obtained from The Nature Conservancy's GDE Pulse application that monitors the health of vegetation and available fish count data from the Santa Cruz County Juvenile Steelhead and Stream Habitat Monitoring Program described in Section 2.1.2.1.

It is expected that based on all the different types of data collected over the first five years of GSP implementation, wherein some of the projects described in Section 4 will be operational, groundwater level proxies for depletion of interconnected surface water will be re-evaluated to determine if they are still needed as the sustainability metric in place of direct measurements of streamflow. At the first five-year review, data collected will also be evaluated to determine whether adjustments to minimum thresholds and measurable objectives are needed, or whether additional monitoring features are needed. It is expected that the participants of the Surface Water Working Group (see Section 2.2.4.7) established as part of GSP development will be involved in this re-evaluation process.

3.3.4.2 Streamflow Monitoring Data Gaps

Associated with the shallow groundwater level monitoring wells identified above, streamflow gauges to monitor changes in streamflow are needed to correlate changes in streamflow from groundwater extraction. The shallow monitoring wells and streamflow gauges need to be located adjacent to each other for the data to be meaningful. Figure 3-10 shows the locations of five proposed streamflow gauges that would be associated with shallow monitoring wells.

Section 5 on Plan Implementation outlines how the MGA plans to finance and construct the streamflow gauges.

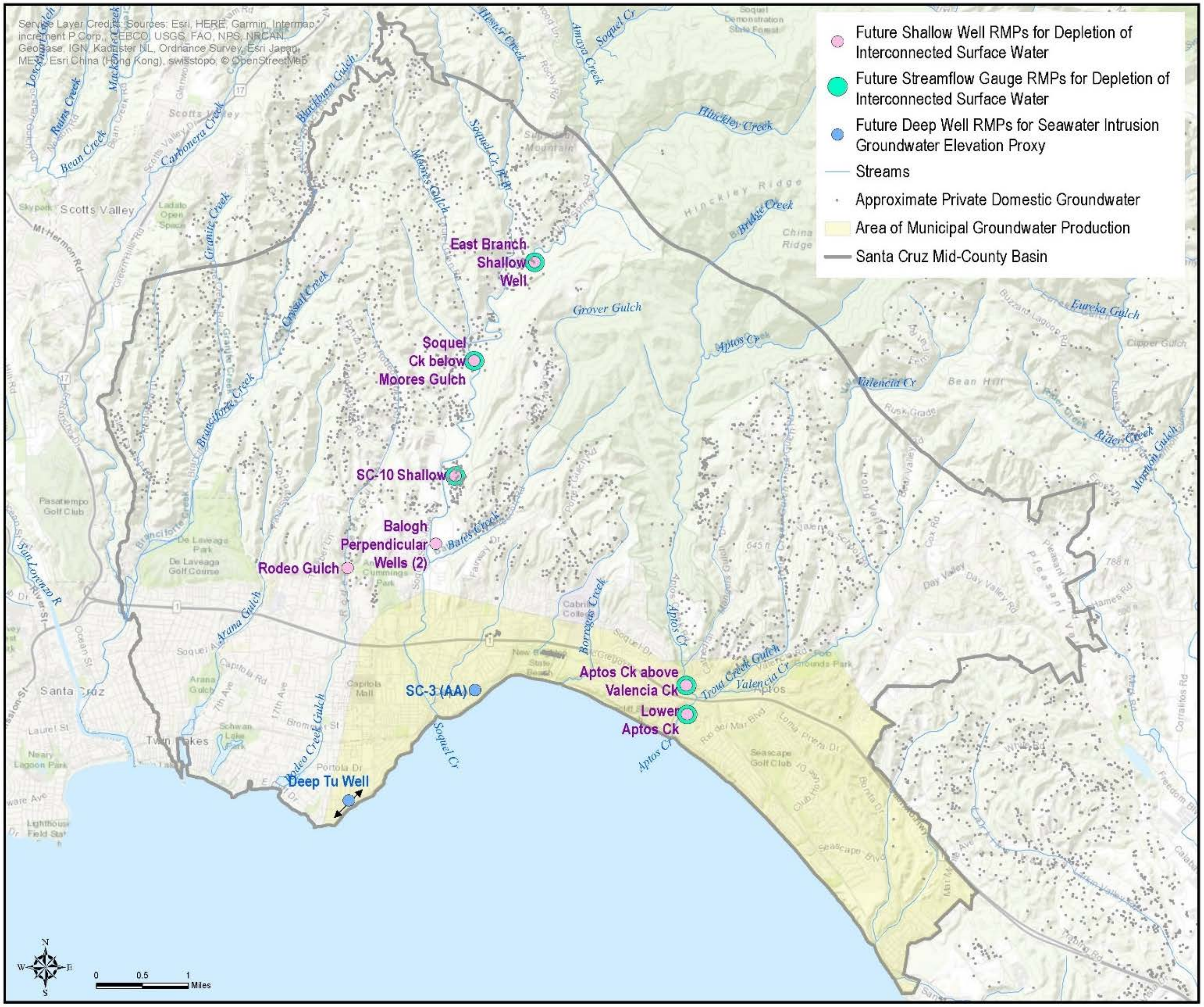


Figure 3-10. Groundwater Level and Streamflow Monitoring Data Gaps

3.3.4.3 Groundwater Extraction Monitoring Data Gaps

As part of GSP implementation, the MGA will initiate a new well metering program on all private non-de minimis wells that meet the following criteria:

- Pump more than two (2) acre-feet per year within priority management zones to be defined by the County of Santa Cruz. These will be related to seawater intrusion and depletion of interconnected surface water.
- Wells outside of priority management zones that pump more than 5 acre-feet per year.

Implementation of a planned metering program is described in more detail in Section 5 on Plan Implementation.

3.4 Chronic Lowering of Groundwater Levels Sustainable Management Criteria

3.4.1 Undesirable Results - Chronic Lowering of Groundwater Levels

Chronic lowering of groundwater levels is considered significant and unreasonable when:

> *A significant number of private, agricultural, industrial, and municipal production wells can no longer provide enough groundwater to supply beneficial uses.*

In the late 1980's, groundwater levels in parts of the Basin were between 35 and 140 feet lower than they are currently. Even at these lower levels, production wells were still able to extract groundwater to supply beneficial uses. Based on what is considered significant and unreasonable described above, chronic lowering of groundwater levels has not historically occurred and is not currently occurring in the Basin. Although groundwater users did not lose significant capacity historically during periods of lowered groundwater levels, those lower groundwater levels caused seawater intrusion which is the reason why the Basin is classified as critically overdrafted by DWR.

3.4.1.1 Criteria for Defining Chronic Lowering of Groundwater Levels Undesirable Results

Specific groundwater level conditions that constitute undesirable results for chronic lowering of groundwater levels are:

> *Any average monthly representative monitoring point's groundwater elevation falls below its minimum threshold.*

The definition of undesirable results is based on MGA sentiment that groundwater levels in the Basin should be managed to support all existing and/or proposed overlying land uses and environmental water user's beneficial needs. Using the criteria of monthly average groundwater levels adequately monitors and identifies seasonal low groundwater elevations that could be much lower than average annual groundwater levels

3.4.1.2 Potential Causes of Undesirable Results

The possible causes of undesirable chronic lowering of groundwater level results are:

- a significant change in Basin pumping distribution and volumes, or
- a significant reduction in natural recharge as a result of climate change.

If the location and volumes of groundwater pumping change as a result of unforeseen rural residential, agricultural, and urban growth that depend on groundwater as a water supply without supplemental supplies, these increased demands might lower groundwater to undesirable levels. Reduction in recharge or changes in rainfall patterns could also lead to more prolonged periods of lowered groundwater levels than have occurred historically.

3.4.1.3 Effects on Beneficial Users and Land Use

Undesirable results will prevent a significant number of private, agricultural, industrial, and municipal production wells from supplying groundwater to meet their water demands. Lowered groundwater levels will reduce the thickness of saturated aquifer from which wells can pump. Some wells may even go dry and new much deeper wells will need to be drilled. This would effectively increase the cost of using groundwater as a water source for all users.

3.4.2 Minimum Thresholds - Chronic Lowering of Groundwater Levels

3.4.2.1 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

Information used for establishing the chronic lowering of groundwater levels minimum thresholds and measurable objectives include:

- Definitions of significant and unreasonable conditions and desired groundwater elevations discussed during GSP Advisory Committee meetings.
- Depths, locations, and logged lithology of existing wells used to monitor groundwater levels.
- Historical groundwater elevation data from wells monitored by the MGA agencies.
- Maps of current and historical groundwater elevation data.
- Department of Water Resources well drillers' logs of domestic and agricultural wells for determining aquifers pumped, well depths and diameters, screened intervals, and estimated yield in the vicinity of RMPs.

Minimum thresholds at RMPs for chronic lowering of groundwater levels are based on the groundwater elevation required to meet the typical overlying water demand in the shallowest well in the vicinity of the RMP. The methodology used to estimate the groundwater elevation is based on water demand for overlying land uses and is documented in Appendix 3-A. If the minimum threshold elevation methodology is greater than 30 feet below historic low groundwater elevations, the minimum threshold elevation is increased, even if overlying water demand can be met at these lower levels. Groundwater levels 30 feet below historic low groundwater elevations may conflict with other sustainability indicator minimum thresholds. The 30-foot limit rationale is explained more fully in Appendix 3-A.

3.4.2.2 Chronic Lowering of Groundwater Level Minimum Thresholds

Figure 3-5 shows the location of RMPs with chronic lowering of groundwater levels minimum thresholds. Table 3-12 lists minimum thresholds for all RMPs. Historical hydrographs for RMPs showing historical groundwater elevations versus minimum thresholds and measurable objectives are provided in Appendix 3-B.

Table 3-12. Minimum Thresholds and Measurable Objectives for Chronic Lowering of Groundwater Level Representative Monitoring Points

Representative Monitoring Point	Well Type	Aquifer	Minimum Threshold	Measurable Objective
			Groundwater Elevation, feet above mean sea level	
SC-A7C	Monitoring	Aromas	0	8
Private Well #2	Production	Purisima F	562	596
Black	Monitoring		10	41
CWD-5	Monitoring		140	194
SC-23C	Monitoring		15	49
SC-11RD	Monitoring	Purisima DEF	295	318
SC-23B	Monitoring		50	85
SC-11RB	Monitoring	Purisima BC	120	157
SC-19	Monitoring		56	95
SC-23A	Monitoring		0	44
Coffee Lane Shallow	Monitoring	Purisima A	27	47
SC-22A	Monitoring		2	44
SC-22AA	Monitoring	Purisima AA	0	22
SC-10RAA	Monitoring		35	76
Private Well #1	Production	Purisima AA/Tu	362	387
30th Ave Deep (1)	Monitoring	Tu	0	30
Thurber Lane Deep	Monitoring		-10	33

3.4.2.3 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Section §354.28 of the SGMA regulations requires that a description of all minimum thresholds include a discussion about the relationship between the minimum thresholds for each sustainability indicator. In the Sustainable Management Criteria Best Management Practice Guide (DWR, 2017), DWR has clarified this requirement:

1. The GSP must describe the relationship between each sustainability indicator's minimum threshold (e.g., describe why or how a water level minimum threshold set at a particular representative monitoring site is similar to or different to groundwater level thresholds in nearby RMP).

2. The GSP must describe the relationship between the selected minimum threshold and minimum thresholds for other sustainability indicators (e.g., describe how a groundwater level minimum threshold would not trigger an undesirable result for seawater intrusion).

Minimum thresholds are selected to avoid undesirable results for other sustainability indicators. If the same RMP was selected for chronic lowering of groundwater levels as another sustainability indicator's RMP that uses groundwater elevation as a metric, the shallowest groundwater elevation minimum threshold of the two sustainability indicators is set at that RMP and assigned to the sustainability indicator that has the shallowest elevation. The relationship between chronic lowering of groundwater level minimum thresholds and minimum thresholds for other sustainability indicators are discussed below.

- **Reduction of groundwater in storage**. The metrics for chronic lowering of groundwater level minimum thresholds (groundwater elevations) and reduction of groundwater in storage (volume of groundwater extracted) are different. However, since the reduction of groundwater in storage minimum thresholds are dependent on avoiding undesirable results for the Basin's other sustainability indicators, maintaining the chronic lowering of groundwater level minimum thresholds does not result in an undesirable reduction of groundwater in storage.
- **Seawater intrusion**. All near-coastal minimum thresholds for chronic lowering of groundwater levels are set at elevations no deeper than sea level so as to not interfere with seawater intrusion minimum thresholds (Figure 3-11). Where groundwater levels close to the coast determined from an estimated minimum saturated thickness are deeper than seawater intrusion's groundwater level proxy minimum thresholds, the chronic lowering of groundwater level minimum threshold is increased to ensure that it does not restrict the ability to meet or exceed protective elevations for seawater intrusion. One of the chronic lowering of groundwater levels RMPs, Thurber Lane Deep, is inland and far enough away from RMPs for seawater intrusion that groundwater levels in the Tu unit are allowed to fall below sea level without causing undesirable seawater intrusion.
- **Degraded groundwater quality**. Protecting groundwater quality is critically important to all who depend upon the groundwater resource. A significant and unreasonable condition for

degraded water quality is exceeding drinking water standards for constituents of concern in supply wells due to projects and management actions proposed in the GSP. Although chronic lowering of groundwater level minimum thresholds does not directly affect degraded quality, groundwater quality could potentially be affected by projects and management action induced changes in groundwater elevations and gradients. These changes could potentially cause poor quality groundwater to flow towards supply wells that would not have otherwise been impacted. Currently, apart from one location with 1,2,3-TCP and more widespread nitrate in parts of the Aromas Red Sands aquifers, and saline water associated with seawater intrusion in two areas along the coast, the Basin's groundwater quality is good with no non-native poor groundwater quality present within productive aquifers.

- **Subsidence**. This sustainability indicator is not applicable in the Basin.
- **Depletion of interconnected surface water**. Minimum thresholds for depletion of interconnected surface water are mostly set in shallow alluvial sediments and are based on shallow groundwater levels between 2001 and 2015. Chronic lowering of groundwater level minimum thresholds are set in the deeper Purisima aquifers where the majority of production occurs and are set substantially lower than groundwater levels observed between 2001-2015. As described in more detail in Section 2, there is no immediate measurable influence on surface water flow from extraction in the deeper Purisima aquifers, but there is likely some long-term indirect connection between the deeper Purisima aquifers and shallow groundwater. In the unlikely event that groundwater levels drop to minimum thresholds for chronic lowering of groundwater levels, the vertical gradient between shallow and deep aquifers will increase and may cause undesirable results in the shallow aquifers and interconnected surface waters.

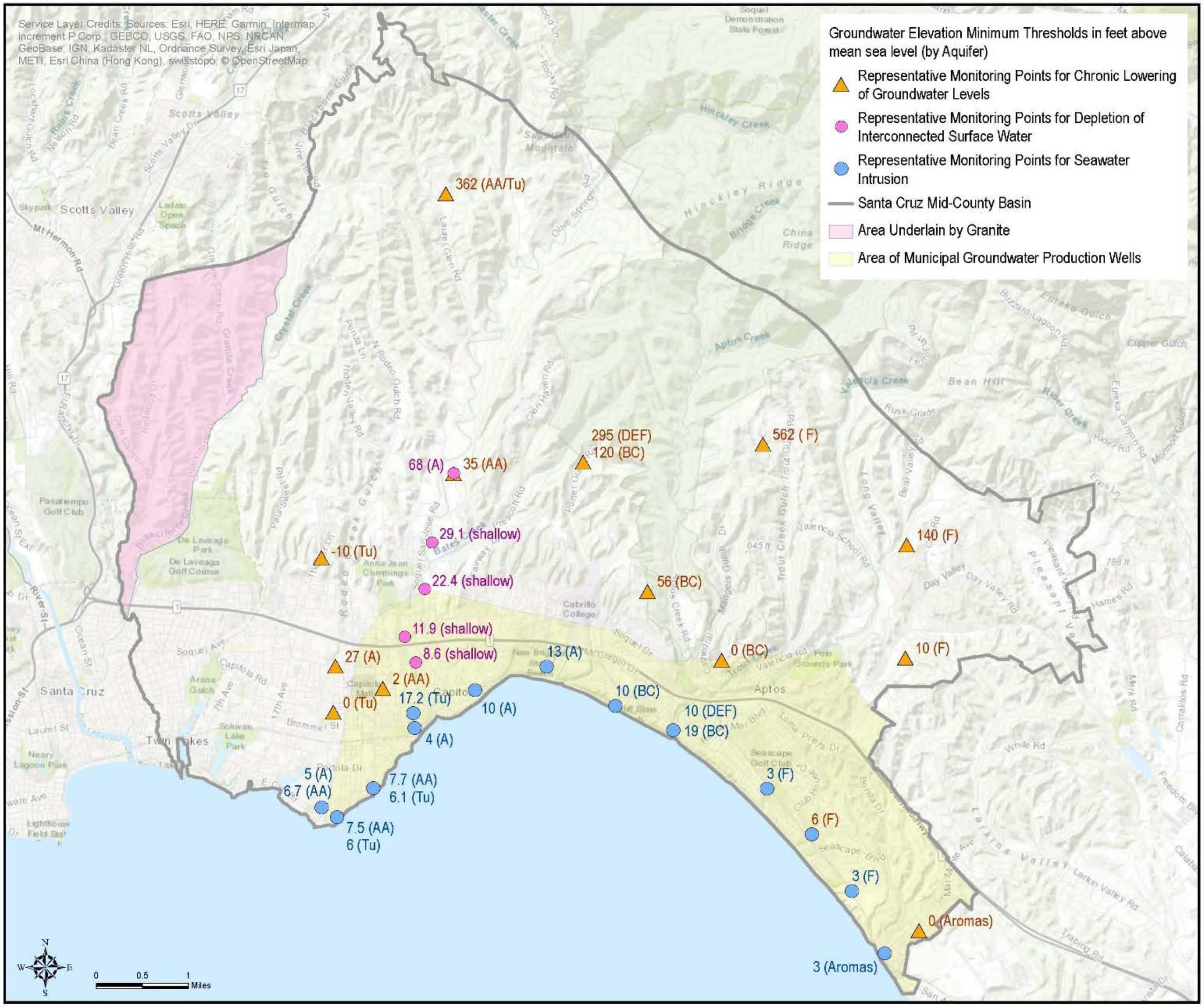


Figure 3-11. Minumum Thresholds for All Sustainability Indicators with Groundwater Elevation Minimum Thresholds

3.4.2.4 Effect of Minimum Thresholds on Neighboring Basins

Two neighboring groundwater basins are required to develop and adopt GSPs or have submitted an alternative: the medium-priority Santa Margarita Basin (to the northwest) and the critically-overdrafted Pajaro Valley Subbasin of the Corralitos Basin (to the east). There are two additional groundwater basins prioritized as very low and do not require GSPs: the Purisima Highlands Subbasin of the Corralitos Basin (to the north) and the West Santa Cruz Terrace Basin (to the west). Since the West Santa Cruz Terrace Basin is not significantly connected to the Santa Cruz Mid-County Basin due to the Purisima aquifers not extending westwards into that basin, effects of minimum thresholds on that basin are not discussed further. Anticipated effects of chronic lowering of groundwater levels minimum thresholds on the other three neighboring basins are addressed below and for subsequent sustainability indicators.

Pajaro Valley Subbasin of the Corralitos Basin (critically-overdrafted). The Pajaro Valley Subbasin is hydrogeological down- to cross-gradient of the Santa Cruz Mid-County Basin. Because of lower groundwater elevations in the Pajaro Valley Subbasin, groundwater along the coastal portion of the boundary generally flows from the Santa Cruz Mid-County Basin into the Pajaro Valley Subbasin. Purisima aquifers are not a major source of groundwater in the Pajaro Valley and are only pumped by a few deeper wells (Carollo Engineers, 2014). The Aromas Red Sands aquifer is the major producing aquifer within the Pajaro Valley Subbasin (Carollo Engineers, 2014). The Aromas Red Sands aquifer RMP (SC-A7A) in the Santa Cruz Mid-County Basin near the boundary with Pajaro Valley Subbasin has a minimum threshold that is a few feet lower than current levels. In the unlikely event that groundwater levels in this area fall to minimum thresholds, it may slightly reduce the amount of subsurface outflow to the Pajaro Valley Subbasin but would not be expected to hinder it from achieving sustainability.

Santa Margarita Basin (medium-priority). The Santa Margarita Basin is required to develop a GSP by 2022. Santa Margarita Basin is hydrogeologically downgradient of the Santa Cruz Mid-County Basin and based on the water budget, less than 400 acre-feet of groundwater flows from the Santa Cruz Mid-County Basin into the Santa Margarita Basin annually. The boundary where subsurface flows occur between the two basins is north of the Aptos Fault and four miles inland of the area where GSP projects and management actions would take place. Current groundwater levels are already well above the minimum thresholds for all RMPs and no GSP induced changes in elevations are expected as GSP activities are some distance away so it is not expected that Santa Margarita Basin will be adversely affected by activities under this GSP. However, if groundwater levels near the Santa Margarita basin drop to the minimum thresholds, flow from the Santa Cruz Mid-County Basin to Santa Margarita Basin could be reduced and could affect Santa Margarita Basin's ability to achieve sustainability.

Purisima Highlands Subbasin of the Corralitos Basin (very low-priority). The Purisima Highlands Subbasin is hydrogeological up-gradient of the Santa Cruz Mid-County Basin. Groundwater flow, historically and projected in the future, will continue to be from the higher elevation Purisima Highlands Subbasin into the Santa Cruz Mid-County Basin. If groundwater levels in the northern portion of the Basin declined to minimum thresholds, the rate of subsurface outflow may increase slightly from the Purisima Highlands Subbasin.

3.4.2.5 Effects of Minimum Thresholds on Beneficial Users and Land Uses

Chronic lowering of groundwater elevation minimum thresholds may have several effects on beneficial users and land uses in the Basin.

Rural residential land uses and users. The chronic lowering of groundwater level minimum thresholds protects most domestic users of groundwater by protecting their ability to pump from domestic wells. However, if groundwater elevations fall to minimum thresholds, there may be limited water in some of the shallowest domestic wells (less than 100 feet deep) that may require well owners to drill deeper wells.

Agricultural land uses and users. Similar to rural residential uses and users, chronic lowering of groundwater level minimum thresholds protects agricultural users of groundwater by protecting their ability to meet their typical demands. Minimum thresholds for chronic lowering of groundwater level will not limit use of land for agricultural purposes.

Urban land uses and users. The chronic lowering of groundwater level minimum thresholds are set so that all users, including municipal groundwater pumpers can still meet their typical water demands. As most of the RMPs for the chronic lowering of groundwater levels are located inland of the area of municipal pumping which covers the majority of the Basin's urban area, it is the groundwater level proxy minimum thresholds for seawater that have a bigger influence on urban/municipal users of groundwater.

Ecological land uses and users. As described in Section 3.2.3.2, chronic lowering of groundwater level minimum thresholds are not set to protect the groundwater resource including those existing ecological habitats that rely upon it. In the unlikely event that groundwater levels drop to minimum thresholds for chronic lowering of groundwater levels, it could lead to a significant and unreasonable reduction of flow of groundwater toward streams, which could adversely affect ecological habitats.

3.4.2.6 Relevant Federal, State, or Local Standards

No federal, state, or local standards exist for chronic lowering of groundwater elevations.

3.4.2.7 Method for Quantitative Measurement of Minimum Thresholds

Groundwater elevations in RMPs will be directly measured to determine where groundwater levels are in relation to minimum thresholds. Groundwater level monitoring will be conducted in accordance with the monitoring plan outlined in Section 3.3. All RMPs will be equipped with continuous data loggers.

There are two privately-owned wells that do not currently have data loggers. Section 5 on Plan Implementation includes planned implementation budget to purchase, install and monitor those additional RMPs. All other agency monitoring wells assigned as RMPs already have data loggers installed.

3.4.3 Measurable Objectives - Chronic Lowering of Groundwater Levels

3.4.3.1 Measurable Objectives

Measurable objectives for RMPs are the 75th percentile of historical groundwater elevations for the period of record of each monitoring point. The 75th percentile is higher than median or average groundwater elevations and reflects where the MGA would like groundwater elevations to be in the future whilst allowing for operational flexibility.

Representative monitoring point hydrographs in Appendix 3-B include measurable objectives for chronic lowering of groundwater levels compared to minimum thresholds.

3.4.3.2 Interim Milestones

Groundwater levels in the Basin are currently above minimum thresholds for all RMPs with no significant changes in levels expected from projects and management actions implemented to achieve sustainability. Since the measurable objectives effectively represent current conditions, interim milestones are set at the same elevations as measurable objectives shown in Table 3-12.

3.5 Reduction of Groundwater in Storage Sustainable Management Criteria

3.5.1 Undesirable Results - Reduction of Groundwater in Storage

The reduction in storage sustainability indicator is not measured by a change in groundwater in storage. Rather, the reduction in groundwater in storage sustainability indicator is measured by “a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results.” (§354.28 (c)(2)).

Locally defined significant and unreasonable conditions for a reduction of groundwater in storage in the Basin are defined as:

> *A net volume of groundwater extracted (pumping minus annual volume of managed aquifer recharge) that will likely cause other sustainability indicators to have undesirable results.*

3.5.1.1 Criteria for Defining Reduction of Groundwater in Storage Undesirable Results

The net volume of groundwater extracted that constitutes undesirable results for reduction of groundwater storage is:

> *Five-year average net extraction exceeding the sustainable yield (minimum threshold) for any one of the groups of aquifers:*
>
> - *Aromas Red Sands aquifer and Purisima F aquifer units,*
> - *Purisima DEF, BC, A, and AA aquifer units, and*
> - *Tu aquifer.*

Although only a total volume for the whole basin is required as a metric for the reduction of groundwater in storage sustainability indicator per the SGMA regulations, this GSP has separate SMC for three aquifer groups in the Basin: (1) Aromas Red Sands and Purisima F, (2) Purisima DEF, BC, A, and AA aquifers, and (3) the Tu aquifer. The SMC metrics for this indicator are based on the sustainable yields for each of the three aquifer groups estimated in Section 2.2.3.7: Projected Sustainable Yield.

Developing reduction of groundwater storage SMC for separate aquifer units reflects the stacked aquifer units of the Basin where groundwater supply in different areas of the Basin are provided by different aquifer units. To maximize capacity, municipal wells are often screened across multiple aquifers: The aquifer groupings are based on how municipal wells are typically screened. Most municipal wells screened in the Aromas Red Sands aquifer are also screened in the deeper Purisima F-unit aquifer. Other typical multiple aquifer screened wells include: the Purisima DEF and BC-units; the Purisima BC and A-units; and the Purisima A and AA-units. Although municipal wells screened in the Tu unit are also screened in the Purisima AA-unit, a high percentage of the flow in these wells is observed to be from the Tu unit. Additionally, the vertical separation of flow between the Purisima AA and Tu units is observed to be greater than the vertical separation between the Purisima A and AA-units, which further supports the Tu unit being in a group on its own.

Although sustainable yield can be estimated for individual aquifers, monitoring how much is pumped from each aquifer is not possible because of production wells being screened through multiple aquifers. Therefore, the aquifer groupings account for the extraction from the aquifers production wells are typically screened in.

The purpose of this sustainability indicator is to prevent undesirable results for other sustainability indicators. Each of these sustainability indicators are monitored by individual aquifer units. If undesirable results are observed in any aquifer unit or related to pumping from a specific aquifer unit, the most likely management action to eliminate the undesirable result is to change net pumping from the aquifer unit. The change in net pumping will be determined by what is necessary to eliminate the undesirable result, not based on the reduction of groundwater in storage criteria. Recognizing this, developing reduction of storage SMC for each aquifer unit is not necessary for planning groundwater management and may restrict operational flexibility.

3.5.1.2 Potential Causes of Undesirable Results

Future increased well density and pumping amounts can contribute to reduction of groundwater in storage undesirable results. Since the locations of groundwater extraction and MAR are not static, new private or municipal wells, or changed operations could cause localized undesirable results. To optimize operations or locations of new high-capacity wells and MAR, groundwater modeling can be used to predict if undesirable results may occur.

3.5.1.3 Effects on Beneficial Users and Land Use

Undesirable reduced groundwater in storage caused by over-pumping may cause undesirable results in any of the other four applicable sustainability indicators that potentially impact beneficial users and land uses. Groundwater levels that are too low as a result of implementing the GSP may:

1. Prevent a significant number of private, agricultural, industrial, and municipal production wells from supplying groundwater to meet their water demands.

2. Induce seawater intrusion that will render impacted portions of the Basin’s aquifers unusable to its beneficial users. Land uses completely overlying seawater intrusion, such as agriculture, will need alternative sources of water if their wells are located in the affected areas.

3. Cause more surface water depletion in interconnected streams that support priority species than has occurred over the past 18 years.

4. Degrade groundwater quality if by implementation of the GSP there are changes in groundwater elevations and gradients that cause non-native poor-quality groundwater to flow towards extraction wells that were previously not impacted. Groundwater quality that does not meet state drinking water standards will need to be treated, which is a significant cost to users. For municipal pumpers, impacted wells can be taken offline until a solution is found. This will add stress on their water system by having to make up pumping in other unimpacted wells and increase the potential for further declines in groundwater levels.

3.5.2 Minimum Thresholds - Reduction of Groundwater in Storage

3.5.2.1 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

Information used for establishing the reduction of groundwater in storage minimum thresholds and measurable objectives include:

- Definitions of significant and unreasonable conditions discussed during GSP Advisory Committee meetings.
- Projected municipal agency, private domestic, institutional, and agricultural pumping at specific well locations.
- Projected injection for Pure Water Soquel and City of Santa Cruz ASR at assumed locations.
- Projected hydrographs comparing simulated groundwater levels compared to minimum thresholds for seawater intrusion and depletion of interconnected surface water.
- Sustainable yield estimates from Section 2.2.3.7.

The Basin's sustainable yields for three aquifer groups used as minimum thresholds for the reduction of groundwater in storage sustainability indicator rely on projected net pumping with GSP implementation, as described in Section 2.2.3.7: Projected Sustainable Yield. Net projected pumping for Water Years 2016 – 2069 is pumping that has been adjusted to avoid undesirable results. Adjustments to achieve minimum thresholds include redistributing pumping and the operation of City of Santa Cruz ASR and SqCWD's Pure Water Soquel.

3.5.2.2 Reduction of Groundwater in Storage Minimum Thresholds

Minimum thresholds for reduction of groundwater storage are the sustainable yields representing net annual volume of groundwater extracted (pumping minus volume of managed aquifer recharge) for each of the three groups of aquifers, as summarized in Table 3-13.

Table 3-13. Minimum Thresholds and Measurable Objectives for Reduction of Groundwater of Storage

Aquifer Unit Group	Minimum Threshold	Measurable Objective
	Groundwater Extracted, acre-feet per year	
Aromas Red Sands and Purisima F	1,740	1,680
Purisima DEF, BC, A and AA	2,280	960
Tu	930	620

3.5.2.3 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

As the sustainable yields for the three aquifer groups are based on avoiding undesirable results for all the other applicable sustainability indicators, net pumping at or below the sustainable yield should not conflict with minimum thresholds for the other sustainability indicators.

However, there could be discrepancies observed between the sustainable yields used as minimum thresholds and undesirable results observed for other sustainability indicators. Undesirable results in the other applicable sustainability indicators could still occur if net pumping is below minimum thresholds and undesirable results in the other applicable sustainability indicators might not occur if net pumping exceeds minimum thresholds. In addition to hydrologic uncertainty of the estimates for sustainable yield used for minimum thresholds, the sustainable yield estimates are highly dependent on the location of groundwater extraction and managed aquifer recharge (MAR) used to derive the estimates. Depending on the location of these activities, pumping within the sustainable yield may still cause seawater intrusion at the coast, such as if new production wells are located close to existing wells and close to the coastline.

If discrepancies with other sustainability indicators occur, the estimate for sustainable yields and the minimum thresholds should be revised to be consistent with whether or not there are undesirable results for the other sustainability indicators.

3.5.2.4 Effect of Minimum Thresholds on Neighboring Basins

Anticipated effects of the reduction of groundwater in storage minimum thresholds on neighboring basins are addressed below.

Pajaro Valley Subbasin of the Corralitos Basin (critically-overdrafted). To avoid undesirable seawater intrusion results in the Aromas area near the Basin's boundary with the Pajaro Valley, municipal extraction is currently and projected to be in the future very limited, unless a recharge project can provide supplemental water supplies. As a result of almost eliminating municipal extraction, groundwater levels in the Aromas area near the boundary with Pajaro Valley Subbasin are close to seawater intrusion proxy minimum thresholds. With GSP implementation, groundwater levels are expected to increase slightly higher and closer to measurable objectives at the Basin boundary. Decreased pumping in the Aromas, included in the reduction of groundwater in storage minimum threshold for the Aromas and Purisima F-unit aquifer group, is beneficial to both basins for controlling seawater intrusion. Therefore, it is unlikely that the reduction of groundwater storage minimum thresholds established for the Basin will prevent the Pajaro Valley Subbasin from achieving sustainability.

Santa Margarita Basin (medium-priority). The area of the Basin with potential to influence the Santa Margarita Basin is the western area north of the Aptos Fault where unsustainable conditions have not historically nor currently occurred. Groundwater use in this area is all for private use: mostly for *de minimis* private domestic purposes with two retreats that are non-*de minimis* users of groundwater. Groundwater use in this part of the Basin, as part of the sustainable yield, is projected to remain similar to historic use and therefore minimum thresholds for reduction of groundwater in storage will not negatively impact groundwater conditions in the Santa Margarita Basin.

Purisima Highlands Subbasin of the Corralitos Basin (very low-priority). Similar to the Basin's relationship with the Santa Margarita Basin, the area of the Basin that is closest to the Purisima Highlands Subbasin is mainly pumped by private *de minimis* groundwater users. Pumping in this area is projected to remain similar to historic use and therefore minimum thresholds for reduction of groundwater in storage will not negatively impact groundwater conditions in the Santa Margarita Basin.

3.5.2.5 Effects of Minimum Thresholds on Beneficial Users and Land Uses

The reduction of groundwater in storage (sustainable yield) minimum thresholds may have several effects on beneficial users and land uses in the Basin.

Rural residential land uses and users. Twenty-one percent of the projected sustainable yield comprises estimated pumping from *de-minimis* domestic wells. As changes in pumping in the Basin are focused on municipal wells closer to the coast to avoid undesirable seawater intrusion conditions, rural residential users are not impacted by required reductions in pumping. The model indicated that impacts of inland rural residential pumping on seawater intrusion is minimal and therefore reductions to their pumping would not help achieve protective groundwater elevations. There are therefore no effects on rural residential land uses and users from the reduction of groundwater in storage minimum thresholds.

Agricultural land uses and users. Nine percent of the projected sustainable yield comprises estimated pumping for agricultural purposes. At this time, reductions in agricultural pumping for irrigation purposes are not included in meeting the projected sustainable yield. Therefore, there are no effects on agricultural land uses and users from reduction of groundwater in storage minimum thresholds.

Urban land uses and users. Urban users and land uses are concentrated in a corridor along the coast. Municipal wells that supply water to these users are also located in this area and are therefore also close to the coast. Reductions in municipal pumping needed to increase coastal groundwater levels to control seawater intrusion need to be offset by other water sources. Reducing the amount of municipal groundwater pumping increases the cost of water for municipal users in the Basin because water agencies need to find other, more expensive water sources.

Ecological land uses and users. Groundwater dependent ecosystems would generally benefit from the reduction of groundwater in storage minimum threshold in the area of municipal pumping. Increasing groundwater levels above current levels will generally improve conditions for groundwater dependent ecosystems.

3.5.2.6 Relevant Federal, State, or Local Standards

No federal, state, or local standards exist for reduction of groundwater in storage related groundwater extraction.

3.5.2.7 Method for Quantitative Measurement of Minimum Thresholds

Groundwater extractions in municipal and small water systems RMPs will be directly measured with water meters to determine the volume of groundwater produced in relation to minimum thresholds. Groundwater extraction monitoring will be conducted in accordance with the monitoring plan outlined in Section 3.3.2.4. For *de minimis* domestic and agricultural users that are unmetered, the groundwater extracted by these users will be estimated as described in Section 0.

Annual Basin extractions from each the three aquifer groups will be used in a five-year running average to compare against minimum thresholds to determine if undesirable results have occurred in any of the aquifer groups.

3.5.3 Measurable Objectives - Reduction of Groundwater Storage

3.5.3.1 Measurable Objectives

The reduction of groundwater in storage measurable objectives for each of the three aquifer groups are the maximum net annual amount of groundwater that can be extracted while ensuring that if there were four subsequent years of maximum projected net groundwater extraction, net annual groundwater extractions greater than the minimum threshold will not occur for any one of the three aquifer groups. Table 3-13 lists the measurable objectives for the three aquifer groups.

Annual net extractions for the different aquifer groups will be used to compare against measurable objectives, and not the five-year average of net extractions. This is because the measurable objective is the maximum that can be pumped if the next four years all had maximum projected pumping for undesirable results to be avoided.

It is not expected that the planned projects will achieve the measurable objective for the Purisima DEF, BC, A, and AA aquifer group; i.e., the planned projects will not provide for four consecutive years of maximum net pumping without avoiding undesirable results.

3.5.3.2 Interim Milestones

Interim milestones for this sustainability indicator track implementation of projects planned to meet sustainability described in Section 4. Section 4 describes the expected benefits of Soquel Creek Water District's Pure Water Soquel project and the City of Santa Cruz's Aquifer Storage and Recovery project as preventing undesirable results in the Basin and meeting measurable objectives in much of the Basin. The interim milestones are therefore the projected net pumping for the Basin as the projects get implemented. The interim milestones for 2025, 2030, and 2035 are the five-year averages for net pumping covering Water Years 2021-2025, Water Years 2026-2030, and Water Years 2031-2035, respectively.

Interim milestones for Water Year 2025 do not meet all of the sustainable yields because the operation of Pure Water Soquel with approximately 1,500 acre-feet per year of injection is not scheduled to begin operation until Water Year 2023. The interim milestones for 2030 and 2035 are lower than sustainable yield (minimum threshold) with planned operation of both projects occurring simultaneously by 2026. There will be no undesirable results for reduction of groundwater in storage by 2030.

Although below sustainable yield (minimum threshold), interim milestones are higher in 2035 than 2030 due to projected climate. Evaluations of net pumping versus interim milestones should consider effect of climate on injection and pumping volumes for the previous five years.

Table 3-14. Interim Milestones for Reduction of Groundwater of Storage

Aquifer Unit Group	Interim Milestone 1 2025	Interim Milestone 2 2030	Interim Milestone 3 2035
	Trailing 5 Year Average of Groundwater Extracted, acre-feet per year		
Aromas Red Sands and Purisima F	1,930	1,630	1,670
Purisima DEF, BC, A and AA	2,110	1,970	2,120
Tu	720	710	760

3.6 Seawater Intrusion Sustainable Management Criteria

3.6.1 Undesirable Results - Seawater Intrusion

Locally defined significant and unreasonable seawater intrusion in the Basin is:

> *Seawater moving farther inland than has been observed from 2013 through 2017.*

This statement reflects that the MGA does not want seawater intrusion to advance further into the Basin. The period from 2013 through 2017 is included in the statement because although there has not been much recent change in the distribution of seawater intrusion, there has been one seawater intruded monitoring well (Moran Lake Medium) that has experienced decreased chloride concentrations which are now below 250 mg/L. By specifying the years 2013-2017, we ensure that intrusion is not allowed back into this area, whereas if the historical maximum chloride concentration was used, Moran Lake Medium chloride concentrations could be allowed to increase back to 700 mg/L. Table 3-15 summarizes 2013-2017 average and maximum chloride concentrations for all coastal monitoring wells.

Table 3-15. Summary of Chloride Concentrations in Monitoring and Production Wells at the Coast

Well	Aquifer Unit	Historical Maximum Year	Historical Maximum	2013-2017 Average	2018 / 2017*
			Chloride Concentrations, mg/L		
Coastal Monitoring Wells - Intruded					
SC-A3A	Aromas	2010	22,000	17,955	18,000
SC-A3B	Aromas	2005	4,330	676	1,100
SC-A8A	Purisima F	2015	8,000	7,258	7,500
SC-A2RA	Purisima F	2001	18,480	14,259	15,000
SC-A2RB	Purisima F	2015 & 2018	470	355	470
Moran Lake Medium	Purisima A	2005	700	147	78
Soquel Point Medium	Purisima A	2005	1,300	1,104	1,100
Coastal Monitoring Wells - Unintruded					
SC-A8B	Aromas	2014	38	33	33
SC-A1B	Purisima F	2009	38	26	22
SC-A1A	Purisima DEF	2009	37	28	26
SC-8RD	Purisima DEF	2016	65	28	66
SC-9RC	Purisima BC	1984	63	28	31
SC-8RB	Purisima BC	2003	32	14	13
Pleasure Point Medium	Purisima A	2012	38	34	36
SC-1A	Purisima A	2013	51	41	38
SC-5RA	Purisima A	2001	94	55	58

Well	Aquifer Unit	Historical Maximum Year	Historical Maximum	2013-2017 Average	2018 / 2017*
			Chloride Concentrations, mg/L		
SC-3RA	Purisima A	1984	66	39	38
Moran Lake Deep	Purisima AA	2012	66	64	62*
Pleasure Point Deep	Purisima AA	2006	87	22	21*
Soquel Point Deep	Purisima AA	2016	144	137	140*
SC-13A	Tu	1986	114	NA	NA
Inland Monitoring and Production Wells - Unintruded					
SC-A5A	Purisima F	2015	9,800	8,575	53
SC-A5B	Purisima F	2018	130	95	83
San Andreas PW	Purisima F	2011	79	21	21
Seascape PW	Purisima F	1996	29	20	16
T. Hopkins PW	Purisima DEF	2011	71	46	42
Estates PW	Purisima BC & A	1990	63	45	45
Ledyard PW	Purisima BC	1986	87	35	33
Garnet PW	Purisima A	2009	90	81	84
Beltz #2	Purisima A	2008	97	63	61*
Beltz #8 PW	Purisima A	2012	56	51	52*
SC-22AA	Purisima AA	2018	45	39	36
Corcoran Lagoon Deep	Purisima AA	2011	120	20	21
Schwan Lake	Purisima AA	2008	97	91	94*

PW = production well; NA = not available

3.6.1.1 Criteria for Defining Seawater Intrusion Undesirable Results

Undesirable results for seawater intrusion listed below are related to the inland movement of the chloride isocontour which would be considered significant and unreasonable seawater intrusion. To be able to monitor the location of the isocontour, chloride concentrations in monitoring and production wells either side of the chloride isocontours are used in the definition of undesirable results. In addition to the chloride isocontour minimum threshold, protective groundwater elevations at coastal monitoring wells are used as a proxy for seawater intrusion minimum thresholds. For a decade, seawater intrusion in the Basin has been managed using protective groundwater elevations. Experience has shown that protective groundwater elevations are easier to measure and manage with respect to controlling seawater intrusion, compared to relying purely on chloride concentrations.

The Basin's seawater intrusion undesirable results are split into three categories as defined below.

1. Undesirable results for intruded coastal monitoring wells.

2. Undesirable results for unintruded coastal monitoring wells, and inland monitoring and production wells.
3. Undesirable results for protective groundwater elevations.

If any of these occur, undesirable results from seawater intrusion are occurring.

Undesirable Results for Intruded Coastal Monitoring Wells

Undesirable results for coastal wells hat already have experienced seawater intrusion are:

> *Any coastal monitoring well with current intrusion has a chloride concentration above the 2013–2017 maximum chloride concentration. This concentration must be exceeded in 2 or more of the last 4 consecutive quarterly samples.*

The rationale for this statement is that if seawater intrusion had not been reported in wells inland of the coastal monitoring wells when chloride concentrations in the coastal monitoring wells were at their historic high, the likelihood of seawater intruding them in the future if coastal monitoring well concentrations increased back to that level again is low. Using a five-year (2013 – 2017) historical maximum chloride concentration provides greater flexibility in avoiding undesirable results than using a five-year average concentration and is more protective than using the historical maximum, which is mostly higher than the 2013–2017 maximum concentration.

The number of chloride concentration exceedances should be set at two per year to account for occasional fluctuations not related to seawater intrusion. Two to four samples exceeding the recent historical maximum indicates that seawater intrusion has advanced farther inland, which would be considered significant and unreasonable. Table 3-15 includes a list of historical maximum chloride values versus 2013–2017 average and 2013–2017 maximum chloride concentrations for monitoring and production wells that have had or have seawater intrusion. Note that Moran Lake was previously impacted by seawater (700 mg/L) and its chloride concentration has decreased to below 250 mg/L.

Undesirable Results for Unintruded Coastal Monitoring Wells, and Inland Monitoring and Production Wells

Undesirable results for wells unintruded by seawater are broken down by general proximity to the coast:

A. Unintruded coastal monitoring wells

B. Unintruded inland wells (which includes municipal production wells closest to the coast and other non-coastal monitoring wells).

Undesirable results for unintruded coastal monitoring wells (A) are:

> *Any unintruded coastal monitoring well has a chloride concentration above 250 mg/L. This concentration must be exceeded in 2 or more of the last 4 consecutive samples (quarterly sampled wells).*

Coastal monitoring wells have been constructed to be the Basin's early warning system and first line of defense against seawater intrusion. If their chloride concentrations increase to 250 mg/L, this is a clear indication that seawater is advancing father onshore than it is currently. There are seven coastal monitoring well sites (each site contains several multi-depth monitoring wells) that currently do not show seawater intrusion. These wells' chloride concentrations are summarized in Table 3-15. Groundwater with more than 250 mg/L chloride has a salty taste but is still drinkable to 500 mg/L, which is the state's upper maximum contaminant level. To increase confidence that tested groundwater concentrations are not anomalies, the exceedance of 250 mg/L must be repeated within a year (quarterly sampled wells) to be undesirable.

Undesirable Results for unintruded inland monitoring wells (B) are:

> *Any Unintruded Inland Monitoring Well (which includes municipal production wells closest to the coast and other non-coastal monitoring wells) has a chloride concentration above 150 mg/L. This concentration must be exceeded in 2 or more of the last 4 consecutive quarterly samples*.

All unintruded wells used as data points to develop the chloride isocontour will have TDS and chloride tested on at least a semi-annual schedule until an exceedance occurs, which triggers quarterly testing. Additionally, for an undesirable result to occur, seawater must be the cause of the chloride increase and not another source, such as a localized chemical spill. These wells' chloride concentrations are summarized in Table 3-15.

Undesirable Results for Protective Groundwater Elevations

For coastal representative monitoring wells which have protective elevations:

> *Five-year average groundwater elevations below protective groundwater elevations for any Coastal representative monitoring well.*

A five-year averaging period is selected based on the reasoning that follows:

> Cross-sectional models used to develop most of the protective elevations are quasi-steady state models (HydroMetrics LLC, 2009). Therefore, the protective elevations estimated by the models represent long-term averages that need to be achieved to maintain the freshwater-seawater interface at the desired location. The Basin is currently considered in critical overdraft because groundwater levels are below protective elevations in a number of coastal monitoring wells. Therefore, seawater intrusion groundwater level proxies for minimum thresholds that define sustainability are based on a multi-year average to ensure that critical overdraft is considered eliminated only when groundwater levels achieve the long-term average estimated to maintain the freshwater-seawater interface at the desired location. Achieving protective elevations in a single year should not represent elimination of the Basin's critical overdraft condition.
>
> However, the multi-year averaging period cannot be too long because once protective elevations are achieved with a multi-year average, an overly long averaging period would allow for long periods of groundwater levels being below protective elevations and seawater to advance inland during those periods. A five-year period also corresponds with SGMA requirements for five-year updates of the GSP.

Currently, undesirable results are occurring within the Basin for seawater intrusion because five-year average groundwater elevations do not meet protective elevations at all 13 representative monitoring points. Eliminating undesirable results for seawater intrusion is essential to achieve Basin sustainability.

3.6.1.2 Potential Causes of Undesirable Results

Seawater intrusion is a direct result of groundwater levels falling below elevations that would keep seawater offshore. Water supply wells pumping close to the coast have the potential to cause seawater intrusion if the volumes extracted cause groundwater elevations to fall close to or below sea level. The effects on groundwater levels are increased when multiple wells pump cumulative in close proximity to each other.

3.6.1.3 Effects on Beneficial Users and Land Use

The primary detrimental effect on beneficial users and land users from seawater intrusion is that the groundwater supply will become saltier and thus impact the use of groundwater for domestic/municipal and agricultural purposes. Although groundwater with greater than 250 mg/L chloride has a salty taste, it is still drinkable. The state's upper maximum contaminant level is set at 500 mg/L, when it becomes undrinkable by humans.

Regarding effects on agriculture, chloride moves readily within soil and water and is taken up by the roots of plants. It is then transported to the stems and leaves. Sensitive berries and avocado rootstocks can tolerate only up to 120 mg/L of chloride, while grapes can tolerate up to 700 mg/L or more (Grattan, 2002).

Seawater intrusion renders impacted groundwater essentially unusable to its beneficial users without treatment. Desalinization would significantly increase the cost of water for all users. Land uses completely overlying seawater intrusion, such as agriculture, will need alternative sources of water if their wells are located in the affected areas. For municipal pumpers, impacted wells can be taken offline until a solution is found. This will add stress on their water system by having to make up pumping in other unimpacted wells and increase the potential for further declines in groundwater levels and possibly more seawater intrusion.

3.6.2 Minimum Thresholds - Seawater Intrusion

Contrary to the general rule for setting minimum thresholds for other sustainability indicators, seawater intrusion minimum thresholds do not have to be set at individual monitoring sites. Rather, the minimum threshold is set along an isocontour line in a basin or management area. However, for practical purposes of monitoring the isocontour, minimum thresholds are set at selected monitoring and production wells used to define the isocontour. Groundwater elevation minimum thresholds are also included as a proxy for seawater intrusion.

3.6.2.1 Information Used and Methodology for Establishing Seawater Intrusion Minimum Thresholds

3.6.2.1.1 Chloride Isocontours

Information used for establishing the chloride isocontour seawater intrusion minimum thresholds and measurable objectives include:

- Definitions of significant and unreasonable conditions and desired groundwater quality discussed during GSP Advisory Committee meetings.
- Depths, locations, and logged lithology of existing wells used to monitor groundwater quality.
- Historical and current chloride concentrations in monitoring and production wells near the coast as summarized in Table 3-15.

To provide for more spatial certainty of the chloride isocontour, the isocontour is anchored, where possible, to coastal monitoring wells which are mostly located within 1,000 feet of the coastline. Anchoring the isocontour at coastal monitoring wells provides a consistent point to ascertain if concentrations at a data point on the isocontour (coastal monitoring well) have increased beyond the minimum threshold concentration set for the isocontour. There are 12 points on the isocontour represented by a monitoring well from which concentration data can be obtained and no interpolation is necessary. Additionally, because the statement of significant and unreasonable seawater intrusion conditions is based on historical observations at monitoring wells, it is appropriate to use the same monitoring wells to gauge changes to the location of the isocontour in the future. It is difficult to monitor the chloride isocontour if it is set at the coast because there are no data points on the coast from which to obtain concentration data to know if that concentration has been exceeded or not.

3.6.2.1.2 Groundwater Elevations as a Proxy

The information used for establishing the seawater intrusion groundwater level proxy minimum thresholds and measurable objectives include:

- Information about local definitions of significant and unreasonable conditions and desired groundwater elevations discussed during GSP Advisory Committee meetings.
- Depths and locations of existing coastal monitoring wells used to monitor groundwater levels and seawater intrusion.
- Historical groundwater elevation data from wells monitored by the MGA agencies.
- Maps of current and historical groundwater elevation data.
- Model output from a variable density (SEAWAT 2000) cross-sectional groundwater models.
- SkyTEM geophysical resistivity data.

Cross-sectional models were used to develop both protective and target groundwater levels at coastal monitoring well clusters (HydroMetrics LLC, 2009). Using Monte Carlo uncertainty analysis, a range of protective groundwater levels were developed for each coastal monitoring well cluster (HydroMetrics LLC, 2009). This range represents the uncertainty in the aquifer characteristics. Protective groundwater elevations developed using the cross-sectional models have successfully been used by SqCWD to manage seawater intrusion in the Basin.

Protective groundwater elevations for the Basin are established using two different methods dependent on availability of cross-sectional models:

1. Cross-sectional model data available: minimum thresholds are groundwater elevations that represents at least 70% of cross-sectional model simulations being protective against seawater intrusion for each monitoring well with a protective elevation[1]. For wells where seawater intrusion has not been observed, cross-sectional models estimate protective elevations to protect the entire depth of the aquifer unit of the monitoring wells' lowest screen. For wells where seawater intrusion has been observed, the cross-sectional models estimate protective elevations to prevent seawater intrusion from advancing.

[1] The cross-sectional modeling to develop protective groundwater elevations could not use specific hydrogeologic properties (properties that influence how groundwater flows) with any certainty because there are insufficient data to calibrate the models to groundwater level or concentration data. Additionally, there are limited data for hydrogeologic parameter values offshore, adding further uncertainty. To develop reliable protective groundwater levels, it was necessary to perform an uncertainty analysis that evaluates the range of reasonable outcomes given the lack of precise hydrogeologic property/parameter data.

Each coastal monitoring well location where protective groundwater elevations were developed included 99 randomized parameters model simulations Parameters varied are horizontal hydraulic conductivities of the production unit and underlying unit, and vertical conductivities of the aquitards above the production unit.

2. Cross-sectional model data not available: minimum thresholds are groundwater elevations that represent protective groundwater elevation estimated by using the Ghyben-Herzberg analytical method to protect to the bottom of the monitoring well screen.

3.6.2.1.3 Consideration of Sea-Level Rise

The chloride isocontour and associated well chloride concentrations established as seawater intrusion minimum thresholds are based on the description of significant and unreasonable conditions for the sustainability indicator. This describes seawater moving farther inland than has been observed in the past five years as significant and unreasonable conditions. Undesirable results that occur when chloride concentrations exceed minimum thresholds represent significant and unreasonable conditions even when the intrusion is a result of sea level rise. By defining chloride concentrations as minimum thresholds, the MGA is required to prevent significant and unreasonable seawater intrusion in the Basin resulting from sea level rise.

Groundwater level proxies for the seawater intrusion minimum thresholds also take into account current and rising sea levels. The seawater intrusion groundwater level proxies are established as groundwater elevations above mean sea level. The current datum is therefore current sea levels but the datum will rise in the future as sea levels rise. Although the elevation relative to sea level is set by the groundwater level proxy, the absolute elevations that define undesirable results will increase with rising sea levels.

This consideration of 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 level proxies for minimum thresholds. The model incorporates projected sea level rise in the offshore boundary condition for simulations of future conditions. The boundary condition head for sea level is increased over time to 2.3 feet in 2070 over current sea level rise based on state of California projections for Monterey representing 5% probability under a High Emissions scenario (California Natural Resources Agency, 2018). Since the datum in the model is set at current sea level, simulated future groundwater levels were compared to the groundwater level 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 level proxies relative to projections of higher sea levels.

3.6.2.2 Chloride Isocontour Minimum Threshold

The current extent of seawater intrusion is indicated by the circle symbols on Figure 3-12. The larger the symbol the greater the chloride concentration. The symbols are also colored by aquifer to indicate depth. Figure 3-12 shows that in the Basin, the Aromas Red Sands aquifer has seawater intrusion only in the La Selva Beach area. However, the SC-A4 monitoring well outside of the Basin in the Pajaro Valley is also intruded thus it is assumed that seawater intrusion in the Aromas Red Sands aquifer extends southwards across the Basin boundary. Current seawater intrusion in the Purisima aquifers is found in one Purisima A-unit monitoring well in the Soquel Point area with a chloride concentration of 1,100 mg/L, and in the Seascape area where chloride concentrations up to 15,000 mg/L occur in three Purisima F-unit monitoring wells (Figure 3-12).

Considering the extent of current seawater intrusion, the chloride isocontours on Figure 3-12 represents seawater intrusion minimum thresholds in both the Aromas and Purisima aquifers. A chloride concentration of 250 mg/L is selected for the minimum threshold for the Basin because native chloride concentrations in groundwater are generally below 100 mg/L. Thus, an increase up to the basin water quality objective and state drinking water standard of 250 mg/L is considered significant and unreasonable. A chloride concentration of 250 mg/L is relatively low and likely represents some seawater mixed with native groundwater. Full strength seawater has a chloride concentration of 19,000 mg/L.

Since the location of the chloride isocontour is defined by concentrations in wells, wells either side of the contour are assigned minimum threshold concentrations that determine if the isocontour is moving inland. It is not required in the SGMA regulations but as discussed in the measurable objectives subsection, chloride concentration in these wells are also used to trigger early management actions if concentrations increase above measurable objectives but are still below minimum thresholds.

If chloride concentrations inland of the isocontour increase to above the minimum threshold concentration of 250 mg/L, this indicates that seawater is moving inland and management actions to remedy it need to take place to ensure that by 2040, chloride concentrations inland of the 250 mg/L isocontour remain below the minimum threshold of 250 mg/L.

Table 3-16 summarizes the minimum thresholds for each of the wells used to define the chloride isocontour.

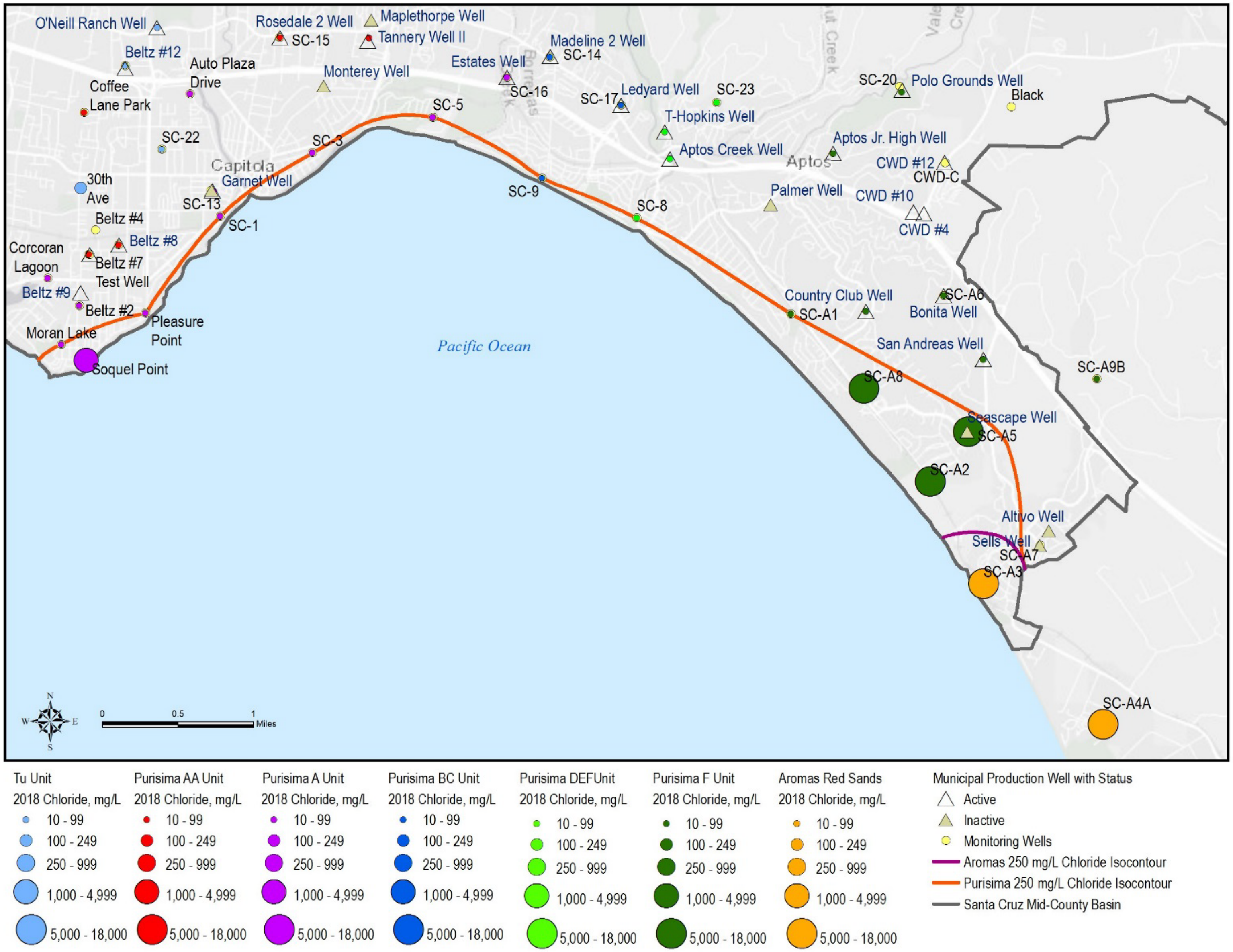


Figure 3-12. 250 mg/L Chloride Isocontour for the Aromas and Pursima Aquifers

Table 3-16. Chloride Minimum Thresholds and Measurable Objectives for Coastal and Inland Wells

Monitoring Well	Aquifer	Minimum Threshold	Measurable Objective
		Chloride Concentration, mg/L	
Coastal Monitoring Wells - Intruded			
SC-A3A	Aromas	22,000	17,955
SC-A3B	Aromas	4,330	676
SC-A8A	Purisima F	8,000	7,258
SC-A2RA	Purisima F	18,480	14,259
SC-A2RB	Purisima F	470	355
Moran Lake Med	Purisima A	700	147
Soquel Point Med	Purisima A	1,300	1,104
Coastal Monitoring Wells - Unintruded			
SC-A8B	Aromas	250	100
SC-A1B	Purisima F	250	100
SC-A1A	Purisima DEF	250	100
SC-8RD	Purisima DEF	250	100
SC-9RC	Purisima BC	250	100
SC-8RB	Purisima BC	250	100
Pleasure Point Medium	Purisima A	250	100
SC-1A	Purisima A	250	100
SC-5RA	Purisima A	250	100
SC-3RA	Purisima A	250	100
Moran Lake Deep	Purisima AA	250	100
Pleasure Point Deep	Purisima AA	250	100
Soquel Point Deep	Purisima AA	250	100
SC-13A	Tu	250	100
Inland Production and Monitoring Wells - Unintruded			
SC-A5A	Purisima F	150	100
SC-A5B	Purisima F	150	100
San Andreas PW	Purisima F	150	100
Seascape PW	Purisima F	150	100
T. Hopkins PW	Purisima DEF	150	100
Estates PW	Purisima BC & A	150	100
Ledyard PW	Purisima BC	150	100
Garnet PW	Purisima A	150	100

Monitoring Well	Aquifer	Minimum Threshold	Measurable Objective
		Chloride Concentration, mg/L	
Beltz #2	Purisima A	150	100
Beltz #8 PW	Purisima A	150	100
SC-22AA	Purisima AA	150	100
Corcoran Lagoon Deep	Purisima AA	150	100
Schwan Lake	Purisima AA	150	100

PW = production well

3.6.2.3 Groundwater Elevations as a Proxy for Seawater Intrusion Minimum Thresholds

As indicated in the SGMA Regulations Section §354.36(b) "*groundwater elevations may be used as a proxy for monitoring other sustainability indicators*." For seawater intrusion, protective groundwater elevations are used as proxies for additional minimum thresholds. Use of a proxy is appropriate because there is significant correlation between groundwater elevations and seawater intrusion. When coastal groundwater levels in aquifers connected to the ocean fall to near or below sea level, flows across the ocean/land boundary become predominantly onshore flows. As higher density seawater flows inland, a wedge forms under the less dense fresh groundwater until the water table achieves equilibrium. The lower groundwater levels are, the less pressure there is from freshwater within the aquifer to resist the intruding seawater.

Minimum thresholds for seawater intrusion using groundwater elevation proxies are the current protective groundwater elevations set at coastal monitoring wells and used for groundwater management over the past 10 years. Current protective elevations for coastal monitoring wells are listed in Table 3-17 and shown on a map as Figure 3-13. New deep monitoring wells need to be constructed in the early part of GSP implementation and protective elevations will be established when the construction details of those wells are available. Table 3-17 and Figure 3-13 identify the two new deep Tu-unit monitoring wells.

Table 3-17. Minimum Thresholds and Measurable Objectives for Groundwater Elevations Used as Proxies at Seawater Intrusion Representative Monitoring Points

Coastal Monitoring Well with Aquifer Unit in Parenthesis	Minimum Threshold (feet mean sea level)	Basis for Minimum Threshold	Measurable Objective (feet mean sea level)	Basis for Measurable Objective	Trigger for Early Management Action (feet mean sea level)
SC-A3A (Aromas)	3	XS 70th	4	XS >99th	1
SC-A1B (F)	3	XS 70th	5	XS >99th	1
SC-A8RA (F)	6	XS 70th	7	XS >99th	2
SC-A2RA (F)	3	XS 70th	4	XS >99th	1
SC-8RD (DEF)	10	XS 70th	11	XS >99th	2
SC-9RC (BC)	10	XS 70th	11	XS >99th	2
SC-8RB (BC)	19	XS 70th	20	SC-8RD + GH	2
SC-5RA (A)	13	XS 70th	15	XS >99th	2
SC-3RA (A)	10	XS 70th	12	XS >99th	2
SC-1A (A)	4	XS 70th	6	XS >99th	2
Moran Lake Medium (A)	5	GH BS	6.8	GH BU	2
Soquel Point Medium (A)	6	GH BS	7.1	GH BU	2
Pleasure Point Medium (A)	6.1	GH BS	6.5	GH BU	2
Moran Lake Deep (AA)	6.7	GH BS	16	GH BU	2
Soquel Point Deep (AA)	7.5	GH BS	16	GH BU	2
Pleasure Point Deep (AA)	7.7	GH BS	16	GH BU	2
SC-13A (Tu)	17.2	GH BS	19	GH BU	2

Notes:
GH BS = Ghyben-Herzberg bottom of screen
GH BU = Ghyben-Herzberg bottom of aquifer unit
XS 70th = Cross-sectional model with 70th percentile of runs being protective
XS >99th = Cross-sectional model with greater than 99th percentile of runs being protective

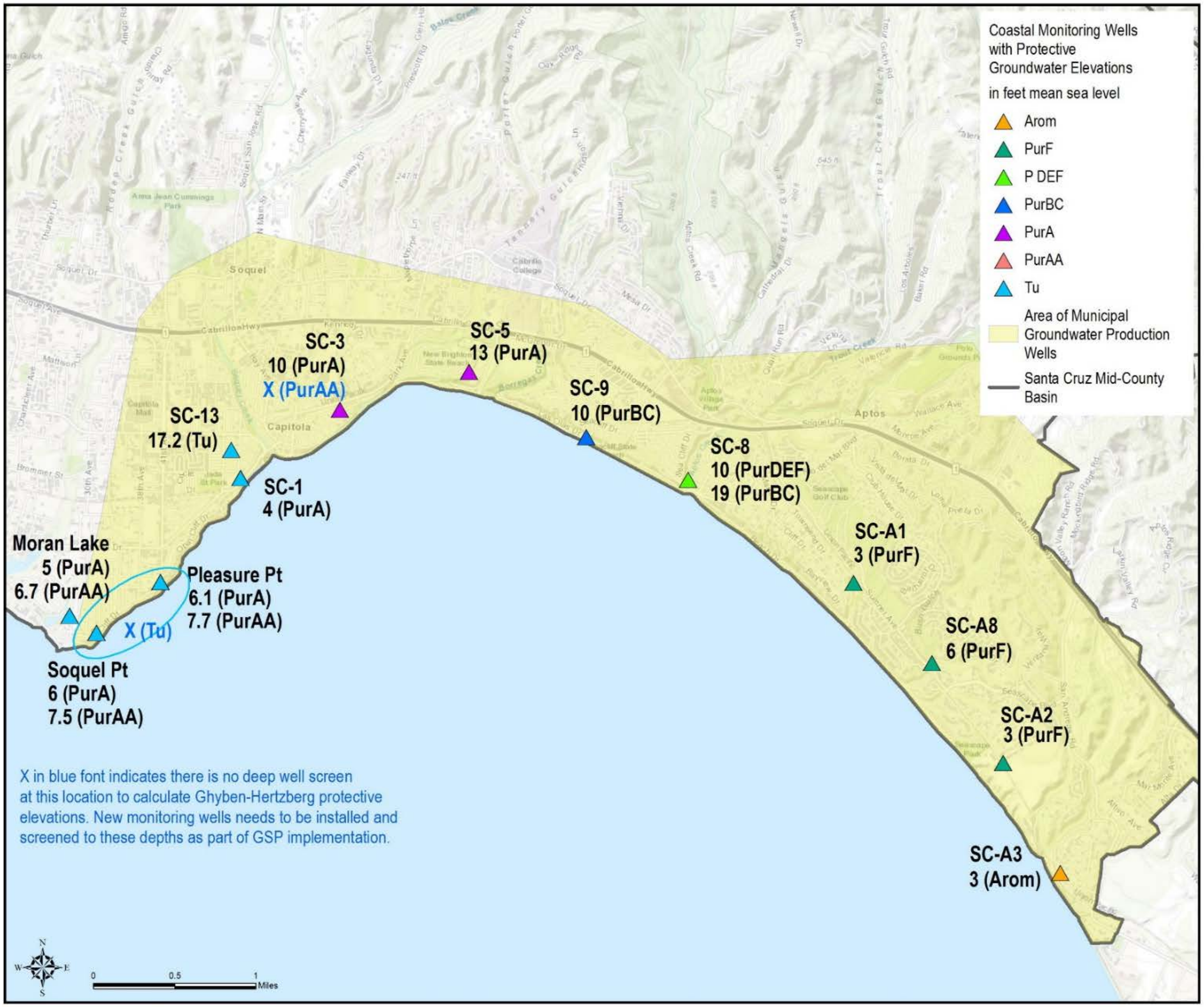


Figure 3-13. Protective Groundwater Elevations at Coastal Monitoring Wells

3.6.2.4 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Considering the minimum thresholds for seawater intrusion are both groundwater quality and groundwater elevation metrics, the bullets below address the relationship between the seawater intrusion minimum thresholds and other sustainability indicator minimum thresholds.

- **Chronic lowering of groundwater levels.** Groundwater elevations associated with proxy minimum thresholds for seawater intrusion are more stringent than groundwater elevations that represent chronic lowering of groundwater levels. Minimum threshold groundwater elevations for chronic lowering of groundwater levels are raised from the level that would meet overlying demands so that they do not interfere with attaining minimum threshold elevations for seawater intrusion.

- **Reduction of groundwater in storage.** Minimum thresholds for reduction of groundwater in storage and seawater intrusion are dependent on each other. Minimum thresholds for reduction of groundwater in storage are volumes of groundwater, for each of the three aquifer groups that do not cause undesirable results in the other applicable sustainability indicators such as seawater intrusion.

- **Degraded groundwater quality.** The chloride isocontour minimum threshold for seawater intrusion is the same minimum threshold concentration assigned to chloride for degradation of groundwater quality. For the unintruded inland wells, a seawater intrusion chloride minimum threshold of 150 mg/L, although less than the degraded groundwater quality minimum threshold of 250 mg/L, is only used to represent if the chloride isocontour has moved inland and does not signify degraded quality.

- **Subsidence.** This sustainability indicator is not applicable to the Basin.

- **Depletion of interconnected surface water**. Minimum thresholds for interconnected surface water are shallow groundwater levels (as a proxy) that have been set in existing RMPs. Groundwater elevations used as a proxy minimum threshold shown on Figure 3-11 are above sea level and do not interfere with the ability to attain proxy seawater intrusion groundwater elevation thresholds. Since shallow groundwater level proxies set as minimum thresholds for depletion of interconnected surface water are based on observations from 2001-2015, proxy seawater intrusion groundwater elevation minimum thresholds that are generally higher than groundwater elevations from 2001-2015 should not interfere with the ability to avoid undesirable results for depletion of interconnected surface water.

3.6.2.5 Effect of Minimum Thresholds on Neighboring Basins

The anticipated effect of the degraded groundwater quality minimum thresholds on each of the neighboring basins/subbasins are addressed below.

Pajaro Valley Subbasin of the Corralitos Basin (critically-overdrafted). The Pajaro Valley Subbasin is hydrogeological down- to cross-gradient of the Santa Cruz Mid-County Basin. Because of lower groundwater elevations in the Pajaro Valley Subbasin, groundwater along the coastal portion of the boundary flows from the Santa Cruz Mid-County Basin into the Pajaro Valley Subbasin. Chloride concentrations in the La Selva area of the Basin are similar to those in the Pajaro Valley Subbasin, which has more extensive seawater intrusion along its entire length of coastline (Figure 3-12 and Figure 3-14). The goal for seawater intrusion conditions in Pajaro Valley is to halt intrusion by reducing the rate of intrusion (Carollo Engineers, 2014). Since the groundwater level proxy minimum thresholds in the Santa Cruz Mid-County Basin in the Aromas area are intended to keep seawater intrusion where it is currently, the seawater intrusion minimum thresholds assist Pajaro Valley achieve its sustainability goals for seawater intrusion by causing increased subsurface flow into Pajaro Valley thus helping to reduce the rate of intrusion. The increase in outflows to Pajaro Valley when minimum thresholds are achieved is supported by the projected groundwater budget in Section 2.

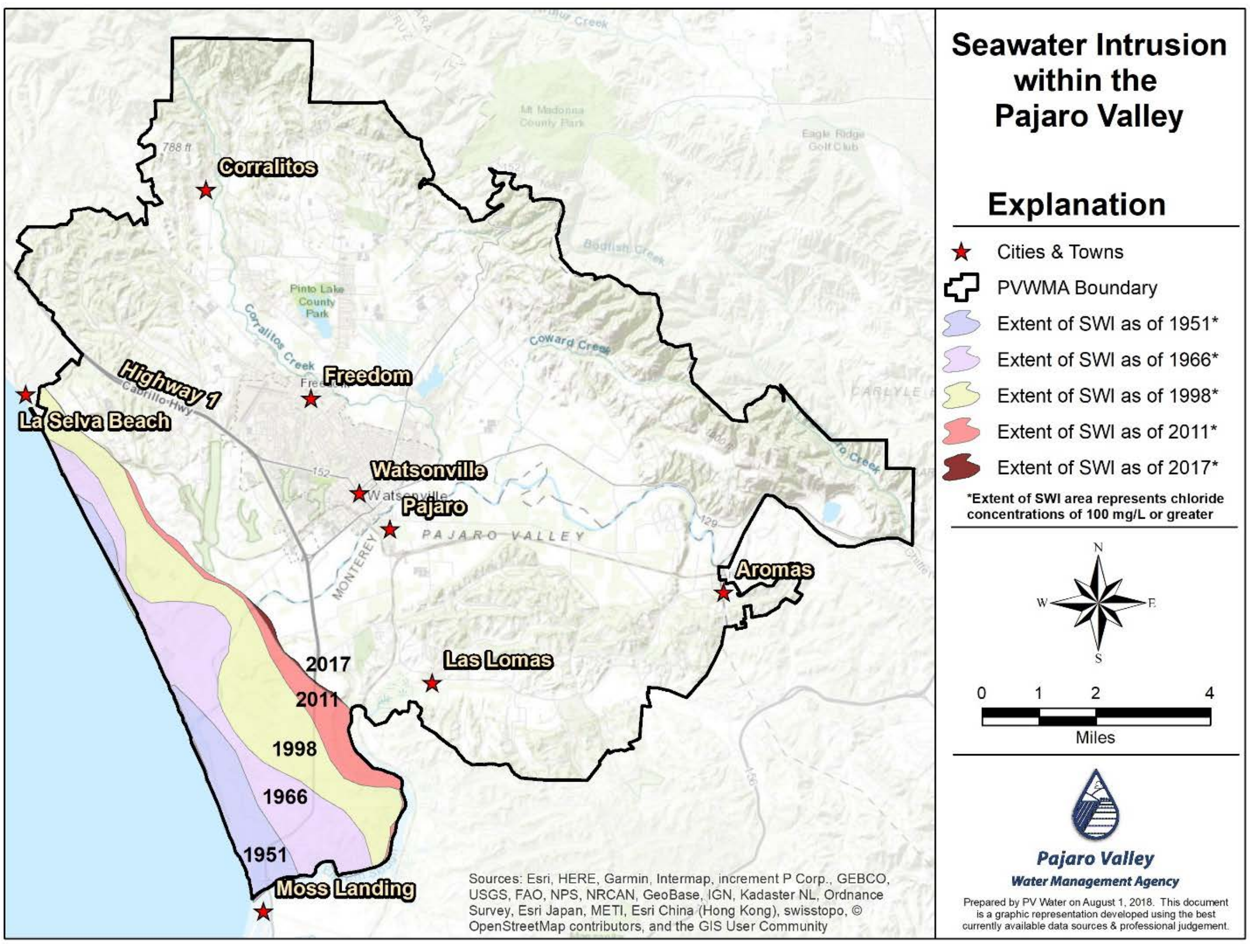


Figure 3-14. Seawater Intrusion within the Pajaro Valley (Source: PV Water)

Santa Margarita Basin (medium-priority). The Santa Margarita Basin is an inland basin being at least 5.8 miles from the coast. Because of this distance and the fact that groundwater elevations at the chloride isocontour near the coast are roughly 550 feet lower than groundwater elevations at the boundary between the two basins, there is no potential for seawater intrusion minimum thresholds established for the Santa Cruz Mid-County Basin to affect the Santa Margarita Basin from achieving sustainability.

Purisima Highlands Subbasin of the Corralitos Basin (very low-priority). Similar to the Santa Margarita Basin, the Purisima Highlands Subbasin is an inland basin that is at an elevation of at least 340 feet above sea level and will not be impacted by seawater intrusion minimum thresholds at the coast.

3.6.2.6 Effects of Minimum Thresholds on Beneficial Users and Land Uses

Between the ocean and the chloride isocontour, land use is predominantly recreational, open space, agricultural, and residential. Private and agricultural users have their own wells while residential users of groundwater are supplied municipal water pumped in other parts of the Basin. Restricting the advancement of seawater intrusion to where it is currently will not impact more wells and an area greater than already impacted. Also, wells inland of the chloride isocontour will not be impacted by the seawater minimum thresholds.

3.6.2.7 Relevant Federal, State, or Local Standards

No federal or state standards exist for seawater intrusion. Locally, the City of Santa Cruz and Soquel Creek Water District have a cooperative monitoring / adaptive groundwater management agreement to: (1) ensure protection of the shared groundwater resource from seawater intrusion, (2) allow for the redistribution of pumping inland away from the Purisima A-unit offshore outcrop area, (3) maintain inland groundwater levels that promote continued groundwater flow toward coastal wells and the Purisima A offshore outcrop area while maintaining coastal groundwater levels that will abate seawater intrusion, and (4) provide both agencies adequate flexibility to respond to changing water demands, changing water supply availability, and infrastructure limitations. Protective groundwater elevations used as proxy measurements for seawater intrusion are aligned with the cooperative agreement's target groundwater elevations.

3.6.2.8 Method for Quantitative Measurement of Minimum Thresholds

Chloride concentrations used to define the chloride isocontour in production and monitoring well RMPs will be directly measured to determine where chloride concentrations are in relation to minimum thresholds. Groundwater quality samples will be collected and tested in accordance with the monitoring plan outlined in Section 3.3. Sampling for all coastal monitoring wells is quarterly and unintruded inland wells are sampled semi-annually, unless an exceedance of a minimum threshold is measured, whereupon the sampling frequency will be increased to quarterly.

Groundwater elevations in RMPs will be directly measured to determine where groundwater levels are in relation to minimum thresholds used a proxy metric for seawater intrusion.

Groundwater level monitoring will be conducted in accordance with the monitoring plan outlined in Section 3.3. All RMPs will be equipped with continuous data loggers.

3.6.3 Measurable Objectives - Seawater Intrusion

3.6.3.1 Chloride Isocontour Measurable Objective

3.6.3.1.1 Measurable Objectives

The measurable objective chloride isocontour has the same location as the minimum threshold isocontour shown on Figure 3-12. Since all historical unintruded coastal monitoring well concentrations are below 100 mg/L (Table 3-16), the isocontour concentration for measurable objectives is reduced from 250 mg/L (minimum threshold) to 100 mg/L (measurable objective). Having the measurable objective isocontour at the same location as the minimum threshold allows the same monitoring wells along that isocontour to be used to define its location. The measurable objectives for intruded wells are their 2013 – 2017 average concentration and is 100 mg/L for all unintruded wells. Table 3-16 lists the minimum threshold and measurable objective concentrations for all wells used to define the isocontour.

3.6.3.1.2 Chloride Concentration Triggers

Although not required by the SGMA regulations, the MGA will use chloride concentration exceedances of measurable objectives as a trigger for preemptive actions to prevent significant and unreasonable conditions from occurring. This approach is being taken for this specific sustainability indicator because it is the indicator for which the Basin is in critical overdraft. If chloride concentrations exceed measurable objectives and have a continuing increasing trend, it indicates that concentrations are moving toward minimum thresholds that define undesirable results. Such a trend will be addressed immediately.

For unintruded monitoring wells where chloride concentrations are below 250 mg/L, the measurable objective for chloride concentration is 100 mg/L. Variation of chloride concentrations below 100 mg/L is not necessarily indicative of seawater intrusion. Chloride concentrations above 100 mg/L in two of four quarterly samples are more likely indicative of seawater intrusion and warrant early management action.

For intruded monitoring wells where chloride concentrations are currently above 250 mg/L, the measurable objective for chloride concentrations is the 2013-2017average concentration. As this average concentration includes seasonal and measurement variation, an annual average of four quarterly chloride samples above the measurable objective is indicative of seawater intrusion moving inland and warrants early management action.

The recommended management action for exceedances of chloride measurable objectives is for pumping to be reduced at the municipal well nearest to the monitoring well with the exceedance. The objective of this action is to raise groundwater levels in the monitoring well and prevent further increases of chloride concentrations that could result in significant and unreasonable conditions.

If the groundwater level proxy minimum threshold is being met but chloride measurable objective is exceeded at any monitoring well, this indicates that the groundwater level proxy is not protective for preventing further seawater intrusion than observed over 2013-2017. In this case, the groundwater level proxy should be revised. The groundwater level proxy may not be sufficient because the level is too low or because the multi-year averaging period is too long. Based on an evaluation of groundwater levels and chloride concentrations for what appears insufficient, the level should be raised and/or the averaging period should be shortened.

3.6.3.1.3 Interim Milestones for Chloride

The measurable objective chloride isocontour of 100 mg/L is defined in part by RMPs that currently have chloride concentrations below their measurable objective of 100 mg/L (Figure 3-12). Inland of the isocontour, RMPs are also below their measurable objectives (Table 3-15). Projects and management actions included in the GSP are designed so that current seawater intrusion does not advance inland. Therefore, interim milestones are set at the same concentration as measurable objectives (100 mg/L) as no change in inland chloride concentrations are expected as the GSP is implemented.

For RMPs currently impacted by seawater intrusion and located on the coast-side of the chloride isocontour, current concentrations represented by average 2013 – 2017 chloride concentrations are their measurable objectives. Interim milestones for these wells are set at the same concentrations as measurable objectives shown in Table 3-16, effectively representing conditions that do not allow seawater intrusion to get worse than it is currently.

3.6.3.2 Groundwater Elevations as a Proxy Measurable Objectives

3.6.3.2.1 Measurable Objectives

Groundwater elevations as a proxy measurable objectives are determined based on whether the cross-sectional groundwater model is available for the area or not.

1. Cross-sectional model available: measurable objectives are groundwater elevations that represents >99% of cross-sectional model simulations being protective against seawater intrusion for each monitoring well with a protective elevation. For wells where seawater intrusion has not been observed, cross-sectional models estimate protective elevations to protect the entire depth of the aquifer unit of the monitoring wells' lowest screen. For wells where seawater intrusion has been observed, the cross-sectional models estimate protective elevations to prevent seawater intrusion from advancing.

2. Cross-sectional model not available: measurable objectives are the groundwater elevations that represent protective groundwater elevation estimated by using the Ghyben-Herzberg method to protect the entire depth of the aquifer unit the monitoring wells are screened in.

Measurable objectives established based on the approaches above are provided in Table 3-17.

3.6.3.2.2 Protective Groundwater Elevation Triggers

Similar to the chloride concentration triggers described in Section 3.6.3.1 that initiate action based on exceeding chloride concentration measurable objectives in monitoring and production wells near the chloride isocontour, groundwater level proxy triggers at coastal monitoring wells will also initiate early management actions. As with the chloride concentration triggers, these triggers are not required by SGMA regulations but are included in the GSP as a preemptive action to prevent significant and unreasonable conditions from occurring. This approach is being taken for this specific sustainability indicator because seawater intrusion is the indicator for which the Basin is in critical overdraft. Groundwater elevations dropping below these triggers over the short-term indicate an increased risk of seawater intrusion that may not be fully addressed by minimum thresholds and measurable objectives based on five-year average elevations.

The groundwater level proxy trigger is based on the minimum groundwater elevation at coastal monitoring wells included in the existing cooperative monitoring/adaptive management groundwater management agreement between the City of Santa Cruz and Soquel Creek Water District that has been in effect since 2015. The agreement lists a minimum groundwater elevation as 2 feet above mean sea level applied to a 30 day running average at the coastal monitoring wells Moran Lake Medium, Soquel Point Medium, Pleasure Point Medium, and SC-1A. In order to maintain consistency with the cooperative agreement, the following groundwater level proxy triggers are set for other coastal monitoring wells:

- 2 feet above mean sea level is set as the groundwater elevation trigger for wells with minimum threshold groundwater level proxies for seawater intrusion of 4 feet or higher: SC-A8RA, SC-A8RD, SC-9RC, SC-8RB, SC-5RA, SC-3RA, SC-1A, Moran Lake Medium, Soquel Point Medium, Pleasure Point Medium, Moran Lake Deep, Soquel Point Deep, Pleasure Point Deep, and SC-13A.

- In order to provide operational flexibility, 1 foot above mean sea level is set as the groundwater elevation trigger for wells with minimum threshold groundwater level proxies of less than 4 feet: SC-A3A, SC-A1B, and SC-A2RA.

Table 3-17 lists the groundwater elevation triggers for early management action compared to minimum thresholds and measurable objectives for RMPs that use proxy groundwater elevations for SMC.

If data show that a 30-day running average groundwater elevation has dropped below the groundwater elevation trigger at a coastal monitoring well, MGA member agencies that pump from the aquifer unit of the monitoring well will evaluate how municipal pumping quantities and distribution may have caused the decline in groundwater levels. The MGA member agencies will then adjust municipal pumping based on the evaluation to avoid future groundwater elevations below the triggers. If municipal pumping does not appear to have caused the groundwater elevations falling below triggers, the MGA will investigate the cause of the drop.

3.6.3.2.3 Interim Milestones for Groundwater Elevation Proxies

Groundwater elevations as proxy interim milestones are based on model simulations of projects showing how projects will raise coastal groundwater levels over time to prevent undesirable results related to seawater intrusion. Section 4 contains the model results which are used to describe the expected benefits of the projects.

Interim milestones are established at each of the coastal RMPs with proxy groundwater elevations for seawater intrusion. Interim milestones are based on the five year average of model simulated groundwater elevations in Water Years 2025, 2030, and 2035.

Interim milestones at Soquel Creek Water District's coastal monitoring wells (with names beginning in SC) are based on model simulation of Pure Water Soquel because the expected benefits of that project are to raise groundwater levels above or approaching measurable objectives at the District's wells as described in Section 4. The interim milestones at City of Santa Cruz's coastal monitoring wells (Moran Lake, Soquel Point, and Pleasure Point) are based on model simulation of Pure Water Soquel and City of Santa Cruz ASR in combination because the expected benefits of the City of Santa Cruz project are to raise groundwater levels above minimum thresholds at the City's wells as described in Section 4. Table 3-18 summarizes the interim milestones for coastal RMPs.

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.

The model does not reliably simulate groundwater elevations in the Purisima DEF unit where SC-8RD is located. The interim milestone for this well are set at the minimum threshold so that the MGA will evaluate whether Purisima DEF unit pumping is sustainable at each five year interval (Table 3-18).

Interim milestones at Moran Lake Deep well drop slightly between 2030 and 2035. This is a result of reduced surface water supply for City ASR during this time based on projected climate variability. Evaluation of groundwater elevations against these interim milestones should account for actual surface water supply used to recharge the Basin and climate variability.

Table 3-18. Interim MIlestones for Seawater Intrusion Groundwater Elevation Proxies

Representative Monitoring Well with Aquifer Unit in Parenthesis	Minimum Threshold (feet mean seal level)	Measurable Objective (feet mean sea level)	Interim Milestone 2025 (feet mean sea level)	Interim Milestone 2030 (feet mean sea level)	Interim Milestone 2035 (feet 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

3.7 Degraded Groundwater Quality Sustainable Management Criteria

3.7.1 Undesirable Results - Degraded Groundwater Quality

Locally defined significant and unreasonable groundwater quality degradation in the Basin is:

> *Groundwater quality, attributable to groundwater pumping or managed aquifer recharge, that fails to meet state drinking water standards.*

Recognizing there are naturally occurring groundwater quality issues in the Basin, this statement reflects that any project implemented or management actions taken by the MGA to achieve sustainability must not cause groundwater quality degradation that results in groundwater quality to be worse than drinking water standards.

3.7.1.1 Criteria for Defining Degraded Groundwater Quality Undesirable Results

For the Santa Cruz Mid-County Basin, groundwater quality degradation is unacceptable as a direct result of GSP implementation. Therefore, the degradation of groundwater quality undesirable result is:

> *Groundwater quality undesirable results in the Basin occur when as a result of groundwater pumping or managed aquifer recharge, any representative monitoring well exceeds any state drinking water standard.*

Because degraded groundwater quality undesirable results can only occur due to projects and management actions implemented to achieve sustainability in the GSP, it is important to correlate groundwater quality impacts to RMPs with quality and hydraulic gradient changes caused by projects implemented or management actions taken to achieve sustainability.

3.7.1.2 Potential Causes of Undesirable Results

Conditions that may lead to undesirable results for degraded groundwater quality include the following:

- **Changes to Basin Pumping**. If the location and rates of groundwater pumping change as a result of projects implemented or management actions taken under the GSP, these changes could alter hydraulic gradients and cause movement of poor-quality groundwater towards a supply well at concentrations that exceed state drinking water standards.
- **Groundwater Recharge.** Active recharge of water or captured runoff could modify groundwater gradients and move poor-quality groundwater towards a supply well in concentrations that exceed state drinking water standards.
- **Recharge of Poor-Quality Water.** Recharging the Basin with water that exceeds state drinking water standards may lead to an undesirable result. Since the State Water Control Board who is responsible for regulating recharge activities enforces an anti-degradation policy, there is minimal likelihood of poor-quality water being recharged into the Basin.

3.7.1.3 Effects on Beneficial Users and Land Use

The undesirable result for degradation of groundwater quality is groundwater degradation due to actions directly resulting from GSP implementation. Degradation for this sustainability indicator only occurs if two conditions occur together: (1) there are induced changes in groundwater elevations and gradients, and (2) there is non-native poor-quality groundwater. If both these conditions occur together, the changed hydraulic gradients may move poor-quality groundwater flows towards supply wells that would not have otherwise been impacted.

Currently, apart from one location with 1,2,3-TCP and more widespread nitrate in parts of the Aromas Red Sands aquifers and saline water associated with seawater intrusion in two areas along the coast, the Basin's groundwater quality is good with no non-native poor-quality groundwater present within productive aquifers.

If undesirable results are allowed to take place, groundwater quality that does not meet state drinking water standards needs to be treated, which is a significant cost to users. For municipal suppliers, impacted wells can be taken offline until a solution is found. This will add stress on their water system by having to make up pumping in other unimpacted wells and increase the potential for further declines in groundwater levels.

This undesirable result does not apply to groundwater quality changes that occur due to other causes not in the control of the MGA. There are a number of federal, state, and local regulatory policies related to the protection of groundwater quality that will continue to be enforced by relevant federal, state, and local agencies. A summary of these regulations is included in Appendix 3-C.

3.7.2 Minimum Thresholds - Degraded Groundwater Quality

3.7.2.1 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

The information used for establishing the degraded groundwater quality minimum thresholds included:

- Feedback about significant and unreasonable conditions from the GSP Advisory Committee and the public.
- Historical and current groundwater quality data from production and monitoring wells in the Basin.
- Federal and state drinking water quality standards.
- Depths, locations, and logged lithology of existing wells used to monitor groundwater quality.

The historical and current groundwater quality used to establish groundwater quality minimum thresholds are discussed in Section 2.2.2.4: Groundwater Quality. Based on review of historical and current groundwater quality data, federal and state drinking water standards, and irrigation water quality needs, the MGA agreed that state drinking water standards are appropriate to define degraded groundwater quality minimum thresholds.

3.7.2.2 Degraded Groundwater Quality Minimum Thresholds

Minimum thresholds are state drinking water standards for constituents of concern monitored in RMPs for degraded groundwater quality. Table 3-19 lists the constituents of concern in the Basin together with why it is of concern and their state drinking water standards that represent minimum thresholds.

Table 3-19. Constituents of Concern with Minimum Thresholds

Constituent of Concern	Reason for Concern	Minimum Threshold/ Drinking Water Standard
Total dissolved solids	basic health of basin	1,000 mg/L
Chloride	basic health of basin	250 mg/L
Iron	naturally elevated	300 µg/L
Manganese	naturally elevated	50 µg/L
Arsenic	naturally elevated	10 µg/L
Chromium (Total)	naturally elevated	50 µg/L
Chromium VI	naturally elevated	none set yet
Nitrate as Nitrogen	septic systems & agriculture	10 mg/L
Perchlorate	agriculture related	6 µg/L
Organic compounds	human introduced	various

Each project implemented as part of the GSP will have its own unique constituents of concern that will apply to monitoring and production wells included in their use permits granted by the State Water Resources Control Board Division (SWRCB) of Drinking Water (DDW). For example, projects injecting purified recycled water into the Basin are classified as groundwater replenishment reuse projects (GRRP) and permits from SWRCB DDW are required. A compendium of groundwater replenishment reuse regulations (GRRR) (Title 22, Division 4, Chapter 3) were issued by the SWRCB in 2014 (SWRCB, 2018). Specific monitoring wells and a list of constituents to monitor are part of specific permit conditions. The GRRR Section 60320.200 (c) requires at least four quarters of background groundwater quality data to characterize groundwater quality in each aquifer that will be receiving recycled water before injection of purified recycled water starts.

For Aquifer Storage & Recovery (ASR) projects, the SWRCB has adopted general waste discharge requirements for ASR projects that inject water of drinking water quality into groundwater (Order No. 2012-0010-DWQ or ASR General Order). The ASR General Order provides a consistent statewide regulatory framework for authorizing both pilot ASR testing and permanent ASR projects. Oversight of these regulations is through the Regional Water Quality Control Board (RWQCB) and obtaining coverage under the General ASR Order requires the preparation and submission of a Notice of Intent (NOI) application package. The NOI includes a technical report that, amongst other things, identifies and describes target aquifers, delineates the Areas of Hydrologic Influence, identifies all land uses within the delineated Areas of Hydrologic Influence, identifies known areas of contamination within the Areas of Hydrologic Influence, identifies project-specific constituents of concern, and groundwater degradation assessment.

3.7.2.3 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

As SGMA regulations do not require projects or management actions to improve existing groundwater quality, there are no direct actions under the GSP associated with achieving groundwater quality minimum thresholds. Therefore, there are no actions that directly influence other sustainability indicators. However, preventing migration of poor-quality groundwater may limit activities needed to achieve minimum thresholds for other sustainability indicators.

- **Chronic lowering of groundwater levels.** Degraded groundwater quality minimum thresholds could influence groundwater level minimum thresholds by limiting the types of water that can be used for recharge to raise groundwater levels in the unlikely event that levels started to approach minimum thresholds.
- **Change in groundwater storage**. Degraded groundwater quality minimum thresholds do not promote pumping in excess of the sustainable yield. Therefore, the degraded groundwater quality minimum thresholds will not result in an exceedance of the groundwater storage minimum threshold.
- **Seawater intrusion**. Degraded groundwater quality minimum thresholds could influence groundwater level proxy minimum thresholds for seawater intrusion by limiting the types of water that can be used for recharge to raise groundwater levels.
- **Subsidence**. This sustainability indicator is not applicable to this Subbasin
- **Depletion of interconnected surface waters.** Degraded groundwater quality minimum thresholds do not promote additional pumping or lower groundwater elevations adjacent to interconnected surface waters. Therefore, the degraded groundwater quality minimum thresholds will not result in a significant or unreasonable depletion of interconnected surface waters.

Minimum thresholds for all constituents of concern and RMPs are uniform throughout the Basin, thus there is no conflict between individual minimum thresholds.

3.7.2.4 Effect of Minimum Thresholds on Neighboring Basins

The anticipated effect of the degraded groundwater quality minimum thresholds on each of the neighboring basins is addressed below.

Pajaro Valley Subbasin of the Corralitos Basin (critically-overdrafted). The Pajaro Valley Subbasin is hydrogeological down- to cross-gradient of the Santa Cruz Mid-County Basin. Because of lower groundwater elevations in the Pajaro Valley Subbasin, groundwater along the coastal portion of the boundary generally flows from the Santa Cruz Mid-County Basin into the Pajaro Valley Subbasin (Figure 2-50. Groundwater Budget Subareas). The groundwater quality on either side of the Basin boundary with the Pajaro Valley Subbasin is similar; having overall good quality with the exception of elevated nitrates and salinity associated with seawater intrusion at the coast. The quality of groundwater in Pajaro Valley is documented in its Salt and Nutrient Management Plan (PVWMA, 2016). The degraded groundwater quality minimum threshold is set to maintain the good-quality groundwater in the Basin that flows into the Pajaro Valley Subbasin. Therefore, it is unlikely that the groundwater quality minimum thresholds established for the Basin will prevent the Pajaro Valley Subbasin from achieving sustainability with regards to groundwater quality.

Santa Margarita Basin (medium-priority). Limited groundwater currently flows from the Santa Cruz Mid-County Basin into the Santa Margarita Basin. Groundwater quality in the vicinity of the basins' boundary is generally good with the exception of naturally occurring elevated iron, manganese, and occasionally arsenic. No GSP projects or management actions are likely in this area as it is far from the coast where projects and management actions to raise coastal groundwater levels preventing seawater intrusion will take place. Therefore, it is unlikely that the groundwater quality minimum thresholds established for the Basin will prevent the Santa Margarita Basin from achieving sustainability.

Purisima Highlands Subbasin of the Corralitos Basin (very low-priority). The Purisima Highlands Subbasin is hydrogeological up-gradient of the Santa Cruz Mid-County Basin. Groundwater flow, historically and projected in the future, is from the Purisima Highlands Subbasin into the Santa Cruz Mid-County Basin. For this reason, there is no possibility of groundwater quality in the Basin impacting the Purisima Highlands Subbasin. Furthermore, minimum thresholds for groundwater quality are set to maintain the good groundwater quality in both basins.

3.7.2.5 Effects of Minimum Thresholds on Beneficial Users and Land Uses

In general, degraded groundwater quality minimum thresholds will not have any negative effects on beneficial users and land uses in the Basin.

Rural residential land uses and users. The degraded groundwater quality minimum thresholds benefit domestic water users in the Basin. Ensuring constituents of concern in additional drinking water supply wells remain below state drinking water standard protects groundwater for domestic use.

Agricultural land uses and users. The degraded groundwater quality minimum thresholds generally benefit agricultural water users in the Basin. Drinking water standards are more stringent than some agricultural water quality standards, with the exception of strawberries which are very sensitive to salt in irrigation water.

Urban land uses and users. The degraded groundwater quality minimum thresholds benefit the urban water users in the Basin. Preventing groundwater for drinking water supply from exceeding state drinking water standards ensures an adequate supply of groundwater for municipal use.

Ecological land uses and users. Although the groundwater quality minimum thresholds do not directly benefit ecological uses, it can be inferred that the degraded groundwater quality minimum thresholds generally benefit the ecological water uses in the Basin. Preventing poor-quality groundwater from migrating will prevent unwanted contaminants from impacting groundwater dependent ecosystems.

3.7.2.6 Relevant Federal, State, or Local Standards

The degraded groundwater quality minimum thresholds specifically incorporate state drinking water standards.

3.7.2.7 Method for Quantitative Measurement of Minimum Thresholds

Groundwater quality in production and monitoring well RMPs will be directly measured to determine where groundwater quality concentrations are in relation to minimum thresholds. Groundwater quality samples will be collected and tested in accordance with the monitoring plan outlined in Section 3.3.

3.7.3 Measurable Objectives - Degraded Groundwater Quality

3.7.3.1 Measurable Objectives

Measurable objectives for each RMP are the 2013 – 2017 average concentrations for each constituent of concern for each RMP. Table 3-20 summarizes the measurable objectives for each RMP. If a representative monitoring well does not have groundwater quality data during this period, the most recent concentrations are used.

3.7.3.2 Interim Milestones

Groundwater quality in the Basin is currently above minimum thresholds for all RMPs with no changes in quality expected from projects and management actions implemented to achieve sustainability. Since the measurable objectives effectively represent current conditions (average of 2013 – 2017 concentrations), interim milestones are set at the same concentration as measurable objectives shown in Table 3-20.

Table 3-20. Measurable Objectives for Degradation of Groundwater Quality

Aquifer Unit	Well Name	Total Dissolved Solids, mg/L	Chloride, mg/L	Iron, µg/L	Manganese, µg/L	Arsenic, µg/L	Chromium (Total), µg/L	Chromium VI, µg/L	Nitrate as Nitrogen, mg/L	Perchlorate, µg/L	Organic compounds
	Minimum Threshold	**1,000**	**250**	**300**	**50**	**10**	**50**	**NA**	**10**	**6**	**various**
Aromas	Altivo PW	209	18.9	41	4	0.2	26.5	22	1	0.2	ND
	CWD-10 PW	340	26	ND	ND	ND	11	ND	25	ND	ND
	SC-A1C	348	29	232	1378	ND	ND	ND	1	ND	ND
	SC-A2RC	355	41	114	11	ND	6	ND	4	ND	ND
	SC-A3A*	33,000	17,995	478	258	ND	1	ND	ND	ND	ND
	SC-A3C	390	62	251	17	ND	8	ND	7	ND	ND
	SC-A8B	321	33	20	188	ND	ND	ND	ND	ND	ND
	SC-A8C	298	35	23	8	ND	12	ND	4	ND	ND
Aromas/ Purisima F	Polo Grounds PW	265	21	18	181	0.4	ND	ND	ND	0.3	ND
	Aptos Jr. High 2 PW	301	31	28	181	0.9	0.9	ND	ND	ND	ND
	Country Club PW	311	34	18	6	0.4	7.5	6	4	ND	ND
	Bonita PW	287	27	21	4	0.4	9.3	11	3	ND	ND
	San Andreas PW	242	21	10	5	0.7	17.5	16	2	ND	ND
	Seascape PW	288	20	34	6	0.3	15	16	1	ND	ND
Purisima F	CWD-4 PW	30	30	0	0	ND	12	ND	25	ND	ND
	CWD-12 PW	310	24	0	0	ND	ND	ND	1.2	ND	ND

Aquifer Unit	Well Name	Total Dissolved Solids, mg/L	Chloride, mg/L	Iron, µg/L	Manganese, µg/L	Arsenic, µg/L	Chromium (Total), µg/L	Chromium VI, µg/L	Nitrate as Nitrogen, mg/L	Perchlorate, µg/L	Organic compounds
	Minimum Threshold	**1,000**	**250**	**300**	**50**	**10**	**50**	**NA**	**10**	**6**	**various**
	SC-A2RA*	28,947	14,259	1,019	1,608	ND	ND	ND	ND	ND	ND
	SC-A8A*	15,174	7,258	380	3,633	ND	6	ND	1	ND	ND
Purisima DEF	SC-8RD	319	28	5	9	ND	ND	ND	2	ND	ND
	SC-9RE	507	28	46	57	ND	ND	ND	ND	ND	ND
	SC-A1A	224	28	1842	57	ND	ND	ND	ND	ND	ND
	T. Hopkins PW	355	46	33	106	2.3	2.4	ND	ND	ND	ND
Purisima BC	Ledyard PW	363	35	98	12	0.2	0.2	ND	ND	ND	ND
	Madeline 2 PW	408	34	187	10	ND	ND	ND	ND	ND	ND
	Aptos Creek PW	463	40	405	412	4	ND	ND	ND	ND	ND
	SC-23A	272	20	530	12	ND	ND	ND	ND	ND	ND
	SC-8RB	433	14	87	10	ND	ND	ND	2	ND	ND
	SC-9RC	381	27	16	9	ND	ND	ND	ND	ND	ND
Purisima A	30th Ave Shallow (3)	822	56	107	1,231	NT	NT	NT	ND	NT	NT
	Pleasure Point Shallow	288	37	106	119	NT	NT	NT	ND	NT	NT
	Estates PW	465	45	212	99	0.2	0.2	ND	ND	ND	ND
	Garnet PW	619	81	1,400	416	ND	ND	ND	ND	ND	ND
	Tannery 2 PW	574	60	224	140	0.18	ND	ND	ND	ND	ND

Aquifer Unit	Well Name	Total Dissolved Solids, mg/L	Chloride, mg/L	Iron, µg/L	Manganese, µg/L	Arsenic, µg/L	Chromium (Total), µg/L	Chromium VI, µg/L	Nitrate as Nitrogen, mg/L	Perchlorate, µg/L	Organic compounds
	Minimum Threshold	**1,000**	**250**	**300**	**50**	**10**	**50**	**NA**	**10**	**6**	**various**
	Rosedale 2 PW	496	44	715	255	0.18	ND	ND	ND	ND	ND
	Beltz #8 PW	448	51	1478	178	2	ND	ND	ND	ND	ND
	Beltz #9 PW	447	50	47	747	200	ND	ND	ND	ND	ND
	SC-3RC	461	46	63	36	ND	ND	ND	ND	ND	ND
	SC-5RA	534	55	2,778	180	ND	ND	ND	ND	ND	ND
	SC-9RA	390	15	14,424	19	ND	ND	ND	ND	ND	ND
	SC-10RA	349	29	223	522	ND	ND	ND	ND	ND	ND
	SC-22A	419	20	502	540	ND	ND	ND	ND	ND	ND
Purisima A/AA	Beltz #10 PW	621	58	836	277	2	ND	ND	ND	ND	ND
Purisima AA	SC-10RAA	231	10	93	72	ND	ND	ND	ND	ND	ND
	SC-22AAA	579	57	21	36	ND	ND	ND	ND	ND	ND
	Coffee Lane Deep	928	41	8	134	NT	NT	NT	ND	NT	NT
	Pleasure Point Deep	610	22	553	208	NT	NT	NT	ND	NT	NT
	Thurber Lane Shallow	No samples collected since 2006									
	Schwan Lake	400	91	316	113	NT	NT	NT	ND	NT	ND
Purisima	O'Neill Ranch PW	402	34	651	281	0.18	ND	ND	ND	3	ND

Aquifer Unit	Well Name	Total Dissolved Solids, mg/L	Chloride, mg/L	Iron, µg/L	Manganese, µg/L	Arsenic, µg/L	Chromium (Total), µg/L	Chromium VI, µg/L	Nitrate as Nitrogen, mg/L	Perchlorate, µg/L	Organic compounds
	Minimum Threshold	**1,000**	**250**	**300**	**50**	**10**	**50**	**NA**	**10**	**6**	**various**
AA/Tu	Beltz #12 PW	472	33	1,021	354	ND	ND	ND	ND	ND	ND
Tu	SC-18RAA	243	18	64	77	ND	ND	ND	ND	ND	ND
	Thurber Lane Deep	No samples collected since 2006									

NA = State Water Resources Control Board is still developing the maximum contaminant level for Chromium VI

ND = non-detect; NT = not tested

* well impacted by seawater intrusion therefore measurable objective is the same as the seawater intrusion measurable objective.

3.8 Land Subsidence Sustainable Management Criteria

3.8.1 Undesirable Results - Land Subsidence

The sustainability indicator is not applicable in the Santa Cruz Mid-County Basin as an indicator of groundwater sustainability and therefore no SMC are set. Section 2.2.2.5: Land Subsidence provides the evidence for subsidence's inapplicability as an indicator of groundwater sustainability. Even though the indicator is not applicable, a statement of significant and unreasonable subsidence caused by lowering of groundwater levels was discussed by the GSP Advisory Committee and is included below:

> *Any land subsidence caused by lowering of groundwater levels occurring in the basin would be considered significant and unreasonable.*

3.8.2 Minimum Thresholds - Land Subsidence

Subsidence is not applicable in the Santa Cruz Mid-County Basin as an indicator of groundwater sustainability and therefore no minimum thresholds are set.

3.8.3 Measurable Objectives - Land Subsidence

Land subsidence is not applicable in the Santa Cruz Mid-County Basin as an indicator of groundwater sustainability and therefore no measurable objectives or interim milestones are set.

3.9 Depletion of Interconnected Surface Water Sustainable Management Criteria

Development of sustainable management criteria for depletion of interconnected surface water is based on the only shallow well and associated streamflow data available in the Basin. Figure 3-3 shows the monitoring features concentrated along the lower Soquel Creek where the closest municipal pumping center occurs to surface water. From these data and other studies, it is understood that late summer streamflow in the mainstem of Soquel Creek between its forks and the USGS streamflow gauge is influenced by many other factors in addition to contributions by groundwater. Annual rainfall, flows from the upper Soquel Creek watershed outside of the Basin, temperature and evapotranspiration individually have a much greater measurable influence on streamflow than groundwater pumping. For this reach of Soquel Creek, it has been concluded over several years of monitoring that there is not a direct measurable depletion of surface water flow correlated with municipal pumping. There are, however, indications that there is an indirect influence where shallow groundwater levels mimic deeper regional groundwater level trends, which have been influenced by municipal pumping. As these observations are made from a few wells on the lower Soquel Creek only, further study as part of GSP implementation will revise the current understanding. This might necessitate a future change in the sustainable management criteria for this sustainability indicator.

3.9.1 Undesirable Results - Depletion of Interconnected Surface Water

Significant and unreasonable depletion of surface water due to groundwater extraction, in interconnected streams supporting priority species, would be undesirable if there is more depletion than experienced since the start of shallow groundwater level monitoring through 2015.

3.9.1.1 Groundwater Elevations as a Proxy for Depletion of Interconnected Surface Water Minimum Thresholds

The metric for depletion of interconnected surface water is a volume or rate of surface water depletion. This is a very difficult metric to quantify in the Basin since the depletion of interconnected surface water by municipal groundwater extraction is so small that it is not possible to directly measure through changes in streamflow. The SGMA regulations allow for the use of groundwater elevations as a proxy for volume or rate of surface water depletion. To use a groundwater elevation proxy there must be significant correlation between groundwater elevations and the sustainability indicator for which groundwater elevation measurements are to serve as a proxy. Significant correlation is difficult to prove because depletion of surface water by groundwater extractions is so small compared to the other streamflow factors mentioned in Section 3.9 above, and is not directly measurable in the streamflow. Even though changes in streamflow from groundwater extractions cannot be directly measured, those changes can be simulated by a model.

An example of the complexities of showing significant correlation can be seen at the Main Street SW 1 shallow well. Data collected at the well site show precipitation and creek stage to have much greater impact on shallow groundwater levels than nearby municipal pumping. Since undesirable results are related to significant and unreasonable depletion of surface water due to groundwater extraction, future monitoring and analysis efforts need to specifically identify groundwater level changes resulting from groundwater extractions. If groundwater levels are responding to factors other than groundwater extractions, it will be challenging to determine whether minimum thresholds are not being met due to just groundwater extractions or because of these other factors.

If groundwater elevations connected to streams are kept at or above current elevations, which are close to record high levels, there will be no more depletion in surface water than experienced over the past 18 years. Essentially, the minimum thresholds seek to maintain a groundwater gradient toward the stream by controlling groundwater levels near the stream. Lower minimum thresholds than those included in this GSP may also prevent increased surface water depletion. However, as there is uncertainty around this relationship, higher minimum thresholds have initially been selected to be more conservative for habitat and sensitive species.

In an effort to show correlation between volume or rate of streamflow and groundwater level proxies for minimum thresholds, groundwater model output is used to estimate the relationship. The groundwater model is used to estimate streamflow depletion from pumping during the 2001-2015 period, which is the period where shallow groundwater level data are available and from which minimum thresholds are derived. The streamflow depletion estimate is derived by testing the sensitivity of simulated groundwater contribution of streamflow to pumping within the Basin. It is important to acknowledge that data quantifying flows between the stream and shallow groundwater are not available for calibration so there is high uncertainty of the magnitude of simulated flows between stream and aquifer calculated by the model. Adding to the uncertainty of the estimate, this sensitivity test is outside the bounds of real world conditions (i.e., removing all Basin pumping) under which the model is calibrated to shallow groundwater elevation and streamflow data. Due to this uncertainty, the model results represent an estimate of historical streamflow depletion, but the model result value should not be used as quantitative criteria.

Figure 3-15 shows the sensitivity results of groundwater contribution to streamflow from changes in Basin pumping. This analysis is for the entire Soquel Creek watershed during minimum flow months. Removing all modeled private domestic, agricultural, and municipal pumping within the Basin, while continuing pumping outside of the Basin, results in an increased groundwater contribution to Soquel Creek of up to 1.4 cubic-feet per second (cfs) for the 2001-2015 modeled period. This is an estimate of the relationship between the groundwater level proxies for minimum thresholds and streamflow depletion, but it is too uncertain to represent a value to specify as a minimum threshold. For this reason and due to the difficulty measuring streamflow depletion from pumping, it is appropriate to use a groundwater level proxy to prevent the undesirable result of increases in streamflow depletion above what occurred from 2001-2015.

The estimate of historical streamflow depletion may be revised in the future as more information becomes available as a result of more refined modeling, collection of additional monitoring data, or future testing of aquifer and stream properties. In addition, future methods or use of new information may be able to better quantify current depletion from pumping. In order to assess whether undesirable results have occurred, values estimated by different methods or new estimates should be compared to streamflow depletion for 2001-2015 estimated in a consistent manner as opposed to the 1.4 cfs estimated above.

Sections 3.3.4.1 and 3.3.4.2 discuss data gaps associated with establishment of minimum thresholds for depletion of interconnected surface water and the plan to address them.

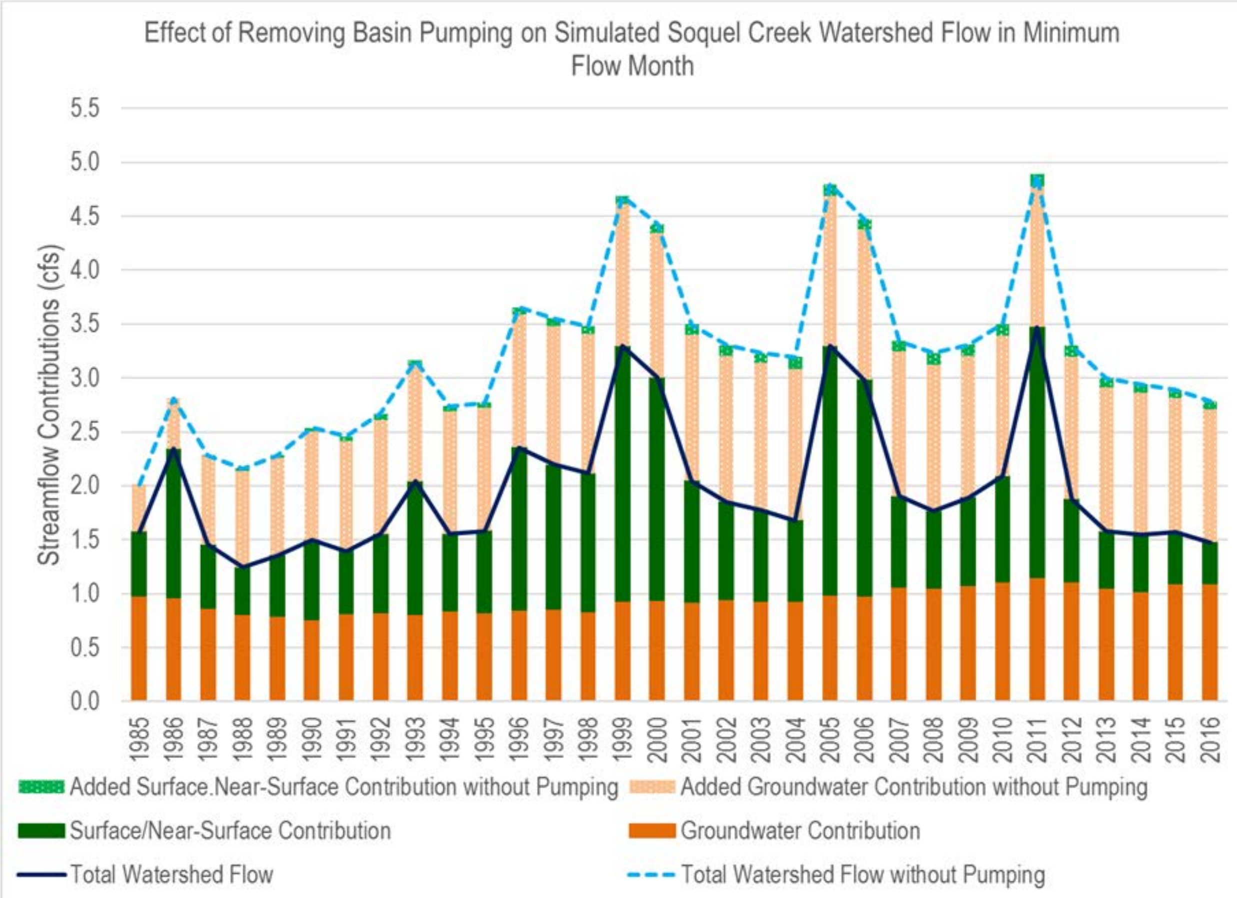


Figure 3-15. Simulated Contributions to Streamflow for Soquel Creek Watershed with and without Historical Pumping

3.9.1.2 Criteria for Defining Depletion of Interconnected Surface Water Undesirable Results

There was support in the Surface Water Working Group to move towards managing shallow groundwater so that interconnected streams have gaining flow from groundwater and are not losing flow to groundwater. Additionally, ensuring that streams do not experience more depletion than has occurred since the start of shallow groundwater level monitoring was another key condition. The Surface Water Working Group elected to take a conservative approach to defining undesirable results where any shallow RMP's groundwater elevation falling below its minimum threshold would be an undesirable result.

It should be noted that since the direct relationship between impacts on sensitive species or habitat and shallow groundwater levels has not been established, current observations do not indicate shallow well groundwater levels below minimum thresholds have a significant and unreasonable impact on sensitive species or habitat. Separate from the GSP, MGA member agencies are monitoring streams within the Basin for fish abundance and habitat conditions. Where feasible, these observations will be compared to groundwater levels and streamflow to attempt to establish a better understanding of the relationships between them.

3.9.1.3 Potential Causes of Undesirable Results

As mentioned previously, there are many factors aside from groundwater that effect streamflow in Soquel Creek and likely other streams in the Basin. Undesirable results for depletion of interconnected surface water in the context of the GSP are related purely to the extraction of groundwater from the Basin. Increased pumping is a potential cause of undesirable results that may manifest itself in reduced groundwater levels in both the shallow and deeper underlying Purisima aquifers. Shallow groundwater data show a relationship with long-term trends in groundwater levels of deeper underlying Purisima aquifers resulting from changes in pumping. However, deep aquifer pumping by municipal wells near Soquel Creek has not found any direct measurable impact on creek flows in studies done to date (HydroMetrics, 2015; HydroMetrics, 2016; HydroMetrics, 2017). Long-term impacts from this pumping on streamflow are being studied as part of the monitoring program outlined in Section 3,4,1,1 of this GSP.

From well permit records it is known there are private domestic wells screened in shallow alluvial sediments and upper Purisima units that are directly connected to surface water. It is possible these wells may have a larger impact on shallow groundwater levels than municipal pumping from the deeper Purisima aquifers. A sensitivity run documented in the model calibration report in Appendix 2-F assumes that non-municipal pumping occurs in the stream alluvium as opposed to the underlying aquifer unit and shows there would be impacts on shallow groundwater levels of pumping the shallow aquifer as opposed to the deeper aquifer.

3.9.1.4 Effects on Beneficial Users and Land Use

Undesirable results for the depletion of interconnected surface water from groundwater extraction will affect aquatic systems mainly during the late summer. Under low flow conditions, there is a direct linear relationship between streamflow and the amount of suitable habitat. Reduction of flow directly reduces the amount of suitable rearing habitat for steelhead, by reducing the amount of wetted area, stream depth, flow velocity, cover, and dissolved oxygen. Reduced flow can also result in increased temperature. In extreme conditions, dewatering of channel segments eliminates the ability of the fish to move to more suitable areas and can cause outright mortality. In even more extreme conditions lowering of groundwater levels below the root zone of riparian vegetation can result in the loss of that vegetation.

3.9.2 Minimum Thresholds - Depletion of Interconnected Surface Water

Using shallow groundwater levels adjacent to streams as a proxy for surface water depletion, undesirable results will occur if the average monthly groundwater levels fall below the minimum threshold, which is established as the highest seasonal low elevation during below- average rainfall years from the start of monitoring through 2015.

3.9.2.1 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

Information used to establish the depletion of interconnected surface water minimum thresholds and measurable objectives include:

- Definitions of significant and unreasonable conditions and desired groundwater elevations discussed during Surface Water Working Group and GSP Advisory Committee meetings.
- Depths, locations, and logged lithology of existing wells used to monitor shallow groundwater levels near creeks.
- Historical groundwater elevation data from shallow wells monitored by SqCWD.
- Streamflow and stream stage data collected by the USGS, SqCWD, County of Santa Cruz, and Trout Unlimited.
- Past hydrologic reports, including annual reports for SqCWD's Soquel Creek Monitoring and Adaptive Management Plan.

The approach for developing minimum thresholds for the depletion of interconnected surface water sustainability indicator is to select groundwater elevations in shallow RMPs below which significant and unreasonable depletion of surface water due to groundwater extractions would occur.

Initially, minimum thresholds were proposed as the lowest groundwater level measured in the shallow wells over the period of record since those years did not appear to have significant or unreasonable conditions. The Surface Water Working Group, however, selected a more conservative minimum threshold due to uncertainty in the relationship between shallow groundwater levels and groundwater contributions to creek flow. It should be noted that there was not consensus around use of specific minimum thresholds, and that these thresholds may need to be adjusted in future updates to the GSP as better monitoring data or more refined modeling results become available.

Based on Surface Water Working Group input, minimum thresholds for shallow groundwater elevations in the vicinity of interconnected streams are the highest seasonal-low groundwater elevation during below-average rainfall years, over the period from the start of shallow groundwater level monitoring through 2015. The years after 2015 are not included because 2016 was an average rainfall year and 2017 was extremely wet, which increased overall Basin shallow groundwater elevations above all previous levels.

3.9.2.2 Depletion of Interconnected Surface Water Minimum Thresholds

Table 3-21 lists the minimum thresholds for RMPs currently available to monitor depletion of interconnected surface water. Hydrographs showing historical groundwater elevation data compared to the minimum threshold are provided in Appendix 3-D. An example of one of the RMP hydrographs with its minimum threshold is shown on Figure 3-16.

Table 3-21. Minimum Thresholds and Measurable Objectives for Representative Monitoring Points for Depletion of Interconnected Surface Water

Aquifer Unit	Well Name	Minimum Threshold	Measurable Objective
		Groundwater Elevation, feet above mean sea level	
Shallow Groundwater	Balogh	29.1	30.6
	Main St. SW 1	22.4	25.3
	Wharf Road SW	11.9	12.1
	Nob Hill SW 2	8.6	10.3
Purisima A	SC-10RA	68	70

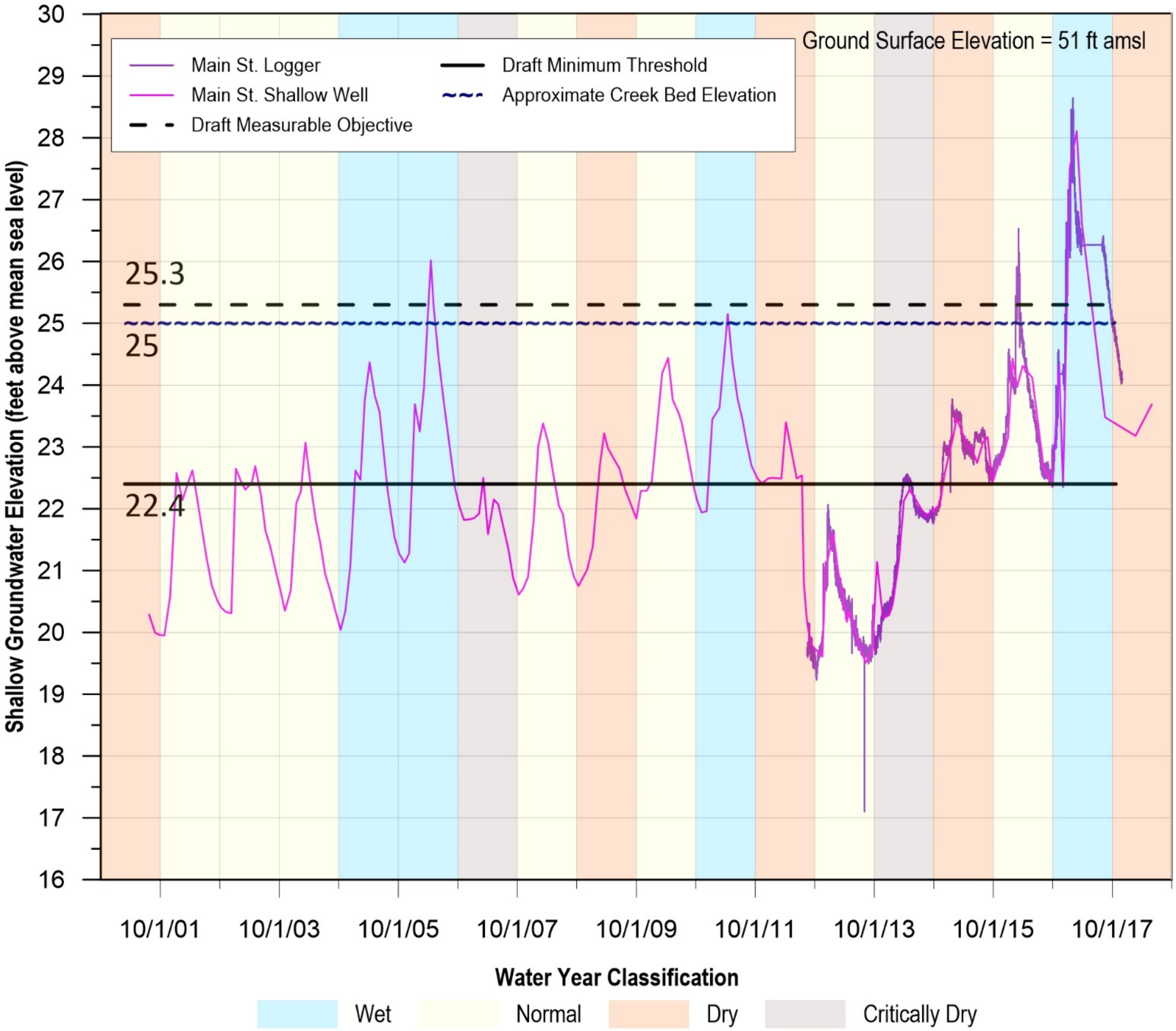


Figure 3-16. Main Street SW 1 Shallow Monitoring Well Hydrograph with Minimum Threshold and Measureable Objective

3.9.2.3 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Figure 3-11 shows proxy shallow groundwater elevations in relation to both individual minimum thresholds and other sustainability indicator minimum thresholds that use groundwater levels as a metric. Proxy groundwater elevation minimum thresholds decline in elevation downstream thereby following the surface elevation and avoiding unnatural groundwater elevations that would not be physically attainable. There are also no conflicts with other sustainability indicator minimum thresholds as upper Purisima unit RMPs for other indicators close to the creek were purposely avoided because the groundwater elevations for the depletion of interconnected surface water are much more stringent than for other indicators.

3.9.2.4 Effect of Minimum Thresholds on Neighboring Basins

None of the creeks in the Basin are upstream of any of the neighboring basins. Therefore, there will be no effects on those basins from depletion of interconnected surface water minimum thresholds.

3.9.2.5 Effects of Minimum Thresholds on Beneficial Users and Land Uses

Maintenance of interconnected surface water minimum thresholds will not have any negative effects on beneficial users and land uses in the Basin.

Rural residential and agricultural land uses and users. With the minimum thresholds for depletion of interconnected surface water being similar to shallow groundwater levels over the past few years, there will be no declines in shallow groundwater which is a general benefit for private domestic and agricultural well groundwater users. There is a possibility that when additional studies are conducted to improve understanding of this sustainability indicator, restrictions on pumping of wells close to streams may be instituted for wells screened in shallow alluvium that have a direct connection to the stream. The few existing older shallow wells could be replaced by deeper wells screened in the deeper units to minimize any direct impact on flow. There are no other anticipated effects on rural residential or agricultural land uses from the minimum thresholds.

Urban land uses and users. Where streams and creeks flow through urban areas of the Basin, there will be a small increase to no change in shallow groundwater levels. Since there are no major changes in shallow groundwater levels expected in urban areas, the depletion of interconnected surface water minimum thresholds will not negatively impact urban land uses. Urban users of groundwater, the City of Santa Cruz and SqCWD, may be negatively impacted since some of the municipal production wells that are part of their water supply are located near Soquel Creek and potential restrictions on pumping to meet minimum thresholds in RMP shallow wells may impact their ability to provide drinking water to their customers. For example, SqCWD groundwater extractions from the Purisima A and AA-units, and Tu aquifer that occur below Soquel Creek are approximately 2,000 acre-feet per year and account for about 50% of the water served to its customers.

Ecological land uses and users. The main benefit of these minimum thresholds is to protected species and GDEs in streams connected to groundwater. Meeting minimum thresholds effectively increases overall hydraulic gradients from the shallow groundwater to the streams allowing for more groundwater to flow into the stream.

3.9.2.6 Relevant Federal, State, or Local Standards

No explicit federal, state, or local standards exist for depletion of interconnected surface water. However, both state and federal endangered species provisions call for the protection and restoration of conditions necessary for steelhead and coho salmon habitat in Soquel and Aptos Creeks.

3.9.2.7 Method for Quantitative Measurement of Minimum Thresholds

Groundwater elevations in RMPs will be directly measured to determine where groundwater levels are in relation to minimum thresholds. Groundwater level monitoring will be conducted in accordance with the monitoring plan outlined in Section 3.3. All RMPs will be equipped with continuous data loggers.

In the future, as the MGA increases its understanding of groundwater and surface water interconnections along other reaches of Soquel Creek and other streams, areas where measurable depletion from groundwater extraction may be identified. Where these conditions exist, RMPs to monitor streamflow will be added to the representative monitoring network.

3.9.3 Measurable Objectives - Depletion of Interconnected Surface Water

3.9.3.1 Measurable Objectives

Measurable objectives at RMPs are groundwater elevations greater than the minimum thresholds by the range in seasonal-low shallow elevations over the period of record through 2015. In all cases, this results in groundwater elevations that are higher than the creek bed elevation at each RMP. Increased hydraulic gradient increases groundwater contributions to streamflow.

The range in seasonal-low elevations represents known change in seasonal-low elevations that can occur and includes the years when overall groundwater elevations in the Basin have increased. The range effectively provides the operational flexibility that measurable objectives are intended to provide.

3.9.3.2 Interim Milestones

Groundwater elevations as proxy interim milestones are based on model simulations of projects and management actions to prevent undesirable results related to seawater intrusion will also raise shallow groundwater levels along Soquel Creek over time. These model results are shown in Section 4 describing the expected benefits of the projects.

Interim milestones are established at each of the shallow RMPs with proxy groundwater elevations for surface water depletion. Since the groundwater elevation proxies for surface water depletion are compared to minimum groundwater elevations each year and the minimums vary from year to year due to climate, the interim milestones are based on minimum simulated groundwater elevations at the wells over five-year periods in order to be less dependent on climate simulated for a specific year. The interim milestones for Water Years 2025, 2030, and 2035 are based on the minimum model simulated groundwater elevations over Water Years 2021-2025, Water Years 2026-2030, and 2031-2035, respectively.

Interim milestones are based on model simulation of Pure Water Soquel because the expected benefits of that project are to raise groundwater levels above or approaching measurable objectives at shallow wells, as described in Section 4.

If modeled groundwater levels for 2021- 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. Table 3-22 summarizes the interim milestone for each RMP.

Table 3-22. Interim Milestones for Depletion of Interconnected Surface Water Groundwater Elevation Proxies

Representative Monitoring Point	Minimum Threshold (feet mean seal level)	Measurable Objective (feet mean sea level)	Interim Milestone 2025 (feet mean sea level)	Interim Milestone 2030 (feet mean sea level)	Interim Milestone 2035 (feet 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

Section 4 Contents

Tables

Figures

4 PROJECTS AND MANAGEMENT ACTIONS

DWR regulations require each GSP to include a description of projects and management actions necessary to achieve the basin sustainability goal. This must include projects and management actions to respond to changing conditions in the Basin.

In November 2018, the MGA Board discussed the MGA's role in implementing projects and management actions and agreed that the most efficient approach to project and management action implementation was to have the MGA member agencies perform this function. A major rationale for this decision was the long-standing engagement of MGA member agencies in groundwater management and water supply reliability planning work. In particular, both the City of Santa Cruz Water Department (SCWD) and the Soquel Creek Water District (SqCWD) have evaluated a number of supplemental supply options over the last five years, and in several cases work has proceeded far enough to make it significantly more efficient for these agencies to continue their efforts rather than switching project implementation actions to the MGA.

Projects and management actions discussed in this section are in the process of being developed to address sustainability goals, measurable objectives, and undesirable results identified for the Basin in Section 3. The primary applicable undesirable result that must be avoided is seawater intrusion. In addition, surface water depletions and impacts to groundwater dependent ecosystems (GDEs) were separately evaluated. The GSP's approach to address seawater intrusion is anticipated to provide ancillary benefits to interconnected surface waters and GDEs. Because the SCWD water system relies heavily on surface water, an additional focus of several of the management actions discussed in this section is creation of a supplemental drought supply to improve the reliability of the Santa Cruz water supply. SCWD is pursuing several alternative approaches for storing available wet season surface water flows in regional aquifers for eventual use in augmenting supply during dry conditions. SCWD acknowledges that the operation of its existing groundwater system in the Basin and the design and operation of any new facilities for groundwater storage and recovery would need to function in a manner that supports Basin sustainability.

Each MGA member agency will manage the permitting and other specific implementation oversite for its own projects. Inclusion in this GSP does not forego any obligations under local, state, or federal regulatory programs. While the MGA does have an obligation to oversee progress towards groundwater sustainability, it is not the primary regulator of land use, water quality, or environmental project compliance. It is the responsibility of the implementing agency to ensure that it is working with outside regulatory agencies to keep its projects and management actions in compliance with all applicable laws. That said, the MGA may choose to collaborate with regulatory agencies on specific overlapping interests such as water quality monitoring and oversight of projects developed within the Basin.

Section 4 is presented in three groups to provide the clearest description of how and when projects and management actions will be taken to reach sustainability.

Baseline Projects and Management Actions (Group 1)

Activities in Group 1 are considered existing commitments by MGA member agencies. These include projects and management actions that are currently being implemented and are expected to continue to be implemented, as needed, to assist in achieving the sustainability goal throughout the GSP implementation period. In the groundwater modeling scenarios, the Group 1 projects and management actions are incorporated into baseline conditions. As shown in modeling results of the baseline condition for seawater intrusion presented later in this section, Group 1 projects and management actions, by themselves, are not sufficient to achieve groundwater sustainability (see Table 4-1).

Projects and Management Actions Evaluated Against the Sustainable Management Criteria (Group 2)

Activities in Group 2 have been developed and thoroughly vetted by MGA member agencies and are planned for near-term implementation by individual member agencies. The MGA used an integrated groundwater/surface water model (model) to evaluate the Group 2 projects against the Sustainable Management Criteria to determine if they contribute to achieving sustainability. The expected benefits of each of the projects presented in Section 4.2 as informed by the groundwater modeling simulations and documented in the model simulations report (Appendix 2-I), show that the implementation of a combination of these projects will be sufficient to achieve and maintain sustainability even under climate change scenarios. Therefore, ongoing implementation of Group 1 activities, coupled with the implementation of Group 2 projects and management actions, are required to reach sustainability to comply with SGMA (see Table 4-1).

Identified Projects and Management Actions That May Be Evaluated in the Future (Group 3)

The MGA's analysis indicates that the ongoing implementation of Group 1 and the added implementation of Group 2 projects and management actions will bring the Basin into sustainability. However, if one of the projects and management actions required for sustainability in Group 2 either fails to be implemented or does not have the expected results, further actions will be required to achieve sustainability. In that case, appropriate projects and/or management actions will be chosen from those listed under Group 3. As work on supplemental water supply and resource management efforts is ongoing, it may be the case that additional projects will be identified and added to the list in future GSP updates (see Table 4-2).

The specific Group 3 activity selected would be based on factors such as size of the water shortage, speed of implementation, scale of regulatory and political hurdles, and the metrics of success achieved in basin sustainability. The level of detail provided for Group 3 is significantly less detailed than Groups 1 and 2 because the activities listed are not currently planned for implementation.

Table 4-1. Projects and Management Actions (Groups 1 and 2)

Description	Agency	Category	Status	Anticipated Timeframe[1]
Group 1 – Baseline Projects and Management Actions				
Water Conservation and Demand Management	All	Mgmt. Actions	Ongoing	2020-2070 adaptive management
Installation and Redistribution of Municipal Groundwater Pumping	SCWD; SqCWD	Mgmt. Actions & Projects	Ongoing	2020-2070 adaptive management

Description	Agency	Category	Status	Anticipated Timeframe[2]
Group 2 – Projects and Management Actions Planned to Reach Sustainability				
Pure Water Soquel	SqCWD	Project	Permitting	2020-2022 development 2023-2070 operations & adaptive management
Aquifer Storage and Recovery (ASR)	SCWD	Project	Pilot Testing	2021-2027 development 2021-2070 operations & adaptive management
Water Transfers / In Lieu Groundwater Recharge	SCWD ; SqCWD	Project	Pilot Testing	2020-2025 development 2025-2070 operations & adaptive management
Distributed Storm Water Managed Aquifer Recharge (DSWMAR)	SCCo; SqCWD	Project	Few current facilities; ongoing assessment	Timing is project specific; ongoing operations & adaptive management

1. SGMA's required planning implementation horizon is 50 years.
2. Phased projects may include overlapping periods of development and operations. Adaptive management is ongoing during implementation.

Table 4-2. Identified Potential Future Projects and Management Actions (Group 3)

Group 3 - Identified Projects and Management Actions That May Be Evaluated in the Future		
Description	Category	Comment
Recycled Water – Groundwater Replenishment and Reuse (GRR)	Project	A new or expanded centralized GRR project could be developed by SCWD, the Soquel Creek Water District or as a joint project of these agencies. SCWD Recycled Water Facilities Planning Study (2018) identifies a GRR project as a future (mid-term) possibility requiring additional studies to confirm feasibility to meet drought shortfall needs and/or support basin sustainability goals in either or both the Mid-County and Santa Margarita groundwater basins. In addition, the Soquel Creek Water District Feasibility Study (2017) and the Pure Water Soquel EIR (2018) also identify expansion opportunities, if needed. Future need anticipated to be assessed as GSP Implementation proceeds.
Recycled Water – Surface Water (Reservoir) Water Augmentation	Project	Reservoir Augmentation would use advanced treated Santa Cruz WWTF effluent, to replenish Santa Cruz's Loch Lomond Reservoir. SCWD evaluated this option in its 2018 Recycled Water Facilities Planning Study and did not identify it as a preferred alternative. Conceptually this approach could serve to augment supply to the Basin as well as improve the reliability of Santa Cruz's water supply. Future need anticipated to be assessed as GSP Implementation proceeds.
Recycled Water – Direct Potable Reuse	Project	Current state regulations do not allow the introduction of advanced treated recycled water directly into a public water system. State drinking water and public health regulatory agencies continue to assess the possible framework for the regulation of potable reuse projects. As state regulations develop, the feasibility and potential future need for this option will continue to be evaluated.
Groundwater Pumping Curtailment and/or Restrictions	Mgmt. Action	Potential policy to curtail and/or restrict groundwater extractions from areas at high risk of seawater intrusion or surface water depletions would be considered if the planned Projects and Management Actions are insufficient to reach and/or maintain sustainability and one or more sustainability indicator is likely to dip below the minimum threshold by 2040.
Local Desalination	Project	Previously considered by SCWD in partnership with SqCWD. This is no longer being actively pursued, but given the Basin's proximity to the Pacific Ocean this option will continue to be a potential option.
Regional Desalination	Project	DeepWater Desal LLC., is a private company seeking to establish a regional supply facility in Moss Landing. It would produce an estimated 25,000 acre-fee per year (22 million gallons per day) of treated desalinated water available for purchase by local agencies.

4.1 Baseline Projects and Management Actions (Group 1)

4.1.1 Water Conservation and Demand Management

As described in Section 2, the MGA's member water agencies have a full range of water conservation programs in place and have actively and successfully implemented policies and programs promoting and incentivizing water conservation and efficient water use. SCWD's and SqCWD's residential water usage (gallons capita per day) are among the lowest in the state. All MGA member agencies participate in the Water Conservation Coalition of Santa Cruz County (watersavingtips.org). The Coalition serves as a regional information source for county-wide water reduction measures, rebates, and resources.

Soquel Creek Water District's Water Demand Offset (WDO) program is a targeted water conservation program developed to mitigate the water demand of new and expanded development in Soquel Creek Water District's service area. This management action originally required new development to be "net neutral" to ensure that each new project contributed toward conservation projects proportional to their expected new water demand. Development project applicants have met this requirement through direct replacement of inefficient water fixtures for SqCWD customers or through payment into a SqCWD conservation fund that supports similar demand management projects and programs. Since 2013, WDO requires new development to offset 200% of their project's expected water demand so that new development will actually reduce water use in the Basin. Participation in this program is required to be eligible for SqCWD will-serve approval and installation of the new water service. Will-serve letters are also required to obtain building permits from land use jurisdictions where the new development is located.

The City of Santa Cruz Water Department (SCWD) uses fees paid by developers to support a robust rebate program that, along with its "retrofit on resale" program has resulted in a significant reduction in water demand from current customers and a long term demand forecast that is flat rather than increasing. The County of Santa Cruz (County), in order to promote more efficient water use in rural areas, adopted code requirements that all small water systems meter and report monthly water production beginning in October 2015. Additionally, by October 2017, all small water systems with 15 or more connections were required to install individual meters on each connection to be able to track individual water use and potentially excessive usage.

4.1.1.1 Project Implementation Discussion

Water Conservation and Demand Management strategies use a variety of management actions to reduce water demand that then results in reduced groundwater pumping. Depending on where pumping reductions occur, groundwater levels near the coast may increase, which results in reducing the threat of seawater intrusion, and surface water depletions may also be reduced, which supports maintaining or enhancing groundwater levels where groundwater dependent ecosystems exist. These management actions are implemented, planned to continue, and will continue to evolve with technological advances and future legislative requirements to reduce regional water demand.

Management actions to reduce water demand were initially implemented in the 1990s and there is no plan to end these successful water use reduction strategies. Benefits are monitored with the Basin-wide groundwater monitoring network by comparing groundwater levels and groundwater quality against past observations. Costs of conservation and demand management programs are built into MGA member agency ongoing budgetary commitments and are not anticipated to be passed on to the MGA.

As water conservation and demand management projects and management actions within the Basin continue to evolve over time, any significant changes will be publicly noticed as necessary by MGA member's governing bodies. Existing California state law gives water districts the authority to implement water conservation programs. Local land use jurisdictions have police powers to develop similar permitting programs to conserve water. The Sustainable Groundwater Management Act of 2014 grants the MGA legal authority to pass regulations necessary to achieve sustainability. MGA member agencies are committed to successful implementation of their conservation programs and have among the lowest water consumption rates in California.

4.1.2 Planning and Redistribution of Municipal Groundwater Pumping

Municipal water agencies serve the majority of the population within the Basin. Although surface water from the Santa Cruz water system serves some customers in the Basin, all municipal groundwater supplies that are produced within the Basin come solely from groundwater pumped by MGA member agencies within their respective service areas.

Prior to SGMA, regional groundwater management planning identified the need to move groundwater production further from the coast to reduce the threat of seawater intrusion related to pumping impacts from municipal wells. MGA member agencies developed and have already begun implementing plans to move municipal groundwater production further inland to reduce these pumping impacts. The SCWD has completed its planning and well development project with the installation of its Beltz 12 well and supporting infrastructure at its Research Park facility (SCWD 2012). Soquel Creek Water District's Well Master Plan (ESA 2010), identified moving pumping further inland by developing four new groundwater production well locations and the conversion of an existing irrigation well at a fifth location. The Polo Grounds irrigation well conversion in Aptos was completed in 2012. Two of the four new well sites, O'Neill Ranch in Soquel (completed in 2015) and Granite Way in Aptos (anticipated completion in 2019) have been constructed. Two remaining production well sites at Cunnison Lane in Soquel and Austrian Way in Aptos have yet to be constructed.

MGA member agencies have also adjusted the timing, and pumping amounts from existing wells to redistribute pumping both vertically and horizontally within Basin aquifers. These efforts have been used to achieve more uniform drawdown of the Basin, to minimize localized pumping depressions, and reduce the Basin's susceptibility to seawater intrusion. In addition, in 2015 the

City of Santa Cruz and Soquel Creek Water District signed the Cooperative Monitoring and Adaptive Groundwater Management Agreement to more conservatively manage groundwater pumping in the shared aquifer units of the Basin. Redistribution of municipal pumping is designed to be paired with projects (such as Pure Water Soquel, In-Lieu Recharge, and ASR) as a way to rest and reduce pumping of coastal wells and be consistent with Basin sustainability goals to protect the groundwater supply against seawater intrusion; prevent overdraft within the Basin, and resolve problems resulting from prior overdraft; support reliable groundwater supply and quality to promote public health and welfare; maintain or enhance groundwater levels where groundwater dependent ecosystems exist; and maintain or enhance groundwater contributions to streamflow.

4.1.2.1 Implementation Discussion

Planning, municipal well construction at locations further from the coast, and redistribution of municipal groundwater pumping is used to reduce the ongoing threat of seawater intrusion within the Basin. These projects and management actions are implemented, planned to continue, and will continue to evolve as we learn more about Basin groundwater management and climate change. Additional well construction within the Basin will be publicly noticed and permitted as necessary by MGA member agencies. Redistribution of municipal groundwater pumping was initially implemented in 1995 and has improved with careful expansion of municipal production wells further from the coast. There is no plan to end these successful water production strategies which have made significant progress to reduce groundwater pumping depressions and improve groundwater levels at the coast. Benefits are monitored using municipal production well meters, the Basin-wide groundwater monitoring network, and data management systems to compare production impacts with groundwater levels and groundwater quality over time.

Redistribution of groundwater pumping is direct management of groundwater extraction. While these management actions don't reduce overall Basin groundwater production, they do allow municipal groundwater production to consider and respond to changes in groundwater levels across the portions of the Basin within municipal service areas. These groundwater production management strategies do not require an additional water source. Costs of planning, new municipal well construction, and redistribution of municipal groundwater pumping are or are anticipated to be built into the City of Santa Cruz's, Central Water District's, and Soquel Creek Water District's operational budgetary commitments that would be paid for through water rates and/or grant funds. These costs are not anticipated to be passed on to the MGA. Redistributed groundwater pumping has contributed to increased Basin groundwater levels and supports the additional GSP elements outlined in section 2.1.4 and the Basin's sustainability goals to protect groundwater supplies against seawater intrusion and maintain or enhance groundwater levels where groundwater dependent ecosystems exist.

4.2 Projects and Management Actions Planned to Reach Sustainability (Group 2)

4.2.1 Pure Water Soquel

4.2.1.1 Project Description

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 the Basin with approximately 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 Soquel Creek Water District's service area to mix with native groundwater. Purified water would contribute to the restoration of the groundwater 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 AFY of purified water (ESA 2018).

4.2.1.2 Measurable Objective

Use of advanced purified water made from highly treated wastewater as a source has a proven track record and is already widely used in California and elsewhere throughout the world as a water supply. Model results indicate that consistent and ongoing recharge of advanced purified water into the groundwater basin would create a barrier against further seawater intrusion and could be leveraged to shift groundwater production to improve sustainability throughout the entire Basin.

4.2.1.3 Circumstances for Implementation

Groundwater management policies that predate this GSP established protective groundwater elevations at 13 coastal monitoring well locations necessary to prevent seawater intrusion. Protective elevations have been included in this GSP as a sustainability indicator for seawater intrusion. Currently, protective elevations have been met at eight of the 13 coastal monitoring locations, which is an increase since these wells were installed in the mid-1980s. Projects identified by the MGA and its member agencies to improve Basin sustainability will be implemented to achieve and maintain protective elevations at all 13 well locations. Pure Water Soquel is included in Group 2 projects, along with Aquifer Storage and Recovery (ASR), Water Transfer/In Lieu Groundwater Recharge, and Distributed Storm Water Managed Aquifer Recharge as projects planned for near-term implementation by MGA partner agencies to reach Basin sustainability.

4.2.1.4 Public Noticing

PWS was developed from public input received during Soquel Creek Water District's Community Water Plan (CWP) to develop a timely solution to seawater intrusion. The PWS project was developed by staff and refined during Soquel Creek Water District's publicly noticed

Board of Director's meetings as well as community meetings, workshops during the development of the CWP and the evaluation of the PWS project. The project is also discussed at publicly noticed meetings of Soquel Creek Water District's Water Resources Management and Infrastructure Committee. CEQA environmental review of PWS was first publicly noticed through the State Clearinghouse in November 2016 and review completed in December 2018. Applicable PWS project permits will be publicly noticed for meetings of the issuing agencies, as required.

4.2.1.5 Overdraft Mitigation and Management Actions

The Santa Cruz Mid-County Basin (Basin 3-001 (DWR 2016)) is identified by the State of California as a high priority basin in critical overdraft (DWR 2019). Groundwater levels have recovered from critically low levels identified in the 1980s. However, seawater intrusion exists in several Basin locations and remains a significant threat to regional groundwater supplies as groundwater levels at five of the Basin's 13 key coastal monitoring wells remain below protective elevations. In 2018, groundwater levels declined between 0.4 feet to 4.0 feet at various Basin locations from all-time highs recorded in Water Year 2017. As the first line of defense along the coastline, the replenishment with advanced purified water will increase Basin groundwater levels and create a fresh water barrier to reduce the threat of further seawater intrusion into the Basin.

4.2.1.6 Permitting and Regulatory Process

Soquel Creek Water District completed the California Environmental Quality Act (CEQA) review for Pure Water Soquel in December 2018 and is undergoing the permitting phase of project implementation. Implementation could require several permits for construction and operations as described in the Pure Water Soquel Environmental Impact Report (EIR) (ESA 2018).

4.2.1.7 Time-table for Implementation

The Pure Water Soquel 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 complete in late 2022 with the project to come online in early 2023.

4.2.1.8 Expected Benefits

The Pure Water Soquel project is designed to replenish the Basin with approximately 1,500 acre-feet per year of advanced purified water into three locations in the Basin to increase groundwater elevations and create a seawater intrusion barrier (ESA 2018). The tertiary treatment portion of the project is also designed to produce an additional 300 acre-feet per year tertiary treated wastewater supply for reuse by the City of Santa Cruz suitable for non-potable landscape and other uses. PWS also supports in-lieu recharge in aquifer units and areas where water is not injected. In the simulation of PWS for the GSP, in-lieu recharge is facilitated by increasing pumping from the Purisima A and BC aquifer units that benefit from PWS injection to allow for pumping reductions in the Tu, Purisima F, and Aromas Red Sands aquifer units. Therefore, project benefits are expected to raise groundwater elevations at all of Soquel Creek Water District's coastal monitoring wells to prevent seawater intrusion and improve groundwater levels at shallow wells along Soquel Creek to prevent additional surface water depletions. Expected benefits will be evaluated using the existing monitoring well network and data management systems to compare groundwater levels over time.

A simulation of the PWS project under projected future climate conditions using the model (Appendix 2-I) demonstrates expected Basin sustainability benefits including raising average groundwater levels at coastal monitoring wells throughout Soquel Creek Water District's service area to reduce the risk of seawater intrusion (Figure 4-1 and Figure 4-2). The figures below show running five-year averages of simulated groundwater levels at representative monitoring points for seawater intrusion (section 3.3.3.3) in the SqCWD's service area. The simulated groundwater levels are compared to groundwater level proxies (section 3.6) for minimum thresholds (black dots) and measurable objectives (black dashes) adjusted for sea level rise.[1]

Without the project (yellow line labeled Baseline), five-year averages of simulated groundwater levels are projected to be below the minimum threshold in the aquifer units pumped by Soquel Creek Water District. 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. 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 4-5 in Section 4.2.3.8 below shows how pumping reduction from the 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.

[1] Projected sea level rise of 2.3 feet is added to the groundwater level proxies (see Section 3.6.2.1.1).

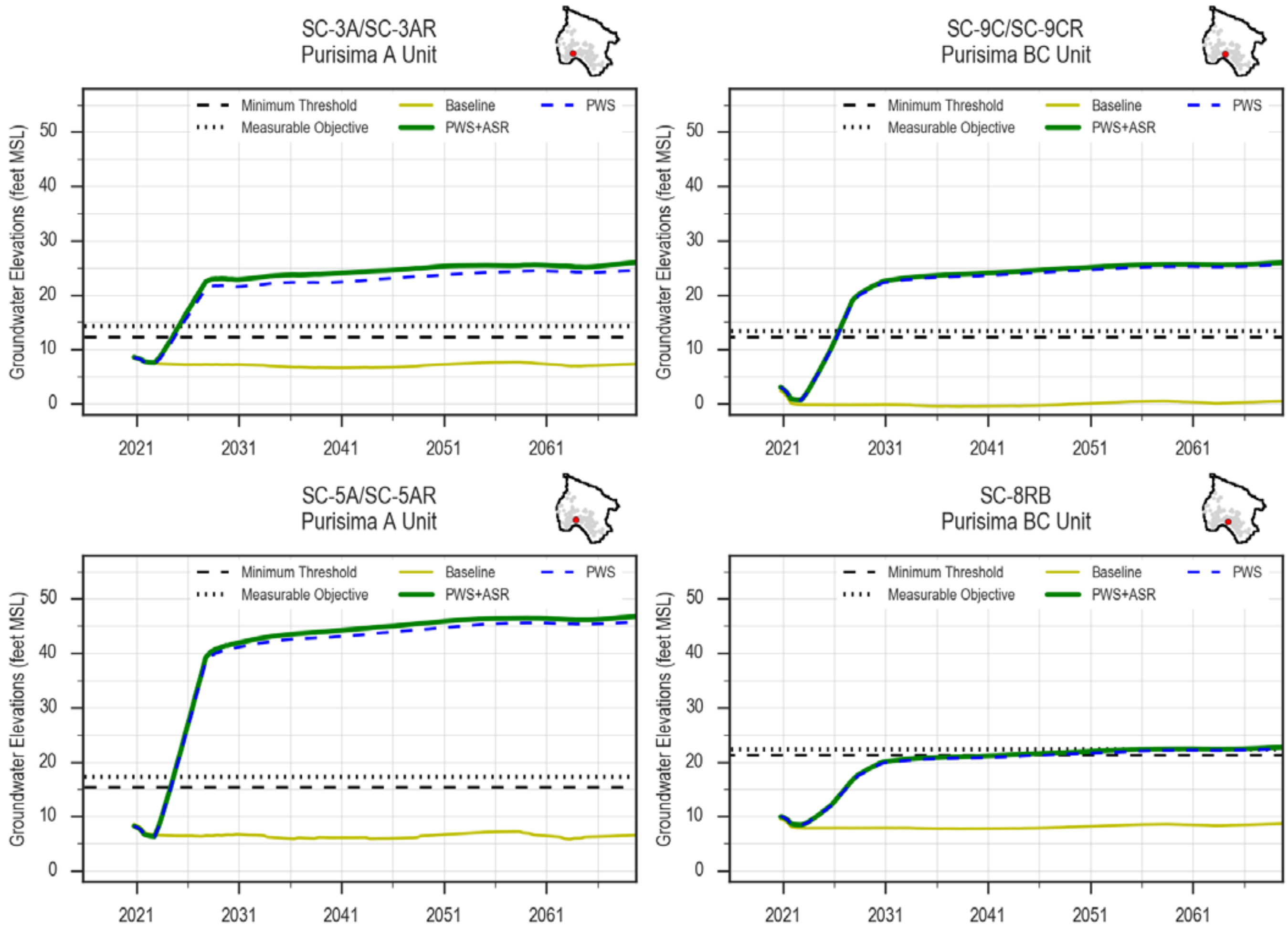


Figure 4-1. Five Year Averages of Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima A and BC Units

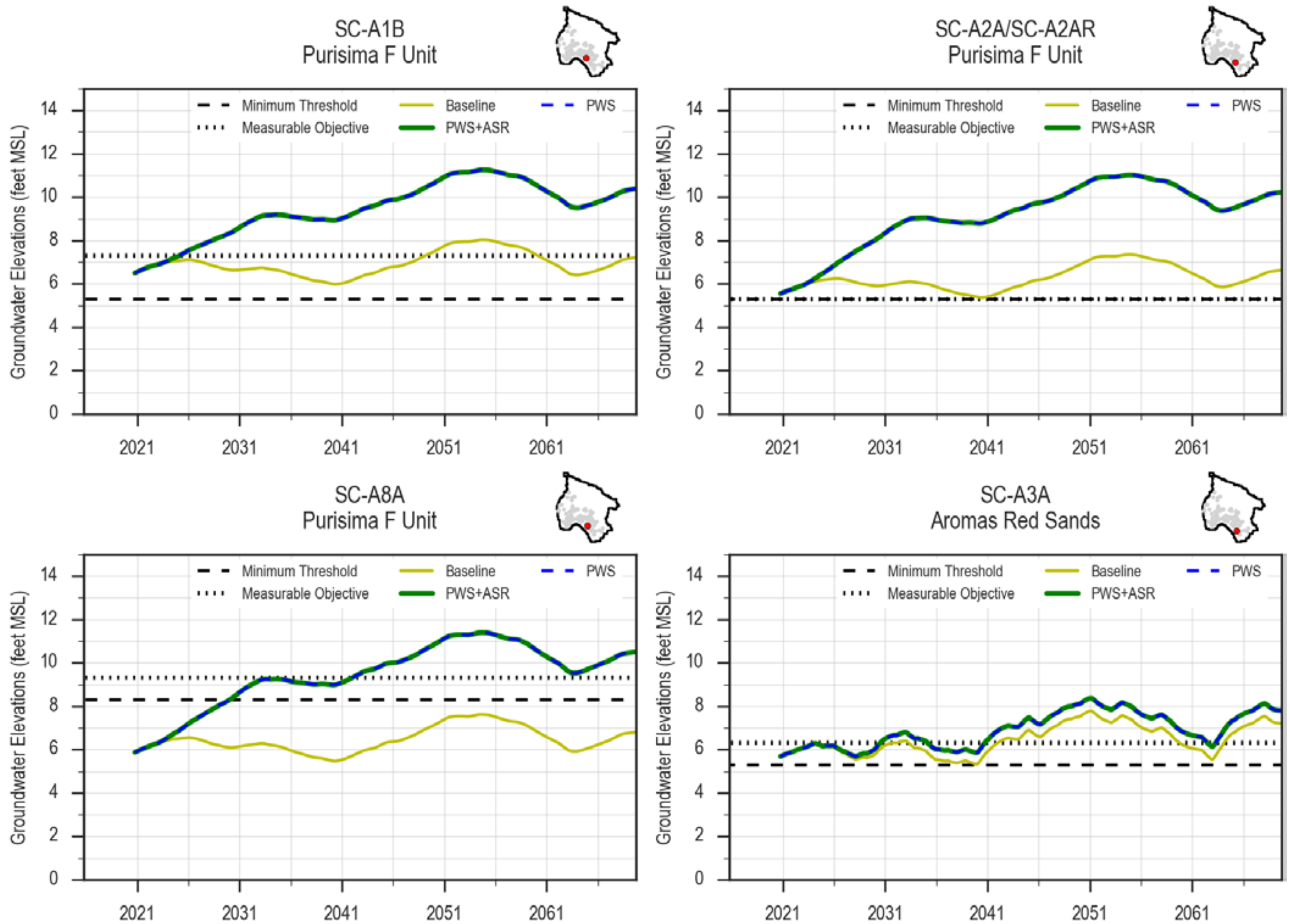


Figure 4-2. Five Year Averages of Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima F and Aromas Red Sands Units

Pure Water Soquel replenishment into the Purisima A unit also is expected to benefit the streamflow depletions indicator by raising shallow groundwater levels along Soquel Creek. Without the project (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 4-3).

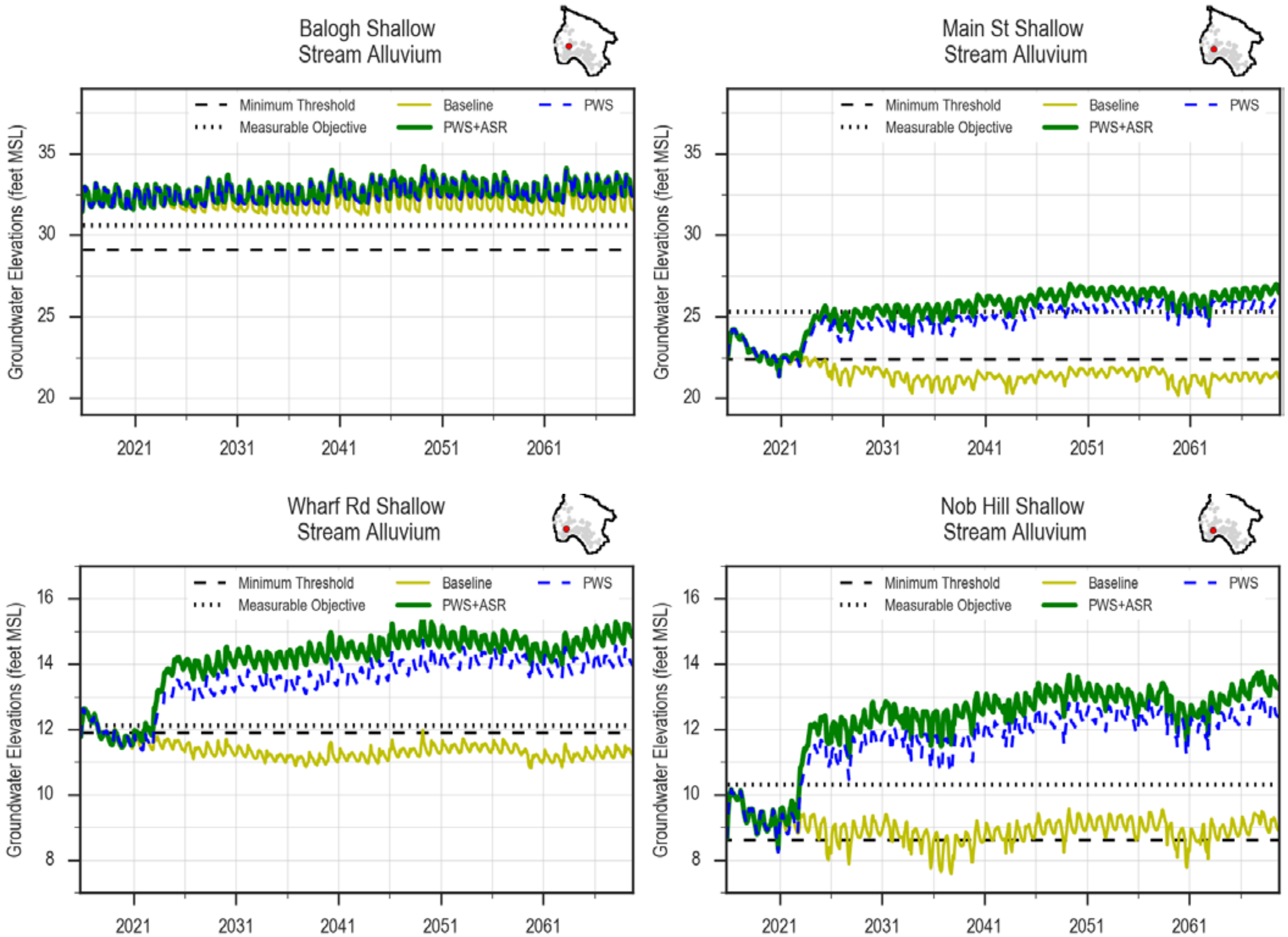


Figure 4-3. Monthly Model Simulated Groundwater Elevations in Shallow Wells along Soquel Creek

The hydrographs also show that the expected benefits are maintained when combining SCWD's ASR project to Pure Water Soquel (green line labeled PWS+ASR).

4.2.1.9 How the Project will be Accomplished

Pure Water Soquel would use advanced water treatment technology to reuse locally available treated secondary effluent for advanced purified water that meets or exceeds drinking water standards. Advanced purified water would then be replenished into the groundwater aquifer to ultimately mix with native groundwater and contribute to the restoration of the groundwater basin, provide a barrier to seawater intrusion, and contribute to a sustainable water supply. The source of supply is secondary treated wastewater from the City of Santa Cruz Wastewater Treatment Plant. In 2019, Soquel Creek Water District and the City of Santa Cruz approved a 35 year contractual project agreement to supply Soquel Creek Water District with enough secondary effluent to produce 1,500 acre-feet per year of advanced treated water for replenishment and an additional amount of secondary effluent for PWS to provide the City with 300 acre-feet per year of tertiary treated water for non-potable reuse by the City for irrigation and other purposes. At the end of the 35 year wastewater agreement, the project agreement contractual terms for source water automatically renews for consecutive 5 year periods. The proposed amount of secondary effluent to be provided is approximately 25% of the annual wastewater treated by the City Wastewater Treatment Plant.

If needed, the project has potential to be expanded if Basin sustainability goals have not been achieved.

4.2.1.10 Legal authority

California state law gives Water Districts the authority to take actions necessary to supply sufficient water for present or future beneficial use. Land use jurisdictions have regulatory authority to develop similar programs.

4.2.1.11 Estimated Costs and Funding Plan

Pure Water Soquel is projected to cost $90 million to permit and construct to deliver the 1,500 AFY of purified water to the Basin and ~300 AFY of tertiary treated water for City uses. The project will be funded entirely through SqCWD's water rates and/or low interest loans or grant funds; no direct costs are anticipated to the MGA. Soquel Creek Water District has received over $2M in planning grants from the State Water Resources Control Board and a $150,000 planning grant from the US Bureau of Reclamation to evaluate the PWS project. The project is eligible to compete for implementation money ($50M under Prop 1 Groundwater and $20M under Title XVI). Both grant applications were submitted in early 2019. SqCWD is also pursuing low-interest loans through USEPA's Water Infrastructure Finance and Innovation Act (WIFIA) program and State Revolving Funds (SFR).

4.2.1.12 Management of groundwater extractions and recharge

Monitoring wells and data management systems are used to record and compare groundwater elevations in the Basin to evaluate pumping impacts and ongoing sustainability. Municipal groundwater extraction is monitored by metering municipal production wells operated by SCWD and Soquel Creek Water District in the areas where the Pure Water Soquel project would be located. Project recharge wells to recharge the aquifer would be metered to control the amount and rate of water injected into the regional aquifer.

4.2.1.13 Relationship to Additional GSP Elements

Soquel Creek Water District's Pure Water Soquel project will be managed to ensure no negative impacts to any of the additional GSP elements outlined in GSP Section 2.1.4. The project will recharge the groundwater with purified recycled water to support groundwater replenishment. Increased groundwater levels will improve progress toward the Basin's sustainability goals to protect groundwater supplies against seawater intrusion and to maintain or enhance groundwater levels where groundwater dependent ecosystems exist.

4.2.2 Aquifer Storage and Recovery

4.2.2.1 Project Description

Aquifer Storage and Recovery (ASR) would inject excess surface water, treated to drinking water standards, into the natural structure of Basin aquifers for use as an underground storage reservoir. The ASR project modeled for this 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 new infrastructure. SCWD can produce excess surface water by improving the treatment process at its Graham Hill Water Treatment Plant to improve its ability to treat available surface water (within its water rights, above the amount of water required for City operations, and respecting water for fish flows). Drinking water stored in the Basin as a result of an ASR project would provide a drought supply for the SCWD service area and any ASR project would need to be designed with additional capacity to contribute to the restoration of the Basin. (Note: A SCWD ASR project to store treated drinking water in the Santa Margarita Groundwater Basin is also being evaluated.)

SCWD is actively evaluating the feasibility of injecting treated drinking water from its surface water sources into regional groundwater aquifers and is currently conducting pilot tests of ASR in the Basin. Pilot testing involves injecting potable drinking water into the Basin's aquifers and recovering it to assess injection and recovery capacities and monitor water quality impacts to native groundwater resources. Information generated by pilot test evaluations will help inform the degree to which ASR is a feasible part of SCWD's strategy to improve the reliability of its water supply, along with helping to evaluate whether or not an ASR project can be developed and operated in a manner that will achieve both supply reliability and groundwater sustainability benefits.

4.2.2.2 Measurable Objective

A well designed and operated ASR project has the potential to raise groundwater levels in the Basin, thus reducing the threat of seawater intrusion, and store available surface water in regional aquifers for use as drought supply. However, any ASR project would need to manage groundwater extractions to prevent adverse impacts.

4.2.2.3 Circumstances for Implementation

SCWD water system simulation model analyses of projected water availability from SCWD surface water sources indicates that surface water from SCWD's water system, as a sole source, is insufficient to meet both drought supply demands and restore the Basin within the 20-year planning horizon. This result is based on an assessment of the availability of surface water to either offset existing pumping or create a reliable supply for a seawater barrier after the SCWD meets its own needs to provide instream flows, meet daily municipal and industrial demand and store water for its drought supply. Availability of surface water for possible use to achieve both Basin sustainability and SCWD drought supply objectives is constrained by a number of factors, including drinking water treatment capacity, water rights, fish flows, and potential climate change impacts on the availability of surface water resources. To determine the feasibility of an ASR project, the SCWD will be looking at:

- Basin hydrogeologic characteristics (well efficiency, specific capacity and injectivity)
- Loses of injected water due to off-shore movement
- Injection well plugging rates (both active and residual)
- Long-term sustainable injection rates
- Local aquifer response to injection and extraction, particularly to ensure that protective groundwater elevations are maintained at the coast.
- Water-quality changes during aquifer storage and recovery pumping

If any of these issues yields unfavorable results or information, it may result in a project that doesn't meet the SCWD's Basin sustainability and drought supply objectives.

4.2.2.4 Public Noticing

Public notice for aspects of the ASR pilot project was carried out by SCWD and the Santa Cruz City Council prior to initiating of the ASR project pilot tests (SCWD 2018). For the full-scale ASR project, public noticing is anticipated to occur through compliance with the California Environmental Quality Act (CEQA) for any facilities or plans associated with the project, as part of development of a Groundwater Storage Supplement to permit the storage of water from the City's water rights in the Basin that is required by the State Water Resources Control Board and through publically noticed discussions of the proposed project at City Water Commission and City Council meetings.

4.2.2.5 Overdraft Mitigation and Management Actions

The Department of Water Resources designates the Santa Cruz Mid-County Basin (Basin 3-001 (DWR 2016)) as a high priority basin in critical overdraft (DWR 2019). To respond both to the state's designation and to the Basin's condition, which has been a high priority focus of local agencies for decades, in 2015 the City and the Soquel Creek Water District entered into the Cooperative Monitoring/Adaptive Groundwater Management Agreement. This agreement sets limits for each agency's use of groundwater under normal and drought conditions. Basin pumping limits in this agreement were specifically intended to support stabilizing basin drawdown and restoring and maintaining protective groundwater levels at the coast. Work done as part of that agreement, along with work done as part of ongoing groundwater management for the Basin indicates that groundwater levels have improved. However, seawater intrusion exists in some locations throughout the basin and remains a significant threat to regional groundwater supplies as groundwater levels at five of the Basin's 13 key coastal monitoring wells remain below protective elevations including the Soquel Point Medium well in the SCWD area. In 2018, groundwater levels declined between 0.4 feet to 4.0 feet from all-time highs recorded in Water Year 2017. ASR, if withdrawals are carefully managed, may help to increase groundwater levels and reduce the threat of further seawater intrusion into the Basin.

4.2.2.6 Permitting and Regulatory Process

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, the SCWD has initiated a water rights change process with the State Water Resources Control Board (State Water Board). No additional water rights are being requested. SCWD is also working with the State Water Board to obtain the necessary Groundwater Storage Supplement for an ASR project in the Basin. An Environmental Impact Report is being developed to comply with CEQA and updated water rights and petitions are expected to be noticed for public comment before the end of calendar year 2019. Upon completion of the CEQA water rights process, and any necessary ASR CEQA process for a full-scale project, the Santa Cruz Water Commission and the City Council take actions to certify the CEQA work and approve projects.

The State Water Resources Control Board (SWRCB) has recently recognized that it in the best interest of the state to develop a comprehensive regulatory approach for ASR projects and has adopted general waste discharge requirements for ASR projects that inject drinking water into groundwater (Order No. 2012-0010-DWQ or ASR General Order). The ASR General Order provides a consistent statewide regulatory framework for authorizing both pilot ASR testing and permanent ASR projects. The City's ASR Pilot Tests and any future permanent ASR facility will be permitted under the ASR General Order. Oversight of these regulations is done through the

Regional Water Quality Control Boards (RWQCBs) and will require SCWD to comply with the monitoring and reporting requirements of the ASR General Order. Any additional permits required for the construction and operation of an ASR facility would be obtained as needed.

4.2.2.7 Time-table for Implementation

ASR pilot tests began in early 2019 at SCWD's Beltz 12 well. Additional pilot testing at an additional Beltz well is slated to occur this coming winter. Assuming results from the initial pilot testing conducted at SCWD's Beltz 12 well during 2019 continues to be favorable, full scale implementation of ASR at that facility would occur on a phased basis beginning in 2021. The current plan for developing ASR in the Basin would utilize to the greatest extent possible existing infrastructure, meaning that new infrastructure would be greatly limited and allowing for both incremental drought supply and groundwater sustainability benefits to begin accruing as early as 2022.

4.2.2.8 Expected Benefits

Basin groundwater elevations are expected to increase with ASR's injection of excess surface water, treated to drinking water standards, and continued basin management. ASR withdrawals would be managed to ensure they do not impact the attainment of or ongoing Basin sustainability. Benefits are evaluated using the existing groundwater monitoring well network and data management systems to compare groundwater levels over time. Potential impacts of recovering water from the Basin through ASR would be monitored to ensure ongoing groundwater sustainability is maintained.

Expected benefits for sustainability are evaluated based on a simulation of a potential ASR project, in combination with the Pure Water Soquel project, under projected future climate conditions using the model (Appendix 2-I). The potential ASR project simulated for evaluation of expected benefits is based on using existing SCWD Beltz wells for injection and recovery pumping. SCWD is in the process of evaluating different configurations of the project so the ASR project simulated for the GSP likely does not represent the ASR project that will be implemented.

The model simulation shows that expected benefits for sustainability are to raise average groundwater levels at coastal monitoring in SCWD's service area and reduce the risk of seawater intrusion. The figure below (Figure 4-4) shows running five-year averages of simulated groundwater levels at representative monitoring points for seawater intrusion (section 3.3.3.3) in SCWD's service area. The simulated groundwater levels are compared to groundwater level proxies (section 3.6) for minimum thresholds (black dots) and measurable objectives (black dashes) adjusted for sea level rise. Projected sea level rise of 2.3 feet is added to the groundwater level proxies (see Section 3.6.2.1.1).

Without a SCWD ASR project, five-year averages of simulated groundwater levels are not projected to achieve and maintain measurable objectives at the representative monitoring points and are below the minimum threshold in the AA unit. This is the case whether or not the Pure Water Soquel project is implemented (yellow line labeled Baseline without Pure Water Soquel and blue dashes labeled PWS with Pure Water Soquel but no ASR) as the simulated Pure Water Soquel project does not substantially raise groundwater levels in much of the SCWD service area. With a simulated project that injects water at the existing SCWD Beltz wells and reduces overall pumping at the Beltz wells (green line labeled PWS+ASR), it is projected that measurable objectives will be achieved and maintained in the A unit that is the main source of groundwater supply for SCWD and minimum thresholds will be achieved and maintained in the AA unit such that undesirable results for seawater intrusion do not occur. The project 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.

The model simulation also shows that an ASR project can help prevent undesirable results for the interconnected surface water depletion indicator. Figure 4-3 shows that adding an ASR project to Pure Water Soquel (green line labeled PWS+ASR) is projected to raise groundwater levels in shallow wells along Soquel Creek in almost all times and groundwater levels are maintained above the groundwater elevation proxies set as minimum thresholds.

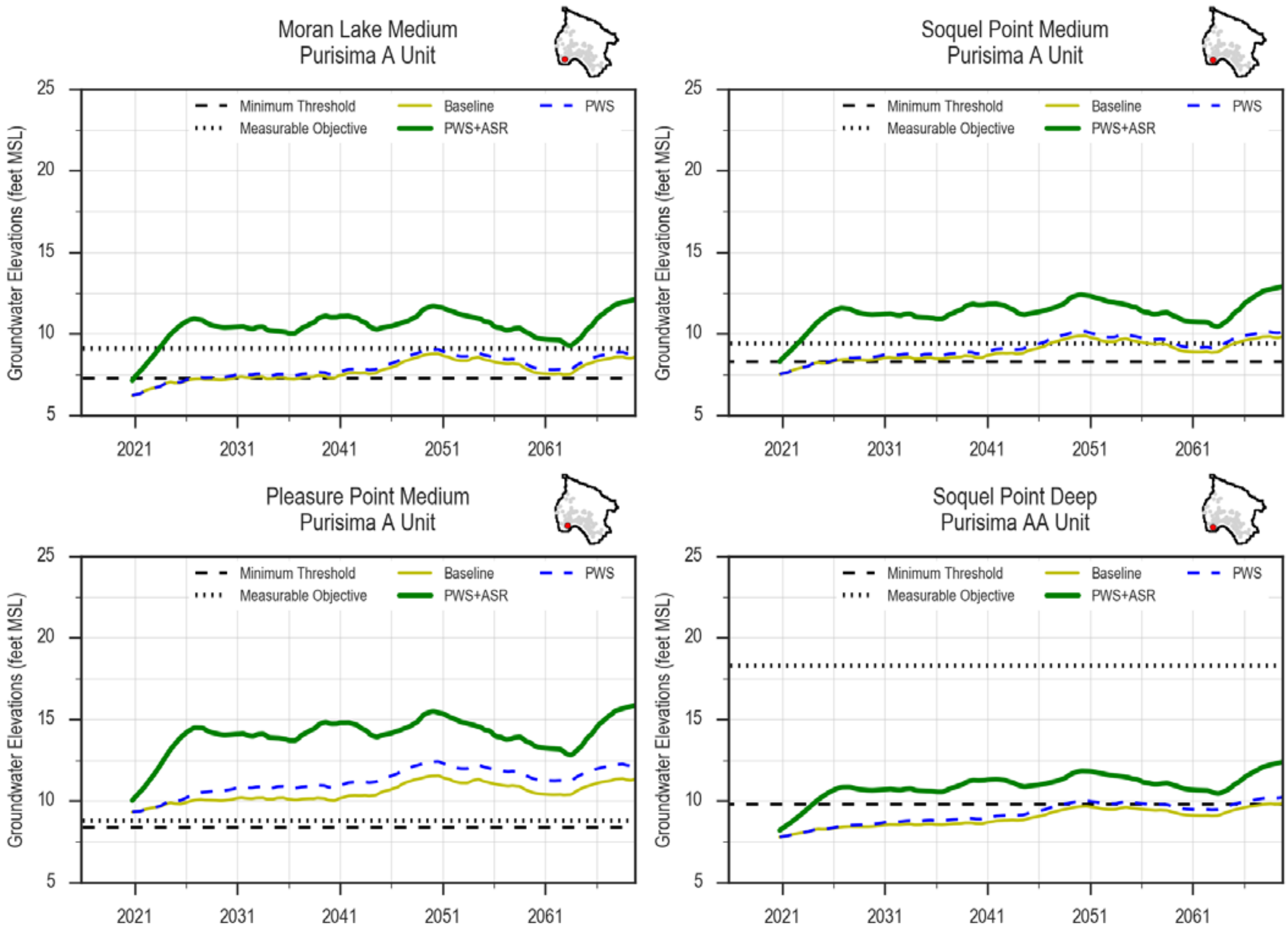


Figure 4-4. Five Year Averages of Groundwater Elevations at Purisima AA and A Units

4.2.2.9 How the Project will be Accomplished

Following the successful completion of additional ASR pilot testing, SCWD would develop a phased implementation plan for ASR in the Basin. The initial phases would emphasize leveraging existing water system infrastructure to the greatest extent possible, with new infrastructure being mostly limited to retrofitting existing wells in the Beltz system to function as both injection and extraction wells rather than just extraction wells. Available wet season surface water within the City's existing water rights quantities and diversion rates and after fish flow commitments are met would be treated to meet both primary and secondary federal and state drinking water standards at the Graham Hill Water Treatment Plant and distributed to the Beltz wells using existing water system infrastructure. During the dry season or drought periods, ASR water and native groundwater would be withdrawn from the Basin, treated as needed at existing groundwater treatment facilities and delivered to water system customers using existing water system infrastructure. Operation of an ASR system would be conducted in such a way that it avoids negative impacts on protective groundwater elevations and chloride concentrations at coastal monitoring wells. Over time, and depending on the availability of both additional surface water and aquifer storage space, additional ASR system facilities in the western part of the Basin could be developed and operated to protect groundwater resources and provide additional drought supply.

4.2.2.10 Legal Authority

The City of Santa Cruz is a land use jurisdiction with police powers necessary to take actions to supply sufficient water for present and future beneficial uses. The City also has the authority to work with the State Water Resources Control Board as needed to pursue necessary updates to its water rights and authorization to store surface water in regional aquifers for both water supply benefits and to provide groundwater sustainability benefits.

4.2.2.11 Estimated Costs and Funding Plan

As described above, the current plan for development of ASR in the basin is intended to leverage the use of existing infrastructure to the greatest extent feasible. As proposed, this approach is substantially less expensive than an ASR project that was discussed by the Water Supply Advisory Committee during its work between April of 2014 and October of 2015. SCWD hasn't necessarily abandoned a potentially larger and significantly more expensive ASR project that might involve storing water and supporting groundwater sustainability objectives in both the Mid-County and Santa Margarita groundwater basins but, rather is pursuing a project in the Mid-County Basin first. This direction provides the opportunity to make near-term incremental improvements in the reliability of SCWD's water supply and also to take near term action to address and mitigate the threat of further seawater intrusion in the Basin.

SCWD staff have estimated that a more limited ASR project using existing Beltz well infrastructure as simulated for the GSP would cost roughly $21,000,000 in 2019 dollars. These funds would be used to support ongoing pilot testing of ASR at Beltz system wells, necessary design for permanent retrofitting of existing wells, any needed improvements or modifications to SCWD's groundwater treatment facilities, and planning for additional ASR facilities in the western portion of the Basin if and as needed. The SCWD will continue to develop and fund the ASR project planning and implementation through its individual agency budget at no cost to the MGA. Project funding is expected to come from the SCWD water rate payers generated funds and from grant programs if such funds are available and can be successfully obtained.

4.2.2.12 Management of Groundwater Extractions and Recharge

Monitoring wells and data management systems are in use in the Basin to record and compare groundwater elevations to evaluate pumping impacts and for monitoring the performance of the basin relative to the various Sustainable Management Criteria. SCWD's ASR project would inject potable drinking water into the Basin during the wet season, storing injected water for use during the dry season and during droughts, along with allowing the stored water to recover the Basin. Groundwater levels exceeding minimum thresholds may allow SCWD to also extract additional groundwater when needed.

4.2.2.13 Relationship to Additional GSP Elements

SCWD's ASR project is a conjunctive use project that will be managed to ensure no negative impacts to any of the additional GSP elements outlined in GSP Section 2.1.4. Injection of surface water, treated to potable drinking water standards, is expected to support groundwater replenishment and improve progress toward the Basin's sustainability goals. An ASR project will help protect groundwater supplies against seawater intrusion and maintain or enhance groundwater levels where groundwater dependent ecosystems exist, as well as provide drought supply to City water system customers.

4.2.3 Water Transfers / In Lieu Groundwater Recharge

4.2.3.1 Project Description

Water Transfers/In Lieu Groundwater Recharge would deliver excess SCWD surface water, treated to drinking water standards, to SqCWD to reduce groundwater pumping and allow an increase in groundwater in storage in order to help prevent seawater intrusion. If water transfers benefit groundwater levels, is sustainable over time, and the Basin's performance consistently reaches sustainability targets, then SCWD could recover some of the increase in groundwater in storage as a supplemental supply during droughts.

In the summer of 2016, SCWD and SqCWD signed an agreement to work together to conduct a five-year pilot water transfer project. Prior to initiating the pilot, evaluations of the potential for unintended consequences due to differing chemical characteristics of surface and groundwater resources were completed.

A water transfer pilot test was conducted between December 2018 and April 2019 in which SCWD delivered treated drinking water to SqCWD to serve a portion of SqCWD's service area. The pilot test used an existing intertie between the two water agencies, providing on average 400,000 gallons per day to SqCWD. During the pilot test, SqCWD reduced or eliminated pumping in its O'Neill Ranch, Garnet, and Main Street wells. It also tracked water quality as concerns about the potential incompatibility of surface and groundwater sources, particularly related to elevated levels of lead, copper, or colored water from exposing public and private plumbing used to less corrosive groundwater to more corrosive surface water. Additional pilot testing is expected to begin in late 2019 with a larger pilot area within SqCWD's service area to continue evaluating operational and water quality conditions to help inform the feasibility for a long-term transfer. For a long term project, additional surface water could be provided from the City's North Coast sources and the San Lorenzo River (if water rights allow) to meet more of Soquel Creek Water District's wet season demand, rebuild groundwater storage by eliminating or reducing pumping during some part of the year within the SqCWD's western area of its service area.

4.2.3.2 Measurable Objective

Water Transfers/In Lieu Groundwater Recharge is a project to passively recharge groundwater by resting SqCWD's groundwater wells using treated drinking water from SCWD as a source of supply. In Lieu Groundwater Recharge has the potential to reduce the threat of seawater intrusion and possibly create additional groundwater in storage if adequate amounts of treated surface water are consistently and reliably available when SqCWD customers have the demand needed to use SCWD excess surface water.

4.2.3.3 Circumstances for Implementation

Water Transfers/In Lieu Groundwater Recharge is in pilot testing. Availability of excess surface water is constrained by a number of factors, including drinking water treatment capacity, water rights place of use restrictions, required minimum fish flows, and availability of adequate surface water supplies to serve SCWD's customers prior to selling excess drinking water outside the SCWD's service area. Climate change factors could also impact water availability. The amount of in lieu groundwater recharge that can be achieved is also limited by the relatively low water demand in SqCWD's service area during the winter months when SCWD has excess surface water available.

4.2.3.4 Public Noticing

In Lieu Groundwater Recharge pilot testing began in the winter of 2018-2019. Public Notice for all aspects of the project was carried out by SCWD and SqCWD prior to the start of pilot tests, including a CEQA Negative Declaration adopted for the pilot project (SCWD 2016). Future notification of the public for any additional pilot testing or long-term implementation would be done prior to initiation of the transfer.

4.2.3.5 Overdraft Mitigation and Management Actions

The Department of Water Resources designates the Basin 3-001 as in a state of critical overdraft. To respond both to the state's designation and to the Basin's condition, which has been a high priority focus of local agencies for decades, in 2015 SCWD and SqCWD entered into the Cooperative Monitoring/Adaptive Groundwater Management Agreement. This agreement sets limits for each agency's use of groundwater under normal and drought conditions. Basin pumping limits in this agreement were specifically intended to support stabilizing basin drawdown and restoring and maintaining protective groundwater levels at the coast. Work done as part of the development of the GSP indicates that groundwater levels have recovered from critically low levels identified in the 1980s. However, seawater intrusion exists in several locations and remains a significant threat to regional groundwater supplies as groundwater levels at five of the Basin's 13 key coastal monitoring wells remain below protective elevations. In 2018, groundwater levels declined between 0.4 feet to 4.0 feet from all-time highs recorded during Water Year 2017. Water Transfer/In Lieu Groundwater Recharge would reduce groundwater pumping and is likely to increase Basin groundwater levels and reduce the threat of further seawater intrusion into the Basin. Surface water transfers from SCWD would be expected to reduce regional groundwater dependence.

4.2.3.6 Permitting and Regulatory Process

SCWD completed a CEQA analysis, including opportunity for public comment, for the Pilot Water Transfer project (SCWD 2016). That CEQA analysis was completed in 2016 and focused on water from the City's North Coast Sources pre-1914 water rights, which are not constrained by formalized places of use. The City has initiated a process with the State Water Resources Control Board to update its San Lorenzo River water rights, and one of its requests to the State Board is to expand the places of use for all its San Lorenzo River water rights (Newell Creek License, Felton Permits, and Tait Diversion Licenses) to cover the boundaries of the municipal water providers and the general basin boundaries for the Santa Cruz Mid-County and Santa Margarita groundwater basins. No new water rights are being requested in this effort. An Environmental Impact Report (EIR) on the City's water rights changes is underdevelopment and is expected to be released for public review in the fall of 2019. A final EIR and State Board action on the requests is anticipated during calendar year 2020.

Prior to initiating the Pilot Water Transfer, SqCWD was required work with the State Division of Drinking Water (DDW) to modify its Operating Permit to allow it to take surface water during the pilot testing efforts. Any long-term water transfer would also need to be reflected in its Operating Permit from DDW.

4.2.3.7 Time-table for Implementation

Water Transfer/In Lieu Groundwater Recharge projects have been in the planning and engineering process for four years. In Lieu Groundwater Recharge is in pilot tested now and pilot testing will continue through at least the winter of 2019/2020. Longer term implementation of water transfers will require a new agreement, including compliance with Proposition 218 requirements to set the cost of service for water delivered and, depending on the annual quantity transferred, waiting for resolution of the places of use changes of the City's San Lorenzo River water rights. Given these factors, a likely timeline for implementation of a longer-term water transfer project is a minimum of two years.

The Basin is expected to see groundwater elevations continue to improve but model analysis of projected water availability from all surface water sources and groundwater recharge projections appear insufficient to restore the Basin within the 20-year planning horizon without additional water augmentation projects. The Basin is required to be sustainable by 2040, even during times of drought, which could limit large scale water transfers back to SCWD.

4.2.3.8 Expected Benefits

Groundwater elevations are expected to continue to increase with continued basin management and implementation of In Lieu Groundwater Recharge. Benefits are evaluated using the existing groundwater monitoring well network and data management systems to compare groundwater levels over time. The potential expected benefits of in-lieu recharge is demonstrated by model simulations of the Pure Water Soquel project (Appendix 2-I), which similarly implements in-lieu recharge by reducing pumping in the three westernmost SqCWD production wells. It is most feasible for operation of a surface water transfer from SCWD to facilitate reduction of pumping at these wells closest to the interchange between SCWD and SqCWD. Reduction of pumping at these wells can raise groundwater levels at nearby representative monitoring points for seawater intrusion as shown by plots of five-year average simulated groundwater levels at the wells under Pure Water Soquel (blue dashes labeled PWS) compared to the baseline (yellow line labeled Baseline) in Figure 4-5. The simulation of Pure Water Soquel shows the concept of benefits of in-lieu recharge in this area, but does not simulate expected volumes of surface water transfer, the seasonality of the transfer, or any additional pumping to transfer water to SCWD to meet its drought shortage needs.

The MGA will continue to evaluate the amount and timing of water transferred between SCWD and SqCWD as part of the pilot and permanent In Lieu Groundwater Recharge projects. Use of this collected data and any changes to groundwater elevations will be used to better analyze the effect of project implementation on groundwater sustainability over time.

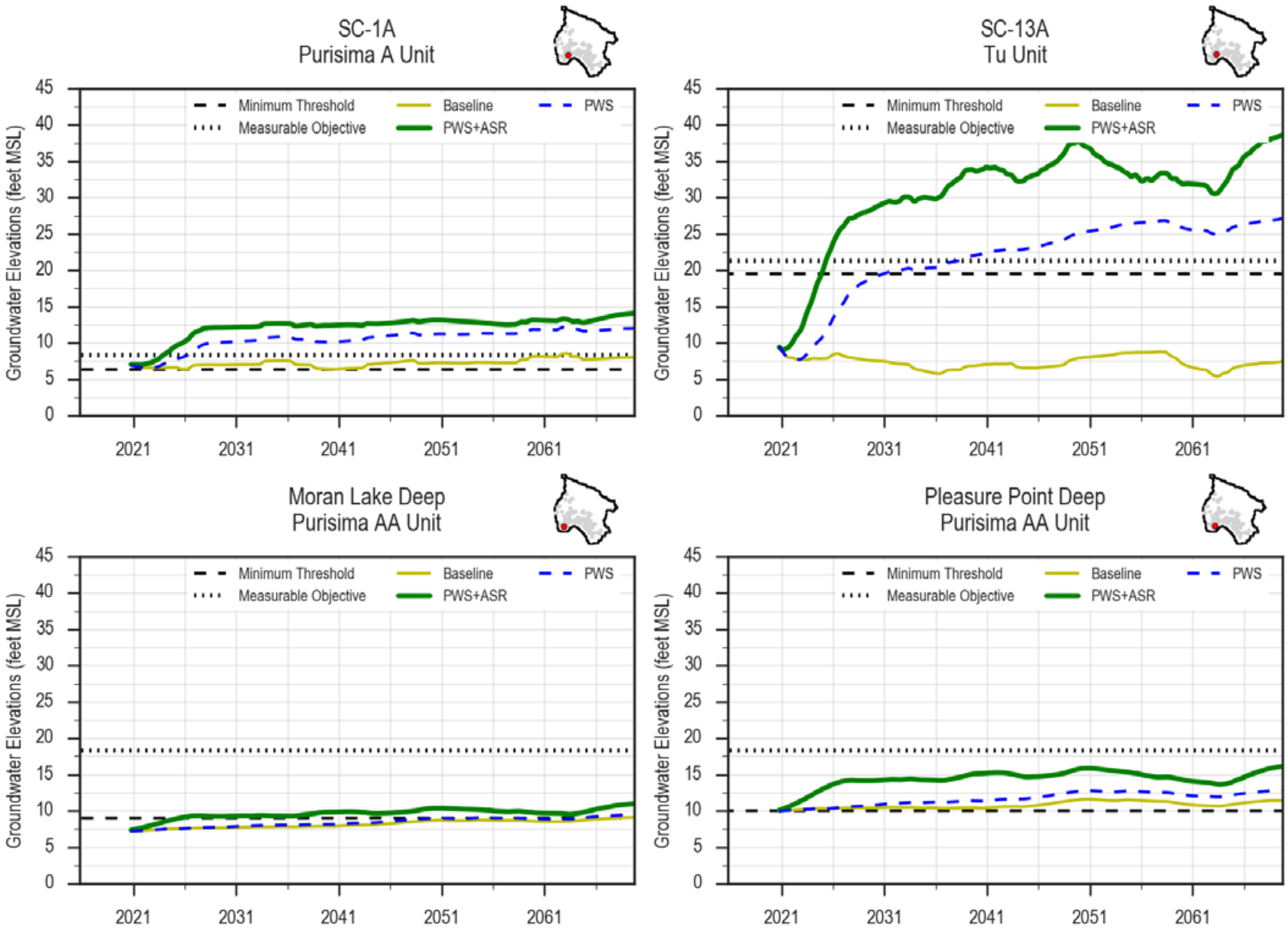


Figure 4-5. Five Year Averages of Groundwater Elevations at Coastal Monitoring Wells in Tu and Purisima AA and A Units (includes in-lieu recharge from Group 2 projects)

4.2.3.9 How the Project will be Accomplished

Water Transfers/In Lieu Groundwater Recharge projects can be implemented when SCWD has available excess surface water to provide to SqCWD. When available, water would come from SCWD's surface water sources and treated at the Graham Hill Water Treatment Plant, then delivered to the SqCWD via existing infrastructure at the O'Neill Ranch intertie. Excess surface water transferred by SCWD to SqCWD is treated at SCWD's Graham Hill Water Treatment Plant to meet both primary and secondary federal and state drinking water standards. Treated water delivered to customers is sampled by SqCWD, as required by the State Water Resource Control Board (SWRCB) regulators and tested to ensure the water delivered to its customers meets safe drinking water standards, these water quality sampling results will be reported monthly to SWRCB. If any water quality samples fail to meet safe drinking water standards, then notification of customers will be directed by the SWRCB staff.

Because of San Lorenzo surface water place of use restrictions, the volume of water available could be limited until place of use issues with the San Lorenzo River water rights are resolved. Volumes of water in the range of 300 to 500 acre feet per year (≈100 to 165 million gallons per year) are consistently available from the City's North Coast Sources. Larger volumes may be available in some years, but likely require use of water from San Lorenzo River sources. Analysis by SCWD shows that there is insufficient water available via Water Transfers to meet SCWD's drought supply requirements. In addition, Water transfers are constrained by both, the availability of water in the SCWD system and the demands of SqCWD's customers. There is no evidence to date that indicates an In Lieu Groundwater Recharge project by itself would achieve Basin sustainability.

4.2.3.10 Legal authority

California state law gives water districts the authority to take actions necessary to supply sufficient water for present or future beneficial use. Land use jurisdictions have police powers to develop similar programs. The Sustainable Groundwater Management Act of 2014 grants MGA legal authority to pass regulations necessary to achieve sustainability. San Lorenzo River water rights are restricted to place of use areas within SCWD water service areas. The City is applying to the State Water Board to expand the places of use for its San Lorenzo River water rights to allow for the expansion of the In Lieu Groundwater Recharge project.

4.2.3.11 Estimated Costs and Funding Plan

Water Transfer/In Lieu Groundwater Recharge projects utilize a significant amount of existing infrastructure. Costs for additional infrastructure to optimize In Lieu/Water Transfers are largely in the form of increased operating costs and could include increased water quality monitoring, increased public notification, and the cost of purchased water. Cost of water purchases between SCWD and SqCWD must comply with the legal requirements of Proposition 218, which sets the cost of service for water delivered.

4.2.3.12 Management of groundwater extractions and recharge

Water Transfer/In Lieu Groundwater Recharge projects are conjunctive use projects. In Lieu Groundwater Recharge reduces groundwater pumping to allow passive recharge that can contribute to groundwater level increases. Monitoring wells and data management systems are used to record and compare groundwater elevations in the Basin to evaluate pumping impacts and ongoing sustainability. Relationship to Additional GSP Elements

4.2.3.13 Relationship to Additional GSP Elements

SCWD and SqCWD's joint Water Transfer/In Lieu Groundwater Recharge projects are conjunctive use projects that will be managed to ensure no negative impacts to any of the additional GSP elements outlined in GSP Section 2.1.4. Passive recharge through resting groundwater wells by delivering excess surface water treated to drinking water standards to SqCWD customers is expected to support groundwater replenishment. Increased groundwater levels will improve progress toward the Basin's sustainability goals to protect groundwater supplies against seawater intrusion and to maintain or enhance groundwater levels where groundwater dependent ecosystems exist.

4.2.4 Distributed Storm Water Managed Aquifer Recharge (DSWMAR)

4.2.4.1 Project Description

Distributed Storm Water Managed Aquifer Recharge (DSWMAR) redirects storm water flows for use as a groundwater recharge supply to increase groundwater storage (RCD 2014). Where feasible, small to medium scale facilities (up to 10 acre-feet/year/site) are installed to capture and treat storm water for shallow groundwater recharge zones in Basin groundwater aquifers. Projects would be accomplished through surface spreading and/or the construction of dry wells.

4.2.4.2 Measurable Objective

DSWMAR is a groundwater recharge project to increase groundwater storage in the shallow aquifer layers in the Basin for increased groundwater storage and added protection against seawater intrusion and improved surface water quality.

4.2.4.3 Circumstances for Implementation

The County has installed DSWMAR projects in the Live Oak and Aptos areas of the Basin. Bioswale filtration systems and dry wells were installed at Brommer Street County Park with a capacity to recharge 1 acre-foot per year from the parking lot runoff. Bioswales and dry wells were also installed to capture runoff from two parking lots at Polo Grounds County Park with a capacity to recharge 19 acre-feet per year. Eight more DSWMAR sites were evaluated in 2018. Three of these sites were identified for further site investigation. One of these sites was recently eliminated because depth to groundwater was too shallow for recharge to be effective at that site. The availability of suitable sites and the limited scale of DSWMAR projects may be a constraint to project implementation.

Topography, ground cover, local vegetation, and surface and sub-surface geology/hydrogeology can provide significant constraints for siting DSWMAR projects. DSWMAR introduces water to the upper levels of aquifers and most drinking water production draws from deeper levels. Depending on the configuration of aquifers, DSWMAR may never reach the aquifers from which drinking water is produced. DSWMAR projects vary in size and benefit to the Basin and are likely to be prioritized according to recharge efficiency/needs and implemented when funding is available.

4.2.4.4 Public Noticing

Installed DSWMAR projects were publicly noticed and approved by the Santa Cruz County Board of Supervisors during its regularly scheduled board meetings. This process included statewide notice of the submission of Negative Declarations under CEQA to the state clearing house. Future DSWMAR projects would be noticed by the lead agency when a DSWMAR project is proposed.

4.2.4.5 Overdraft Mitigation and Management Actions

Groundwater levels have recovered from critically low levels identified in the 1980s. However, seawater intrusion exists in several Basin locations and remains a significant threat to regional groundwater supplies as groundwater levels at five of the Basin's 13 key coastal monitoring wells remain below protective elevations. In 2018, groundwater levels declined between 0.4 feet to 4.0 feet at various Basin locations from all-time highs recorded in Water Year 2017. The introduction of storm water into shallow Basin aquifers may increase groundwater levels in localized areas where DSWMAR projects are installed.

4.2.4.6 Permitting and Regulatory Process

Installed DSWMAR projects required permits from or notice to the following agencies:

- CEQA documentation
- Santa Cruz County grading permit
- USEPA - Class 7 dry well notice

Future projects may also require:

- Regional Water Quality Control Board - may require notice/permit

4.2.4.7 Time-table for Implementation

The County has developed and installed two DSWMAR projects to date, one in Aptos and another in Live Oak. The County installed dry wells in Aptos at Polo Grounds County Park became operational in 2012 and are estimated to add 19 acre-feet per year to the local shallow groundwater aquifer. In Live Oak, dry wells were installed and became operational at Brommer Street County Park in 2015 to add an estimated one acre-foot per year to the local shallow groundwater aquifer. The Polo Grounds project was accomplished with planning and funding through the Integrated Regional Water Management (IRWM) program and the Live Oak project was completed with IRWM and storm water grant funding.

Eight potential future sites were screened in 2018. Three of these eight potential sites were identified for further investigation, and one was eliminated after borings showed depth to groundwater too shallow to provide adequate conditions for recharge at that location. The two remaining sites are still under investigation. Time-table for development and expected benefits to groundwater recharge at these or any other potential future DSWMAR project sites are not available and would be speculative at this time

4.2.4.8 Expected Benefits

DSWMAR projects are expected to recharge shallow groundwater aquifers. Future projects of small to medium scale would be installed where feasible to capture storm water and recharge more shallow zones of aquifers through surface spreading or construction of dry wells. Existing projects in Live Oak and Aptos use recorded local rainfall observations and project design parameters to estimate project recharge rates. Future DSWMAR projects would likely be designed to more accurately measure recharge rates to the groundwater aquifer. The expected benefit from each project would vary based on both project design parameters and the amount/timing of storm water runoff. Benefits are evaluated using the existing monitoring well network and data management systems to compare groundwater levels over time. Time-table for accrual of expected benefits to groundwater recharge for potential future DSWMAR projects is not currently available and would be speculative at this time.

Although a specific DSWMAR project was not specifically modeled, a theoretical project in Aptos was modelled and was shown to raise groundwater levels in the Aromas Red Sands aquifer and allow for pumping from the aquifer unit more than what simulations of Pure Water Soquel show is necessary to achieve measurable objectives to prevent seawater intrusion into the aquifer.

4.2.4.9 How the Project will be Accomplished

Future DSWMAR projects would be developed by identifying sites receptive to groundwater recharge in areas where shallow groundwater recharge would be beneficial to the Basin. The Resource Conservation District of Santa Cruz County (RCD) is working with land owners in the neighboring Pajaro Valley Sub-basin on surface spreading projects and has developed data to show project effectiveness with the right surface and subsurface hydrogeologic conditions. The County has installed dry wells to capture and recharge storm water in Live Oak and Aptos. MGA member agencies will leverage existing project information from members and regional partner agencies, like the RCD, to identify sites and design future DSWMAR projects within the Basin. DSWMAR water supply would come from redirecting local storm water runoff to areas suitable for shallow groundwater recharge.

4.2.4.10 Legal authority

California state law gives Water Districts the authority to take actions necessary to supply sufficient water for present or future beneficial use. Land Use Jurisdictions have police powers to develop similar programs. The Sustainable Groundwater Management Act of 2014 grants MGA legal authority to pass regulations necessary to achieve sustainability.

4.2.4.11 Estimated Costs and Funding Plan

Existing DSWMAR projects were developed with local and grant funding sources. Future DSWMAR projects sites are under investigation. Two of the three potential storm water recharge sites evaluated in a report prepared for the County (MME, June 2019) were found suitable for project development. Both suitable sites are at different locations on Seascape Golf Course. The MME report estimates costs per unit of water infiltrated over a 20 year project lifespan. These costs were developed per acre-foot of storm water recharge and varied between $1,649 and $2,786 per acre-foot. Project development costs for initial project installation were estimated at $450,000 at the Los Altos site and $650,000 at the 14th Fairway site. MGA policy developed to date indicates project funding would come from member agencies and grants.

4.2.4.12 Management of groundwater extractions and recharge

Groundwater extraction is monitored by metering municipal production wells, small water systems, and the model estimates production by non-municipal private wells. DSWMAR projects recharge shallow groundwater. Basin recharge attributable to DWSMAR projects is estimated according to project design parameters and recorded precipitation. Basin groundwater recharge is monitored through a basin wide monitoring well network and data management system.

4.2.4.13 Relationship to Additional GSP Elements

Environmental impacts of future DSWMAR projects will be reviewed under the California Environmental Quality Act (CEQA). If implemented, future projects would avoid significant impacts to the environment including to the additional GSP elements outlined in GSP Section 2.1.4. Groundwater recharge related to DSWMAR is expected to support shallow groundwater replenishment and improve progress toward the Basin's sustainability goals to maintain or enhance groundwater levels where groundwater dependent ecosystems exist.

4.3 Identified Projects and Management Actions That May Be Evaluated in the Future (Group 3)

4.3.1 Recycled Water - Groundwater Replenishment and Reuse

Soquel Creek Water District: The Soquel Creek Water District Feasibility Study (Carollo 2017) and the Pure Water Soquel EIR (ESA 2018) both identify expansion opportunities for the Pure Water Soquel Project. The conveyance infrastructure of the Pure Water Soquel Project is currently sized to accommodate the potential for future expansion of the Project's treatment system (if desired at a later time) which is centrally-located and could convey up to approximately 3,000 AFY of purified water. This could be developed should SCWD need supplemental water supplies to meet drought needs or the Basin needs additional supplies to meet MGA sustainability goals based on project performance and monitoring of the GSP's implementation measures.

City of Santa Cruz: SCWD conducted planning and assessments of the potential use of recycled water to supplement SCWD's water supply. The City's Water Supply Advisory Committee's (WSAC) 2015 recommendations were to pursue a strategy of water conservation and enhanced groundwater storage, with a back-up option of advanced treated recycled water or desalinated water. WSAC recommended further evaluation of these water supply alternatives (SCWD 2015). The WSAC's charge, as represented in its final recommendations, was focused on addressing SCWD's water supply gap of 3,700 acre-feet (or 1.2 billion gallons) per year during times of extended drought. However, the potential recycled water strategies to augment

SCWD's water supply could also potentially benefit the Basin if implemented in a manner that targeted groundwater storage or seawater intrusion prevention.

In 2018, in response to WSAC's recommendations, SCWD concluded a Recycled Water Facilities Planning Study (RWFPS) that evaluated recycled water alternatives (Kennedy/Jenks 2018). This included a high-level feasibility study and conceptual level design of alternatives for recycled water. In addition to evaluating water supply benefit to SCWD, the RWFPS also provided a broader range of potential beneficial uses of the treated effluent from the regional Santa Cruz Wastewater Treatment Facility (WWTF). The RWFPS evaluated eight project alternatives, which included:

1) Centralized Non-Potable Reuse
2) Decentralized Non-Potable Reuse
3) SqCWD Led Groundwater Replenishment Reuse Project (Includes Pure Water Soquel)
4) Santa Cruz Led Groundwater Replenishment Reuse Project
5) Surface Water Augmentation
6) Streamflow Augmentation
7) Direct Potable Reuse
8) Regional Groundwater Replenishment Reuse Project (GRRP)

The evaluation of the project alternatives consisted of a conceptual-level engineering analysis to evaluate each project and to score and rank projects based on screening criteria for engineering and operational considerations, economic factors, environmental, and social considerations.

The RWFPS identified the near-term preferred alternative as strategies/projects under Alternative 1 Centralized Non-Potable Reuse; this consists of two separate projects (1. SCPWD Title 22 Upgrade (Alternative 1A) and 2. BayCycle (Alternative 1B Phase 4)) to increase production and recycled water reuse. Both would benefit SCWD but they are located outside of the Basin and would not assist in achieving sustainability within the Basin and therefore are not under consideration by the MGA.

The RWFPS identified a mid-term opportunity for a centralized Groundwater Replenishment Reuse Project (GRRP) led by the SCWD (Alternative 4). This alternative evaluated a GRRP (independent of Pure Water Soquel) in the Santa Cruz service area with a centralized Advanced Water Treatment Facility (AWTF) at or near the Santa Cruz Wastewater Treatment Facility (WWTF) to send advanced treated water for injection in the Beltz wellfield area and also deliver advanced treated water for non-potable reuse (NPR) along the way.

The Beltz wellfield is located in the Basin, so this potential project to assist with replenishing the Purisima aquifer and protecting against seawater intrusion. Santa Cruz WWTF secondary effluent would serve as the source of the water. The effluent would receive advanced water treatment at or near Santa Cruz WWTF employing full advanced treatment with microfiltration, reverse osmosis (RO) and ultra-violet (UV)/Peroxide for advanced oxidation. It is estimated the project would provide up to 2.0 MGD (2,240 AFY) advanced treated water for groundwater replenishment at the Beltz Wellfield. In addition, it would provide an estimated 0.11 MGD (120 AFY) for NPR irrigation at approximately 35 customer sites in City along the pipeline alignment from the AWTF to SCWD's GRR injection sites. The RWFPS summarizes the other infrastructure required to implement the project including: advanced treated water pump station; approximately 43,000 linear feet (LF) of new advanced treated water pipeline (6 to 12-inch) to distribute water to the Beltz wellfield; 5 injection wells and 5 monitoring wells and associated buildings. The study's summary of probable costs estimated the total capital costs at $70.5 million (includes treatment, pipelines, pump station, site retrofit costs, wells) and presents a summary of loaded capital costs, by facility component, as well an annual unit life cycle costs.

The RWFPS summarizes the significant limitations and challenges of the project as:

1. Operational complexity and energy for treatment and injection;
2. Additional studies to confirm the groundwater basin capacity, ability to capture recharged flow and meet all regulatory requirements;
3. The produced water quality exceeds the needs for non-potable reuse.

Based upon the identified limitations and challenges, this project is included in Group 3 because there is insufficient information at this stage to fully evaluate its feasibility and merits. Pending the potential implementation of Group 2 projects and management actions and the Basin's hydrologic response as indicated in the assessments of the sustainable management criteria during the GSP implementation, the MGA may reevaluate the need and further evaluate a centralized Groundwater Replenishment Reuse Project (GRRP) led by SCWD.

4.3.2 Recycled Water – Surface Water (Reservoir) Augmentation

As discussed in Section 4.3.1 above, SCWD's Recycled Water Facilities Planning Study (RWFPS) evaluated recycled water alternatives (Kennedy/Jenks 2018). This included an evaluation of recycled water use for a Surface Water Augmentation (SWA) project (Alternative 5) to convey advanced treated water from the Santa Cruz WWTF to blend with raw water and store in Loch Lomond Reservoir, a source of municipal drinking water supply for the SCWD service area. Water from Loch Lomond would be conveyed to and treated at SCWD's Graham Hill Water Treatment Plan (GHWTP) before entering SCWD's potable water distribution system.

The study found that a SWA project at Loch Lomond would maximize the beneficial reuse of wastewater in summer months, and potentially provide more operational flexibility for reservoir operations. Instead of preserving storage to assure sufficient water supply for SCWD in the dry months, in all seasons Loch Lomond could be used as a climate independent resource for the region. Based upon the project assumptions and operational conditions, the project is estimated to produce up to 1,777 AFY of recycled water. The available supply for a SWA project would depend on the amount of secondary effluent available for reuse, the dilution ratio and the retention time in the reservoir needed to meet state regulations on the use of recycled water.

Due to the distance and lift required to convey advanced treated water to Loch Lomond Reservoir, there would be significant additional infrastructure, pumping and energy requirements for conveyance. The study estimated the total cost at $106.5 million and presents a summary of loaded capital costs, by facility component, as well an annual unit life cycle costs.

The RWFPS identifies the project's significant limitations and challenges as:

- High capital and unit costs due to extensive infrastructure required
- Challenging Regulatory, CEQA/NEPA And Permitting Requirements
- Operational complexity for treatment and reservoir management
- Significant energy for conveyance and treatment
- May limit future expansion at the Santa Cruz WWTF
- Additional limnological studies needed to confirm assumptions

The SWA project was not selected as a preferred alternative in the RWFPS; in the evaluation and sensitivity analysis of the eight alternatives, the SWA ranked towards the bottom. It should be noted that the assessment of this project was done within the context of the WSAC recommendations, to evaluate supplemental supply alternatives to address SCWD's water supply gap during times of extended drought. The MGA's principal planning objective is the Basin's sustainability goal. The initial feasibility assessment did not identify any regulatory "fatal flaws" for the implementation of a SWA project at Loch Lomond Reservoir. The identified limitations and challenges pertain to either addressing drought supply or the MGA's needs. Pending the potential implementation of Group 2 projects and management actions and the Basin's hydrologic response as indicated in the assessments of the sustainable management criteria as the GSP implementation progresses, the MGA may reevaluate the need to further evaluate SWA.

4.3.3 Recycled Water – Direct Potable Reuse

Current California regulations do not allow for the use of recycled water for Direct Potable Reuse (DPR). DRP is generally defined as the introduction of recycled water directly into a public water system. In 2010, the California Senate enacted legislation[2] to expand the Water Code regarding potable reuse of recycled water. In the decade since, state drinking water and public health regulatory agencies have continued the assessment and possible framework for the regulation of potable reuse projects. In its 2016 *Investigation on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse,* the State Water Resources Control Board concluded "the use of recycled water for DPR has great potential but it presents very real scientific and technical challenges that must be addressed to ensure the public's health is reliably protected at all times (SWRCB, 2016).

No DPR projects currently exist in California and existing regulations have not been developed. However, it is conceivable that DPR will become a future strategy to augment public water

[2] Senate Bill (SB) 918 (Chapter 700, Statutes of 2010), which added sections 13560-13569 (Division 7, Chapter 7.3)

supplies. Accordingly, SCWD's Recycled Water Facilities Planning Study (RWFPS) evaluated the use of recycled water for Direct Potable Reuse (DPR) (Alternative 7) (Kennedy/Jenks, 2018). The source of supply would be wastewater effluent receiving secondary at the Santa Cruz WWTF. This effluent would receive full advanced treatment prior to blending with raw water coming from City's other flowing sources for further treatment at the GHWTP prior to distribution as potable water. The Advanced Water Treatment Facility's (AWTF) capacity would be sized based on the secondary effluent available in the summer, less secondary effluent delivered for other potential project demands. Up to 3.2 MGD (3,585 AFY) of advanced treated water production capacity at the City's WWTF would be utilized year-round. The study estimated the total cost at $110.6 million. In the future, if a mandate for additional treatment of wastewater effluent or a ban on ocean discharge is enacted SCWD would evaluate water recycling to achieve zero or near-zero discharge. If this situation occurs, DPR could be revisited to increase the amount of beneficial reuse.

The RWFPS evaluated these alternatives principally as a means to address SCWD's water supply needs during drought. However, conceptually DPR could serve to as a supplemental supply to address the sustainability goals of the GSP by reducing the need for groundwater pumping in the Basin. Conceptually, this would likely entail a dual-purpose approach designed to meet SCWD's drought needs and as well as serve as a supplemental supply to the MGA to assist in maintaining or enhancing protective water level elevations.

Based upon the current regulations and considerable uncertainty related to scientific, technical, and social considerations, DPR is not considered a viable strategy to achieve the basin sustainability goal. However, as the GSP implementation proceeds over the coming decades, the MGA anticipates evaluating the potential applicability of DPR in managing the Basin in a sustainable manner.

4.3.4 Groundwater Pumping Curtailment and/or Restrictions

In many of the groundwater basins subject to SGMA throughout the State, pumping restrictions are one of the key components of the GSP. The MGA believes that the current level of Basin pumping can be continued with the effective implementation of the Group 1 and Group 2 Projects and Management Actions. However, the MGA also acknowledges that pumping restrictions are an effective tool to achieve groundwater sustainability that may need to be used in the future.

For the purpose of the GSP, pumping restrictions are defined as reductions or limitations in the amount of water a current or future groundwater user can pump from the Basin. This would be applied in the case of a situation where the planned Projects and Management Actions are insufficient to reach and/or maintain sustainability and one or more sustainability indicator is likely to dip below the minimum threshold by 2040. Under such a curtailment scenario, the MGA would determine the amount of water that affected pumpers could take sustainably, and the pumpers would be required to reduce their groundwater extraction to that allocation. All pumpers subject to allocations and restriction would be required to be metered.

SGMA legislation allows for charging fees for pumping in excess of allocations or non-compliance with other GSA regulations (CWC Section 10732 (a)). The MGA will consider the adoption of fees and/or other penalties for violations of pumping allowance and/or reporting in the event that restrictions are implemented.

In the event of a need to restrict pumping, pumping restrictions could also be placed on new wells. Restrictions on permits for new groundwater wells would be considered if there was high demand for wells that, if constructed, could lead to the basin water extractions exceeding the sustainable yield for the basin. Alternatively, restrictions on permits in specific areas would be considered if additional localized pumping could drive one or more sustainability indicators below the minimum threshold. Limits could also be placed on which aquifers could be drawn from if there was a potential adverse impact in a particular zone that might affect seawater intrusion or surface water depletions. In the absence of a basin adjudication, pumping restrictions on new uses would need to be applied equitably and in a similar proportion to restrictions on existing users.

Considerably more work and discussion would need to be done to define the policies and procedures for pumping restrictions in the event that pumping restrictions are determined necessary to attain and maintain sustainability.

4.3.5 Local Desalination

The treatment techniques and processes used to produce drinking water from seawater have a track record of performance and are in use in California and elsewhere in the United States and the world. Concerns raised during the consideration of an earlier local desalination project known as scwd^2 jointly sponsored by SCWD and the SqCWD included the energy intensive nature of desalination facilities and potential impacts to marine life in the Monterey Bay National Marine Sanctuary related to the proposed project intake.

The City's Water Supply Advisory Committee (WSAC) identified local desalination as an element 3 project that could be pursued if element 1 and 2 projects either failed to be feasible or failed to fulfill SCWD's agreed upon water supply shortfall in a cost efficient manner (SCWD 2015). However, since WSAC prioritized projects in 2015, additional state regulatory requirements have substantially increased to permit a desalination ocean intake. These additional regulatory requirements and the potential project timing issues related to them, have led the City to further de-prioritize local desalination as a potential water supply source. In addition to regulatory hurdles, any project involving the City of Santa Cruz would also require voter approval before a legislative action could authorize, permit, construct, operate and/or acquire a desalination plant or incur any indebtedness for that purpose by the City.

While desalination is technologically feasible it has become an unlikely source of water supply in the foreseeable future based on local political opposition, environmental concerns, and regulatory uncertainties.

4.3.6 Regional Desalination

After the scwd[2] local desalination project was put on hold in 2014, SqCWD completed its Community Water Plan (SqCWD 2015). During the development of that Plan, community input gathered identified the need for a timely solution to the threat of seawater intrusion. Along with ongoing conservation projects, community members rated regional desalination among three water augmentation strategies for SqCWD to pursue to increase its water supply and reduce groundwater pumping in the Basin.

Based on the Community Water Plan, SqCWD entered into a memorandum of interest (MOI) with DeepWater Desal, LLC to express its interest in purchasing up to 1,500 acre-feet per year of desalinated water produced from a proposed desalination facility in Moss Landing. The MOI is non-binding and does not obligate SqCWD to make any financial commitment.

The DeepWater Desal project is in evaluation, with development of a draft Environmental Impact Report (EIR) and studies to support compliance with the California Ocean Plan Desalination Amendments (State Water Board 2015). There is uncertainty regarding the potential availability of water from the proposed regional desalination facility to meet the sustainability goals of the Basin. The regulatory hurdles required to permit an ocean intake for the desalination plant within the Monterey Bay National Marine Sanctuary and other factors contribute to this project uncertainty.

Section 5 Contents

Tables

Figures

5 PLAN IMPLEMENTATION

5.1 Estimate of GSP Implementation Costs

This subsection provides an estimate of the cost to implement the Groundwater Sustainability Plan (GSP or Plan) and a general description of how the Santa Cruz Mid-County Groundwater Agency (MGA) plans to meet those costs. Implementation cost considerations include MGA administration, management actions, monitoring protocols, data management, maintaining a prudent fiscal reserve, and other costs estimated over a twenty-year time horizon. The estimated costs of projects and management actions are presented in this section. The funding sources and mechanisms and an estimated schedule for GSP implementation are also presented.

As noted in prior Sections of the GSP, the MGA Board is in agreement that the individual MGA member agencies will principally lead the implementation of projects and management actions. A major rationale for this decision was the long-standing engagement of MGA member agencies in groundwater management and water supply reliability planning work. The City of Santa Cruz Water Department (SCWD) and Soquel Creek Water District (SqCWD) have evaluated a number of supplemental supply options over the last five years, and in several cases work has proceeded far enough to make it significantly more efficient for these agencies to continue their efforts rather than switching project implementation actions to the MGA.

5.1.1 Estimate of Ongoing Costs by Major Category

This subsection presents estimates of costs by the major categories. Presented are the estimated annual cost of ongoing activities as well as the estimated cost of events for activities that do not occur annually but are anticipated within the next five years. This approach enables calculation of a 5-year total cost estimate which is annualized to better inform the MGA's general estimate of costs by the major categories. Since costs are based on the best estimates at the time of this report, actual costs may vary from those used in the projections below.

5.1.1.1 Agency Administration and Operations

This category includes the costs related to the administration of the MGA, including administrative staff support, finance staff support and related expenses, insurance, organizational memberships and conferences, miscellaneous supplies and materials. These estimated costs are presented in Table 5-1.

The MGA uses a collaborative staffing model to accomplish its work. Professional and technical staff from MGA member agencies provide staff leadership, management, work products, and administrative support for the MGA. Since 2016, the MGA has contracted with the Regional Water Management Foundation (RWMF), a subsidiary of the Community Foundation of Santa Cruz County, to provide core staff support to the MGA for planning and administration. As the MGA shifts from GSP development into implementation starting in 2020, the staffing support needs will be further evaluated to determine the ongoing administrative and management framework. It is anticipated staffing needs will be evaluated annually during the early years of GSP implementation as a clearer understanding of the support required evolves over time.

Table 5-1. Estimated Agency Costs by Major Category

Category	Annual Cost	Event Cost	5-Year Total	Annualized Cost (5-Years)
Agency Administration & Operations				
Administrative Staff Support	$150,000	$0	$750,000	$ 150,000
Treasurer & Finance Staff	$12,000	$0	$60,000	$ 12,000
Accounting and other software	$2,500	$0	$12,500	$ 2,500
Annual financial audit	$9,000	$0	$45,000	$ 9,000
Professional organizations	$2,500	$0	$12,500	$ 2,500
Insurance	$1,000	$0	$5,000	$ 1,000
Office supplies, materials, misc. expenses	$2,500	$0	$12,500	$ 2,500
Legal	$20,000	$0	$100,000	$ 20,000
Management & Coordination				
Technical Work: Groundwater Model	$20,000	$100,000	$200,000	$ 40,000
Technical Work: Consultants	$15,000	$0	$75,000	$ 15,000
Planning/Program Staff Support	$25,000	$0	$125,000	$ 25,000
Data Collection, Analysis, & Reporting				
Monitoring: Groundwater Elevation	$10,000	$160,000	$210,000	$ 42,000
Monitoring: Groundwater Quality[1]	$0	$0	$0	$ 0
Monitoring: Groundwater Extractions	$15,000	$15,000	$90,000	$ 18,000
Monitoring: Streamflow	$12,500	$80,000	$142,500	$ 28,500
Data Collection: Offshore AEM Surveys	$0	$150,000	$150,000	$ 30,000
Data Collection: Other	$10,000	$0	$50,000	$ 10,000
Data Management	$20,000	$50,000	$150,000	$ 30,000
GSP Reporting				
Annual Reports	$25,000	$0	$125,000	$ 25,000
5-year GSP Evaluations	$0	$100,000	$100,000	$ 20,000
Outreach & Education	$20,000	$0	$100,000	$ 20,000
Contingency (10%)	$37,200	$65,500	$251,500	$ 50,300
TOTAL	$409,200	$720,500	$2,766,500	$ 553,300

1. Groundwater quality monitoring is conducted by the individual member agencies

The SqCWD Finance Manager serves as MGA Treasurer and is responsible, with support from the SqCWD finance staff, for the accounting and billing functions of the MGA. This budget category includes finance related costs for accounting software and the annual financial audit. Also included is the annual membership dues for the Association of California Water Agencies (ACWA) and the annual insurance costs from Association of California Water Agencies Joint Powers Insurance Authority (ACWA/JPIA).

5.1.1.2 Legal Services

The MGA receives legal services from the County of Santa Cruz (County) on an as-needed basis. If legal services are needed on issues requiring specific expertise on groundwater, the Sustainable Groundwater Management Act (SMGA), other specific matters as necessary, or if there is a conflict of interest for County Counsel, the MGA will employ other counsel. The estimated cost of legal services is presented in Table 5-1.

5.1.1.3 Management and Coordination

5.1.1.3.1 Technical Work: Groundwater Model Simulations and Updates

The Basin groundwater model informs the management activities and ongoing performance assessment of the sustainable management criteria. Periodic updates to the groundwater model will be required to continue to refine and improve its capabilities and maintain ongoing functionality. This includes incorporating new model tools and features, updates to data, and related work to support ongoing simulations of projects and management actions. The model will be an important tool to inform the evaluation of Basin management strategies over time. This task will be performed by technical consultants. The estimated cost of this task is presented in Table 5-1.

5.1.1.3.2 Technical Work: Consultants

It is anticipated the MGA will have an ongoing need for technical support to inform Basin management. The specific needs and costs are yet to be identified but it is expected, as the initial GSP implementation efforts proceed, that these needs will become evident. Examples of technical consultant support are potential tasks such as: hydrologic technical support (not groundwater model specific); economic (e.g., cost-benefit analysis) and programmatic assessment of funding mechanisms; supplemental studies to address data gaps; vulnerability assessments for climate change and sea-level rise; additional assessment of managed aquifer recharge opportunities; among other tasks. In recognition of the potential need for technical support, the funding for this category is included in Table 5-1.

5.1.1.3.3 Planning/Program Staff Support

This category is broadly intended to include various planning and programmatic support to the MGA for ongoing GSP and SGMA related requirements.

5.1.1.4 Data Collection, Analysis, and Reporting

The MGA's proposed monitoring program is presented in the monitoring section (Section 3.3). The individual member agencies will continue to lead the semi-annual monitoring of groundwater elevation and water quality within their jurisdictions to inform the management of their respective agencies. It is anticipated that costs resulting from improvements to or expansion of existing monitoring networks necessary to evaluate the Sustainable Management Criteria (SMC), or otherwise added at the request of the MGA, will be funded by the MGA. Individual member agencies conduct streamflow monitoring. It is anticipated the MGA will assume responsibility to coordinate and fund streamflow monitoring within the Basin and this is to be a phased transition over the next five years.

5.1.1.4.1 Monitoring: Groundwater Elevation

There is a combined network of 174 wells in the Basin monitored at least twice a year. This network is made up of individual member agency wells combined into the Groundwater Management Plan (GMP) monitoring network, as described in Section 2.1.2: Water Resources Monitoring and Management Programs. This existing network is sufficient to evaluate short-term, seasonal, and long-term trends in groundwater elevations for groundwater management purposes. Each individual member agency will continue to use its own resources to monitor its wells as the GSP is implemented. Monitoring is described in detail in Section 3.1.1.1 Groundwater Level Monitoring Network.

<u>Deep Wells:</u> Section 3.3.4.1 presents the Groundwater Level Monitoring Data Gaps. To fill an identified data gap to improve the ability to monitor seawater intrusion requires installation of two new deep coastal monitoring wells. One of these is a deep Tu-Unit monitoring well within the SCWD service area and the other is a Purisima AA-Unit at the site where existing monitoring well SC-3 is located within SqCWD's service area. The well data will inform groundwater management by the respective member agencies within the Basin. It is anticipated the construction and operation of these wells will be funded by the respective member agencies, not the MGA.

<u>Shallow Wells:</u> As discussed in Section 3.3.4.1, the addition of up to eight new shallow monitoring wells is proposed to improve the ability to monitor surface water/groundwater interactions. These wells will serve to inform the performance assessment of the sustainable management criteria for depletion of interconnected surface waters, as required under SGMA. The proposed eight shallow monitoring wells are anticipated to be installed in a phased approach at prioritized locations within the next 5 years. The MGA will continue to assess the prioritization and schedule for new shallow well locations as the network expands. Because this is monitoring that would not otherwise be conducted by the individual member agencies, the MGA will assume the costs associated with this monitoring. The MGA's cost to improve the monitoring network with the addition up to 8 new shallow monitoring wells. This includes costs related to site assessment, planning, design, construction, and instrumentation. These are approximate cost estimates as there are uncertainties such as site-specific considerations,

construction bid environment as well as a variety of other factors that will ultimately determine the cost to install and operate each shallow monitoring well.

5.1.1.4.2 Monitoring: Groundwater Quality

Each MGA member agency has its own network of dedicated monitoring wells and production wells to monitor groundwater quality in its service area or area of jurisdiction. These are described in detail in Section 3.1.1.2 Groundwater Quality Monitoring Network. Each agency will use its own resources to continue to sample these wells as the GSP is implemented. No new MGA-specific groundwater quality monitoring wells are proposed at this time. Monitoring for seawater intrusion will continue; the cost of the efforts is captured under groundwater elevation and other categories. The future need for new MGA groundwater quality monitoring wells will continue to be periodically evaluated as projects and management actions are implemented.

5.1.1.4.3 Groundwater Extraction Monitoring

5.1.1.4.3.1 Metered Groundwater Extraction Public and Small Water Systems

Each MGA municipal water agency meters its own groundwater extraction by individual well and utilizes Supervisory Control and Data Acquisition (SCADA) systems to record groundwater extraction data. Each individual member agency will continue to use its own resources to monitor these groundwater production wells as the GSP is implemented.

As described in Section 3.1.1.3, small water systems with 5 to 199 connections and other applicable businesses/operations are required to be metered groundwater extraction and report annually to Santa Cruz County. The cost to meter and report groundwater use will continue to be the responsibility of individual small water systems and applicable businesses/operations.

5.1.1.4.3.2 Metered Groundwater Extraction Non-*De Minimis* Users

The MGA will initiate a new well metering program to collect volumetric data on groundwater usage in the Basin that will inform the assessment and refinement of the sustainable yield of the Basin. The program will apply to two categories of users: (1) all non-de minimis pumping operations expected to extract more than 5 acre-feet per year, and (2) all non-de minimis pumping operations expected to extract more than 2 acre-feet per year that may impact seawater intrusion or an interconnected stream where groundwater dependent ecosystems are identified in Section 3.9. The boundaries of these zones will be established when the enabling ordinances are developed, but it is anticipated the zones will include the areas along the coast where groundwater is less than 50 feet above sea level and areas within 500 -1000 feet of Soquel Creek.

The costs to implement the metering program include: program administration; coordination of program set-up and implementation; participant tracking; and coordination of annual reporting by the participants. The MGA will initiate planning in 2020 to develop the program. It is anticipated the participating users are responsible for all costs related to the purchase, installation, calibration, and operation of the meters as well as annual reporting to the MGA.

5.1.1.4.4 Monitoring: Streamflow

As detailed in Section 3.1.1.4, streamflow monitoring is conducted by MGA member agencies and partners to assess possible streamflow depletion related to groundwater extractions, monitor stream conditions related to fish habitat, and help preserve other beneficial uses of surface water.

To inform assessment and performance of Basin SMCs, there are up to five new streamflow gauges associated with shallow monitoring wells that need to be installed by the MGA. The paired wells and gauges (adjacently located) are to evaluate a potential correlation between streamflow, shallow groundwater levels, and groundwater extraction.

The MGA's estimated costs to install, calibrate and maintain the streamflow gauges are presented in Table 5-1. This estimate includes one-time costs related to the initial establishment of the five new stations. The cost estimate includes planning, site selection, design specifications, and related pre-installation tasks. It includes the cost to install the monitoring instrumentation, conduct surveys and related work to establish each monitoring site and costs to develop rating curves to establish a stream stage-discharge relationship for each site. It includes the costs of routine data collection and station maintenance. The assignment of roles and responsibilities (consultants and agency staff) will be evaluated as GSP implementation proceeds.

It is anticipated the new monitoring locations will be installed in a phased approach over the next five years. The MGA's Proposition 1 GSP Planning grant is providing $125,000 towards funding at least one streamflow and/or shallow groundwater elevation monitoring installation. The MGA will seek additional grant funding available from the Department of Water Resources (DWR) and consider other state and federal programs to partially fund the installation of new streamflow gauges and related monitoring.

5.1.1.4.5 Data Collection: Offshore Airborne Electromagnetics Geophysical Surveys

In May 2017, the MGA successfully completed an offshore Airborne Electromagnetic (AEM) geophysical survey to assess groundwater salinity levels and map the approximate location of the saltwater/freshwater interface in the offshore groundwater aquifers. This important data will inform the assessment of the extent and progress of seawater intrusion into the Basin and the management responses. The MGA anticipates repeating the AEM survey on a five-year interval (2022) to identify movement of the interface and assess seawater intrusion. The estimated cost is presented in Table 5-1.

5.1.1.4.6 Data Collection: Other

Additional data collection costs include a funding contribution toward a countywide fish and stream habitat monitoring program. Since 2006, this multi-agency partnership between the County and local water agencies has measured juvenile steelhead population density at more than 40 sites throughout the San Lorenzo, Soquel, Aptos, and Pajaro watersheds. The program also assesses habitat conditions for steelhead and coho salmon and helps inform conservation priorities throughout the County. These data are anticipated to generally inform the MGA's ongoing consideration of potential groundwater management impacts to groundwater dependent ecosystems.

5.1.1.4.7 Data Management

The MGA's anticipated initial costs in this category include engaging a consultant to conduct a data management assessment and develop a data management plan that is based upon the monitoring protocols outlined in Section 3 and leverages the existing data management efforts of the member agencies. Ongoing costs in this category include maintaining a data management system (DMS) that provides necessary functions and capabilities for data, such as: input, organization, storage, accessibility; quality assurance/quality control; security and redundancy; report outputs; and data sharing.

SCWD and SqCWD utilize a data management system (DMS) based upon the commercial software platform Water Information Systems by KISTERS (WISKI). This DMS is used for management and analyses of groundwater elevation, groundwater quality, groundwater extractions, streamflow, precipitation / weather data. For data management consistency, it is anticipated the MGA will also use WISKI as its principal data management platform. The platform options will be evaluated further. The anticipated MGA costs for data management are presented in Table 5-1. Costs include software purchase and license, set-up and configuration, software annual support and maintenance.

5.1.1.5 GSP Reporting to DWR

5.1.1.5.1 Annual Reports

SGMA regulations require the MGA submit annual reports to DWR on the status of GSP implementation. The reporting requirements are presented in Section 5.3. It is anticipated these reports will be prepared by technical consultants in coordination with the MGA member agency staff. The estimated cost of the annual reports is presented in Table 5-1.

5.1.1.5.2 Periodic (5-year) Evaluations

SGMA regulations require the MGA evaluate the GSP at least every 5 years and whenever the Plan is amended. The reporting requirements for the periodic evaluation are presented in Section 5.3. The initial 5-year GSP evaluation is due to DWR in April 2025. The roles and responsibilities for preparation of the updated GSP are not yet determined. In recognition that this mandatory requirement will be completed by the MGA, for purposes of estimating the costs, the cost for preparation of the 5-year GSP evaluation document by technical consultants is presented in Table 5-1.

5.1.1.6 Community Outreach & Education

In 2018, the MGA Board approved a Communication and Engagement Plan that outlined a phased approach for conducting stakeholder outreach, engagement, and education activities. Ongoing activities in the GSP implementation phase starting in 2020 are anticipated to include outreach such as: maintaining the MGA website and related online/social media through the member agencies (e.g., Facebook; Nextdoor); electronic newsletter; promoting and conducting community meetings, workshops, events; coordination with the Water Conservation Coalition of Santa Cruz County; conducting informational surveys; youth engagement efforts; developing brochures and print materials; and similar community engagement activities. The estimated costs for these activities are presented in Table 5-1.

5.1.1.7 Financial Reserves and Contingencies

Prudent financial management requires that the MGA carry a general reserve in order to manage cash flow and mitigate the risk of expense overruns due to unanticipated expenditures and in case actual expenses are greater than anticipated in the MGA's annual budget. General reserves have no restrictions on the types of expenses they can be used to fund. The ending balance in general reserves becomes the beginning balance of cash reserves for the next fiscal year.

The MGA annual budget includes a contingency amount in recognition that the MGA and the GSP implementation is new and there is the potential for unanticipated expenses. Since 2016, the MGA's contingency fund been set annually at either 5% or 10% of the total annual operating budget. For purposes of conservatively estimating the cost to implement the GSP, the budget estimate includes a 10% contingency based upon the annual fiscal year budget estimate.

5.1.2 Activities of the MGA Member Agencies

5.1.2.1 Monitoring Activities

The individual MGA member agencies conduct groundwater, streamflow, and watershed monitoring activities in the Basin that inform the management of their respective agencies. The MGA does not contribute towards these individual monitoring efforts and these costs are not included in the MGA's estimate of the cost to implement the GSP. However, the results of monitoring activities relevant to the MGA will be included in the MGA's data management system. Annual MGA member agency monitoring costs are provided in Table 5-2 and Table 5-3 to provide context for the extent of relevant monitoring activities that are conducted within Basin.

Table 5-2. Member Agency Groundwater Elevation and Quality Monitoring Annual Costs in Basin

AGENCY	Equipment	Data Mgmt & Software	Lab/ Analytical	Personnel	Estimated Total[1]
Soquel Creek Water District	$ 7,500	$ 7,500	$ 20,000	$ 65,000	$ 100,000
City of Santa Cruz[2]	$ 3,000	$ 5,000	$ 10,000	$ 37,000	$ 55,000
Central Water District	$ 1,000	$ 1,000		$ 1,000	$ 3,000
County of Santa Cruz	$ 1,000	$0	$0	$ 10,000	$ 11,000

1. Costs estimates based upon FY 2018-19 amounts
2. City's Live Oak Groundwater Monitoring Program

Table 5-3. Member Agency Streamflow, Precipitation, and Fish Monitoring Annual Costs in Basin

AGENCY	Services[1]	Site Use	Fish Monitoring	Personnel	Estimated Total[2]
Soquel Creek Water District	$17,000	$1,500	$12,000	$4,500	$35,000
County of Santa Cruz			$10,000	$10,000	$20,000
1. Consultants and USGS; 2. Costs estimates based upon FY 2018-19 amounts; 3. These are approximate costs within the MGA Basin only; 4. City of Santa Cruz contributes to Fish Monitoring program in Soquel Creek and groundwater impacts monitoring.					

5.1.2.2 Member Agency Projects

The MGA's individual member agencies are implementing projects and management actions. This includes the continuation of existing programs, such as demand management and water conservation programs that have been in place for many years and have proven effective to reduce per capita water demand in the region to among the lowest levels in the state. Also included are specific existing and proposed projects of the individual member agencies to provide supplemental supply to the Basin. It is largely the projects and management actions of individual agencies, rather than any direct actions taken by the MGA, that will collectively determine the sustainable management of the Basin. While these project costs are not included the MGA's budget, the costs outlined in Table 5-4 provide context for the level of member agency investment in the Basin's long-term sustainability.

Table 5-4. Member Agency Projects

Project	Agency	Cost Considerations
Aquifer Storage and Recovery (ASR)	SCWD	Approximate cost of this project within the Purisima aquifer locations only is $21M.
Water Transfers / In Lieu Groundwater Recharge and	SCWD; SqCWD	To be determined after the pilot project is complete. This will need to consider Prop. 218 if/when the SCWD provides water to SqCWD to determine appropriate cost for the water.
Pure Water Soquel	SqCWD	Projected cost is $90 million to permit and construct. The project will be funded entirely through water rates and/or low interest loans or grant funds; at no direct costs are anticipated to the MGA.
Distributed Storm Water Managed Aquifer Recharge (DSWMAR)	County; SqCWD	A report developed for the County estimates costs per acre-foot of water infiltrated over a 20 year project lifespan varied between $1,649 and $2,786 per acre-foot for the specific projects evaluated. Project development costs for initial project installation were estimated at $450,000 (Los Altos) and $650,000 (14th Fairway) (MME, 2019).

5.1.3 Total Estimated Implementation Costs Through 2040

The estimated total cost to implement the GSP over the 20-year planning horizon is $15,866,700 (Table 5-5). This projection uses the 2020 annualized cost (5-Year) for the baseline. The estimated cost is presented by major budget category, which includes: Agency Administration and Operations; Legal; Management and Coordination; Data Collection, Analysis, and Reporting; GSP Annual and Periodic (5-Year) Reporting to DWR; and, Outreach and Education. The annual costs include a 10% contingency and an annual rate of inflation of 3.0%. These estimated costs are based on the best available information at the time of Plan preparation. Grant awards may offset some costs. This represents the current understanding of Basin conditions and the current roles and responsibilities of the MGA under SGMA.

Table 5-5. Groundwater Sustainability Plan Estimated Implementation Cost Through 2040

Fiscal Year	Agency Administration & Operations	Legal	Management & Coordination	Data Collection, Analysis, & Reporting	GSP Reporting (Annual & 5-Year)	Outreach & Education	10% Contingency	Total
2020	$179,500	$20,000	$80,000	$158,500	$45,000	$20,000	$50,300	$553,300
2021	$184,885	$20,600	$82,400	$163,255	$46,350	$20,600	$51,809	$569,899
2022	$190,432	$21,218	$84,872	$168,153	$47,741	$21,218	$53,363	$586,996
2023	$196,144	$21,855	$87,418	$173,197	$49,173	$21,855	$54,964	$604,606
2024	$202,029	$22,510	$90,041	$178,393	$50,648	$22,510	$56,613	$622,744
2025	$208,090	$23,185	$92,742	$183,745	$52,167	$23,185	$58,311	$641,426
2026	$214,332	$23,881	$95,524	$189,257	$53,732	$23,881	$60,061	$660,669
2027	$220,762	$24,597	$98,390	$194,935	$55,344	$24,597	$61,863	$680,489
2028	$227,385	$25,335	$101,342	$200,783	$57,005	$25,335	$63,719	$700,904
2029	$234,207	$26,095	$104,382	$206,807	$58,715	$26,095	$65,630	$721,931
2030	$241,233	$26,878	$107,513	$213,011	$60,476	$26,878	$67,599	$743,589
2031	$248,470	$27,685	$110,739	$219,401	$62,291	$27,685	$69,627	$765,897
2032	$255,924	$28,515	$114,061	$225,983	$64,159	$28,515	$71,716	$788,873
2033	$263,602	$29,371	$117,483	$232,763	$66,084	$29,371	$73,867	$812,540
2034	$271,510	$30,252	$121,007	$239,745	$68,067	$30,252	$76,083	$836,916
2035	$279,655	$31,159	$124,637	$246,938	$70,109	$31,159	$78,366	$862,023
2036	$288,045	$32,094	$128,377	$254,346	$72,212	$32,094	$80,717	$887,884
2037	$296,686	$33,057	$132,228	$261,976	$74,378	$33,057	$83,138	$914,521
2038	$305,587	$34,049	$136,195	$269,836	$76,609	$34,049	$85,632	$941,956
2039	$314,754	$35,070	$140,280	$277,931	$78,908	$35,070	$88,201	$970,215
2040	$324,197	$36,122	$144,489	$286,269	$81,275	$36,122	$90,847	$999,321
Total	$5,147,429	$573,530	$2,294,119	$4,545,223	$1,290,442	$573,530	$1,442,427	$15,866,700

1. Assumes inflation factor of 3% annually

5.1.4 Funding sources and mechanisms

Initial GSP Implementation Phase (2020 – 2025)

The initial funding for GSP implementation will be obtained from the annual contributions of the four MGA member agencies. MGA bases annual member contributions on estimated Basin sustainability impacts. Costs are currently allocated 70% to Soquel Creek Water District and 10% each to the County, the City, and Central Water District. This funding approach has been used since the MGA's formation in 2016. This cost allocation may change as the MGA learns more about Basin sustainability impacts through GSP data collection and the beneficial impacts of agency projects and management actions that improve sustainability. The annual contribution total and individual agency amounts are assessed annually based upon the MGA's annual budget. In 2017, the MGA was awarded a $1.5M grant from DWR's Sustainable Groundwater Management Program to fund, in part, the development of the GSP. The MGA will continue to pursue funding from state and federal sources to support GSP planning and implementation.

Ongoing GSP Implementation (2026 – 2040)

SGMA authorizes groundwater sustainability agencies to charge fees necessary to fund the costs of groundwater management, pumping, permitting, and other groundwater sustainability programs. A public finance consulting firm prepared a detailed memorandum outlining the funding mechanisms, necessary policies, and data required to develop a fee program that is equitable, complies with SGMA and California's complex public finance laws. This detailed memorandum from Raftelis is included for reference only as Appendix 5-A. In its memorandum Raftelis:

1. Presents a suite of options to recover MGA costs from large private groundwater pumpers based on geographic location, proximity to surface water and the coast, volume of water pumped, and other criteria;
2. Calculates fees using preliminary data based on parcels, acreage, and volumetric production of water
3. Assesses the costs and benefits of each fee structure and mechanism for implementing each fee
4. Relates the implications of each fee type to the requirements of Proposition 218 and Proposition 26
5. Describes the conditions, if any, whereby de-minimis users can be charged for a fair share of MGA costs

As initial GSP implementation proceeds, the MGA will further evaluate funding mechanisms, potential application of fees, and fee criteria. The MGA may perform a cost-benefit analysis regarding fee collection to build upon the initial funding mechanism assessment and to better inform its evaluation of fee alternatives.

5.2 Schedule for Implementation

The final GSP was presented to the MGA Board for adoption at its November 21, 2019 meeting and will be submitted to DWR no later than January 31, 2020. Figure 5-1 provides an overview of the preliminary schedule for agency administration, management and coordination activities, GSP reporting, and community outreach and education. Many of these categories consist of ongoing tasks and efforts that will continue throughout GSP implementation.

Management & coordination in the schedule at Figure 5-1 includes data collection, analysis, and reporting. This category includes the installation of stream gages and development of associated shallow wells to fill data gaps for depletion of interconnected surface water monitoring discussed in Section 3.3.4.1 and 3.3.4.2. MGA has applied for and been awarded grant funds that include both grant and match funding to make these improvements to the monitoring network. In early 2020 MGA will release a request for proposal (RFP) to acquire land access and conduct installation of stream gages and shallow monitoring wells. MGA staff expects the work included in the RFP to begin prior to October 2022.

The timing of periodic events, such as offshore aerial electromagnetics (AEM) surveys of the freshwater-saline water interface, are best estimates and may shift as GSP implementation proceeds based upon the needs at the time. GSP reporting will occur on an annual and a 5-year basis as required under SGMA. Annual reports will be submitted to DWR by April 1 of each year. Periodic reports (every 5-years or following substantial GSP amendments) will be submitted to DWR by April 1 at least every 5 years (2025, 2030, 2035, and 2040). The contents of Annual and Periodic reports are described in the following Sections 5.3 and 5.4.

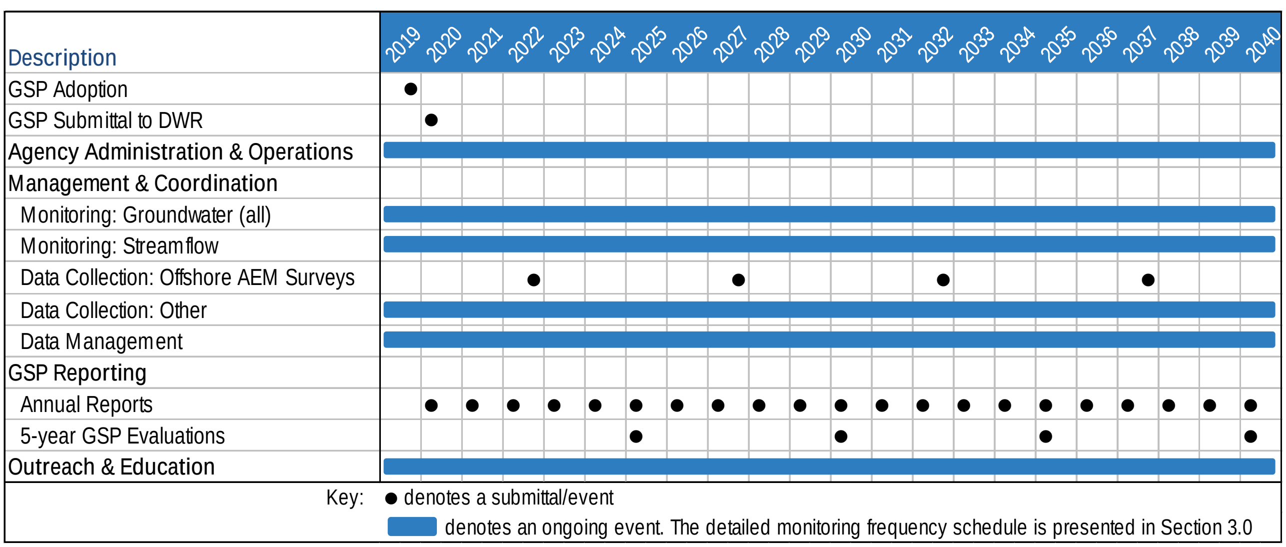


Figure 5-1. GSP Implementation Schedule

5.2.1 Projects and Management Actions

The estimated schedule for the individual MGA member agency projects and management actions is presented in Figure 5-2. The Group 1 Baseline projects are anticipated to be evaluated through the GSP planning and implementation horizon of 50 years. All of these efforts will be periodically assessed as part of an ongoing adaptive management approach.

The Group 2 estimated schedules for the individual member agency projects are also provided. These schedules are based upon current estimates. Some projects, such as Distributed Stormwater Managed Aquifer Recharge include multiple individual projects at separate locations, thus the overlap in the phases of development and implementation. Each of the projects is dependent upon individual factors such as permitting, approval, and funding that may impact the estimated general timeline presented below.

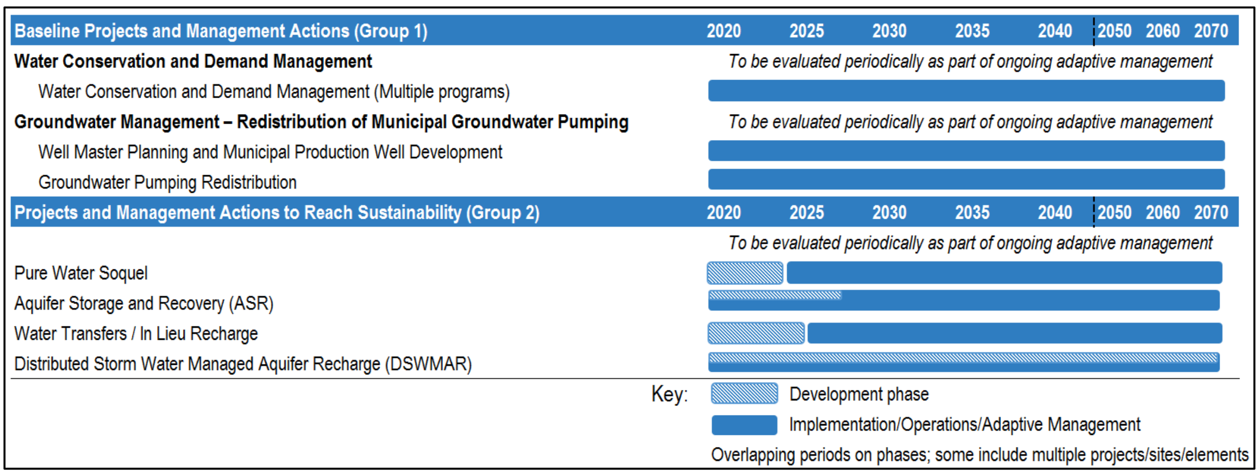


Figure 5-2. Member Agency Projects and Management Actions Estimated Timeline

5.3 Annual Reporting

SGMA regulations require GSAs to submit an annual report on the implementation of the GSP to DWR (Water Code 10727.2, 10728, and 10733.2). An outline of the procedural and substantive requirements for the annual reports is presented below.

The MGA shall submit an annual report to DWR by April 1 of each year following the adoption of the Plan. The annual report shall include the following components for the preceding water year:

1. General information, including an executive summary and a location map depicting the basin covered by the report.

2. A detailed description and graphical representation of the following conditions of the basin managed in the Plan:

a. Groundwater elevation data from monitoring wells identified in the monitoring network shall be analyzed and displayed as follows:

    i. Groundwater elevation contour maps for each principal aquifer in the basin illustrating, at a minimum, the seasonal high and seasonal low groundwater conditions.

    ii. Hydrographs of groundwater elevations and water year type using historical data to the greatest extent available, including from January 1, 2015, to current reporting year.

b. Groundwater extraction for the preceding water year. Data shall be collected using the best available measurement methods and shall be presented in a table that summarizes groundwater extractions by water use sector, and identifies the method of measurement (direct or estimate) and accuracy of measurements, and a map that illustrates the general location and volume of groundwater extractions.

c. Surface water supply used or available for use, for groundwater recharge or in-lieu use shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.

d. Total water use shall be collected using the best available measurement methods and shall be reported in a table that summarizes total water use by water use sector, water source type, and identifies the method of measurement (direct or estimate) and accuracy of measurements. Existing water use data from the most recent Urban Water Management Plans or Agricultural Water Management Plans within the basin may be used, as long as the data are reported by water year.

e. Change in groundwater in storage shall include the following:

    i. Change in groundwater in storage maps for each principal aquifer in the basin.

    ii. A graph depicting water year type, groundwater use, the annual change in groundwater in storage, and the cumulative change in groundwater in storage for the basin based on historical data to the greatest extent available, including from January 1, 2015, to the current reporting year.

3. A description of progress towards implementing the Plan, including achieving interim milestones, and implementation of projects or management actions since the previous annual report.

5.4 Periodic (5-Year) Evaluations

SGMA regulations require the MGA to evaluate this GSP at least every five years and whenever the Plan is amended, and provide a written assessment to the DWR. (Water Code Sections 10727.2, 10728, 10728.2, 10733.2, and 10733.8). An outline of the procedural and substantive requirements for the periodic evaluations reports is presented below.

To comply with the regulations, the MGA's assessment shall describe whether the Plan implementation, including implementation of projects and management actions, are meeting the sustainability goal in the Basin, and shall include the following:

1. A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones, and minimum thresholds.

2. A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.

3. Elements of the GSP, including the Basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.

4. An evaluation of the Basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the MGA's evaluation shows that the Basin is experiencing overdraft conditions, the MGA shall include an assessment of measures to mitigate that overdraft.

5. A description of the monitoring network within the Basin, including whether data gaps exist, or any areas within the Basin are represented by data that does not satisfy the requirements of Sections 352.4 and 354.34(c). The description shall include the following:

    a. An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of Section 354.38.

    b. If the MGA identifies data gaps, the Plan shall describe a program for the acquisition of additional data sources, including an estimate of the timing of that acquisition, and for incorporation of newly obtained information into the Plan.

    c. The Plan shall prioritize the installation of new data collection facilities and analysis of new data based on the needs of the basin.

6. A description of significant new information that has been made available since Plan adoption or amendment, or the last five-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including

the evaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.

7. A description of relevant actions taken by the MGA, including a summary of regulations or ordinances related to the Plan.
8. Information describing any enforcement or legal actions taken by the MGA in furtherance of the sustainability goal for the basin.
9. A description of completed or proposed Plan amendments.
10. Where appropriate, a summary of coordination that occurred between multiple agencies in a single basin, agencies in hydrologically connected basins, and land use agencies.
11. Other information the MGA deems appropriate, along with any information required by the DWR to conduct a periodic review as required by Water Code Section 10733.

6 REFERENCES AND TECHNICAL STUDIES

Alexander, C.S., 1953, The marine and stream terraces of the Capitola-Watsonville area. University of California Publications in Geography, v.10, p. 1-44. https://babel.hathitrust.org/cgi/pt?id=inu.30000121830677&view=1up&seq=13

Association of Monterey Bay Area Governments (AMBAG), 2018, 2018 Regional Growth Forecast. Technical Documentation, Association of Monterey Bay Area Governments. https://ambag.org/programs-services/planning/regional-growth-forecast

California Department of Fish and Wildlife (CDFW), 2018, California Natural Diversity Database (CNDDB) – Government version dated June 1, 2018. Retrieved June 08, 2018 from https://www.wildlife.ca.gov/Data/CNDDB

California Department of Water Resources (DWR), 2013, California Water Plan 2013 Update, Central Coast Regional Report. https://water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates

California Department of Water Resources (DWR), 2016, SGMA Best Management Practices and Guidance Documents. https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GD_GSP_Outline_Final_2016-12-23.pdf.

California Department of Water Resources (DWR), 2016, California's Groundwater Working Toward Sustainability, Bulletin 118 Interim Update 2016. December 22. https://water.ca.gov/LegacyFiles/groundwater/bulletin118/docs/Bulletin_118_Interim_Update_2016.pdf

California Department of Water Resources (DWR), 2017, Sustainable Management Criteria Best Management Practices. November. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-6-Sustainable-Management-Criteria-DRAFT_ay_19.pdf

California Department of Water Resources (DWR), 2018, WR. 2018a. Water Available For Replenishment. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Statewide-Reports/WAFR/Final/Water-Available-for-Replenishment---Final-Report.pdf

California Department of Water Resources (DWR), 2018, 2018b. California Department of Water Resources SGMA Portal. https://sgma.water.ca.gov/portal/.

California Department of Water Resources (DWR), 2019, SGMA Basin Prioritization Dashboard. April 30. Accessed April April 30, 2019, 2019. https://gis.water.ca.gov/app/bp-dashboard/p2/.

California Natural Resources Agency, 2018, State of California Sea-Level Rise Guidance, update 2018. Accessed online on June 23, 2019. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf

California State Water Resources Control Board (SWRCB) and California Environmental Protection Agency 2015, Water Quality Control Plan, Ocean Waters of California. https://www.waterboards.ca.gov/water_issues/programs/ocean/docs/cop2015.pdf

California State Water Resources Control Board (SWRCB), 2016, Investigation on the Feasibility Of Developing Uniform Water Recycling Criteria For Direct Potable Reuse. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf

California State Water Resources Control Board (SWRCB), 2018, Regulations Related to Recycled Water. October 1. Access online on July 3, 2019: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/RWregulations_20181001.pdf

Carollo Engineers, 2014, Basin Management Plan Update. Prepared for Pajaro Valley Water Management Agency. February. https://www.pvwater.org/bmp-update

Carollo Engineers, 2017, Regional Recycled Water Feasibility Study. Prepared for Soquel Creek Water District. November. http://www.soquelcreekwater.org/sites/default/files/documents/Reports/RecycledWaterFeasibilityStudy_FinalReport-no-appendices.pdf

City of Santa Cruz, 2011, Climate Adaptation Plan, An Update to the 2007 Local Hazard Mitigation Plan 2012-2017. October. http://www.cityofsantacruz.com/home/showdocument?id=23644

City of Santa Cruz Water Department (SCWD), 2012, Beltz Well No.12 Project EIR. Environmental Impact Report, Santa Cruz: City of Santa Cruz. https://ceqanet.opr.ca.gov/2010122030/3 or http://www.cityofsantacruz.com/home/showdocument?id=78718

City of Santa Cruz Water Department (SCWD), 2015, Water Supply Advisory Committee Final Report on Agreements and Recommendations. Report, Santa Cruz: City of Santa Cruz Water Department. http://www.cityofsantacruz.com/home/showdocument?id=48993

City of Santa Cruz Water Department (SCWD), 2016, 2015 Urban Water Management Plan. http://www.cityofsantacruz.com/home/showdocument?id=55168

City of Santa Cruz Water Department (SCWD), 2016, Cooperative Water Transfer, Groundwater Recharge, and Resources Management Pilot Project. CEQA document http://www.cityofsantacruz.com/home/showdocument?id=48891

City of Santa Cruz Water Department (SCWD), 2018, Aquifer Storage and Recovery Pilot Test Program at Beltz 12 Well. Notice of Exemption, Santa Cruz: City of Santa Cruz Water Department. Accessed May 30, 2019. https://ceqanet.opr.ca.gov/2018098371.

City of Santa Cruz Water Department (SCWD), 2019, Water Commission Information Report on Joint Workshop with Former Water Supply Advisory Committee. Attachment 2 (Water Demand). March 27. http://scsire.cityofsantacruz.com/sirepub_watercom/cache/2/fh2z0ssbgvs5pwb0f41ussju/482022012262019054824346.PDF, http://scsire.cityofsantacruz.com/sirepub_watercom/cache/2/fh2z0ssbgvs5pwb0f41ussju/482022112262019054607783.PDF, and http://scsire.cityofsantacruz.com/sirepub_watercom/cache/2/fh2z0ssbgvs5pwb0f41ussju/482022212262019054648936.PDF.

County of Santa Cruz Environmental Health Services, 2015, Final Report Conjunctive Use and Water Transfers – Phase II (Task 6). May. http://www.midcountygroundwater.org/sites/default/files/uploads/05-19-15%20Item%206.3.2%20Attachment%202%20Surface%20Water%20Exchange%20Report.pdf

County of Santa Cruz Environmental Health Services, 2017, Santa Cruz County Water Resources Management Status Report for 2017. http://scceh.com/Portals/6/2017WaterStatusReportFinal.pdf

County of Santa Cruz Environmental Health Services, 2018, Santa Cruz County Water Resources Management Status Report for 2018. http://scceh.com/Portals/6/2018WaterStatusReportFinal.pdf

Environmental Science Associates (ESA), 2010, Soquel Creek Water District Well Master Plan. Environmental Impact Report, San Francisco. https://www.soquelcreekwater.org/sites/default/files/documents/Reports/WellMasterPlanEIRincludingResponsetoComments.pdf

Environmental Science Associates (ESA), 2018, Pure Water Soquel: Groundwater Replenishment and Seawater Intrusion Prevention Project. Environmental Impact Report, San Francisco. https://www.soquelcreekwater.org/sites/default/files/documents/Advanced-Water-Purification/Draft_EIR/Pure_Water_Soquel_Draft_EIR_no_Appendices.pdf

Fisher, A.T., S. Lozano, S. Beganskas, E. Teo, W. Weir, R. Harmon, 2017, Regional Managed Aquifer Recharge and Runoff Analyses in Santa Cruz and northern Monterey Counties, California. Accessed online on 11/10/2019 at http://www.rcdsantacruz.org/managed-aquifer-recharge

Flint, L.E., and Flint, A.L., 2012, Simulation of climate change in San Francisco Bay Basins, California: Case studies in the Russian River Valley and Santa Cruz Mountains: U.S. Geological Survey Scientific Investigations Report 2012–5132, 55 p. Accessed online on 10/28/2019 at https://pubs.usgs.gov/sir/2012/5132/pdf/sir20125132.pdf.

Grattan, S, 2002, Irrigation Water Salinity and Crop Production. Farm Water Quality Planning. Publication 8066. Accessed online on July 4, 2019 at: https://anrcatalog.ucanr.edu/pdf/8066.pdf

Hickey, J. J., 1968, Hydrogeologic Study of the Soquel-Aptos Area, Santa Cruz County, California, United States Geological Survey (USGS) open file report. April 10. https://pubs.usgs.gov/of/1968/0129/report.pdf

HydroMetrics LLC, 2009, Groundwater Levels to Protect against Seawater Intrusion and Store Freshwater Offshore. Prepared for Soquel Creek Water District. January. https://www.soquelcreekwater.org/sites/default/files/documents/Reports/groundwater_levels_to_protect_against_seawater_intrusion_and_store_freshwater_offshore_0.pdf

HydroMetrics LLC, 2015, Letter to Soquel Creek Water District: Soquel Creek monitoring and adaptive management plan baseline report. August 31. (PDF provided)

HydroMetrics LLC, 2016, Letter to Soquel Creek Water District: Soquel Creek monitoring and adaptive management plan (MAMP) – 2nd Report. December 19. (PDF provided)

HydroMetrics LLC, 2017, Letter to Soquel Creek Water District: Soquel Creek monitoring and adaptive management plan (MAMP) – 3rd Report. October 30. (PDF provided)

HydroMetrics WRI, 2017, Santa Cruz Mid-County Basin Groundwater Management Biennial Review and Report, Water Years 2015-2016. Prepared for the Santa Cruz Mid-County Groundwater Agency. July. http://www.midcountygroundwater.org/sites/default/files/uploads/Water%20Year%202015-2016.pdf

HydroMetrics WRI, 2018, Management Implications of SkyTEM Seawater Intrusion Results. Prepared for Santa Cruz Mid-County Groundwater Agency. March. (PDF provided)

Johnson N.M., Williams, D.E., Yates, E.B., and Thrupp, G., 2004, Groundwater Assessment of Alternative Conjunctive Use Scenarios, Technical Memorandum 2: Hydrogeologic Conceptual Model. Prepared for Soquel Creek Water District, Soquel, California. September. https://www.soquelcreekwater.org/sites/default/files/documents/Reports/groundwater_assessment_of_alternative_conjuctive_use_scenarios_technical_memorandum_2_hydrogeologic_conceptual_model_0.pdf

Johnson, N.M., 2009, Drinking Water Source Assessments (DWAPs). Prepared for Central Water District, Aptos, California. March. (PDF provided)

Kennedy, E.J., 1984, Discharge ratings at gaging stations. Report prepared by U.S. Geological Survey. Series title: Techniques of Water-Resources Investigations. Washington, D.C.: U.S. Govt. Print. Office. Book 3, Chapter A10: Applications of Hydraulics. 65 pp. https://pubs.usgs.gov/twri/twri3-a10/pdf/TWRI_3-A10.pdf

Kenney, T.A., 2010, Levels at gaging stations: U.S. Geological Survey Techniques and Methods 3-A19, 60 p. https://pubs.usgs.gov/tm/tm3A19/

Kennedy/Jenks, 2018, Final Santa Cruz Regional Recycled Water Facilities Planning Study. Report, San Francisco: Kennedy/Jenks Consultants. http://www.cityofsantacruz.com/home/showdocument?id=71304 (report), http://www.cityofsantacruz.com/home/showdocument?id=71306 (appendices)

M.Cubed, 2019, Comparative Analysis of Projected and Actual Water Demand in 2018. Prepared for City of Santa Cruz Water Department. February. (PDF provided)

McLaughlin, R.J. and J.C. Clark, 2004, Stratigraphy and Structure across the San Andreas Fault Zone in the Loma Prieta Region and Deformation During the Earthquake, in The Loma Prieta, California, Earthquake of October 17, 1989-Geologic Setting and Crustal Structure, United States Geological Survey (USGS) Professional Paper 1550-E, Ray E. Wells editor. Accessed on 10/18/19 at https://pubs.usgs.gov/pp/pp1550/pp1550e/pp1550e.pdf

Muir, K. S., 1980, Seawater Intrusion and Potential Yield of Aquifers in Soquel–Aptos Area, Santa Cruz County, California, United States Geological Survey (USGS) Water-Resources Investigation 80-84, October. https://pubs.er.usgs.gov/publication/wri8084

Nature Conservancy, The (TNC), 2018, Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act, Guidance for Preparing Groundwater Sustainability Plans. January. https://www.scienceforconservation.org/assets/downloads/GDEsUnderSGMA.pdf

Nature Conservancy, The (TNC), 2019, SGMA Tools - Mapping Indicators of Groundwater Dependent Ecosystems in California. Access on 10/6/2019 at https://groundwaterresourcehub.org/sgma-tools/mapping-indicators-of-gdes/

Pajaro Valley Water Management Agency (PVWMA), 1984, Pajaro Valley Water Management Agency Act, 1984, ACT 760. Pajaro Valley Water Management Agency (1984 ch 257) Cal Uncod Water Deer Act 760 (2008). https://www.pvwater.org/images/about-pvwma/assets/agency_act_assets/Agency%20Act%20-%202009_Act%20760.PVWMA.pdf

Pajaro Valley Water Management Agency (PVWMA), 2016, Pajaro Valley Water Management Agency Salt and Nutrient Management Plan. Final. October. https://www.pvwater.org/images/board-and-committees/snmp_assets/SNMP_FinalReport_Web.pdf

Ramboll, 2018 Hydrogeological Investigation Salt-Fresh Water Interface – Monterey. February. (PDF provided)

Rantz, S.E. and others, 1982, Water Supply Paper 2175, Measurement and Computation of Streamflow; Volume 1. Measurement of Stage and Discharge; Volume 2. Computation of Discharge; U.S. Geological Survey (https://pubs.usgs.gov/wsp/wsp2175/)

Resource Conservation District (RCD), 2014, Distributed Stormwater Collection and Managed Aquifer Recharge. Accessed March 14, 2019. https://www.rcdsantacruz.org/managed-aquifer-recharge.

Roberts, Carter W., Jachens R.C., Ponce, D.A., and Langenheim, V.E., 2004, Isostatic residual gravity map of The Santa Clara Valley and vicinity, California, U.S. Geological Survey Open-File Report 2004-1297. Accessed on 10/18/19 at https://pubs.usgs.gov/of/2004/1297/

Russo, T. A., A. T. Fisher, and B. S. Lockwood, 2014, Assessment of managed aquifer recharge potential and impacts using a geographical information system and numerical modeling Groundwater, https://ngwa.onlinelibrary.wiley.com/doi/abs/10.1111/gwat.12213 or https://websites.pmc.ucsc.edu/~afisher/CVpubs/pubs/Russo2014_GW_PV-MAR.pdf

Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p. (available at http://pubs.usgs.gov/tm/tm3-a7/.)

Santa Cruz Mid-County Groundwater Agency, 2019, Evaluation of Private Pumper Funding Mechanisms and Fee Criteria, Raftelis, May. (See appendix A-5)

Sleeter, B.M. et. al, 2004, Earthquakes and Faults in the San Francisco Bay Area (1970-2003). U.S. Geological Survey Scientific Investigations Map 2848. Accessed on 10/29/2019 at https://pubs.usgs.gov/sim/2004/2848/SIM2848.pdf.

Soquel Creek Water District (SqCWD), 2015, Community Water Plan. Plan, Soquel. https://www.soquelcreekwater.org/sites/default/files/documents/Handouts/CWP-3-30-16.pdf

Soquel Creek Water District (SqCWD), 2019, Drinking Water Source Assessment and Protection (DWSAP) reports accessed on 10/28/2019 at https://www.soquelcreekwater.org/documents/reports (use Report type “Water Quality”, keyword “DWSAP” in search fields).

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (available at http://pubs.usgs.gov/tm/tm3-a8/.)

UNAVCO Community, 2006, PBO GPS Network - P212-LarkinVly_CN2006 P.S., UNAVCO, GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5RN35T5.

UNAVCO Community, 2007, PBO GPS Network - P214-CorralitosCN2007 P.S., UNAVCO, GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5FN1464.

United States Census Bureau (US Census Bureau), 2012, "2010 Census Gazetteer Files.". August 12. https://www2.census.gov/geo/docs/maps-data/data/gazetteer/counties_list_06.txt.

7 ACRONYMS

AFY ....acre-feet per year
AMBAG ....Association of Monterey Bay Area Governments
AMR ....Automated Meter Reading
amsl.................above mean sea level
ASR ....aquifer storage and recovery
Basin ....Santa Cruz Mid-County Groundwater Basin
bgs...................below ground surface
BIG ....Basin Implementation Group
BMP.................Best Management Practices
CASGEM.........California Statewide Groundwater Elevation Monitoring
CCA.................California Coastal Act
CDP.................Coastal Development Permit
CEC.................Constituent of Emerging Concern
CEQA ....California Environmental Quality Act
CESA...............California Endangered Species Act
cfs....................cubic feet per second
CGMA.............Cooperative Monitoring/Adaptive Groundwater Management Agreement
CGPS ....Continuous Global Positioning System
CGS.................California Geological Survey
CNDDB............California Natural Diversity Database
County.............Santa Cruz County
CUPA ....Certified Unified Program Agency
CWD................Central Water District
DAC.................disadvantaged community
DDW................State Water Resources Control Board, Division of Drinking Water
DoD ....Department of Defense
DTW ....Depth to water
DWR ....California Department of Water Resources
DWSAP ....Drinking Water Source Assessment and Protection
EDF ....Environmental Defense Fund
EH ....Environmental Health
EIR ....Environmental Impact Report (under CEQA)
EIS...................Environmental Impact Study (under NEPA)
EPA .................U.S. Environmental Protection Agency
ESA ....Endangered Species Act
ET....................evapotranspiration
ft/d ....feet per day
ft/yr ....feet per year
ft^2/d ....square feet per day
ft msl................feet above mean sea level
GCM................global circulation model
GDE.................Groundwater Dependent Ecosystems

GIS ....geographic information system
GMP ....Groundwater Management Plan
gpd/ft ....gallons per day per foot
gpm ....gallons per minute
GPS.................global positioning system
GSA ....Groundwater Sustainability Agency
GSFLOW.........Groundwater and Surface-water Flow model
GSP ....Groundwater Sustainability Plan
GWE ....Groundwater Elevation
HCM ....hydrogeologic conceptual model
IRWM ....Integrated Regional Water Management
JPA..................Joint Powers Agreement
LUFT ....leaking underground fuel tank
MAMP.............Monitoring and Adaptive Management Plan
MAR ....managed aquifer recharge
μg/L ....microgram per liter
mg/L ....milligrams per liter
MGA ....Santa Cruz Mid-County Groundwater Agency
MGA Model .....MGA integrated groundwater and surface water model
MMP................Monitoring and Mitigation Program
MODFLOW .....Modular Finite-difference Flow model
MRMP ....Mitigation Monitoring and Reporting Program
MTBE ....methyl tertiary-butyl ether
NEPA...............National Environmental Policy Act
NGVD 29.........National Geodetic Vertical Datum of 1929
NMFS ....National Marine Fisheries Service
NRCS ....Natural Resources Conservation Service
ºC.....................degrees Celsius
ºF.....................degrees Fahrenheit
PET ....potential evapotranspiration
PFAS...............per- and polyfluoroalkyl substances
ppm ....parts per million
ppt ....parts per trillion
PRMS..............Precipitation-Runoff Modeling System
PUC.................Public Utilities Commission
PV Water.........Pajaro Valley Water Management Agency
QA/QC ....quality assurance / quality control
RCD.................Resource Conservation District of Santa Cruz County
RMP ....representative monitoring point
RP ....reference point potential evapotranspiration
RPE ....reference point elevation
SCADA ....Supervisory Control aAnd Data Acquisition
SCWD ....City of Santa Cruz Water Department
SFR ....Streamflow-Routing
SGMA ....Sustainable Groundwater Management Act

SLIC...............Spills-Leaks-Investigations-Cleanup
SMC ....Sustainable Management Criteria
SMGWA ....Santa Margarita Groundwater Agency
SqCWD ....Soquel Creek Water District
SSURGO.........Soil Survey Geographic Database
SWRCB...........State Water Resources Control Board
TAC ....Technical Advisory Committee
TCP 1,2,3-trichloropropane
TDS ....total dissolved solids
TNC.................The Nature Conservancy
UCMR.............Unregulated Contaminant Monitoring Rule
USEPA............U.S. Environmental Protection Agency
USGS.............U.S. Geological Survey
USDA .............U.S. Department of Agriculture
UST ....underground storage tank
UWMP............Urban Water Management Plan
UZF................unsaturated-zone flow
VOC................volatile organic chemical
WAAP.............Wasteload Allocation Attainment Program

8 GLOSSARY

Act: The Groundwater Sustainability Management Act of 2014.

Agency: A groundwater sustainability agency as defined in the Sustainable Groundwater Management Act.

Alternative: An alternative to a Plan described in Water Code Section 10733.6.

Annual Report: The report required by Water Code Section 10728.

Aquifer Storage and Recovery (ASR): Method to store excess surface water underground for a variety of purposes (e.g., to increase groundwater levels, prevent seawater intrusion or subsidence, increase groundwater in storage) and to recover available water in the future as a water supply source.

Baseline or **Baseline Conditions**: Historic information used to project future conditions for hydrology, water demand, and availability of surface water and to evaluate potential sustainable management practices of a basin.

Basin: A groundwater basin or subbasin identified and defined in Bulletin 118 or as modified pursuant to Water Code 10722 et seq.

Basin Setting: The information about the physical setting, characteristics, and current conditions of the basin as described by the Agency in the hydrogeologic conceptual model, the groundwater conditions, and the water budget, pursuant to Subarticle 2 of Article 5.

Best Available Science: The use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice.

Best Management Practice: A practice, or combination of practices, that are designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science.

Board: Refers to the State Water Resources Control Board.

CASGEM: The California Statewide Groundwater Elevation Monitoring Program developed by the Department pursuant to Water Code Section 10920 et seq., or as amended.

Continuous Global Positioning System (CGPS): Stations used to monitor subsidence in California. A CGPS station continuously measures the three-dimensional (3D) position of a point on, or more specifically, near the earth's surface. There are more than 1,000 Continuous Global Positioning System Stations operating in Western North America, and hundreds of them in California alone; many of them are managed by the Plate Boundary Observatory/UNAVCO and by Scripps Orbit and Permanent Arrary Center (SOPAC), but other groups such as Caltrans, also operate some of them as part of their Central Valley Spatial Reference Network.

Data Gap: A lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation, and could limit the ability to assess whether a basin is being sustainably managed.

De Minimis Extractor - a person who extracts, for domestic purposes, two acre-feet or less (of groundwater) per year.

Department: California Department of Water Resources (see acronym DWR).

Groundwater Dependent Ecosystem: Ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface.

Groundwater Flow: The volume and direction of groundwater movement into, out of, or throughout a basin.

Groundwater Sustainability Plan (GSP): In groundwater basins designated by the Department of Water Resources (DWR) as critically-overdrafted high and medium priority, local public agencies and GSAs are required to develop and implement GSPs by January 31, 2020. All other groundwater basins designated as high or medium priority basins are to be managed under a GSP by January 31, 2022.

Interconnected Surface Water: Surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted.

Interested Parties: Persons and entities on the list of interested persons established by the Agency pursuant to Water Code Section 10723.4.

Interim Milestones: a target value representing measurable groundwater conditions defined in the Plan at five-year increments at each monitoring site using the same metrics as the measurable objectives and minimum thresholds. Interim milestones will be used by the MGA and the Department of Water Resources (DWR) to track progress toward meeting the Basin’s Sustainability Goal. Interim milestones are coordinated with projects and management actions proposed by the MGA to achieve the sustainability goal.

Management Area: An area within a basin for which the Plan may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors.

Measurable Objectives: Specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin. Measurable objectives reflect the MGA’s desired groundwater conditions in the Basin and will guide the MGA to achieve its sustainability goal within 20 years. Measurable objectives are set for each sustainability indicator at the same representative monitoring points and using the same metrics as minimum thresholds.

Measurable Objectives are set so there is a reasonable margin of operational flexibility between the minimum threshold and measurable objective that will accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities.

For some sustainability indicators, projects and management actions are needed to achieve measurable objectives. Although measurable objectives are not enforceable during implementation of the GSP, the GSP needs to demonstrate that there is a planned path toward achieving measurable objectives.

Minimum Threshold: quantitative values that represent groundwater conditions at representative monitoring points. These numeric values are defined for each sustainability indicator and used to define undesirable results.

Non-de Minimis Extractor – a person or entity that extracts more than two acre-feet (of groundwater) per year for domestic or non-domestic uses.

Plain Language: Language that the intended audience can readily understand and use because that language is concise, well-organized, uses simple vocabulary, avoids excessive acronyms and technical language, and follows other best practices of plain language writing.

Plan: A groundwater sustainability plan as defined in the Act.

Plan Implementation: An Agency's exercise of the powers and authorities described in the Act, which commences after an Agency adopts and submits a Plan or Alternative to the Department and begins exercising such powers and authorities.

Plan Manager: An employee or authorized representative of an Agency, or Agencies, appointed through a coordination agreement or other agreement, who has been delegated management authority for submitting the Plan and serving as the point of contact between the Agency and the Department.

Principal Aquifers: aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems.

Reference Point: A permanent, stationary and readily identifiable mark or point on a well, such as a mark on the top of casing, from which groundwater level measurements are taken, or other monitoring site. For most production wells, the RP is the top of the well's concrete pedestal.

Representative Monitoring: A monitoring site within a broader network of sites that typifies one or more conditions within the basin or an area of the basin.

Seasonal High: The highest annual static groundwater elevation that is typically measured in the Spring and associated with stable aquifer conditions following a period of lowest annual groundwater demand.

Seasonal Low: The lowest annual static groundwater elevation that is typically measured in the Summer or Fall, and associated with a period of stable aquifer conditions following a period of highest annual groundwater demand.

Seawater Intrusion: The advancement of seawater into a groundwater supply that results in degradation of water quality in the basin, and includes seawater from any source.

Supervisory Control and Data Acquisition (SCADA): A control system architecture that uses computers, networked data communications, and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices to interface with the process plant or machinery.

Statutory Deadline: The date by which an Agency must be managing a basin pursuant to an adopted Plan, as described in Water Code Sections 10720.7 or 10722.4.

Sustainability Indicator: Any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results, as described in Water Code Section 10721(x). Undesirable results are one or more of the following effects: (1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods; (2)Significant and unreasonable reduction of groundwater storage; (3) Significant and unreasonable seawater intrusion; (4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies; (5) Significant and unreasonable land subsidence that substantially interferes with surface land uses; (6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Uncertainty: A lack of understanding of the basin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a Plan, or to evaluate the efficacy of Plan implementation, and therefore may limit the ability to assess whether a basin is being sustainably managed.

Undesirable Results: Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators defined by the Sustainable Groundwater Management Act (SGMA) are caused by groundwater conditions occurring in the Basin. Undesirable results are included as SMC as a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin. Undesirable results may be defined by minimum threshold exceedances at a single monitoring site, multiple monitoring sites, a portion of a basin, a management area, or an entire basin.

Urban Water Management Plan: A plan adopted pursuant to the Urban Water Management Planning Act as described in Part 2.6 of Division 6 of the Water Code, commencing with Section 10610 et seq.

Water Source Type: The source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies.

Water Use Sector: Categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation.

Water Year: The period from October 1 through the following September 30, inclusive, as defined in the Act.

Water Year Type: The classification provided by the Department to assess the amount of annual precipitation in a basin.

APPENDICES

APPENDIX A

BASIN POINT OF CONTACT AND MAILING ADDRESS

APPENDIX A

Contact information for Plan Manager and GSA Mailing Address (Reg. § 354.6):

MGA's plan manager is:

Sierra Ryan, Water Resources Planner
County of Santa Cruz Environmental Health
Health Services Agency
701 Ocean Street **|** Room 312 | 831.454.3133
Sierra.Ryan@santacruzcounty.us
www.midcountygroundwater.org

MGA mailing address is:

Santa Cruz Mid-County Groundwater Agency
c/o Soquel Creek Water District
Attention: Board Secretary
5180 Soquel Drive
Soquel, CA 95073

APPENDIX B

SUMMARY OF PUBLIC COMMENTS RECEIVED ON THE DRAFT GSP AND RESPONSES

APPENDIX B – COMMENTS RECIEVED

Draft Groundwater Sustainability Plan – Public Comments Received		
ID and Commenter	Document Type and Date	Separate Attachments
1. The Nature Conservancy	Letter dated 9/9/2019	Attachments A, B, C, D & E
2. NOAA - National Marine Fisheries Service	Letter dated 9/10/2019	
3. California Department of Fish and Wildlife	Letter dated 9/12/2019	
4. Audubon California; Clean Water Action and Clean Water Fund; Local Government Commission; The Nature Conservancy; Union of Concerned Scientists	Letter dated 9/19/2019	Appendix A
5. Jerome Paul	Letter dated 9/19/2019[1]	
6. Soquel Creek Water District	Letter dated 9/19/2019	
7. Becky Steinbruner	Email 8/14/2019	
8. Becky Steinbruner	Email 8/28/2019	
9. Becky Steinbruner	Email 8/29/2019	
10. Ramona Andre	Email 9/14/2019	
11. Richard Andre	Email 9/14/2019	
12. Cliff Bixler	Email 9/16/2019	
13. Larry Freeman	Email 9/16/2019	Attachment
14. Becky Steinbruner	Email 9/17/2019	
15. Scott McGilvray	Email 9/18/2019	2 Attachments
16. Linda Wilshusen	Email 9/18/2019	
17. Debra Wirkman	Email 9/18/2019	
18. Tom Butler	Email 9/19/2019	
19. Douglas Deitch	Email 9/19/2019	13 Attachments
20. Douglas Deitch	Email 9/19/2019	2 Attachments
21. Erica Stanojevic	Email 9/19/2019	Attachment
22. Becky Steinbruner	Email 9/19/2019	
23. Becky Steinbruner	Comment Card dated 1/17/2019[2]	
24. Becky Steinbruner	Comment Card dated 1/17/2019[2]	
25. Becky Steinbruner	Comment Card dated 1/18/2019[2]	
26. Craig	Comment Card dated 7/20/2019	
27. Becky Steinbruner	Comment Card dated 7/22/2019	
28. Becky Steinbruner	Comment Card dated 7/22/2019	
29. Becky Steinbruner	Comment Card dated 7/22/2019	
30. Michael M.	Comment Card undated[2]	
31. Becky Steinbruner	Oral Comment 9/19/2019	
[1] Draft GSP comment letter hand delivered at 9/19/2019 MGA Board Meeting during another agenda item. [2]Draft GSP comment cards were not produced and available until the July 18, 2019 MGA Board meeting		

See Draft Groundwater Sustainability Plan Public Comments here.

Draft Groundwater Sustainability Plan – Public Comments & Responses

Comment Theme	Main point(s)	Comment ID[1]	Comments Resulting in GSP changes
Beneficial Users	Concerns regarding adequate representation	1, 4, 27	1, 4, 27
	Disadvantaged Communities	2, 4	2, 4
Committees	Composition of Committees	1, 4, 22, 27	1, 4, 22, 27
	GSP Advisory Committee did not develop its own recommendations for MGA board (rubber stamp)	27	27
Document Presentation	Document organization is confusing, lack of Table of Contents	8, 27	
Fees/Raftelis	Private Pumper Future Fees & Raftelis White Paper	25, 28	25, 28
GW Modeling	Pumping, modeling and groundwater levels	29	29
	Water Budget/climate change	4, 6	4, 6
Mapping	Add elements to maps	1, 3, 4	1, 3, 4
Monitoring	Stream gage monitoring cost critique	13	13
	Stream monitoring text review and proposed technique	1, 2, 3, 4, 13	1, 2, 3, 4, 13
	Monitoring network	1, 2, 3, 4, 6, 31	10, 11, 12, 18, 26, 30, 31
Outreach	July & August 2019 GSP oral presentation criticisms	9, 10, 26	
	Communications and Engagement Plan	4	4
Projects & Mgmt. Actions	Support Pure Water Soquel (PWS)	12, 18	
	Oppose PWS	10, 11, 26	
	Questions about projects and management actions	5, 15, 25, 30	5, 15,
	Criticism of project analysis	5, 15	
	Clarify project description	13, 16	13, 16
	Clarify project costs or assumptions for ASR	16	16
	Fails to adequately assess project alternatives	5, 15, 21, 23, 24	5, 15, 21, 23, 24
Public Comment	Public comments on Draft GSP should be made available to the public verbatim	22, 23, 31	
	Extend public comment period by 60-days (Nov. 8)	21	
Overall	GSP is inadequate	5, 21	21
	State should manage Basin	19, 20	
	Basin boundary concerns	1, 22	1
	Typos/corrections	13	13
References	References not available; lack of citations	1, 2, 4, 8, 14, 16, 21, 27	1, 2, 4, 8, 14, 16, 21, 27

[1] ID from comment table included in *Compiled Comments on the Draft GSP* found here or www.midcountygroundwater.org/sites/default/files/uploads/Draft_GSP_Public_Comments_2019-1004.pdf

Comment Theme	Main point(s)	Comment ID[1]	Comments Resulting in GSP changes
Surface Water Sustainable Management Criteria	Poor correlation between stream flow and GW levels	1, 2, 3, 4, 6	1, 2, 3, 4, 6
	Limitations in existing GW & SW monitoring network	1, 2, 6	1, 2, 6
	Concerns regarding stream flow estimate and Basin impacts	2, 4, 6	2, 4, 6
	Groundwater Dependent Ecosystems (GDE) definition criteria/resources used and GDE management	1, 4	1, 4
	Effects on Environmental Beneficial Users & GDE	1, 4, 6	1, 4, 6
	Concerns re SW & GW modeling adequacy/calibration	1, 2, 6	1, 2, 6
Water Quality	Water quality comments	7, 8, 10, 11 12, 14, 18, 17, 26 30	7, 8, 10, 11 12, 14, 18, 17, 26, 30

Continued

[1] ID from comment table included in *Compiled Comments on the Draft GSP* found here or www.midcountygroundwater.org/sites/default/files/uploads/Draft_GSP_Public_Comments_2019-1004.pdf

APPENDIX C

SUMMARY LIST OF PUBLIC MEETINGS AND OUTREACH

APPENDIX C

List of Public Meetings and Outreach

Topic	Detail
Public Meetings	• 12 private well owner/stakeholder meetings between May 2014 and June 2018 • 6 informational sessions between October 2017 and April 2019 • 2-hour community drop-in sessions every other month since 2016 • 20 GSP Advisory committee meetings between October 2017 and June 2019 • 2 GSP Workshops and 1 GSP Q&A Session planned between July 2019 and August 2019 • 37 MGA, SAGMC, BIG, GSA FC meetings between February 2014 and November 2019
Postcard Mailings and letters	• June 2019 – GSP Survey and Plan update to all Basin residents and owners • March 2018 – GSP update to private well owners and small water systems • June 2017 – GSP update meeting to private well owners and small water systems • January 2017 - GSP update meeting to Basin agricultural and commercial pumpers • December 2015 – GSP update meeting to private well owners
Survey	• June 2019 - GSP outreach mechanism and to inform future MGA outreach efforts • Nov 2017 to May 2018 - Private well owner outreach to inform GSP planning process
Email List-Serve	• Monthly E-newsletter to approximately 650 unique email addresses, including interested parties
Brochure	Targeted at rural users mailed to all private well owners and small water systems
Open House	3 GSP Open House events during Draft GSP public comment period
Road Signs	4 message boards placed at prominent thoroughfares before meetings and events
Public MGA Board Meetings	37 public Board meetings between February 2014 and November 2019 for MGA, and predecessor agencies
GSP Advisory Committee	Total of 20 monthly public meetings from October 2017 through June 2019
Surface Water-Groundwater Working Group	4 Surface Water Working Group meetings consisting of GSP Advisory Committee participants, resource agencies, local planning agencies, and environmental groups.
Tabling and Presentations	Connecting the Drops, Water Harvest Festival, presentations and conferences
Website	midcountygroundwater.org
Miscellaneous	Newspaper articles/editorials, social media through partner agencies, handouts, tour, tabling events

APPENDIX 1-A

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY JOINT EXERCISE OF POWERS AGREEMENT

JOINT EXERCISE OF POWERS AGREEMENT

by and among

CENTRAL WATER DISTRICT

CITY OF SANTA CRUZ

COUNTY OF SANTA CRUZ

and

SOQUEL CREEK WATER DISTRICT

creating the

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY

March 17, 2016

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

JOINT EXERCISE OF POWERS AGREEMENT OF THE SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY

This **Joint Exercise of Powers Agreement ("Agreement")** is made and entered into as of March 17, 2016 ("Effective Date"), by and among the Central Water District, the City of Santa Cruz, the County of Santa Cruz, and the Soquel Creek Water District, sometimes referred to herein individually as a "**Member**" and collectively as the "**Members**" for purposes of forming the Santa Cruz Mid-County Groundwater Agency ("**Agency**") and setting forth the terms pursuant to which the Agency shall operate. Capitalized defined terms used herein shall have the meanings given to them in Article 1 of this Agreement.

RECITALS

A. Each of the Members is a local agency, as defined by the Sustainable Groundwater Management Act of 2014 ("**SGMA**"), duly organized and existing under and by virtue of the laws of the State of California, and each Member can exercise powers related to groundwater management.

B. SGMA requires designation of a groundwater sustainability agency ("**GSA**") by June 30, 2017, for groundwater basins designated by the California Department of Water Resources ("**DWR**") as medium- and high-priority basins.

C. SGMA requires adoption of a groundwater sustainability plan ("**GSP**") by January 31, 2020, for all medium- and high-priority basins identified as being subject to critical conditions of overdraft.

D. Each of the Members either extracts groundwater from or regulates land use activities overlying a common groundwater basin located within the mid-county coastal region of the County of Santa Cruz. This Basin includes all or part of four basins identified in DWR's Bulletin Number 118, including the following basins (designated by the name of the basin and number assigned to it in DWR-Bulletin No. 118): Soquel Valley (3-1), West Santa Cruz Terrace (3-26), Santa Cruz Purisima Formation (3-21), and Pajaro Valley Basin (3-2). All or some of these basins have been designated as medium or high priority basins. Through the Agency, the Members provided modifications to the Bulletin-118 boundaries as allowed by Title 23 of the California Code of Regulations to create a new consolidated basin called the "Santa Cruz Mid-County Groundwater Basin" with 3-1 as the number for the consolidated basin under DWR Bulletin No. 118 (hereafter "**Basin**").

E. The Members intend for the Agency to develop a GSP and manage the Basin pursuant to SGMA.

F. Under SGMA, a combination of local agencies may form a GSA through a joint powers agreement.

G. The Members have determined that the sustainable management of the Basin pursuant to SGMA may best be achieved through the cooperation of the Members operating through a joint powers agency.

H. The Joint Exercise of Powers Act of 2000 ("Act") authorizes the Members to create a joint powers authority, to jointly exercise any power common to the Members, and to exercise additional powers granted under the Act.

I. The Act, including the Marks-Roos Local Bond Pooling Act of 1985 (Government Code sections 6584, *et seq.*), authorizes an entity created pursuant to the Act to issue bonds, and under certain circumstances, to purchase bonds issued by, or to make loans to, the Members for financing public capital improvements, working capital, liability and other insurance needs or projects whenever doing so results in significant public benefits, as determined by the Members. The Act further authorizes and empowers a joint powers authority to sell bonds so issued or purchased to public or private purchasers at public or negotiated sales.

J. The Members have a history of collaborating on groundwater management issues in the Santa Cruz Mid-County Groundwater Basin, originally with a joint powers agreement formed in 1995 by the Soquel Creek Water District and the Central Water District, which was subsequently amended in August of 2015 to include the City of Santa Cruz and the County of Santa Cruz, to form the Soquel-Aptos Groundwater Management Committee.

K. The Members agree that by approving the creation of the Santa Cruz Mid-County Groundwater Agency they are withdrawing from and disbanding the joint powers agency formed as a result of earlier joint powers agreements originally creating the Basin Implementation Group as subsequently amended to create the Soquel-Aptos Groundwater Management Committee.

L. Based on the foregoing legal authority, the Members desire to create a joint powers authority for the purpose of taking all actions deemed necessary by the joint powers authority to ensure sustainable management of the Basin as required by SGMA.

M. The governing board of each Member has determined it to be in the Member's best interest and in the public interest that this Agreement be executed.

TERMS OF AGREEMENT

In consideration of the mutual promises and covenants herein contained, the Members agree as follows:

ARTICLE 1
DEFINITIONS

The following terms have the following meanings for purposes of this Agreement:

1.1 "Act" means the Joint Exercise of Powers Act, set forth in Chapter 5 of Division 7 of Title 1 of the Government Code, sections 6500, *et seq.*, including all laws supplemental thereto.

1.2 "Agreement" has the meaning assigned thereto in the Preamble.

1.3 "Auditor" means the auditor of the financial affairs of the Agency appointed by the Board of Directors pursuant to Section 14.3 of this Agreement.

1.4 "Agency" has the meaning assigned thereto in the Preamble.

1.5 "Basin" has the meaning assigned thereto in Recital D.

1.6 "Board of Directors" or "Board" means the governing body of the Agency as established by Article 6 of this Agreement.

1.7 "Bylaws" means the bylaws, if any, adopted by the Board of Directors pursuant to Article 11 of this Agreement to govern the day-to-day operations of the Agency.

1.8 "Director" and "Alternate Director" mean a director or alternate director appointed pursuant to Sections 6.3 and 6.4 of this Agreement. "Member Director" is a Director or Alternate Director appointed by and representing a Member agency pursuant to Section 6.1.1 of this agreement.

1.9 "DWR" has the meaning assigned thereto in Recital B.

1.10 "GSA" has the meaning assigned thereto in Recital B.

1.11 "GSP" has the meaning assigned thereto in Recital C.

1.12 "Member" means each party to this Agreement that satisfies the requirements of Section 5.1 of this Agreement, including any new members as may be authorized by the Board, pursuant to Section 5.2 of this Agreement.

1.13 "Officer(s)" means the Chair, Vice Chair, Secretary, or Treasurer of the Agency to be appointed by the Board of Directors pursuant to Section 7.1 of this Agreement.

1.14 "SGMA" has the meaning assigned thereto in Recital A.

1.15 "State" means the State of California.

ARTICLE 2
CREATION OF THE AGENCY

2.1 Creation of a Joint Powers Authority. There is hereby created pursuant to the Act a joint powers authority, which will be a public entity separate from the Members to this Agreement, and shall be known as the Santa Cruz Mid-County Joint Powers Agency ("**Agency**"). Within 30 days after the Effective Date of this Agreement and after any amendment, the Agency shall cause a notice of this Agreement or amendment to be prepared and filed with the office of the California Secretary of State containing the information required by Government Code section 6503.5. Within 10 days after the Effective Date of this Agreement, the Agency shall cause a statement of the information concerning the Agency, required by Government Code section 53051, to be filed with the office of the California Secretary of State and with the County Clerk for the County of Santa Cruz, setting forth the facts required to be stated pursuant to Government Code section 53051(a).

2.2 Purpose of the Agency. Each Member to this Agreement has in common the power to study, plan, develop, finance, acquire, construct, maintain, repair, manage, operate, control, and govern the water supply and water management within the Basin, either alone or in cooperation with other public or private non-member entities, and each is a local agency eligible to serve as a GSA within the Basin, either alone or jointly through a joint powers agreement as provided for by SGMA. The purpose of this Agency is to serve as the GSA for the Basin and to develop, adopt, and implement the GSP for the Basin pursuant to SGMA and other applicable provisions of law.

ARTICLE 3
TERM

This Agreement shall become effective upon execution by each of the Members and shall remain in effect until terminated pursuant to the provisions of Article 17 (Withdrawal of Members) of this Agreement.

ARTICLE 4
POWERS

The Agency shall possess the power in its own name to exercise any and all common powers of its Members reasonably related to the purposes of the Agency, including but not limited to the following powers, together with such other powers as are expressly set forth in the Act and in SGMA. For purposes of Government Code section 6509, the powers of the Agency shall be exercised subject to the restrictions upon the manner of exercising such powers as are imposed on the County of Santa Cruz, and in the event of the withdrawal of the County of Santa Cruz as a Member under this Agreement, then the manner of exercising the Agency's powers shall be those restrictions imposed on the City of Santa Cruz.

4.1 To exercise all powers afforded to a GSA pursuant to and as permitted by SGMA.

4.2 To develop, adopt and implement the GSP pursuant to SGMA.

4.3 To adopt rules, regulations, policies, bylaws and procedures governing the operation of the Agency and adoption and implementation of the GSP.

4.4 To obtain rights, permits and other authorizations for or pertaining to implementation of the GSP.

4.5 To perform other ancillary tasks relating to the operation of the Agency pursuant to SGMA, including without limitation, environmental review, engineering, and design.

4.6 To make and enter into all contracts necessary to the full exercise of the Agency's power.

4.7 To employ, designate or otherwise contract for the services of agents, officers, employees, attorneys, engineers, planners, financial consultants, technical specialists, advisors, and independent contractors.

4.8 To exercise jointly the common powers of the Members, as directed by the Board, in developing and implementing a GSP for the Basin.

4.9 To investigate legislation and proposed legislation affecting the Basin and to make appearances regarding such matters.

4.10 To cooperate and to act in conjunction and contract with the United States, the State of California or any agency thereof, counties, municipalities, public and private corporations of any kind (including without limitation, investor-owned utilities), and individuals, or any of them, for any and all purposes necessary or convenient for the full exercise of the powers of the Agency.

4.11 To incur debts, liabilities or obligations, to issue bonds, notes, certificates of participation, guarantees, equipment leases, reimbursement obligations and other indebtedness, and, to the extent provided for in a duly adopted Agency to impose assessments, groundwater extraction fees or other charges, and other means of financing the Agency as provided in Chapter 8 of SGMA commencing at Section 10730 of the Water Code.

4.12 To collect and monitor data on the extraction of groundwater from, and the quality of groundwater in, the Basin.

4.13 To establish and administer a conjunctive use program for the purposes of maintaining sustainable yields in the Basin consistent with the requirements of SGMA.

4.14 To exchange and distribute water.

4.15 To regulate groundwater extractions as permitted by SGMA.

4.16 To impose groundwater extraction fees as permitted by SGMA.

4.17 To spread, sink and inject water into the Basin.

4.18 To store, transport, recapture, recycle, purify, treat or otherwise manage and control water for beneficial use.

4.19 To apply for, accept and receive licenses, permits, water rights, approvals, agreements, grants, loans, contributions, donations or other aid from any agency of the United States, the State of California, or other public agencies or private persons or entities necessary for the Agency's purposes.

4.20 To develop and facilitate market-based solutions for the use and management of water rights.

4.21 To acquire property and other assets by grant, lease, purchase, bequest, devise, gift or eminent domain, and to hold, enjoy, lease or sell, or otherwise dispose of, property, including real property, water rights, and personal property, necessary for the full exercise of the Agency's powers.

4.22 To sue and be sued in its own name.

4.23 To provide for the prosecution of, defense of, or other participation in actions or proceedings at law or in public hearings in which the Members, pursuant to this Agreement, may have an interest and may employ counsel and other expert assistance for these purposes.

4.24 To exercise the common powers of its Members to develop, collect, provide, and disseminate information that furthers the purposes of the Agency, including but not limited to the operation of the Agency and adoption and implementation of the GSP to the Members, legislative, administrative, and judicial bodies, as well the public generally.

4.25 To accumulate operating and reserve funds for the purposes herein stated.

4.26 To invest money that is not required for the immediate necessities of the Agency, as the Agency determines is advisable, in the same manner and upon the same conditions as Members, pursuant to Government Code section 53601, as it now exists or may hereafter be amended.

4.27 To undertake any investigations, studies, and matters of general administration.

4.28 To perform all other acts necessary or proper to carry out fully the purposes of this Agreement.

ARTICLE 5
MEMBERSHIP

5.1 Members. The Members of the Agency shall be the Central Water District, the City of Santa Cruz, the County of Santa Cruz, and the Soquel Creek Water District, as long as they have not, pursuant to the provisions hereof, withdrawn from this Agreement.

5.2 New Members. Any public agency (as defined by the Act) that is not a Member on the Effective Date of this Agreement may become a Member upon: (a) the approval of the Board of Directors by a supermajority of at least seventy-five (75%) of the votes held among all Directors as specified in Article 9 (Member Voting); (b) payment of a pro rata share of all previously incurred costs that the Board of Directors determines have resulted in benefit to the public agency, and are appropriate for assessment on the public agency; and (c) execution of a written agreement subjecting the public agency to the terms and conditions of this Agreement.

ARTICLE 6
BOARD OF DIRECTORS AND OFFICERS

6.1 Formation of the Board of Directors. The Agency shall be governed by a Board of Directors ("**Board**"). The Board shall consist of eleven (11) Directors consisting of the following representatives who shall be appointed in the manner set forth in Section 6.3:

6.1.1 Two representatives appointed by the governing board of each of the following public agency Members: the Central Water District, the City of Santa Cruz, the County of Santa Cruz, and the Soquel Creek Water District.

6.1.2 Three representatives of private well owners within the boundaries of the Agency.

6.2 Duties of the Board of Directors. The business and affairs of the Agency, and all of its powers, including without limitation all powers set forth in Article 4 (Powers), are reserved to and shall be exercised by and through the Board of Directors, except as may be expressly delegated to the staff or others pursuant to this Agreement, Bylaws, or by specific action of the Board of Directors.

6.3 Appointment of Directors. The Directors shall be appointed as follows:

6.3.1 The two representatives from the Central Water District shall be appointed by resolution of the Central Water District Board of Directors.

6.3.2 The two representatives from the City of Santa Cruz shall be appointed by resolution of the City of Santa Cruz City Council.

6.3.3 The two representatives from the County of Santa Cruz shall be appointed by resolution of the County of Santa Cruz Board of Supervisors.

6.3.4 The two representatives from the Soquel Creek Water District shall be appointed by resolution of the Soquel Creek Water District Board of Directors.

6.3.5 The three representatives of private well owners shall be appointed by majority vote of the eight public agency Member Directors. The procedures for nominating the private well owners shall be set forth in the Bylaws.

6.4 Alternate Directors. Each Member may have one Alternate to act as a substitute Director for either of the Member's Directors. One Alternate shall also be appointed to act as a substitute Director for any of the three Directors representing private well owners. All Alternates shall be appointed in the same manner as set forth in Section 6.3. Alternate Directors shall have no vote, and shall not participate in any discussions or deliberations of the Board unless appearing as a substitute for a Director due to absence or conflict of interest. If the Director is not present, or if the Director has a conflict of interest which precludes participation by the Director in any decision-making process of the Board, the Alternate Director appointed to act in his/her place shall assume all rights of the Director, and shall have the authority to act in his/her absence, including casting votes on matters before the Board. Each Alternate Director shall be appointed prior to the third meeting of the Board. Alternates are strongly encouraged to attend all Board meetings and stay informed on current issues before the Board.

6.5 Requirements. Each Member's Directors and Alternate Director shall be appointed by resolution of that Member's governing body to serve for a term of four years except, for the purpose of establishing staggered terms, one of the initially-appointed Directors of each Member shall, as designated by the Member, serve an initial term of two years. A Member's Director or Alternate Director may be removed during his or her term or reappointed for multiple terms at the pleasure of the Member that appointed him or her. A Director representing private well owners may be removed or reappointed in the same manner as he or she was appointed as set forth in Section 6.3. No individual Director may be removed in any other manner, including by the affirmative vote of the other Directors.

6.6 Vacancies. A vacancy on the Board of Directors shall occur when a Director resigns or at the end of the Director's term as set forth in Section 6.5. For Member Directors, a vacancy shall also occur when he or she is removed by his or her appointing Member. For Directors representing private well owners, a vacancy shall also occur when the Director is removed as set forth in Section 6.5. Upon the vacancy of a Director, the Alternate Director shall serve as Director until a new Director is appointed as set forth in Section 6.3 unless the Alternate is already serving as a substitute Director in the event of a prior vacancy, in which case, the seat shall remain vacant until a replacement Director is appointed as set forth in Section 6.3. Members shall provide notice of any changes in Director or Alternate Director positions to the Board of Directors or its designee in writing and signed by an authorized representative of the Member.

ARTICLE 7
OFFICERS

7.1 Officers. Officers of the Agency shall be a Chair, Vice Chair, Secretary, and Treasurer. The Treasurer shall be appointed consistent with the provisions of Section 14.3. The Vice Chair, or in the Vice Chair's absence, the Secretary, shall exercise all powers of the Chair in the Chair's absence or inability to act.

7.2 Appointment of Officers. Officers shall be elected annually by, and serve at the pleasure of, the Board of Directors. Officers shall be elected at the first Board meeting, and thereafter at the first Board meeting following January 1st of each year, or as duly continued by the Board. An Officer may serve for multiple consecutive terms, with no term limit. Any Officer may resign at any time upon written notice to the Board, and may be removed and replaced by a simple majority vote of the Board.

7.3 Principal Office. The principal office of the Agency shall be established by the Board of Directors, and may thereafter be changed by a simple majority vote of the Board.

ARTICLE 8
DIRECTOR MEETINGS

8.1 Initial Meeting. The initial meeting of the Board of Directors shall be held in the County of Santa Cruz, California, within thirty (30) days of the Effective Date of this Agreement.

8.2 Time and Place. The Board of Directors shall meet at least quarterly, at a date, time and place set by the Board within the jurisdictional boundaries of one or more of the Members, and at such other times as may be determined by the Board.

8.3 Special Meetings. Special meetings of the Board of Directors may be called by the Chair or by a simple majority of Directors, in accordance with the provisions of Government Code section 54956.

8.4 Conduct. All meetings of the Board of Directors, including special meetings, shall be noticed, held, and conducted in accordance with the Ralph M. Brown Act (Government Code sections 54950, *et seq*.). The Board may use teleconferencing in connection with any meeting in conformance with and to the extent authorized by applicable law.

8.5 Local Conflict of Interest Code. The Board of Directors shall adopt a local conflict of interest code pursuant to the provisions of the Political Reform Act of 1974 (Government Code sections 81000, *et seq*.)

ARTICLE 9
MEMBER VOTING

9.1 Quorum. A quorum of any meeting of the Board of Directors shall consist of an absolute majority of Directors plus one Director. In the absence of a quorum, any meeting of the Directors may be adjourned by a vote of the simple majority of Directors present, but no other business may be transacted. For purposes of this Article, a Director shall be deemed present if the Director appears at the meeting in person or participates telephonically, provided that the telephone appearance is consistent with the requirements of the Ralph M. Brown Act.

9.2 Director Votes. Voting by the Board of Directors shall be made on the basis of one vote for each Director. A Director, or an Alternate Director when acting in the absence of his or her Director, may vote on all matters of Agency business unless disqualified because of a conflict of interest pursuant to California law or the local conflict of interest code adopted by the Board of Directors.

9.3 Affirmative Decisions of the Board of Directors. Except as otherwise specified in this Agreement, all affirmative decisions of the Board of Directors shall require the affirmative vote of a simple majority of all appointed Directors participating in voting on a matter of Agency business, provided that if a Director is disqualified from voting on a matter before the Board because of a conflict of interest, that Director shall be excluded from the calculation of the total number of Directors that constitute a majority. Notwithstanding the foregoing, a unanimous vote of all Member Directors participating in voting shall be required to approve any of the following: (i) any capital expenditure that is estimated to cost $100,000 or more; (ii) the annual budget; (iii) the GSP for the Basin or any amendment thereto; (iv) the levying of assessments or fees; (v) issuance of indebtedness; or (vi) any stipulation to resolve litigation concerning groundwater rights within or groundwater management for the Basin.

ARTICLE 10
AGENCY ADMINISTRATION, MANAGEMENT AND OPERATION

The Board of Directors may select and implement an approach to Agency administration and management that is appropriate to the circumstances and adapted to the GSA's needs as they may evolve over time. Details of the Board's decision on Agency administration, management and operation shall be incorporated into the GSA's bylaws and reviewed and revised as needed using the established process for revising the GSA's bylaws.

ARTICLE 11
BYLAWS

The Board of Directors shall cause to be drafted, approve, and amend Bylaws of the Agency to govern the day-to-day operations of the Agency. The Bylaws shall be adopted at or before the first anniversary of the Board's first meeting.

ARTICLE 12
ADVISORY COMMITTEES

The Board of Directors may from time to time appoint one or more advisory committees or establish standing or ad hoc committees to assist in carrying out the purposes and objectives of the Agency. The Board shall determine the purpose and need for such committees and the necessary qualifications for individuals appointed to them.

ARTICLE 13
OPERATION OF COMMITTEES

Each committee shall include a Director as the chair thereof. Other members of each committee may be constituted by such individuals approved by the Board of Directors for participation on the committee. However, no committee or participant on such committee shall have any authority to act on behalf of the Agency except as duly authorized by the Board.

ARTICLE 14
ACCOUNTING PRACTICES

14.1 General. The Board of Directors shall establish and maintain such funds and accounts as may be required by generally accepted public agency accounting practices. The Agency shall maintain strict accountability of all funds and a report of all receipts and disbursements of the Agency.

14.2 Fiscal Year. Unless the Board of Directors decides otherwise, the fiscal year for the Agency shall run concurrent with the calendar year.

14.3 Appointment of Treasurer and Auditor; Duties. The Treasurer and Auditor shall be appointed in the manner, and shall perform such duties and responsibilities, specified in Sections 6505.5 and 6505.6 of the Act.

ARTICLE 15
BUDGET AND EXPENSES

15.1 Budget. Within 120 after the first meeting of the Board of Directors, and thereafter prior to the commencement of each fiscal year, the Board shall adopt a budget for the Agency for the ensuing fiscal year no later than June 30th. In the event that a budget is not so approved, the prior year's budget shall be deemed approved for the ensuing fiscal year, and any groundwater extraction fee or assessment(s) of contributions of Members, or both, approved by the Board during the prior fiscal year shall again be assessed in the same amount and terms for the ensuing fiscal year.

15.2 Agency Funding and Contributions. For the purpose of funding the expenses and ongoing operations of the Agency, the Board of Directors shall maintain a funding account in connection with the annual budget process. The Board of Directors may fund the Agency and the GSP as provided in Chapter 8 of SGMA, commencing with Section 10730 of the Water Code, and may also issue assessments for contributions by the Members in the amount and frequency determined necessary by the Board. Such Member contributions shall be paid by each Member to the Agency within 30 days of assessment by the Board.

15.3 Return of Contributions. In accordance with Government Code section 6512.1, repayment or return to the Members of all or any part of any contributions made by Members and any revenues by the Agency may be directed by the Board of Directors at such time and upon such terms as the Board of Directors may decide; provided that (1) any distributions shall be made in proportion to the contributions paid by each Member to the Agency, and (2) any capital contribution paid by a Member voluntarily, and without obligation to make such capital contribution pursuant to Section 15.2, shall be returned to the contributing Member, together with accrued interests at the annual rate published as the yield of the Local Agency Investment Fund administered by the California State Treasurer, before any other return of contributions to the Members is made. The Agency shall hold title to all funds and property acquired by the Agency during the term of this Agreement.

15.4 Issuance of Indebtedness. The Agency may issue bonds, notes or other forms of indebtedness, as permitted under Section 4.11, provided such issuance be approved at a meeting of the Board of Directors by unanimous vote of the Member Directors as specified in Article 9 (Member Voting).

ARTICLE 16
LIABILITIES

16.1 Liability. In accordance with Government Code section 6507, the debt, liabilities and obligations of the Agency shall be the debts, liabilities and obligations of the Agency alone, and not the Members.

16.2 Indemnity. Funds of the Agency may be used to defend, indemnify, and hold harmless the Agency, each Member, each Director, and any officers, agents and employees of the Agency for their actions taken within the course and scope of their duties while acting on behalf of the Agency. Other than for gross negligence or intentional acts, to the fullest extent permitted by law, the Agency agrees to save, indemnify, defend and hold harmless each Member from any liability, claims, suits, actions, arbitration proceedings, administrative proceedings, regulatory proceedings, losses, expenses or costs of any kind, whether actual, alleged or threatened, including attorney's fees and costs, court costs, interest, defense costs, and expert witness fees, where the same arise out of, or are in any way attributable, in whole or in part, to negligent acts or omissions of the Agency or its employees, officers or agents or the employees, officers or agents of any Member, while acting within the course and scope of a Member relationship with the Agency.

ARTICLE 17
WITHDRAWAL OF MEMBERS

17.1 Unilateral Withdrawal. Subject to the Dispute Resolution provisions set forth in Section 18.9, a Member may unilaterally withdraw from this Agreement without causing or requiring termination of this Agreement, effective upon 30 days written notice to the Board of Directors or its designee.

17.2 Rescission or Termination of Agency. This Agreement may be rescinded and the Agency terminated by unanimous written consent of all Members, except during the outstanding term of any Agency indebtedness.

17.3 Effect of Withdrawal or Termination. Upon termination of this Agreement or unilateral withdrawal, a Member shall remain obligated to pay its share of all debts, liabilities and obligations of the Agency required of the Member pursuant to terms of this Agreement, and that were incurred or accrued prior to the effective date of such termination or withdrawal, including without limitation those debts, liabilities and obligations pursuant to Sections 4.11 and 15.4. Any Member who withdraws from the Agency shall have no right to participate in the business and affairs of the Agency or to exercise any rights of a Member under this Agreement or the Act, but shall continue to share in distributions from the Agency on the same basis as if such Member had not withdrawn, provided that a Member that has withdrawn from the Agency shall not receive distributions in excess of the contributions made to the Agency while a Member. The right to share in distributions granted under this Section 17.3 shall be in lieu of any right the withdrawn Member may have to receive a distribution or payment of the fair value of the Member's interest in the Agency.

17.4 Return of Contribution. Upon termination of this Agreement, any surplus money on-hand shall be returned to the Members in proportion to their contributions made. The Board of Directors shall first offer any property, works, rights and interests of the Agency for sale to the Members on terms and conditions determined by the Board of Directors. If no such sale to Members is consummated, the Board of Directors shall offer the property, works, rights, and interest of the Agency for sale to any non-member for good and adequate consideration. The net proceeds from any sale shall be distributed among the Members in proportion to their contributions made.

ARTICLE 18
MISCELLANEOUS PROVISIONS

18.1 No Predetermination or Irretrievable Commitment of Resources. Nothing herein shall constitute a determination by the Agency or any of its Members that any action shall be undertaken, or that any unconditional or irretrievable commitment of resources shall be made, until such time as the required compliance with all local, state, or federal laws, including without limitation the California Environmental Quality Act, National Environmental Policy Act, or permit requirements, as applicable, has been completed.

18.2 Notices. Notices to a Director or Member hereunder shall be sufficient if delivered to the respective Director or clerk of the Member agency and addressed to the Director or clerk of the Member agency. Delivery may be accomplished by U.S. Postal Service, private mail service or electronic mail.

18.3 Amendments to Agreement. This Agreement may be amended or modified at any time only by subsequent written agreement approved and executed by all of the Members.

18.4 Agreement Complete. The foregoing constitutes the full and complete Agreement of the Members. This Agreement supersedes all prior agreements and understandings, whether in writing or oral, related to the subject matter of this Agreement that are not set forth in writing herein.

18.5 Severability. Should any part, term or provision of this Agreement be decided by a court of competent jurisdiction to be illegal or in conflict with any applicable federal law or any law of the State of California, or otherwise be rendered unenforceable or ineffectual, the validity of the remaining parts, terms, or provisions hereof shall not be affected thereby, provided however, that if the remaining parts, terms, or provisions do not comply with the Act, this Agreement shall terminate.

18.6 Withdrawal by Operation of Law. Should the participation of any Member to this Agreement be decided by the courts to be illegal or in excess of that Member's authority or in conflict with any law, the validity of the Agreement as to the remaining Members shall not be affected thereby.

18.7 Assignment. The rights and duties of the Members may not be assigned or delegated without the written consent of all other Members. Any attempt to assign or delegate such rights or duties in contravention of this Agreement shall be null and void.

18.8 Binding on Successors. This Agreement shall inure to the benefit of, and be binding upon, the successors and assigns of the Members.

18.9 Dispute Resolution. In the event that any dispute arises among the Members relating to (i) this Agreement, (ii) the rights and obligations arising from this Agreement, or (iii) or a Member proposing to withdraw from membership in the Agency, the aggrieved Member or Member proposing to withdraw from membership shall provide written notice to the other Members of the controversy or proposal to withdraw from membership. Within thirty (30) days thereafter, the Members shall attempt in good faith to resolve the controversy through informal means. If the Members cannot agree upon a resolution of the controversy within thirty (30) days from the providing of written notice specified above, the dispute shall be submitted to mediation prior to commencement of any legal action or prior to withdraw of a Member proposing to withdraw from membership. The mediation shall be no less than a full day (unless agreed otherwise among the Members) and the cost of mediation shall be paid in equal proportion among the Members. The mediator shall be either voluntarily agreed to or appointed by the Superior Court upon a suit and motion for appointment of a neutral mediator. Upon completion of mediation, if the controversy has not been resolved, any Member may exercise all rights to bring a legal action relating to the controversy or (except where such controversy relates to withdrawal of a Member's obligations upon withdrawal) withdraw from membership as otherwise authorized pursuant to this Agreement.

18.10 Counterparts. This Agreement may be executed in counterparts, each of which shall be deemed an original.

18.11 Singular Includes Plural. Whenever used in this Agreement, the singular form of any term includes the plural form and the plural form includes the singular form.

18.12 Member Authorization. The legislative bodies of the Members have each authorized execution of this Agreement, as evidenced by their respective signatures below.

IN WITNESS WHEREOF, the Members hereto have executed this Agreement by authorized officials thereof.

CENTRAL WATER DISTRICT

By: [signature]

Title: Board President -CWD

APPROVED AS TO FORM:

By: [signature]

Title: District Counsel

CITY OF SANTA CRUZ

By: [signature]

Title: City Manager

2-23-16

APPROVED AS TO FORM:

By: [signature]

Title: Anthony P. Condotti City Attorney

COUNTY OF SANTA CRUZ

By: [signature]

Title: County Administrative Officer

APPROVED AS TO FORM:

By: [signature]

Title: County Counsel

SOQUEL CREEK WATER DISTRICT

By: Bruce Daniels

Title: President, Board

APPROVED AS TO FORM:

By: [signature]

Title: District Counsel

APPENDIX 2-A

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY COMMUNICATIONS & ENGAGEMENT PLAN

Santa Cruz Mid-County Groundwater Agency Communication & Engagement Plan

Background

Santa Cruz Mid-County's main drinking water supply is groundwater. As a result of decades of past over-pumping, streams do not always have enough water to support fish and wildlife, we have seawater contamination in some private coastal production wells, and the danger of seawater contamination spreading inland to contaminate more water supply wells. We need to work together to ensure a sustainable water supply now and for the future. The Santa Cruz Mid-County Groundwater Agency (MGA) is developing a Groundwater Sustainability Plan (GSP) to ensure a sustainable water supply supporting environmental and human needs, in compliance with the Sustainable Groundwater Management Act of 2014 (SGMA).

Communication Goals

1. Public understanding of the challenges facing groundwater supplies.
2. Public support for practical water supply solutions.
3. Engaged stakeholders who provide input and guidance to develop the Groundwater Sustainability Plan (GSP).
4. Increase public awareness of the need to protect local groundwater resources and increase groundwater levels.

Objectives

Through public meetings, workshops, events, online engagement, and print materials the public will understand:

1. Where we get our water in the Mid-County basin.
2. The nature of groundwater and its relationship to water supply and environmental values.
3. The problems that threaten our groundwater supplies.
4. Possible solutions to managing our groundwater supplies.
5. The state's mandate for a plan to ensure groundwater sustainability by 2020, and attainment by 2040 (SGMA).
6. The role of Santa Cruz Mid-County Groundwater Agency to prepare and implement the GSP.

Audiences/stakeholders

- Basin water users/rate payers.
- Basin landowners/taxpayers.
- Land and ecosystem managers.

Audiences/stakeholders contact strategies:

1) Basin Water Users
    a. City of Santa Cruz Water customers (small portion of total supply)
    How to contact: Bill inserts, presentations to community groups, social media, e-newsletters, press releases, and community parties.

    b. Central Water District (all)
    How to contact: Bill inserts, e-newsletters, press releases, and community parties.

    c. Soquel Creek Water District (SqCWD) customers (all)
    How to contact: Bill inserts and carrier routes, presentations to community groups, social media, e-newsletters, press releases, and community parties.

    d. Private well residential users and small water systems (all)
    How to contact: postcards, presentations to community groups, road signs, small water system quarterly meetings, partnering with RCD, press releases and community parties.

    e. Commercial/institutional/agricultural well users (all)
    How to contact: direct calls, press releases, partnering with RCD, presentations to industry groups.

2) Non-profits: Email lists, presentations to Boards/Councils
3) Government agencies: Presentations to Councils, Boards, and Advisory Committees

Category of Interest	Examples of Stakeholder Groups	Engagement purpose
General Public	• School Boards • Basin Residents	Inform to improve public awareness of sustainable groundwater management
Land Use	• City of Santa Cruz Planning • City of Capitola Planning • County Planning • LAFCO • AMBAG	Consult and involve to ensure land use policies are supporting GSPs, and GSP reflects projected population and development
Private users	• Private domestic pumpers • Soquel High School • Cabrillo College • Seascape Golf Course • Small community systems	Inform and involve to avoid negative impact to these users, and to inform about the need and basis for possible future fees

Urban/ Agriculture users	• Soquel Creek Water District • Central Water District • City of Santa Cruz Water Department • Resource Conservation District of Santa Cruz County • Farm Bureau • Vintners association • Cannabis Licensing Division	Collaborate to ensure sustainable management of groundwater, and to inform about the need and basis for possible future fees
Environmental and Ecosystem	• Federal and State agencies (Fish and Wildlife) • Wetland managers • Environmental groups	Inform and involve to sustain vital groundwater dependent ecosystems
Economic Development	• Chambers of Commerce, SC Business Council; business sectors such as real estate, developers, tourism • Elected officials (Board of Supervisors, City Council members) • State Assembly members • State Senators	Inform and involve to support a stable economy
Human right to water	• Disadvantaged Communities • Environmental Justice Groups • Human Service non-profits (Human Care Alliance etc.)	Inform and involve to provide a safe and secure groundwater supplies to DACs
Integrated Water Management	• Regional water management groups (IRWM regions) • Flood agencies	Inform, involve and collaborate to improve regional sustainability

Audience Survey and Mapping

Organizational stakeholders identified through the interested parties list are already engaged in the process through the MGA partner agencies and receiving email information from the MGA. A survey is available for private well owners at https://www.surveymonkey.com/r/MGAwellowner. The MGA is also planning a baseline phone survey in late 2018 to identify the level of knowledge and interest of the community in the MGA to inform future outreach.

Key stakeholder groups have also been engaged through membership in the GSP Advisory Committee. Advisory Committee members represent diverse social, cultural, economic, technical, and organizational backgrounds, and provide outreach to the stakeholder interest groups they represent.

Key Messages

1) The MGA and its partner agencies must get the Mid-County groundwater basin up to protective levels to prevent seawater intrusion.
2) We are working toward a strategy to bring the basin into sustainability without compromising human or environmental health.
3) Water conservation must continue.

4) Conservation alone will not restore the groundwater basin.
5) MGA and its member agencies have used conservation and water production management strategies to protect groundwater supplies from depletion and seawater intrusion. We need to examine alternative water sources to develop a supplemental water supply to achieve sustainability.
6) To be successful, management efforts and supplemental water supply efforts will require beneficiaries to support funding mechanisms.

Define sustainability:
The use of groundwater to meet our needs without harming the environment or jeopardizing future water supply reliability.

Venues for Engaging

Partnerships to develop consistent groundwater messaging:
The water agencies and partners within and around the Mid-County Basin have been working together closely on joint messaging and outreach strategies around water issues since the early 2000s. The primary mechanism for this effort is the Water Conservation Coalition (WCC) of Santa Cruz County (www. Watersavingtips.org). MGA partner agencies collaborate to develop narrative messages that inform the public about the need for groundwater basin restoration.

Partnerships with existing outreach and youth engagement programs:
The WCC has produced educational booklets for elementary schools, maintains a website with information on water purveyors and rebates, jointly pays for a high school and college level video contest about water in the county, sponsors programs like adult learning classes at Cabrillo College, classroom presentations, and educational campaigns including newspaper ads and bus ads. The Coalition has been featuring information on groundwater hydrology and SGMA at recent tabling events in partnership with the MGA and other GSAs in the region.

Additional outreach to local schools within the basin is done by staff from the Soquel Creek Water District and the City of Santa Cruz. Outreach includes shows at school assemblies, field trips, and in-class presentations that include building a model water system and learning about jobs in the water industry. Starting in Fall 2018, outreach will include 6-8th grade education about water supply systems which includes groundwater generally and the MGA specifically. More information can be found at https://www.soquelcreekwater.org/schools/school-programs.

Social Media:

- MGA e-newsletter
- City of Santa Cruz Water Supply Advisory Committee (WSAC) e-newsletter
- SqCWD e-newsletter and Facebook page
- County and City Water Department Facebook pages
- County supervisor email lists and Facebook pages
- Nextdoor

Informational brochures and handouts: *Sharing and Sustaining Mid-County Groundwater*, *Who Cares About Groundwater?,* Postcards, 2-page information factsheet handout.

Community Groups:

- Parent Teacher Associations
- Public Meetings
- Civic Organizations (e.g. Rotary, Lions, League of Women Voters, etc.)
- Farm Bureau
- Chambers of Commerce and other business organizations/sectors.

Website:

1) Background and basic information about the problem, SGMA, the MGA, and the GSP
2) Projects that have been implemented or are being prepared (recharge, water transfers, see also *Water Supply Augmentation Options for the Santa Cruz Mid-County Groundwater Basin*)
3) Identify gaps in information that we are presenting (how much recharge makes it to aquifer)

Stakeholder Meetings, Community Events:

- At least 2 workshops per year.
- Fun neighborhood events to engage folks that may not come to a meeting.
- Participation at tabling events like Earth Day, the County Fair, and Farmer's Markets either as the MGA or in partnership with the Water Conservation Coalition.
- Connecting the Drops.

Educational Videos and Infographics:

- Soquel Creek has invested in some very good graphical videos.
- Our interest right now is to do a series of short (1-3 minute) videos each covering a simple topic relating to the MGA (see list below for possibilities).
- Develop interactive groundwater games (aquifers, infiltration, supplemental supplies) for use at community events.

Phased Approach Implementation Timeline

The Mid-County Agency has prepared a 3-phase approach to outreach.

Phase 1: Ongoing Efforts

- MGA Website, www.midcountygroundwater.org (regular updates)
- Key press releases and social media information (ongoing as needed)
- Public meetings/workshops (ongoing)
- MGA Drop-Ins (ongoing bi-monthly)
- Mailings (ongoing as needed)
- MGA E-blast (ongoing monthly)
- Recording meetings and having them online

Phase 2: July 1-October 31, 2018.

Purpose: Name recognition, basic information about what the MGA is, what we are doing, and why (both state regulations and the problem):

a. Joint powers of different agencies working together to ensure a sustainable water supply now and for the future.
b. State mandate to write, implement, and monitor a GSP

c. Critical overdraft (stream flow is affected, seawater intrusion impacts basin groundwater supply.)

MGA Considerations and Work to Date:

a. Around the world, 70% of coastal groundwater aquifers have already been ruined by seawater contamination.
b. Locally we have avoided seawater contamination to our municipal supplies through price adjustments, water conservation, and groundwater management, but seawater contamination is on is already onshore at Soquel Point and La Selva Beach.
c. Projected climate change impacts on local rainfall patterns and hotter temperatures will require additional tools to continue to protect our coastal groundwater aquifers.
d. Since its creation in 2016, MGA has used innovative technologies like SkyTEM, DualEM to better understand subsurface geology and aid in planning projects that enhance our water supplies and protect our coastal groundwater from seawater intrusion.

Tasks for Phase 2:

1) Review draft stakeholder engagement plan, make suggestions. Include more text about leveraging existing programs, add the survey (benefits messaging and support), multiple phased approach to outreach.
2) Contract with survey company to provide us with a baseline of outreach priorities.
3) Possible survey questions:
   - *Have you heard about the MGA and if so, what do you know about it?*
   - *Do you know we have groundwater issue?*
   - *Do you think you can conserve more?*
     i. *Do you think more conservation can solve our problem?*
     ii. *Is your water consumption metered?*
     iii. *Do you know how much water your household uses per person/day?*
     iv. *Did your water usage changed in response to drought conditions?*
     v. *Has your water usage gone up since the State drought ended in 2017?*
   - *Do you have a strong feeling about supplemental supplies?:*
     i. *Desalination*
     ii. *River transfers (Explain if needed)*
     iii. *Stormwater infiltration (explain if needed)*
     iv. *Recycled water (explain if needed)*
   - *What would you be willing to pay to keep your groundwater supply sustainable?:*
     i. *A $20-50 annual fee for monitoring and basin management)?*
     ii. *A $50-100 annual fee to share costs to develop additional water supply projects?*
     iii. *A $100-200 annual fee for restoration and environmental stewardship?*
   - *Who do you trust for information on water issues?:*
     i. *Specific individual or agency (please name)*
     ii. *Local county/city governments (please name)*
     iii. *Local water providers (please name)*
     iv. *State water agencies (please name)*
     v. *UCSC research scientists (please name)*
     vi. *Others (please name)*

- *How do you get information about local issues?:*
    - i. *Local daily/weekly newspapers (please name)*
    - ii. *Radio (please name)*
    - iii. *Websites (please name)*
    - iv. *Social Media (please name)*
    - v. *Other (please name)*

4) Design and print a table cloth, stickers, and 2 banners.
5) Finish the "Who cares about groundwater?" brochure/postcard.
6) Hire RogueMark Studies or similar to create story graphics/graphic recording of SkyTEM meeting and the June Stakeholder meeting.
7) Hold stakeholder meeting in June 2018 and periodically through GSP roll out in late 2019/early 2020 similar to past meetings.
8) Create a participatory group of two to four students, called Student Sustainable Groundwater Liaisons, who can observe and occasionally participate in the MGA Board and Advisory Committee meetings. Their role will be to provide us with some guidance on how to engage with youth, provide input to the GSP, and work to inform students that there are careers and other roles in local water governance that benefit from new, young participants. (Students would be recruited from local high schools, Cabrillo College, UCSC, or CSUMB if they have a connection to the MGA area. We would solicit recruitment assistance from teachers and career counselors interested in enriching student experiences through practical work experience.)

Phase 3: November 1, 2018-December 31, 2019

Purpose: to foster trust in GSP process and ultimately support for approval of the plan. Teach people about supplemental water supply and how we pay for it. Provide an opportunity for meaningful input.

Tasks for Phase 3:

1) Create simple infographics for use in e-newsletter, MGA Board meetings, and general public outreach (need to decide topics from list below or others based on survey results).
2) Create videos (need to decide topics from list below or others based on survey results).
3) Hold stakeholder outreach meetings to allow for meaningful input to key GSP sections and document public concerns. Individual stations for GSP topic areas with question and comment cards, note pad, bullet points.
4) Use existing water related meetings and relationships to amplify MGA messages.
5) Decide how to target messages based on survey results.

Infographic/Video concepts – will decide which are needed based on survey results and input from executive team.

- Seawater intrusion/protective levels (already a good video available)
- Conjunctive Use
- Need for supplemental supply
- Growth vs water use
- One water/ All water is recycled – careful what you put down the drain
- Surface water/groundwater levels/groundwater dependent ecosystems/ streamflow (could include data or be conceptual)

- Storage
- Groundwater level
- SGMA process
- GSP content
- Data displays:
  - groundwater production and rainfall over time,
  - water that could be created from various projects,
  - implementation costs,
  - streamflow
  - land use
  - water use and population
  - water quality

Phase 4: January 1, 2020- ongoing

Purpose: Roll out of the final plan, informational meetings, press releases, GSP completion celebration.

Work with Student Sustainable Groundwater Liaisons to improve engagement with local high schools and colleges.

Evaluation and Assessment

By taking a phased approach to outreach, we allow ourselves opportunities to assess to the program and evaluate how our plan is performing against our goals and objectives by asking:

- What worked well
- What didn't work as planned
- Meeting recaps with next steps
- What are the gaps in citizen knowledge that we should focus our outreach towards?

APPENDIX 2-B

SANTA CRUZ MID-COUNTY BASIN GROUNDWATER FLOW MODEL: WATER USE ESTIMATES AND RETURN FLOW IMPLEMENTATION (TASK 2) MEMORANDUM

HydroMetrics WRI
1814 Franklin St, Suite 501
Oakland, CA 94612

TECHNICAL MEMORANDUM

To: John Ricker and Ron Duncan

From: Georgina King and Cameron Tana

Date: March 31, 2017

Subject: Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation (Task 2)

Contents

List of Figures

List of Tables

1.0 INTRODUCTION

This technical memorandum documents the methodologies used for estimating the non-municipal water use component of consumptive use in the basin for input into the Santa Cruz Mid-County basin groundwater model that simulates conditions for Water Years 1985-2015. The components of consumptive use are water use and return flow. Water use estimates are required to estimate groundwater pumping where pumping is not metered or recorded. Water use estimates are also required to estimate return flow, the water used but then returned to the watershed. Watershed processes simulated by the Precipitation Runoff Modeling System (PRMS) will be integrated into the groundwater-surface water model using GSFLOW. An introductory discussion of the approach for estimates for return flow are also discussed in this memorandum.

Municipal pumping within the basin is metered, but for most areas without municipal supplies the amount of water use is not metered or recorded. For these non-metered areas, the amount of water use is estimated based on land use. The estimates for non-municipal domestic water use is described in this memorandum. The methodology for estimating institutional, recreational, and agricultural irrigation water use based on crop type and climate is also described in this memorandum. These estimates of water use will be used to define non-municipal pumping in the model.

The technical memorandum describes a number of assumptions for water use and return flow that will be incorporated into the Mid-County Groundwater Basin groundwater model. The sensitivity of these assumptions will be tested by the model. However, the amount of non-municipal domestic, institutional, recreational, and agricultural water use is small and likely less sensitive compared to some of the other model inputs, such as precipitation, and outputs, such as evapotranspiration.

2.0 NON-MUNICIPAL DOMESTIC WATER USE

2.1 NON-MUNICIPAL DOMESTIC WATER USE METHODOLOGY

For purposes of the groundwater model, non-municipal water use is considered use that is supplied by non-municipal sources of groundwater. Community water systems are included in the non-municipal water use estimate where metered data are not available. Non-municipal water use estimates are used for two purposes: to provide a volume for groundwater extraction where metered data are not available, and to estimate the amount of non-municipal use return flow from septic tanks and landscape irrigation as a proportion of the water used at each residence. Commercial water use is not considered in this estimate because according to Santa Cruz County's (the County's) 1994 land use dataset, there is no significant commercial land use, other than agriculture-related activities, in areas that do not receive municipal water supply.

To estimate the amount of non-municipal domestic water use within the model domain, two sources of data are used. The primary data source is the County's building footprint geographical information systems (GIS) layer that is used to identify individual residential buildings. The second data source, used to supplement the building footprints, is land use data from Santa Cruz County identifying residential parcels.
Santa Cruz County developed the building footprint layer from aerial photograph interpretation using photographs from 2003 and 2007. We applied a filter to exclude buildings that are not classed as habitable structures and have footprints that are less than 500 square feet in area. Residential buildings served by the City of Santa Cruz, Soquel Creek Water District (SqCWD), Central Water District (CWD), City of Watsonville, and Scotts Valley Water District were also excluded. To identify residential buildings served by the list of agencies above, a layer of municipal metered parcels was intersected with the building footprints. All residential building footprints falling within the metered parcel layer or that were part of a multi-parcel residential complex that included one metered parcel were excluded following the assumption that these residences are supplied water by an overlying water supply agency.[1]

Because the building footprint data comprises only residential buildings as of 2007, and because some buildings may have been missed in the County's building footprint layer due to tree cover, we also identified residential parcels that do not receive municipal supply and did not have an identified building footprint from Santa Cruz County's land use dataset. Residential parcels added to the dataset were selected using land use codes listed in Appendix A. Residential parcels not receiving municipal water were identified based on the layer of metered parcels. In order to determine the number of non-municipal water use residential buildings as of 2014, we assumed that each residential parcel without an identified building footprint had one building unless the land use description for the parcel specifically included the number of additional residences.

Table 1 shows the number of non-municipal water use residential buildings as of 2014 in the full model domain and within the Santa Cruz Mid-County Basin. The table also breaks down the number of non-municipal water use homes that are on septic and sewer. Sewered areas are those areas which are connected to sewer lines. The sewer spatial data was provided by the County and SqCWD. It is assumed that those homes not connected to the sewer are on septic systems.

[1] Central Water District does provide water to a few residences that also have private wells; those wells are seasonal and/or not reliable sources of drinking water (Bracamonte, 2016). Therefore, this small amount of private water use is not accounted for in the model. This same assumption was made for other areas supplied municipal water by other agencies.

Table 1: Summary of Non-Municipal Water Use Residential Building Count

Data Source	Number of Non-Municipal Water Use Homes on Septic Systems		Number of Non-Municipal Water Use Homes on Sewer		Total Number of Non-Municipal Water Use Homes	
	Model Area	Mid-County Groundwater Basin	Model Area	Mid-County Groundwater Basin	Model Area	Mid-County Groundwater Basin
Santa Cruz County Building Footprints	4,333	1,728	409	331	**4,742**	**2,059**
Santa Cruz County Land Use Residential Parcels Without Building Footprints	736	326	0	0	**736**	**326**
Total	**5,069**	**2,054**	**409**	**331**	**5,478**	**2,385**

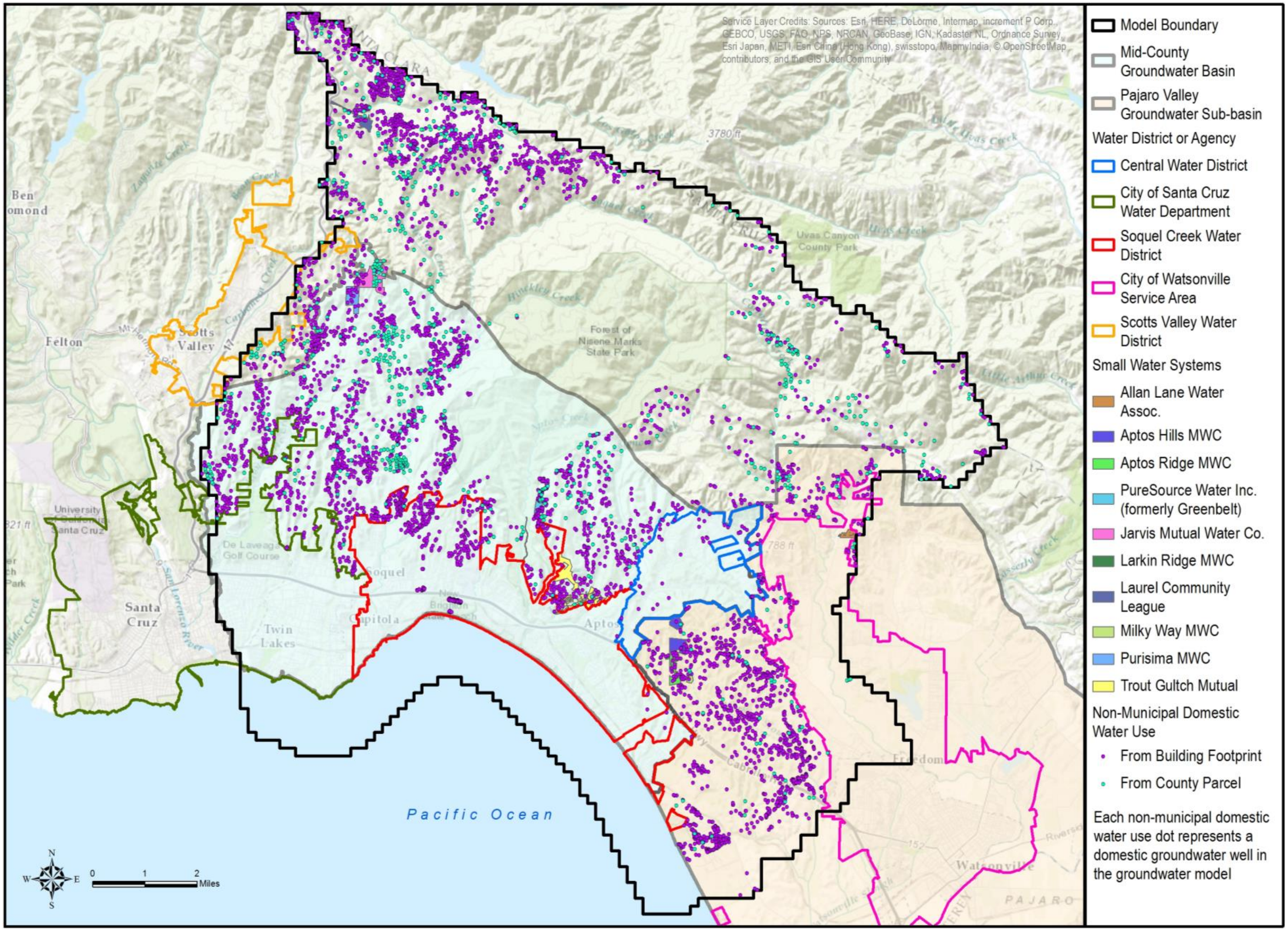


Figure 1: Non-Municipal Water Use Building Footprints and Residential Parcels

2.2 NON-MUNICIPAL DOMESTIC WATER USE FACTOR

An annual water use factor was developed to apply to the total number of non-municipal water use residences to obtain annual volumes of non-municipal groundwater pumped within the model area. The water use factor for 2015 was based on an evaluation of water use in 2015 by small water systems within and in close proximity to the model area (Table 2). From these data provided by the County, it was observed that water use per connection is greater for the larger of the small water systems in the Pajaro Valley Groundwater Sub-basin (Table 2). Based on this, the average 2015 water use factor for small water systems in the Pajaro Valley Groundwater Sub-basin is 0.50 acre-feet per year, and in the Mid-County Groundwater Basin (and remaining area within the model) it is 0.23 acre-feet per year (Table 2). These factors are applied to the non-municipal domestic dataset for Water Year 2015 according to the groundwater basin the water use falls in.

Table 2: Groundwater Pumped by Small Water Systems in 2015

Small System Name	Connections	2015 Use (gallons)	2015 Use / Connection (gallons)	2015 Water Use Factor (AFY)
Allan Lane Water Association	***16***	***4,326,708***	***270,419***	***0.83***
Aptos Hills Mutual Water Co.	***11***	***2,514,698***	***228,609***	***0.70***
Aptos Ridge Mutual Water Co.	***16***	***3,375,425***	***210,964***	***0.65***
Larkin Ridge Mutual Water Co.	***5***	***329,270***	***65,854***	***0.20***
Milky Way Mutual Water Co.	***9***	***420,975***	***46,775***	***0.14***
Trout Gulch Mutual	186	13,754,865	73,951	0.23
Purisima Mutual Water Co.	14	1,767,174	126,227	0.39
PureSource Water Inc.	80	5,315,289	66,441	0.20
Jarvis Mutual Water Co.	36	2,143,690	59,547	0.18
Laurel Community League	24	1,283,012	53,459	0.16
Average All				**0.37**
Average Mid-County Basin				**0.23**
Average Pajaro Valley Sub-basin				**0.50**

Five top small water systems in the table (in bold italics) are located in the Pajaro Valley Groundwater Sub-basin.

The water use factor was assumed to have been higher in years prior to 2015 because water conservation was not practiced to the extent that it is in the most recent years as evidenced by water use metered at several systems with data from 2013 through 2015 (Table 3). Based on this, percentage of water conserved between 2013 and 2015 in Pajaro Valley Groundwater Sub-basin was 20%, and in the Mid-County Groundwater Basin (and remaining area within the model) it was 34% (Table 2). These factors are applied to the 2015 water use factor to arrive at a water use factor for 2013. Water Year 2014's water use factor was assumed to be the mean of 2013 and 215 factors.

The water use factors are increased incrementally from 2013 backwards to the start of the model period. For the non-Pajaro Valley Groundwater Sub-basin areas, the period from 1989 through 2004 is assigned a water use factor 0.44 acre-feet per year based on Wolcott (1999), with a higher factor before that period and a declining factor since that period. For the Pajaro Valley Groundwater Sub-basin, a Proposition 218 service charge study by PVWMA estimated a water use factor of 0.59 acre-feet per year for 2009 based on small water system usage. This water use factor is the same as that estimated for 2015 based on 20% conservation of 2015 use, and thus was applied from 2009 through 2013. The water use factors prior to 2009 were increased incrementally over the same periods as the non-Pajaro Valley Groundwater Sub-basin factors. Table 4 provides the annual water use factors used to estimate historical non-municipal water use for the model area and for the Mid-County Groundwater Basin, as a subset of the model area.

Table 3: Observed Conservation from 2013 through 2015 for Small Water System with Metered Records

Small Water System	July – December Usage (AFY)			Conservation % 2013 – 2015
	2013	2014	2015	WUF (AFY)
Aptos Hills Mutual Water Co.	4.3	6.5	3.5	17%
Aptos Ridge Mutual Water Co.	9.0	3.5	6.9	23%
Trout Gulch Mutual	36.0	24.3	21.7	40%
PureSource Water Inc.	11.7	7.9	8.6	27%
Jarvis Mutual Water Co.	6.2	5.1	2.2	65%
Laurel Community League	2.0	2.0	1.9	4%
Average All				**29%**
Average Mid-County Basin				**34%**
Average Pajaro Valley Sub-basin				**20%**

Table 4: Summary of Non-Municipal Water Use Factors

Water Year	Non-Pajaro Valley Groundwater Sub-Basin (AFY)	Non-Pajaro Valley Groundwater Sub-Basin (AFY)
1985	0.46	0.62
1986	0.46	0.62
1987	0.46	0.62
1988	0.46	0.62
1989	0.44	0.62
1990	0.44	0.62
1991	0.44	0.62
1992	0.44	0.62
1993	0.44	0.62
1994	0.44	0.62
1995	0.44	0.62
1996	0.44	0.62
1997	0.44	0.62
1998	0.44	0.62
1999	0.44	0.62
2000	0.44	0.62
2001	0.44	0.62
2002	0.44	0.62
2003	0.44	0.62
2004	0.44	0.62
2005	0.41	0.61
2006	0.41	0.61
2007	0.41	0.61
2008	0.41	0.61
2009	0.38	0.59
2010	0.38	0.59
2011	0.38	0.59
2012	0.38	0.59
2013	0.35	0.59
2014	0.29	0.54
2015	0.23	0.5

2.3 NON-MUNICIPAL DOMESTIC WATER USE ESTIMATE

To estimate the annual non-municipal water use for all simulated years of the model period, the number of non-municipal residences was extrapolated from the count of residential buildings for 2014 obtained from Santa Cruz County building footprints and residential parcels. The number of buildings was assumed to increase or decrease in proportion to the increase or decrease in the County's unincorporated population relative to 2014's population (Table 5). Spatial distribution of water use was maintained consistent to the distribution for 2014.

Table 5 shows that estimates of annual non-municipal residential groundwater use in the model area have ranged from approximately 2,751 acre-feet in 1985 to a maximum of 3,223 acre-feet in 2000, subsequently falling to a minimum of 2,418 acre-feet in 2015. A subset of non-municipal estimates of groundwater use for the Santa Cruz Mid-County Basin are included in Table 5.

2.4 MONTHLY VARIATION OF NON-MUNICIPAL DOMESTIC WATER USE

Pumping will be applied to the model in monthly stress periods because municipal pumping for Water Years 1985-2015 is recorded on a monthly basis. Monthly variation of non-municipal domestic water use is assumed to result from variation in outdoor water use. Outdoor water use is assumed to average 30% of total domestic water use (Johnson *et al.*, 2004). The variation of outdoor water use by month will be estimated from the variation of potential evapotranspiration (PET) minus actual evapotranspiration of rainfall as calculated by an initial simulation of watershed processes by PRMS.

Table 5: Estimated Non-Municipal Domestic Water Use based on Number of Residential Buildings and Population Change

		Estimated Number of Non-Municipal Supplied Residential Buildings		Non-Municipal Domestic Water Use (AFY)	
Water Year	Unincorporated Population % of 2014	Model Area	Mid-County Groundwater Basin	Model Area	Mid-County Groundwater Basin
1985	90.1%	4,938	2,147	2,880	988
1986	92.1%	5,046	2,194	2,943	1,009
1987	94.0%	5,148	2,239	3,003	1,030
1988	94.8%	5,194	2,259	3,029	1,039
1989	96.5%	5,289	2,300	3,060	1,012
1990	98.3%	5,383	2,341	3,115	1,030
1991	97.3%	5,329	2,317	3,084	1,019
1992	97.8%	5,357	2,330	3,100	1,025
1993	98.5%	5,398	2,347	3,124	1,033
1994	99.3%	5,439	2,365	3,147	1,041
1995	99.6%	5,456	2,372	3,157	1,044
1996	100.2%	5,489	2,387	3,176	1,050
1997	99.5%	5,449	2,370	3,153	1,043
1998	100.1%	5,483	2,384	3,173	1,049
1999	100.7%	5,518	2,399	3,193	1,056
2000	101.7%	5,570	2,422	3,223	1,066
2001	100.4%	5,500	2,392	3,183	1,052
2002	99.9%	5,472	2,379	3,166	1,047
2003	99.1%	5,429	2,361	3,142	1,039
2004	98.0%	5,368	2,334	3,106	1,027
2005	96.7%	5,298	2,304	2,988	945
2006	96.5%	5,287	2,299	2,982	943
2007	96.2%	5,270	2,292	2,973	940
2008	96.8%	5,305	2,307	2,992	946
2009	97.3%	5,333	2,319	2,882	881
2010	97.8%	5,360	2,331	2,897	886
2011	97.9%	5,364	2,332	2,899	886
2012	98.4%	5,392	2,344	2,914	891
2013	99.3%	5,439	2,365	2,900	824
2014	***100.0%***	***5,478***	***2,382***	2,660	689
2015	100.8%	5,520	2,400	2,418	552
			Average	**3,021**	**970**

Note: estimates based on estimated 2014 residential building/parcel count and 2014 unincorporated population

3.0 Institutional Non-Municipal Water Use

Non-municipal, non-agricultural water use that is excluded from non-municipal domestic water use, because it cannot be accounted for by using residential buildings or parcels, is considered institutional non-municipal water use. This is water use by institutions or facilities within the model area that pump their own groundwater primarily for large scale irrigation of recreational turf.

The only small water system in the model area with available and consistent historical usage records is from Trout Gulch Mutual, where data are available from 2008 through 2015. This usage is included as institutional use because it is not supplied by municipal water and does not need to be estimated based on residential building footprints or parcels. Pumping for Trout Gulch Mutual prior to 2008 was assumed to be the same as its 2008 pumping. Estimates of pumping by other small water systems who do not have available and well-documented multi-year records of usage were developed by using the building footprints, parcels and water use factors described in Section 2.0.

Table 6 lists the non-municipal and non-agricultural water use institutions/facilities and provides their estimated water use. Estimates of water use are from a number of sources as referenced in the table. Figure 2 shows the locations of these institutions within the model area.

3.1 Calculation of Irrigation Use

Some of the institutions use privately pumped groundwater to irrigate recreational turf in addition to potable supply for their institutions. Table 6 identifies areas of irrigation for these institutions. The amount of groundwater pumped for outdoor use based on the turf acreage provided will be estimated based on potential evapotranspiration (PET) minus rainfall evapotranspiration (ET demand) calculated by an initial simulation of watershed processes by PRMS that accounts for climatic conditions during the 1985-2015 model period. ET calculated by PRMS is for generalized plant cover, while the estimated irrigation for turf is based on crop evapotranspiration specific to turf (ET_c). ET_c is estimated by multiplying turfgrass' crop coefficient (K_c) by ET demand calculated by PRMS adjusted for the generalized crop coefficient applied in PRMS. Values of K_c for turf vary by month and are listed in Table 7. An irrigation inefficiency of 10-20% will be added to irrigation demand to estimate the pumping needed to meet this demand. Although PRMS calculates soil moisture that could affect irrigation demand, to avoid iterative calculation of irrigation demand using the model, we will estimate irrigation demand based only on ET_c minus actual evapotranspiration of rainfall calculated by PRMS adjusted for crop coefficients.

Table 6 also shows a preliminary estimate for outdoor water use at these areas prior to running the model using average monthly reference potential evapotranspiration (ET_o) from CIMIS Station No. 209 (Watsonville West II), and no irrigation between November and March to account for a typical rainy season. Based on the preliminary estimates, the preliminary water use factor for irrigation is approximately 1.8 acre-feet/acre. As reference, Wolcott (1999) used a similar factor of 1.7 acre-feet/acre.

Estimates by Kennedy (2015) for water use are also shown in Table 6 with notes where there are discrepancies from the preliminary estimates calculated based on the assumptions above.

Table 6: Estimated Groundwater Pumped by Institutions/Facilities in the Model Area

Institution/ Facility	Year	Area of Irrigated Turf (acres)	Preliminary Outdoor Water Use (AFY)	Indoor Water Use (AFY)	Preliminary Pumped Groundwater (AFY)	Kennedy Estimates of Total Water Pumped (AFY)/Comments on Current Status
Aptos High School		2.2	4.0[1]	9.3[3]	13.3	
KOA		-			11 estimate	26.7 - seems high
Monterey Bay Academy	2015	uncertain	577[8]	18[3]	595[6]	
Renaissance High School		1.8	3.2[1]	2.0[3]	5.3	1.7
7th Day Adventist Conference*		-	-	8.0[2]	8.0	11.0 / County confirms no current irrigation
Cabrillo College*	2014	12.7	22.9[1]	55.1	78.0[6]	95
Enchanted Valley*		-	-	5.4[2]	5.4	5 (rounded down)
Kennolyn Camp*		-		Included in non-municipal water use estimate		9
Land of Medicine Buddha*		-	-	1.7[2]	1.7	2 (rounded up)
Mountain Elementary School*		1.9	3.5[1]	1.5[1]	5.0	County has 0.02AFY reported pumping – this seems low given they irrigate turf
Seascape Golf Course*		136.1	108[6]	MS	108[6]	232 / County permit for 108 AFY
Seascape Greens*		11.5	20.6[1]	MS	20.6	Not included
Soquel High School*		6.4	11.5[1]	MS	11.5	Not included
St. Clare's Retreat Home*		-	-	2	2	Not included
Trout Gulch Mutual *	Ave 2008 –2014	-	20.4[7]	47.5[7]	67.9[5]	67.1
Total Model					**932.7**	
***Total Mid-County Groundwater Basin**					**308.1**	

* = Mid-County Groundwater Basin

MS = municipal supply

[1] Irrigated area multiplied by water use factor of 1.8 acre-feet/acre

[2] Wolcott (1999) Appendix E

[3] Using per capita rates and other assumptions for schools from Wolcott (1999) Appendix E

[4] HydroMetrics (2015)

[5] Trout Gulch Mutual's pumping records

[6] Santa Cruz County records

[7] Based on 30/70 Outdoor/Indoor usage

[8] Difference between groundwater pumped and indoor use

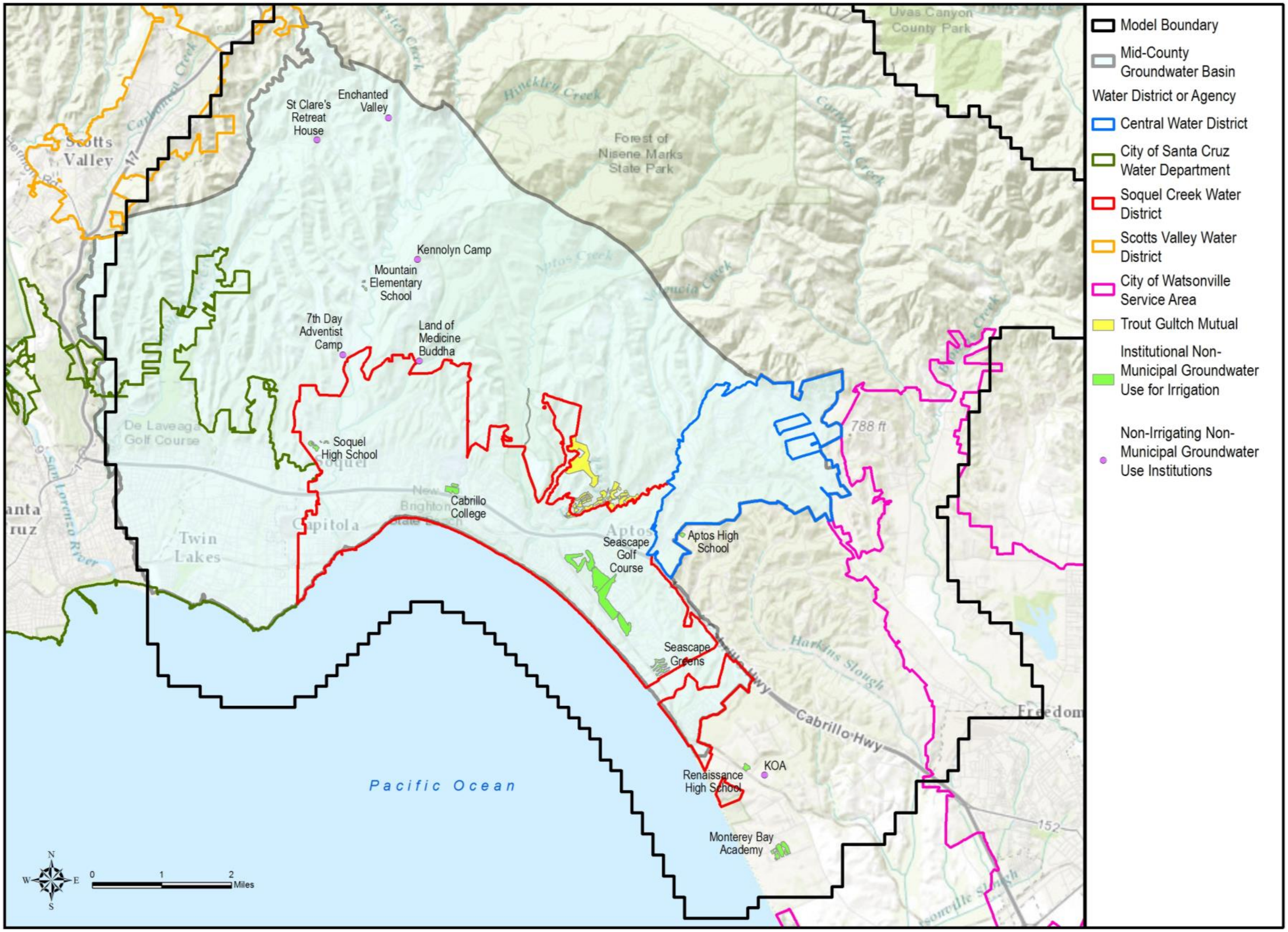


Figure 2: Non-Municipal Groundwater Use Institutions

4.0 AGRICULTURAL WATER USE

4.1 AGRICULTURAL IRRIGATION USE METHODOLOGY

An estimate of the amount of agricultural irrigation applied in the groundwater model is estimated based on crop evapotranspiration (ET_c). The amount of groundwater pumped for agricultural use will be estimated based on potential evapotranspiration (PET) minus rainfall evapotranspiration calculated by an initial simulation of watershed processes by PRMS that accounts for climatic conditions during the 1985-2015 model period as described in the previous section. For agriculture, crop coefficient (K_c) is affected by crop type, stage of growth, soil moisture, the health of the plants, and cultural practices. Values for K_c (unitless) are primarily those used in the PVWMA groundwater model developed by the USGS (Hanson *et al.*, 2014). Exceptions to Pajaro Valley K_c are coefficients for apple orchards, vineyards, pastures, and nurseries/greenhouses.

Apple orchards within the Mid-County Groundwater Basin are mostly well-established and require limited irrigation. We assumed only irrigation in the warmer months of April through October. The Pajaro Valley model April through October K_c values were reduced until the annual water demand approximated measured water use used in the CWD model for apple orchards (HydroMetrics WRI and Kennedy/Jenks, 2014). This same approach of reducing monthly K_c based on measured water use for the CWD model was taken for all vineyards (irrigated April through September) and pastures (irrigated April through November) in the model. The Pajaro Valley model used a K_c value of 0.1 for all 12 months for nurseries/greenhouses. A review of published papers on crop coefficients indicated that the coefficient should be much higher. Therefore we have assumed a K_c of 0.8 for all months for nurseries/greenhouses. The monthly K_c to be used in the GSFLOW model for each crop type are summarized in Table 7.

Table 7: Monthly Crop Coefficients (K_c)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turf (Urban)	0.56	0.56	0.56	0.73	0.73	0.73	0.73	0.7	0.62	0.56	0.56	0.56
Vegetable Row Crops	0.61	0.61	0.61	0.92	0.71	0.6	1.04	0.92	0.59	1	0.85	0.61
Strawberry	0.62	0.62	0.62	0.86	0.66	0.58	1.01	0.9	0.56	1.06	0.86	0.62
MGB Deciduous (Orchards)	0	0	0	0.025	0.075	0.1	0.125	0.15	0.15	0.025	0	0
Non-MGB Deciduous (Orchards)	0.03	0.03	0.03	0.1	0.3	0.4	0.5	0.6	0.6	0.1	0.03	0.03
Subtropical	0.56	0.56	0.56	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.56
Vines/Grapes	0	0	0	0.17	0.22	0.23	0.23	0.22	0.12	0	0	0
Pasture	0	0	0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0
Grains (Field Crops)	0.25	0.25	0.25	1.17	0.87	0.17	0.17	0.17	0.17	0.17	0.17	0.25
Nurseries/Greenhouses	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Raspberries/ Blackberries/Blueberries	0.16	0.16	0.16	0.51	0.75	0.78	0.78	0.75	0.45	0.25	0.2	0.16
Semi-agriculture	0.31	0.31	0.31	0.62	0.74	0.7	0.7	0.53	0.34	0.27	0.27	0.31

Coefficients are unitless
Sources of data: PVWMA Groundwater Model (Hanson *et al.*, 2014) and HydroMetrics WRI & Kennedy/Jenks (2014)

There are some apple orchards and pastures in the model that have been identified by the County as dry farmed and therefore no irrigation demand is estimated for those areas.

Annual agricultural demand is estimated by summing the product of the monthly crop coefficients (K_c), a monthly reference evapotranspiration (ET_o) that is measured at a nearby CIMIS station, and the crop acreage:

$$Agricultural\ Demand\ (acre-feet) = K_c\ (unitless) \times ET_o(feet) \times crop\ area\ (acres)$$

4.2 Preliminary Agricultural Irrigation Demand Estimate

Using the methodology described in the section above, Table 8 summarizes the crops, their 2014 acreages, and preliminary estimates for water demand for 2014 based on monthly reference crop evapotranspiration (ET_o) in 2014 from CIMIS Station No. 209 (Watsonville West II. The acreages and locations of crops were obtained primarily from PVWMA, which maps crop coverages at least annually. Current aerial photographs were used to supplement crop locations and types in areas to the west of the data provided by PVWMA. The County also provided some field verification and identified some areas within the Mid-County Groundwater Basin that are dry farmed.

The locations of horse and cattle related operations were identified through an internet search and confirmed by aerial photographs. Figure 3 shows the 2014 distribution of crops by type within the model area. Some of the agricultural demand in the model area is met by water supplied by CWD, as indicated in Table 8.

For the water demand from livestock related agriculture, horses are estimated by head count instead of acreage. It was assumed that horse boarding, breeding, and training facilities use 30 gallons per horse per day[2]. The number of horses at each facility was estimated by counting the number of stalls from aerial photographs. The one cattle ranch that we have identified has been excluded because it appears small based on aerial photographs. Water use data for the one egg ranch within the model area was provided by CWD.

[2] Horses require on average 10 gallons per day for direct consumption. We assumed 20 gallons per day per horse additional water use for other activities at the facility such as cleaning and dust control. Assuming 35 horses, a total water use of 30 gallons per day per head is also the Barn Boarding Stable's 2005-2015 average metered records from CWD.

Table 8: Summary of 2014 Agricultural Water Demand

Crop/Activity	Unirrigated Acreage (acres)		Irrigated Acreage (acres)		Estimated 2014 Water Demand by Supply (AFY)		Estimated 2014 Water Demand by Area (AFY)	
	Model Area	Mid-County Groundwater Basin	Model Area	Mid-County Groundwater Basin	Private Supply	CWD Supply	Model Area	Mid-County Groundwater Basin
Deciduous (Apple Orchards)	89	89	1,515	350	1,185	10	1,195	81
Strawberries	-	-	653	0	1,706	0	1,706	0
Vegetable Row Crop	-	-	652	88	1,705	33	1,738	235
Nurseries/Flowers/Tropical Plants	-	-	566	27	1,555	0	1,555	74
Raspberries and Blackberries	-	-	520	0	912	0	912	0
Vine/Grapes	-	-	280	186	115	10	125	83
Fallow	-	-	206	0	0	0	0	0
Pasture	33	33	205	74	440	0	440	160
Greenhouse	-	-	75	3	206	0	206	8
Other Agriculture	-	-	31	0	54	0	54	0
Bamboo	-	-	30	30	0	13	13	13
Ag. Unknown	-	-	4	1	6	0	6	3
Olive Orchard (similar to apple orchard demand)	-	-	1	1	0	0.2	0.2	0.2
Citrus	-	-	22	22	48	0	48	48
Horses	-	-	-	-	13.7	0.3	14	7
Egg Ranch	-	-	-	-	0	2	2	2
Total Crops and Livestock	**122**	**122**	**4,759**	**784**	**7,946**	**69**	**8,015**	**715**

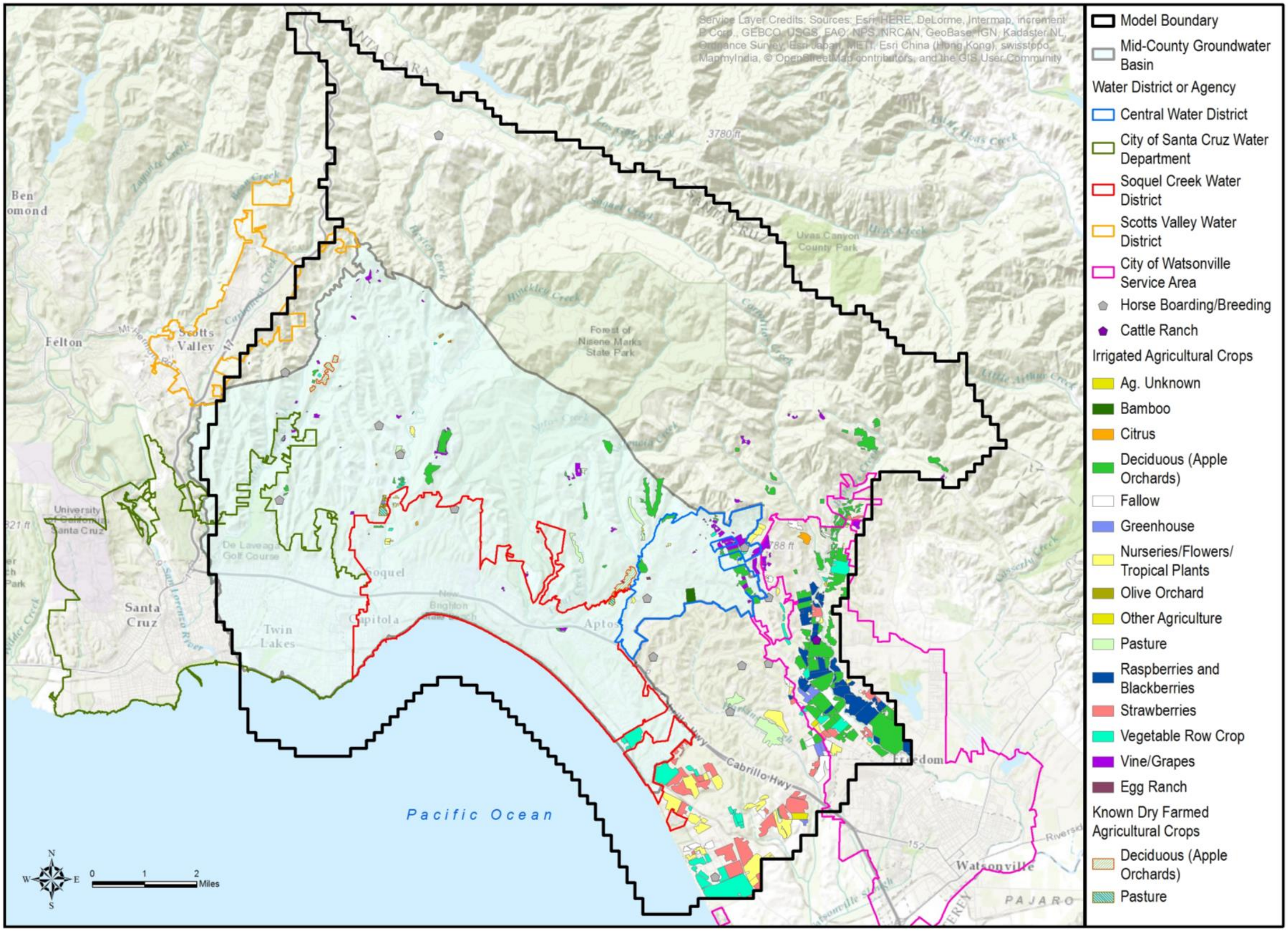


Figure 3: 2014 Agriculture in the Model Area

5.0 IMPLEMENTING NON-MUNICIPAL PUMPING IN MODEL

All non-municipal domestic and institutional, and agricultural water use is assumed to be supplied by privately pumped groundwater. This pumping will be aggregated and estimated for each applicable model cell; specific wells will not be explicitly simulated in the model. The pumping estimates will be added to the Multi-Node Well (MNW2) package file as multi-layer wells screened from the top layer to the lowest likely layer of production for the grid cell. Pumping will be distributed to layers by the model based on simulated layer transmissivity. If the shallowest layers become dry in the model, pumping is distributed to lower saturated layers so that all of the estimated pumping is included in the model's water budget.

6.0 SIMULATING RETURN FLOW COMPONENTS

There are a number of return flow components that will be included in the groundwater model. This memorandum introduces these components and how we propose to estimate them. The final estimates and resultant model input will be discussed in the memorandum documenting the integrated GSFLOW model.

In general, return flow components include:

1. System losses: water, sewer and septic systems,
2. The inefficient portion of municipal and non-municipal domestic and institutional irrigation (outdoor applied water), and
3. The inefficient portion of agricultural irrigation.

A phased approach is planned for implementing return flow components in the GSFLOW model. Initially, all return flow components will be added in GSFLOW's UZF package, which is applied below the root zone (Table 9). The US Geological Survey recently added this capability to UZF under its joint funding agreement with SqCWD. Using only the single package that is integral to GSFLOW will expedite model results that will allow MGA and members evaluate groundwater management alternatives and supplemental supply options by early 2017. However, adding return flow components to UZF will preclude calculation of near surface runoff of the return flow components to surface water.

Future work will continue use of UZF for simulating return flow from water and sewer system losses, and septic systems, which is assumed to occur below the soil root zone. However, there is an option to simulate return flow from the inefficient portions of irrigation using the newly developed Water Use Module (WUM) for PRMS, which adds water to the near surface capillary zone (Table 9). This module effectively allows for the inefficient portions of return flow near surface runoff to surface water as well as groundwater recharge. The need to implement WUM will be evaluated in 2017 when the model will be used to analyze relative impacts from various water use classifications under a County Proposition 1 grant.

Table 9: Summary of Packages Used to Simulate Return Flow in the Model

Return Flow Component	Package used in Model Implementation	
	Initial (2016)	Future Option (2017)
Water system losses	UZF	UZF
Sewer losses	UZF	UZF
Septic system losses	UZF	UZF
Municipal & non-municipal irrigation	UZF	WUM
Agricultural irrigation	UZF	WUM

The following sections describe our proposed approach for simulating the different return flow components using UZF only for this first phase of return flow implementation.

6.1 Water System Losses

Water system losses will be calculated as percentage of estimated deliveries to each service area and applied in UZF to model cells overlying those service areas.

For the Central Water District (CWD) model, the system loss percentage for CWD was varied over time based on unaccounted water losses by fiscal year through 2009 (HydroMetrics WRI and Kennedy/Jenks, 2014). The approximate range of CWD system loss estimated for the CWD model for 1984-2009 was 4-14%. This percentage will be updated for fiscal years through 2015.

For the CWD model, the system loss percentage for Soquel Creek Water District (SqCWD) was estimated as 7% which was confirmed through a SqCWD water audit for 2010-2013 (Mead, 2014) . The Cities of Santa Cruz and Watsonville water system losses will be 7.5% and 6%, respectively, per their 2015 Urban Water Management Plans (UWMP)

6.2 Wastewater Return Flows

Wastewater return flows will be based on indoor use that becomes wastewater. Indoor use has generally been assumed to be 70% of total water use (Johnson et al., 2004 and USEPA, 2008) and 90% of indoor water use is assumed to become wastewater. There are a range of available estimates for this value with measurements at mountain residences in Colorado indicating approximately 81% (Stennard et al, 2010) and California Department of Water Resources (1983) estimating 98%.

For wastewater return flows from sewer losses in sewered areas, the same loss percentage of 7% used in the CWD model based on the SqCWD system loss percentage will be applied to model cells overlying all sewered areas. These sewer losses will be added in UZF to infiltrate below the root zone.

All of indoor water use that becomes wastewater for septic systems will be also be added in UZF below the root zone for model cells in unsewered areas. Although there has been research indicating additional evapotranspiration from septic systems than surrounding areas (Stannard et al., 2010), typical leachfield depth in Santa Cruz County is 4 to 50 feet and County staff has rarely observed increased vegetation overlying or nearby leachfields that would indicate root zone evapotransporation from septic systems (Ricker, 2016).

Santa Cruz County has observed that the percentage of indoor use is influenced by overall water use and climatic conditions (Ricker, personal communication). In years of drought, such as from 2013 – 2015, water conservation is practiced to a greater extent by the public. Outdoor use is usually the first place where water use is cut, thus the percentage of indoor use is greater in those years than years when the overall water use is higher. For the period through 2013, the percentage of indoor use in the model will be 70% and will increase to 75% for 2014, and to 80% for 2015.

6.3 IRRIGATION RETURN FLOWS

The portion of water from irrigation that returns to the watershed as runoff or groundwater recharge is the inefficient portion of irrigation. The amount of water applied in UZF is just the inefficient irrigation calculated in the model cell because UZF represents what is below the capillary zone where the crop's evapotranspiration demand is met. The inefficiency factor, or the percentage of crop ET demand that does not evapotranspirate, will range from 10% (Todd, 2014) to 20% (Johnson et al., 2004).

7.0 Calculating Return Flow Components

Calculation of return flow components depends on water source and wastewater destination in addition to type of water use. The following sections describe our proposed approach for calculating the different return flow components.

7.1 Municipal Return Flow

Figure 4 illustrates how we plan to estimate return flows from municipally supplied water including system losses and wastewater return flows discussed above as well as irrigation return flows. From available water supply records, we will distribute return flows spatially based on land use and service areas. Municipal water use for the Cities of Santa Cruz and Watsonville includes both surface water and groundwater. Land use factors affecting municipal return flow include defining areas of large-scale irrigation versus primarily residential and commercial use where irrigation is at a smaller scale. Figure 5 shows the locations of municipal service areas and various land use categories used for different applied water types.

To estimate the amount of residential and commercial water use for each municipal service area, water system losses as described above and water used for large-scale irrigation will be subtracted from the amount of water supplied to each service area. The amount of irrigation applied will vary monthly based on local potential evapotranspiration (Figure 4). Return flow comprised of the inefficient portion of outdoor use, sewer losses in sewered areas, and septic system leakage will be distributed to model cells overlying those service areas. Areas that are not supplied water, such as open space and undeveloped land will be excluded.

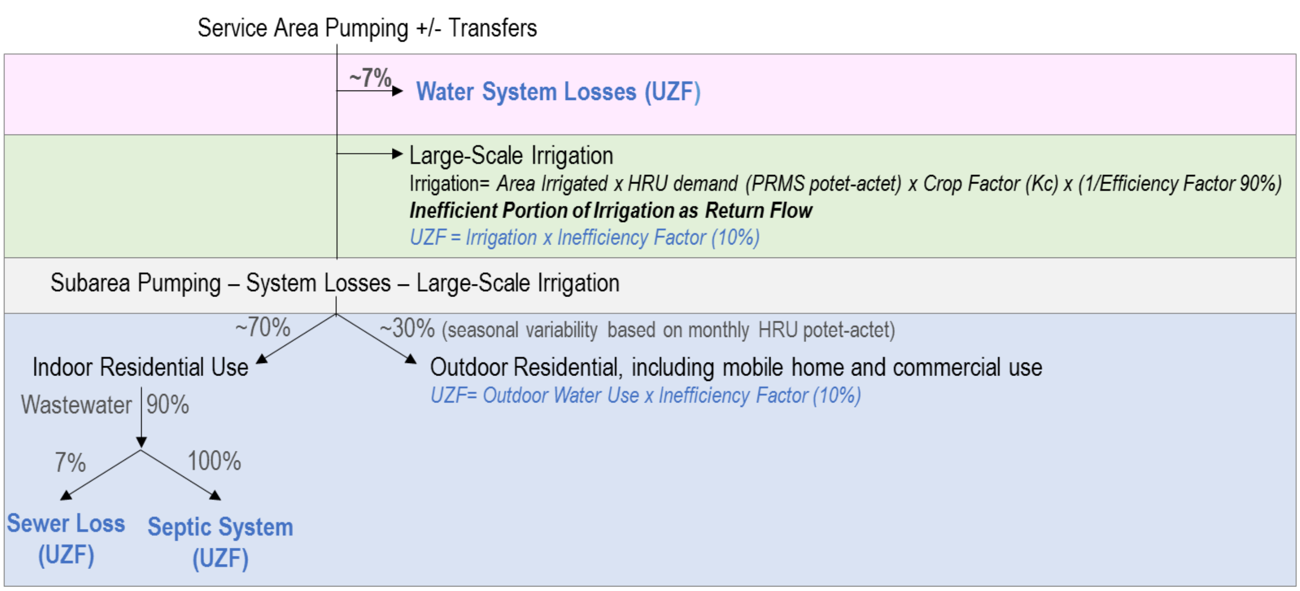


Figure 4: Approach to Estimating Municipal Return Flow

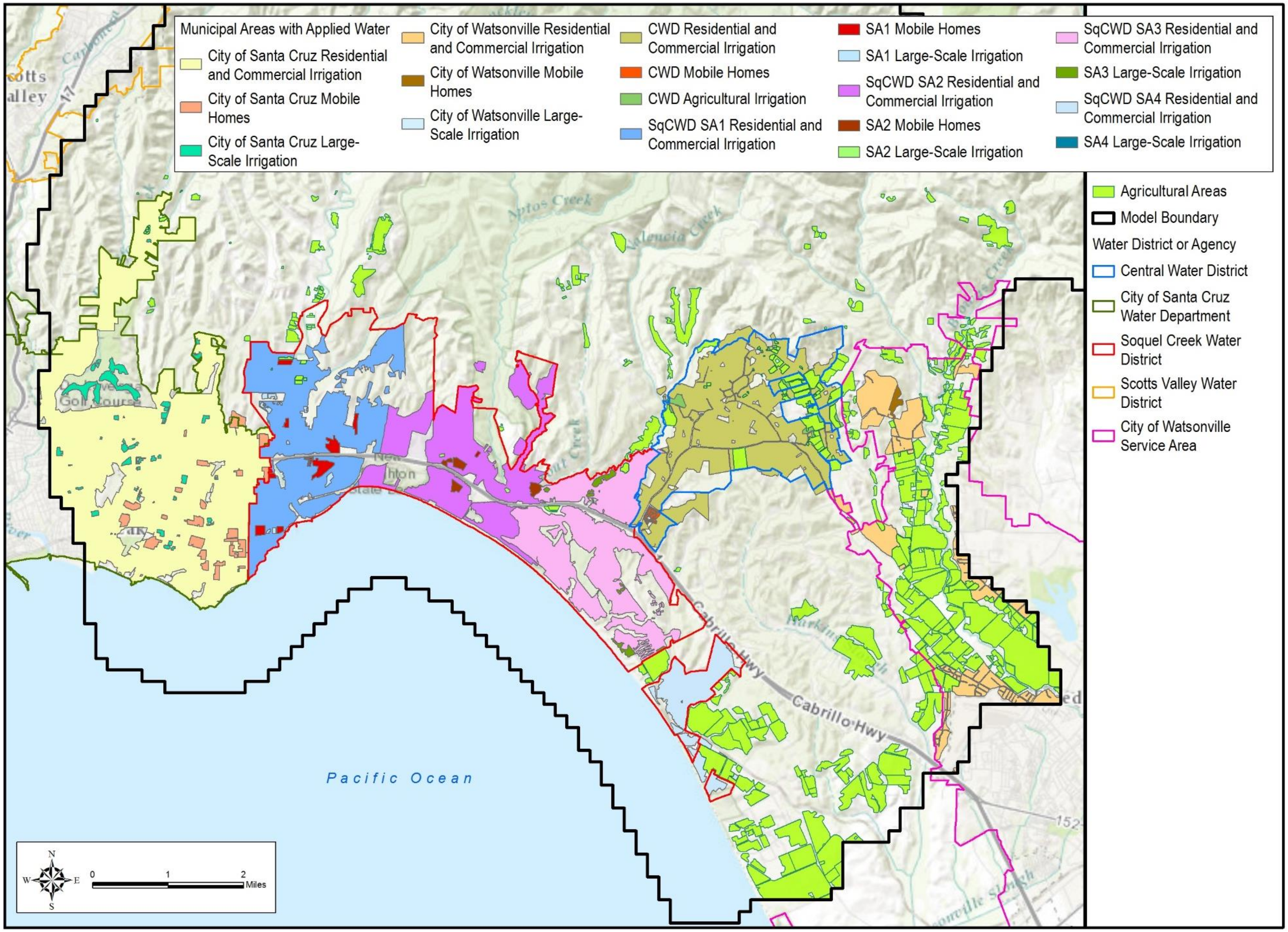


Figure 5: Municipal Applied Water Areas

Return flow represented by the inefficient portion of large-scale irrigation of sports fields and parks will also be applied to model cells that overlie those irrigated areas. Estimates of large-scale irrigation will rely on irrigation demand as estimated by the difference between capillary zone PET and actual rainfall ET simulated by PRMS, the area of the cell being irrigated, a crop factor, and irrigation inefficiency.

7.2 Non-Municipal Domestic Return Flow

The inefficient portion of non-municipal outdoor domestic use will be applied in the model using the non-municipal domestic water use described earlier in this technical memorandum. Figure 6 shows approximately 30% of total domestic water use will be assumed for outdoor use based on the average outdoor water use for 1985-2013, and a portion of this outdoor use, based on an inefficiency factor, will be applied to cells overlying the areas identified in this memo as having non-municipal domestic water use. The percentage of outdoor water use is assumed to decrease for 2014-2015 to achieve recent conservation as described in Section 6.2, and will vary monthly to simulate changing seasonal demands. Figure 6 also shows the wastewater return flow of indoor use from septic systems as described above.

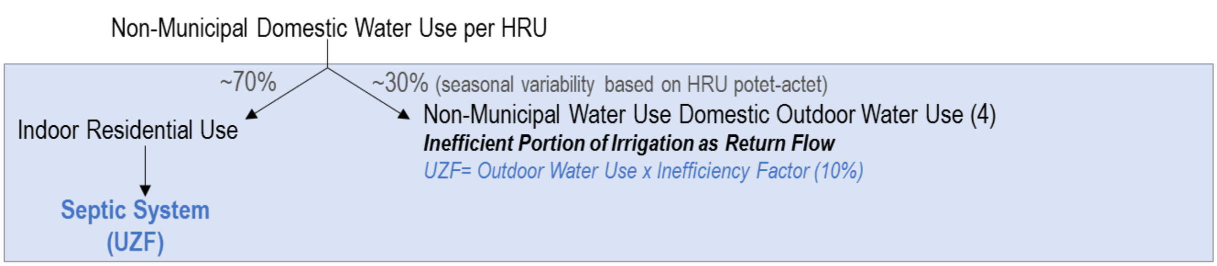


Figure 6: Approach for Estimating Non-Municipal Domestic Return Flow

7.3 Institutional Non-Municipal Irrigation Return Flow

Similar to municipal large-scale irrigation, the inefficient portion of municipal institutional irrigation will be applied to model cells that overlie institutional irrigated areas (Figure 2), and will represent a proportion of applied water based on an assumed inefficiency factor. The calculation of return flow for each model cell is shown in Figure 7.

7.4 Agricultural Irrigation Return Flow

The inefficient portion of agricultural irrigation to apply in the model will be based on the difference between PRMS estimated PET and actual ET (irrigation demand), the area of the cell being irrigated, a specific crop factor, and irrigation inefficiency (Figure 7).

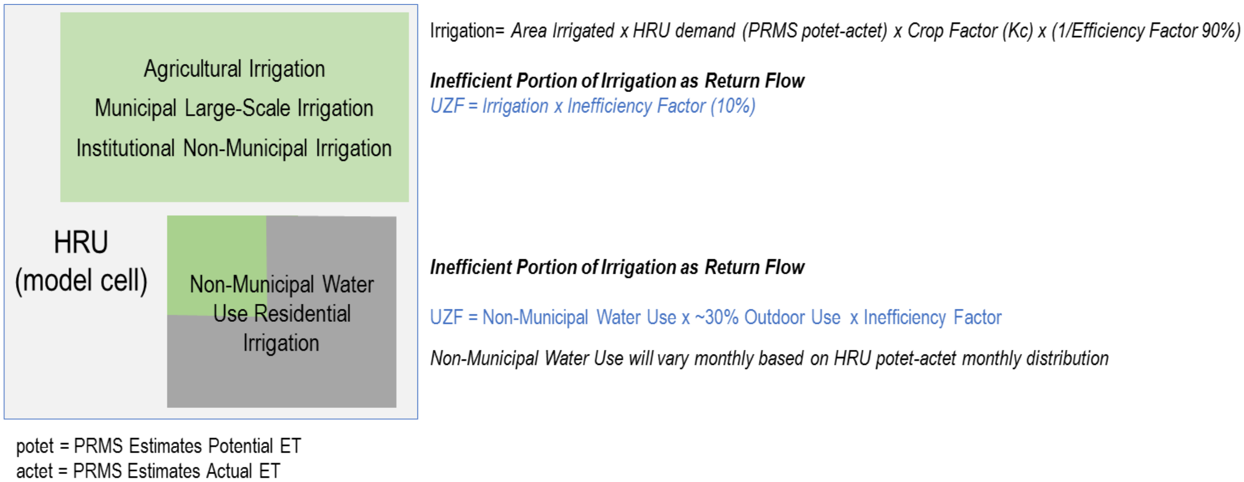


Figure 7: Return Flow Estimate Approach from Irrigation per Model Cell

8.0 SENSITIVITY OF WATER USE AND RETURN FLOW ASSUMPTIONS

This technical memorandum describes a number of assumptions for water use and return flow that will be incorporated into the Mid-County Groundwater Basin groundwater model. These assumptions can be tested with sensitivity runs using the model that test the effect of changing the assumptions on model predictions. However, when making any changes, the model calibration to groundwater level data and streamflow must be checked and the model potentially will need to be re-calibrated based on the changes. Only a calibrated model should be used to assess changes to model predictions.

9.0 References

Bracamonte, R. 2016. Email RE: private water use estimates for model. April 19.

California Department of Water Resources. 1983. Urban water use in California. Bulletin 166-3.

City of Santa Cruz, 2016. 2015 Urban Water Management Plan. August.

City of Watsonville, 2016. 2015 Urban Water Management Plan. June.

Hanson, R. T., Wolfgang Schmid, Claudia C. Faunt, Jonathan Lear, and Brian Lockwood. 2014. Integrated Hydrologic Model of the Pajaro Valley, Santa Cruz and Monterey Counties, California. USGS Scientific Investigations Report 2014-5111.

HydroMetrics WRI and Kennedy/Jenks. 2014. Aromas and Purisima Basin Management Technical Study, Santa Cruz Integrated Regional Water Management Planning Grant Task 4. Prepared for Central Water District. March.

Johnson et al. 2004. Groundwater Assessment of Alternative Conjunctive Use Scenarios Technical Memorandum 2: Hydrogeologic Conceptual Model. Prepared for Soquel Creek Water District. September.

Kennedy, J. 2015. SCWD Private Wells Survey List, version 10.

Mead, C. 2014. Staff Memo for Board of Directions Item 3.17 Annual Water Audit. March 18.

Pingree, R.H. 1998. Groundwater Consumption Analysis of Private Wells within the Aquifers of the Soquel Creek Water District. DRAFT. Soquel Creek Water District. May 28.

Pajaro Valley Water Management Agency (PVWMA). 2010. Proposition 218 Service Charge Study.

Ricker, J. 2016. Email RE: septic system regulations. January 11.

Ricker, J. 2016. Personal communication re: rural outdoor water use. October 11.

Stannard, D.I., W.T. Paul, R. Laws, and E.P. Poeter. 2010. Consumptive use and resulting leach-field water budget of a mountain residence. Journal of Hydrology 388. July.

Todd Groundwater. 2014. Peer Review of Technical Water Resources Studies. Technical Memorandum to Kim Adamson and Taj Dufour, Soquel Creek Water District. July 8.

USEPA 2008. Indoor Water Use in the United States. EPA Water Sense EPA-832-F-06-004, June.

Wolcott, J. 1999. Methodology of calculating water use in the Purisima Aquifer. Santa Cruz County Environmental Health Services. October 29.

Appendix A

List of Santa Cruz County land use codes used to identify non-municipal water use residential parcels. Those in bold are codes that did not contain residential building footprints.

010-LOT/RESIDENTIAL ZONE
015-LOT/MISC RES IMPS
016-BUILDING IN PROGRESS
020-SINGLE RESIDENCE
021-CONDOMINIUM UNIT
023-NON-CONFORMING RES
024-SFR W/ SECONDARY USE
025-AFFORDABLE HOUSING
027-TOWNHOUSE
028-SFR + SECOND UNIT
029-SFR + GRANNY UNIT
030-SINGLE DUPLEX
031-TWO SFRS/1 APN
032-3 OR 4 UNITS/2+ BLDGS
033-TRIPLEX
034-FOUR-PLEX
040-VACANT APARTMENT LOT
041-5 - 10 UNITS
042-11 - 20 UNITS
043-21 - 40 UNITS
044-41 - 60 UNITS
045-60 - 100 UNITS
046-OVER 100 UNITS
050-LOT/RURAL ZONE
051-1-4.9 ACRE/RURAL
052-5-19.9 ACRE/RURAL
053-20- 49.9 ACRE/RURAL
054-50- 99.9 ACRE/RURAL
055-100-199.9 ACRE/RURAL
05B-MISC IMPS 1-4.9 ACRE
05C-MISC IMPS 5-19.9 ACRE
05D-MISC IMPS 20-49.9 ACRE
05F-MISC IMPS 100-199.9 ACR

060-HOMESITE/< 1 ACRE
061-HOMESITE/1-4.9 ACRES
062-HOMESITE/5-19.9 ACRE
063-HOMESITE/20-49.9 ACRES
064-HOMESITE/50-99.9 ACRES
065-HOMESITE/100-199.99 ACRE
068-RURAL DWELLINGS/1 APN
070-MOTEL/UNDER 20 UNITS
071-MOTEL/20 TO 49 UNITS
072-MOTEL/50 + UNITS
074-RESORT MOTEL
080-HOTEL
085-BED AND BREAKFAST
262-NURSERY W/ RES
411-ORCHARD/RESIDENCE
421-VINEYARD/RESIDENCE
431-BERRY FARM/RESIDENCE
432-BERRY FARM/MISC IMPS
451-VEGIE FARM/RESIDENCE
480-POULTRY RANCH
490-DIVERSIFIED FARM
500-TPZ/NO RESIDENCE
501-TPZ/RESIDENCE
511-CLCA/RESIDENCE
520-OSE/NO RESIDENCE
521-OSE/RESIDENCE
711-OTHER CHURCH PROPERTY

APPENDIX 2-C

MUNICIPAL RETURN FLOW MEMORANDUM

TECHNICAL MEMORANDUM

DATE: August 28, 2019

TO: Santa Cruz Mid-County Groundwater Agency

FROM: Georgina King and Cameron Tana

PROJECT: Santa Cruz Mid-County Basin Groundwater Model

SUBJECT: Municipal Return Flow

SERVICE AREA WATER SUPPLY

Water supplied or delivered to the various municipal service areas in the model is the source of water from which different components of return flow are estimated.

Individual municipal return flow components estimated are:

1. Water system losses,
2. Large-scale landscape/field irrigation,
3. Small-scale landscape irrigation (residential and commercial), and
4. Sewer system losses, and septic tank leakage.

The amount of water supplied to each service area is obtained from readily available data provided by the four municipal water agencies in the model area: City of Santa Cruz, Soquel Creek Water District (SqCWD), Central Water District (CWD), and City of Watsonville. If monthly data are not available, annual data are used.

Annual data are used for the Cities of Watsonville and Santa Cruz. Both these municipalities deliver water to customers from both groundwater and surface water sources. Both CWD and SqCWD are able to provide monthly water supply data from well production records as groundwater is their sole source of water.

City of Watsonville

The City of Watsonville was not able to provide readily available water delivery data for the portion of their service area within the model. Their annual water supply (AWS) is estimated as the sum of residential water use and large-scale landscape irrigation, plus 6% to account for water system losses of that water (City of Watsonville, 2016). As an estimate of residential water use, building counts, similar to the approach taken for private water use, are used to estimate annual residential water use to supply areas. The amount of large-scale landscape irrigation is estimated based on irrigated area, water demand, turf crop factor and irrigation inefficiency. The top two rows of Figure 1 show the calculations for estimating AWS for those portions of the City of Watsonville service area within the model.

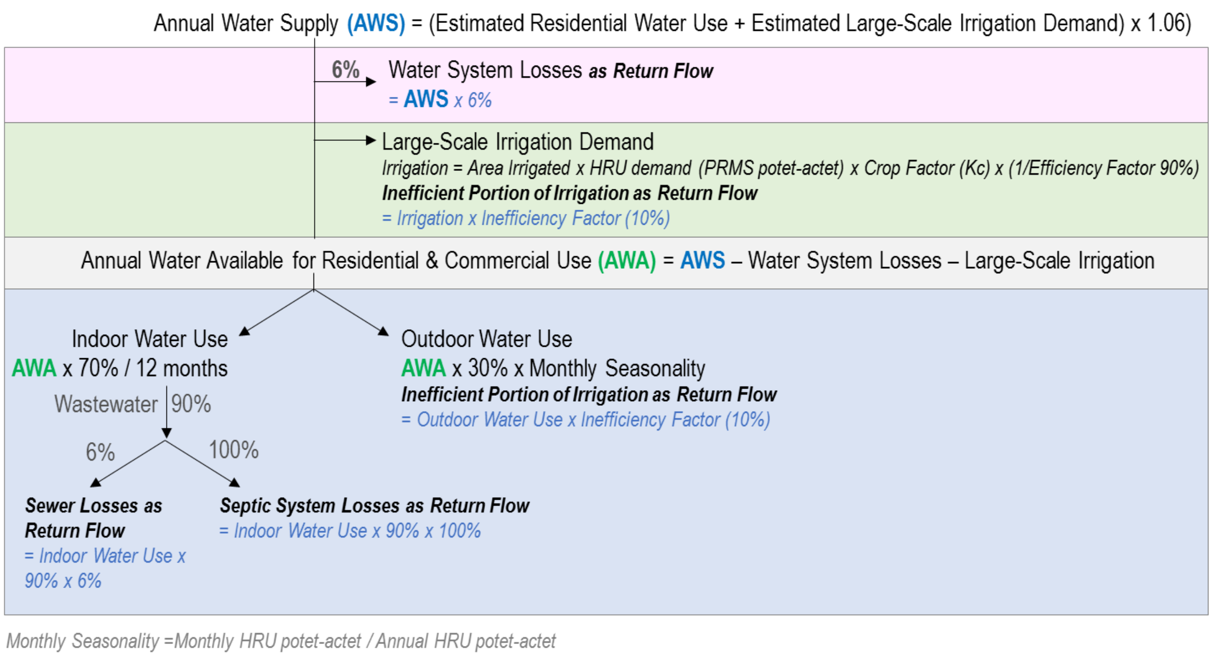


Figure 1: City of Watsonville Return Flow Calculations

City of Santa Cruz

As no delivery data are readily available that are specific to the model area, the City of Santa Cruz provided its entire service area annual consumption data from 1983 – 2015 for its different use types. The amount of water delivered to users in the model area was determined from the percentage of each use type within the model area compared to the entire service area (Table 1). The General Plan land use was used to determine relative land use percentages in the model area. As the City of Santa Cruz's consumption data are generated at meters, 7.5% assumed for water losses (WSC, 2016) was added to the consumption data to estimate AWS within their service area in the model. The top line of Figure 2 shows the calculations to estimate AWS.

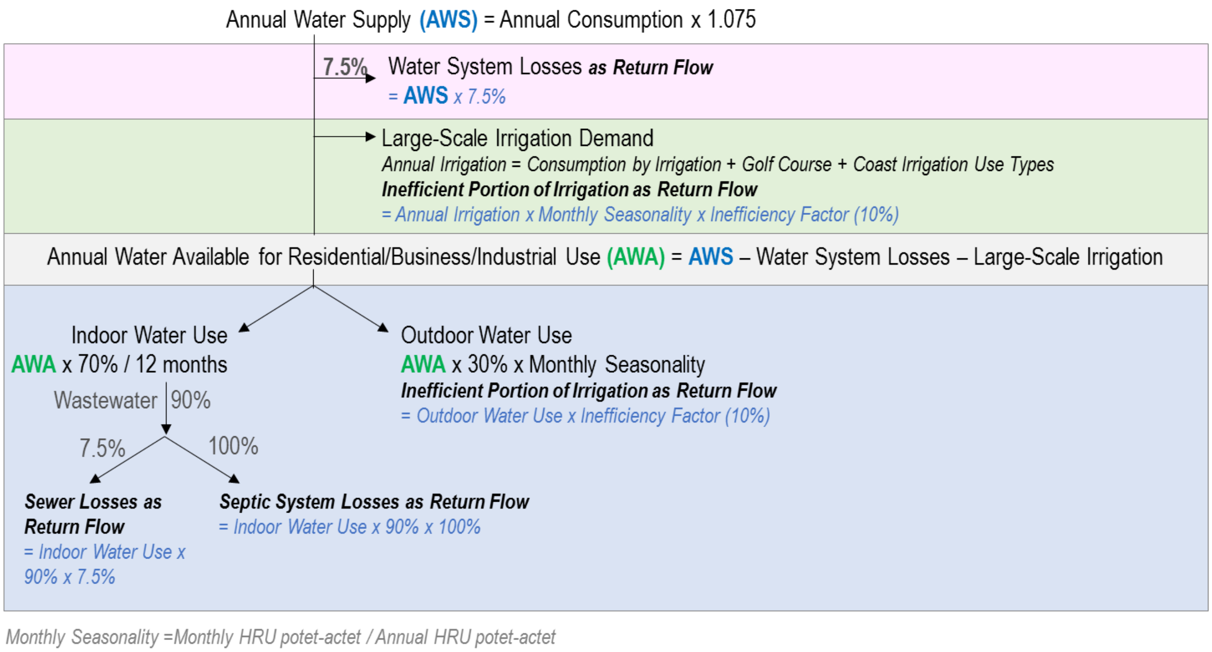


Figure 2: City of Santa Cruz Return Flow Calculations

Table 1: Percentage of All City of Santa Cruz Water Use Types within Model Area

Use Type	Percentage of Total City Land Use within Model Area
Single Family Residential	49%
Multiple Residential	50%
Business	55%
Industrial	34%
Municipal	33%
Irrigation (Large-Scale)	38%
Golf Course Irrigation	100%
Coast Irrigation	55%
Other (Construction & Hydrants)	38% (but negligible return flow assumed)

Central Water District

Groundwater pumped from CWD wells is delivered to both residential/commercial and agricultural customers. The amount of water available for residential/commercial purposes is estimated as the difference between the amount pumped and the amount supplied for agriculture, as shown on Figure 3. Water losses from 1985-1999 are 12%, from 2000-2007 are 7%, and from 2008-2016 are 4%. CWD system loss varies over time based on unaccounted water losses recorded by CWD each fiscal year.

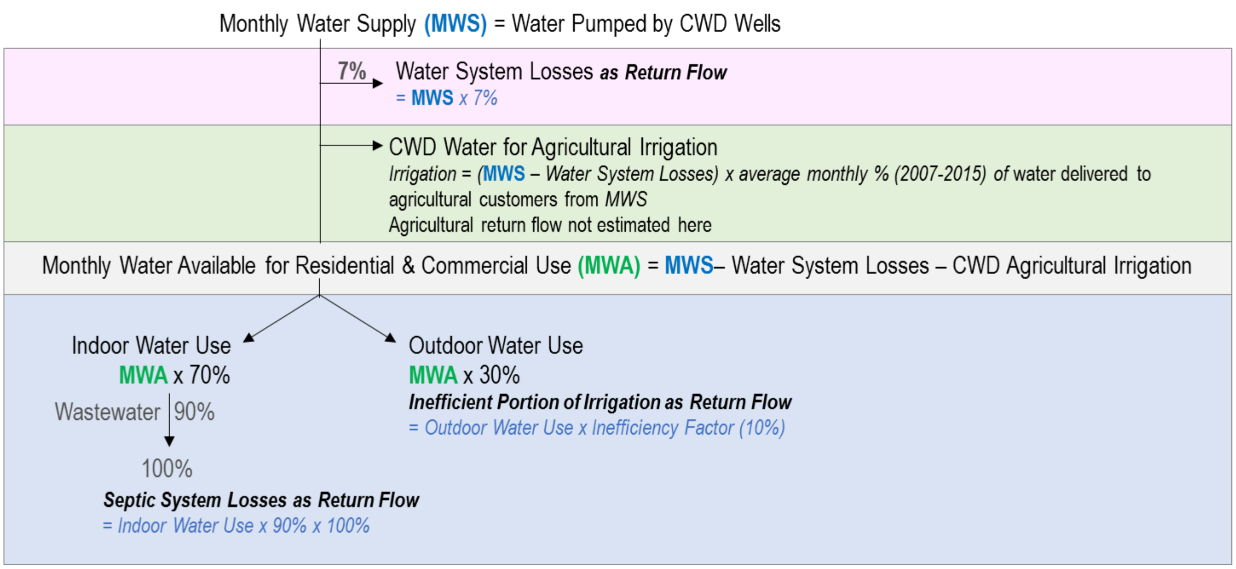


Figure 3: Central Water District Return Flow Calculations

Soquel Creek Water District

Water delivered to each of their four service areas (SA) is determined from the amount of groundwater pumped within each SA plus factoring in transfers that occur between service areas. Delivery data for each SA compared to groundwater pumped within each SA from 2014-2016 was used to estimate the average transfer from SA1 to SA2, SA3 to SA2, and SA3 to SA4. Table 2 summarizes the transfers used to estimate water delivered to each SA that is then used to estimate various components of return flow. The top line on Figure 4 shows the calculation to estimate monthly water supply to each SA. A water loss percentage of 7% is assumed from groundwater pumped (WSC, 2016).

Table 2: Summary of SqCWD Service Area Transfers between 2014 and 2016

Transfer From/To	Percent of Groundwater Produced in Originating Service Area
SA1 to SA2	8.5%
SA 3 to SA2	1.7%
SA3 to SA4	14.3%

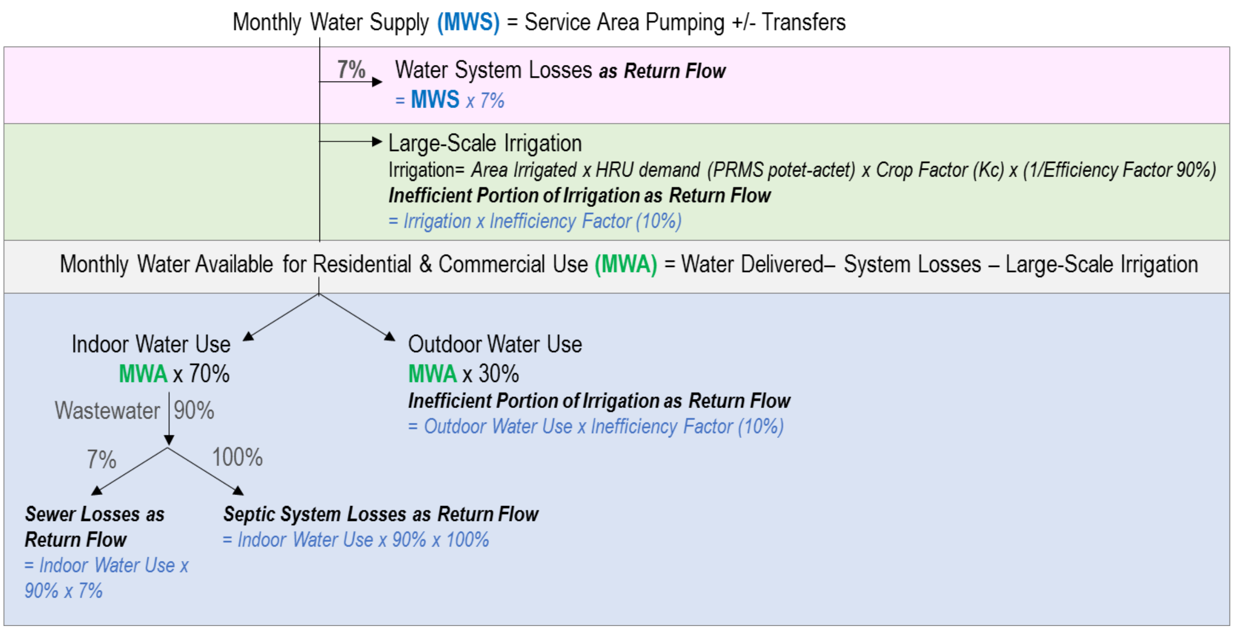


Figure 4: Soquel Creek Water District Return Flow Calculations

RETURN FLOW ESTIMATES

Different municipal water uses have their own proportion of water that percolates into the ground as return flow. Water system losses from both the water distribution and sewer systems are considered return flow. Water system losses are subtracted from water supply and thereafter, any water required to meet large-scale irrigation demand is subtracted from the supply. This leaves an amount of water that can be used for residential/commercial indoor and outdoor use. Assumed indoor and outdoor use is 70% and 30%, respectively. We assume 90% of indoor use becomes wastewater. For areas not connected to sewers, it is further assumed that 100% of wastewater percolates from septic systems into the unsaturated zone as return flow.

Inefficiencies in both residential irrigation (outdoor use) and large-scale irrigation result in an assumed return flow of 10% of the applied water. For the Cities of Santa Cruz and Watsonville, CWD, and SqCWD, Figure 1 through Figure 4, respectively, illustrate the methods for estimating each municipality’s return flow estimates. Summaries by water year of each component of return flow are provided in Table 3 through Table 6. The last column of these tables provides the percentage of the total water supply that comprises return flow.

The return flow estimates are applied to the model cells based on the ratio of the area of the model cell that receives municipal water for residential /commercial use compared to the entire service area. Figure 5 shows the location of the residential/commercial and large-landscape irrigation areas within each service area. Figure 6 shows the location of sewered and unsewered (septic tank) areas. Both figures also show model cell boundaries for the municipal water uses.

HOW WATER DELIVERED IS APPLIED TO MODEL CELLS FOR EACH MONTHLY MODEL STRESS PERIOD

For CWD and SqCWD, where monthly data are available, the deliveries to each service area are obtained from the service area pumping +/- any transfers, as described above. For the Cities of Watsonville and Santa Cruz, where annual data are only available, the amount of water applied to each model cell is distributed differently for indoor residential and irrigation use. Monthly indoor use is estimated as 70% of annual water delivered divided by 12 months. Monthly outdoor residential/commercial and large-scale irrigation use are based on irrigation demand (difference between monthly PRMS modeled potential ET (potet) and actual ET (actet)).

- For the City of Santa Cruz, where the water use type was 100% irrigation, the annual volume is distributed to months based on the ratio of monthly to annual irrigation demand for each model cell. For the outdoor portion of residential and commercial water use, the same ratio of monthly to annual irrigation demand for each model cell is used to distribute the annual volumes to monthly volumes.
- For the City of Watsonville, the amount of water to apply to each model cell for either large-scale or residential irrigation is distributed to months based on the ratio of monthly to annual irrigation demand for each model cell.

REFERENCES

City of Santa Cruz Water Department, 2016, City of Santa Cruz Water Department 2015 Urban Water Management Plan. August 2016.

City of Watsonville, 2016 City of Watsonville 2015 Urban Water Management Plan.

Water Systems Consulting, Inc., 2016, Soquel Creek Water District 2015 Urban Water Management Plan. Prepared for Soquel Creek Water District, June 2016.

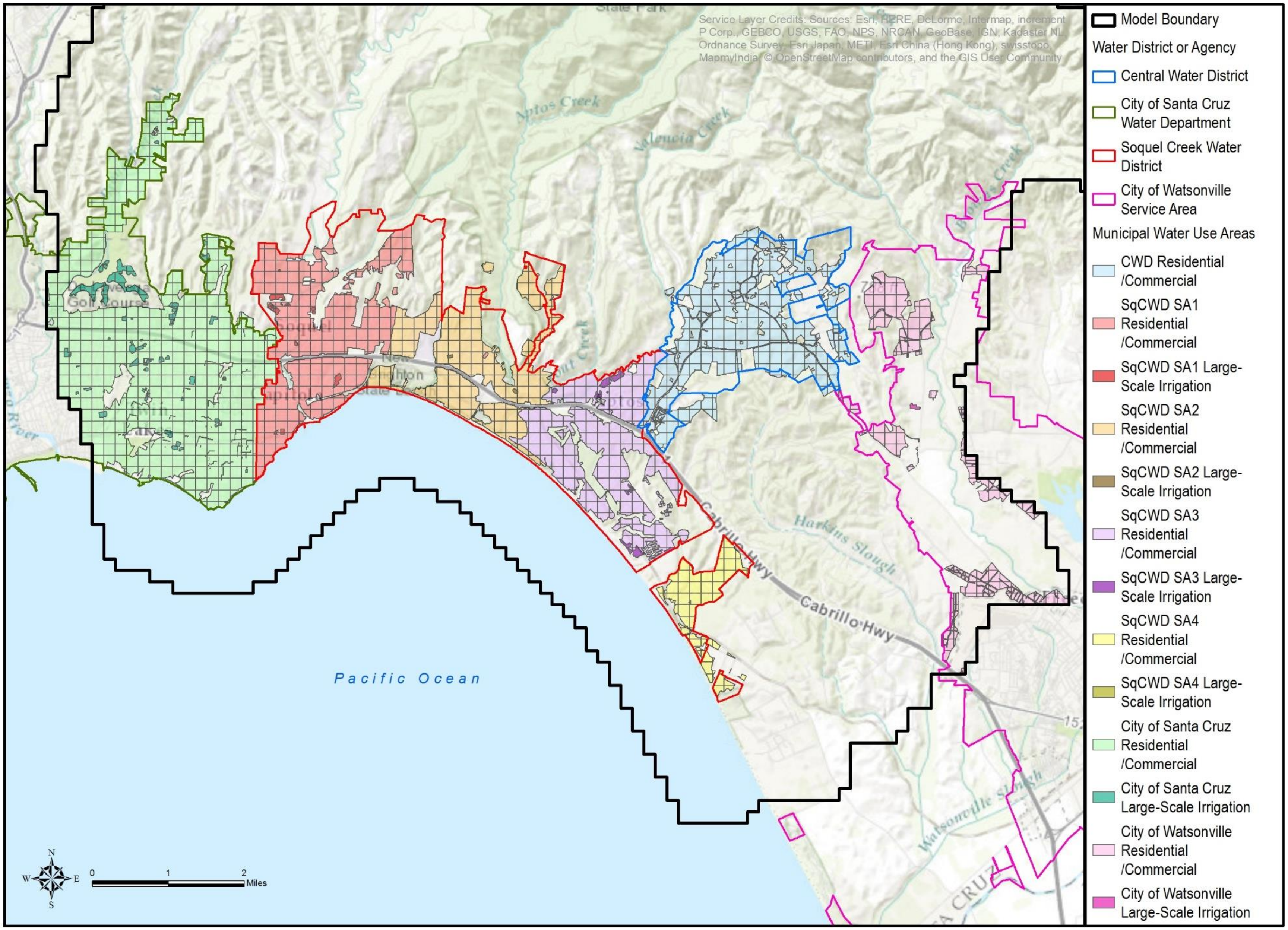


Figure 5: Residential/Commercial and Large-Scale Irrigation Areas within Municipal Service Area

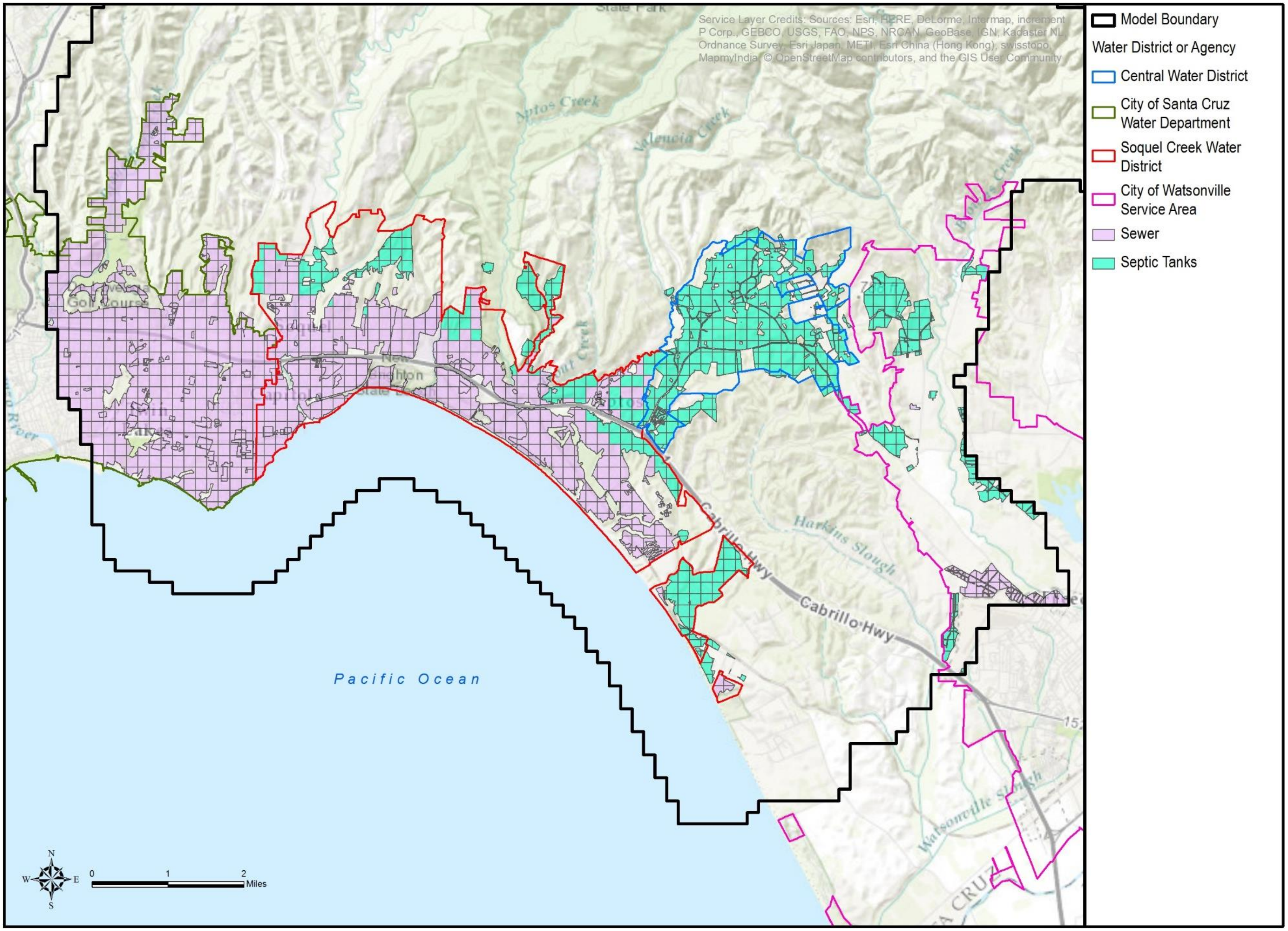


Figure 6: Municipal Sewered and Septic Tank Areas

Table 3: City of Watsonville Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet						Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Septic Systems	Total Return Flow	
1985	478.1	28.7	0.3	14.2	6.5	206.8	227.9	47.7%
1986	497.3	29.8	0.3	14.8	6.7	215.2	237.1	47.7%
1987	511.9	30.7	0.3	15.3	6.9	221.6	244.1	47.7%
1988	529.1	31.7	0.3	15.8	7.2	229.1	252.3	47.7%
1989	543.1	32.6	0.3	16.2	7.4	235.2	259.0	47.7%
1990	561.0	33.7	0.3	16.7	7.6	243.0	267.6	47.7%
1991	577.5	34.6	0.3	17.2	7.8	250.2	275.5	47.7%
1992	596.8	35.8	0.3	17.8	8.1	258.6	284.8	47.7%
1993	614.0	36.8	0.3	18.3	8.3	266.1	293.0	47.7%
1994	633.2	38.0	0.3	18.9	8.6	274.4	302.2	47.7%
1995	650.5	39.0	0.3	19.4	8.8	282.0	310.5	47.7%
1996	708.8	42.5	0.3	21.2	9.6	307.4	338.5	47.7%
1997	724.8	43.5	0.3	21.7	9.8	314.3	346.1	47.7%
1998	742.7	44.6	0.3	22.2	10.1	322.1	354.7	47.8%
1999	766.0	46.0	0.3	22.9	10.4	332.2	365.8	47.8%
2000	816.4	49.0	0.3	24.4	11.1	354.2	390.0	47.8%
2001	823.0	49.4	0.3	24.6	11.2	357.1	393.1	47.8%
2002	819.0	49.1	0.3	24.5	11.1	355.3	391.2	47.8%
2003	828.3	49.7	0.3	24.8	11.2	359.4	395.7	47.8%
2004	850.9	51.1	0.3	25.4	11.5	369.2	406.5	47.8%
2005	843.1	50.6	0.3	25.2	11.4	365.8	402.7	47.8%
2006	860.6	51.6	0.3	25.7	11.7	373.5	411.2	47.8%
2007	868.5	52.1	0.3	26.0	11.8	376.9	414.9	47.8%
2008	872.4	52.3	0.3	26.1	11.8	378.6	416.8	47.8%
2009	850.2	51.0	0.3	25.4	11.5	368.9	406.2	47.8%
2010	852.1	51.1	0.3	25.5	11.6	369.7	407.1	47.8%
2011	858.4	51.5	0.3	25.7	11.6	372.5	410.1	47.8%
2012	861.6	51.7	0.3	25.8	11.7	373.9	411.6	47.8%
2013	866.0	52.0	0.3	25.9	11.8	375.8	413.7	47.8%
2014	798.0	47.9	0.3	23.9	10.8	346.2	381.2	47.8%
2015	744.0	44.6	0.3	22.2	10.1	322.7	355.3	47.8%
Average	727.3	43.6	0.3	21.7	9.9	315.4	347.3	47.7%

Table 4: City of Santa Cruz Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet					Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Total Return Flow	
1985	6,593.7	461.6	72.1	162.3	238.6	934.6	14.2%
1986	6,663.3	466.4	68.7	165.3	243.0	943.4	14.2%
1987	6,941.7	485.9	84.4	168.3	247.4	986.1	14.2%
1988	6,258.3	438.1	77.5	151.3	222.5	889.4	14.2%
1989	5,749.4	402.5	61.8	141.9	208.6	814.7	14.2%
1990	5,209.9	364.7	55.0	126.8	186.4	732.9	14.1%
1991	4,891.0	342.4	53.1	120.3	176.8	692.6	14.2%
1992	5,419.7	379.4	57.6	133.7	196.5	767.2	14.2%
1993	5,455.4	381.9	47.1	137.9	202.8	769.7	14.1%
1994	5,648.9	395.4	47.4	143.2	210.5	796.4	14.1%
1995	5,777.5	404.4	47.1	147.0	216.1	814.6	14.1%
1996	6,143.6	430.1	51.7	155.8	229.0	866.6	14.1%
1997	6,633.3	464.3	64.7	165.5	243.2	937.7	14.1%
1998	5,887.4	412.1	43.9	151.0	221.9	828.9	14.1%
1999	6,192.2	433.5	52.4	156.9	230.7	873.4	14.1%
2000	6,183.4	432.8	51.5	157.0	230.7	872.0	14.1%
2001	6,255.6	437.9	63.6	155.4	228.4	885.2	14.2%
2002	6,072.7	425.1	62.4	150.5	221.3	859.4	14.2%
2003	6,072.7	425.1	69.6	148.4	218.2	861.4	14.2%
2004	6,191.6	433.4	75.0	150.1	220.6	879.2	14.2%
2005	5,780.4	404.6	58.0	143.7	211.3	817.6	14.1%
2006	5,579.3	390.6	62.6	136.8	201.0	790.9	14.2%
2007	5,477.2	383.4	54.7	136.3	200.4	774.8	14.1%
2008	5,537.2	387.6	60.7	136.1	200.1	784.6	14.2%
2009	4,840.5	338.8	44.0	121.7	178.9	683.5	14.1%
2010	4,764.2	333.5	41.4	120.4	177.0	672.4	14.1%
2011	4,569.3	319.8	36.8	116.4	171.1	644.2	14.1%
2012	4,870.7	341.0	47.2	121.7	178.8	688.7	14.1%
2013	5,078.7	355.5	54.5	125.3	184.1	719.4	14.2%
2014	4,083.1	285.8	35.7	103.1	151.6	576.3	14.1%
2015	3,837.2	268.6	42.4	94.3	138.6	543.9	14.2%
Average	5,634.2	394.4	56.3	140.1	206.0	796.8	14.1%

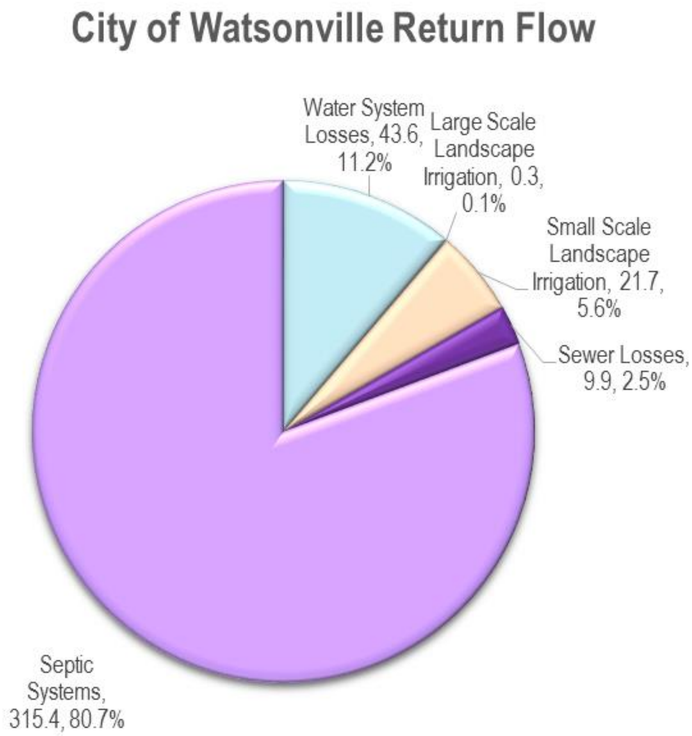
Table 5: Soquel Creek Water District Return Flow Estimates

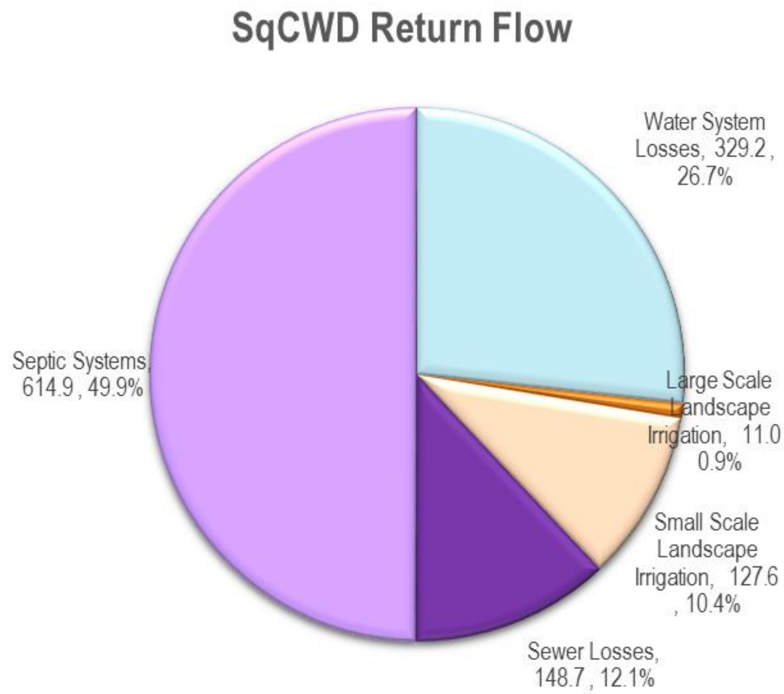
Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet						Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Septic Systems	Total Return Flow	
1985	4,318.5	302.3	13.2	116.5	135.8	559.0	1,126.8	26.1%
1986	4,272.5	299.1	10.3	116.1	137.1	529.0	1,091.6	25.5%
1987	5,234.6	366.4	13.8	141.9	163.7	708.1	1,393.9	26.6%
1988	4,858.7	340.1	14.8	131.1	151.0	658.1	1,295.2	26.7%
1989	4,797.2	335.8	12.7	130.0	149.0	664.8	1,292.3	26.9%
1990	4,818.5	337.3	13.3	130.5	150.6	649.1	1,280.7	26.6%
1991	4,703.0	329.2	10.4	128.1	148.1	634.4	1,250.3	26.6%
1992	4,908.3	343.6	13.9	132.8	152.6	672.0	1,314.9	26.8%
1993	4,863.2	340.4	11.6	132.2	152.2	665.2	1,301.7	26.8%
1994	5,089.3	356.2	10.4	138.9	159.4	706.7	1,371.6	27.0%
1995	4,854.9	339.8	9.9	132.5	153.5	650.6	1,286.3	26.5%
1996	5,183.2	362.8	12.7	140.8	163.4	688.0	1,367.7	26.4%
1997	5,570.8	390.0	14.7	151.0	174.1	755.0	1,484.8	26.7%
1998	4,966.1	347.6	7.8	136.2	157.8	670.0	1,319.4	26.6%
1999	5,211.5	364.8	8.2	142.9	165.0	712.3	1,393.2	26.7%
2000	5,270.8	369.0	9.9	144.1	166.6	712.7	1,402.2	26.6%
2001	5,174.7	362.2	9.7	141.5	164.3	688.2	1,365.9	26.4%
2002	5,375.8	376.3	9.6	147.1	172.6	689.3	1,394.9	25.9%
2003	5,331.8	373.2	11.1	145.4	171.4	667.7	1,368.9	25.7%
2004	5,372.0	376.0	13.0	146.0	172.8	659.2	1,367.0	25.4%
2005	4,543.8	318.1	7.3	124.6	147.2	566.2	1,163.4	25.6%
2006	4,548.6	318.4	10.2	123.9	144.5	591.7	1,188.7	26.1%
2007	4,625.8	323.8	12.0	125.5	144.9	623.6	1,229.7	26.6%
2008	4,557.0	319.0	12.6	123.4	141.7	625.9	1,222.6	26.8%
2009	4,162.1	291.3	12.5	112.4	131.6	529.8	1,077.6	25.9%
2010	3,932.5	275.3	10.3	106.6	127.5	461.6	981.3	25.0%
2011	4,011.2	280.8	8.7	109.3	131.0	467.1	997.0	24.9%
2012	4,159.1	291.1	12.7	112.2	134.0	487.8	1,037.9	25.0%
2013	4,217.5	295.2	19.2	111.9	132.2	509.1	1,067.6	25.3%
2014	3,702.9	259.2	20.0	97.3	115.6	432.6	924.7	25.0%
2015	3,153.9	220.8	22.4	81.3	96.9	355.8	777.2	24.6%
Average	4,702.9	329.2	12.2	127.5	148.6	612.6	1,230.2	26.1%

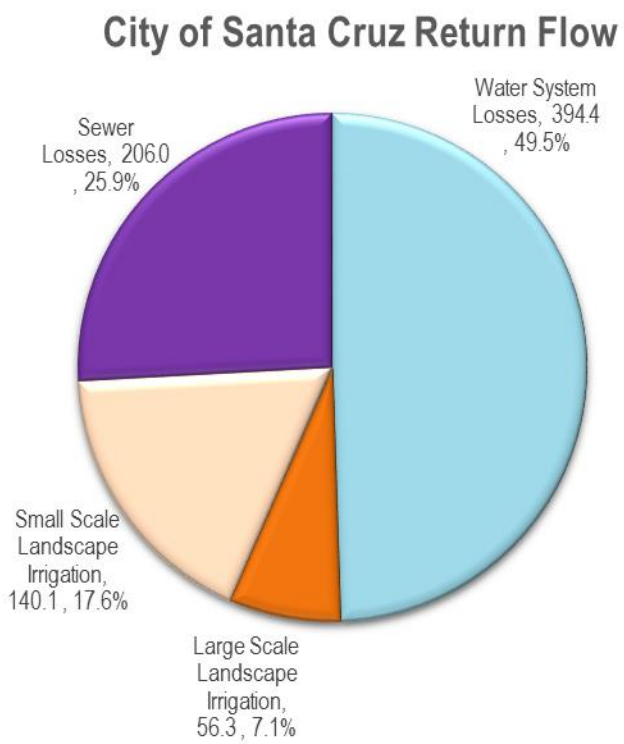
Table 6: Central Water District Return Flow Estimates

Water Year	Water Supply to Service Area in Model*, acre-feet	Return Flow in acre-feet				Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Small-Scale Landscape Irrigation	Septic Systems	Total Return Flow	
1985	352.9	27.5	9.8	205.0	242.3	68.7%
1986	363.0	28.3	10.0	210.9	249.2	68.7%
1987	399.4	31.1	11.1	232.1	274.2	68.6%
1988	393.2	30.6	10.9	228.4	270.0	68.6%
1989	363.2	28.4	10.0	210.9	249.4	68.7%
1990	387.1	30.1	10.7	224.9	265.7	68.6%
1991	383.9	29.8	10.6	223.1	263.5	68.6%
1992	417.5	32.7	11.5	242.5	286.7	68.7%
1993	429.6	33.7	11.9	249.4	295.0	68.7%
1994	431.2	33.7	11.9	250.4	296.1	68.7%
1995	409.5	32.2	11.3	237.7	281.2	68.7%
1996	469.4	36.8	13.0	272.5	322.3	68.7%
1997	539.5	42.3	14.9	313.2	370.4	68.7%
1998	476.0	37.4	13.2	276.3	326.9	68.7%
1999	479.9	37.7	13.3	278.6	329.6	68.7%
2000	489.2	38.3	13.5	284.1	335.9	68.7%
2001	496.7	39.0	13.7	288.4	341.1	68.7%
2002	529.1	41.5	14.6	307.2	363.3	68.7%
2003	519.3	40.8	14.4	301.5	356.7	68.7%
2004	565.6	44.3	15.6	328.4	388.4	68.7%
2005	456.9	36.0	12.6	265.2	313.8	68.7%
2006	483.1	38.1	13.3	280.3	331.8	68.7%
2007	532.3	41.7	14.7	309.1	365.5	68.7%
2008	520.0	40.9	14.4	301.9	357.1	68.7%
2009	530.4	41.6	14.7	307.9	364.2	68.7%
2010	428.8	33.6	11.9	248.9	294.4	68.7%
2011	434.4	34.1	12.0	252.2	298.3	68.7%
2012	479.3	37.5	13.3	278.4	329.1	68.7%
2013	501.2	39.1	13.9	291.1	344.1	68.7%
2014	452.3	35.0	12.5	262.9	310.4	68.6%
2015	352.7	27.4	9.8	204.9	242.1	68.6%
Average	453.8	35.5	12.5	263.5	311.6	68.7%

* This column is water supply for residential/commercial use only, and does not include water delivered for agricultural use.







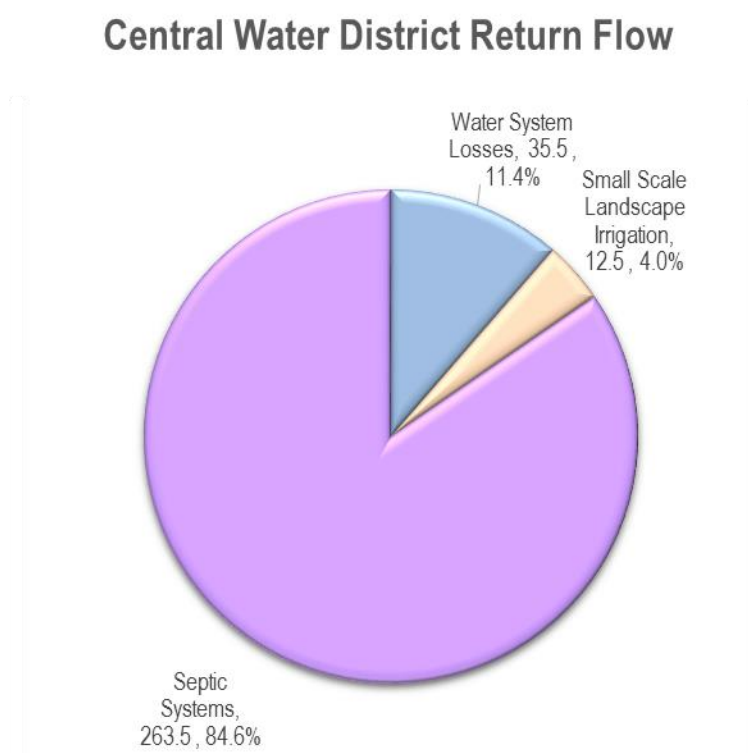


Figure 7: Municipal Return Flow Pie Charts (in acre-feet per year)

APPENDIX 2-D

SOQUEL-APTOS GROUNDWATER FLOW MODEL: SUBSURFACE MODEL (TASK 3) MEMORANDUM

HydroMetrics WRI

1814 Franklin St, Suite 501
Oakland, CA 94612

TECHNICAL MEMORANDUM

To: Ron Duncan

From: Sean Culkin P.G., C. Hg.
Mike Cloud, P.G.
Cameron Tana, P.E.

Date: November 24, 2015

Subject: Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction (Task 3)

1.0 INTRODUCTION

This technical memorandum documents the completed and ongoing activities to develop the conceptual model, hydrostratigraphy, and subsurface boundary conditions for construction of the groundwater flow model of the Soquel-Aptos groundwater basin (basin). Subsequent technical memoranda on model construction will document the development of the watershed model, land use analysis for water use and return flow, integration of the watershed model with the groundwater model using GSFLOW, and the incorporation of code to simulate seawater intrusion. After the model is constructed and calibrated, the model will be used by the Soquel-Aptos Groundwater Management Committee (SAGMC) to evaluate long-term options for raising groundwater elevations in the basin and eliminating overdraft.

The modeling effort documented in this technical memorandum identifies the model extent and boundaries, as well as translates the Purisima Formation and Aromas Red Sands conceptual model into groundwater model layers. The conceptual model for the basin has been reported in detail in the *Groundwater Assessment of Alternative Conjunctive Use Scenarios, Technical Memorandum 2: Hydrogeologic Conceptual Model* (Johnson *et al*., 2004).

The groundwater component of the groundwater flow model will be built using the U.S. Geological Survey's (USGS) MODFLOW software for groundwater modeling applications. This MODFLOW groundwater flow model will be integrated with a watershed model using the USGS's Precipitation-Runoff Modeling System (PRMS) to create a USGS GSFLOW model.

2.0 DATA COMPILATION

For developing the model stratigraphy, a set of 67 available down-hole electrical resistivity logs (e-logs) were compiled for wells/borings drilled into the Purisima Formation in central Santa Cruz County. These e-logs are from public and private wells, as well as oil and gas wells. Available surface geologic and gravity anomaly maps from USGS, and seafloor maps were also used to update the conceptual basin stratigraphy.

Data for boundary condition development are primarily in the form of monitoring well groundwater elevation data from City of Santa Cruz, Soquel Creek Water District (SqCWD), Central Water District (CWD), and Pajaro Valley Water Management Agency (PVWMA) wells within the basin model domain. Groundwater elevation data from City of Santa Cruz, SqCWD, and CWD are reported by HydroMetrics WRI annually, and updated data from selected PVWMA wells near the southeastern boundary of the model were obtained by request from that agency.

3.0 DOMAIN EXTENT AND MODEL HYDROSTRATIGRAPHY

The lateral extent of the basin model domain is similar to the domain of the previously-constructed PRMS model (HydroMetrics WRI, 2011). The domain covers watersheds that may recharge the aquifers pumped in the area managed by SAGMC. The western boundary of the model is the boundary between the Carbonara Creek and Branciforte Creek watersheds approximately parallel to California State Route 17 from the City of Santa Cruz in the south to Redwood Estates in the north. Outcrops of granite and metamorphic rocks along Carbonara Creek indicate that there is no connectivity of groundwater flow into or out of water-bearing units of the basin along this margin.

The northern watershed boundary of the model approximately follows Summit Road and Loma Prieta Avenue for a distance of about 17 miles along a northwest to southeast alignment. Unlike the previous PRMS model, the oceanic southern boundary of the model has been extended approximately one mile offshore, parallel to the coastline. This allows for adequate contact of outcropping Purisima and Aromas Formation units with the seafloor, in order to simulate saltwater-freshwater interactions such as seawater intrusion.

The eastern boundary of the model follows the eastern boundary of the Corralitos Creek watershed. The extent of the southeastern boundary of the basin model has also been revised from the previous PRMS boundary, in that it extends beyond Buena Vista Drive in Watsonville nearly one-half mile. This boundary is approximately the same as the southeastern boundary of the groundwater model previously developed for CWD covering the Aromas area (HydroMetrics WRI and Kennedy/Jenks, 2014), and it limits the extent of the Pajaro Valley basin included in the groundwater model. It is expected that PVWMA will manage the rest of the Pajaro Valley basin excluded from this model, which will be used for management by SAGMC for the area to the west. As much as is practicable, the selected boundaries are intended to coincide with known hydrologic boundaries. Figure 1 shows the active extent of the groundwater model domain.

Vertically, the groundwater model domain includes surficial alluvium and the more extensive regional hydrostratigraphic units. Earlier reports for the SqCWD had correlated several distinct stratigraphic intervals in this area (Luhdorff & Scalmanini, 1984). Johnson *et al.* (2004) more accurately defined and partitioned these intervals as aquifer or aquitard units. These hydrostratigraphic units were named the Purisima AA aquifer, A aquifer, B aquitard, BC aquifer, D aquitard, DEF aquifer, and F aquifer or, TpAA through TpF for short. The TpAA is the lowermost unit in the Purisima and the TpF is the uppermost unit (Figure 2). Underlying the sedimentary units in this area is a granitic basement complex, except in areas underlain by an undefined Tertiary unit referred to as the Tu unit by Johnson et al. (2004) or the Santa Margarita by others. South of the Zayante Fault (Figure 1), each unit outcrops at the ground surface. The TpAA outcrops primarily in the western portion of the groundwater basin and the TpF outcrops in the east. The units outcrop in this pattern because the Purisima Formation shallowly dips in a southeast direction towards the Pajaro Valley. Outcrop patterns were later projected across the basin and into Monterey Bay (SqCWD and CWD, 2007). In the southeastern portion of the model, the Purisima Formation is overlain by a unit known as the Aromas Red Sands (labeled as Qua and Qa on Figure 2), which is the shallowest water-bearing unit in this area. This unit of poorly consolidated interbedded fluvial, marine, and aeolian material

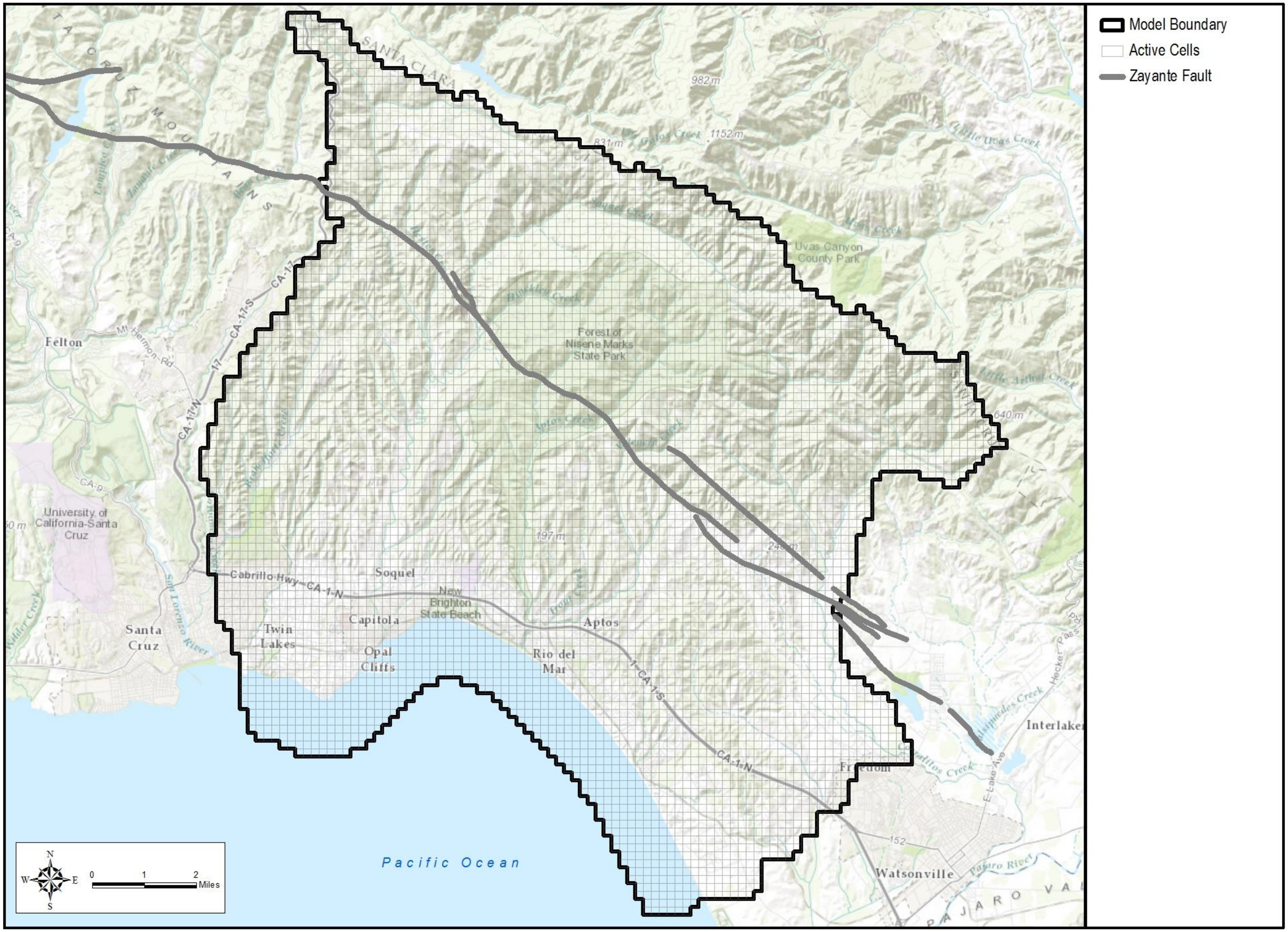
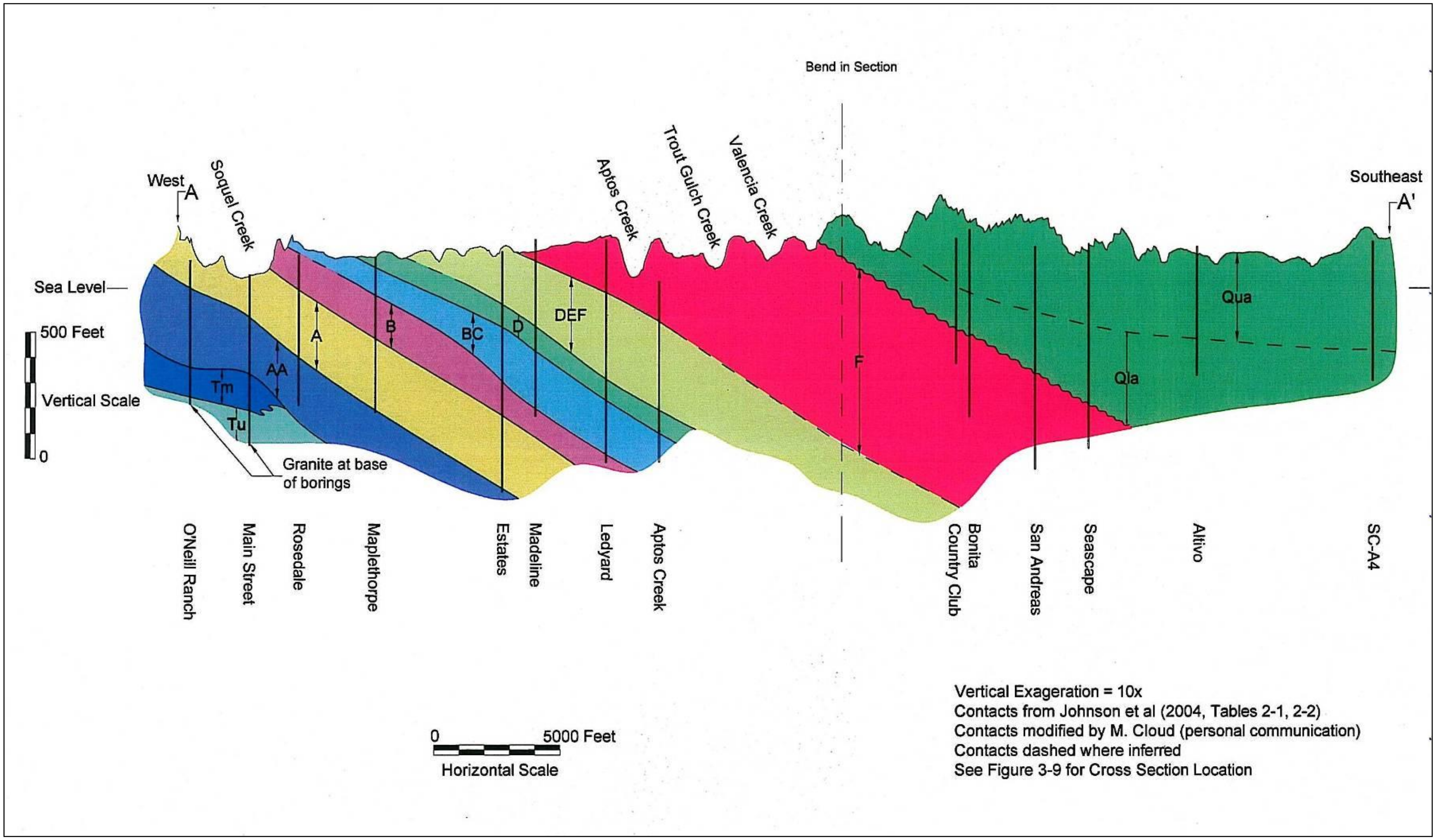


Figure 1: Basin Model Domain Extent



v

Figure 2: Generalized Hydrostratigraphic Cross-Section

overlays the Purisima Formation in the hills and coastal terraces east and southeast of Aptos. A large portion of this unit may be unsaturated, especially where the groundwater table is drawn down to near sea level (Johnson *et. al.*, 2004).

The groundwater model domain encompasses the Aromas Red Sands, the units of the Purisima Formation, and the underlying undifferentiated tertiary deposits. The granitic basement rock of the basin constitutes the base of the groundwater model. To simplify the groundwater model, Purisima Formation units were reduced from the original seven e-log hydrostratigraphic units defined by Johnson et al. (2004) down to six groundwater model layers by combining the DEF and F aquifer units. The laterally-extensive model layers are considered to be either aquifers or aquitards. Aquifer units are those zones dominated with sandstone and aquitards are the zones dominated by mudstone. Table 1 summarizes the hydrostratigraphic units applied in the groundwater model (see also Appendix A). Detailed descriptions of the Aromas Red Sands and Purisima Formation aquifer and aquitard units are available in previous documents (Johnson et. al., 2004; HydroMetrics WRI, 2011).

Table 1: Groundwater Model Hydrostratigraphic Unit Summary

Unit Name (Geologic Unit)	Model Layer	Unit Type
Stream Alluvium	1-9[1]	Stream-associated water-bearing surficial alluvium
Terrace Deposits	1-9[1]	Alluvial terrace deposits near coast
Aromas Red Sands	2	Interbedded sand, silt, and clay deposits
Purisima TpDEF, TpF	3	Aquifer
Purisima TpD	4	Aquitard
Purisima TpBC	5	Aquifer
Purisima TpB	6	Aquitard
Purisima TpA	7	Aquifer
Purisima TpAA	8	Aquifer
Tu[2]	9	Aquifer

[1]Alluvium and terrace deposits assigned to various model layers as described in sections below
[2]Tu unit includes all non-Purisima water-bearing units between base of TpAA Aquifer and top of granitic model base.

Another noteworthy feature of the model domain is the Zayante Fault, which is a northwest-southeast trending fault that runs through the groundwater model domain (Figure 1). North of this fault, the Purisima Formation consists of a number of steeply dipping and folded materials which are offset from Purisima Formation units south of the fault (Johnson et al., 2004). The Purisima Formation materials north of the fault are not well defined as hydrostratigraphic units like they are south of the fault. The material properties of the groundwater model layers north of this fault will likely reflect this lack of differentiation. The area north of the Zayante Fault was retained in the model domain due to the watershed's necessary contribution to the surface water and near-surface flow component of the GSFLOW model. This fault also likely acts as a barrier to deeper groundwater flow between the folded units of the Glenwood Syncline north of the fault and units of the Purisima and Aromas south of the fault (Johnson *et al.*, 2004).

4.0 CONCEPTUAL MODEL METHODOLOGY

In general, the conceptual model as it pertains to the basin groundwater model will follow the conceptual model outlined in the Johnson et. al. report (2004); recent work building upon this model is described in the sections below. As documented in previous studies (Luhdorff & Scalmanini, 1984), the Purisima Formation dips shallowly to the southeast. In the eastern region of the basin, the bedding has a consistent dip of 3 to 4 degrees to the east. West of Soquel Creek, the dip shallows to 2 to 3 degrees to the east. The dip of the Purisima beds appears to mimic the underlying granitic basement structure, suggesting that the Purisima Formation may have been deposited horizontally on the granitic basement, then tilted by the uplift of the basement rock.

HydroMetrics WRI recently updated the Central Water District's (CWD) groundwater model (HydroMetrics WRI and Kennedy/Jenks, 2014). This model covers most of the Aromas area and has layers representing the Aromas Red Sands, TpF unit, and TpDEF unit. Where applicable, the conceptual model of the CWD model will be merged into the larger basin model. For example, the hydrostratigraphic contact between the Aromas Red Sands and Purisima Formation is extracted from the CWD model for use in the larger basin model.

4.1 STRATIGRAPHIC ANALYSIS

HydroMetrics WRI made various assumptions and simplifications during the evaluation of the Purisima Formation stratigraphy and structure for the basin groundwater model. A summary of some of the primary assumptions are as follows:

1) Individual Purisima units tend to maintain relatively constant thicknesses across the groundwater basin.
2) The angle and dip direction of the Purisima Formation units generally reflects the underlying basement structure.
3) The regional gravity anomaly distribution (USGS, 2004) reflects the basement structure.
4) Faults were not used to explain structure unless there was compelling evidence or need for them. No faults other than the Zayante fault are known to significantly offset the hydrostratigraphy such that groundwater flow across the fault zone is impeded. Therefore, we assumed that any other faults are not barriers to groundwater flow.
5) A cemented zone within the lower TpB Aquitard unit is visible in resistivity logs as a spike in resistivity across a large area of the model domain, and is also identifiable in local surface outcrops. As such, the base of the TpB Aquitard is used as a reference elevation surface to aid in defining the hydrostratigraphy of overlying and underlying units within the Purisima Formation.

As in previous analyses (Luhdorff & Scalmanini, 1984), the e-log signatures from different boreholes were compared to identify specific stratigraphic intervals in the Purisima Formation. If individual sedimentary beds are laterally extensive, the same layered sequence of the sedimentary units can be identified at multiple locations. By correlating the elevation of specific intervals from borehole to borehole, the structure of the bedding layers is determined.

Most of the bedding layers can be readily correlated from borehole to borehole. Units TpB through TpF have very distinct e-log signatures, which facilitates correlation between boreholes because they consist of a mixture of sandstone and mudstone beds. The distinctive TpA/TpB contact, which is readily identifiable on every e-log that encounters it, was used as a reference point for stratigraphic analysis. The base of the Purisima Formation is clearly identified on e-logs for sufficiently deep boreholes. The structure of the granitic basement of the model domain was also identifiable in boreholes, gravity anomaly studies, and regional outcrops, which were used to develop inform the basement structure of the model. An example stratigraphic column summarizing the conceptual hydrostratigraphy developed from this investigation is show on Figure 3, and unit thicknesses are summarized in Table 2. Details of the granitic basement structure are shown in Figure 4 through Figure 6, the elevation of the base of individual units, as well as borehole locations used in part to define the base of each unit, are shown on Figure 7 through Figure 14, and the stratigraphic picks made from borehole logs are tabulated in Appendix A.

The TpA and TpAA units have an assumed combined thickness of 600 feet. These units do not have lithologically consistent internal sedimentary layers and therefore it is difficult to identify the contact surface between them in the boring logs and e-logs. As such, both the TpA and TpAA units are assigned a uniform thickness of 300 feet each over most of the model domain. Where the contact between these units is detectable in e-logs, primarily in the southwestern portion of the model domain, they are assigned variable thicknesses, with the thickness of the TpA varying between approximately 200 and 300 feet, and the thickness of the TpAA varying between approximately 300 and 400 feet; generally maintaining the total combined thickness of 600 feet.

The Tu unit is assumed to constitute all the sediments where the granitic basement is lower than the base of the Purisima Formation (i.e. lower than the TpAA). As such, it's thickness is variable between approximately 10 and 3,000 feet. This unit is generally found in the western portion of the basin and pinches out where the base of the Purisima intersects the granitic basement. East of the pinch-out margin of the Tu, the base of the Purisima Formation sits directly on top of the granitic basement. The base of the TpAA generally follows the structure of the granitic basement, but where necessary, the thickness of the TpAA was adjusted to that it met the interpolated granitic basement surface. As such, the thickness of the TpAA and the combined thickness of 600 feet for the TpA and TpAA has some local variation from 300 feet and 600 feet respectively east of the Tu to accommodate the granitic basement structure, but the TpAA generally maintains a thickness of approximately 300 feet.

One significant geologic feature observed in the stratigraphic analysis is a granitic structural high near the western boundary of the model domain, south of the Zayante Fault. West of this structural high, the elevation of the granitic basement dips steeply towards the northwest into a trough.

The location and structure of the granitic high is shown in Figure 4. This figure shows granite elevation contours developed as a part of this analysis, as well as surficial geologic data (USGS, 1997). The western boundary of the model domain is aligned with the watershed boundary shown in the figure, and the strike of the granitic high is shown as the “Granitic Divide” line. The structure of the granitic basement is supported by gravity anomaly surveys of the area (USGS, 2004), from which granite elevation contours can also be inferred (Figure 5).

The structure of the granitic basement in the western area of the model domain has also been documented by Todd Engineers (1997) and ETIC Engineering (2006) in groundwater modeling technical studies of the area. Figure 6 presents a cross-section from a previous modeling study (Kennedy/Jenks, 2015) that crosses the western edge of the model domain. In this figure, the granitic structural trough is evident in the area of the model domain boundary near Carbonera Creek, and the eastward-dipping Purisima Formation is shown to be underlain by geologic units usually associated with the Santa Margarita Basin to the west. As modeling progresses, different material properties may be assigned to the sediments west of the granite high to differentiate them from the Tu unit that dips towards the east beneath the Purisima Formation, since the Tu west of the divide may be more closely associated with westward-dipping stratigraphic units of the adjacent Santa Margarita Basin. Boundary conditions in this area will also be modified to represent groundwater flow conditions out of the Soquel-Aptos Basin.

The highest density of available e-log data is in the coastal terrace area of mid Santa Cruz County, where most urban development has occurred and depth to groundwater is the shallowest. Available e-logs in the inland, hilly areas of the Purisima Formation are sparse, which makes correlation more difficult. Appendix A shows the depth and elevation of each geologic contact in the logs the overlying Aromas Red Sands down to the granitic basement. This Appendix also includes estimated contact depths/elevations where they could be reliably estimated.

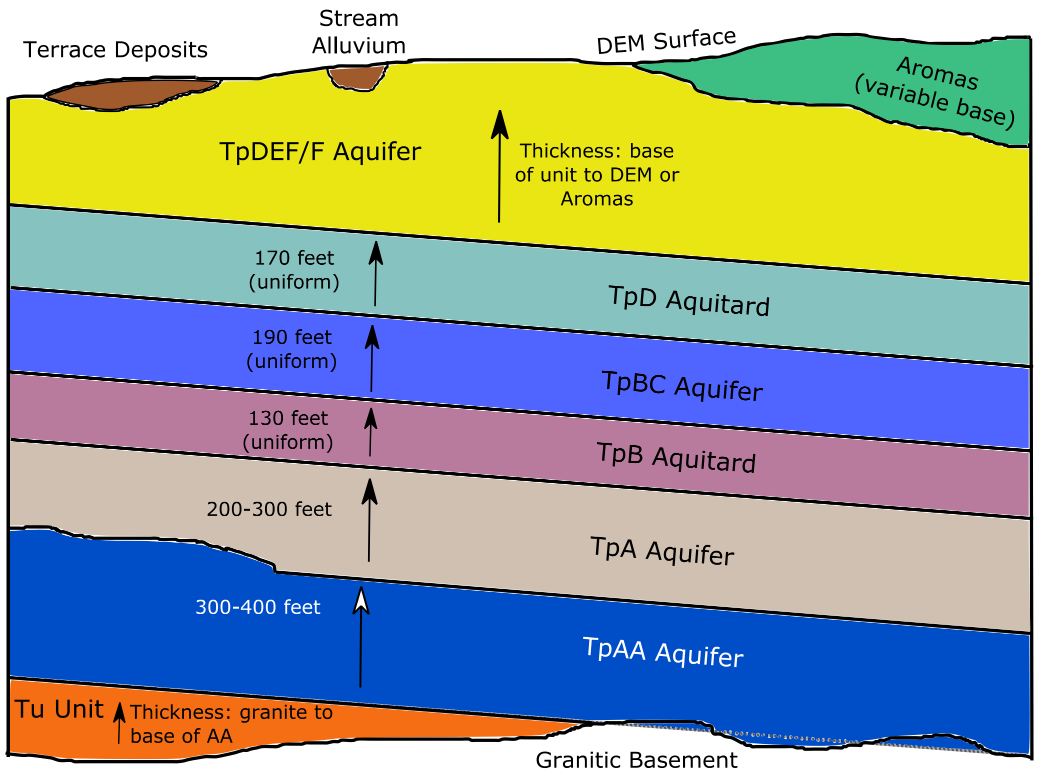


Figure 3: Example Stratigraphic Column of Model Hydrostratigraphy

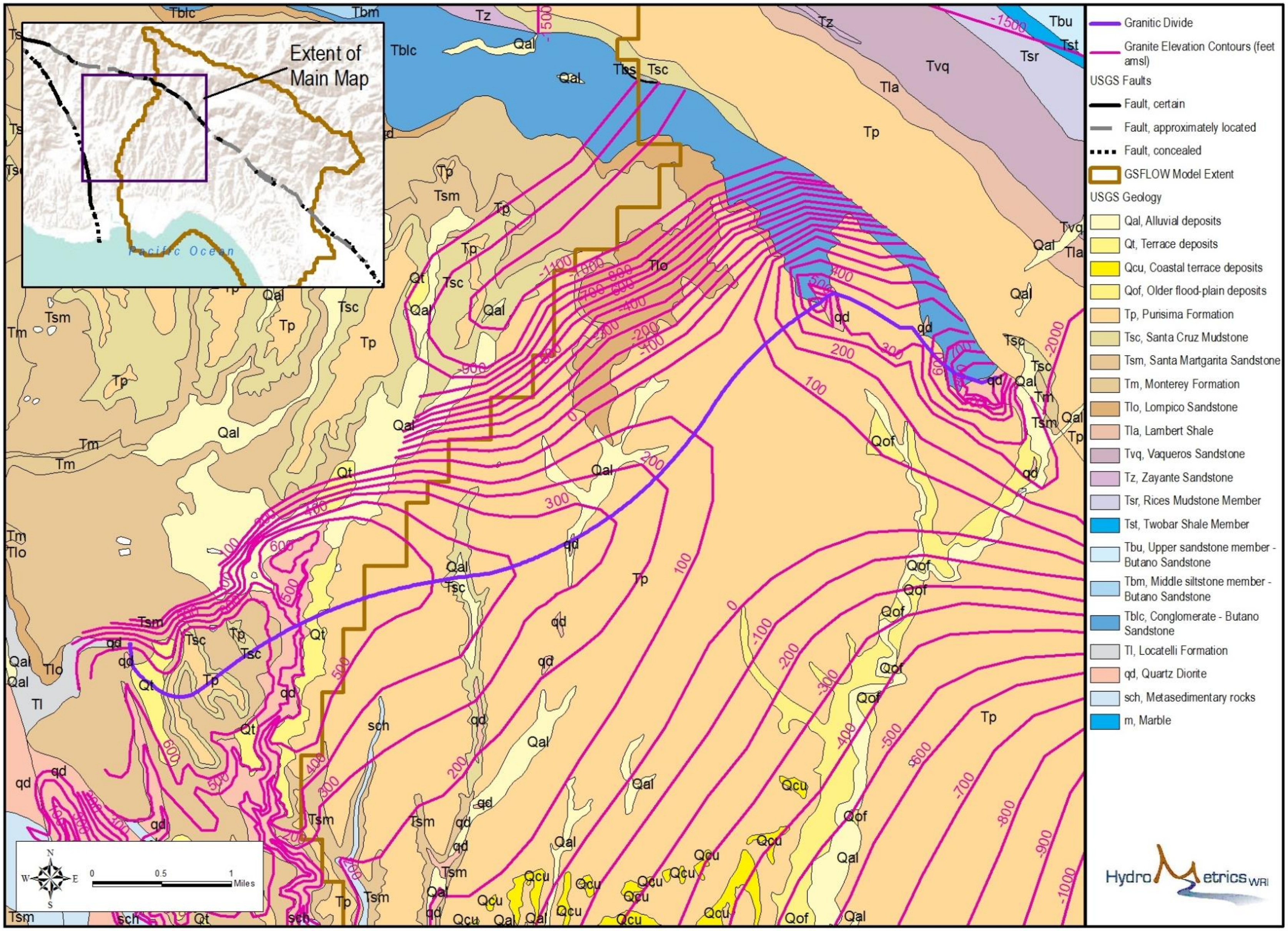


Figure 4: Structure of Granitic Basement Elevation, Western Area of Model Domain

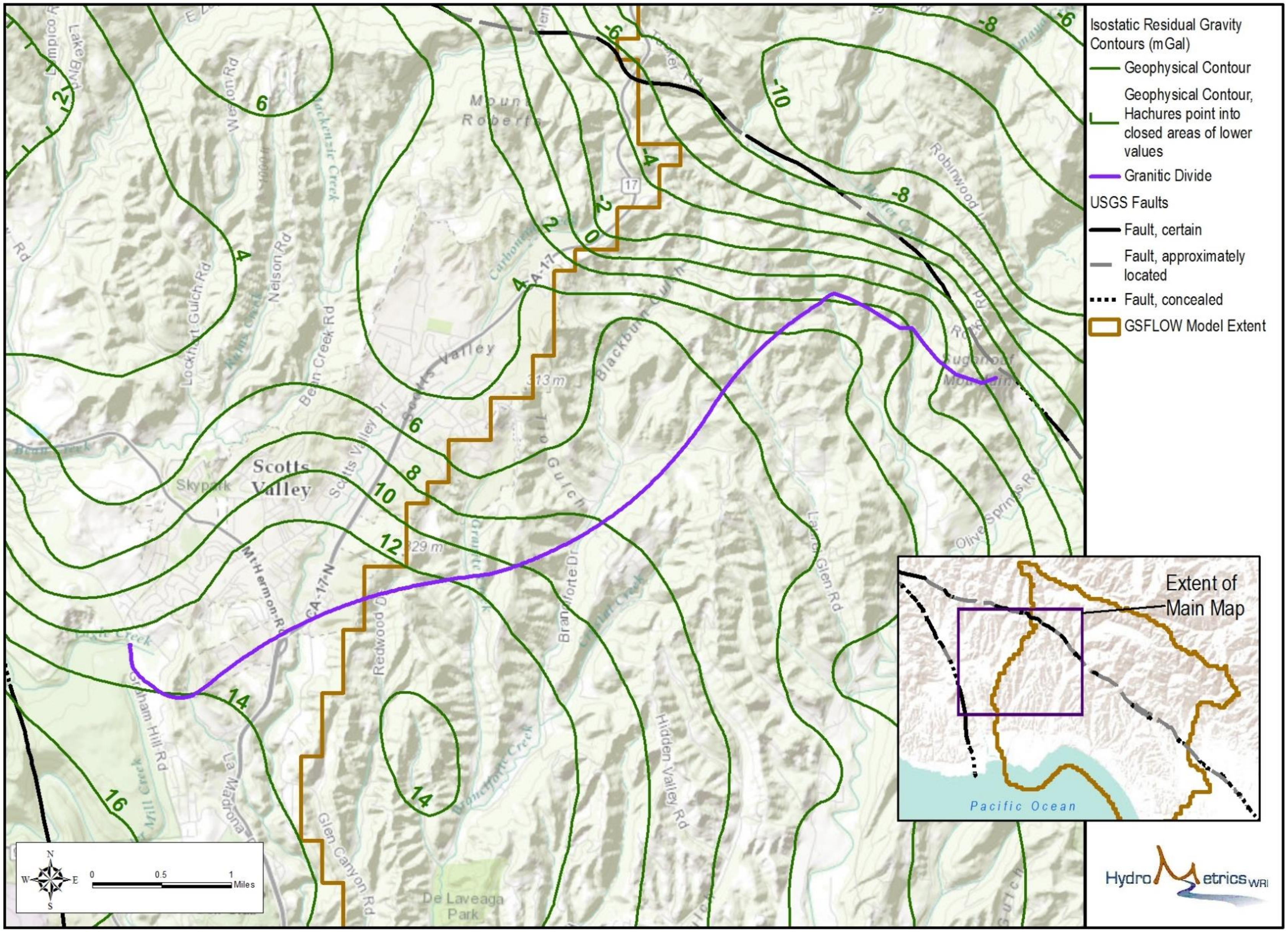


Figure 5: Gravity Anomaly Contours, Western Area of Model Domain

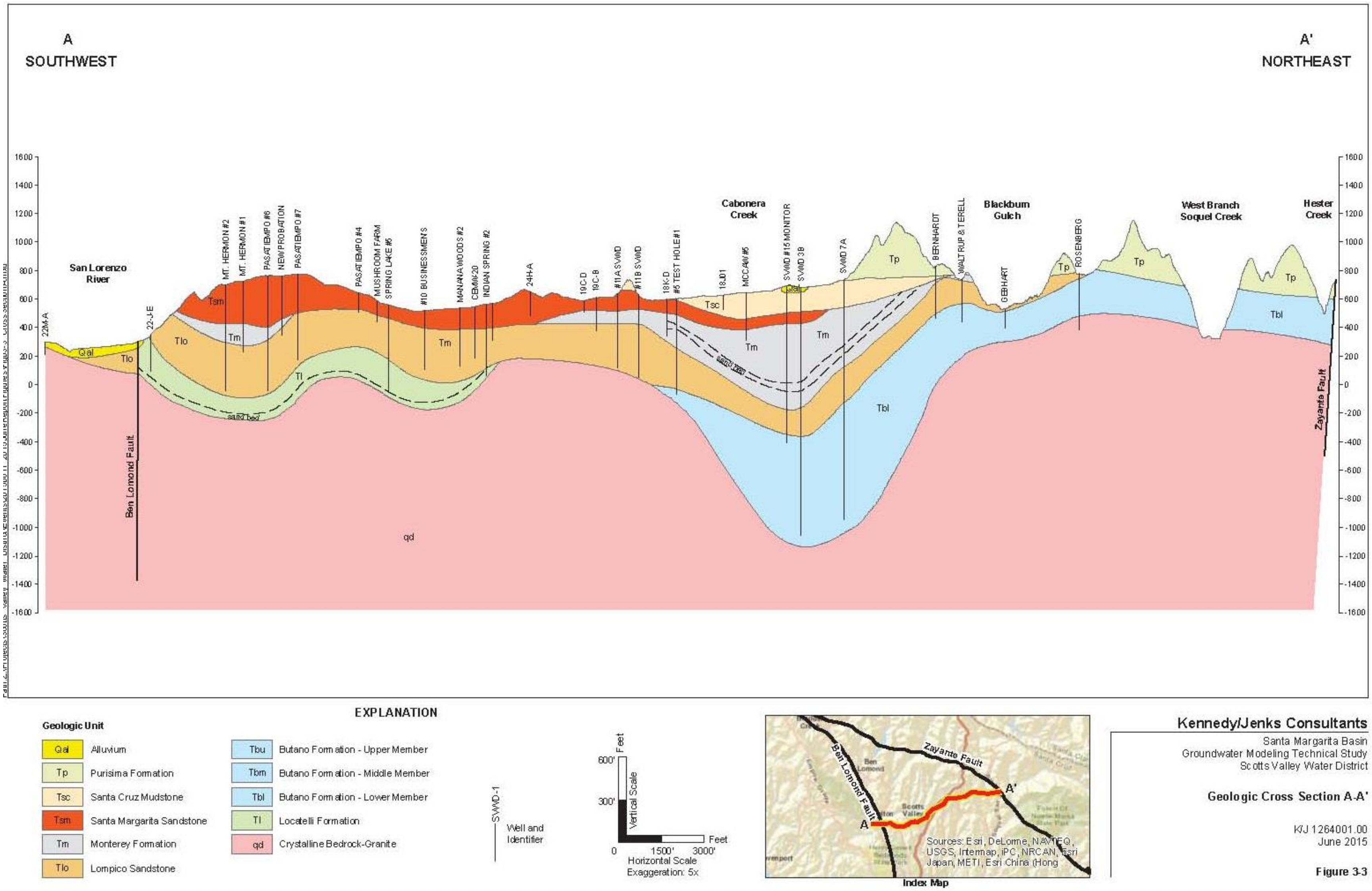


Figure 6: Cross-Section Near Western Boundary of Model Domain (from Kennedy/Jenks Consultants, 2015)

Table 2: Model Hydrostratigraphic Unit Thicknesses

Unit Name	Thickness
Stream Alluvium	Uniform (20 feet)
Terrace Deposits	Uniform (50 feet)
Aromas Red Sands	Variable (approximately 10 to 1,000 feet - consistent with CWD model)
Purisima TpDEF, TpF	Variable (base of Aromas to top of D Aquitard)
Purisima TpD	Uniform (170 feet)
Purisima TpBC	Uniform (190 Feet)
Purisima TpB	Uniform (130 feet)
Purisima TpA	Variable (approximately 200 to 300 feet)
Purisima TpAA	Variable (approximately 300 to 400 feet)
Tu	Variable (approximately 10 to 3,000 feet - distance from base of Purisima to top of granitic basement)

4.2 Model Geometry and Grid

The groundwater model domain consists of 135 rows and 105 columns of uniformly-sized grid cells. Only the grid cells contained within the area shown on Figure 1 will actively simulate groundwater flow. The size of each grid cell is 800 feet by 800 feet. The selection of an 800-foot uniform grid cell size followed an analysis that showed this resolution would sufficiently capture surface elevation features for the hydrologic response units (HRU) of the PRMS watershed model. For GSFLOW models, the USGS recommends using HRUs in PRMS that match the size and dimensions of the MODFLOW grid cells.

4.3 Groundwater Model Layers

The hydrostratigraphy of much of the groundwater model domain was developed using three reference elevations: the land surface, the base of the Purisima TpB aquitard (i.e. the identifiable basal TpB marker unit), and the top of the granitic basement. The land surface was defined using a digital elevation model (DEM) interpolated to the 800-foot uniform groundwater grid spacing. The bottom of the Purisima TpB aquitard and the top of the granitic basement were developed by manually picking the depths of these surfaces from borehole logs, as described in the sections above. The structure of the granitic basement was also informed by regional gravity anomaly maps. Top of the granitic basement and base of the Purisima TpB aquitard elevations as intersected by boreholes were hand-contoured over the groundwater model domain south of the Zayante Fault, and revised using GIS software to ensure the outcrop patterns of each surface were consistent with the previously mapped and reported outcrop patterns of the region (Johnson et al., 2004 and SqCWD and CWD, 2007). North of the Zayante Fault, the granite and bottom of the Purisima TpB aquitard surfaces were extended uniformly and perpendicular to the general trend and dip of the fault because Purisima Formation layers are not well defined north of the fault and differentiation of the layers likely will not be simulated.

The contact elevations between each hydrogeologic unit in the model are mapped on Figure 7 through Figure 14, along with applicable borehole control points estimated from available e-logs. The bottom of the Purisima TpB aquitard was interpolated to the uniform grid spacing of the groundwater model via kriging within the Surfer® software program. The Purisima TpB aquitard elevations are used as a reference surface for defining the depths of the other Purisima Formation units. Thicknesses were assigned to aquifer and aquitard units based on the e-log analysis described in the previous section (see Table 2). The bottom elevations of the DEF/F aquifer, D aquitard, and BC aquifer layers are determined by adding the uniform thicknesses to the B aquitard bottom elevations, while the bottom elevations of the AA aquifer layer are determined by subtracting the total A/AA thickness of 600 feet from the B aquitard bottom elevations. This combined A/AA unit is subdivided into two units of generally uniform, but locally variable thickness as described in the section above.

The Tu unit model layer, which combines any units below the Purisima Formation and above the granitic basement into one model layer, extends from the base of the TpAA aquifer model layer to the top of the granitic basement. Where granitic basement meets the base of the Purisima Formation in the eastern part of the domain, the Tu unit is inactive. Additionally, the Tu unit was made inactive within the model domain east of the limit shown in Figure 7, based on the assumed pinch-out margin of the Tu. As such, the bottom of the model is represented by the base of the Tu with elevations of the granitic basement west of the pinchout margin as shown in Figure 7. The bottom of the model is represented by the base of the AA aquifer with elevations of the granitic basement east of this margin as shown in Figure 9.

The depth of the bottom of the Aromas model layer is also variable over parts of the model domain. This surface contact was interpolated from the base of the deepest Aromas layer in the CWD model to the 800-foot uniform model grid. Model elevations in the CWD model (HydroMetrics WRI and Kennedy/Jenks, 2014) were based on Johnson (2006). This surface was contoured, and the contours were extended beyond the CWD model domain to areas of the Aromas Red Sands that are outside of that domain, but within the basin wide model domain. The CWD model domain shown on Figure 14. The distance between the top of the D aquitard layer to either the land surface or the bottom of the Aromas layer was assigned as the same thickness of the DEF/F aquifer layer.

Model layer contact surfaces were assigned to the model grid using the Groundwater Modeling System (GMS) software package, where layer thicknesses were determined according to the variable or uniform thickness between the reference surfaces of the base of the B aquitard and the granitic basement. The top of all model layers were cropped to the DEM land surface, and inactivated where those layers artificially extended above the land surface according to the imposed dip and interpolation method. Therefore, thicknesses of layers as they outcrop are less than the uniform thicknesses shown in Table 2. The result is an outcrop map that reasonably approximates available maps of surface units. Some simplification was applied to the model grid so that disconnected islands of active cells, usually in upland areas within a given hydrostratigraphic unit, were minimized. Where the granitic basement surface was interpolated to extend close to DEM surface (within approximately 10 feet), all model layers were inactivated to represent the no-flow areas where granite outcrops to the surface.

Figure 15 shows the extent of the outcropping model layers representing the Aromas and Purisima units and location of cross-sections A-A', B-B', and C-C'. Figure 16 through Figure 18 show the simulated model layers along these cross-section lines. Cross-section A-A' runs roughly parallel to California State Route 1, and shows that the southeasterly-dipping Purisima units are well-represented in the groundwater model domain. The variable thickness of the Aromas layer is also evident, as is the pinch-out of the Tu layer where the Purisima Formation extends to the granitic basement in the western portion of the model domain. Cross-section B-B' runs roughly parallel to Soquel Creek, and shows an area where the model grid is inactive due a surface outcrop of granite, Cross-section C-C' runs parallel to the model domain's southern offshore boundary, showing a similar dip direction as in cross-section A-A', and the geologic units that outcrop to the ocean floor along that line.

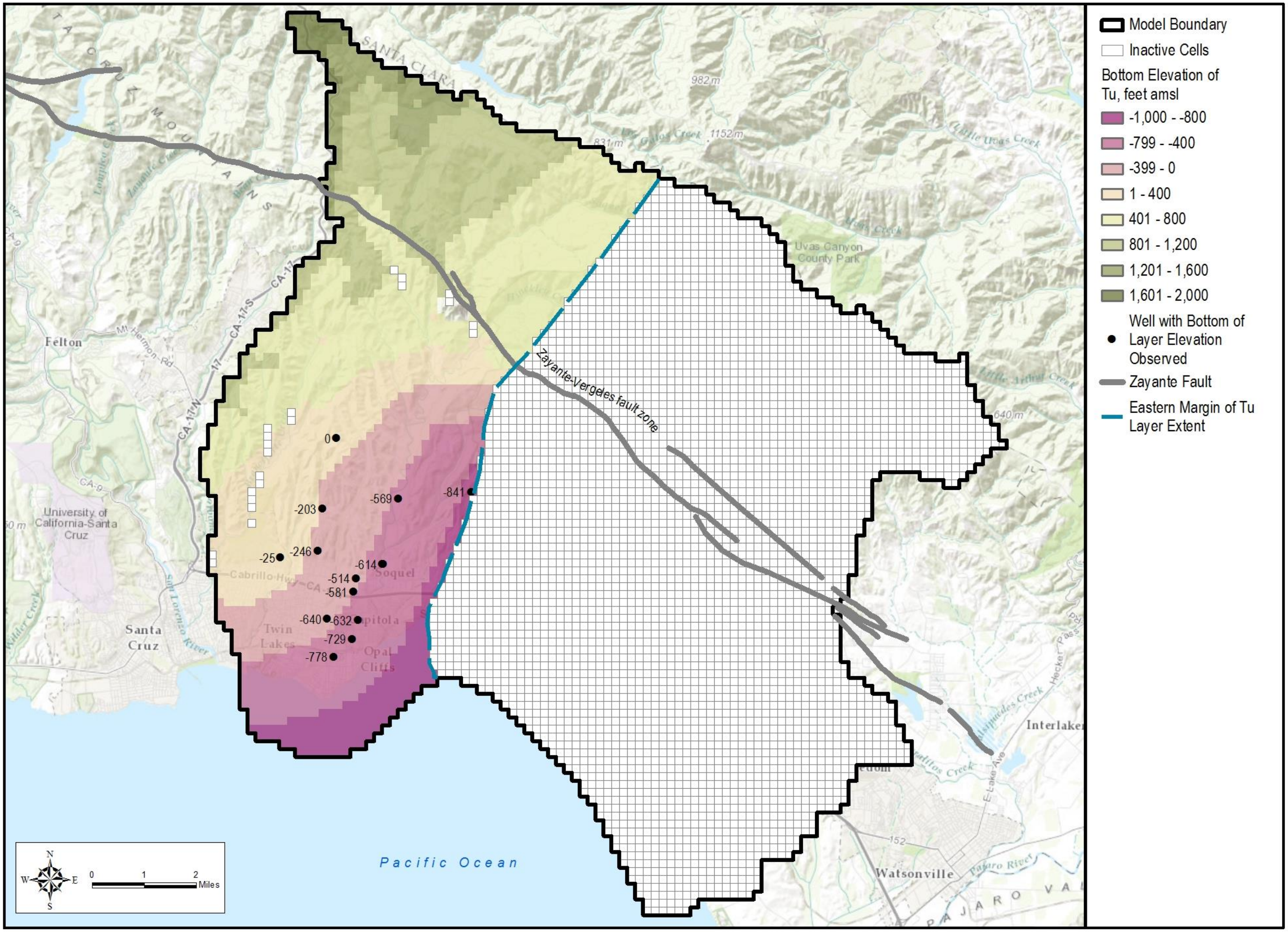


Figure 7: Base of Tu Unit Elevations in Model

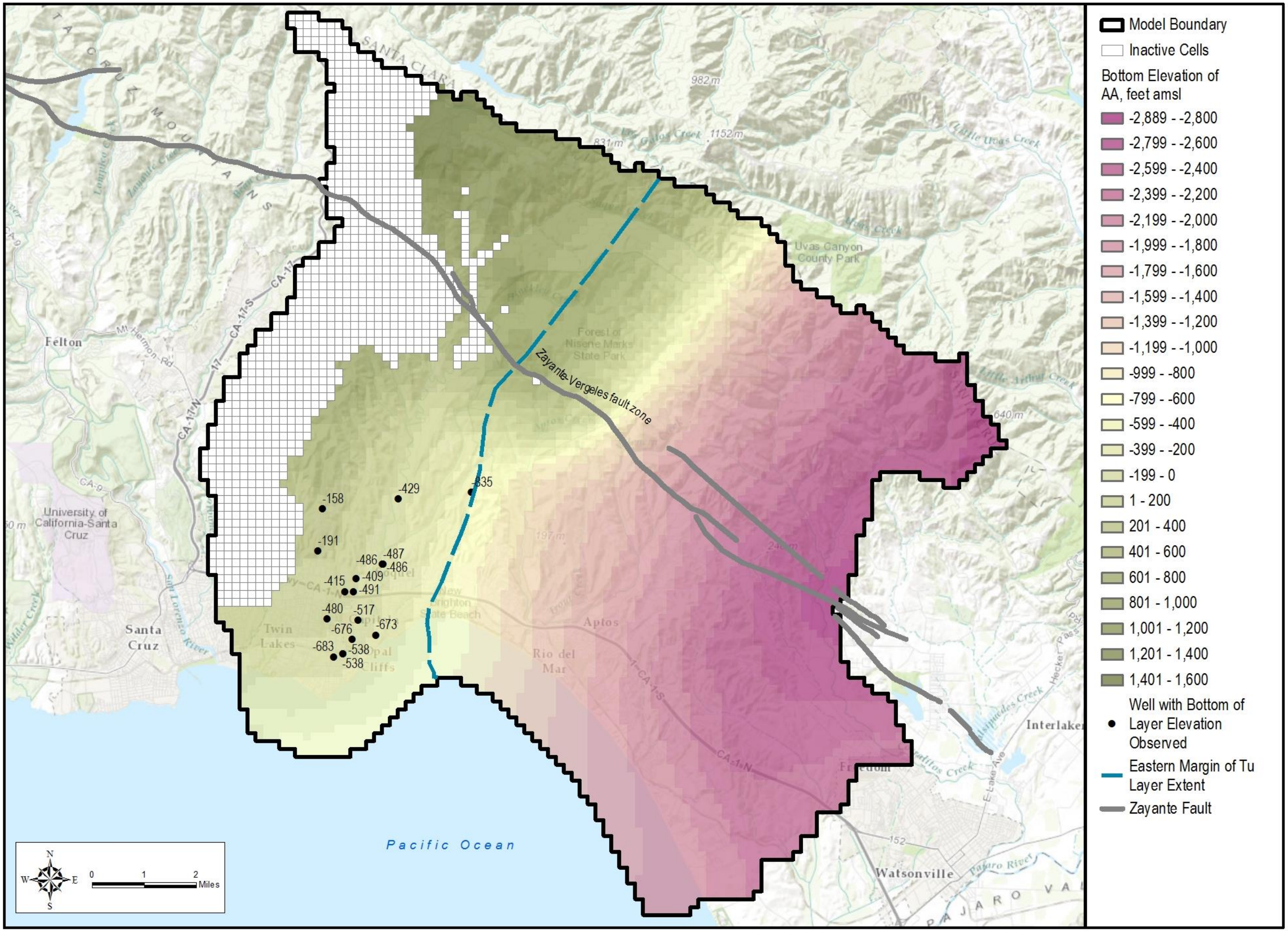


Figure 8: Base of TpAA Unit Elevations in Model

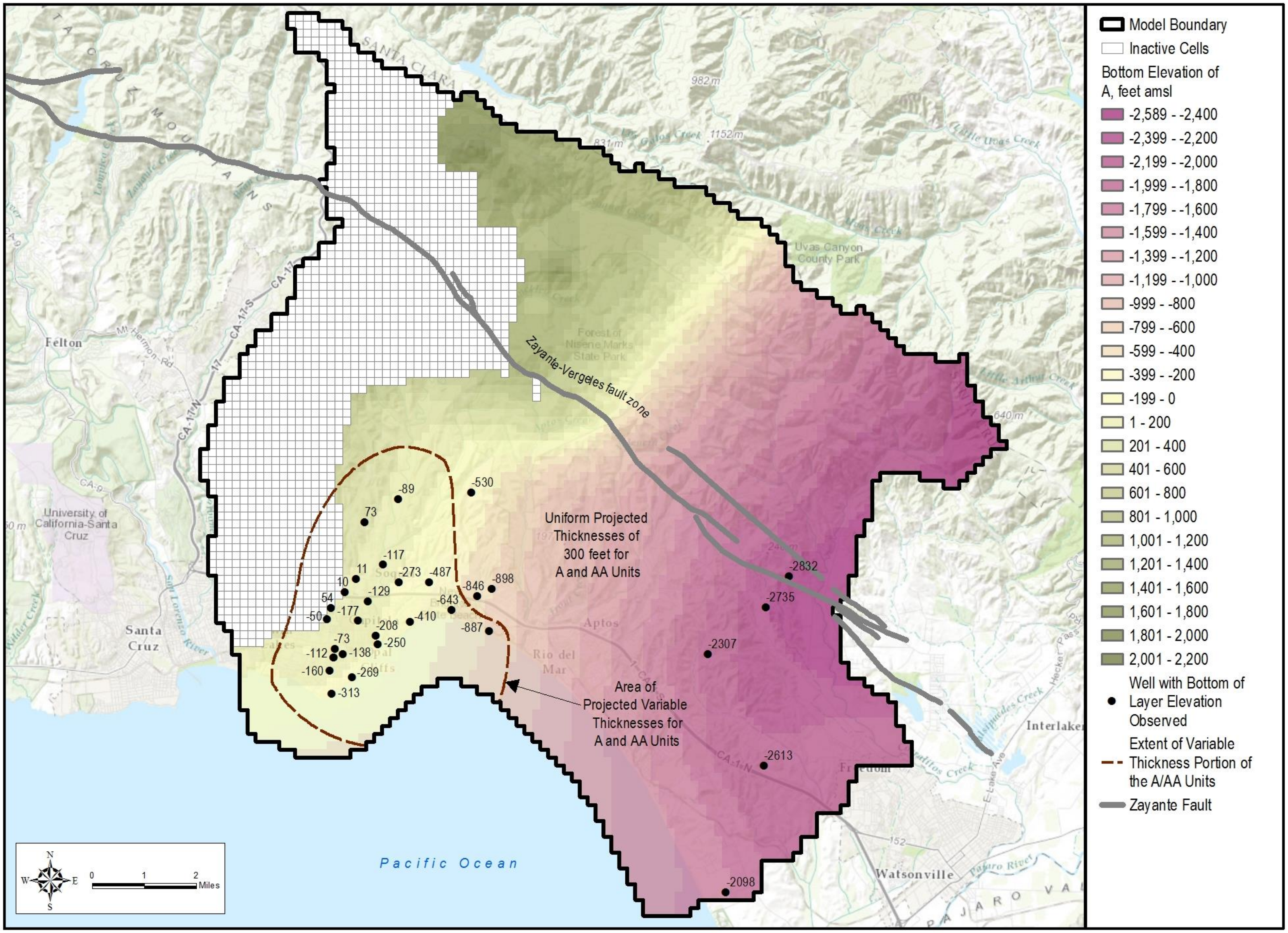


Figure 9: Base of TpA Unit Elevations in Model

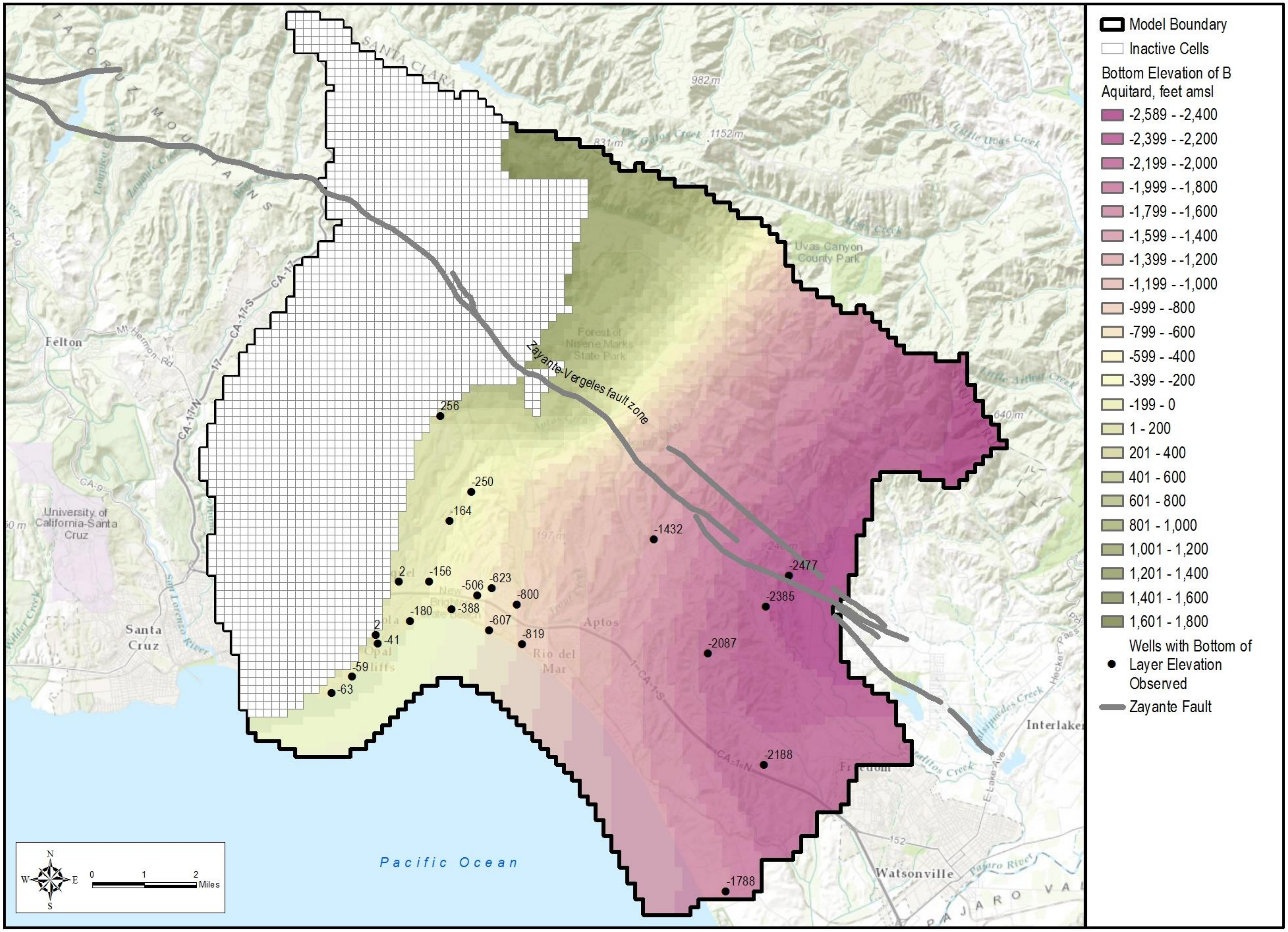


Figure 10: Base of TpB Aquitard Elevations in Model

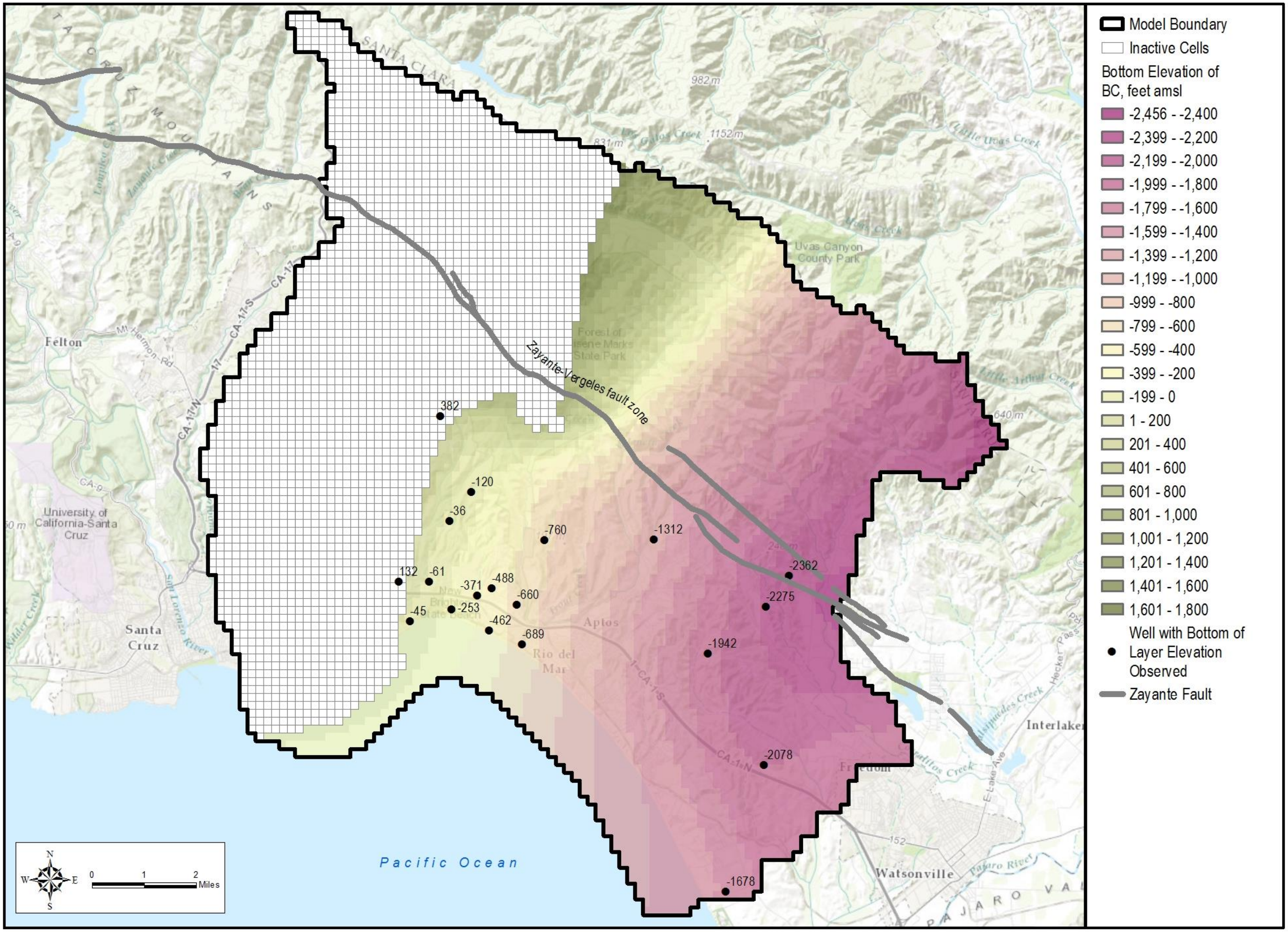


Figure 11: Base of TpBC Unit Elevations in Model

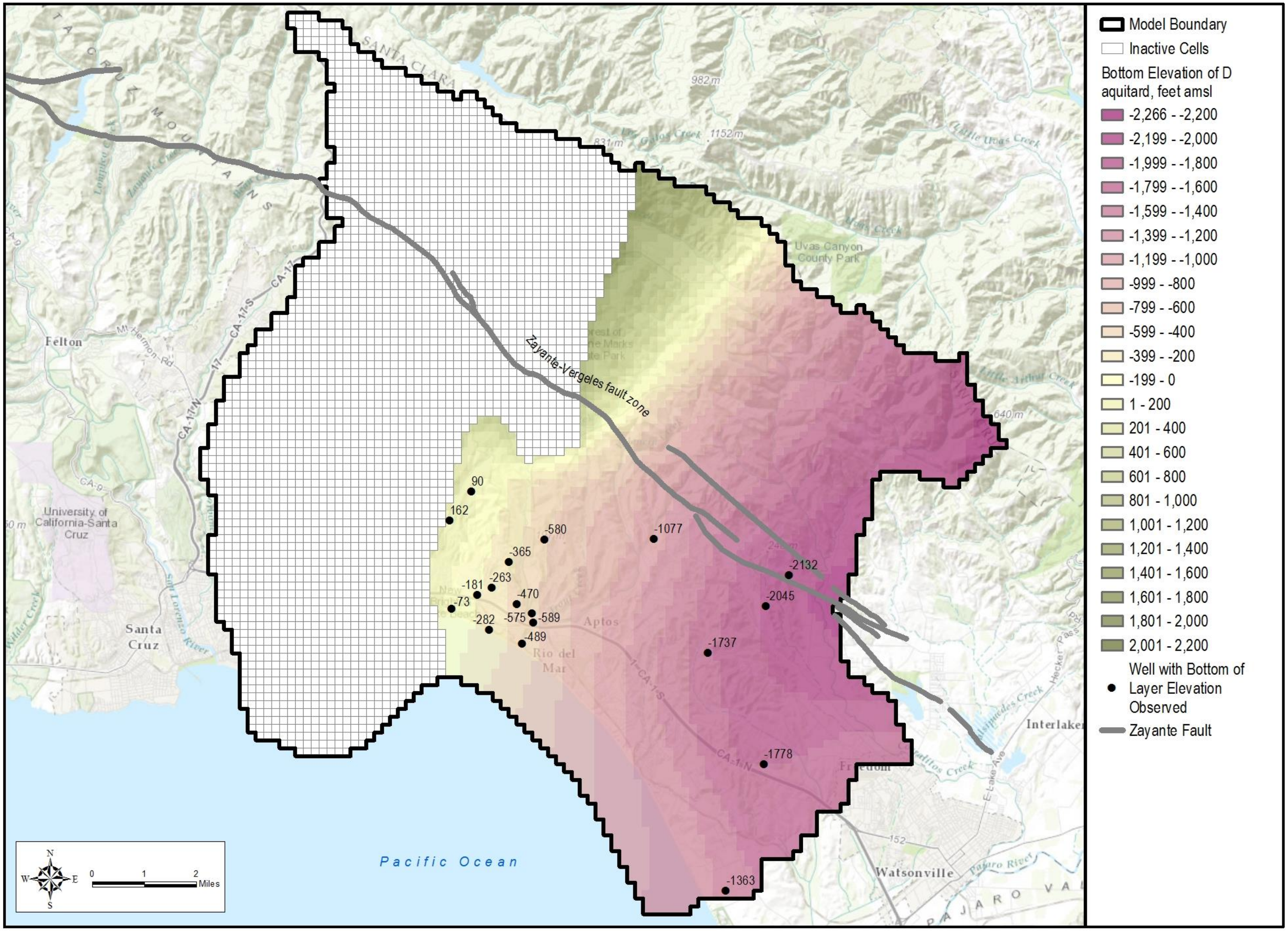


Figure 12: Base of TpD Aquitard Elevations in Model

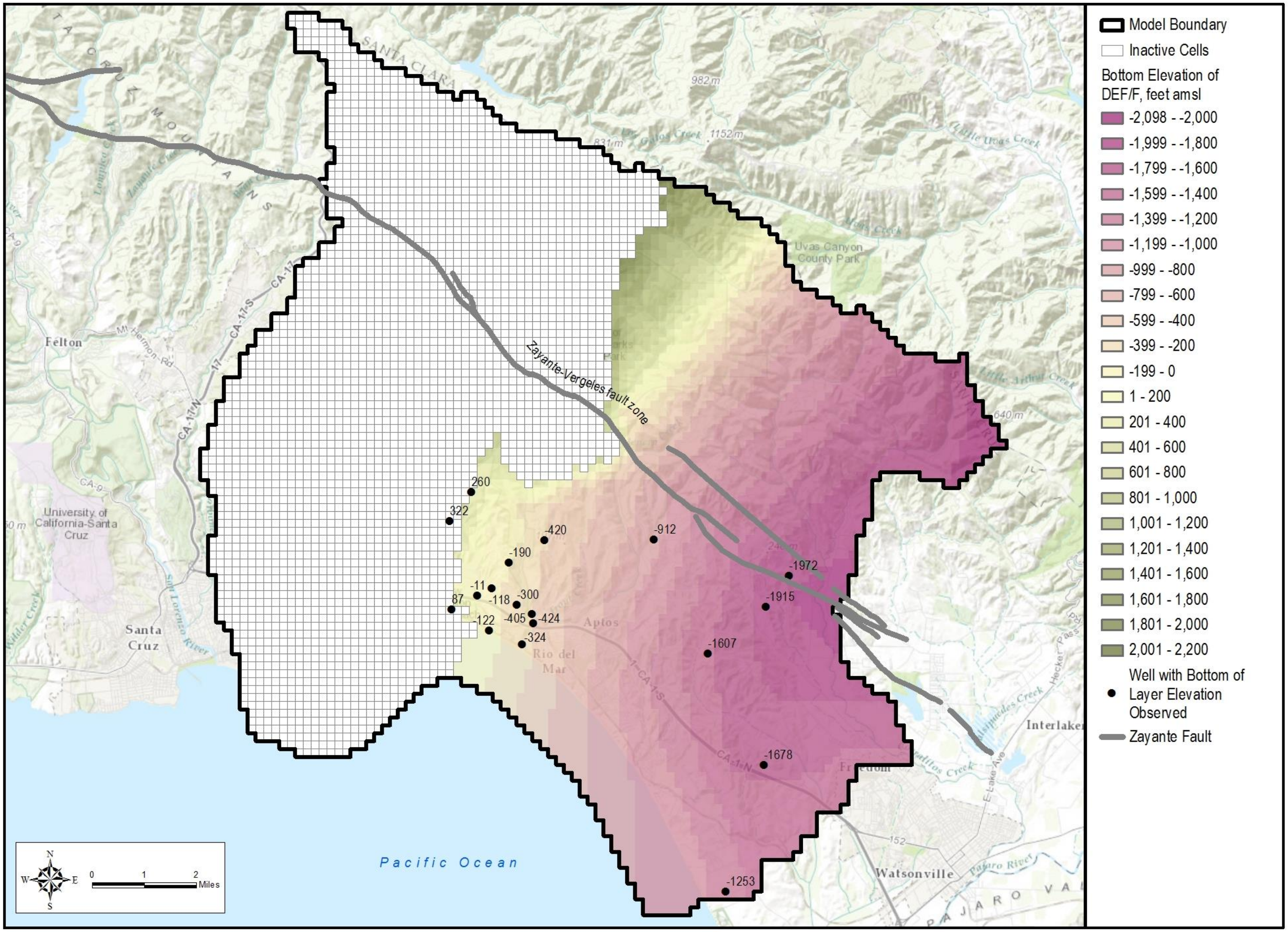


Figure 13: Base of TpDEF/F Unit Elevations in Model

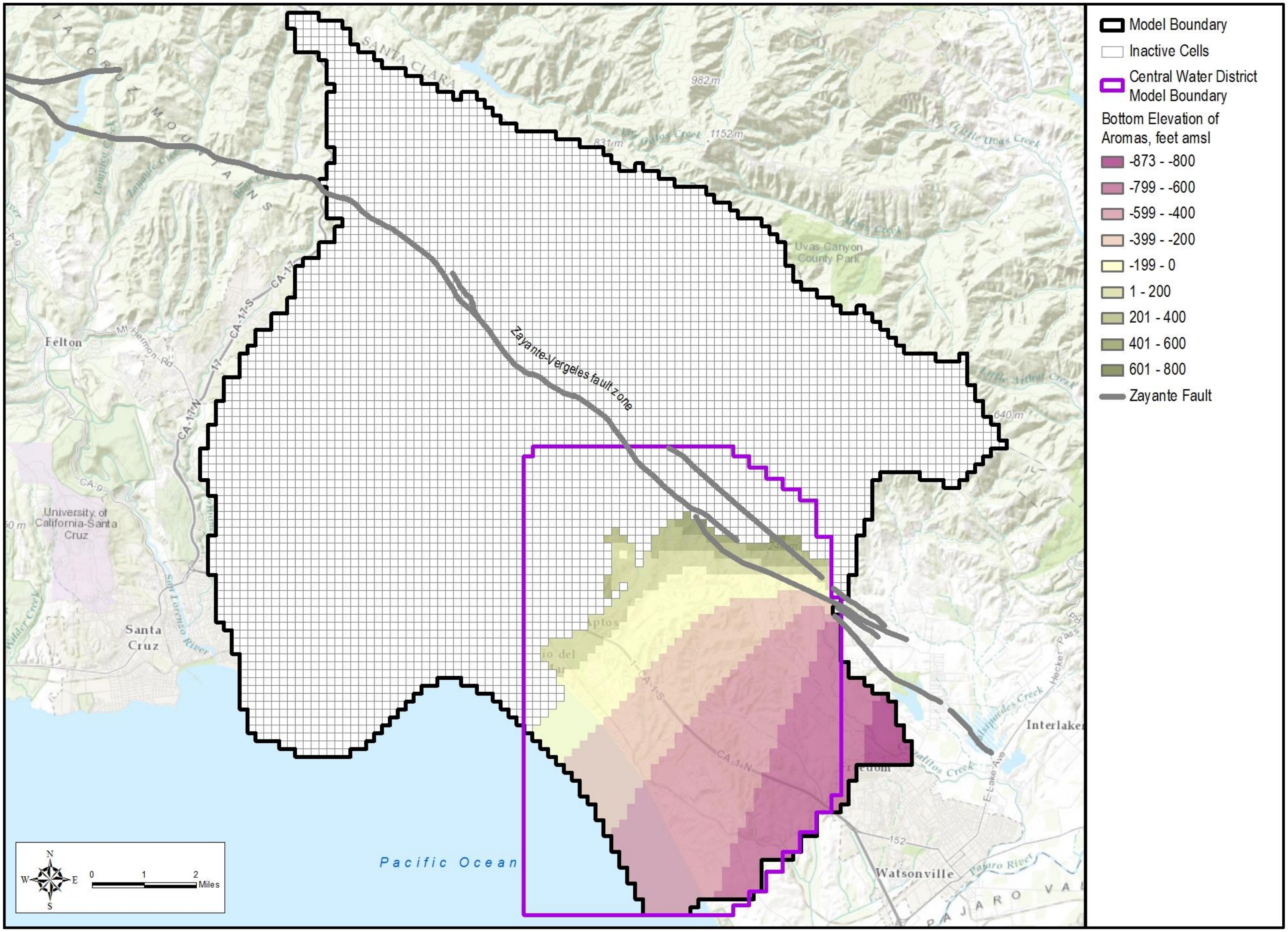


Figure 14: Base of Aromas Red Sands Elevations in Model

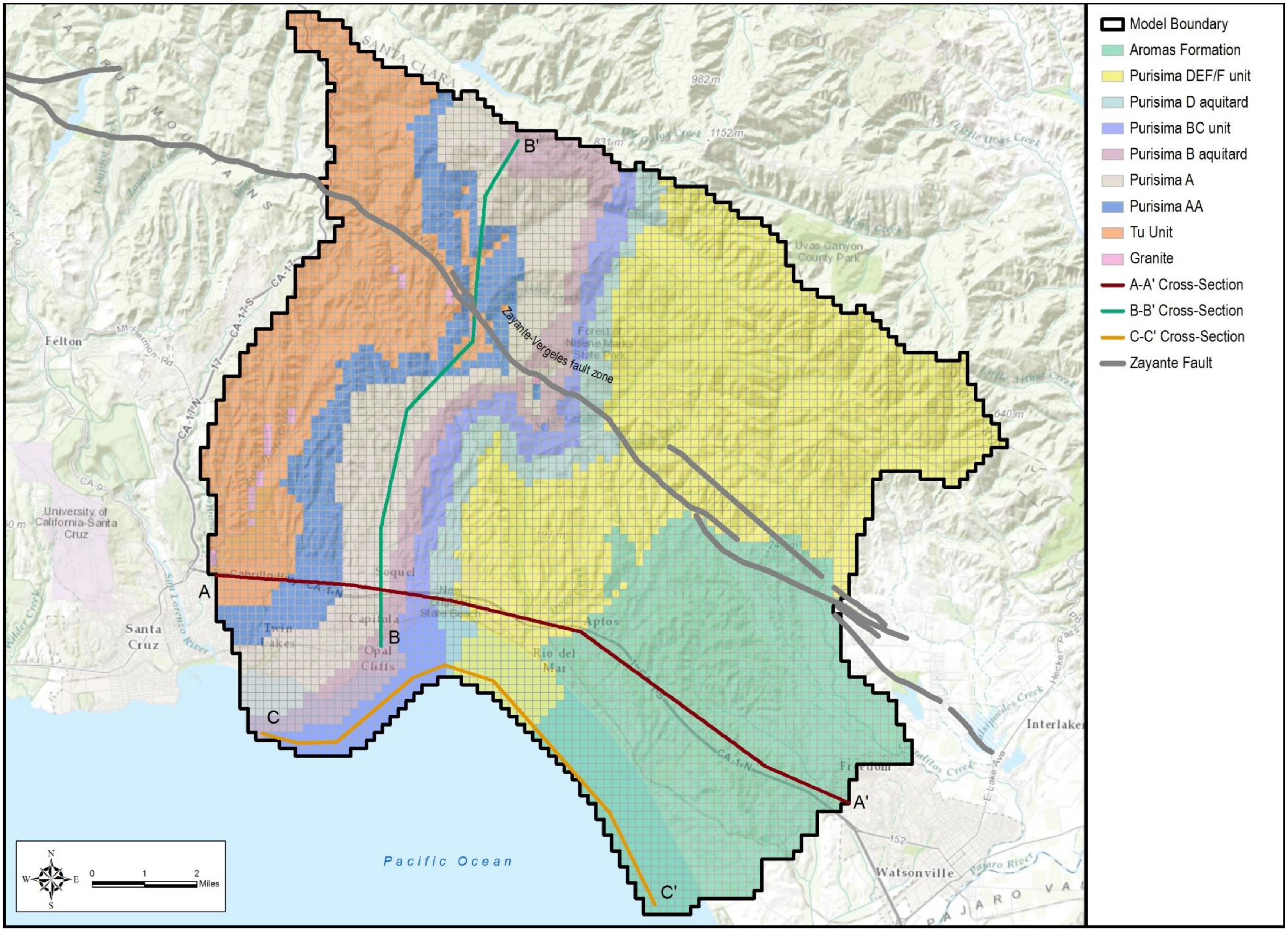


Figure 15: Simulated Aromas and Purisima Outcrop Extents

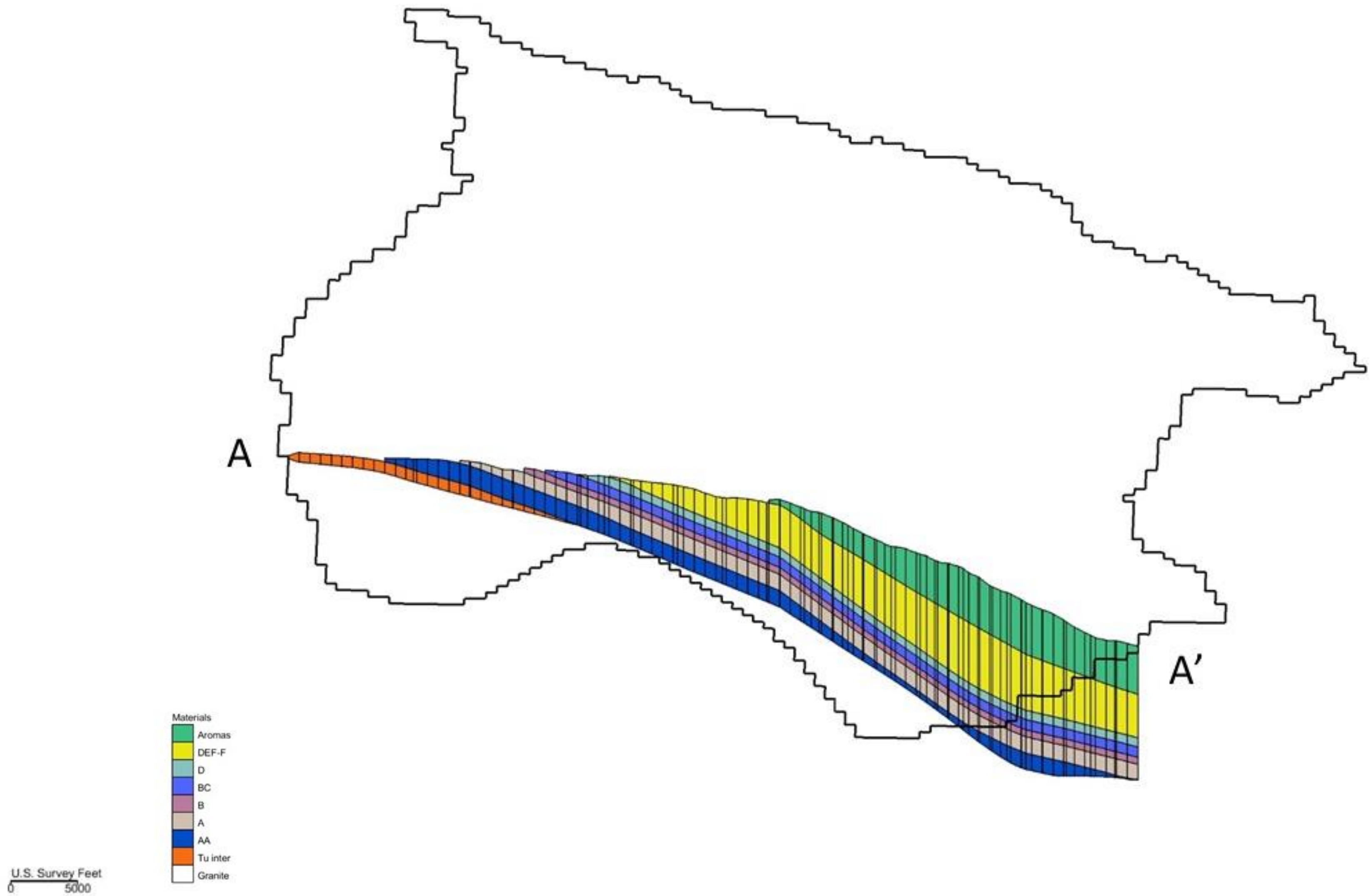


Figure 16: Simulated Cross-Section A-A'

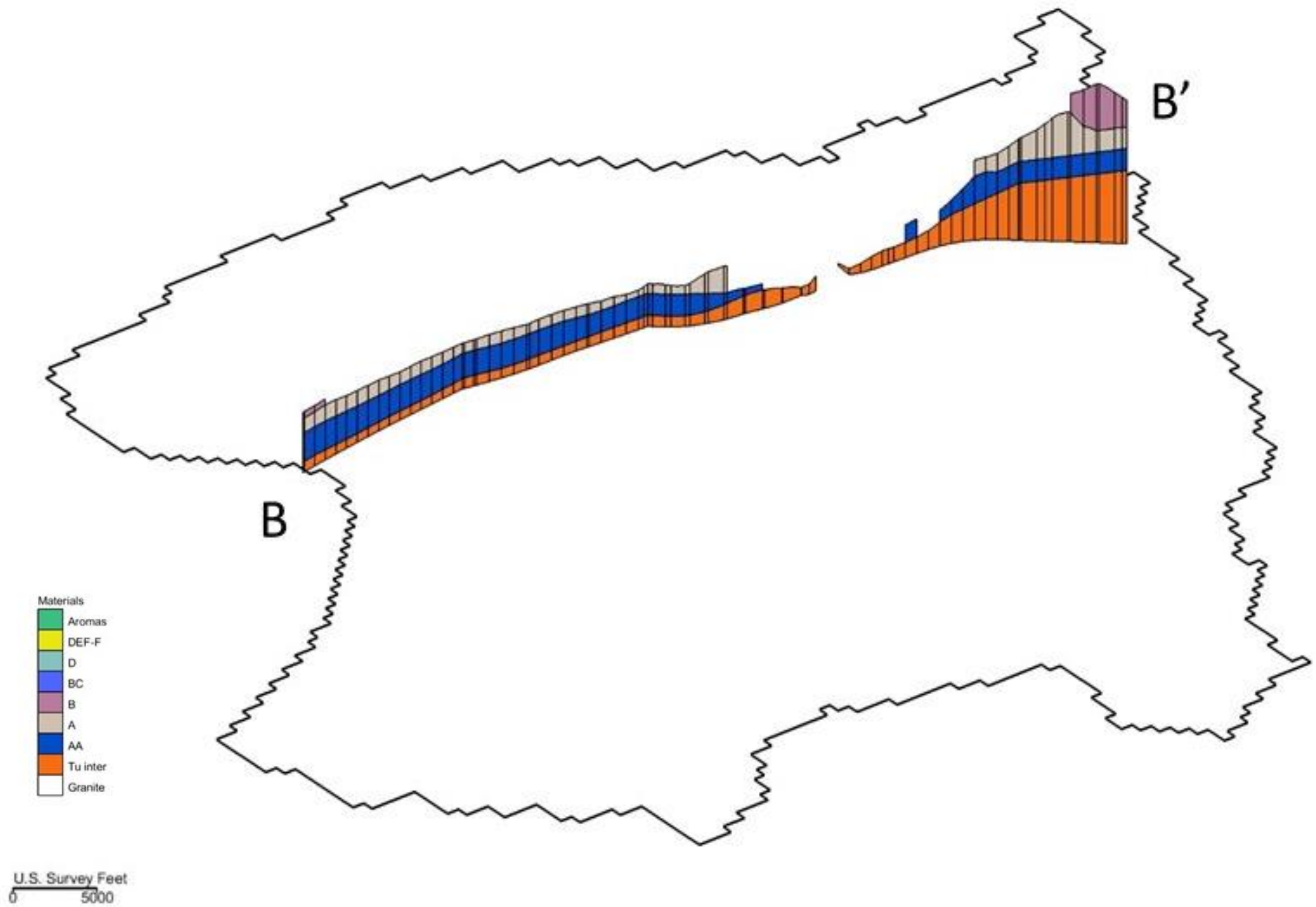


Figure 17: Simulated Cross-Section B-B′

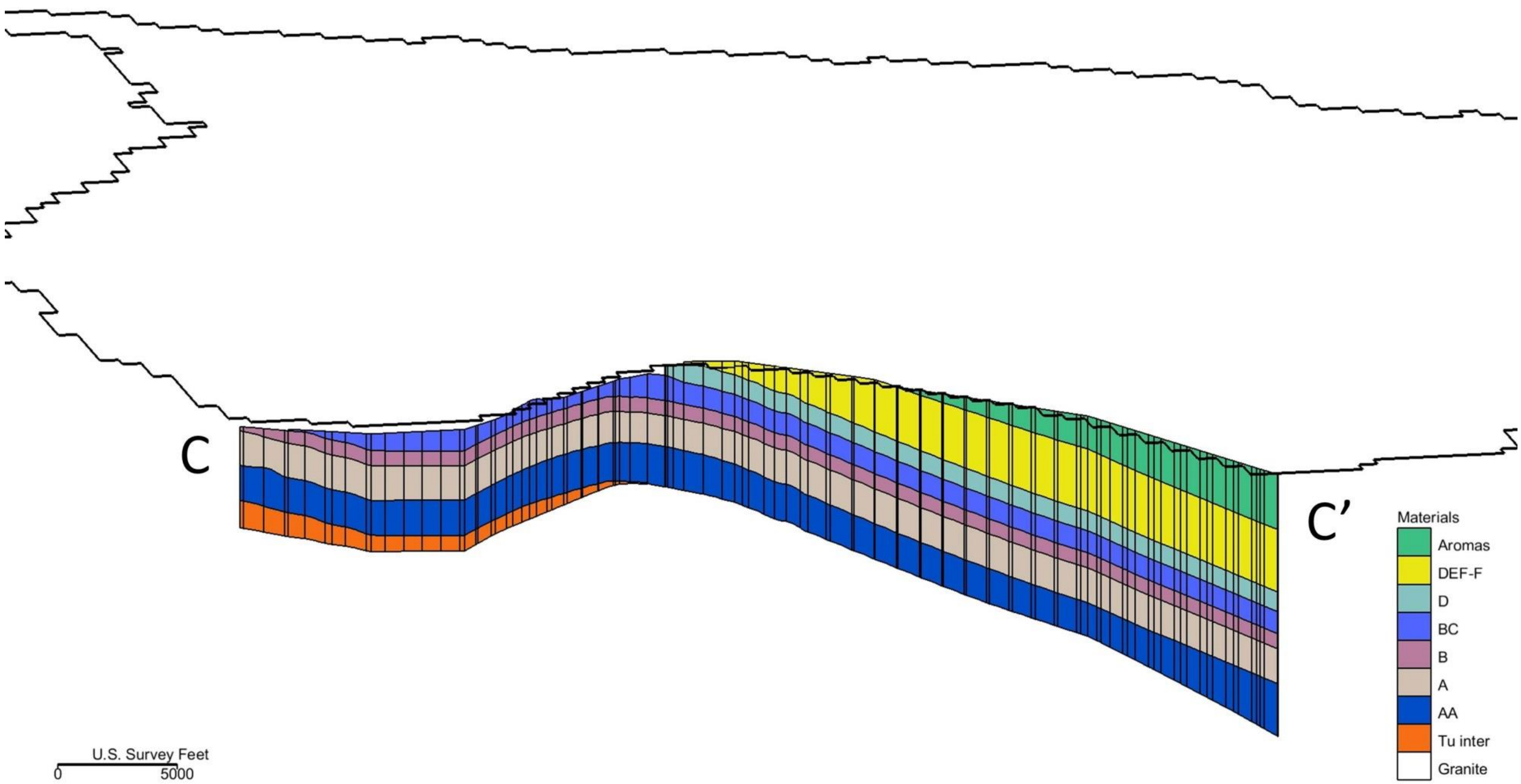


Figure 18: Simulated Cross-Section C-C′

4.4 EXTENT AND DEFINITION OF SIMULATED ALLUVIAL MATERIAL

In addition to the Aromas Red Sands and Purisima Formation, alluvial material associated with streambed deposits and coastal terrace deposits are defined within the model domain. Streambed sand and gravel deposits may be of relatively higher-permeability material than the surrounding surficial geology, so they are considered necessary to represent the groundwater-surface water interactions that occur in the integrated GSFLOW model. Terrace deposits consist of unconsolidated sediments formed by surf erosion in periods of high sea levels during the Pleistocene epoch. While they may yield only relatively minor quantities of groundwater to wells, they were added to the model to accommodate their potential for affecting recharge to the underlying aquifer units. The simulated thicknesses of these alluvial materials is simplified to be uniform wherever they exist within the model domain.

Because the Aromas and Purisima Formation outcrop over the extent of the model domain, the ground surface is defined by various model layers. The alluvium may be found overlying any of these outcropping model layers; therefore the alluvium cannot be defined as a single layer within the model. Rather, alluvium will be assigned to whatever model layer overlies the regional aquifers where that alluvium is identified to exist. The exact material properties of the alluvium will be documented in a future technical memorandum. To accommodate the alluvium thickness, the top-of-layer elevations of the underlying units are revised by subtracting the alluvium thickness from the interpolated DEM surface. Figure 19 and Figure 20 show the simulated extents of active streambed alluvium and terrace deposit materials within the model domain, respectively. The streambed alluvial areas are congruent with the anticipated extent of stream cells developed for the PRMS component of the model. The extent of terrace deposits was inferred from existing USGS surficial geology maps.

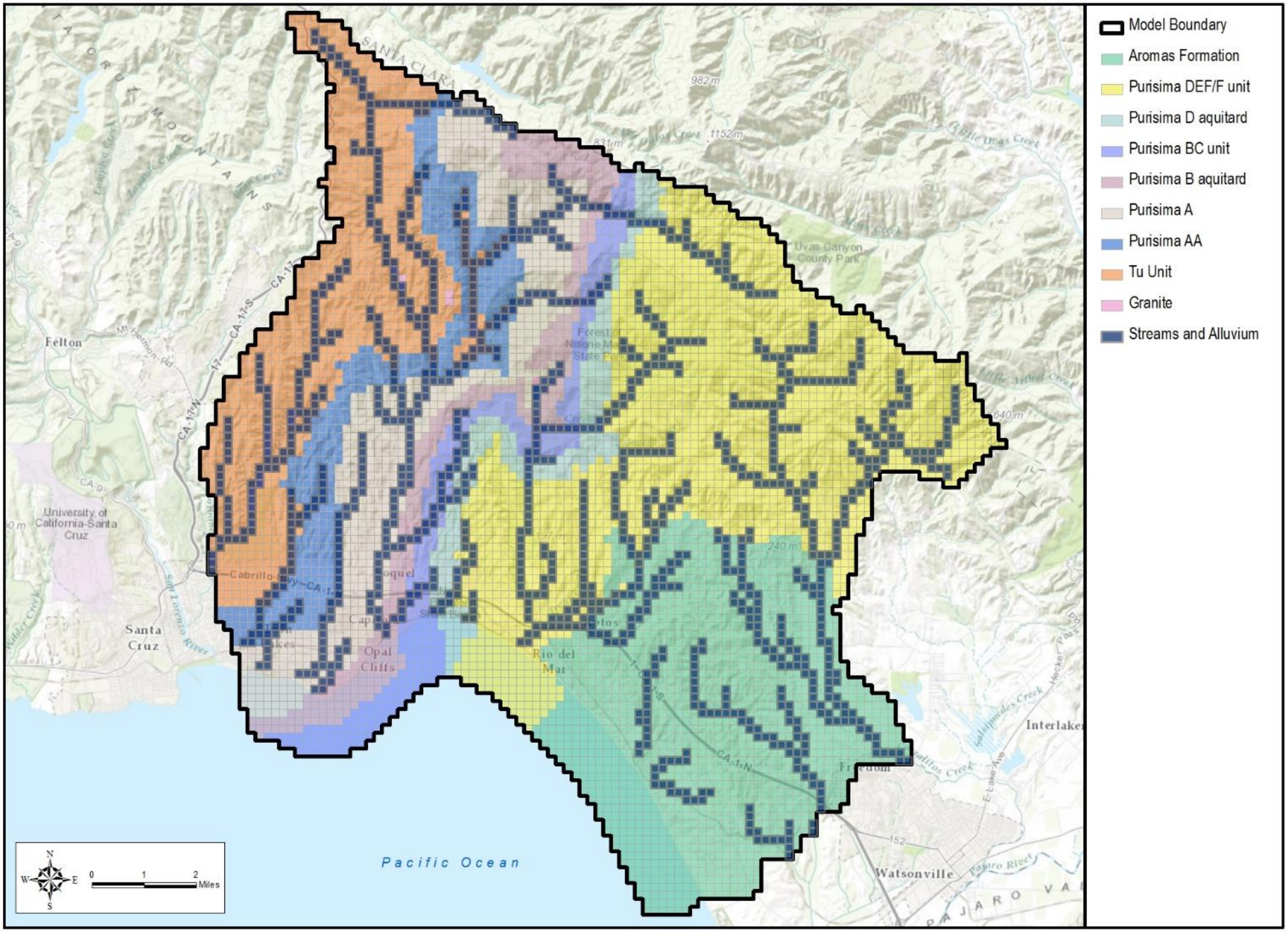


Figure 19: Simulated Extent of Streambed Alluvium

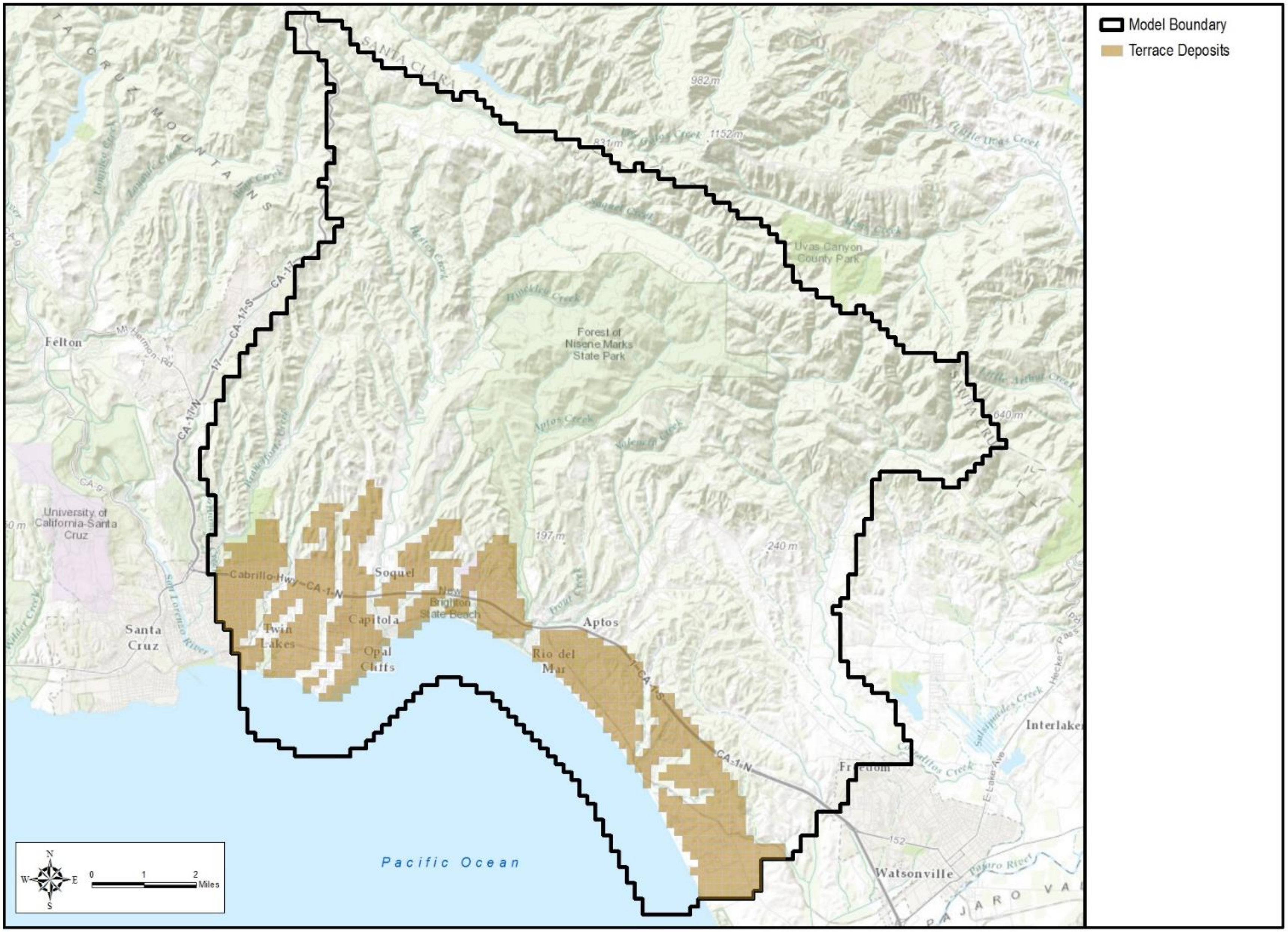


Figure 20: Simulated Extent of Terrace Deposits

Assigning streambed alluvium to various model layers was complicated by areas where streams cross simulated outcrop boundaries. In order to allow for hydraulic connectivity in these streambed units, additional layering was necessary to ensure that flow within the streambed units is not impeded by an effective boundary created where adjacent stream cells are assigned to different model layers. Figure 21 shows a diagram outlining the stream alluvial layering approach within the groundwater model where streams cross outcrop boundaries. In these instances, an additional vertical layer of alluvium is added to create a stack of cells connecting the alluvium overlapping the different outcropping aquifers. Minimal vertical anisotropy applied to the alluvial cells will facilitate a continuous flow path laterally out of the upstream alluvial cell, downward or upward through the stacked alluvial cells, and then laterally in the downstream direction through the alluvium. Without this additional layering, no lateral flow would occur in the alluvial cells of streams that cross outcrop boundaries.

As developed for PRMS, simulated streamflow may occur between adjacent stream cells, but also between cells that overlay diagonally-aligned model cells. However, groundwater flow is not simulated between diagonally-aligned model cells. As such, “bridge” streambed alluvium cells were defined to maintain lateral hydraulic connectivity between model cells representing the alluvium of a diagonally-flowing stream, with a continuous flow path maintained using stacking of two or more layers at the bridge cell as described above. Figure 22 demonstrates the process by which these additional bridge cells were defined, including cases where the stream crosses an outcrop boundary, as described above.

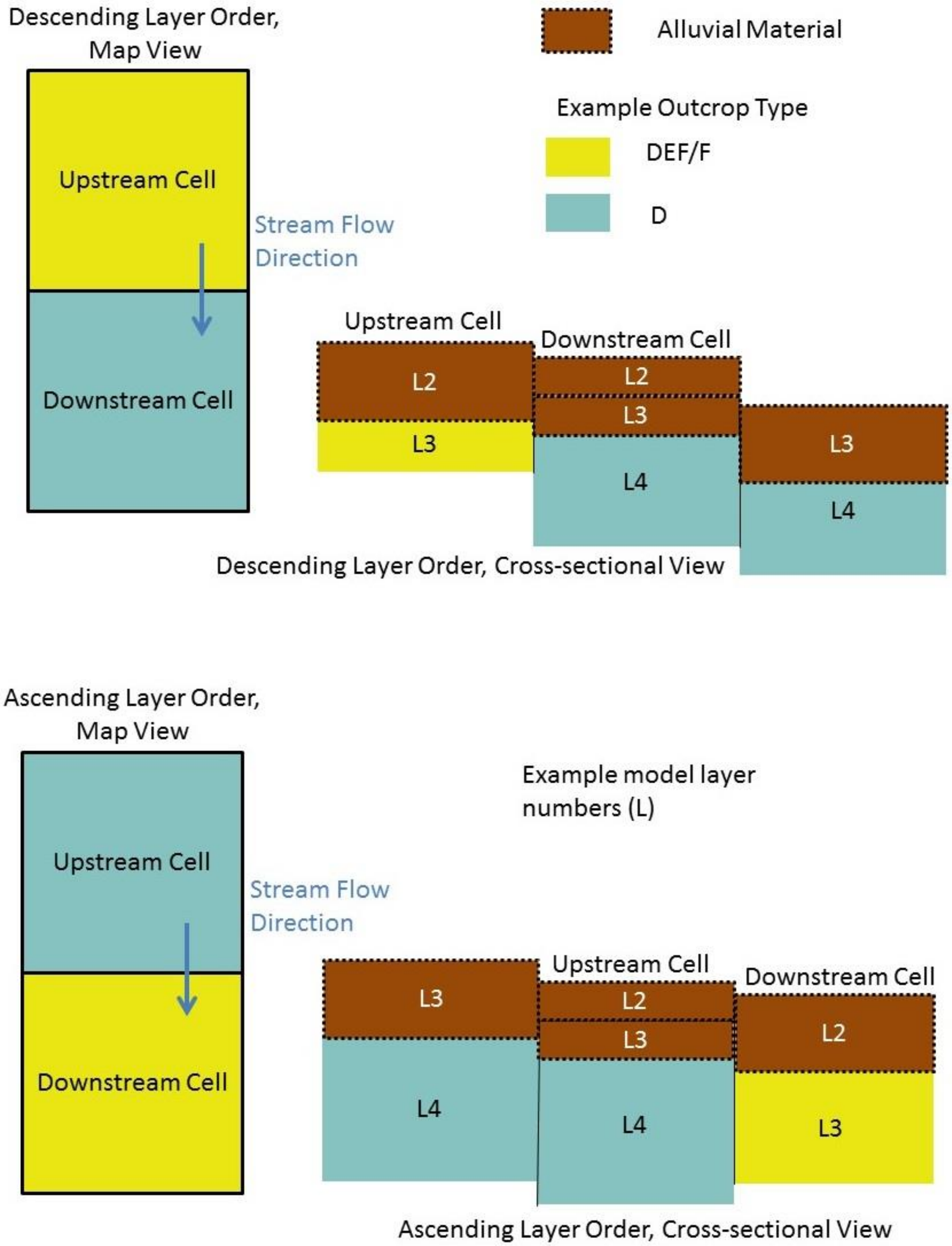


Figure 21: Example Stream Alluvium Layer Assignment

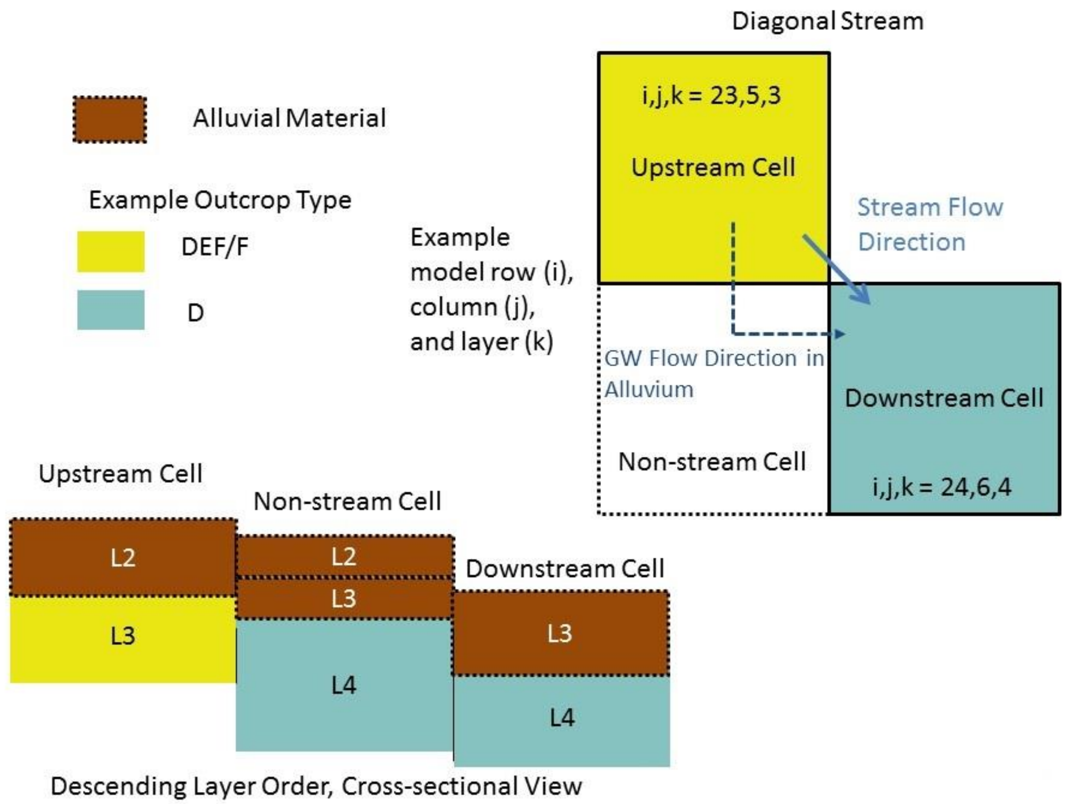


Figure 22: Example Stream Alluvium Layer Assignment for Diagonally-aligned Streams

5.0 BOUNDARY CONDITIONS

Model boundaries have been selected so that they generally follow existing watershed boundaries or other hydraulic boundaries within the model domain. As such, the northern, western, and eastern edges of the model will be assigned no-flow boundary conditions. The extent and type of anticipated boundary conditions is shown on Figure 23.

Active Aromas or Purisima model cells that outcrop beyond the coastline will be assigned as general head boundary (GHB) cells where the simulated head value is equivalent to mean sea level similar to the CWD model (HydroMetrics WRI and Kennedy/Jenks, 2014). Conductance will be estimated as model construction and calibration proceeds. Conductance values will also be varied spatially to account for changes in seafloor sediment type and thickness.

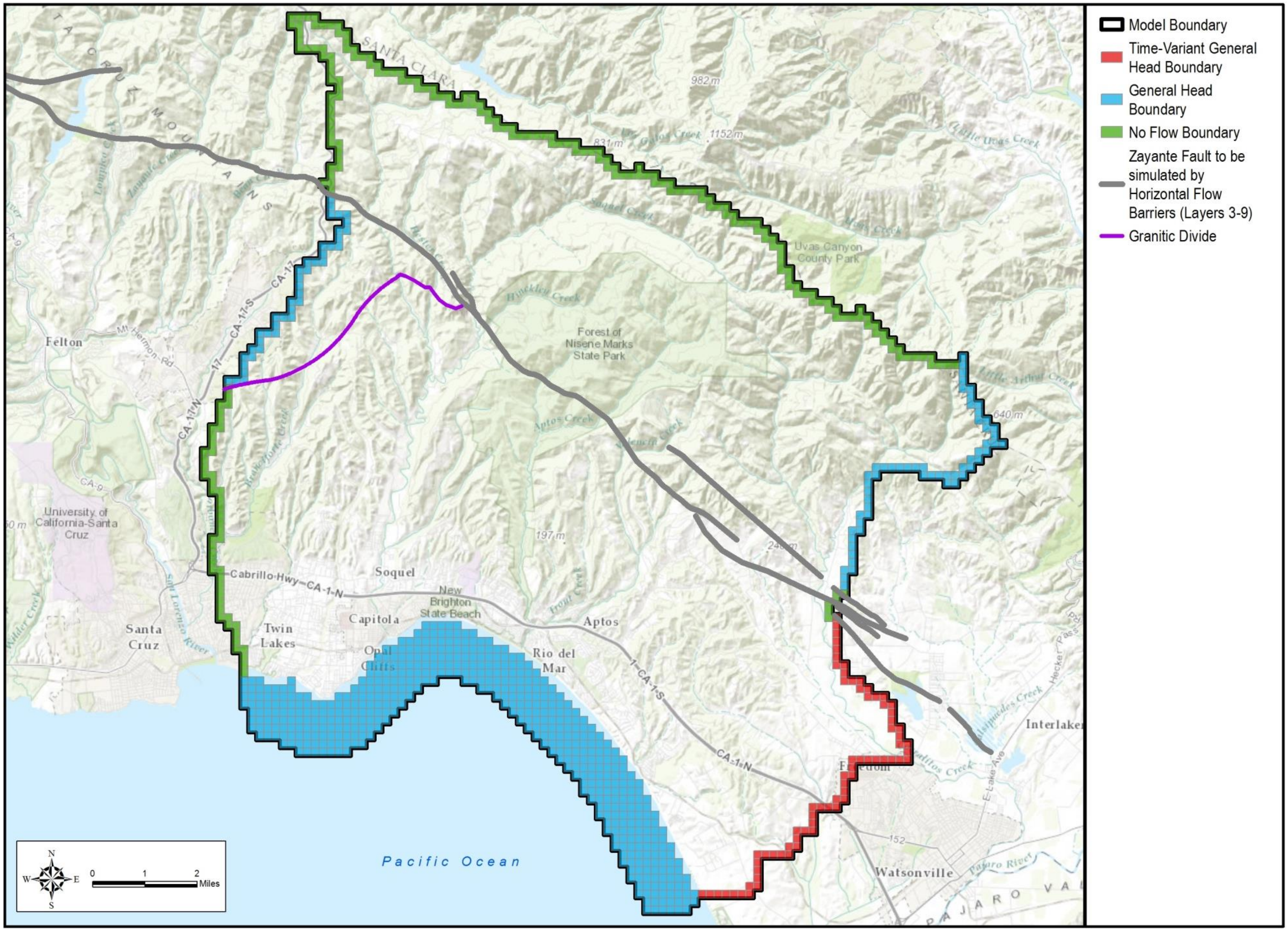


Figure 23: Generalized groundwater model boundary conditions.

The Zayante Fault will be represented by the horizontal flow barrier (HFB) package. Implementing these flow barriers between cells north and south of the fault will provide resistance to flow between the well-defined Purisima unit layers south of the fault and the undefined Purisima Formation north of the fault as described in section 4.3. HFB conductance will be estimated during model calibration.

The area of the model north of the Zayante Fault is within the watershed area of the Soquel-Aptos Basin, and will receive surface water in the form of precipitation and streamflow. However, groundwater flow from infiltration into the simulated undifferentiated Purisima units north of the fault will be impeded by the fault HFB. In order to avoid mounding and unreasonably high groundwater levels in this area, an additional GHB will be applied to the eastern boundary of the model north of the fault. The head and conductance along this boundary will be varied as model work progresses to maintain reasonable groundwater head elevations north of the Zayante Fault. It is unlikely that model calibration will be sensitive to this boundary condition, as the majority of pumping wells and groundwater calibration targets will be south of the fault.

Groundwater modeling studies of the Santa Margarita Basin and Scotts Valley area (Todd Engineers, 1997; ETIC Engineering, 2006; Kennedy/Jenks Consultants, 2015) indicate that groundwater flow west of the granitic structural divide shown on Figure 4, Figure 5, and Figure 23 within the aquifer units below the Purisima Formation is directed roughly westward, away from the Soquel-Aptos Basin. As such, assigning a no flow boundary west of this structural divide may result in unreasonable mounding and flow directions to occur in the thick portion of the simulated Tu unit west of the divide. It may also be problematic to inactivate model cells west of the structural divide as at the surface, this area is still within the Soquel-Aptos watershed and contains steams that necessarily contribute flow to model domain. To accommodate this feature of the hydrostratigraphy, a GHB will be applied to the western boundary of the model between the intersection of the granitic structural divide with the western model boundary and the Zayante Fault, which is also the northern boundary of the Santa Margarita Basin. This will induce westward groundwater flow out of the model domain west of the structural divide and maintain reasonable groundwater elevations within the Tu unit in this area.

The southeastern boundary is the only boundary that does not intersect a watershed or naturally-occurring hydraulic barrier. Rather, it is similar to the southeastern boundary of the CWD model in the coastal plain area of the City of Watsonville. Model cells representing this boundary will be defined as GHB cells via similar method as was applied to the CWD model (Hydrometrics WRI and Kennedy/Jenks, 2014). In the CWD model, a GHB boundary with transient heads estimated for the entire boundary length was developed based on groundwater elevation data provided by PVWMA. As groundwater data in this area are relatively limited, the transient heads were assigned to three separate segments of the boundary according to a function for seasonally-fluctuating groundwater elevations that was fit to historical water level data at the PVWMA wells. Historical lateral groundwater gradients were used to apply a generalized spatial trend to each segment of the boundary (Hydrometrics WRI and Kennedy/Jenks, 2014). These interpolated time series extend through 2012 for the CWD model, and will be updated to extend through 2015 to be applied to the basin wide model. The CWD model did not extend vertically into the Purisima along this southeastern boundary, and groundwater level data from PVMWA wells in this area are limited to the Aromas Formation. To account for this, a consistent vertical gradient will be estimated, and transient and spatial head data will be interpolated according to the gradient at GHB cells in the underlying Purisima layers along the boundary in the basin wide groundwater model. Where necessary, the extent of each boundary segment, the function applied to develop transient head conditions, or the vertical gradient will be adjusted as model construction and calibration proceeds. Figure 24 shows the area of the southeastern model boundary, the wells used to define the spatial variability of the boundary in the CWD model, as well as other PVMWA wells in the vicinity that may be used as sources of groundwater elevation data to define the boundary heads. Pumping from the City of Watsonville also occurs in this area, and will be explicitly defined by pumping wells in the model. City of Watsonville wells that fall within the model domain are also shown in Figure 24. Future changes to pumping at other City of Watsonville wells will need to be simulated by adjusting the boundary condition.

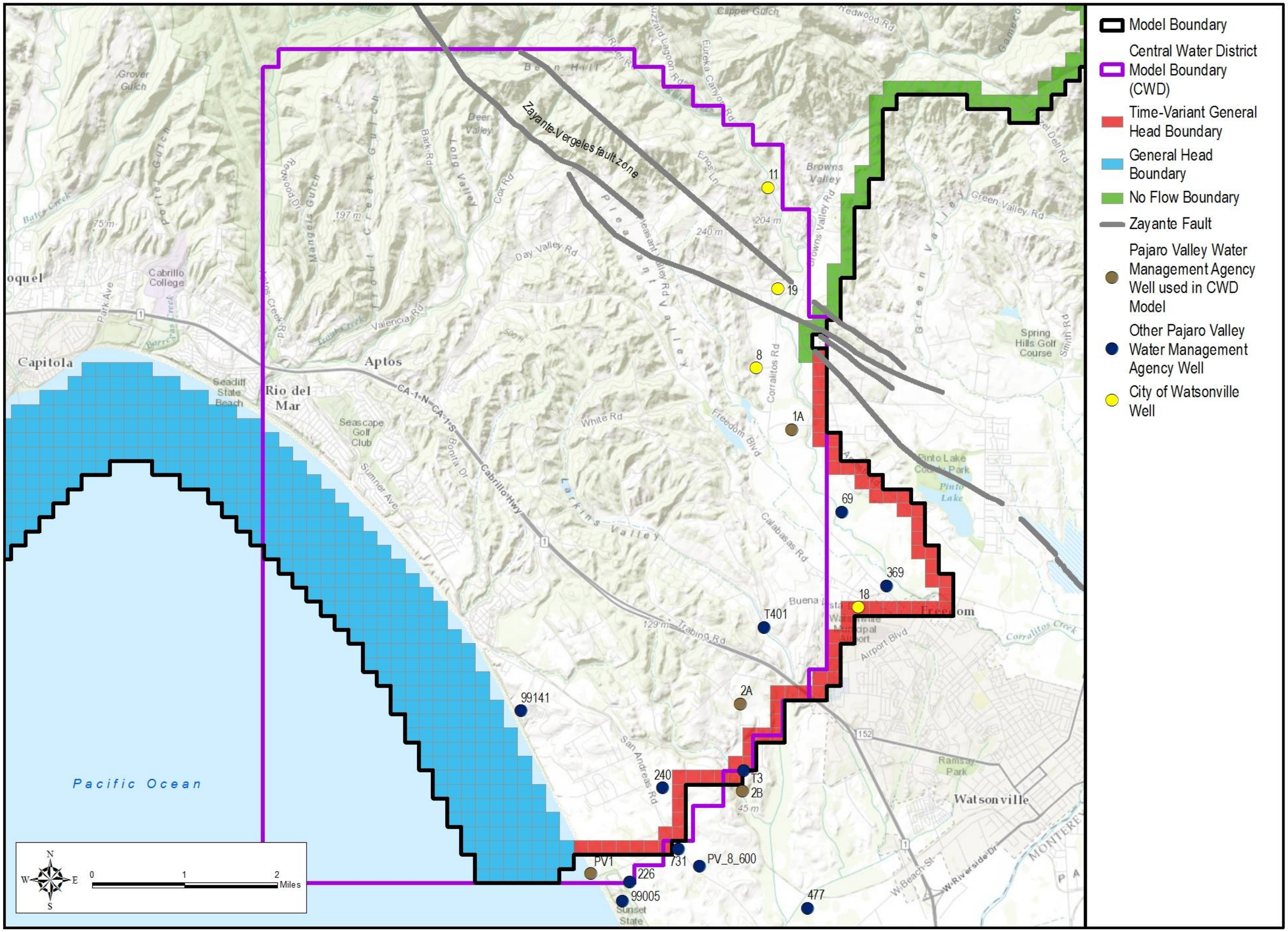


Figure 24: Southeastern Model Boundary

There may also be the need for boundary conditions in layer 9, the deepest active layer, to the west. As discussed in section 4.1, sediments in this layer west of the granitic high shown in Figure 4 may be more closely associated with the Santa Margarita basin and a boundary condition representing this association may need to be added. This will be evaluated as modeling proceeds.

6.0 NEXT STEPS

This memorandum will be reviewed by the model Technical Advisory Committee (TAC) and a meeting with the TAC and SAGMC member staff will be held by November 17, 2015 to discuss the memorandum and subsurface model construction. The next draft memorandums that will be produced are:

- A memorandum on estimates for non-agency water use and basinwide return flow (Task 2). This memorandum will be first reviewed by the SAGMC subcommittee on estimating private water use.
- A memorandum on construction of the PRMS watershed model (Task 2)

The above two memorandums will be provided to the TAC for review in advance of a meeting by early December 2015. Any necessary changes to the model setup based on TAC comments will be made and the model components discussed in the three memorandums will be integrated into a GSFLOW model. After integration, the following memorandums will mark project milestones.

- GSFLOW Integration (February 2016)
- Model Calibration (May 2016)
- Model Simulations of Groundwater Management Alternatives (July 2016)
- Integration of Seawater Interface Package and Seawater Intrusion Simulation (October 2016)

7.0 REFERENCES

ETIC Engineering, 2006, *Groundwater Modeling Study of the Santa Margarita Groundwater Basin, Scotts Valley Water District*. Prepared for Scotts Valley Water District. May.

HydroMetrics WRI, 2011, *Estimation of Deep Groundwater Recharge Using as Precipitation-Runoff Watershed Model, Soquel-Aptos, California*, prepared for Soquel Creek Water District, Central Water District, City of Santa Cruz, August.

HydroMetrics WRI, 2014, *Proposal for developing groundwater model,* Letter to Kim Adamson. July 10.

HydroMetrics WRI and Kennedy/Jenks, 2014, *Aromas and Purisima Basin Management Technical Study, Santa Cruz Integrated Regional Water Management Planning Grant Task 4*, prepared for Central Water District, March.

Johnson, N.M., D. Williams, E.B. Yates, and G.T. Thrupp, 2004, *Technical Memorandum 2: Hydrogeological Conceptual Model,* Prepared for Soquel Creek Water District, September.

Johnson, N.M. 2006. *Supplement to Hydrogeologic Conceptual Model,* technical memorandum to Clarke Wales, Central Water District, December.

Kennedy/Jenks Consultants, 2015, *Santa Margarita Groundwater Modeling Technical Study*. Prepared for Scotts Valley Water District. June.

Luhdorff and Scalmanini, Consulting Engineers, 1984, *Groundwater Resources and Management Report, 1983*, Soquel Creek Water District, January.

Soquel Creek Water District and Central Water District, 2007, *Groundwater management plan -2007 Soquel-Aptos area,* Santa Cruz County, California, April.

Todd Engineers, 1997, *Computer Modeling for Groundwater Management, Scotts Valley Groundwater Basin*. Prepared for Scotts Valley Water District. June.

U.S. Geological Survey (USGS), 1997, Geologic Map of Santa Cruz County, California, Open File Report 97-489.

USGS, 2004, Isostatic residual gravity map of The Santa Clara Valley and vicinity, California. Open-File Report 2004-1297.

Appendix A: List of Stratigraphic Unit Elevation Data

Well or Borehole	Elevation Interpolated from E-Log (feet above mean sea level)						
	Bottom Tu / top of Granite	Bottom TpAA	Bottom TpA	Bottom TpB	Bottom TpBC	Bottom TpD	Bottom TpDEF/F
Aptos Creek	--	--	--	--	--	-588.78	-423.78
Aptos School	--	--	--	--	--	--	--
Austrian Way	--	--	--	--	--	-365	-190
Cornwell	--	--	73	328	--	--	--
Estates	--	--	-845.7	-505.7	-370.7	-180.7	-10.7
Ledyard	--	--	--	-799.59	-659.59	-469.59	-299.59
Madeline	--	--	-897.92	-622.92	-487.92	-262.92	-117.92
Main St.	-614.5	-486.5	-116.5	--	--	--	--
Monte Toyon Test	--	--	--	--	-760	-580	-420
Opal #5 (Garnet)	--	-673	-208	2	--	--	--
Rosedale	--	--	--	2	132	--	--
T. Hopkins	--	--	--	--	--	-574.51	-404.51
Tannery	--	--	-486.48	-156.48	-61.48	--	--
O'Neill Test	-514	-409	11	256	--	--	--
SC-1A,B (Prospect)	--	--	-249.67	-40.67	--	--	--
SC-3A,B,C (Escalona)	--	--	-410	-180	-45	--	--
SC-5A,B,C,D,E (New Brighton)	--	--	-643	-388	-253	-73	87
SC-8A,B,C,D,E,F	--	--	--	-819.36	-689.36	-489.36	-324.36

Well or Borehole	Elevation Interpolated from E-Log (feet above mean sea level) Bottom Tu / top of Granite	Bottom TpAA	Bottom TpA	Bottom TpB	Bottom TpBC	Bottom TpD	Bottom TpDEF/F
(Aptos Crk)							
SC-9A,B,C,D,E (Seacliff)	--	--	-887	-607	-462	-282	-122
SC-10AA,A (Cherryvale)	-568.75	-428.75	-88.75	--	--	--	--
SC-11A,B,C,D	-841	-835	-530	-250	-120	90	260
SC-12	--	--	--	-1432	-1312	-1077	-912
SC-18A	-614	-486	--	--	--	--	--
SC-18AA	-614	-486	--	--	--	--	--
SC-22 Tu	-632	-517	-177	--	--	--	--
Rosedale	--	--	-273	--	--	--	--
Foster-Gamble	--	--	--	-164	-36	162	322
Anderson	0	--	-50	--	--	--	--
65GHR	--	--	--	256	382	--	--
Auto Plaza Drive	--	--	-129	--	--	--	--
Axford Rd	-640	-480	-50	--	--	--	--
Beltz #4	--	--	-73	--	--	--	--
Beltz #6 (TH-3)	--	-538	-138	--	--	--	--
Beltz #7 (TH-2)	--	--	-112	--	--	--	--
Beltz #8 (TH-3)	--	-538	--	--	--	--	--
Beltz #9 (TH-1)	--	--	-160	--	--	--	--

Well or Borehole	Elevation Interpolated from E-Log (feet above mean sea level) Bottom Tu / top of Granite	Bottom TpAA	Bottom TpA	Bottom TpB	Bottom TpBC	Bottom TpD	Bottom TpDEF/F
Coffey Lane	--	--	54	--	--	--	--
Beltz #12 Cory St	--	-415	10	--	--	--	--
Delaveaga Test	-25	15	--	--	--	--	--
Pleasure Pt A,B,C	--	--	-268.72	-58.72	--	--	--
SC TH-1 (57)	-581	-491	--	--	--	--	--
SC TH-2 (57)	-729	-676	--	--	--	--	--
SC TH-3 (57)	-119	-64	--	--	--	--	--
Thurber Lane Pump Sta	-246	-191	--	--	--	--	--
Thurber Lane (North)	-203	-158	--	--	--	--	--
Santa Margarita Test (TH-2)	-778	-683	-112	--	--	--	--
Soquel Point	--	--	-313	-63	--	--	--
Blake (O&G)	-2153	--	-2098	-1788	-1678	-1363	-1253
Carpenter (O&G)	-2748	--	-2613	-2188	-2078	-1778	-1678
J.H. Blake (O&G)	--	--	-2832	-2477	-2362	-2132	-1972
Light (O&G)	--	--	-2735	-2385	-2275	-2045	-1915
Pierce (O&G)	--	--	-2307	-2087	-1942	-1737	-1607
Leonardich (O&G)	--	--	--	-2645	-2530	-2300	-2165
Dicicco	--	--	--	-2470	-2340	-1950	-1820

Note: “-- “ indicates data for given stratigraphic interval is unavailable at that well or borehole

APPENDIX 2-E

SANTA CRUZ MID-COUNTY BASIN CONCEPTUAL MODEL UPDATE MEMORANDUM

HydroMetrics WRI

1814 Franklin St, Suite 501
Oakland, CA 94612

TECHNICAL MEMORANDUM

To: Ron Duncan

From: Sean Culkin, Cameron Tana

Date: March 31, 2017

Subject: Santa Cruz Mid-County Basin Conceptual Model Update

1. INTRODUCTION

In November 2015, HydroMetrics Water Resources Inc. (HydroMetrics WRI) prepared the *Soquel-Aptos Groundwater Flow Model: Subsurface Construction (Task 3)* technical memorandum (HydroMetrics WRI, 2015). This memorandum documented the development of the conceptual model, the hydrostratigraphy, and the subsurface boundary conditions for the Santa Cruz Mid-County Basin (Mid-County Basin or the basin) groundwater-surface water model (the model). In August 2016, HydroMetrics WRI submitted the *Santa Cruz Mid-County Basin Groundwater Model Boundaries Update* technical memorandum (HydroMetrics WRI, 2016), which is an addendum to the initial conceptual model document. Since August 2016, HydroMetrics WRI has made progress calibrating the surface water and groundwater components of the model, and as developed an integrated groundwater-surface water model using the GSFLOW model code.

This document serves as an addendum to both previous memorandums, and summarizes additional recent changes to the model. Calibration efforts have yielded insights into groundwater elevation distribution and dynamics within the basin that were not satisfactorily represented by the previously-presented conceptual model. Therefore, the changes to the conceptual model documented here have been incorporated into the simulated hydrostratigraphy of the basin to allow for a more comprehensive calibration to basinwide groundwater elevations.

2. CONCEPTUAL MODEL CHANGES

This section describes two general conceptual model changes applied to the basin and the model.

2.1. Fault Distribution within the Basin

Previous descriptions of the basin include one major fault, the Zayante Fault, which roughly bisects the model domain along a northwest-southeast trending line (Figure 1). This fault divides all layers of the groundwater model, including layers representing the Aromas Formation, Purisima Formation, and the composite hydrostratigraphic unit between the base of the Purisima Formation and the granitic base of the basin (HydroMetrics WRI, 2015). Following basin boundary modification in 2016, the Zayante Fault is also currently the northern boundary of the Santa Cruz Mid-County Basin. North of the Zayante Fault, there are no groundwater elevation observation points that have been added to the model, and the hydrostratigraphy of the area is considered to be "undifferentiated." South of the Zayante Fault, groundwater level observations can be evaluated in each aquifer or aquitard layer, which are each simulated by individual model layers.

Within the basin, relatively high seasonal or annual average groundwater elevations of 100 feet or more above mean sea level (MSL) exist at observation well locations clustered south of the Zayante Fault. Farther south of the fault in coastal areas, average groundwater elevations are closer to MSL, or below MSL in cases where groundwater has been depressed by pumping wells. Additionally, lateral groundwater gradients are relatively flatter in coastal areas than inland areas. This trend results in an area of relatively steep lateral groundwater gradients approximately 1.5 miles south of the Zayante Fault, as shown in groundwater elevation maps produced for the previous Central Water District (CWD) model (Figure 2). This trend is especially prevalent in units of the Purisima Formation (model layers 3 through 7), but general trends of higher-to-lower groundwater elevations from inland to coastal areas is observed throughout the basin.

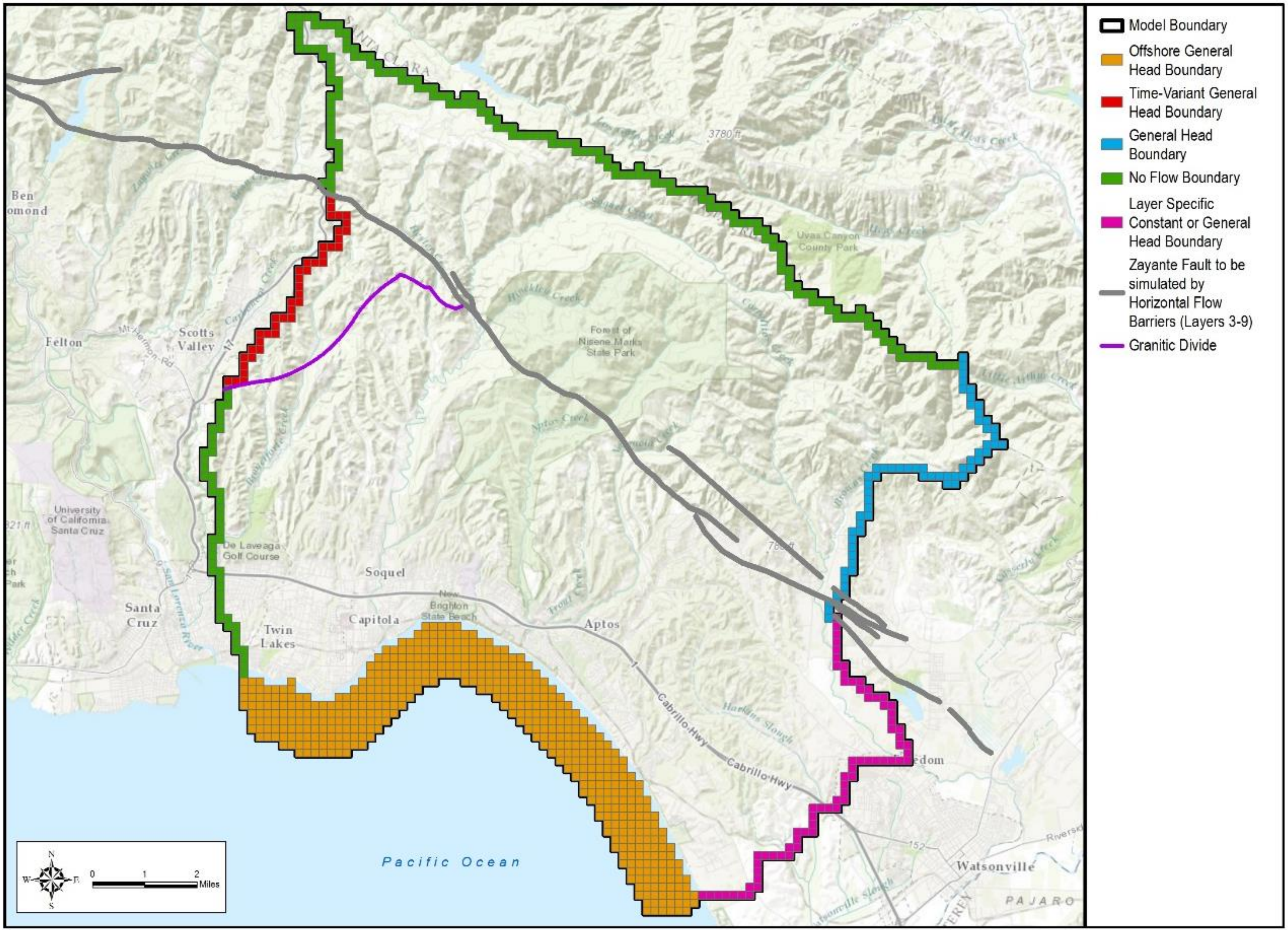


Figure 1: Summary of Model Domain Area and Boundaries (HydroMetrics WRI, 2015)

A similar area of steep lateral gradients was also evident in results from the groundwater model prepared for the CWD, documented in *Aromas and Purisima Basin Management Technical Study, Santa Cruz Integrated Regional Water Management Planning Grant Task 4* (HydroMetrics WRI, 2014). Figure 2 shows an example of simulated groundwater elevation contours in the Purisima formation with an area of steep groundwater gradient in the CWD service area south of the Zayante Fault. One step taken to achieve this simulated gradient in the calibration of the CWD model was to apply a relatively high range of hydraulic conductivity, where low conductivity areas result in steeper gradients by resisting lateral groundwater flow. Figure 3 shows the distribution of hydraulic conductivity values applied to the Purisima Formation in the CWD model, ranging over four to five orders of magnitude.

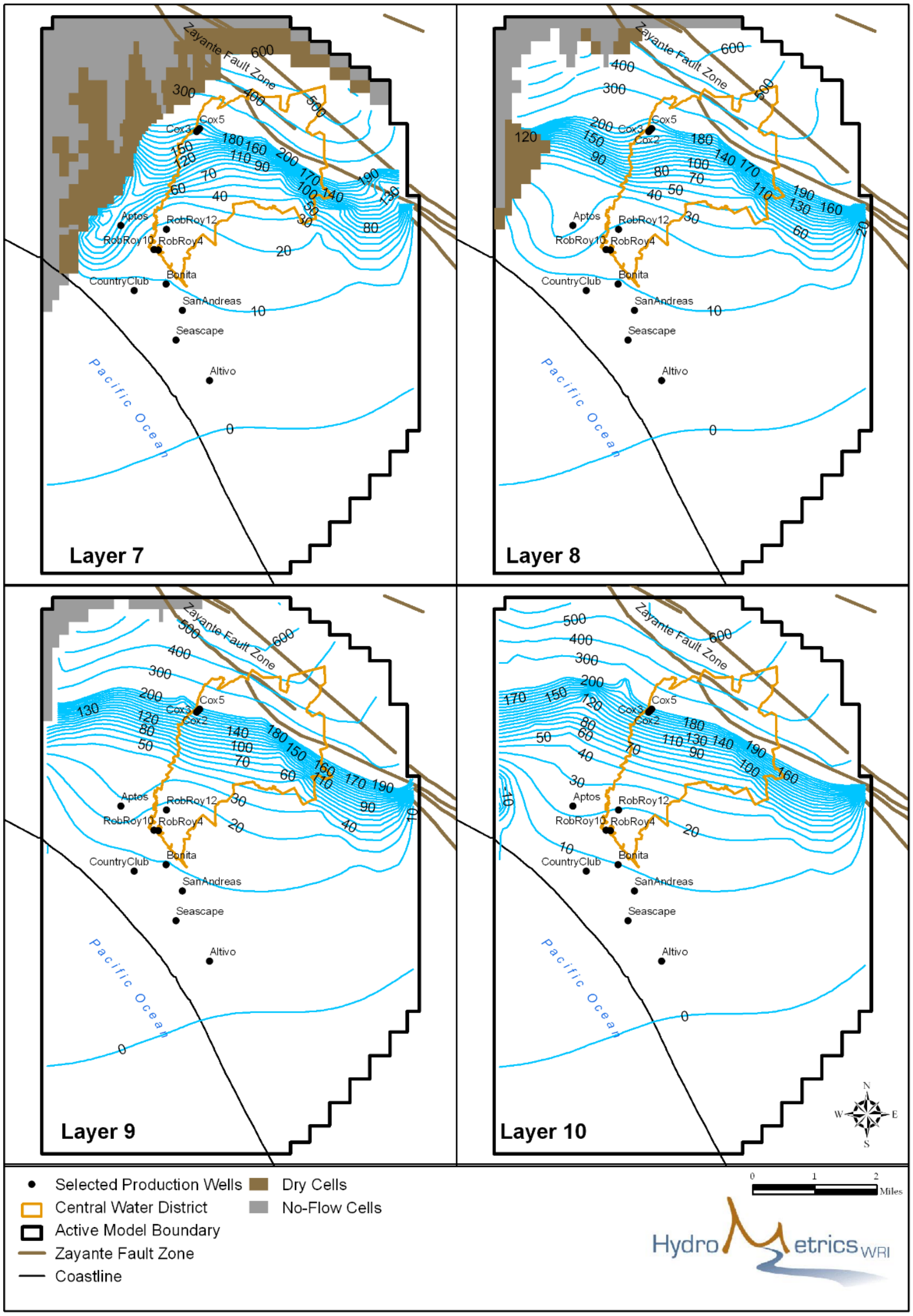


Figure 2: Simulated Groundwater Elevations (feet MSL) in Purisima Formation (HydroMetrics WRI, 2014)

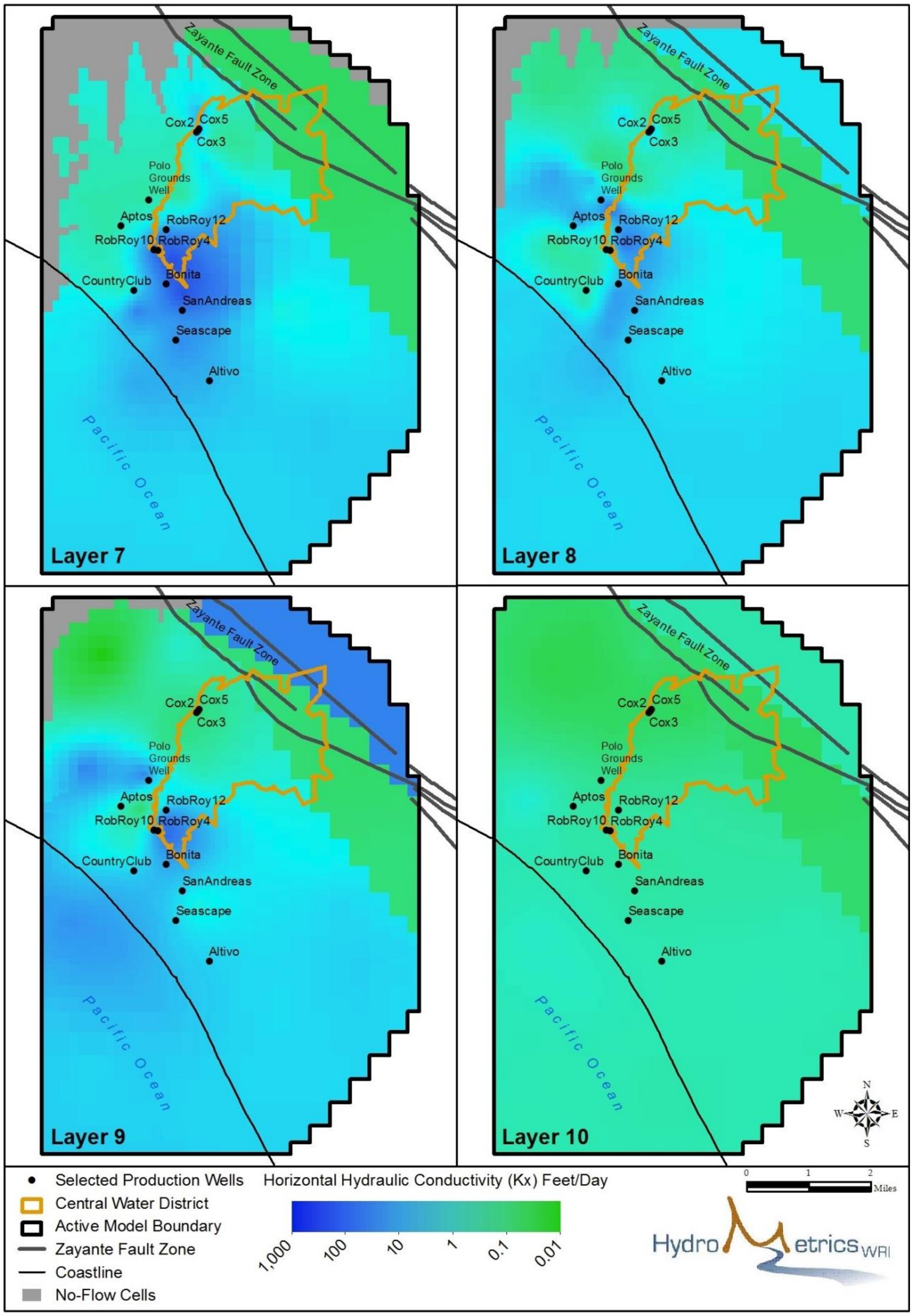


Figure 3: Horizontal Hydraulic Conductivity for Purisima Formation (HydroMetrics WRI, 2014)

To investigate alternatives to applying a large hydraulic conductivity range to simulated Purisima Formation layers within the Mid-County Basin model, HydroMetrics WRI investigated the potential for additional faulting in this area of the basin. Often, faulting can act as a barrier to groundwater flow due to lower conductivity clays within the fault, or by causing an abrupt change in formation conductivity across the fault. This can facilitate large changes in groundwater elevation on either side of the fault. Discussions with former Santa Cruz County geologist Mike Cloud led to our review of a U.S. Geological Survey (USGS) report of earthquakes and faults within the greater San Francisco Bay Area, including Santa Cruz county (USGS, 2004). This investigation indicates that, based on seismic activity in the area, there is evidence of some faulting south of the Zayante Fault within the domain of the Mid-County Model. HydroMetrics WRI has projected the location of the faults mapped by the USGS as shown in Figure 4. Although the mapped extent of this additional faulting is relatively limited in the USGS report, it generally corresponds with the area of steep groundwater gradients observed in the Mid-County Basin.

Academic thesis work performed in the 1950s has also yielded some evidence of additional faulting in this area of the basin. Alexander (1953) observed deformation of the marine terraces near Capitola between Aptos and Rio del Mar. This axis of deformation appears to have an east-west alignment similar to faulting found in the USGS report and inferred from regional groundwater elevation gradients.

Based on these studies and lines of evidence, HydroMetrics WRI added a second fault generally aligned with the data shown in the USGS report. This second fault is tentatively named the Aptos Fault. The simulated Aptos Fault is south of the Zayante Fault, and follows a similar northwest-southeast trend. For modeling purposes, the Aptos Fault extends through all Purisima Formation model layers, and extends from approximately the western outcrop of the Purisima Formation through the USGS-mapped fault zones. The location of the simulated fault in relation to the Zayante and USGS-mapped faults is shown in Figure 4.

Adding the Aptos Fault results in improved model fit to observed groundwater elevations north and south of the fault. HydroMetrics WRI will maintain this hydraulic flow barrier within the model domain through calibration of the model; the final conductance, position, and extent of the simulated fault will be presented in the report of final model calibration. We believe that based on the evidence available, a hydraulic flow barrier is preferable and more consistent with regional geology than assigning other hydraulic parameters such as hydraulic conductivity to achieve model calibration.

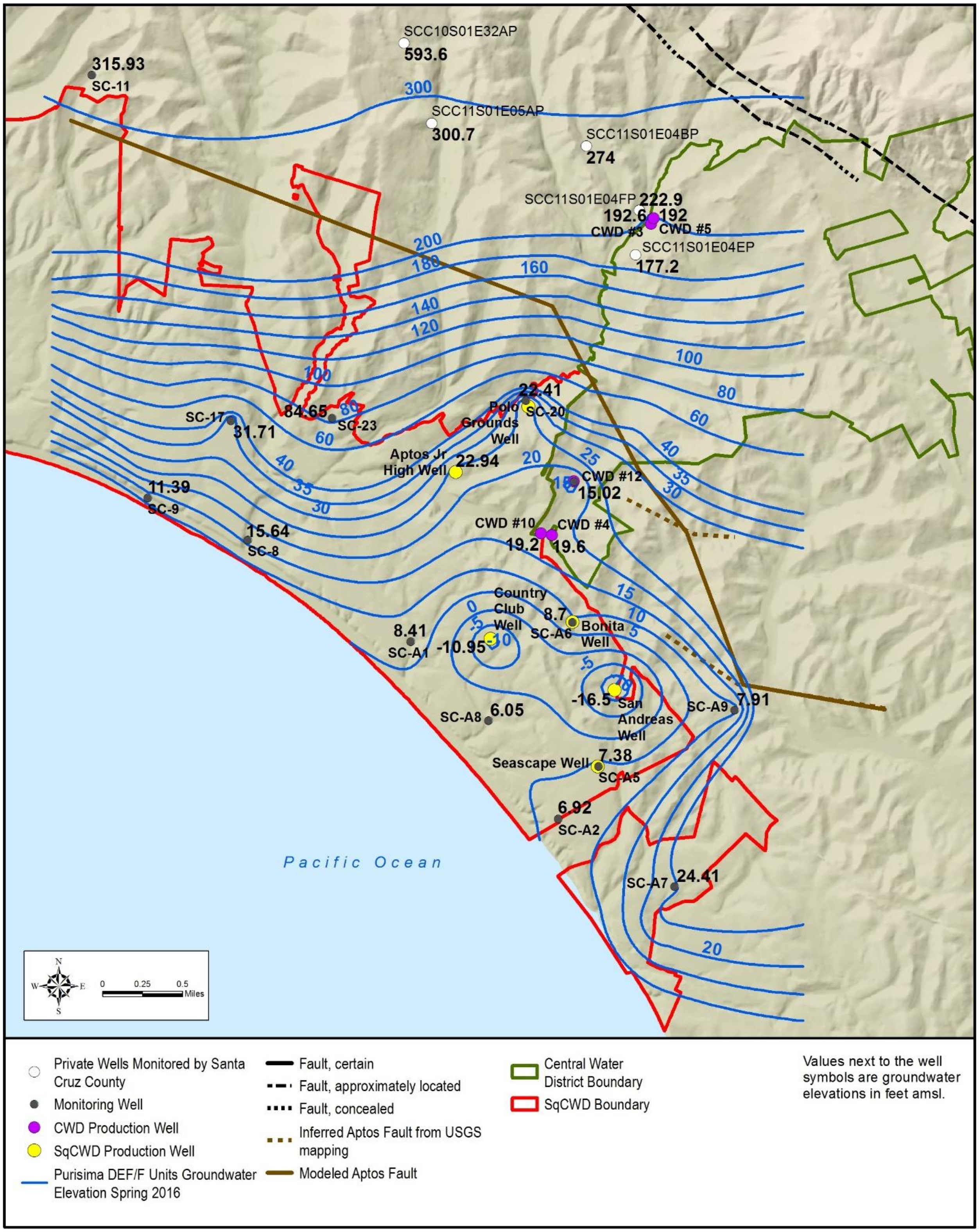


Figure 4: Faulting and Groundwater Elevations in the Aptos Area of the Santa Cruz Mid-County Basin

2.2. Pajaro Area Boundary Condition

The Mid-County Basin model contains a general head boundary (GHB) north of the Zayante Fault along the eastern boundary of the model domain near the service area of Pajaro Valley Water Management Agency (PVWMA; see blue line on Figure 1). This boundary is intended to allow an outlet for groundwater to flow east out of Mid-County Basin into the Pajaro Basin per the conceptual model of the shared boundary area (HydroMetrics WRI, 2015).

Few groundwater monitoring locations or estimates of groundwater elevation north of the Zayante Fault are available. However, through calibration we determined that assigning a relatively low general head value to this GHB boundary as described in the previous memo resulted in simulated heads north of the fault that are too low to maintain the relatively high heads observed south of the Zayante fault in the Purisima Formation. Reviewing the CWD model boundary conditions indicates that constant head conditions were applied to that model north of the Zayante Fault corresponding with Ryder Gulch (Figure 5). The head values applied to this boundary condition in the CWD model are relatively high, and exceed 200 feet MSL, corresponding with the relatively high elevation of discharging streams in this area.

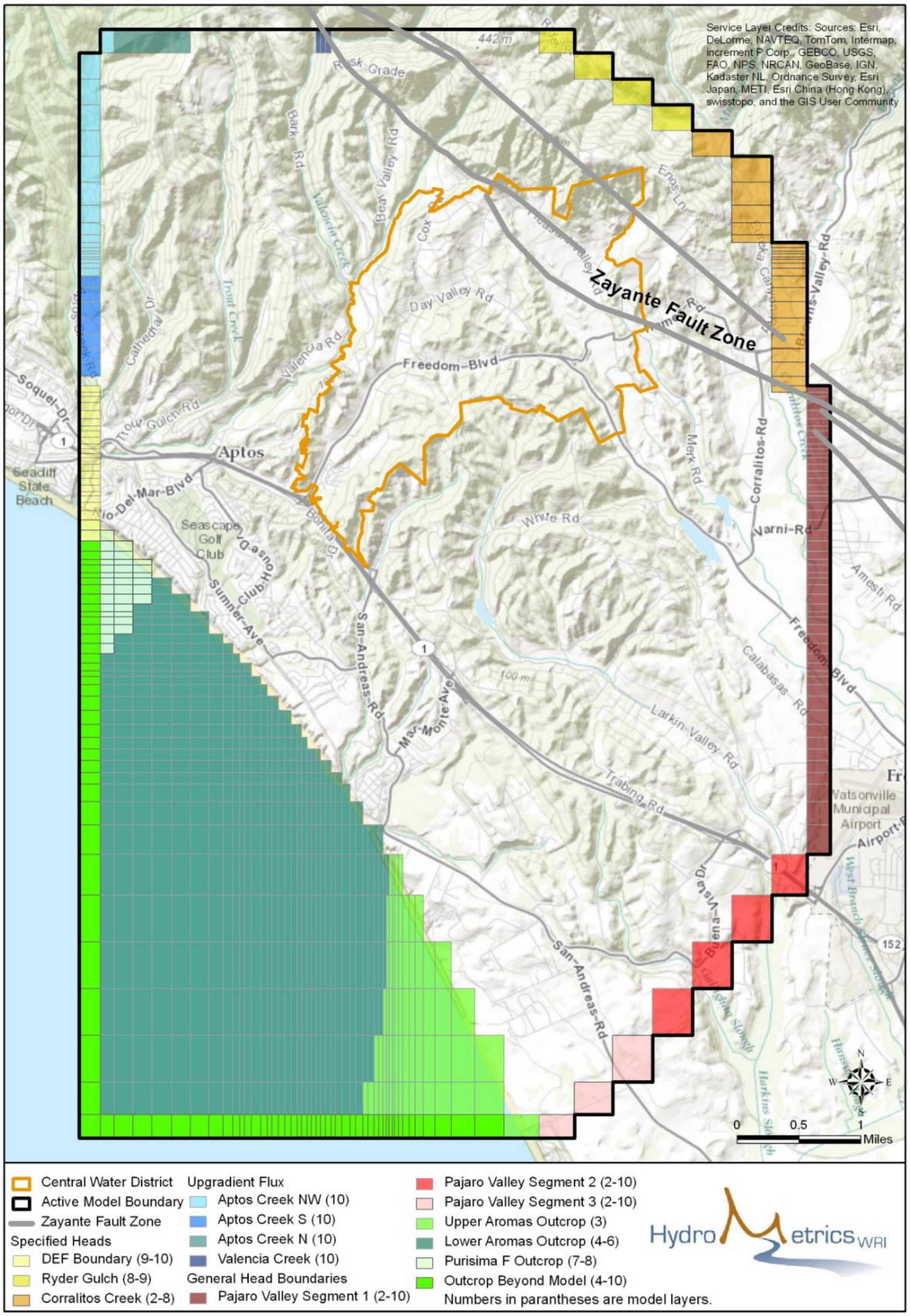


Figure 5: CWD Model Boundary Conditions (HydroMetrics WRI, 2014)

The GHB boundary of the Mid-County model has been updated to reflect higher general heads, consistent with previous modeling efforts. This has resulted in a more reasonable simulated groundwater elevation change across the Zayante Fault and has contributed to more accurately represented groundwater elevations at observation points south of the Zayante Fault. The final configuration of this boundary that results in the best fit to observed data will be presented following final calibration.

3. References

Alexander, C.S., 1953. The marine and stream terraces of the Capitola-Watsonville area. University of California Publications in Geography, v.10, p. 144.

HydroMetrics WRI, 2014. *Integrated Regional Water Management Planning Grant Task* Prepared for Central Water District. February.

HydroMetrics WRI, 2015. *Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction (Task 3)*. November.

HydroMetrics WRI, 2016. *Santa Cruz Mid-County Basin Groundwater Model Boundaries Update.* August.

Sleeter, B.M. et. al, 2004. *Earthquakes and Faults in the San Francisco Bay Area (1970-2003)*. U.S. Geological Survey Scientific Investigations Map 2848.

APPENDIX 2-F

SANTA CRUZ MID-COUNTY BASIN MODEL INTEGRATION AND CALIBRATION

September 6, 2019

Santa Cruz Mid-County Basin
Model Integration and Calibration

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY

GSP REVIEW DRAFT

Contents

Tables

Figures

Plates

Appendices

1 BACKGROUND

This report documents the calibration of the integrated surface water-groundwater model ("the model") of the Santa Cruz Mid-County Basin ("the Basin"). It also documents the linkages between the surface and groundwater processes within the model. The model simulates groundwater and surface water processes for a calibration period from Water Year 1984 through 2015, and will be used to project future Basin conditions to evaluate water management scenarios. These scenarios will support groundwater management alternatives for the Santa Cruz Mid-County Groundwater Agency (MGA), Pure Water Soquel (PWS) advanced purified groundwater replenishment, City of Santa Cruz aquifer storage and recovery (ASR) projects, and other water supply alternatives. This report follows and builds upon previous model documentation regarding conceptual model development and model input development referenced throughout the report.

The MGA provided funding for most of the model development, including calibration, but some tasks documented in this report were funded by Santa Cruz County's Prop 1 grant for counties with stressed basins. The tasks funded by the County's grant are identified in the report.

2 MODEL SOFTWARE SUMMARY

As documented in previous memoranda (HydroMetrics WRI, 2015; HydroMetrics WRI, 2016a), the model is built using the U.S. Geological Survey's (USGS) GSFLOW software, which is an integrated watershed-groundwater model (Makstrom *et al.*, 2008). USGS release 1.2.2 (Regan *et al.*, 2018) is used for the model. Figure 1 summarizes the relationship between groundwater and surface water processes implemented within GSFLOW. GSFLOW integrates the Precipitation-Runoff Modeling System (PRMS) watershed model code (Leavesley *et al.*, 1983) with the MODFLOW groundwater model code. PRMS simulates watershed flows (Region 1 on Figure 1), while MODFLOW simulates flow beneath the base of the soil zone within the three-dimensional aquifer system (Region 3). The MODFLOW Streamflow-Routing (SFR) package simulates flows in streams (Region 2).

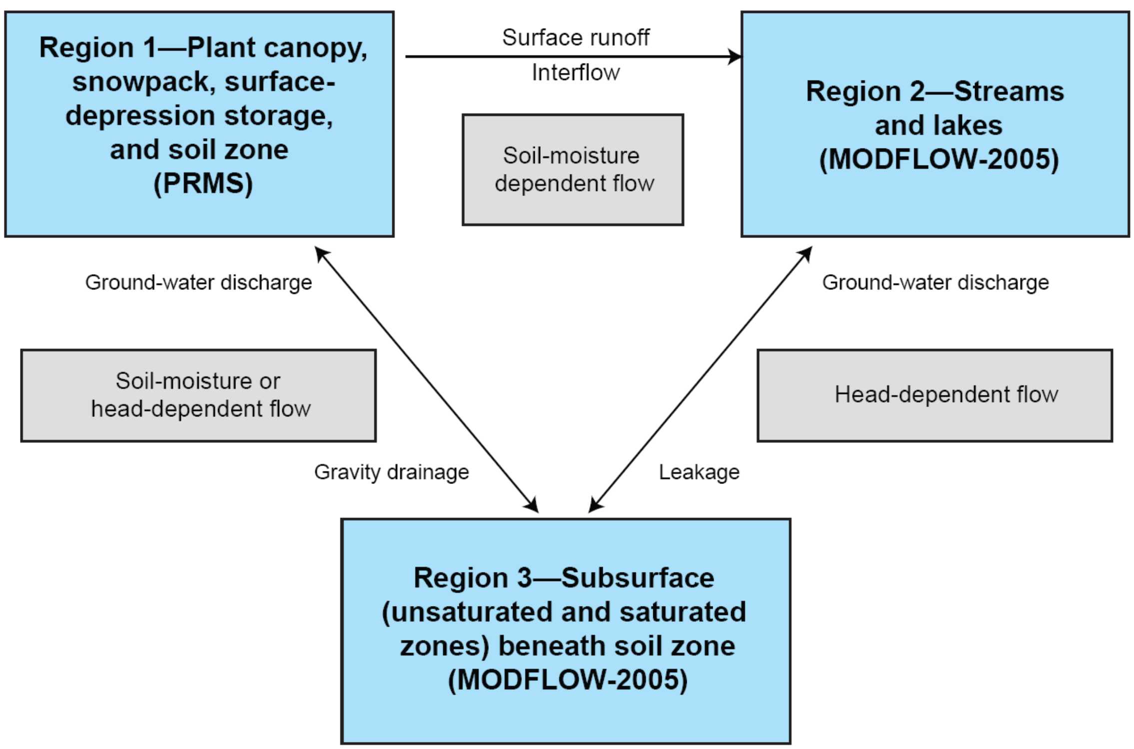


Figure 1. Diagram of Flow Exchange within GSFLOW Calculations Processes (Markstrom et. al., 2008)

Figure 2 provides more detail about watershed flows simulated by PRMS and the flows that integrate PRMS and MODFLOW in GSFLOW. PRMS uses climate inputs of precipitation and temperature, and simulates evapotranspiration, runoff and infiltration.

Figure 3 shows the different flow types in the soil-zone reservoir that are associated with parameters requiring calibration. The MODFLOW Unsaturated-Zone Flow (UZF) package is required to simulate groundwater recharge and discharge between the soil zone and the groundwater table. The MODFLOW SFR package receives runoff from PRMS and also calculates flows between streams and groundwater.

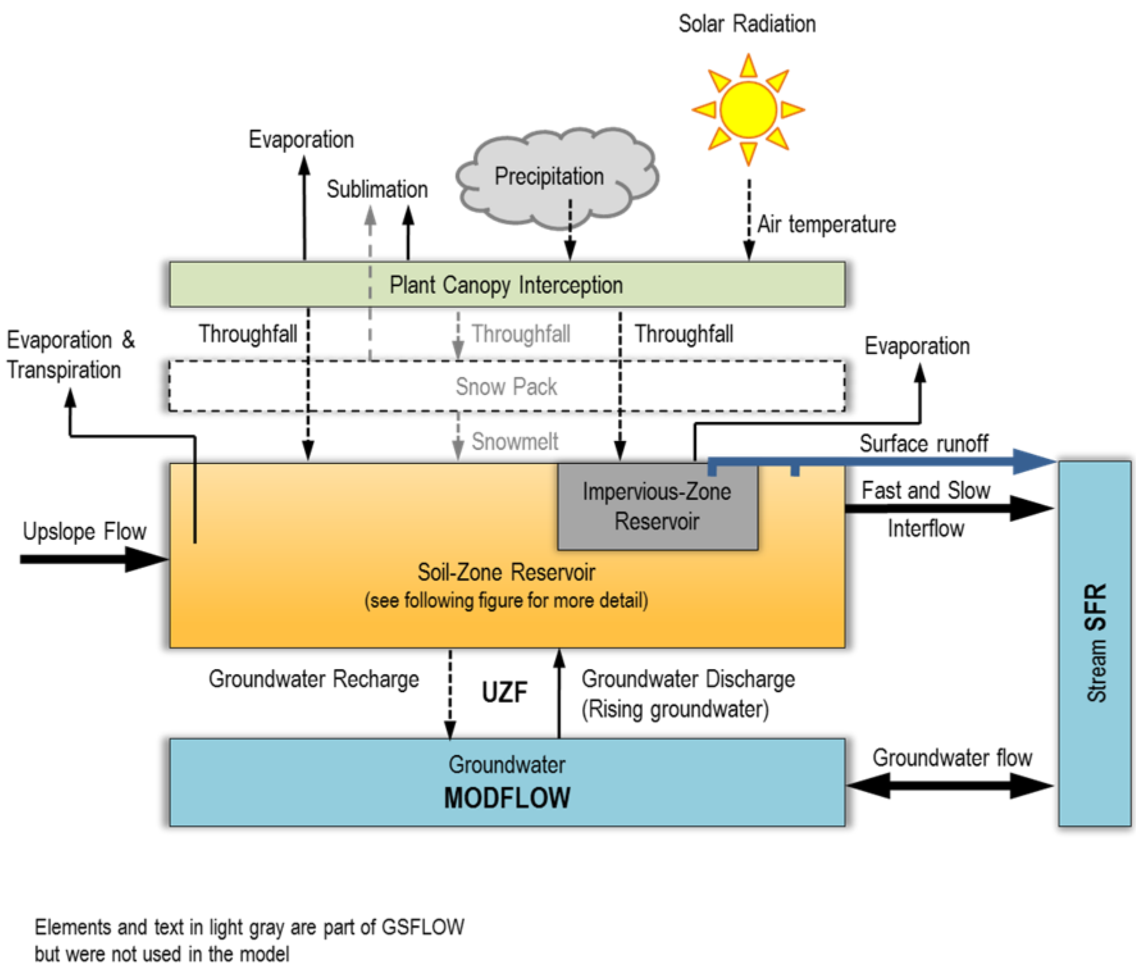


Figure 2. Summary of Watershed and Climate Inputs for GSFLOW

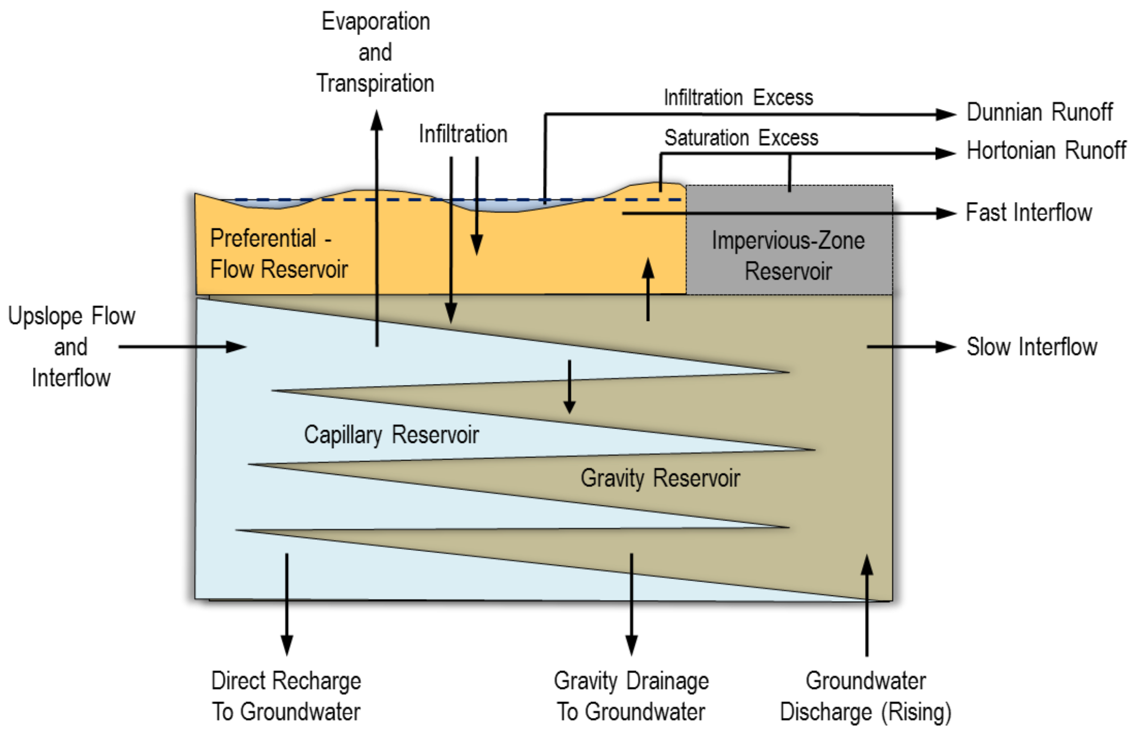


Figure 3. Soil-Zone Reservoirs Inflows and Outflows

3 MODEL CONSTRUCTION

This section summarizes the construction of the Santa Cruz Mid-County Basin groundwater-surface water model ("the model").

3.1 Model Domain

As described in the *Santa Cruz Mid-County Basin Groundwater Flow Model: Precipitation-Runoff Modeling System Setup (Task 2)* memorandum (HydroMetrics WRI, 2016), the model domain covers the watershed area that potentially contributes flow to the stacked aquifer units of the Santa Cruz Mid-County Basin. This includes the Basin area along with portions of adjacent basins including the Santa Margarita Basin, the Purisima Highlands Subbasin, and the Pajaro Valley Subbasin (Figure 4). The western boundary of the model domain is the boundary of the Carbonara Creek and Branciforte Creek watersheds, which approximates the westernmost outcrop of the major aquifers in the Santa Cruz Mid-County Basin. The northern watershed boundary of the model approximately follows Summit Road and Loma Prieta Avenue for a distance of about 17 miles along a northwest to southeast alignment. The eastern boundary of the model follows the eastern boundary of the Corralitos Creek watershed. This boundary is farther east than necessary for encompassing the entire area that likely contributes flow to the Santa Cruz Mid-County Basin; but using this boundary allows the model to include the Corralitos Creek stream gauge at Freedom (Figure 5) which is the only active gauge on Corralitos Creek.

The southern boundary of the model extends approximately one mile offshore, parallel to the coastline. This allows for contact of outcropping Purisima and Aromas Formation units with the seafloor that serves as a density corrected head boundary condition and a potential source of seawater intrusion. The one mile offshore length is also longer than the cross-sectional models that were originally designed to evaluate protective groundwater elevations. Offshore distances of up to 3,500 feet ensured that the simulated freshwater-salt water interface did not intersect the end of the model (HydroMetrics LLC, 2009)

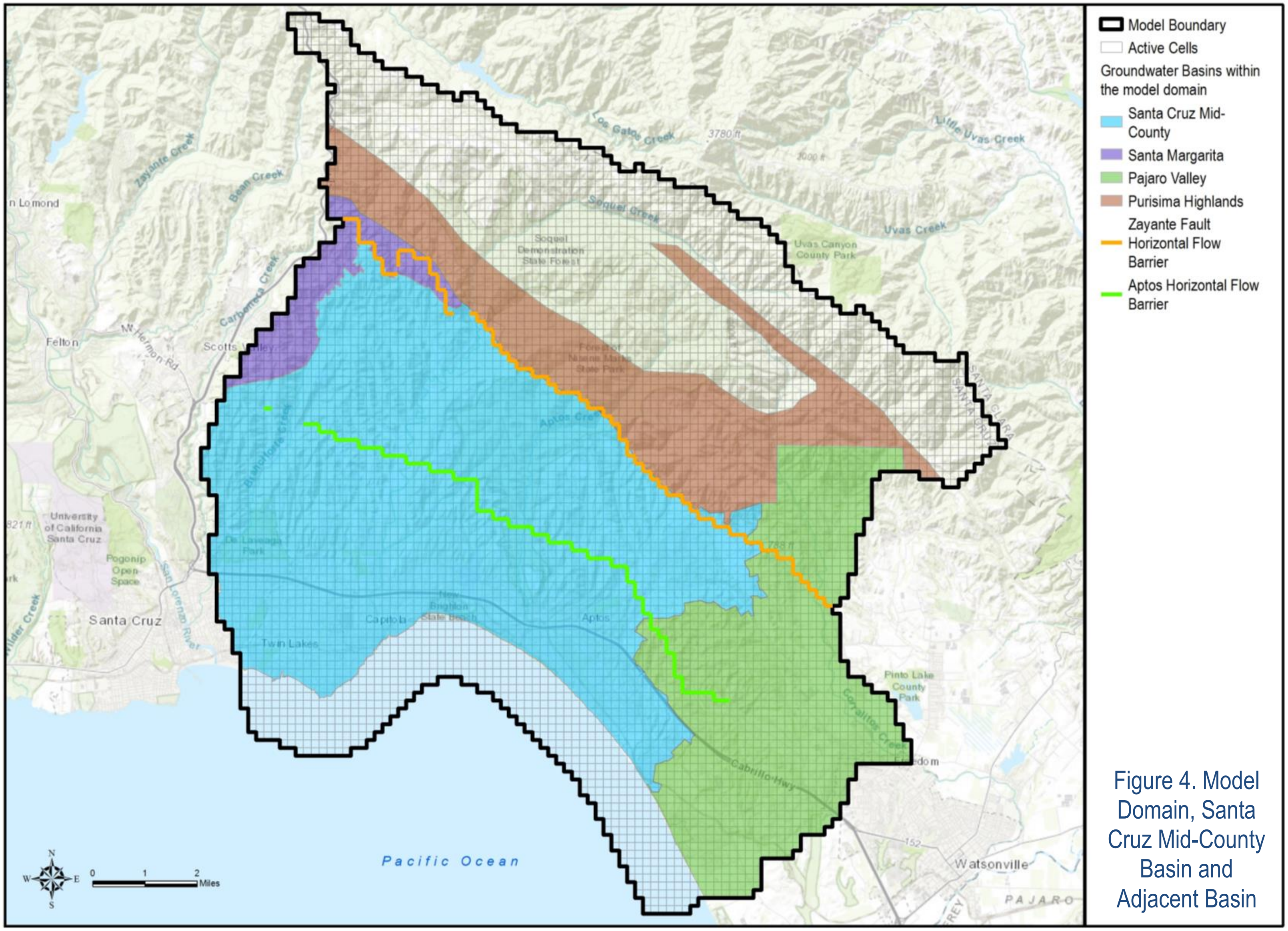


Figure 4. Model Domain, Santa Cruz Mid-County Basin and Adjacent Basin

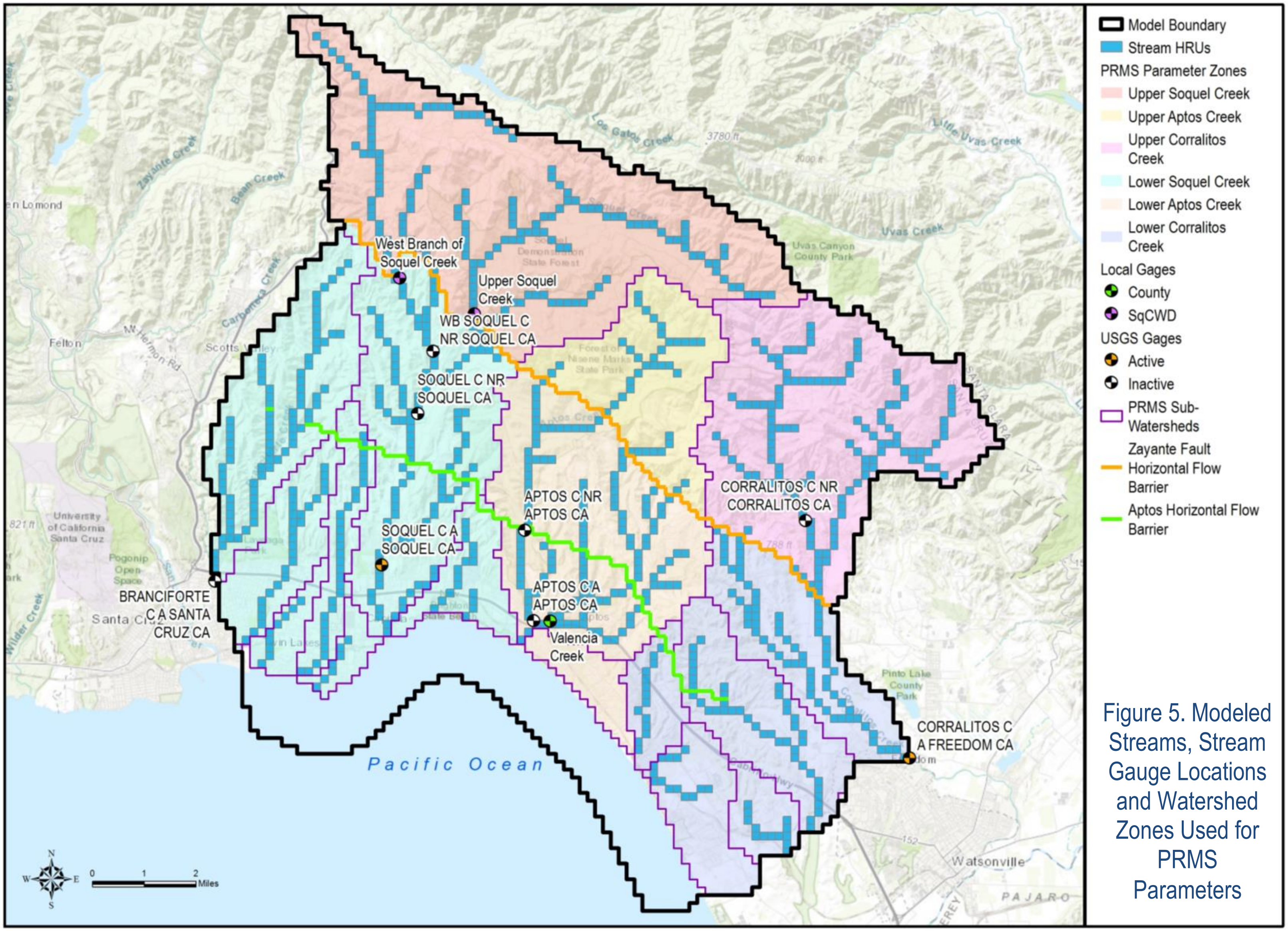


Figure 5. Modeled Streams, Stream Gauge Locations and Watershed Zones Used for PRMS Parameters

3.2 Model Discretization

Both the MODFLOW portion and the PRMS portion of GSFLOW must be discretized. As described previously (HydroMetrics WRI, 2016a), PRMS requires that the model area be divided into discrete units that are assigned physical characteristics such as slope, aspect, elevation, vegetation type, soil type, land use, and precipitation. These units are called hydrologic response units (HRU). Daily water and energy balances are calculated for each HRU, and the sum of these area weighted responses for all HRUs results in the daily watershed response for the model area.

The US Geological Survey recommends that the discretization of PRMS HRUs match the discretization of MODFLOW model cells. Therefore, the model has been discretized into a uniform rectilinear grid of 800 by 800 foot HRUs that overlay a groundwater model grid including 135 rows and 105 columns of cells with the same dimensions. A grid size of 800 feet is the largest grid size that best preserved finer scale elevation distributions across the study area (HydroMetrics WRI, 2016a).

Figure 5 illustrates how stream reaches were assigned to model HRUs and the MODFLOW SFR package.

3.3 Model Layering

The layering of the MODFLOW model follows the conceptual model of stacked aquifer units in the Basin described in previous documents, notably the *Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction (Task 3)* technical memorandum (HydroMetrics WRI, 2015). This conceptual model draws heavily on work by Johnson *et al.* in the *Technical Memorandum 2: Hydrogeologic Conceptual Model* (2004), as well as input from former Santa Cruz County geologist, Mike Cloud.

Model layers 2 through 9 represent the stacked hydrostratigraphic units of the Santa Cruz Mid-County Basin. Model layer 2 primarily represents the Aromas Red Sands Formation. Model layers 3-8 primarily represent aquifer and aquitard units of the Purisima Formation. Model layer 9 represents the unit underlying the Purisima Formation, referred to by Johnson *et al.* (2004) as the Tu unit. Table 1 shows the relationship between model layers and hydrostratigraphic units. Plate 1 shows thicknesses of model layers for aquifer units and Figure 6 shows thicknesses of model layers for aquitard units. These figures also illustrate how the model layer outcrops pinch out to the west.

Stream alluvium and Terrace Deposits are represented in model layers 1-8 overlying the layers of the aquifer and aquitard units where they outcrop.

Table 1. Model Layers and Hydrostratigraphic Units

Model Layers	Hydrostratigraphic Unit	Aquifer/Aquitard
1-8	Stream Alluvium	N/A
1-8	Terrace Deposits	N/A
2	Aromas Red Sands	Aquifer
3	Purisima F and DEF	Aquifer
4	Purisima D	Aquitard
5	Purisima BC	Aquifer
6	Purisima B	Aquitard
7	Purisima A	Aquifer
8	Purisima AA	Aquifer
9	Tu	Aquifer

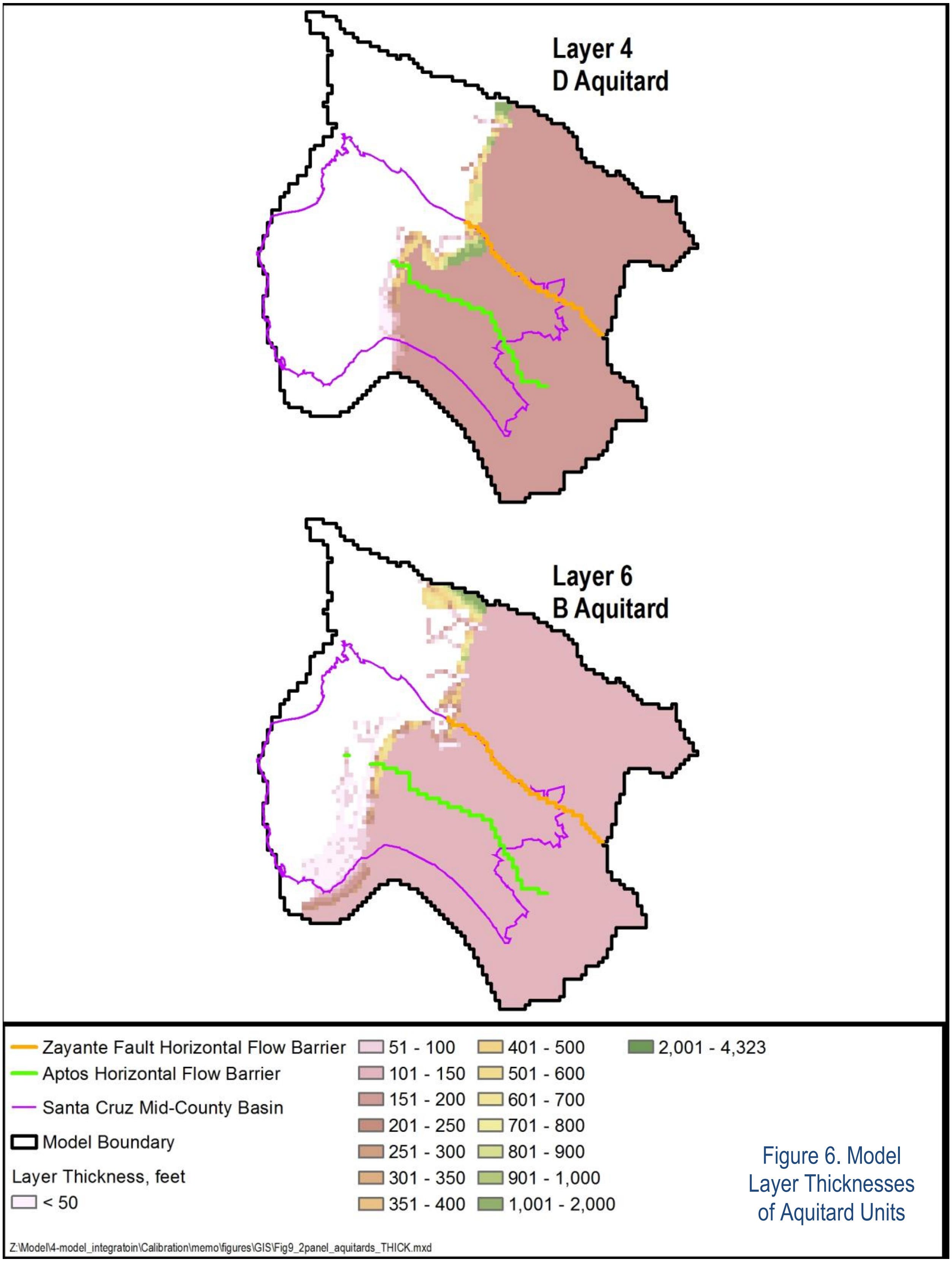


Figure 6. Model Layer Thicknesses of Aquitard Units

3.4 PRMS Modules Used to Calculate Watershed Flows

PRMS uses different modules to simulate various water and energy processes in the watershed. The modules selected for the Santa Cruz Mid-County Basin GSFLOW model were based on the availability of data and appropriateness for local conditions. Modules used are summarized in Table 2.

Table 2: PRMS Modules used to Calculate Watershed Flows in Santa Cruz Mid-County Basin GSFLOW Model

Module Name	Module Description
basin	Defines shared watershed-wide and HRU physical parameters and variables
cascade	Determines computational order of the HRUs and groundwater reservoirs for routing flow downslope
soltab	Computes potential solar radiation and sunlight hours for each HRU for each day of the year
temp_laps	Distributes maximum and minimum temperatures to each HRU using temperature data measured at least two temperature stations at different elevations, based on an estimated lapse rate between pairs of stations
precip_1sta	Determines the form of precipitation and distributes it to each HRU using on the basis of a measured value of precipitation and parameters used to account for elevation, spatial variation, topography, gauge location, and deficiencies in gauge catch
ddsolrad	Distributes solar radiation to each HRU and estimates missing solar radiation data using a maximum temperature per degree-day relation
transp_tindex	Computes transpiration using a temperature index that is the cumulative sum of daily maximum temperature for each HRU after the model reaches the transpiration starting month. The period of transpiration for each HRU ends when the simulation reaches the month specified
potet_pt	Computes the potential evapotranspiration by using the Priestley-Taylor formulation (Priestley and Taylor, 1972). Revised formulation in GSFLOW 1.2.2 (Regan *et al.*, 2018) used instead of Jensen-Haise formulation used in previous versions of the Basin model because Priestley-Taylor more appropriate for hotter temperatures of future climate scenarios (Milly and Dunne, 2011)
intcp	Computes volume of intercepted precipitation, evaporation from intercepted precipitation, and throughfall that reaches the soil or snowpack
srunoff_smidx	Computes surface runoff and infiltration for each HRU using a non-linear variable-source-area method allowing for cascading flow
soilzone	Computes inflows to and outflows from soil zone of each HRU and includes inflows from infiltration, groundwater, and upslope HRUs, and outflows to gravity drainage, interflow, and surface runoff to downslope HRUs

3.5 MODFLOW Packages Used to Calculate Groundwater Flows

MODFLOW uses modular packages for simulating different aspects of groundwater flow. The MODFLOW packages selected for the Santa Cruz Mid-County Basin GSFLOW model were based on GSFLOW requirements and consistency with the conceptual model for the Basin.

Table 3. MODFLOW Packages used to Calculate Groundwater Flows in Santa Cruz Mid-County Basin GSFLOW Model

Package Name	Package Input Use
Basic (BAS)	Defines active cells and initial heads
Discretization (DIS)	Defines model discretization and layer elevations
Upstream Weighted Flows (UPW)	Defines groundwater flow parameters
Newton-Raphson Solver (NWT)	Defines numerical solver settings
Multi-Node Well (MNW2)	Defines pumping and recharge by well and package calculates well flows by layer
Stream Flow Routing (SFR)	Defines stream routing and package calculates stream flows based on runoff and groundwater interaction
Time-Variant Specified Head (CHD)	Defines transient specified heads
General Head Boundary (GHB)	Defines head dependent boundaries with associated conductance
Horizontal Flow Barrier (HFB)	Defines low conductance resulting from Zayante Fault and faulting in Aptos area
Unsaturated Zone Flow (UZF)	Defines parameters from flow from soil zone to groundwater

3.5.1 Specified Head Boundary Condition Assignment (CHD)

Specified head boundary conditions were used to simulate the interaction between the Santa Cruz Mid-County Basin and the adjacent Pajaro Valley. HydroMetrics WRI (2015) described how head values for the Constant Head (CHD) package were assigned to layers 2 and 3, representing the Aromas Red Sands and Purisima F and DEF units, along the boundary with the Pajaro Valley Subbasin south of the Zayante Fault. This boundary does not represent a naturally-occurring hydraulic barrier. Transient specified heads were based on available PVWMA groundwater level data, with added seasonal variation. This was the same approach used to develop a similar boundary condition for the Central Water District (CWD) groundwater model (HydroMetrics WRI and Kennedy Jenks, 2014). Plate 2 shows average specified heads for this boundary condition.

3.5.2 General Head Boundary (GHB) Condition Head Assignment

General head boundaries (GHB) simulate flows between the Basin and the ocean, flows between the model and the adjacent Santa Margarita Basin, and flows between the model and the adjacent Pajaro Valley Subbasin. Plate 2 shows the location of the GHB cells in different model layers. GHB conditions are assigned along the western model boundary in the following locations:

- The western model boundary in the Santa Margarita Basin;
- The eastern boundary in the Pajaro Valley Subbasin north of the Zayante Fault;
- The southeastern boundary in the Pajaro Valley Subbasin south of the Zayante Fault for layers 5, 7, and 8 representing Purisima BC, A, and AA aquifer units;
- The offshore model boundary; and
- Offshore cells within the model domain where model layers outcrop below Monterey Bay.

Heads assigned to the western boundary in the Santa Margarita Basin are based on long-term groundwater level trend data from Scotts Valley Water District wells as described in HydroMetrics WRI (2016b). Heads assigned to the eastern boundary north of the Zayante Fault are based on groundwater level used in the CWD model corresponding with the relatively high elevation of discharging streams in the Ryder Gulch watershed as described in HydroMetrics WRI (2017a).

Heads for the southeastern boundary condition in the Purisima BC, A, and AA aquifer units are based on the head of the nearest offshore general head boundary cell. There are little available data in these deeper units and limited pumping or other stress in the Pajaro Valley Subbasin. Therefore, the heads reflect the nearest boundary condition of Monterey Bay.

Heads assigned for the offshore boundary condition at the edge of the model assume that groundwater is fully saline one mile offshore. The heads therefore are the density corrected freshwater equivalent heads based on the average depth below sea level of the model cell.

The heads assigned for the general head boundary condition where model cells outcrop are based on the saline water of Monterey Bay overlying the outcrop. The heads therefore are the density corrected freshwater equivalent heads based on the depth below sea level of the top of the model cell. Plate 2 shows heads assigned to the general head boundaries by layer.

3.5.3 Horizontal Flow Barriers (HFBs) for Faulting

Horizontal flow barrier boundaries represent faulting that reduce horizontal groundwater flow. The Zayante Fault is well mapped on geologic maps and defines the northern boundary of the Basin. Less well mapped is faulting in the Aptos area, but as discussed in HydroMetrics WRI (2017a), evidence of faulting south of the Zayante Fault and steep groundwater gradients support the implementation of a horizontal flow barrier through the Aptos area as shown on Plate 2.

3.5.4 Unsaturated-Zone Flow (UZF)

GSFLOW requires use of the MODFLOW UZF package, which simulates groundwater flow within the unsaturated zone (Hughes *et al.*, 2012). However, the version of the calibrated model presented herein does not explicitly simulate unsaturated zone flow. The infiltration to groundwater as calculated by GSFLOW is applied directly to the saturated zone of the groundwater flow domain. Observations made during calibration, as well as investigations of the connectivity of shallow and deep groundwater within the Basin (HydroMetrics WRI, 2017b), indicated that there was sufficient disconnect between unsaturated parts of the groundwater model, such as stream alluvium and Terrace Deposits, and the productive groundwater aquifers of the Aromas Red Sands, Purisima, and Tu units such that simulating unsaturated flow is not critical for achieving acceptable calibration. Removing unsaturated zone flow from the model process also significantly reduces computational time and resources, which was beneficial to the calibration process requiring large numbers of model runs.

The US Geological Survey also modified the UZF package to allow specification of return flow to be added to the subsurface below the soil zone, which is applied directly the saturated zone for the calibrated model. This was a critical modification for simulating septic return flows. This modification is available in GSFLOW release 1.2.2 (Regan *et al*., 2018).

4 MODEL INPUT DATA

This section describes the hydrologic and geologic data used in the model calibration process.

4.1 Precipitation and Recharge

Recharge to the groundwater portion of the model is controlled by processes within GSFLOW as summarized in Figure 2 and Figure 3, as well as the GSFLOW documentation (Markstrom *et al*., 2008).

Precipitation is spatially distributed across the GSFLOW model domain using the precip_1sta module in PRMS. This module uses a combination of spatial and temporal data is used from DAYMET, a database of gridded daily weather parameters for North America. Using this module, DAYMET's mean monthly precipitation distributions (Thornton *et al*., 1997; Thornton *et al*., 2014) are used to spatially distribute daily precipitation values observed at the National Weather Service (NWS) Santa Cruz Cooperative Observer Network (COOP) and Watsonville Water Works weather stations to the model HRUs. Figure 7 illustrates the spatial distribution of DAYMET mean annual precipitation across the model domain, and also shows the areas where simulated rainfall is based on daily values at the Watsonville Water Works station or the Santa Cruz station.

Temperature is spatially distributed across the GSFLOW model domain using the temp_laps module in PRMS. This module assigns temperature data to different elevations. Observed daily minimum and maximum temperatures from the Santa Cruz Co-op station are used for a lower elevation station. Daily temperature values from DAYMET are used to represent temperatures at a location near the ridgeline for upper elevation temperatures.

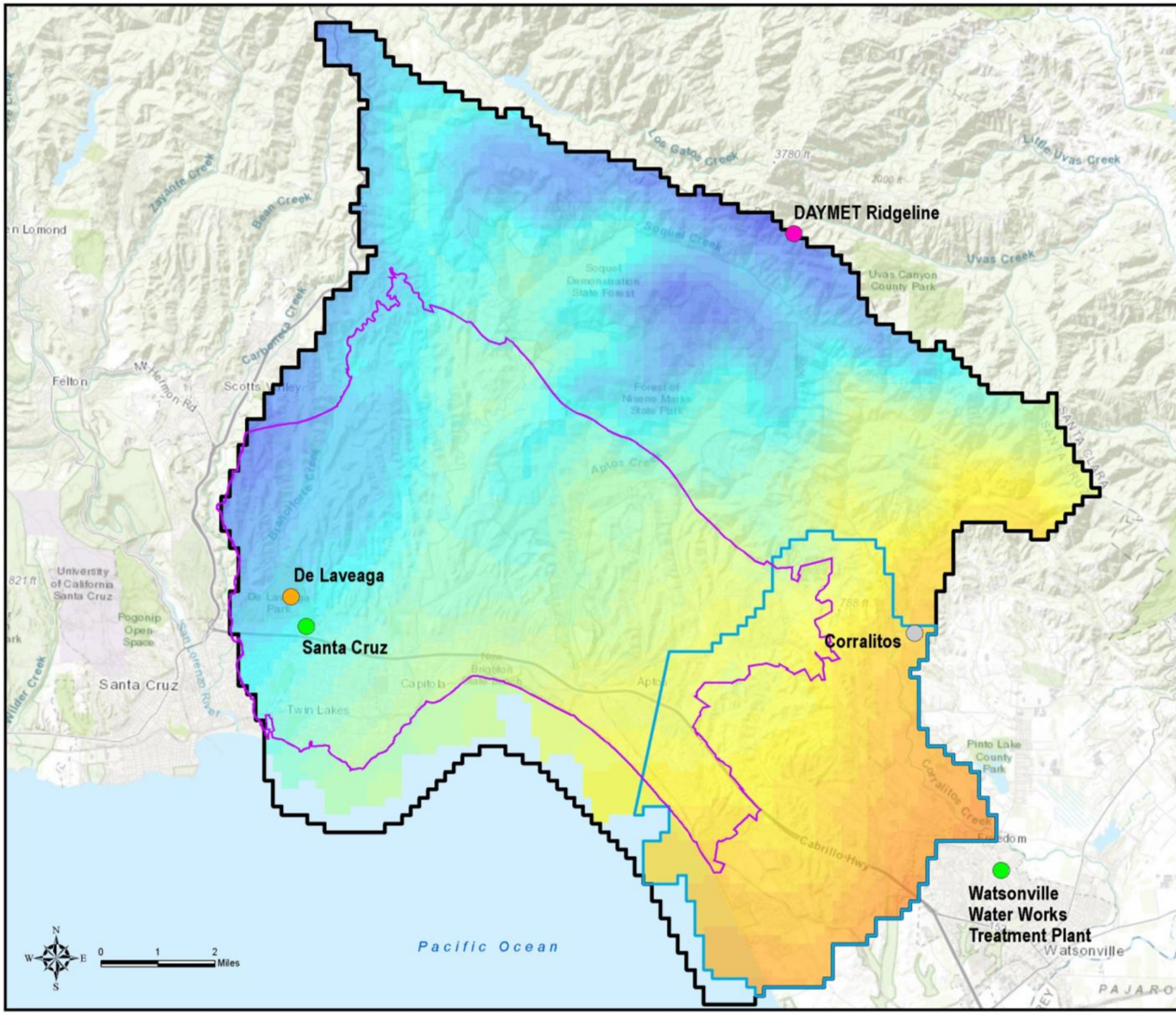


Figure 7: Climate Stations and Spatial Distribution of DAYMET Mean Annual (1981 – 2010) Precipitation Mapped to Model HRUs

4.2 Watershed Parameter Data

Data inputs to the PRMS component of the model include spatial data related to the physical environment such as elevation, slope, aspect, geology, soil type, land use, and vegetation type and density. As described in detail in HydroMetrics WRI (2016a), the following GIS datasets are mapped to HRUs:

- 10 meter resolution digital elevation model (DEM), with derived slope and aspect (National Elevation Dataset, 2015),
- USGS National Hydrography Dataset (NHD)) for streams and creeks,
- LANDFIRE vegetation type and density distributions (LANDFIRE, 2010), and
- SSURGO soils data of percent sand, silt, clay, and available water holding capacity (USDA, 2012).
- Percent impervious from the 2011 National Land Cover Database (Homer et al., 2015)

Maps showing the distribution across the model for most of these datasets are included in HydroMetrics WRI (2016a). Additional mapped distributions for vegetation type (Figure 8), summer vegetation density (Figure 9), winter vegetation density (Figure 10), and percent impervious (Figure 11) are provided in this report for completeness.

HRU-to-HRU connections, PRMS cascade parameters, and stream locations were computed from the DEM using the Cascade Routing Tool (CRT) (Henson *et al.*, 2013). CRT was iteratively executed to optimize stream locations and connections relative to NHD streamlines. Sub-watersheds were delineated according to stream gauge locations and primary tributary confluences and attributed to model stream cells with stream segment and reach identifiers used in the MODFLOW SFR package (Figure 5).

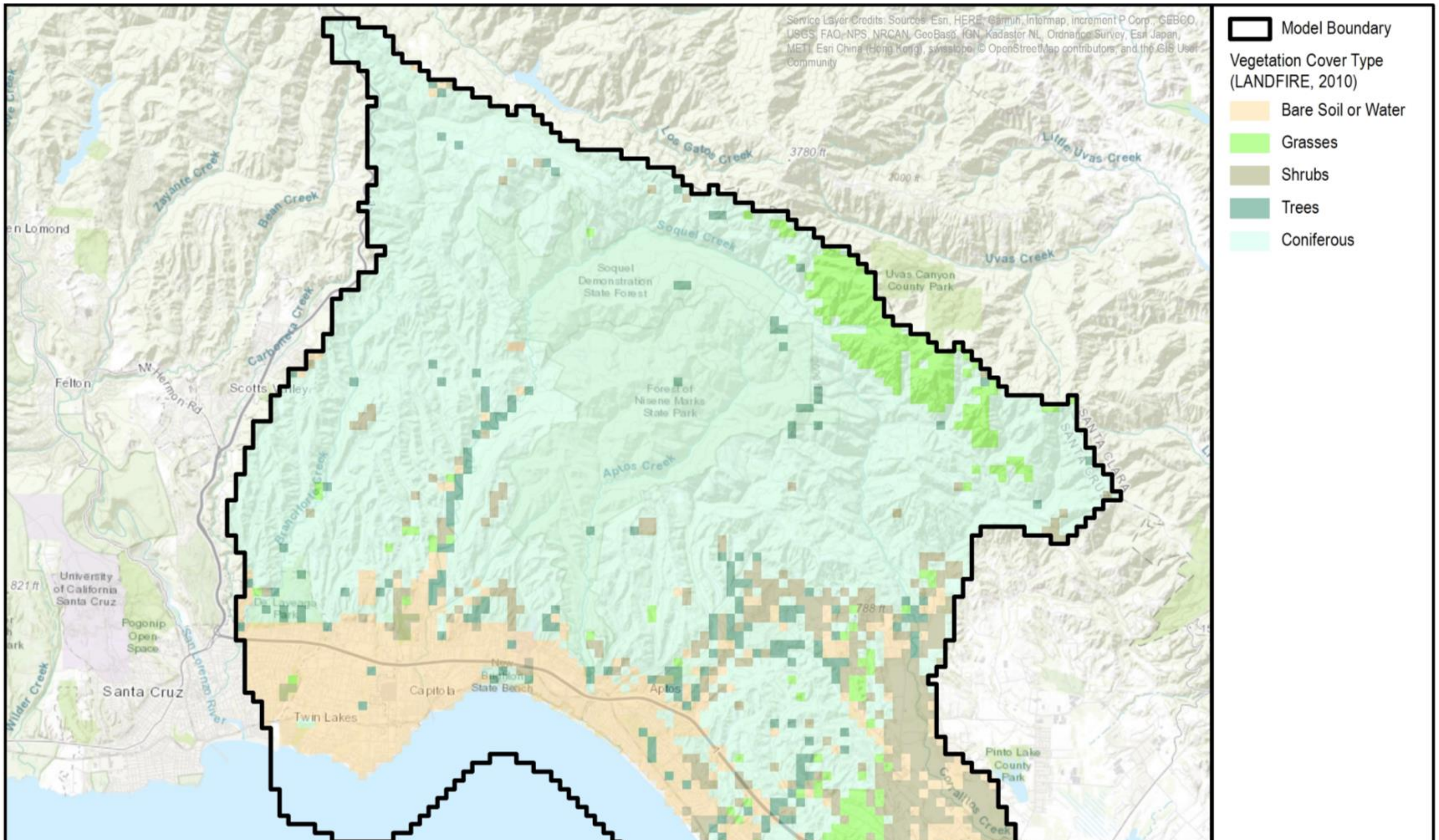


Figure 8: Vegetation Type Distribution Mapped to Model HRUs

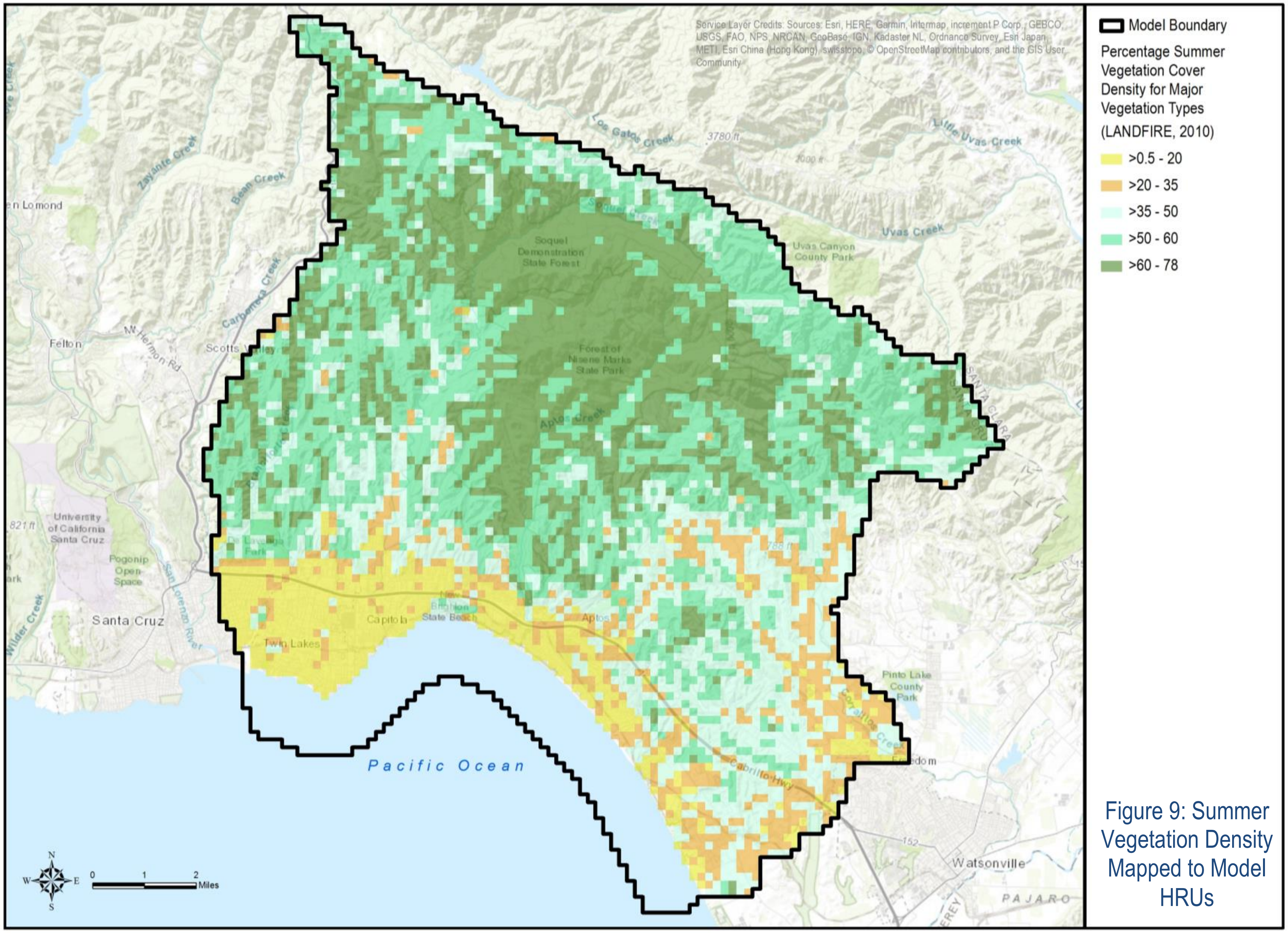


Figure 9: Summer Vegetation Density Mapped to Model HRUs

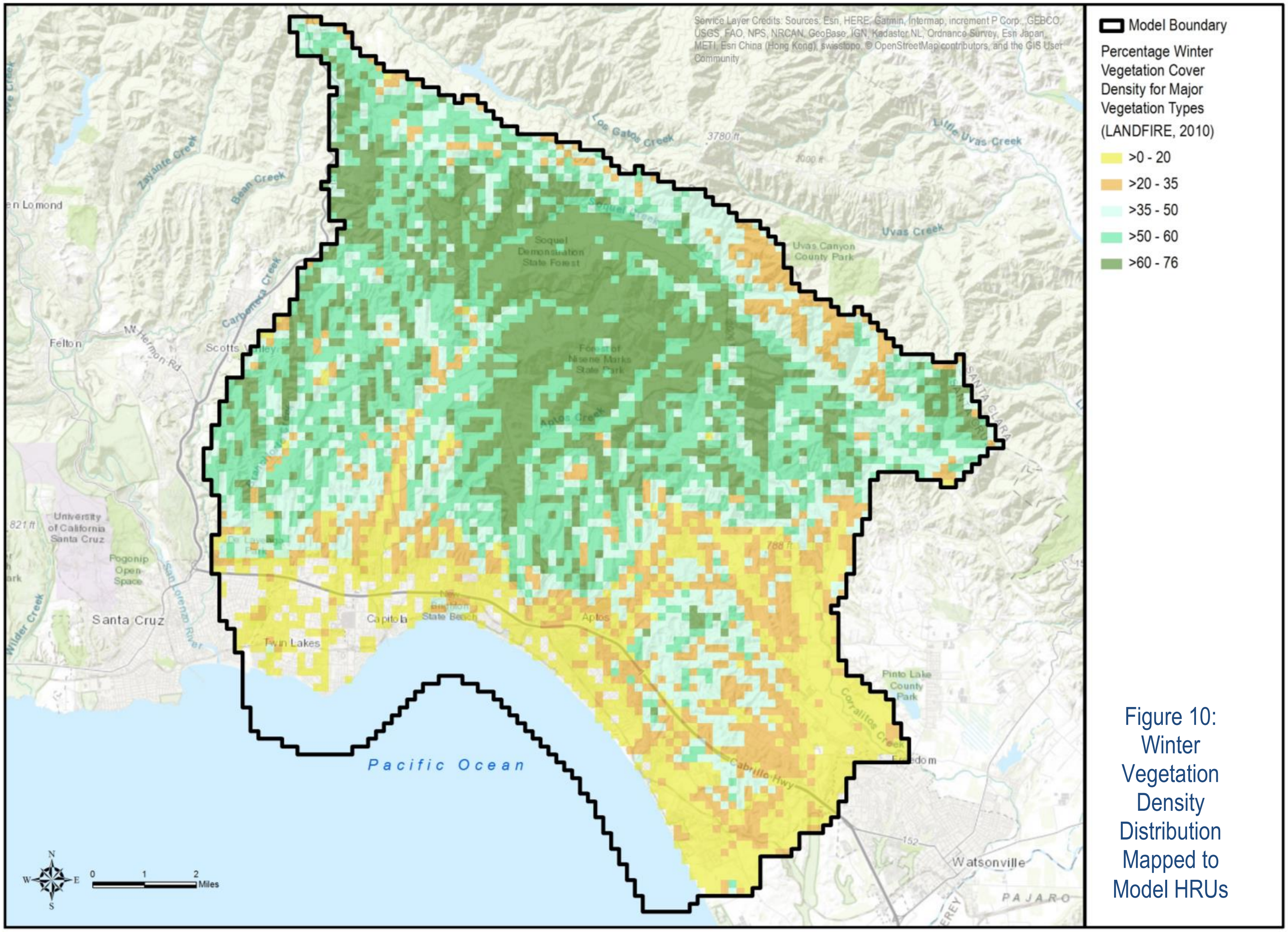


Figure 10: Winter Vegetation Density Distribution Mapped to Model HRUs

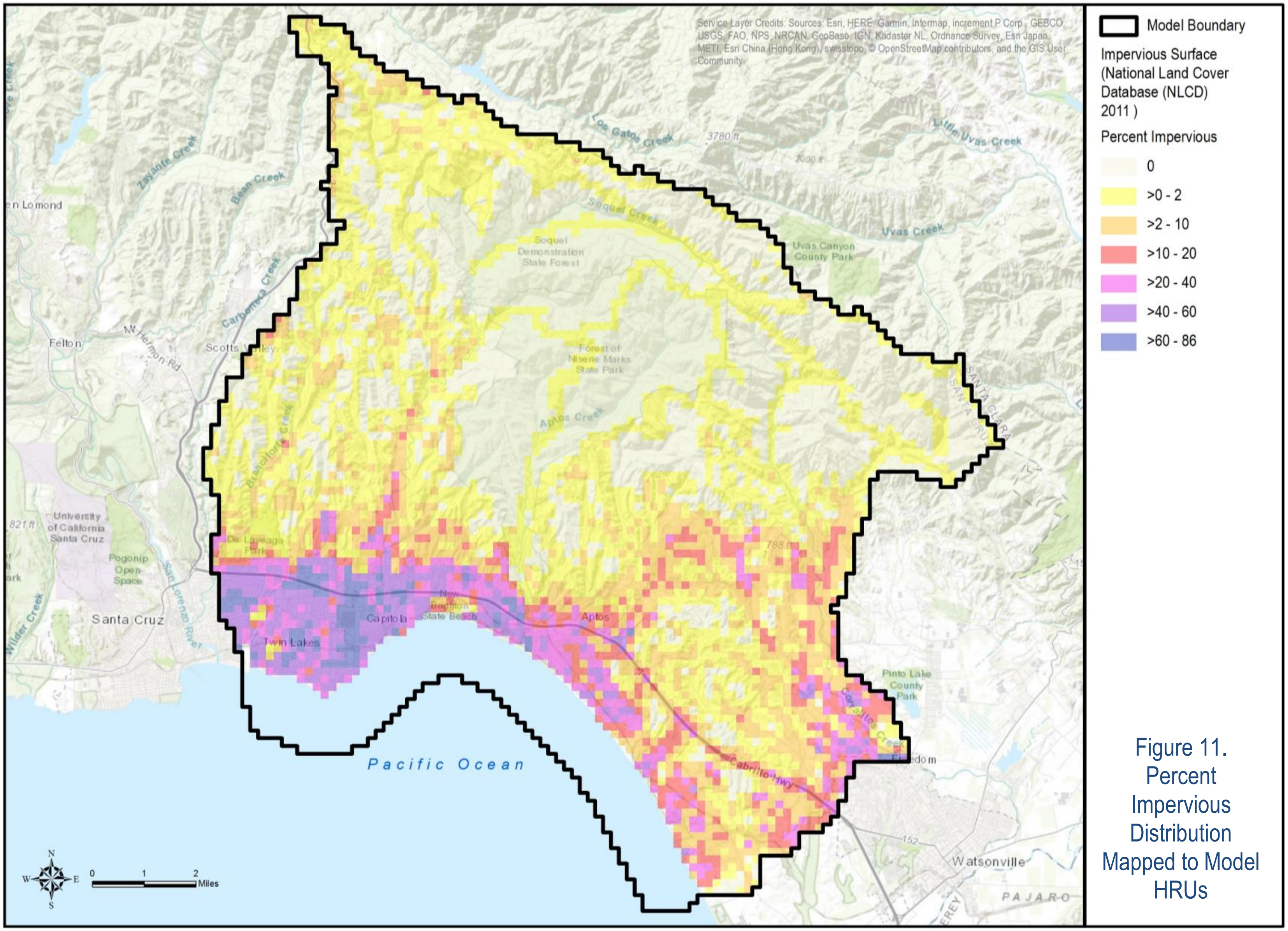


Figure 11. Percent Impervious Distribution Mapped to Model HRUs

4.3 Pumping Well Data

Groundwater pumping is implemented with the Multi-Node Well (MNW2) MODFLOW package. The MNW2 package calculates flow into the well from various model layers based on actual screen elevations. Where available for municipal wells, screened interval elevations are entered in the MNW2 package. An exception to this this is where Soquel Creek Water District (SqCWD) are screened within both the Aromas Red Sands and Purisima F unit. In this case we assigned all pumping to layer 3, representing the Purisima F unit, to simulate a confined aquifer response observed near the coast. As described in the *Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation* memorandum (HydroMetrics WRI, 2017c), most non-municipal pumping is based on land use for a model cell, not actual, identified well locations. Table 4 lists the municipal wells explicitly simulated in the model. Non-municipal pumping is assigned to the layer representing the shallowest aquifer unit that is not outcropping at the estimated well location. Plate 3 shows simulated pumping well locations by model layer for each aquifer unit.

Table 4. Municipal Wells in Model Domain

Well Name	Agency	Pumping Data Range (Water Year)	Aquifer Unit in Model[1]
Beltz #12	City of Santa Cruz	1984-2016	AA, Tu
Beltz #1	City of Santa Cruz	1984-2015	A
Beltz #7	City of Santa Cruz	1984-2015	A, AA
Beltz #10	City of Santa Cruz	1984-2016	A, AA
Beltz #9	City of Santa Cruz	1984-2016	A
Beltz #4	City of Santa Cruz	1985-2015	A
Beltz #8	City of Santa Cruz	1984-2016	A, AA
CWD-2	CWD	1985-2002	DEF/F
CWD-3	CWD	1985-2014	DEF/F
CWD-5	CWD	1985-2014	DEF/F
CWD-4	CWD	1985-2016	Aromas, DEF/F
CWD-10	CWD	1985-2016	Aromas, DEF/F
CWD-12	CWD	1986-2016	Aromas, DEF/F
Cliff Well	SqCWD	1984-1986	DEF/F
O'Neill Ranch Well	SqCWD	2015-2016	AA, Tu
Opal Well #1	SqCWD	1984-2000	A
Polo Grounds Well	SqCWD	1985-2016	DEF/F
Tannery Well II	SqCWD	2002-2016	A, AA
Aptos Jr High Well	SqCWD	1985-2016	DEF/F

Well Name	Agency	Pumping Data Range (Water Year)	Aquifer Unit in Model[1]
Monterey Well	SqCWD	1984-2015	A
T-Hopkins Well	SqCWD	1990-2016	DEF/F
Ledyard Well	SqCWD	1986-2016	BC
Aptos Creek Well	SqCWD	1984-2016	DEF/F, BC
Estates Well	SqCWD	1986-2016	BC, A
Madeline Well #2	SqCWD	1984-2015	BC
Main Street Well	SqCWD	1988-2016	AA, Tu
Rosedale 2 Well	SqCWD	1984-2016	A, AA
Tannery Well	SqCWD	1984-2000	A, AA
Maplethorpe Well	SqCWD	1984-2015	A, AA
Garnet Well	SqCWD	1996-2016	A
Sells Well	SqCWD	1984-2015	Aromas
Altivo Well	SqCWD	1984-2015	Aromas
Bonita Well	SqCWD	1984-2016	DEF/F
Seascape Well	SqCWD	1984-2015	DEF/F
San Andreas Well	SqCWD	1992-2016	DEF/F
Country Club Well	SqCWD	1985-2016	DEF/F

[1]See *Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction* (HydroMetrics WRI, 2015) for detailed model layer description.

Groundwater pumping volumes are based on a number of sources. Municipal pumping within the Basin is metered, and historical records have been supplied by the primary municipal pumping agencies. For non-metered areas, the amount of water use is estimated based on land use. The estimates for non-municipal domestic water use, including the methodology for estimating institutional, recreational, and agricultural irrigation water use, is described in detail in the *Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation* memorandum (HydroMetrics WRI, 2017c).

Pumping data applied to the model are generally grouped into the following categories:

- Municipal pumping for the calibration period of October 1984 through October 2015 were obtained from SqCWD, the City of Santa Cruz, and CWD. Pumping from Watsonville or Pajaro Valley Water Management Agency (PVWMA) wells near the southeastern boundary of the model was not explicitly simulated in the model as the specified head boundary condition incorporates the effects of that pumping.

- Pumping for private water use was based on a count of residential buildings per model cell (HydroMetrics WRI, 2017c)

- Institutional water use was estimated or recorded at specific properties (HydroMetrics WRI, 2017c).
- Agricultural pumping was calculated based on crop demand and evapotranspiration demand (HydroMetrics WRI, 2017c). Evapotranspiration demand is calculated by PRMS for the 1984-2015 period as the difference between potential evapotranspiration and actual evapotranspiration from rainfall.

Figure 12 shows the simulated pumping flows by use type within the Santa Cruz Mid-County Basin (MCB) and in the model domain outside the Basin.

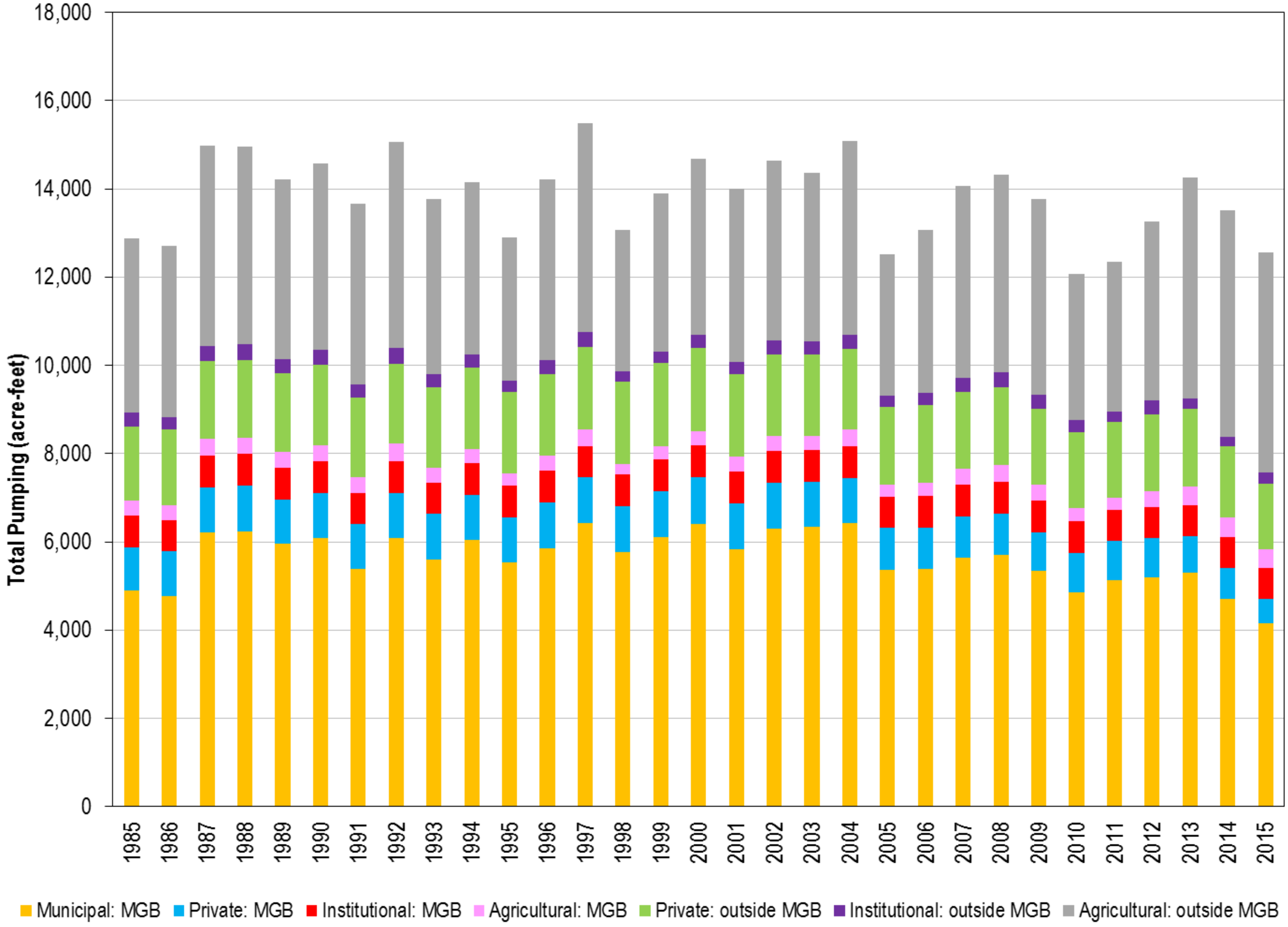


Figure 12. Simulated Groundwater Pumping by Use Type and Location

4.4 Return Flow Data

Return flow is implemented with the UZF package described in Section 3.5.4. There are a number of return flow components included in the groundwater model, as described below.

1. Return flow from system losses, which are losses from water, sewer and septic systems. Water system losses are estimated as a percentage of estimated deliveries to each service area and applied in UZF to model cells overlying those service areas. Details on the approach used to estimate municipal return flow estimates are provided in Appendix A. Municipal areas with system losses are City of Santa Cruz, CWD, SqCWD, and City of Watsonville. Sewer and septic system losses are estimated as a proportion of indoor water use overlying sewered and non-sewered areas, respectively, and applied in UZF to model cells underlying those areas. Indoor use is assumed to be 70% of total water use, and 90% of indoor water use is assumed to become wastewater (HydroMetrics WRI, 2017c). For wastewater return flows in sewered areas, return flows from sewer losses are assumed to be the same percentage used for system losses and losses area applied to model cells overlying sewered areas. For non-sewered areas, it was assumed 90% of wastewater becomes return flow through leakage from septic systems.

2. Return flow from the inefficient portion of municipal and non-municipal domestic and institutional irrigation. Return flow represented by the inefficient portion (10%) of large-scale irrigation of sports fields and parks in both municipal areas and for institutional use outside of municipal served areas is applied to model cells that overlie those irrigated areas. Large-scale irrigation demand is estimated as the difference between capillary zone PET and actual rainfall ET simulated by PRMS, the area being irrigated, and a crop factor. For return flow from non-municipal domestic irrigation, the inefficient portion (10%) of outdoor domestic use is applied in the model using the non-municipal domestic water use described in *Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation* memorandum (HydroMetrics WRI, 2017c). It is assumed that approximately 30% of total domestic water use is outdoor use.

3. Return flow from the inefficient portion of agricultural irrigation. It was assumed that the return flow from agricultural irrigation is 10% of agricultural pumping or demand, described in Section 4.3. As described in the *Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation* memorandum (HydroMetrics WRI, 2017c), agricultural return

flow is applied in UZF to model cells overlying areas with mapped irrigated agriculture.

Figure 13 shows return flows by use type within the Santa Cruz Mid-County Groundwater Basin (MGB) and in the model domain outside the Basin. The largest component of return flow in the model is from private groundwater use, which includes both the inefficient portion of landscape irrigation and leakage from septic systems. The second greatest component of return flow in the model is from municipal uses. This category includes system losses and the inefficient portion of domestic and large-scale landscape irrigation. Within the Mid-County Basin, return flow from municipal use is greater than from private use.

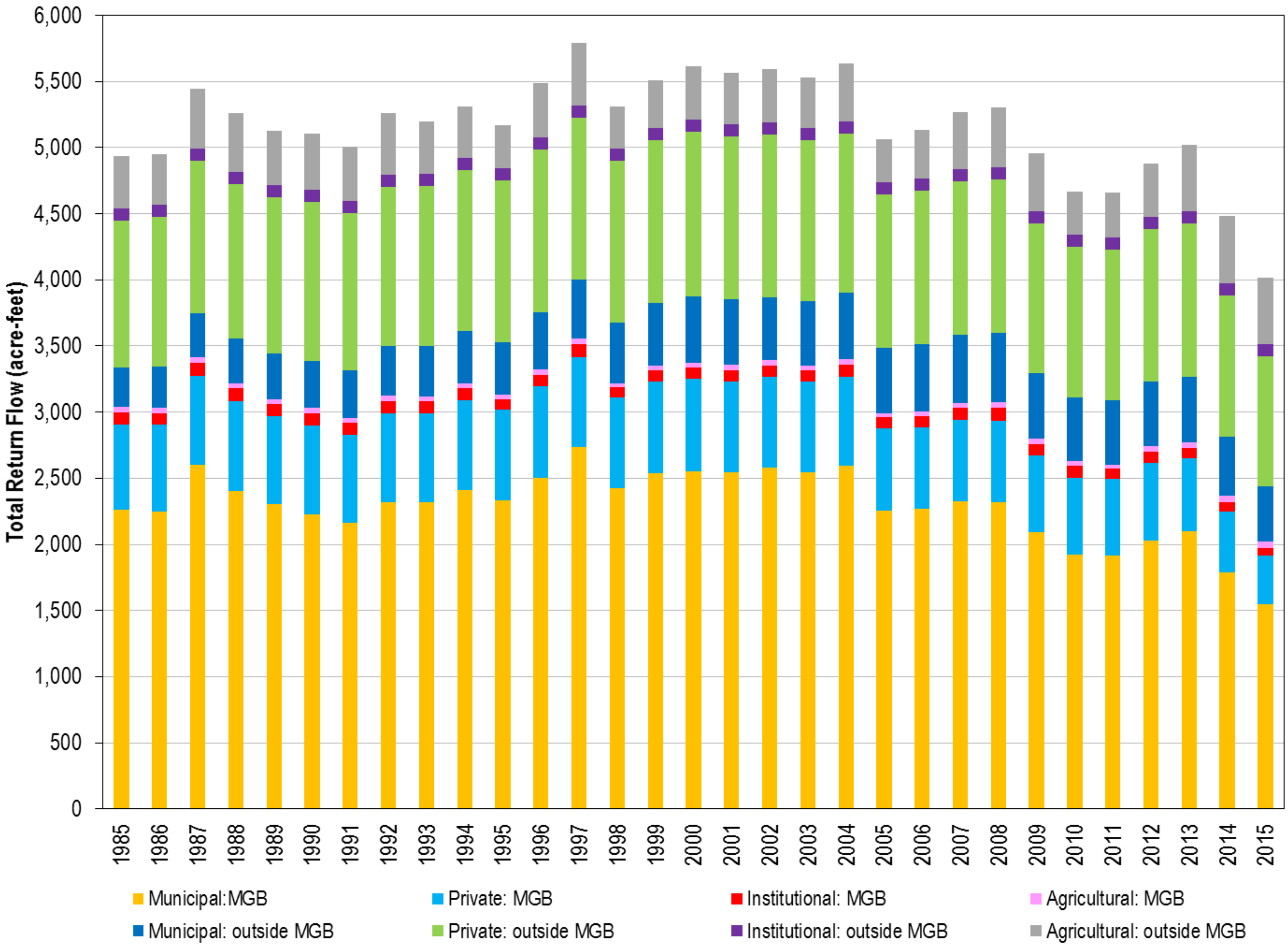


Figure 13: Simulated Return Flow by Use Type and Location

5 CALIBRATION TARGET DATA

This section describes the nature and source of observed data used to compare against simulated results during the calibration process.

5.1 Climate Calibration Targets

The first step in calibrating watershed processes is to calibrate how climate data are translated to available water in the watershed. The available water is the precipitation, less evapotranspiration. Target data that are calibrated in this step are solar radiation and potential evapotranspiration. Solar radiation data are measured at the De Laveaga CIMIS and Corralitos RAWS stations (Figure 7). Calibration target data for potential evapotranspiration at these stations are calculated based on solar radiation, temperature, humidity, and wind speed using the ASCE standard Penmen- Monteith equation for a grass reference surface (ASCE-EWRI, 2005).

5.2 Streamflow Calibration Targets

Streamflow data from eleven stream gauges within the model domain are available for use as calibration targets. Observed daily streamflow values are compared against simulated streamflow values at these gauges during the calibration process. Where data are not available at a gauge for the entire calibration period, synthetic data are produced based on linear regressions from double-mass curves.

Double-mass curves are generated between gauges with incomplete records and one of the two gauges with complete records for the concurrent data period. Linear regression equations are developed for each of the double-mass curves. Double-mass curves are extrapolated to the entire model calibration period based on the linear regression equation. Additional detail on this approach can be found in the *Estimation of Deep Groundwater Recharge Using a Precipitation-Runoff Watershed Model* report (HydroMetrics WRI, 2011)

Table 5 lists the gauges used for calibration of streamflow within the model. The location of these gauges is shown in Figure 5.

Table 5: Summary of Gauge Locations used as Calibration Targets

Gauge Name	Date Range of Available Data	Source of Data
West Branch	1984-2016	SqCWD
Upper Soquel Creek	10/1/1983 - 1/30/1986 11/21/1986 – present[1]	SqCWD
West Branch Soquel Creek near Soquel	10/1/1958 – 10/6/1972[2]	USGS[3]
Soquel Creek near Soquel	10/1/1968 – 9/30/1972[2]	USGS
Soquel Creek at Soquel	5/1/1951 – present	USGS
Aptos Creek near Aptos	10/1/1971 – 9/30/1985[2]	USGS
Aptos Creek at Aptos	10/1/1958 – 10/6/1972	USGS
Valencia Creek	10/1/2008 - 12/31/2009	Santa Cruz Co.
Branciforte Creek at Santa Cruz[4]	Estimated for model period[2]	USGS
Corralitos Creek near Corralitos	10/1/1957 – 10/11/1972[2]	USGS
Corralitos Creek at Freedom	10/1/1956 – present	USGS

[1] Data available intermittently
[2] Estimated for model period based on linear regressions from double-mass curves generated between gauges with incomplete records and one of the two gauges with complete records for overlapped data
[3] U.S. Geological Survey
[4] Part of watershed for gauge outside model domain

5.3 Groundwater Elevation Calibration Targets

5.3.1 Targets in Model Layers Representing Basin Aquifer Units

Groundwater elevations have been measured at a number of production and monitoring wells in the Purisima Formation and Aromas Red Sands within the model domain throughout the calibration period. A total of 121 individual monitoring locations were identified within the model domain, and groundwater level data from those wells were added to the model as calibration targets in model layers representing the Purisima Formation and Aromas Red Sands after excluding observations determined to be anomalous or unreliable. Observations from wells that are screened across multiple model layers are input into the model as composite water levels that are weighted by layer transmissivity according to the percentage of screened interval in each layer. Table 6 lists the wells used as groundwater level calibration targets in Basin aquifer units within the model. Plate 4 shows the location of these wells used as calibration targets within each aquifer layer of the model. Most calibration targets are south of the Aptos area horizontal flow barrier where it is modeled. There are no calibration targets north of the Zayante Fault.

Table 6. Wells used as Groundwater Elevation Calibration Targets in Basin Aquifer Units

Well Name	Associated Agency	Model Layer(s)[1]	Water Year Range of Calibration Data[2]
30th Ave-1	City of Santa Cruz	Tu	2013-2015
30th Ave-2	City of Santa Cruz	AA	2013-2015
Auto Plaza Deep	City of Santa Cruz	AA	2010-2015
Auto Plaza Medium	City of Santa Cruz	AA	2010-2015
Auto Plaza Shallow	City of Santa Cruz	A	2010-2015
Beltz #2	City of Santa Cruz	A	2004-2015
Beltz #6	City of Santa Cruz	A	2004-2015
Beltz #7 Deep	City of Santa Cruz	Tu	2013-2015
Beltz # 7 Test Well	City of Santa Cruz	Tu	2004-2015
Coffee Lane Park Deep	City of Santa Cruz	AA	2010-2015
Coffee Lane Park Shallow	City of Santa Cruz	AA	2010-2015
Corcoran Lagoon Deep	City of Santa Cruz	AA	2004-2015
Corcoran Lagoon Medium	City of Santa Cruz	A	2004-2015
Corcoran Lagoon Shallow	City of Santa Cruz	B Aquitard-A	2004-2015
Cory Street-4	City of Santa Cruz	Tu	2014-2015
Cory Street Deep	City of Santa Cruz	AA	2010-2015
Cory Street Medium	City of Santa Cruz	AA	2010-2015
Cory Street Shallow	City of Santa Cruz	A-AA	2010-2015
Moran Lake Deep	City of Santa Cruz	A	2004-2015
Moran Lake Medium	City of Santa Cruz	A	2004-2015
Moran Lake Shallow	City of Santa Cruz	A	2004-2015
Pleasure Point Deep	City of Santa Cruz	AA	2000-2015
Pleasure Point Medium	City of Santa Cruz	A	2000-2015
Pleasure Point Shallow	City of Santa Cruz	A	1989-2015
Schwan Lake	City of Santa Cruz	A	2004-2015
Soquel Point Deep	City of Santa Cruz	A-AA	2004-2015
Soquel Point Medium	City of Santa Cruz	A	2004-2015
Soquel Point Shallow	City of Santa Cruz	A	2004-2015
Thurber Ln Deep	City of Santa Cruz	Tu	2008-2015
Black	CWD	Aromas	1985-2014
Cox-3	CWD	DEF/F	1985-2015
CWD-B	CWD	Aromas	2006-2015
CWD-C	CWD	DEF/F	2006-2015
Altivo	SqCWD	Aromas	1984-2015
Bonita	SqCWD	Aromas-DEF/F	1984-2015

Well Name	Associated Agency	Model Layer(s)[1]	Water Year Range of Calibration Data[2]
Country Club	SqCWD	Aromas-DEF/F	1984-2015
Rob Roy-4	SqCWD	Aromas-DEF/F	1985-2015
San Andreas	SqCWD	Aromas-DEF/F	1992-2015
SC-10AAA	SqCWD	AA	1986-2015
SC-10AAR	SqCWD	AA	1986-2015
SC-11A-R	SqCWD	A	2006-2015
SC-11B	SqCWD	BC	2006-2013
SC-11C	SqCWD	D Aquitard-BC	2006-2013
SC-11D-R	SqCWD	DEF/F-D Aquitard	2006-2013
SC-11RB	SqCWD	BC	2014-2015
SC-13A	SqCWD	Tu	1995-2015
SC-14A	SqCWD	A-AA	1986-2015
SC-14B	SqCWD	BC-B Aquitard	1986-2015
SC-15A	SqCWD	AA	2006-2015
SC-15B	SqCWD	A	2006-2015
SC-16A	SqCWD	B Aquitard-A	1986-2015
SC-16B	SqCWD	D Aquitard-BC	2016-2015
SC-17A	SqCWD	B Aquitard-A	1986-2015
SC-17B	SqCWD	D Aquitard-BC	1986-2015
SC-17C	SqCWD	DEF/F-D Aquitard	2007-2015
SC-18AAR	SqCWD	Tu	1999-2017
SC-18A-R	SqCWD	AA	1999-2015
SC-19	SqCWD	DEF/F	2007-2015
SC-1A	SqCWD	A-AA	1986-2015
SC-20A	SqCWD	DEF/F	2010-2015
SC-21A	SqCWD	A-AA	2012-2015
SC-21AA	SqCWD	AA	2012-2015
SC-21AAA	SqCWD	Tu	2012-2015
SC-22A	SqCWD	A-AA	2013-2015
SC-22AAA	SqCWD	Tu	2012-2015
SC-23A	SqCWD	D Aquitard-BC	2014-2015
SC-23C	SqCWD	DEF/F	2014-2015
SC-3A-R	SqCWD	A-AA	1986-2009
SC-3B-R	SqCWD	BC-B Aquitard	1986-2005
SC-3C-R	SqCWD	BC	1990-2015
SC-5A-R	SqCWD	A-AA	1986-2015

Well Name	Associated Agency	Model Layer(s)[1]	Water Year Range of Calibration Data[2]
SC-5C-R	SqCWD	BC	1986-2015
SC-5D	SqCWD	D Aquitard-BC	1986-2000
SC-5RB	SqCWD	B Aquitard	2003-2015
SC-8A	SqCWD	A	1986-1992
SC-8B	SqCWD	BC-B Aquitard	1986-1992
SC-8RA	SqCWD	A	1996-2015
SC-8RB	SqCWD	BC	1996-2015
SC-8RD	SqCWD	D Aquitard	1996-2015
SC-9A-R	SqCWD	A	1986-2012
SC-9C-R	SqCWD	BC	1986-2012
SC-9E-R	SqCWD	DEF/F-D Aquitard	1988-2012
SC-A1B	SqCWD	DEF/F	1989-2015
SC-A1D	SqCWD	DEF/F	1989-2015
SC-A2A-R	SqCWD	DEF/F	1989-2015
SC-A2C-R	SqCWD	Aromas	1989-2015
SC-A3A	SqCWD	Aromas	1989-2015
SC-A4A	SqCWD	Aromas	2002-2015
SC-A4B	SqCWD	Aromas	2002-2015
SC-A5A	SqCWD	DEF/F	1994-2015
SC-A5C	SqCWD	Aromas	2002-2015
SC-A6A	SqCWD	DEF/F	2004-2015
SC-A7B	SqCWD	Aromas	2004-2015
SC-A7C	SqCWD	Aromas	2004-2015
SC-A8A	SqCWD	DEF/F	2008-2015
SC-A8C	SqCWD	Aromas	2008-2015
SC-A9A	SqCWD	DEF/F	2014-2015
SC-A9B	SqCWD	Aromas	2014
Seascape	SqCWD	Aromas	1986-2015
Sells	SqCWD	Aromas	1984-2015
01E04BP	Private	DEF/F	2009-2015
01E04DP	Private	Aromas	2009-2014
01E04EP	Private	DEF/F	2009-2015
01E04FP	Private	DEF/F	2009-2015
01E05AP	Private	DEF/F	2008-2015
01E06AS	Private	DEF/F	2009
01E08AS	Private	DEF/F	2008-2011

Well Name	Associated Agency	Model Layer(s)[1]	Water Year Range of Calibration Data[2]
01E08BS	Private	DEF/F	2008-2012
01E09AP	Private	DEF/F	2009-2013
01E09BP	Private	DEF/F	2009-2010
01E15AS	Private	Aromas	2008-2015
01E22AS	Private	Aromas	2009-2011
01E22BS	Private	Aromas	2009-2015
01W06AS	Private	Tu	2009-2015
01W06BS	Private	Tu	2009-2015
01W06DP	Private	Tu	2011-2015
01W14BP	Private	Tu	2008-2015
01W15AP	Private	Tu	2008-2015
01W22AS	Private	Tu	2008-2015
01W30AP	Private	Tu	2008-2015
01W32AS	Private	Tu	2009-2015

[1] See *Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction* (HydroMetrics WRI, 2015) for detailed model layer descriptions
[2] Water year

5.3.2 Targets for Shallow Groundwater along Soquel Creek

As part of a scope for Santa Cruz County's Prop 1 grant for Counties with Stressed Basins, additional calibration was performed including shallow groundwater levels along Soquel Creek as targets. The purpose of this calibration is to improve simulation of stream-aquifer interaction along Soquel Creek to inform development of sustainability management criteria for streamflow depletion from pumping, including use of shallow groundwater levels as groundwater level proxies. Table 7 lists the shallow wells along Soquel Creek used as groundwater elevation targets. Figure 14 shows the locations of these shallow wells.

Table 7. Shallow Wells along Soquel Creek used as Groundwater Elevation Calibration Targets

Well Name	Associated Agency	Model Layer(s)[1]	Water Year Range of Calibration Data[2]
Simons	SqCWD	Alluvium overlying A	2002-2011
Balogh	SqCWD	Alluvium overlying A	2002-2015
Main St SW-1	SqCWD	Alluvium overlying A	2001-2015
Wharf Road SW	SqCWD	Alluvium overlying A	2013-2015
Nob Hil SW 2I	SqCWD	Alluvium overlying A	2001-2015

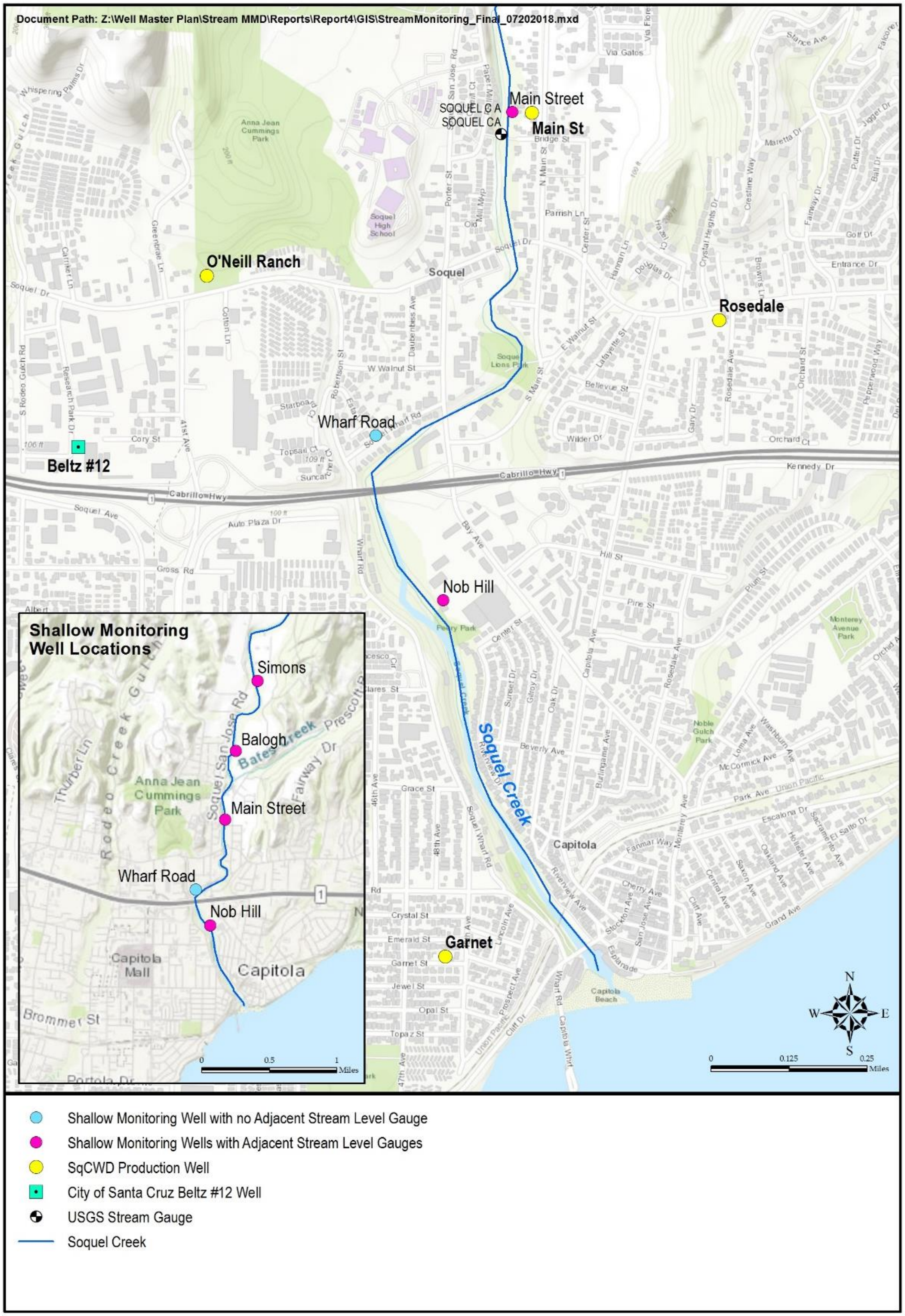


Figure 14. Locations of Shallow Groundwater Elevation Targets along Soquel Creek

These groundwater level targets are located in model layer 6 representing alluvium underlying Soquel Creek and overlying the Purisima A unit. Previous studies (LKA and LSCE, 2003) indicated that at least the Main St SW-1 is screened in the Purisima Formation, but the vertical gradient observed between the shallow groundwater levels and deeper Purisima Formation groundwater levels observed at monitoring well SC-18A justifies simulating the shallow wells in the model layer directly beneath Soquel Creek. Therefore, the model is calibrated to simulate the vertical connection of Soquel Creek to underlying Purisima Formation. The model does not simulate the horizontal connection of Soquel Creek to shallow wells along the Creek as the distance between the Creek and wells are less than the model cell width of 800 feet as shown in Figure 15.

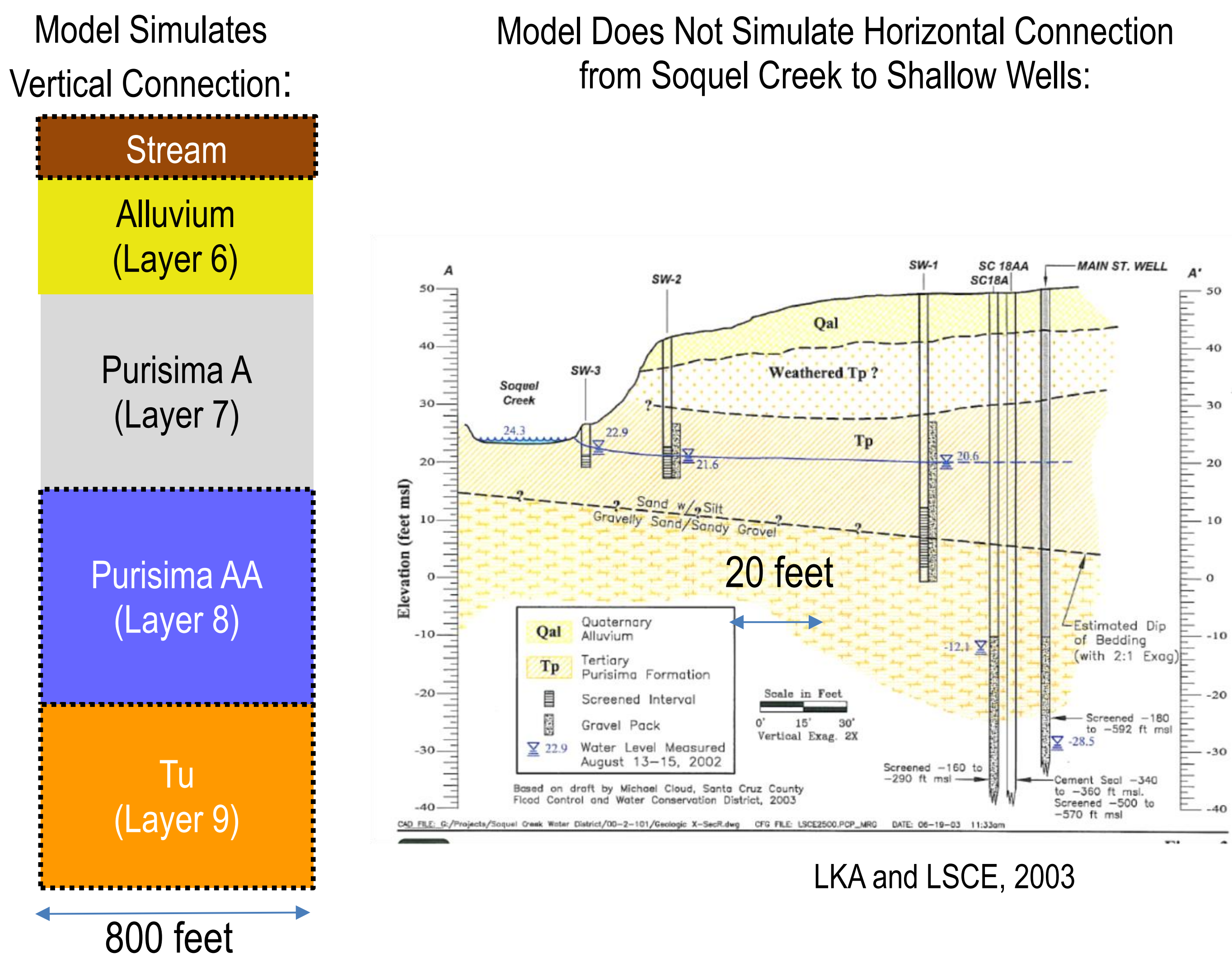


Figure 15. Model Simulation of Vertical Connection between Stream-Aquifers

6 CALIBRATION PROCESS

Calibrating the Basin model involves successive attempts to match simulated output to calibration targets during the calibration period. Simulated climate, streamflow and groundwater elevation data are compared to observed values, and surface and groundwater parameters are adjusted between model runs to improve the fit of simulated to observed values.

Preliminary work calibrating the model involved using separate models. One model calibrated climate and surface water flow using only the PRMS watershed model. A second model calibrated groundwater-only flow using the MODFLOW model. A major factor contributing to this decision was the relative model run times of the separate model packages compared to the integrated GSFLOW model. Separate models used to calibrate different datasets were as follows:

1. PRMS only runs for Water Years 1985-2015 to calibrate to climate output of solar radiation and potential evapotranspiration. Solar radiation and potential evapotranspiration calculations remain consistent when run as part of GSFLOW.

2. GSFLOW runs for Water Years 1992-1995 to calibrate to streamflow. Streamflow calibrated to PRMS only runs did not remain consistent when run as part of GSFLOW due to simulation of groundwater discharge to the soil zone in GSFLOW. The US Geological Survey recommended calibrating to a shorter time period to reduce run times. Water Years 1992-1995 includes variation in climate that makes it appropriate for calibrating streamflow under different climate conditions.

3. MODFLOW only runs for Water Years 1985-2015. When an acceptably-calibrated model fit to streamflow observations was achieved, a GSFLOW run for Water Years 1985-2015 was run to estimate recharge and a corresponding MODFLOW-only model using the recharge estimates was created to change groundwater parameters to achieve calibration to groundwater observations to understand model sensitivities and develop strategies for calibrating to groundwater levels.

4. GSFLOW runs for Water Years 1992-1995 to recalibrate to streamflow again. Changes to groundwater parameters did not change streamflow calibration substantially, but streamflow calibration was adjusted for consistency.

5. GSFLOW runs for Water Years 1985-2015. There are some differences in groundwater results provided by MODFLOW only and GSFLOW runs so final calibration to groundwater levels was based on GSFLOW runs. Further adjustment of climate or watershed parameters was not necessary as part of this calibration.

6. Under the scope for Santa Cruz County's Prop 1 grant. GSFLOW runs for Water Years 1985-2015 to calibrate to shallow groundwater levels along Soquel Creek while maintaining streamflow calibration and calibration in underlying Purisima Formation aquifer units.

7 MODEL CALIBRATION

This section presents the model calibration that includes calibrating to climate, streamflow, and groundwater level targets.

7.1 Climate Calibration

PRMS solar radiation and potential evapotranspiration parameters were first calibrated to measured solar radiation (SR) and calculated potential evapotranspiration (PET) at the Delaveaga CIMIS and Corralitos RAWS stations (HydroMetrics WRI, 2016a). PRMS calculates solar radiation using the ddsolrad module where the parameters are slope and intercept of the maximum temperature per degree day linear relationship. Monthly parameters (dday_intcp and dday_slope) are calibrated (Table 8) to monthly averages of solar radiation (Figure 16 and Figure 17). Based on calibrated solar radiation, monthly coefficients (pt_alpha) for the Priestly-Taylor equation (Table 8) are adjusted to calibrate simulated potential evapotranspiration to average potential evapotranspiration at the stations (Figure 18 and Figure 19). The Priestly-Taylor equation requires relative humidity so average monthly relative humidity from the Santa Cruz Co-op station is used (Table 8).

Table 8. Monthly Parameters for Solar Radiation and Potential Evapotranspiration

Parameter Name	dday_intcp	dday_slope	hum_pct	pt_alpha
Parameter Description	Intercept in temperature degree-day relation	Slope in temperature degree-day relation	Monthly relative humidity percent	Monthly adjustment factor used in Priestly-Taylor PET calculations
January	-13.6453	0.2715	75	0.9116
February	-20.0454	0.3977	72	0.7988
March	-26.6630	0.5290	70	0.7668
April	-34.9496	0.6562	70	0.78520
May	-44.0930	0.7574	72	0.7383
June	-54.5417	0.8769	75	0.7574
July	-54.1731	0.8449	80	0.7514
August	-49.4067	0.7701	82	0.7531
September	-39.2594	0.6358	75	0.7731
October	-28.2960	0.4917	70	0.8563
November	-15.3850	0.3092	70	0.9507
December	-11.2614	0.2698	76	0.9002

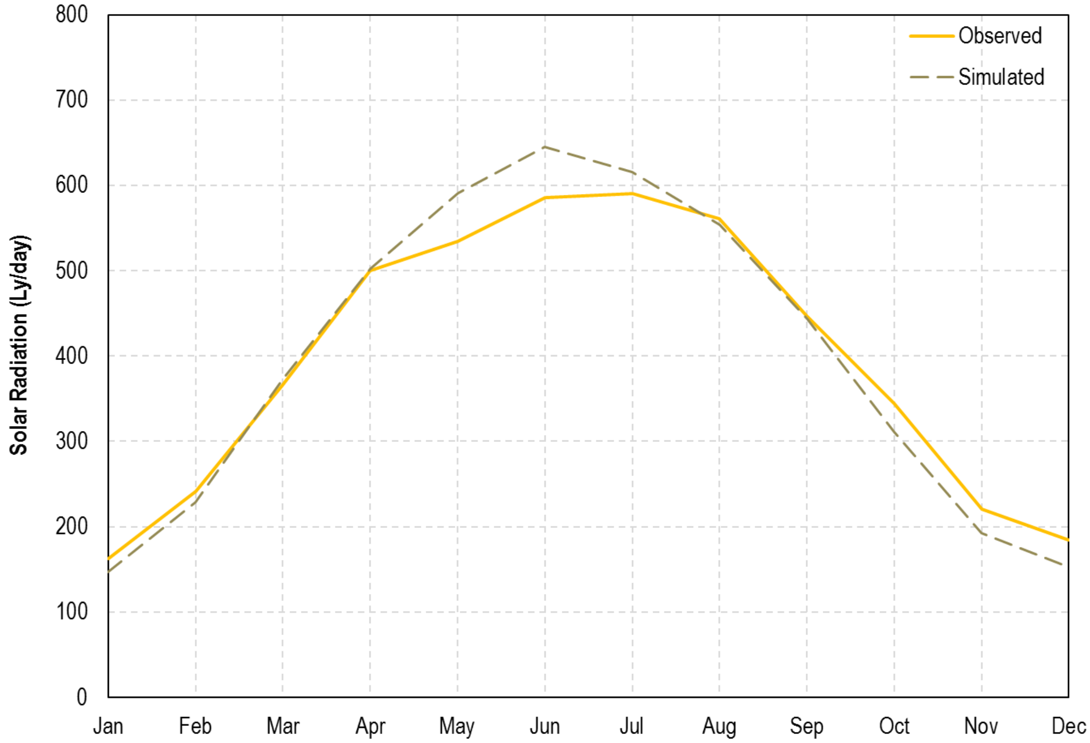


Figure 16. Calibration of Solar Radiation at de Lavega CIMIS Station

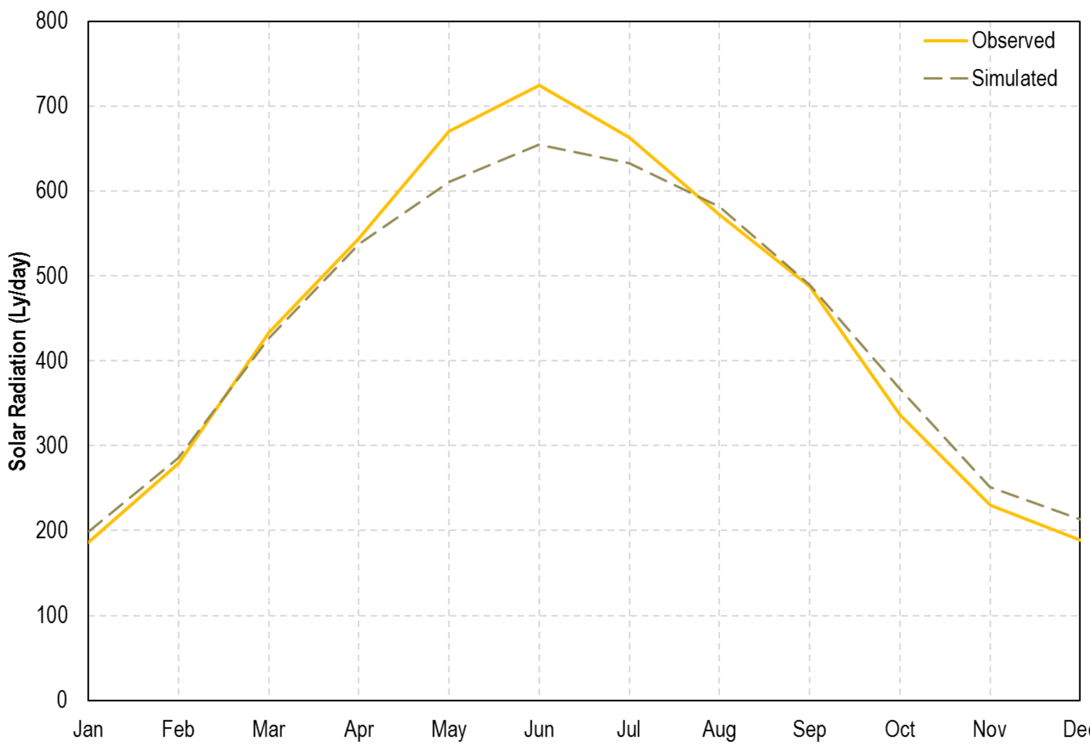


Figure 17. Calibration of Solar Radiation at Corralitos RAWS Station

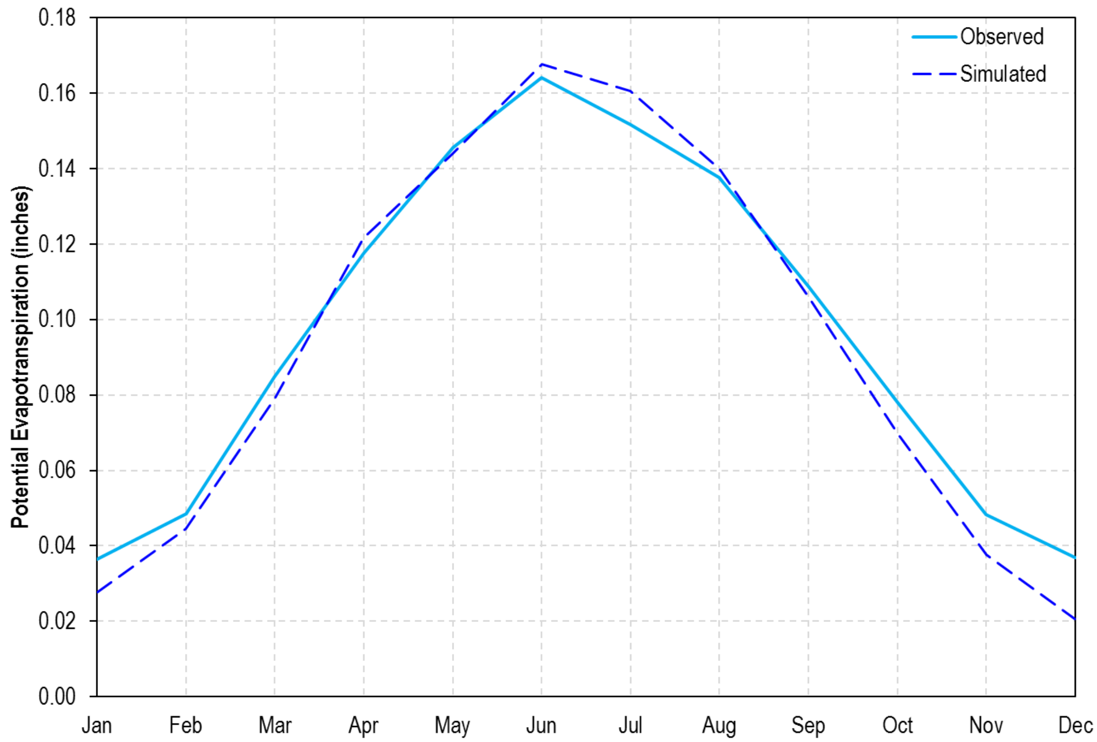


Figure 18. Calibration of Potential Evapotranspiration at de Lavega CIMIS Station

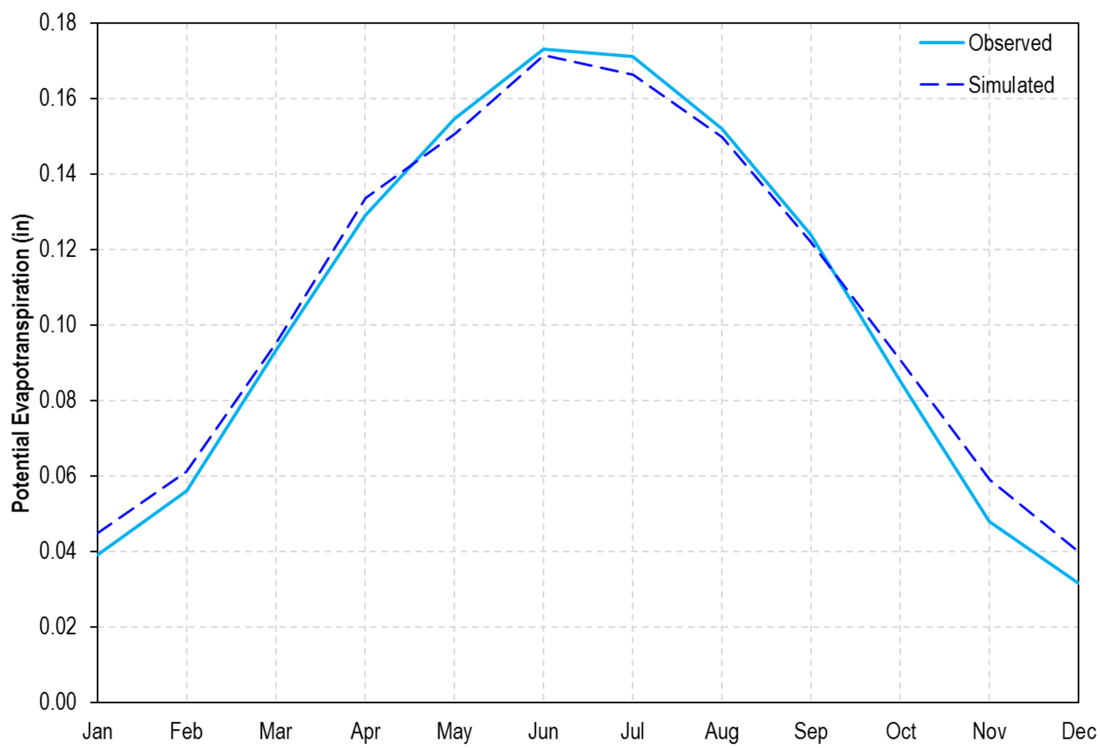


Figure 19. Calibration of Potential Evapotranspiration at Corralitos RAWS Station

7.2 Surface Water Calibration

Calibration of the surface water component of the model with the GSFLOW run simulating Water Years 1992-1995 compares GSFLOW model MODFLOW GAGE package output at stream gauges with daily observations at the stream gauge. Watershed parameters were adjusted to improve the match between simulated output and observations.

7.2.1 Watershed Parameters by Zone

Watershed parameters were adjusted by zones for Soquel Creek, Aptos Creek, and Corralitos Creek upstream and downstream of Zayante Fault, which is the northern boundary of the Basin (Figure 5). Gauges on these creeks can be sorted into upstream and downstream gauges with the simulated streamflow at the upstream gauges primarily affected by parameters in its watershed upstream of Zayante Fault and simulated streamflow at the downstream gauges affected by parameters at both zones in the watershed. The watershed parameters affect the streamflows shown in Figure 22.

Some parameters represent the soil zone reservoir volumes and other parameters represent coefficients for empirical equations describing flows to and from soil zone reservoirs. Table 9 describes the watershed parameters and provides their calibrated values.

The capillary zone capacities soil_moist_max and soil_rechr_max have spatial variation within each PRMS parameter zone based on calculations using the SSUGRO soils dataset for the previous PRMS recharge dataset (HydroMetrics WRI, 2011). Zone based factors multiplying spatial variation within the zones are used for calibration. Figure 20 shows the calibrated results of this multiplication.

In general, parameters representing flows from the soil zone are on the low end of the expected range while parameters representing soil moisture capacities (sat_threshold, soil_moist_max, and soil_rechr_max) are relatively high. This facilitates soil zone only slowly releasing water to streams and groundwater to calibrate slow recession curves observed at stream gauges in the watersheds.

Table 9. Watershed Parameters by Zone

Parameter Name	Parameter Description	Associated Flow	Upper Soquel	Lower Soquel	Upper Aptos	Lower Aptos	Upper Corralitos	Lower Corralitos
fastcoef_lin	Coefficient to route preferential-flow storage down slope	fast interflow	0.023	0.443	0.012	0.010	0.389	0.910
fastcoef_sq	Coefficient to route preferential-flow storage down slope	fast interflow	0.003	0.028	0.000	0.315	0.790	0.818
gwflow_coef	Groundwater routing coefficient	Groundwater Flow	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
gwsink_coef	Groundwater sink coefficient	Groundwater sink	1	1	1	1	1	1
imperv_stor_max	Maximum impervious area retention storage for each HRU	Hortonian Surface Flow	0	0.490	0.126	1	1	1
pref_flow_den	Preferential-flow pore density	Preferential flow	0.1064	0.0912	0.0841	0.2107	1E-05	1E-05
sat_threshold	Soil saturation threshold, above field-capacity threshold	gravity and preferential flow	11.31	250.72	38.20	184.35	7.27	6.96
slowcoef_lin	Coefficient to route gravity-flow storage down slope	slow interflow	0.0023	1.341E-05	0.0143	0.0009	5.146E-05	0.0012
slowcoef_sq	Coefficient to route gravity-flow storage down slope	slow interflow	0.0204	0.000	0.000	0.0041	0.0034	0.1746
smidx_coef	Coefficient in non-linear contributing area lgorithm	Hortonian Surface Flow	0.0011	0.0010	0.0010	0.0023	0.0010	0.0010
smidx_exp	Exponent in non-linear contributing area algorithm	Hortonian Surface Flow	0.1934	0.1	0.2005	0.1271	0.1	0.1

Parameter Name	Parameter Description	Associated Flow	Upper Soquel	Lower Soquel	Upper Aptos	Lower Aptos	Upper Corralitos	Lower Corralitos
soil_moist_max	Maximum available water holding capacity of soil profile. Soil profile is surface to bottom of rooting zone	NA	21.5	8.5	13.3	20.0	24	24
soil_rechr_max	Maximum value for soil recharge zone (upper portion of soil moisture zone where losses occur as both evaporation and transpiration)	NA	13	7.25	9.71	0.67	9.27	13
soil2gw_max	Maximum amount of the capillary reservoir excess that is routed directly to the GWR for each HRU	Direct Recharge	1.98E-05	0.0025	0.0015	0.0414	0.2337	0.0005
ssr2gw_rate	Coefficient in equation used to route water from the subsurface reservoirs to the groundwater reservoirs	Gravity Drainage	2.5909	0.0045	3.9344	0.1350	0.0203	0.2560
ssr2gw_exp	Coefficient in equation used to route water from the subsurface reservoirs to the groundwater reservoirs	Gravity Drainage	0.0079	0.0162	0.0005	0.0010	0.0102	0.2993

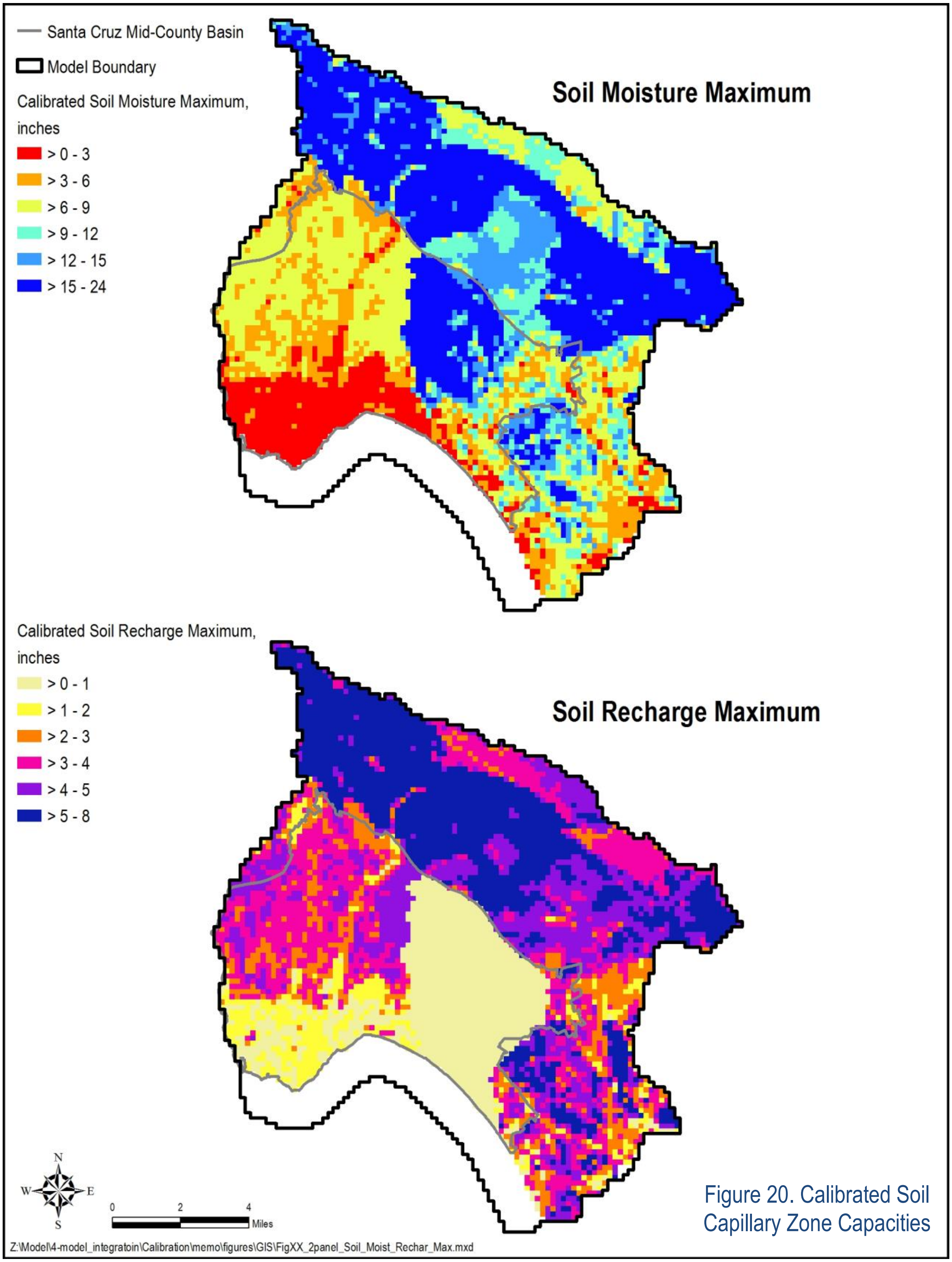


Figure 20. Calibrated Soil Capillary Zone Capacities

7.2.2 MODFLOW SFR Streambed Hydraulic Conductivity

As part of the streamflow calibration with GSFLOW, hydraulic conductivities for streambeds in the MODFLOW SFR package controlling flows between streams and groundwater were calibrated. Figure 21 shows the calibrated streambed hydraulic conductivities by SFR segment. For uniform streambed thickness of 3.28 feet, hydraulic conductivities of 3 x 10^{-}-^{3} feet per day are used for all streams except along lower Soquel Creek where shallow groundwater levels are available for calibration. Values of streambed hydraulic conductivity are relatively low throughout the watershed to facilitate simulation of slow recession curves controlled by soil retention of precipitation.

As calibrated for the Santa Cruz County Prop 1 grant scope, streambed hydraulic conductivities along Soquel Creek are higher (7 x 10^{-2} to 0.3 feet per day) where shallow groundwater level data are available. The data show connection between the shallow groundwater and Soquel Creek because the difference between shallow groundwater and stream stages is relatively small. Therefore, based on these available data, the model simulates more groundwater interaction with the stream for this area than what is simulated for the rest of the model. Simulating a relationship between shallow groundwater levels and flows between groundwater and streams is consistent with use of shallow groundwater levels as groundwater level proxies for streamflow depletion. However, data quantifying flows between the stream and shallow groundwater are not available for calibration so there is high uncertainty of the magnitude of simulated flows between stream and aquifer calculated by the model.

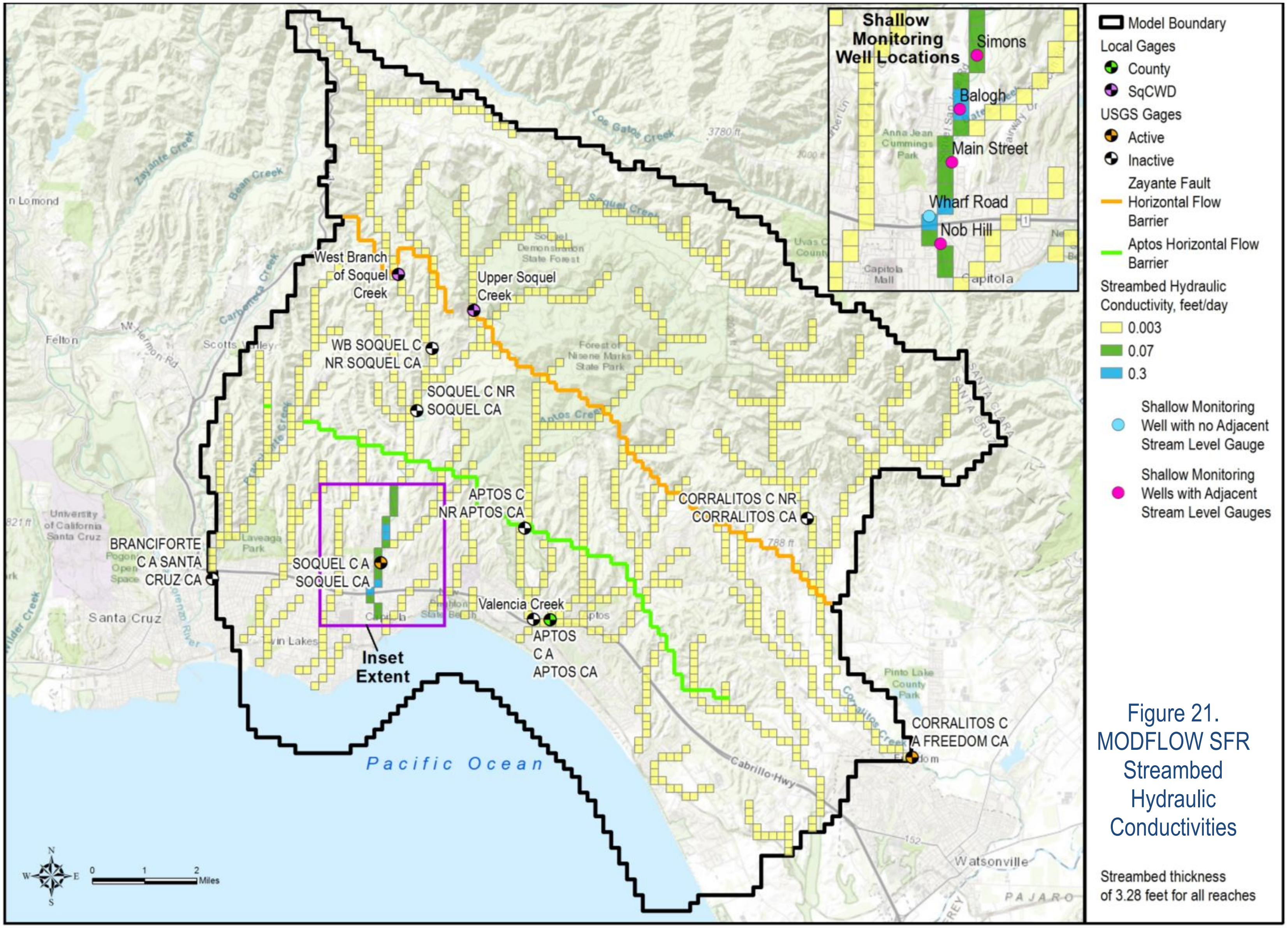


Figure 21. MODFLOW SFR Streambed Hydraulic Conductivities

7.2.2.1 Streamflow Calibration Results

Streamflow calibration results did not change substantially between the second step of streamflow calibration using GSFLOW for Water Years 1992-1995 and final calibration of GSFLOW for Water Years 1985-2015 that calibrated to shallow groundwater levels along Soquel Creek.

Measured streamflows were reasonably simulated at the two stream gauges with the most complete record of data: Soquel Creek at Soquel Gauge and Corralitos Creek at Freedom Gauge (see HydroMetrics WRI, 2016a for preliminary calibration results for PET and streamflow). Figure 22 shows simulated and observed streamflow for the two gauges over time.

Figure 23 and Figure 24 present observed *versus* simulated daily streamflow for calibration targets at the stream gauges with the most complete record of data. Results from an unbiased model (*i.e*., a perfectly-calibrated model) will align with the 45-degree line plotted on the figures. These plots demonstrate good and relatively unbiased calibration over the majority of streamflow ranges observed in the data, with some divergence in the simulated daily flows at very low (<1 cubic feet per second [cfs]) flow rates.

Goodness of fit between the simulated and observed streamflow was initially only assessed at annual time steps for preliminary model simulations, and was further evaluated at monthly and daily time steps using the Nash-Sutcliffe statistic (Nash and Sutcliffe, 1970). As a more quantitative measure of how well the model predicted streamflow, the Nash-Sutcliffe goodness of fit (NS) statistic was calculated for each of the gauges. This statistic has been used previously in other PRMS models to evaluate the performance of the PRMS calibration (Hay et al., 2006; Dudley, 2008; Viger *et al*., 2010). The NS statistic provides a measure of whether the PRMS model is a better predictor of annual streamflows than the average streamflow.

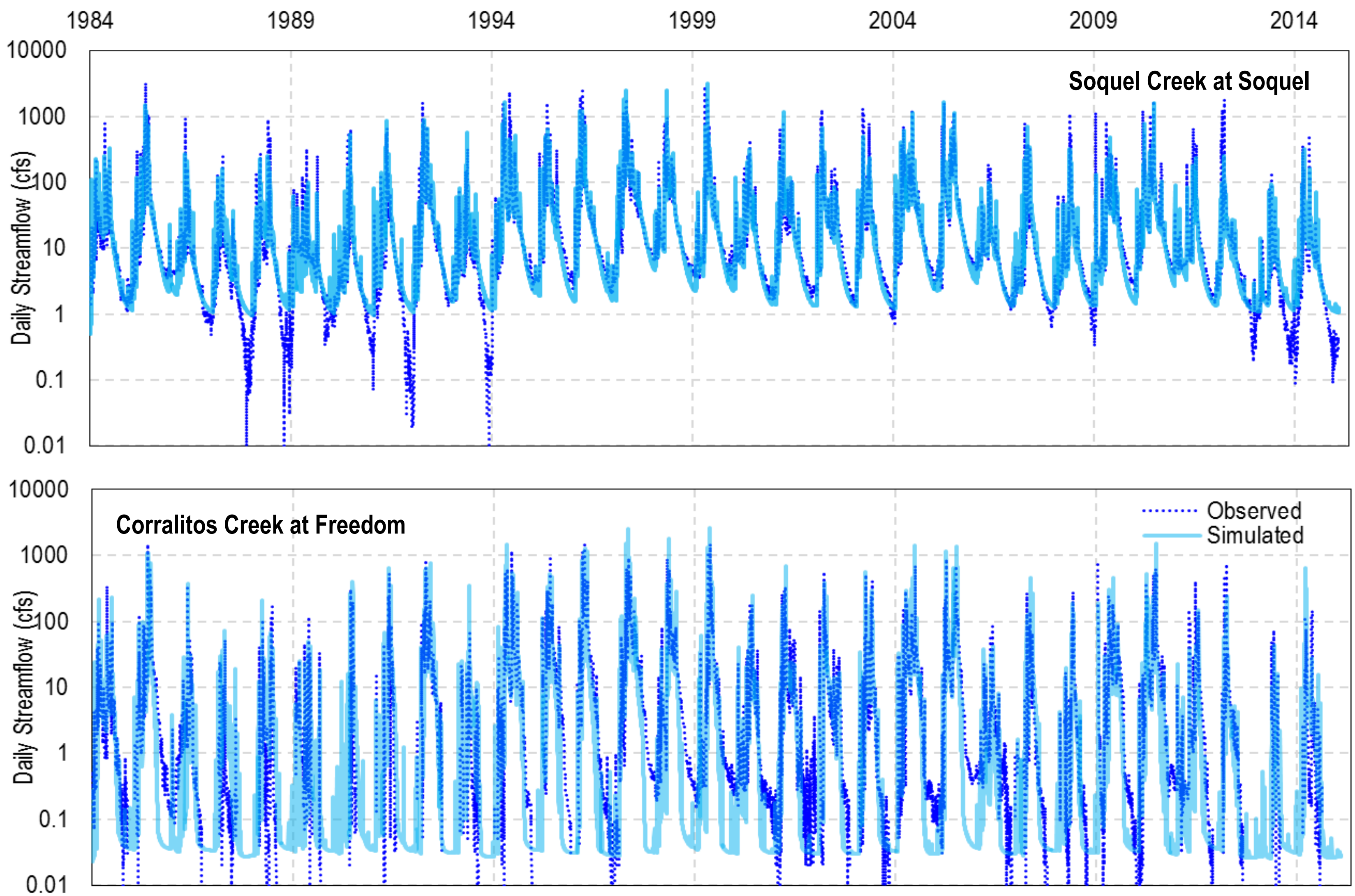


Figure 22. Simulated and Observed Streamflow: Soquel Creek at Soquel and Corralitos Creek at Freedom Gauges

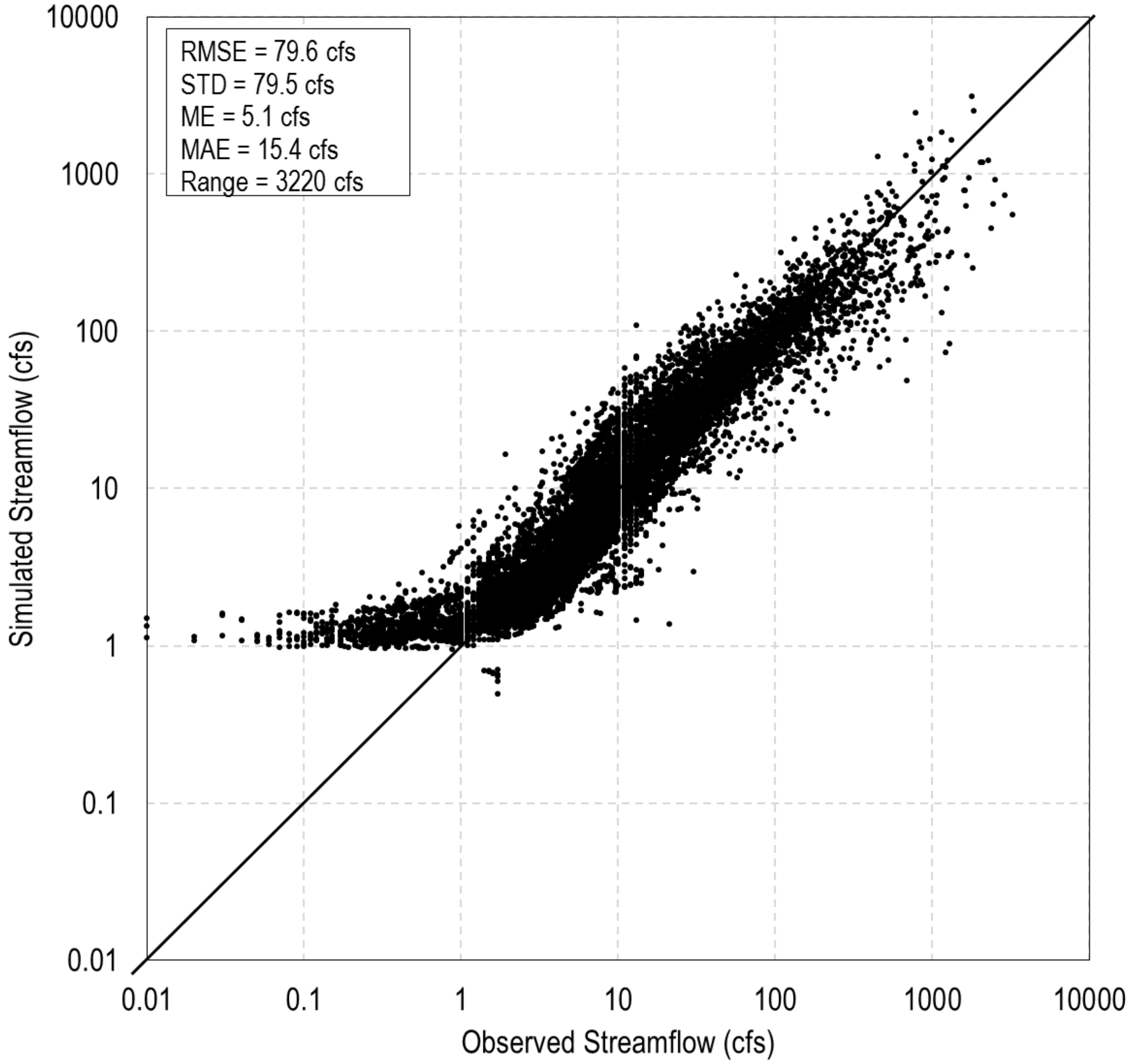


Figure 23. Soquel at Soquel Gauge Observed vs. Simulated Daily Streamflow

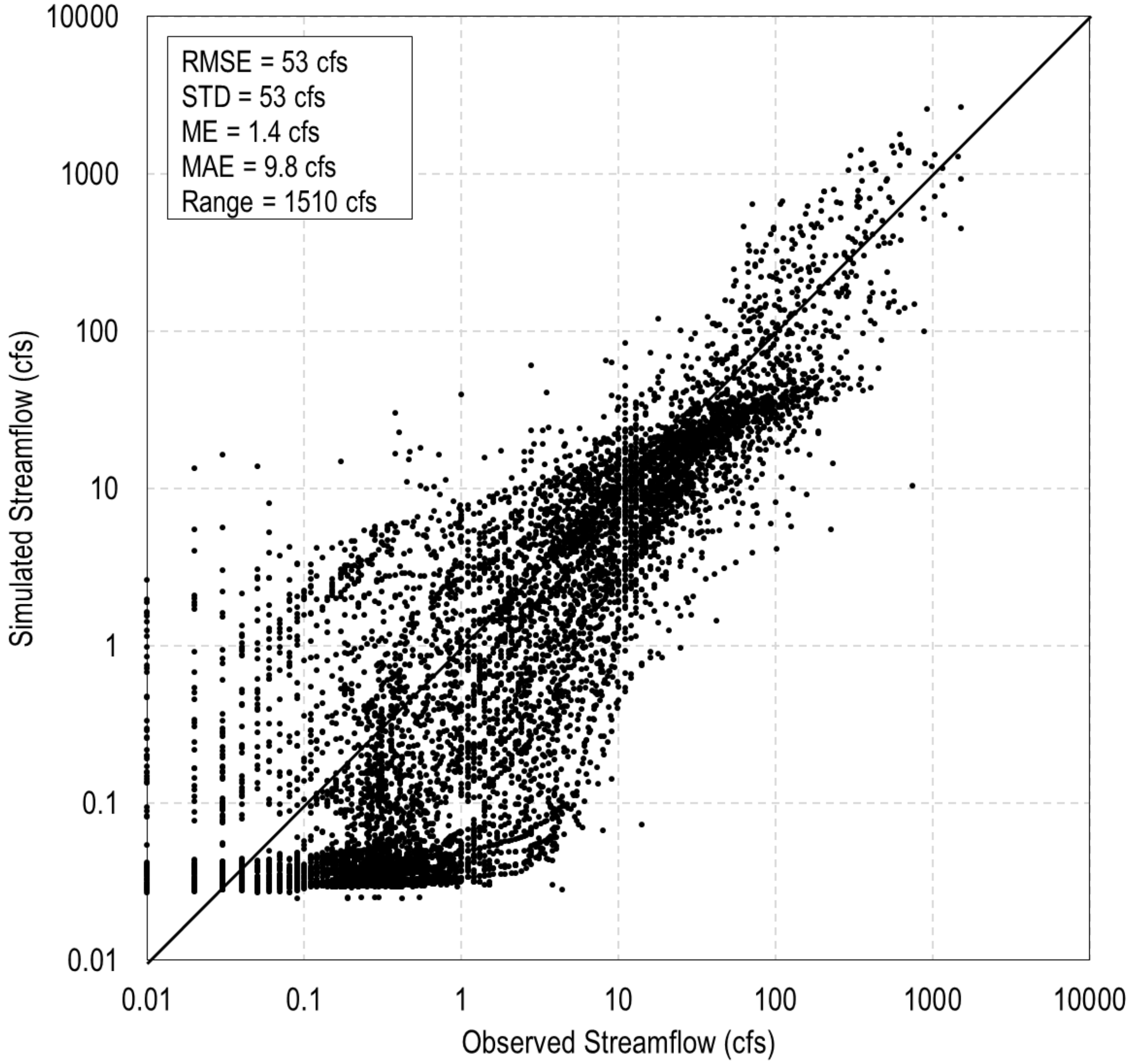


Figure 24. Corralitos at Freedom Gauge Observed vs. Simulated Daily Streamflow

The NS value is calculated for each water year as follows (Moriasi et al., 2007; Nash and Sutcliffe, 1970):

$$NS = 1.0 - \sum_{n=1}^{ndays} (MSD_n - SIM_n)^2 / \sum_{n=1}^{ndays} (MSD_n - MN_n)^2$$

where MSD = measured daily runoff values,

SIM = simulated daily runoff values,

MN = average of the measured values, and

n = the number of values out of a total of n days (ndays).

An NS value of one indicates a perfect fit between observed and simulated. A value of zero indicates that predicting annual streamflows with the PRMS model is as good as using the average value of all the observed data. Any value above zero is considered acceptable, and indicates that predicting annual streamflows with the PRMS model is better than using the average value of all the observed data. Figure 25 and Figure 26 present Nash-Sutcliffe results for stream gauges with the most complete record of data. Based on the NS charts presented for the Soquel at Soquel Gauge and the Corralitos at Freedom Gauge in Figure 25 and Figure 26, it can be inferred that predicting annual streamflows with the current PRMS model is better than using the average value of all the observed data.

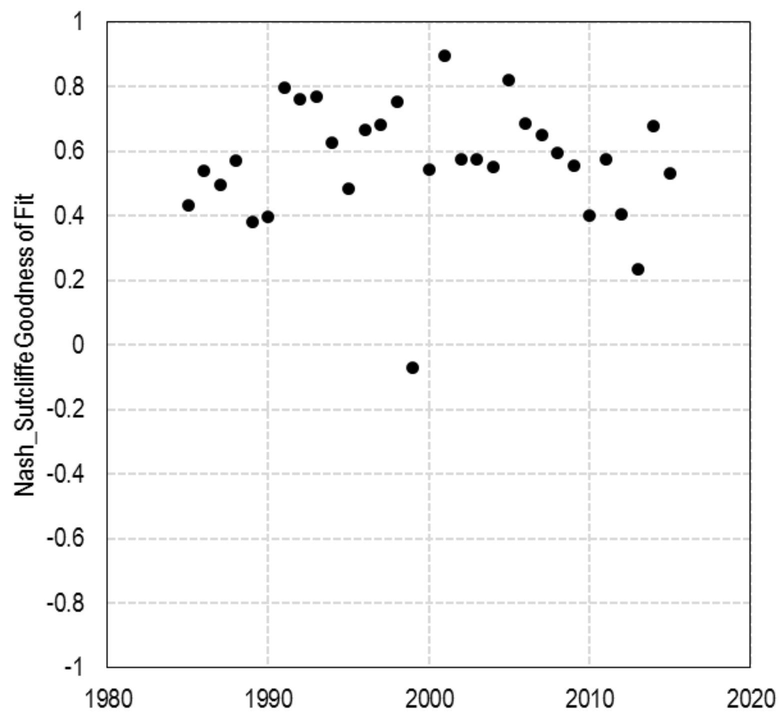


Figure 25. Nash-Sutcliffe Goodness of Fit, Soquel at Soquel Gauge

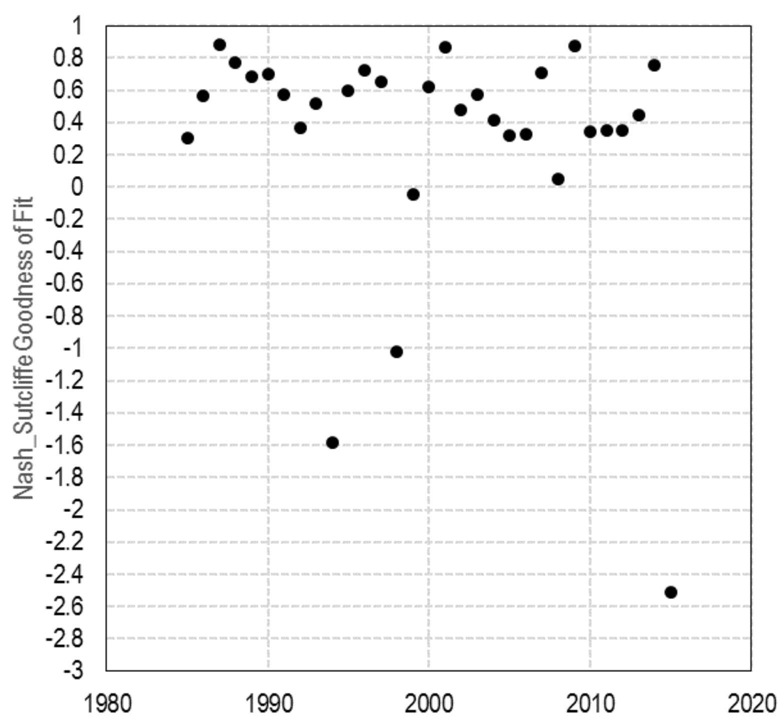


Figure 26. Nash-Sutcliffe Goodness of Fit, Corralitos at Freedom Gauge

7.3 Groundwater Calibration

The primary groundwater model parameters adjusted during calibration were as follows:

- The horizontal and vertical components of hydraulic conductivity (Kh and Kz, respectively.
- Storage parameters specific storage (Ss) and specific yield (Sy).
- GHB conductances of the offshore, seafloor, Santa Margarita Basin, and southeastern GHBs.
- Fault conductances for both the Zayante Fault and Aptos-area faulting, as represented by conductance values within the horizontal flow barrier (HFB) package in MODFLOW.

7.3.1 Groundwater Parameters Distributed by Pilot Point Method

A pilot point approach was taken to distribute the Kh, Kz, Ss, and Sy aquifer properties within the Basin model during calibration. This approach is documented by John Doherty (2003), and is similar to the approach used for the CWD groundwater model (HydroMetrics, 2014b).

The pilot point methodology estimates aquifer properties at specific points within the model domain, and interpolates the values between those points over the entire domain. Pilot points are generally placed where more calibration target data are available; in this Basin model, points clustered near the coastal well areas. Points were also distributed between pumping wells and outflow boundaries, and in areas to eliminate large spatial gaps between points. Pilot points for Kh, Kz, Ss, Sy were co-located, and their distribution in each model layer is presented on Plate 5 and Figure 27.

Plate 6 through Plate 9 show the distribution for calibrated horizontal and vertical hydraulic conductivity, specific storage and specific yield for each model layer. Plate 8 shows the approximate maximum area that is confined where the specific storage aquifer property applies. Plate 9 shows the approximate maximum area that is unconfined where the specific yield aquifer property applies.

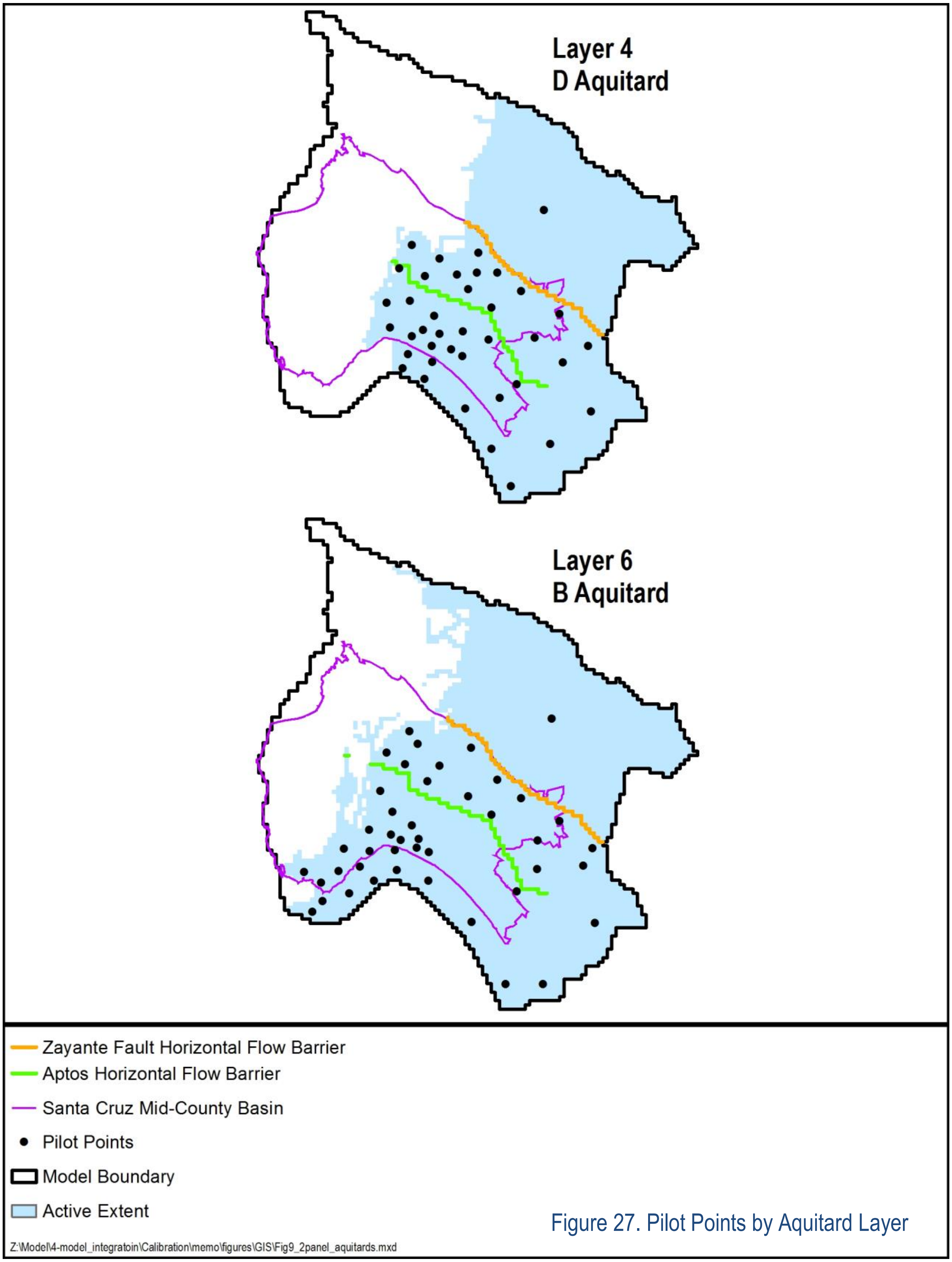


Figure 27. Pilot Points by Aquitard Layer

7.3.2 Hydraulic Properties by Basin Aquifer and Aquitard Layers

The following describes calibrated hydraulic properties by layer, focusing on the area where calibration targets exist. This area includes parts of Santa Cruz Mid-County Basin and Pajaro Valley Subbasin for the Aromas Red Sands Formation (model layer 2), south of the modeled Aptos area fault for the Purisima Formation (model layers 3-8), and the area providing municipal supply in the Tu unit (model layer 9).

- The Aromas Red Sands Formation (model layer 2) generally has higher horizontal hydraulic conductivity than other layers, though hydraulic conductivity in the Santa Cruz Mid-County Basin is generally lower than the Pajaro Valley Subbasin. Specific yield is modeled as relatively homogenous in this layer.

- The harmonic average of calibrated vertical hydraulic conductivity for Aromas Red Sands Formation and Purisima F aquifer units (model layers 2 and 3) that controls vertical flow between the layers is relatively high compared to vertical conductivity in other layers consistent with lack of a well-defined aquitard between the Aromas Red Sands and Purisima Formations.

- The Purisima F Unit (the eastern portion of model layer 3) has higher horizontal hydraulic conductivity than the Purisima DEF Unit (the western portion of model layer 3). The Purisima F Unit area has relatively high specific storage consistent with fast recovery observed at the SqCWD and CWD Rob Roy wells in the area. The Purisima DEF unit area has low specific yield in an area simulated as unconfined; however the DEF unit is more likely confined in this area and the combination of F and DEF units in the model make it difficult to simulate the confined response in the DEF Unit.

- Vertical hydraulic conductivity of the Purisima D Unit (model layer 4) is low consistent with this well-defined hydrostratigraphic unit being an aquitard.

- The Purisima BC Unit (model layer 5) has relatively low horizontal hydraulic conductivity and low specific storage consistent with the low yield and larger drawdowns of the aquifer.

- Vertical hydraulic conductivity of the Purisima B Unit (model layer 6) is low consistent with this well-defined hydrostratigraphic unit being an aquitard.

- The Purisima A Unit (model layer 7) has larger onshore areas of relatively high hydraulic conductivity (> 5 feet/day) compared to layers representing the Purisima Formation DEF, BC, and AA units, consistent with this unit having the largest number of productive wells in the Purisima. There is high hydraulic conductivity offshore to increase the connection with the offshore boundary condition. Specific storage along the coast is low to better match the groundwater level response at coastal monitoring wells to pumping.

- The Purisima AA Unit (model layer 8) has lower horizontal hydraulic conductivity than the Purisima A unit onshore in the Western Purisima area where the two units are pumped, but also has high hydraulic conductivity offshore in the west to increase the connection with where Purisima A unit outcrops. Horizontal hydraulic conductivity is high where Purisima AA unit outcrops inland. Specific storage is relatively high, especially for areas south of the horizontal flow barrier representing Aptos area faulting.

- Vertical hydraulic conductivities of the Purisima A and AA Units (model layers 7 and 8) controlling flow between the aquifer units are higher than for the Purisima D and B units (model layers 4 and 6) representing well defined aquitards. The vertical hydraulic conductivities offshore are high to connect the AA Unit with offshore outcrop that only occurs in the A Unit. In order to calibrate observed response in shallow groundwater levels to deeper Purisima Formation pumping, Purisima A unit vertical hydraulic conductivity is relatively high underlying Soquel Creek.

- The Tu Unit (model layer 9) has high horizontal hydraulic conductivity where SqCWD and City wells pump in the unit with moderate conductivities west to the approximate outcrop of the Santa Margarita Formation. The limited area of moderate and high conductivities is consistent with the apparent limits to recharge supplying the SqCWD and City wells in the unit. The vertical conductivity of the Tu Unit is very low to provide minimal connection between the Tu and the Purisima Formation. Specific storage is low to better match drawdown responses to pumping.

- Properties in areas without calibration data, such as north of the Zayante Fault and in most layers between the Zayante Fault and the HFB representing Aptos area faulting, are simulated as homogenous. Values in these areas are assigned to simulate water budget that facilitates calibration where data are available.

Hydraulic properties for the model were not calibrated to estimates for hydraulic properties obtained from pumping tests at wells in the Basin. The purpose of the Basin model is to simulate regional aquifer response to groundwater use and management in the Basin and therefore calibrating to static groundwater levels at monitoring wells is more appropriate for that purpose. Pumping tests typically provide near-well data for the response at the pumping well to pumping at the same well and therefore are more representative of conditions at the well and the immediately vicinity of the well. For reference, Appendix B provides a comparison of modeled hydraulic properties near wells with pumping test data with estimates of properties from the pumping test data.

7.3.3 Hydraulic Properties for Stream Alluvium and Terrace Deposit

Model cells underlying stream alluvium and representing overlying Terrace Deposits are mostly homogenous with high hydraulic conductivities (Kx=50 feet per day and Kz=0.1 feet per day) and relatively high specific yield of 0.15. These properties were mostly not adjusted during calibration except for two exceptions. Specific yield in the stream alluvium where shallow monitoring wells along Soquel Creek are located were lowered to 0.015 to simulate observed response to seasonal pumping cycles. Hydraulic conductivity was lowered (Kx=1 feet per day and Kz=$1x10^{-4}$ feet per day) for Terrace Deposit in model layers 6 and 7 to reduce vertical recharge into the Purisima Formation from these western areas.

7.3.4 Boundary Condition Calibration

Plate 10 presents calibrated estimates of GHB conductance by aquifer layer. Conductance is the hydraulic conductivity multiplied by cross-sectional area of flow divided by distance to boundary, which represent's the GHB's ability to transmit flow. Most of the GHB conductances represent the conceptual model for the GHB and did not require much adjustment during calibration. These GHBs include the offshore GHBs at the model boundaries, the Pajaro Valley Subbasin GHBs on each side of the Zayante Fault, and the Santa Margarita Basin GHBs.

- GHBs at the model boundary one mile offshore have very high conductances because it is assumed that groundwater is full strength seawater at the location.
- GHBs along the side boundaries that connect the shore out to the boundary one mile offshore have very low conductance to emphasize the effect of GHBs one mile offshore and for outcrops under the Bay.
- GHBs in the Pajaro Valley Subbasin south of Zayante Fault have low conductance to reflect the distance to the offshore location defining the GHB head.
- GHBs in the Pajaro Valley Subbasin north of Zayante Fault have low conductance to reflect stream conductance within Ryder Gulch that defines the GHB head.
- GHBs in the Santa Margarita Basin have high conductance to better represent nearby observations of groundwater levels.

The GHBs with conductances adjusted most in calibration were the GHBs representing offshore outcrops of aquifer units underneath Monterey Bay.

- GHBs in the Aromas Red Sands Formation (model layer 2) have low conductances for a limited connection between onshore groundwater levels with the offshore boundary. Since brackish groundwater occurs in part of the Aromas Red Sands Formation, implementation of the SWI2 seawater intrusion package may improve simulation of onshore groundwater levels in model layer 2 given presence of the freshwater-seawater interface onshore.

- GHBs in the Purisima DEF/F and BC Units (model layers 3 and 5) have low conductances for a limited connection between onshore groundwater levels with the offshore boundary. Since brackish groundwater occurs in part of the the Purisima F unit, implementation of the SWI2 seawater intrusion package may improve simulation of onshore groundwater levels in this area of model layer 3 given presence of the freshwater-seawater interface onshore.

- GHBs in the Purisima A Unit (model layer 7) have high conductances for a greater connection between onshore groundwater levels with the offshore boundary.

Plate 10 also presents calibrated estimates of horizontal flow barrier (HFB) leakance by aquifer layer to represent faulting. Leakance, or the HFB hydraulic characteristic, is equivalent to the hydraulic conductivity of the HFB divided by HFB width that represents the HFB's ability to transmit flow. In general, leakances for the HFB representing faulting in the Aptos area are lower than leakances for the Zayante Fault. Groundwater level data show a large gradient across the Aptos area, while some amount of flow across the Zayante Fault is necessary for the water budget.

7.3.5 Calibration of Groundwater Elevations in Basin Aquifer Units

Groundwater model calibration is commonly evaluated by comparing simulated groundwater levels to observed groundwater levels that make up the groundwater calibration targets as described in the sections above. Hydrographs of simulated groundwater elevations should generally match the trends and fluctuations observed in measured hydrographs. Selected hydrographs showing both observed and simulated groundwater elevations are provided in Appendix C. The hydrographs included in Appendix C were selected to represent different areas and aquifers within the model. Also, monitoring wells separated from production wells are prioritized to represent regional aquifer response to pumping. The hydrographs demonstrate that the model is accurately simulating historical hydrologic trends and response to pumping within the major aquifers of interest in the Basin, particularly at coastal monitoring wells where groundwater levels are evaluated against protective elevations to assess risk of seawater intrusion. Figure 28 through Figure 31 show hydrographs for the coastal monitoring wells that are representative monitoring points in the GSP with groundwater elevations used as proxies for seawater intrusion. The calibration supports use of model results at these wells from simulations of future conditions for comparison to the proxies to evaluate whether sustainability is achieved for the seawater intrusion indicator.

Areas where model fit is less accurate typically fall in to two categories:

- Areas where calibration target wells exhibit a confined response to pumping but fall within areas where the layer in which they are screened are unconfined within the model. This is a limitation in the vertical discretization of the model, as in Layer 3, which is a combination of the DEF and F units of the Purisima.

- Inland areas of the model where calibration target density and associated parameter pilot point density is low. These wells are often private wells with little information in areas relatively far from areas where protective groundwater elevations have been determined.

In general, the accuracy of the model to groundwater conditions within the protected aquifers, especially in regions near the coast, will make this model a robust platform for future predictive scenario of management alternatives and other groundwater infrastructure projects within the Basin.

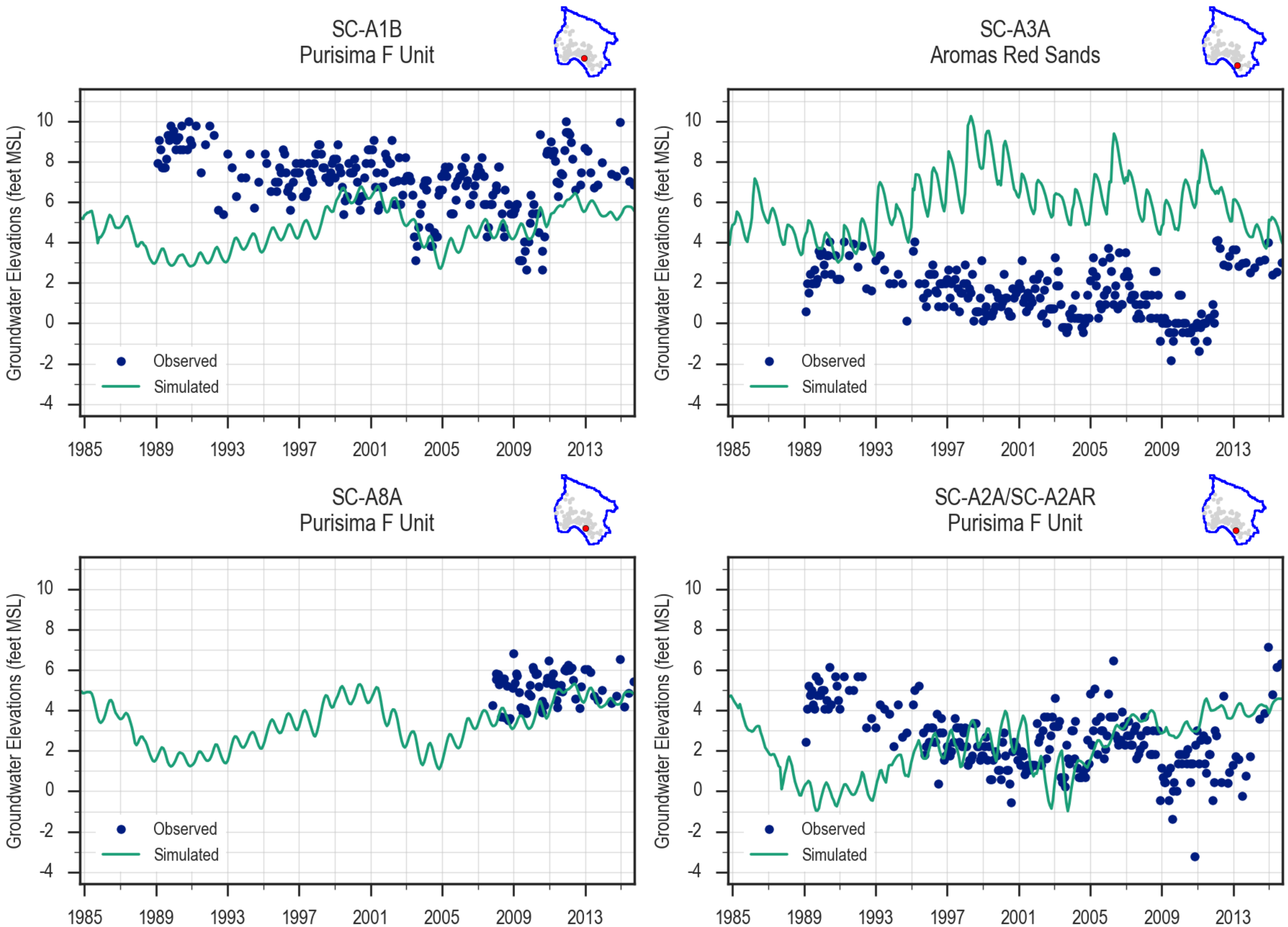


Figure 28. Calibration Hydrographs at Coastal Monitoring Wells in Aromas and Purisima F Units

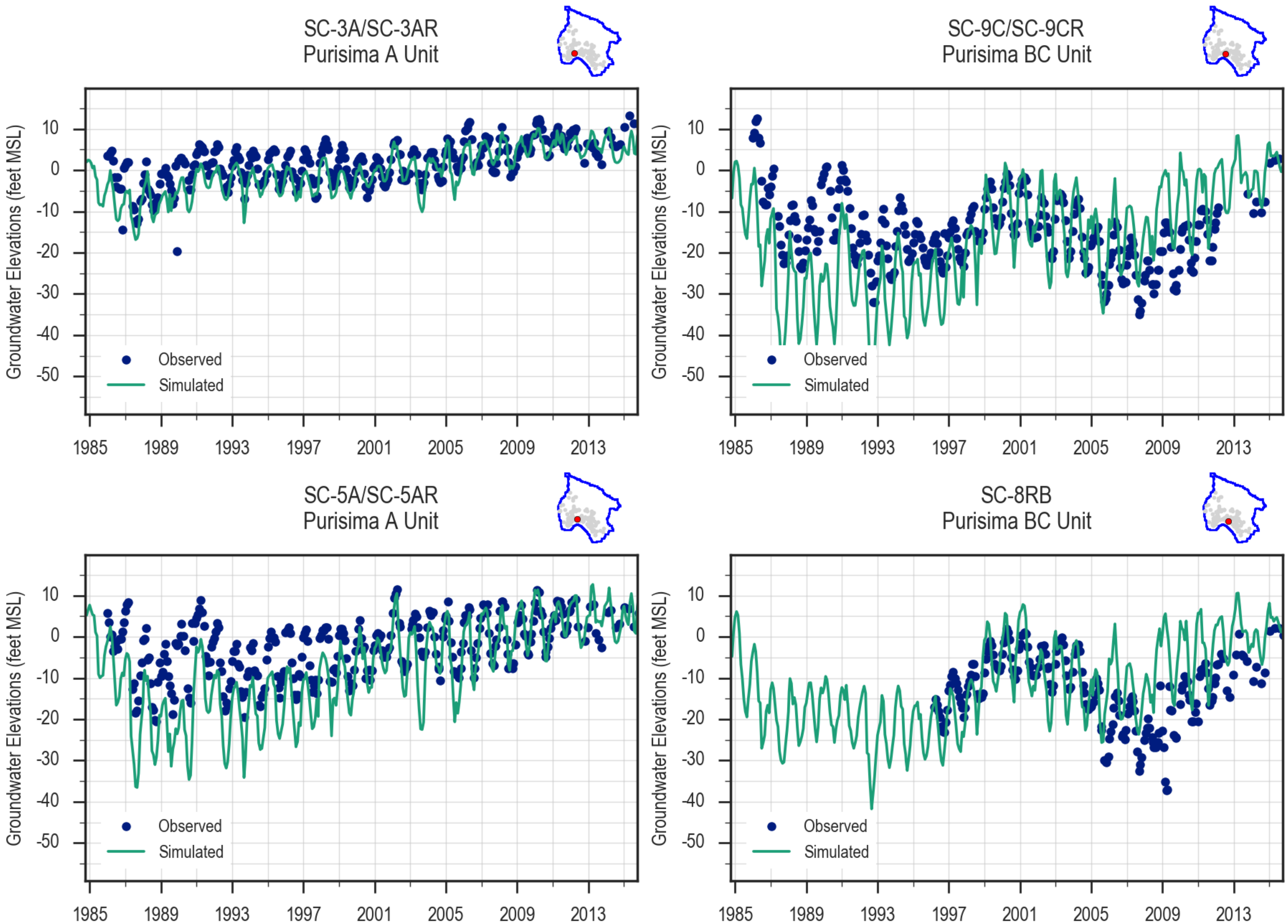


Figure 29. Calibration Hydrographs at Coastal Monitoring Wells in Purisima BC and A Units

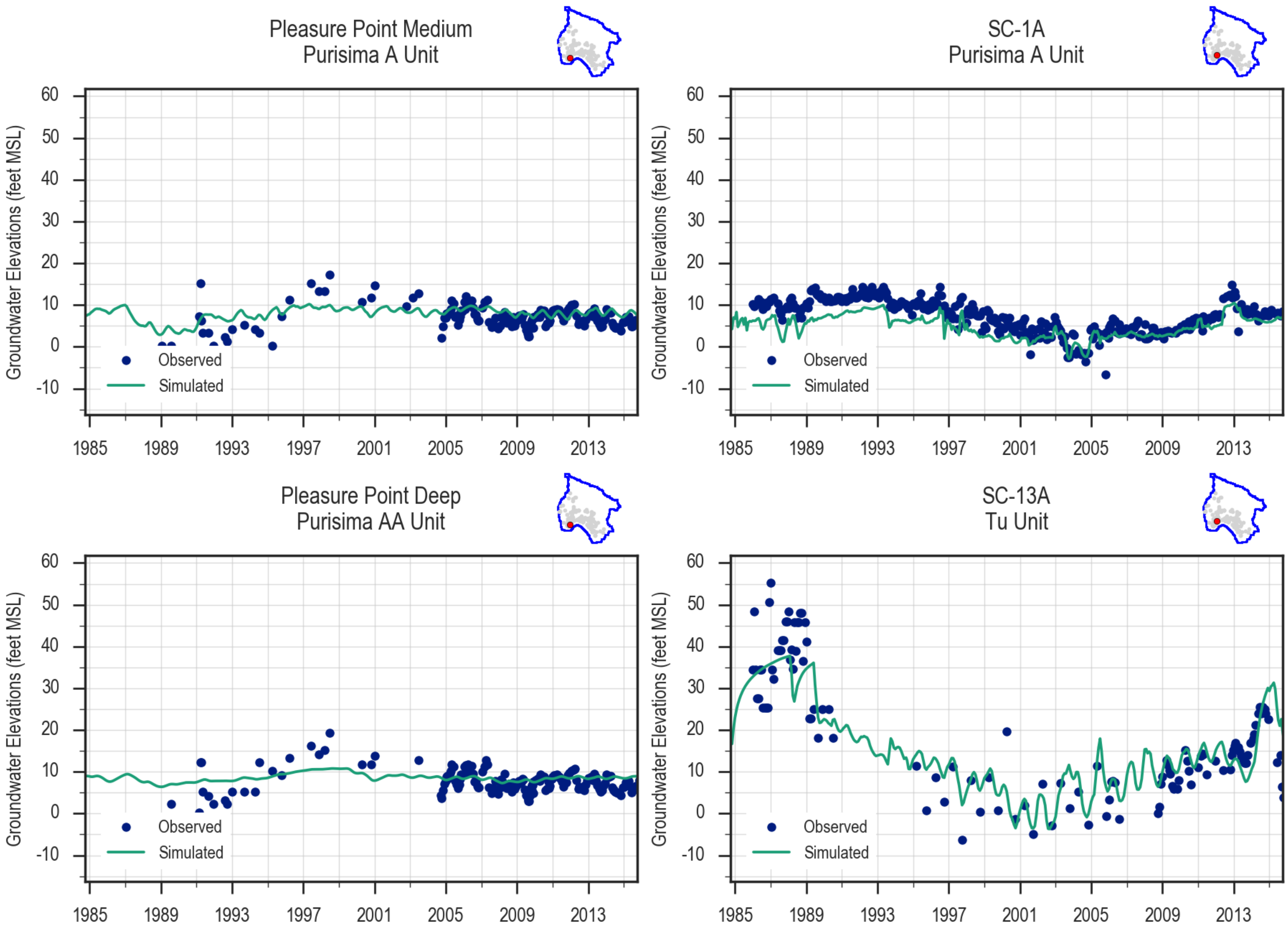


Figure 30. Calibration Hydrographs at Coastal Monitoring Wells in Purisima A and AA Units and Tu Unit

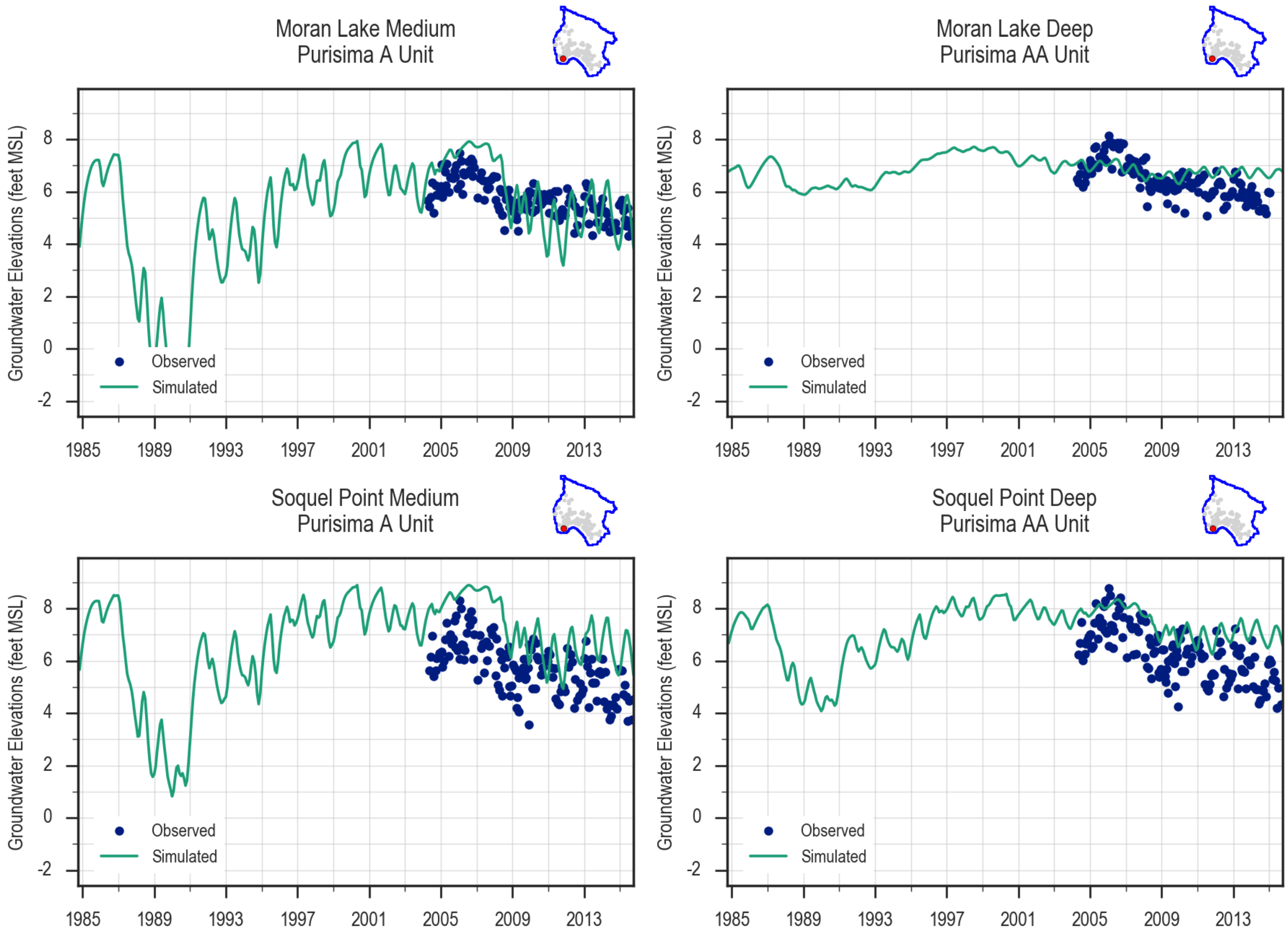


Figure 31. Calibration Hydrographs at Coastal Monitoring Wells in Purisima A and AA Units

Various graphical and statistical methods can be used to demonstrate the magnitude and potential bias of the calibration errors. Figure 32 shows simulated groundwater elevations plotted against observed groundwater elevations for the entire calibration period. Results from an unbiased model will scatter around a 45º line, shown as a solid black line on this graph. If the model has a bias such as exaggerating or underestimating groundwater level differences, the results will diverge from this 45º line. The distribution of data points on Figure 32 show that they cluster along the 45º line, indicating that the model results are not biased towards overestimating or underestimating average groundwater level differences.

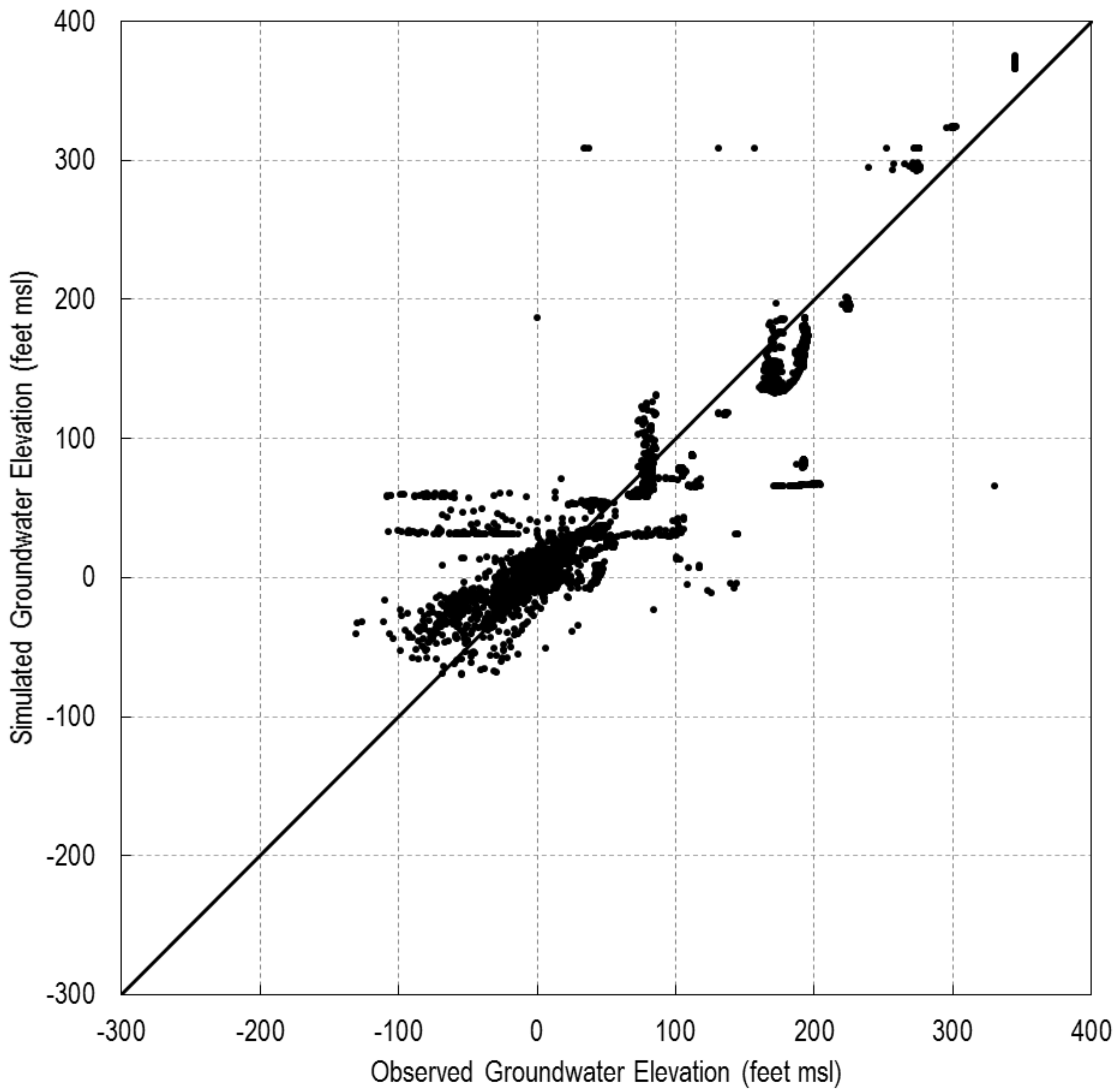


Figure 32. Observed vs. Simulated Groundwater Elevations from Groundwater Calibration Targets in Model

Table 10 includes various statistical measures of calibration accuracy. The four statistical measures used to evaluate calibration are the mean error (ME), the mean absolute error (MAE), the standard deviation of the errors (STD), and the root mean squared error (RMSE). The mean error is the average error between measured and simulated groundwater elevations for all data on Figure 32.

$$ME = \frac{1}{n}\sum_{i=1}^{n}\left(h_m - h_s\right)_i$$

Where h_m is the measured groundwater elevation, h_s is the simulated groundwater elevation, and n is the number of observations.

The mean absolute error is the average of the absolute differences between measured and simulated groundwater elevations.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|h_m - h_s\right|_i$$

The standard deviation of the errors is one measure of the spread of the errors around the 45º line in Figure 32. The population standard deviation is used for these calculations.

$$STD = \sqrt{\frac{n\sum_{i=1}^{n}\left(h_m - h_s\right)_i^2 - \left(\sum_{i=1}^{n}\left(h_m - h_s\right)\right)_i^2}{n^2}}$$

The RMSE is similar to the standard deviation of the error. It also measures the spread of the errors around the 45º line in Figure 32, and is calculated as the square root of the average squared errors.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(h_m - h_s\right)_i^2}$$

As a measure of successful model calibration, Anderson and Woessner (1992) state that the ratio of the spread of the errors to the total head range in the system should be small to ensure that the errors are only a small part of the overall model response. As a general rule, the RMSE should be less than 10% of the total head range in the model. The RMSE of 22.13 feet is approximately 2.3% of the total head range of 983.60 feet. A second general rule that is occasionally used is that the mean absolute error should be less than 5% of the total head range in the model. The mean absolute error of 10.17 feet is approximately 1.0% of the total head range. Therefore, on average, the model errors are within an acceptable range.

Table 10. Statistical Measures of Model Calibration

Statistical Measure	Abbreviation	Measure Value	Ratio of Measure to the Range of Observed Values
Root Mean Square Error	RMSE	22.13	2.3%
Standard Deviation	STD	22.09	2.2%
Mean Error	ME	1.29	0.1%
Mean Absolute Error	MAE	10.17	1.0%
Range of Observed Values	Range	983.60	

7.3.6 Groundwater Elevation Calibration in Shallow Wells along Soquel Creek

Under Santa Cruz County's Prop 1 grant, the model was calibrated to shallow groundwater elevations along Soquel Creek in order to support use of the model to evaluate streamflow depletion from pumping. The purpose of this focused calibration is for the model to simulate the long-term trends where shallow aquifer response to deeper pumping is observed. This is primarily achieved by adjusting hydraulic parameters that control the vertical connection between the stream, the layer representing shallow alluvium, and the deeper Purisima Formation units (Figure 15). The main hydraulic parameters controlling this connection is streambed hydraulic conductivity (Section 7.2.2) and Purisima Formation vertical conductivity (Section 7.3.2).

In order to show the vertical connection, hydrographs of simulated results and observations at shallow wells are shown with hydrographs of simulated results in underlying Purisima Formation layers. As described in Section 7.3.5 , the model is calibrated to simulate response to pumping in the Purisima Formation. Figure 33 shows the hydrographs of the upstream Simons and Balogh shallow wells where observed shallow groundwater levels do not show the long term trend of a response to Basin pumping simulated in the underlying Purisima A unit. The model is calibrated also to not simulate a shallow aquifer response to pumping.

The Main Street shallow well is adjacent to the Main Street production well that is screened in the deeper Purisima AA unit and Tu unit. Figure 34 shows a muted response at the Main Street shallow wells to pumping compared to the response simulated in the Purisima AA unit, but observed groundwater levels at the Main Street shallow well do follow the long-term trend of groundwater level recovery from 2001 to 2011, then a brief increase in drawdown in 2012-2013, with increased pumping from the Main Street well and a rebound thereafter.

Figure 35 shows similar simulation of long-term trends at the Nob Hill shallow well.

These shallow monitoring wells are representative monitoring points in the GSP with groundwater elevations used as proxies for the streamflow depletion sustainable management criteria. The basis for the use of these proxies is that the higher shallow groundwater levels indicate greater groundwater flow to streams, and lower shallow groundwater levels indicate less groundwater flow to streams based on the apparent connection between stream stages and shallow groundwater levels. The model is calibrated to simulate the observed shallow groundwater elevations in response to groundwater levels and pumping in deeper Purisima units. The calibration supports use of model results for simulations of future conditions at these wells. The results can be compared to groundwater level proxies for evaluating whether sustainability is achieved for the depletion of interconnected surface water indicator. Therefore, the model can be used to evaluate effects of projects and management actions in the deeper Purisima units on shallow groundwater levels for comparison to the groundwater level proxies.

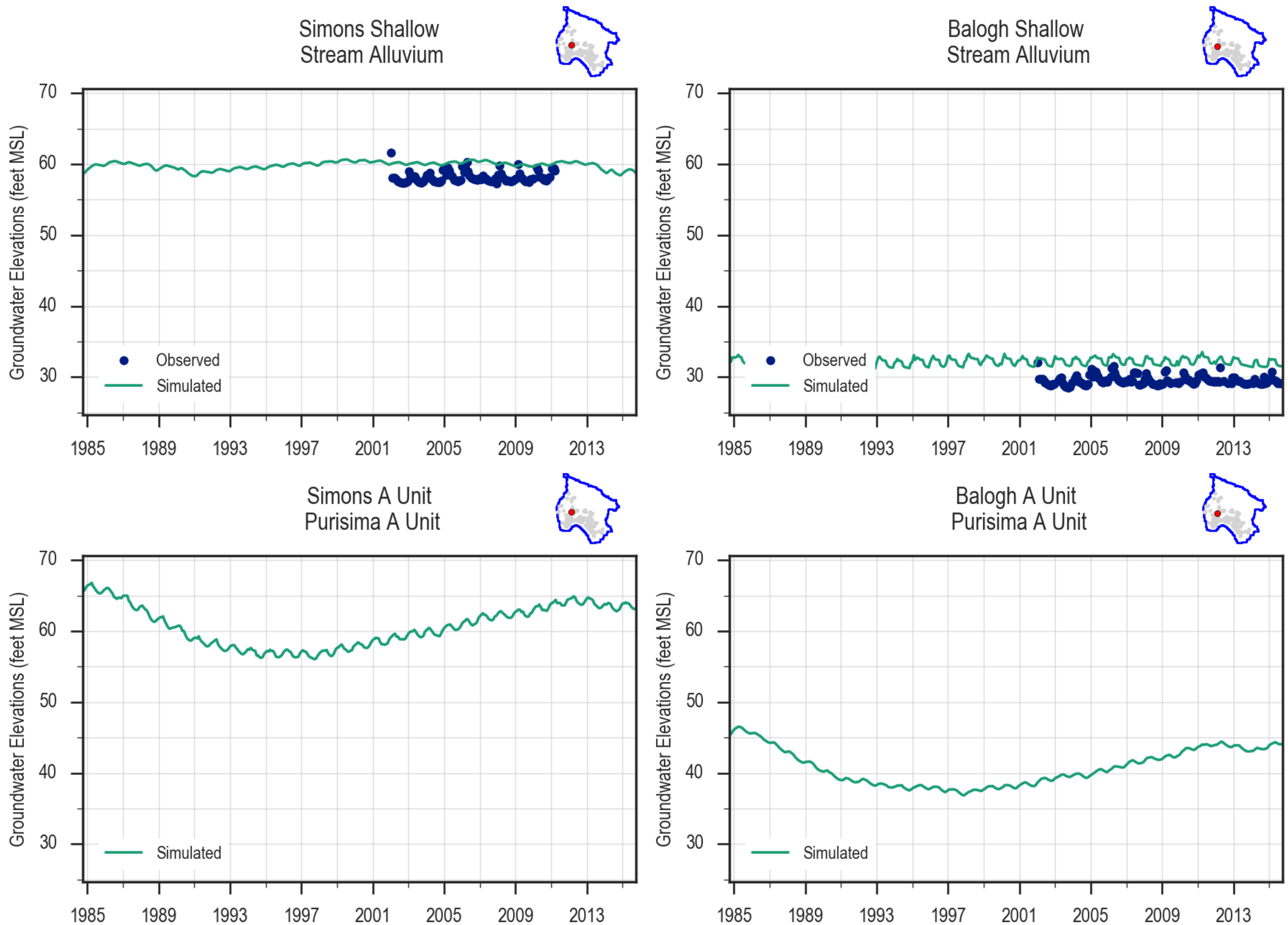


Figure 33. Calibration Hydrographs at Simons and Balogh Shallow Wells and Underlying Purisima A Unit

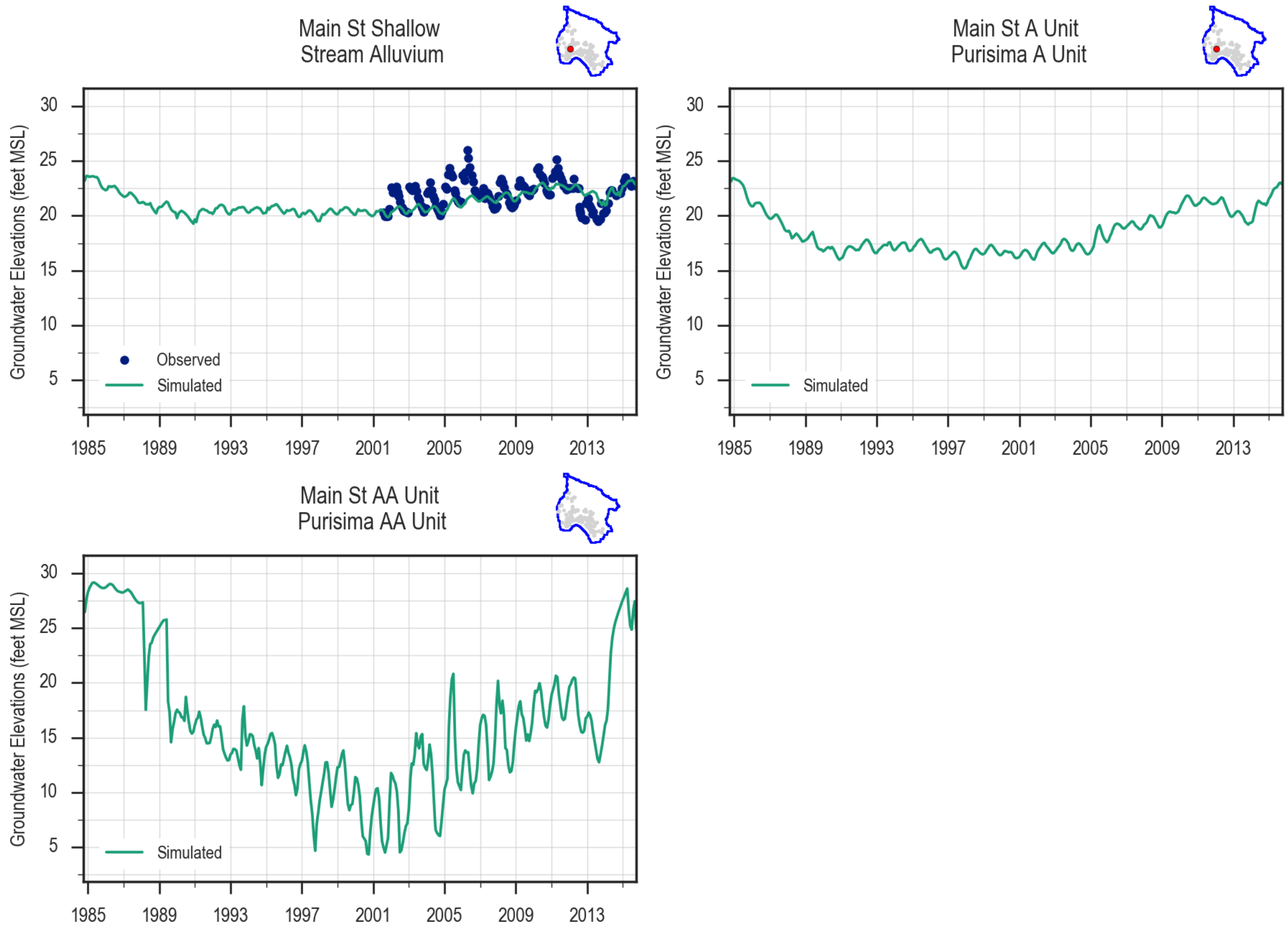


Figure 34. Calibration Hydrographs at Main St. SW 1 and Underlying Purisima A and AA Units

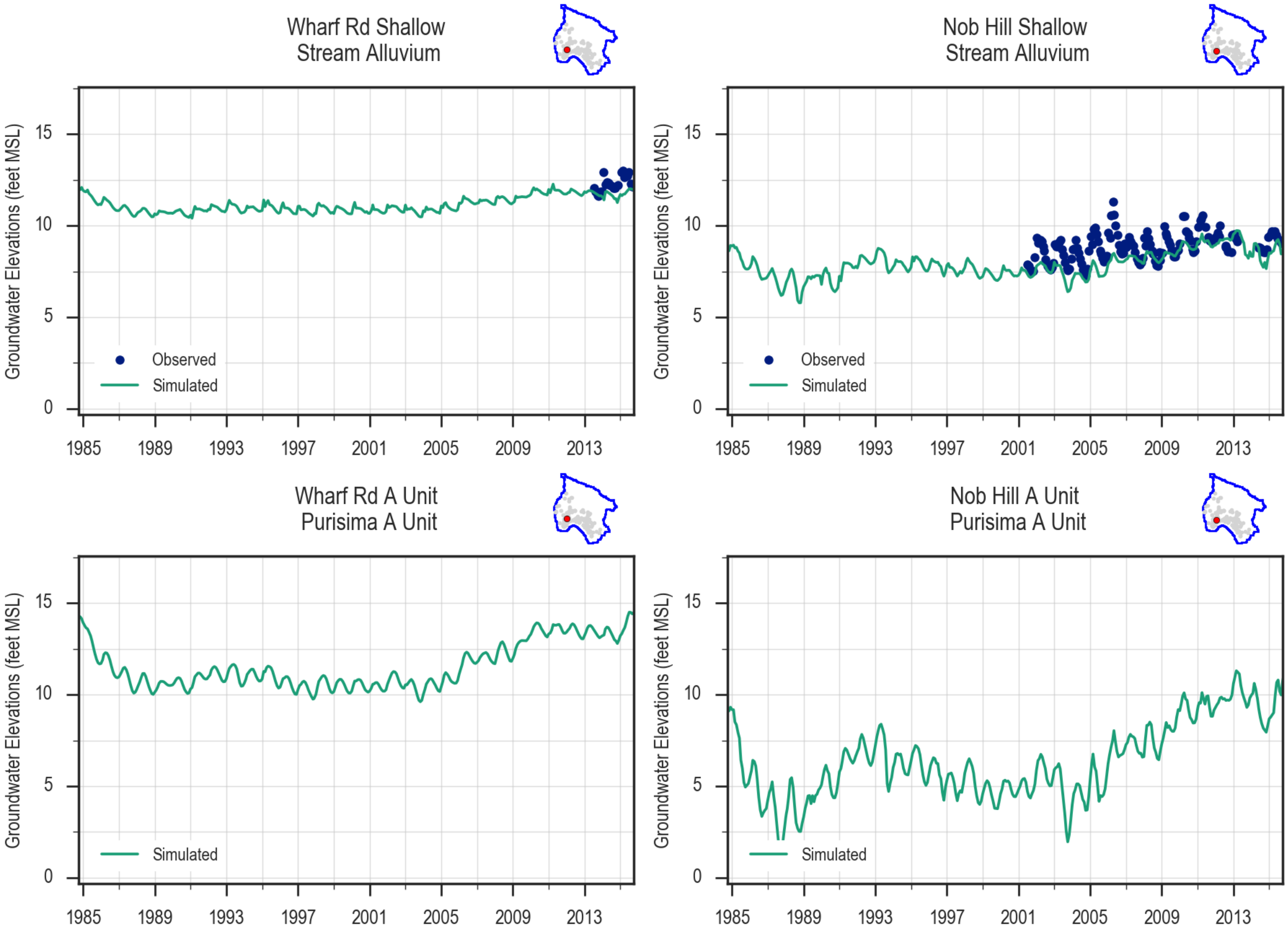


Figure 35. Hydrographs at Wharf Rd. and Nob Hill Shallow Wells and Underlying Purisima A Unit

8 RESULTS FOR CALIBRATED MODEL

8.1 Groundwater Elevation Contours

Plate 11 through Plate 14 show simulated groundwater elevations within each aquifer layer of the model at September 1994 and March 2015. September 1994 is a representative time for when groundwater elevations are low throughout the Basin. March 2015 is the representative time for when groundwater elevations are high throughout the Basin. Plate 11 and Plate 13 show groundwater elevations for these time periods. These maps show the simulated regional groundwater directions and gradients within the Basin by aquifer.

- The Aromas Red Sands Formation (model layer 2) generally shows flow toward the coast within the Basin but the 10 foot above mean sea level (amsl) contour moves toward the coast over time as pumping decreases.

- The Purisima F unit portion (eastern part of layer in Basin) of model layer 3 shows flat gradient of 0-10 feet amsl near the coast, but pumping depressions near the coast are eliminated over time. Inland contours move farther inland over time as pumping at the inland Rob Roy wells, Aptos Jr. High well, and Polo Grounds wells come online.

- The Purisima DEF unit portion (western part of layer) of model layer 3 shows increased pumping depressions over time as pumping shifted from the Aptos Creek well also screened in the BC unit to T. Hopkins well screened only in the DEF time.

- The Purisima BC unit (model layer 5) shows a large pumping depression below sea level that lessens over time such that groundwater elevations rise to and above sea level at the coast.

- The Purisima A unit (model layer 7) shows pumping depressions below sea level that lessen over time such that groundwater elevations rise to and above sea level at the coast.

- The Purisima AA unit (model layer 8) shows a small pumping depression that lessens over time.

- The Tu unit (model layer 9) shows larger pumping depressions in the fall and less in the spring. Spring 2015 is prior to Tu pumping being increased with new wells at Beltz #12 and O'Neill Ranch in summer and fall 2015.

Plate 12 and Plate 14 show the areas that are dry, unconfined, and confined for each aquifer layer of the model. The confined area is where specific storage (Plate 10) applies and the unconfined area is where specific yield (Plate 9) applies. The Aromas Red Sands Formation (model layer 2) is mostly unconfined within the Basin so confined response to pumping that is sometimes observed in the Basin is not well simulated, which is why some wells that may be screened across both the Aromas Red Sands Formation and Purisima F unit (model layer 3) are simulated as pumping from model layer 3 only. Much of the Purisima DEF unit area, western portion of model layer 3, is unconfined, and the model does not simulate the confined response to pumping in this area. Adding more layer discretization to these areas would be necessary to better simulate the confined response that is observed.

8.2 Surface Water Budget

In this sub-section, the surface water budget of the Basin is described. The surface water budget is described for the watershed and for the stream system within the Basin. The watershed budget is based on model results for how precipitation is apportioned. The stream system budget describes inflows and outflows to streams in the Basin.

For the watershed budget, the model simulates annual precipitation over the calibration period in the Basin as ranging from less than 16 inches to over 65 inches (1990 and 1998 respectively). On average, the model simulates 66% of precipitation that lands on the Basin as evaporated or transpired without reaching a surface water body. The model simulates another 27% as overland flow that eventually enters streams and creeks within the Basin. Five percent of precipitation is simulated to percolate beyond the root zone and enters the underlying aquifer as unsaturated zone flow (UZF) recharge, Terrace Deposits recharge, or stream alluvium recharge. The remaining portion (2%) reflects the net change in soil moisture stored in the soil layer over the Basin area. In most years this value is negative, reflecting gaining soil moisture conditions. However, in some years this value is positive, reflecting decreasing moisture in the soil layer. Typically this occurs during relatively dry years following a wet period, as evapotranspiration (ET) receives larger contributions from the soil layer during the drier year. The precipitation budget over time is presented in Figure 36.

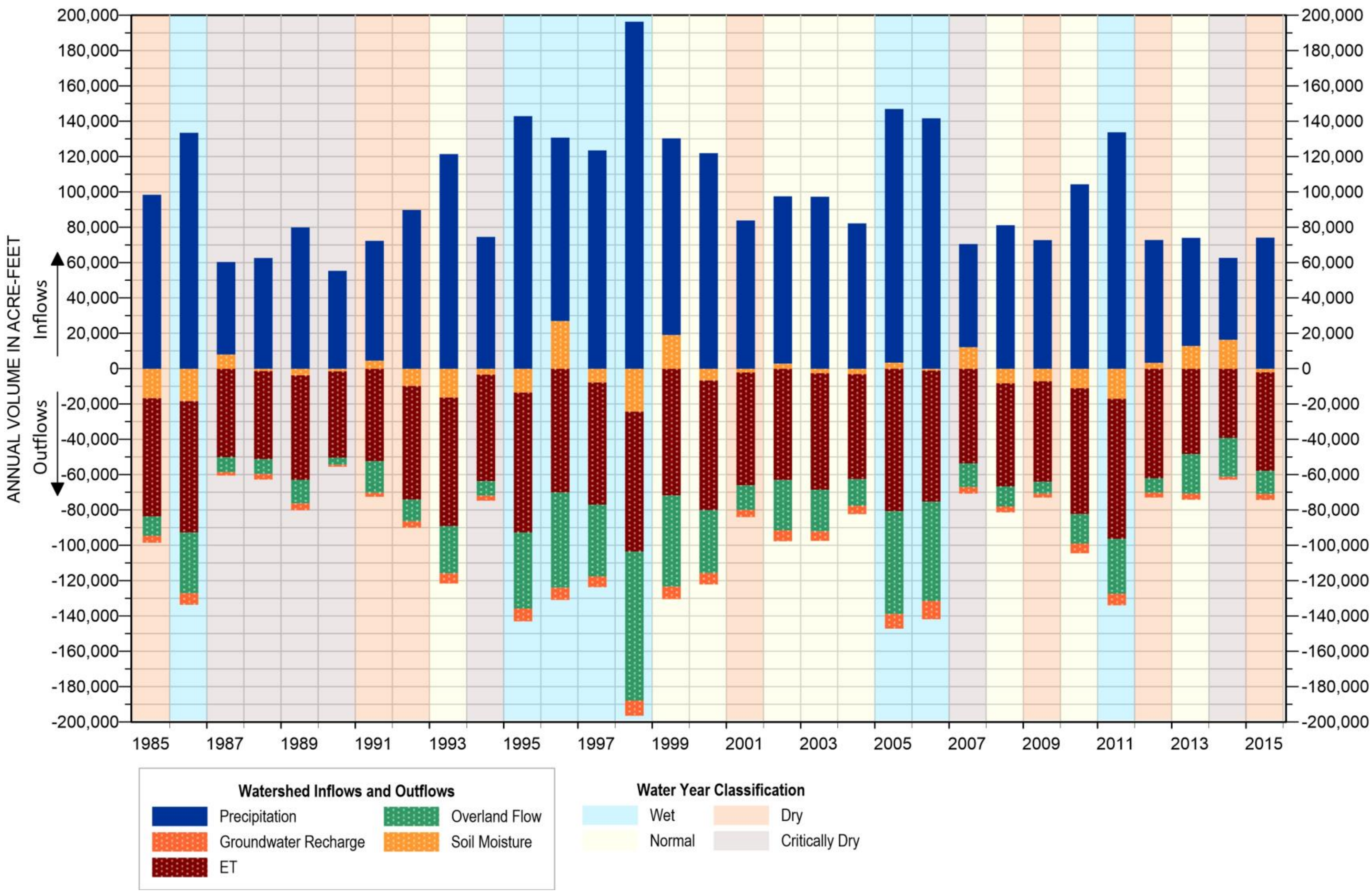


Figure 36. Annual Watershed Budget for Santa Cruz Mid-County Basin

For the stream system budget, the model simulates around 56% of inflow to the Basin's surface water system occurs due to overland flow entering streams and rivers within the Basin. The model simulates an additional 26% as entering the Basin from the area overlying Purisima Highlands Subbasin to the north. Primary water bodies supplying this inflow include Soquel Creek, Hester Creek, Hinckley Creek, and Aptos Creek. The model simulates 16% as entering from the adjacent Santa Margarita Basin, primarily from Branciforte and Granite Creeks. The remaining 3% of inflow to the surface water system is from net inflow from groundwater to streams (2%) and a few small creeks entering from the Pajaro Valley Subbasin (1%).

Surface water outflows in the model are dominated by outflow to ocean (89%). Nine percent leaves the Basin via Carbonara Creek, which enters the area overlying the Santa Cruz Terrace Subbasin just north of the City of Santa Cruz. The remaining 2% comprises minor amounts of surface water flowing into the Pajaro Valley Subbasin and Santa Margarita Basin, and small soil moisture fluctuations in the soil layer. The historical stream system water budget is presented in Figure 37.

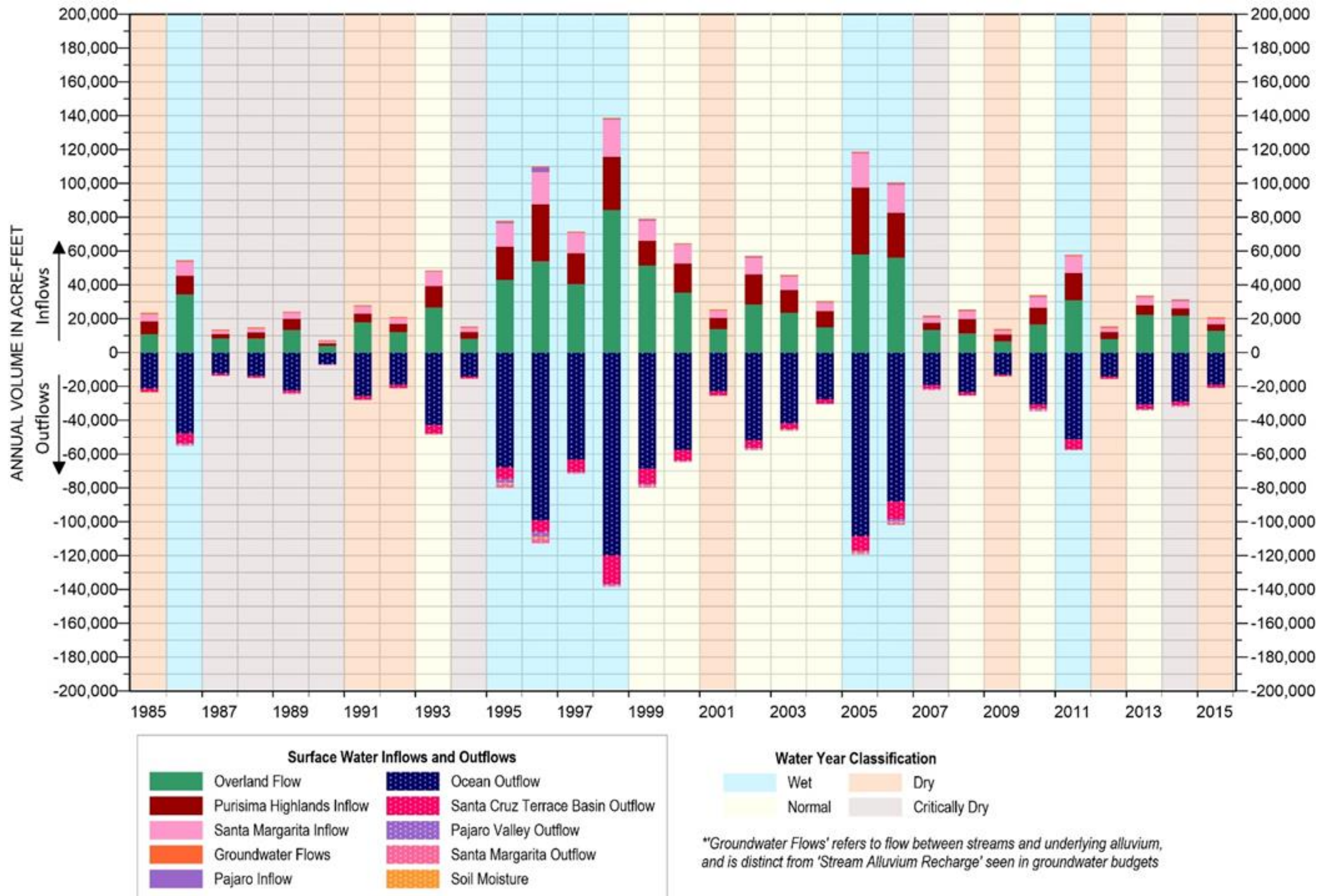


Figure 37. Annual Stream System Budget for Santa Cruz Mid-County Basin

8.3 Groundwater Budget

In this section, the groundwater budget of the Basin is described. Components of the groundwater budget are discussed in the subsections below. The groundwater budget discussion and associated charts separate the areas north and south of the horizontal flow barrier (HFB) representing Aptos area faulting because the groundwater budget south of this HFB Fault is more instructive for evaluating seawater intrusion, which is the sustainability indicator that has driven designation of the Basin as being in critical overdraft. In addition, the majority of pumping in the Basin, including all of the municipal pumping, occurs south of the Aptos area faulting (Figure 12) and most of the calibration data are from south of the Aptos area faulting (Plate 4).

Figure 38 and Figure 39 show the annual groundwater budget either side of the HFB representing Aptos area faulting, within the Basin. As discussed earlier, there are limited pumping activities north of the Aptos area faulting, with the majority of Basin pumping occurring south of Aptosarea faulting. The water budget north of the Aptos area faulting mainly comprises natural areal recharge (included as "UZF Recharge" on figures), stream recharge (shown as "Stream Alluvium" on figures), inflows from Purisima Highlands Subbasin, and outflows to Pajaro Valley Subbasin. Groundwater flows across basin boundaries south of the Aptos area faulting are not as substantial part of the water budget as they are north of the Aptos area faulting. Instead the water budget south of the Aptos area faulting in the Basin is influenced mostly by groundwater pumping, areal recharge, stream recharge, and flows offshore.

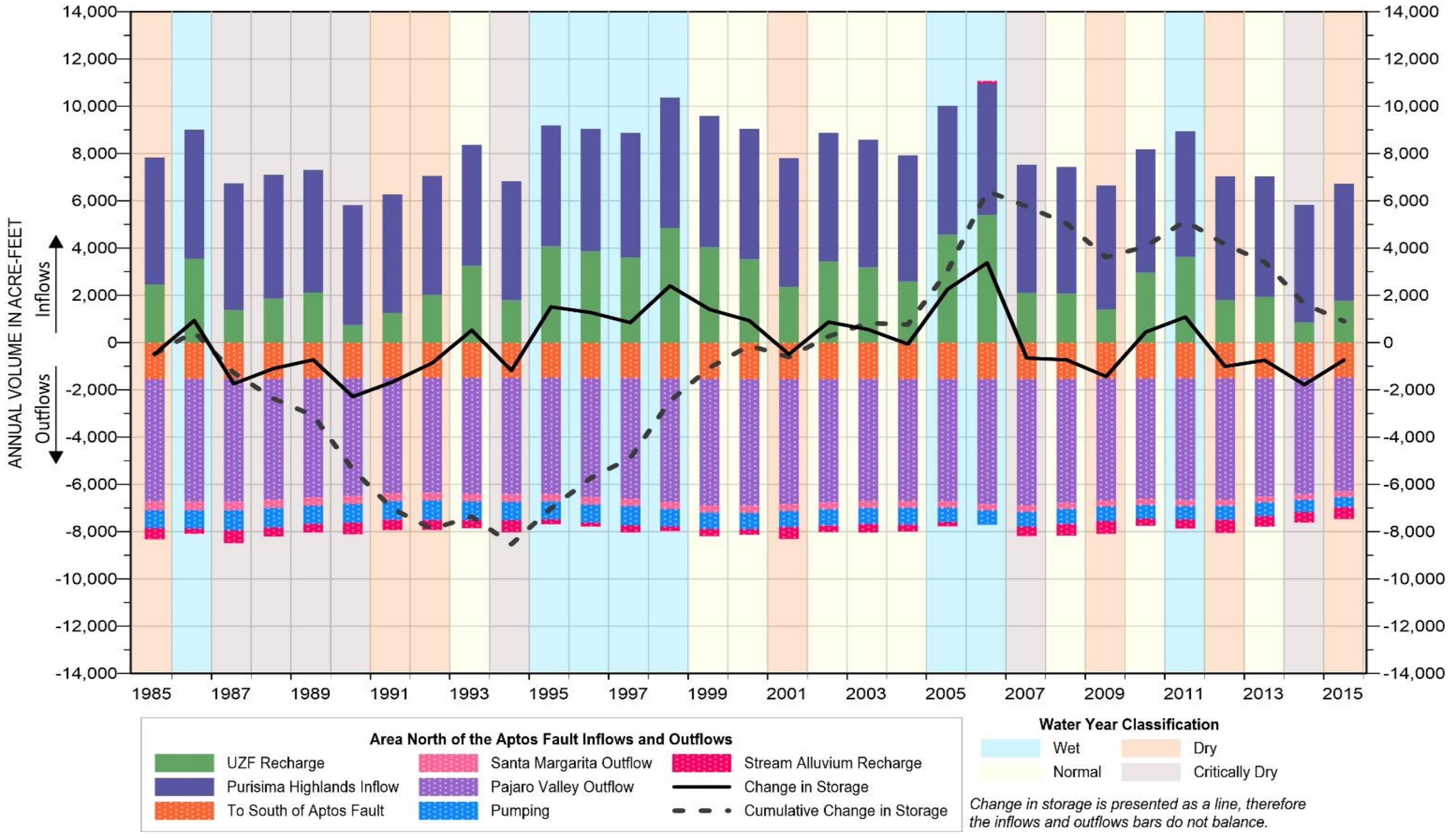


Figure 38. Annual Groundwater Budget in Santa Cruz Mid-County Basin, North of HFB for Aptos Faulting

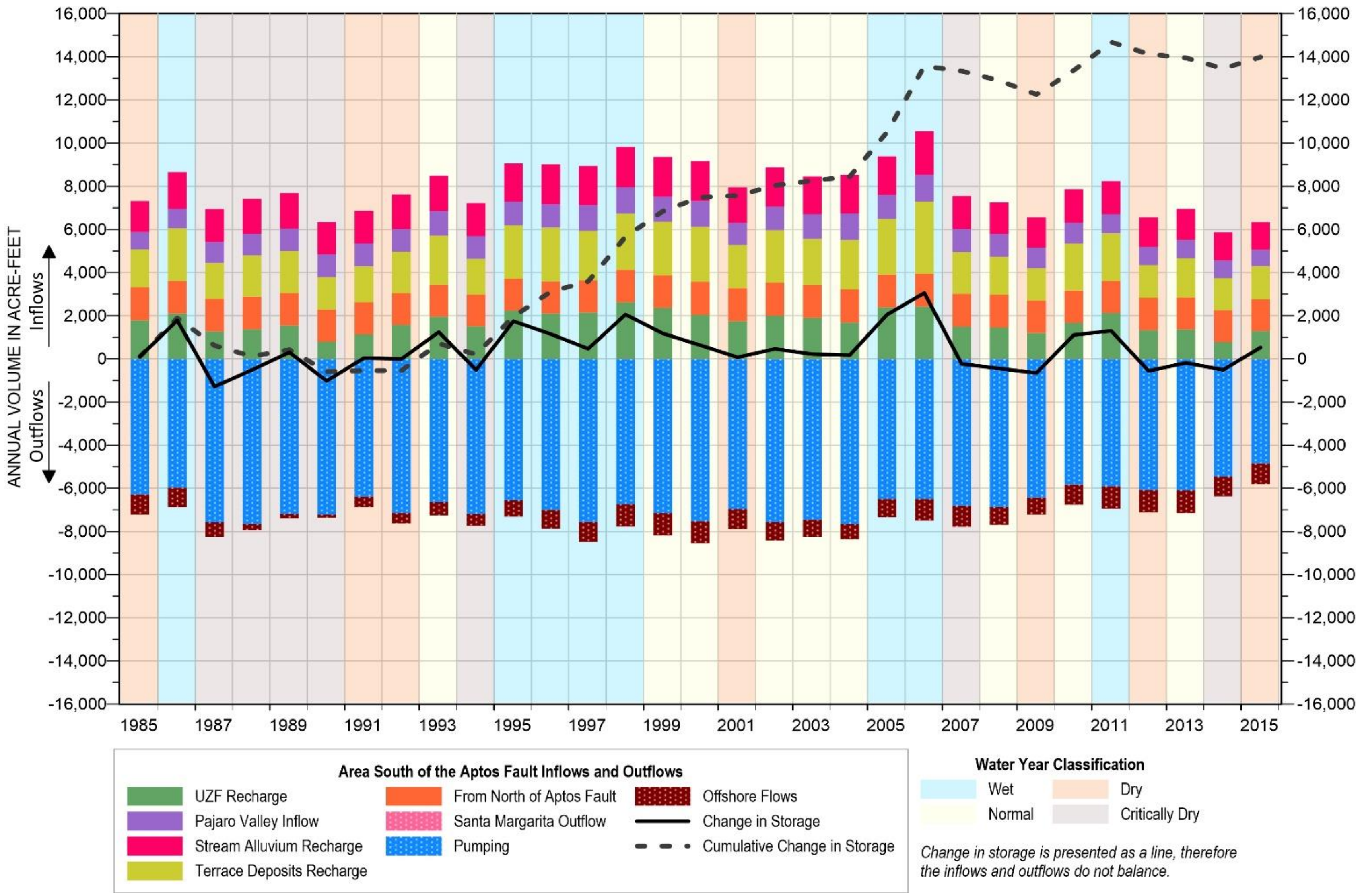


Figure 39. Annual Groundwater Budget in Santa Cruz Mid-County Basin, South of HFB for Aptos Faulting

8.3.1 Flows within Basin Boundaries

8.3.1.1 UZF recharge

This component of the groundwater budget includes components of areal recharge calculated by PRMS from climate inputs (direct recharge and gravity drainage in Figure 3) and return flows that are described in Section 4.4. These flows are always inflows to the Basin.

UZF recharge varies with climatic conditions. UZF recharge is greater north of the HFB representing Aptos area faulting than south of the HFB, but this is partly because recharge to Terrace Deposits is calculated separately from UZF recharge (see subsection below).

8.3.1.2 Flows between Alluvium to Aquifers and Aquitards of the Basin

The groundwater budget is calculated for layers representing the stacked aquifer and aquitard units of the Basin. Aromas Red Sands, Purisima Formation units, and Tu unit. Therefore, the water budget includes flows from overlying cells representing stream alluvium and Terrace Deposits (Figure 40).

Flow from stream alluvium is an important component of the Basin's groundwater budget and includes both streambed recharge and areal recharge through these areas. The volumes shown on the water budget charts represent net flows from stream alluvium to underlying aquifer and aquitard layers. There are areas and months where groundwater from the aquifers and aquitards flow into the stream alluvium, but overall the annual net flow is from stream alluvium to underlying stacked units of the Basin. Meanwhile, the surface water budget (Figure 37) shows net groundwater discharge from stream alluvium to streams. Thus, the stream alluvium is a net source of water for both streams and the underlying stacked aquifer and aquitard units of the Basin.

South of the Aptos area faulting, flow from alluvium includes flow from Terrace Deposits overlying the layers. This is a type of areal recharge to the coastal areas of the Basin and are always inflows.

Appendix D includes the annual water budget for each model layer in the Basin.

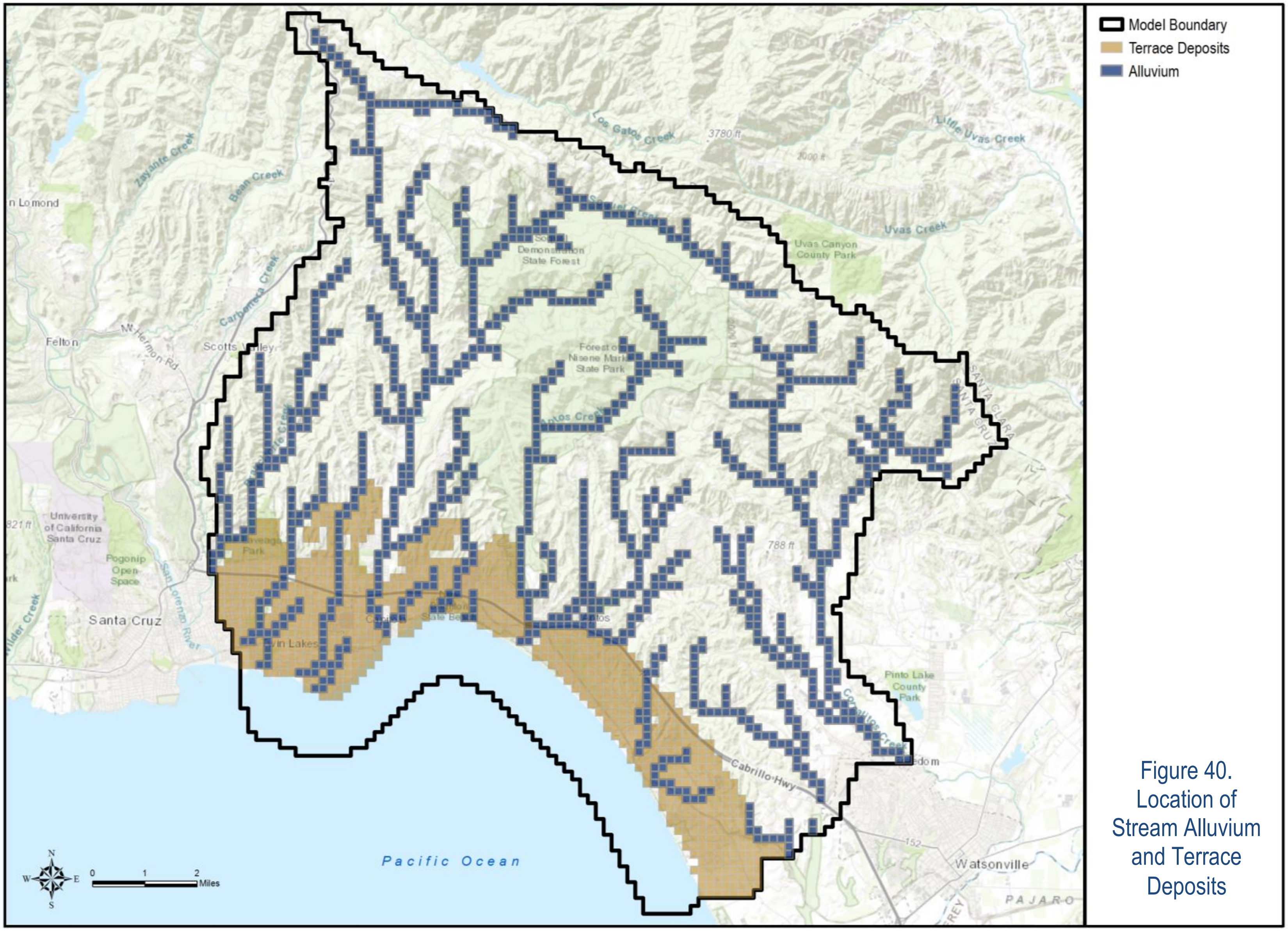


Figure 40. Location of Stream Alluvium and Terrace Deposits

8.3.1.3 Groundwater Pumping

Groundwater pumping is described in Section 4.3. Simulated groundwater pumping is less than the estimates for non-municipal pumping input into the model because pumping at wells in a model cell are turned off if the model cell goes dry.

8.3.2 Flows Across Basin Boundaries

8.3.2.1 Flows between other Basins

Groundwater flow occurs between the Basin and adjacent basins: Purisima Highlands, Pajaro Valley, and Santa Margarita Basins. Substantial inflows occur from Purisima Highlands across the Zayante Fault representing the northern boundary of the Basin. The inflow is relatively constant compared to other inflow components such as UZF recharge and flows from alluvium.

Relatively small flows occur north of HFB representing Aptos area faulting between the Basin and Santa Margarita Basin. These flows only occur in model layer 9 (Tu unit). The basin boundary with Santa Margarita Basin occurs in an area of model layer 9 that is separated from the high conductivity area of model layer 9 representing the Tu unit pumped by the City of Santa Cruz and SqCWD.

Substantial outflows occur from the Basin to the Pajaro Valley Subbasin, but mostly north of the HFB representing Aptos area faulting. This is consistent with observations of high groundwater levels to the northwest and lower groundwater levels in Pajaro Valley near the coast. The model layer with the largest amount of this type of outflow is model layer 3, which represents both the Purisima F and DEF units which are not significantly pumped by pumpers in Pajaro Valley. The model layer with the second largest amount of outflow is model layer 2, representing the Aromas Red Sands, which is the primary aquifer for pumpers in Pajaro Valley.

South of the HFB representing Aptos area faulting, there is net inflow from the Pajaro Valley Subbasin. This is primarily due to the geometry of the basin boundary, which is based on the administrative boundary of Pajaro Valley Water Management Agency (PVWMA). PVWMA covers the area inland of SqCWD Service Areas III and IV so inland groundwater flow to SqCWD production wells in those areas towards the coast is inflow into the Mid-County Basin.

8.3.2.2 Offshore Flows

An important component of the groundwater budget for evaluating groundwater sustainability are flows between the Basin and the ocean (offshore) because seawater intrusion is the sustainability indicator that is the basis for the Basin's overdraft condition. This flow only occurs south of Aptos area faulting. The water budget south the HFB reprenting of Aptosarea faulting (Figure 39) is more instructive for evaluating these flows than the water budget for the entire Basin. Net outflows (negative in the water budget charts) of some magnitude is required to prevent seawater intrusion. Net inflows (positive in the water budget charts) are indicative of flow conditions that will eventually result in seawater intrusion.

Figure 39 shows Basin net offshore outflows and Figure 41 shows the net offshore outflows by layer with the y-axis reversed. Figure 41 shows there has been net inflow in model layers 3 (Purisima F/DEF) and 7 (Purisima A) indicating the high risk of seawater intrusion into these aquifer units historically. Although inflows from the ocean have decreased more recently, inflows still indicate seawater intrusion risk. Net outflows simulated in the Purisima BC and Purisima A aquifer units where seawater intrusion risk has been identified have increased over time. However, water budget results should not be the primary model results for evaluating seawater intrusion because freshwater outflow offshore may not be enough to prevent denser seawater from intruding. In addition, net flows representing flows across the entire coastal boundary may not represent the localized risk near pumping centers. The primary model results for evaluating seawater intrusion should be simulated groundwater levels at coastal monitoring wells compared to established protective elevations.

8.3.3 Change of Groundwater in Storage

Figure 42 shows the cumulative groundwater in storage change for each model layer as well as the entire Basin. Figure 42 depicts that the loss of groundwater in storage in the Basin early in the period was mainly governed by the groundwater in storage loss in model layers 3 (Purisima F/DEF) and 7 (Purisima A); where the majority of Basin pumping occurs. Figure 43 and Figure 44 show the cumulative groundwater in storage change for each model layer in the Basin north and south of the HFB representing Aptos area faulting respectively. The same conclusion can be drawn on these figures as from Figure 42 which is that the loss of groundwater in storage was governed by the loss of storage in model layers 3 and 7, south of the Aptos area faulting where the most pumping occurs in the basin (Figure 39).

An important note is that a reduction of groundwater in storage is not the reason behind the critical overdraft conditions in the Basin. The cause has been the risk of seawater intrusion, which has been due to low groundwater levels near the coast in specific aquifer units. Figure 38 and Figure 39 show that offshore flows are a small part of the water budget compared to changes in groundwater in storage, but offshore flows are what indicate seawater intrusion risk.

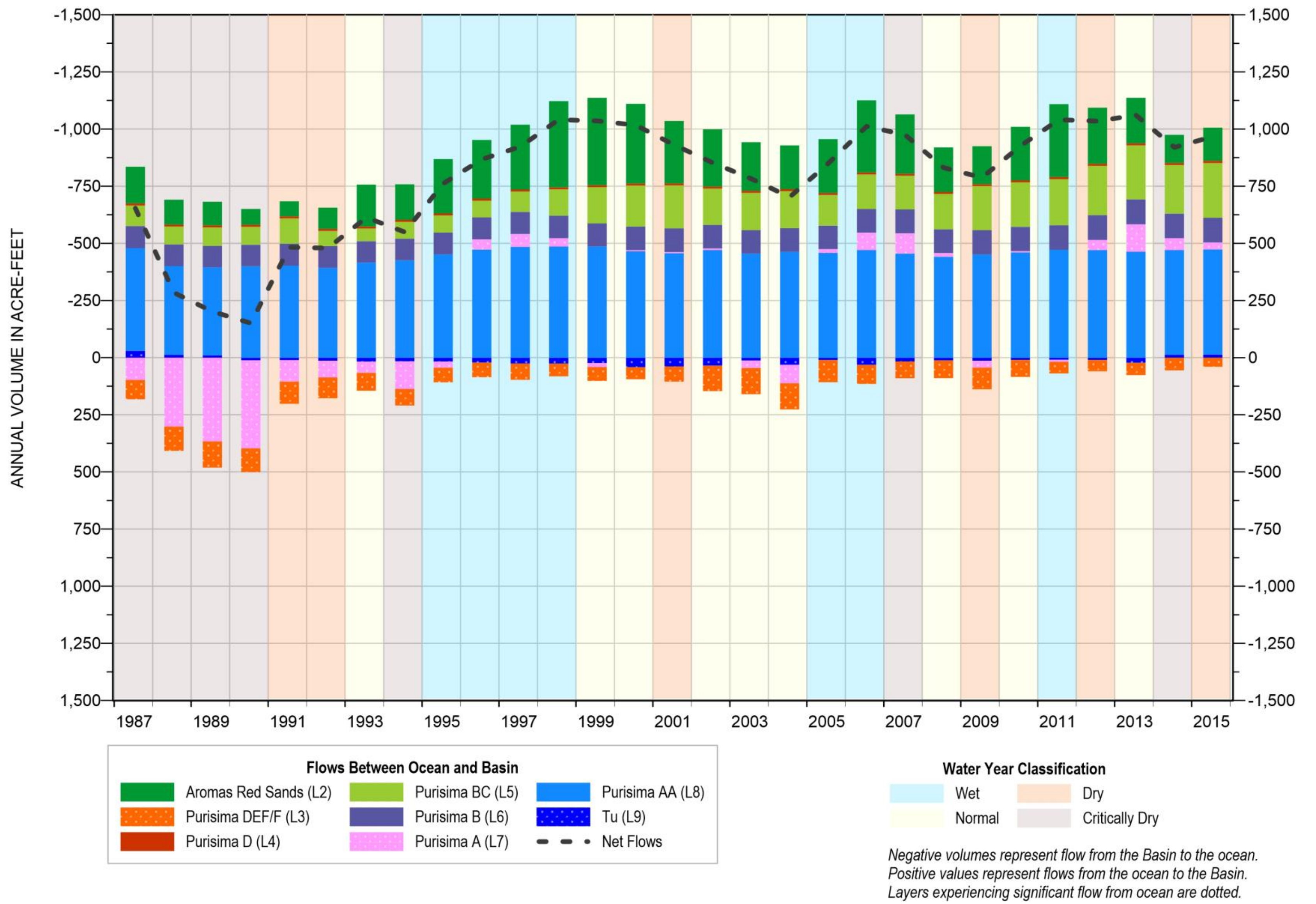


Figure 41. Offshore Groundwater Flow to Mid-County Basin for each Model Layer

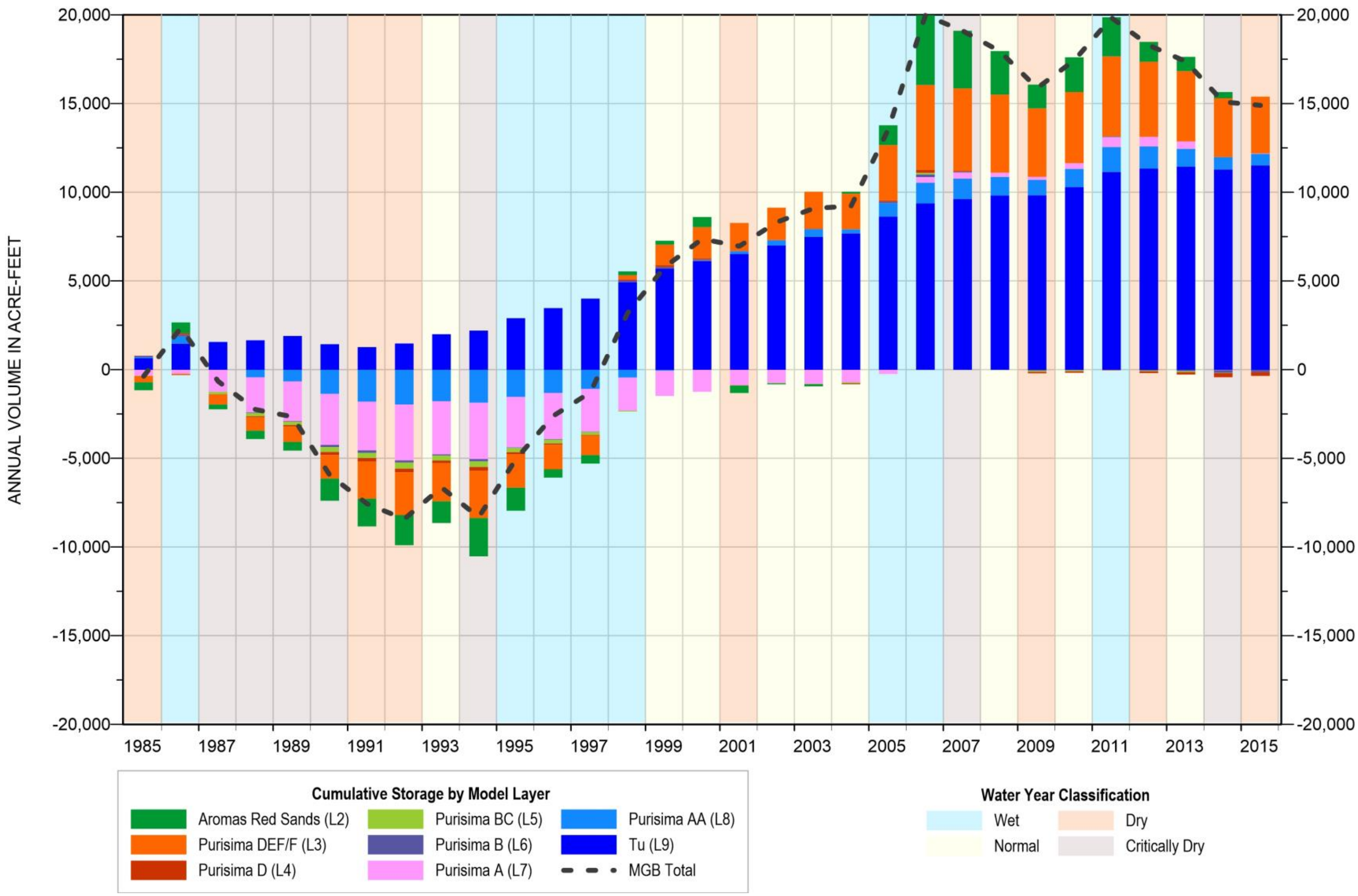


Figure 42. Cumulative Change in Storage Change in Mid-County Basin

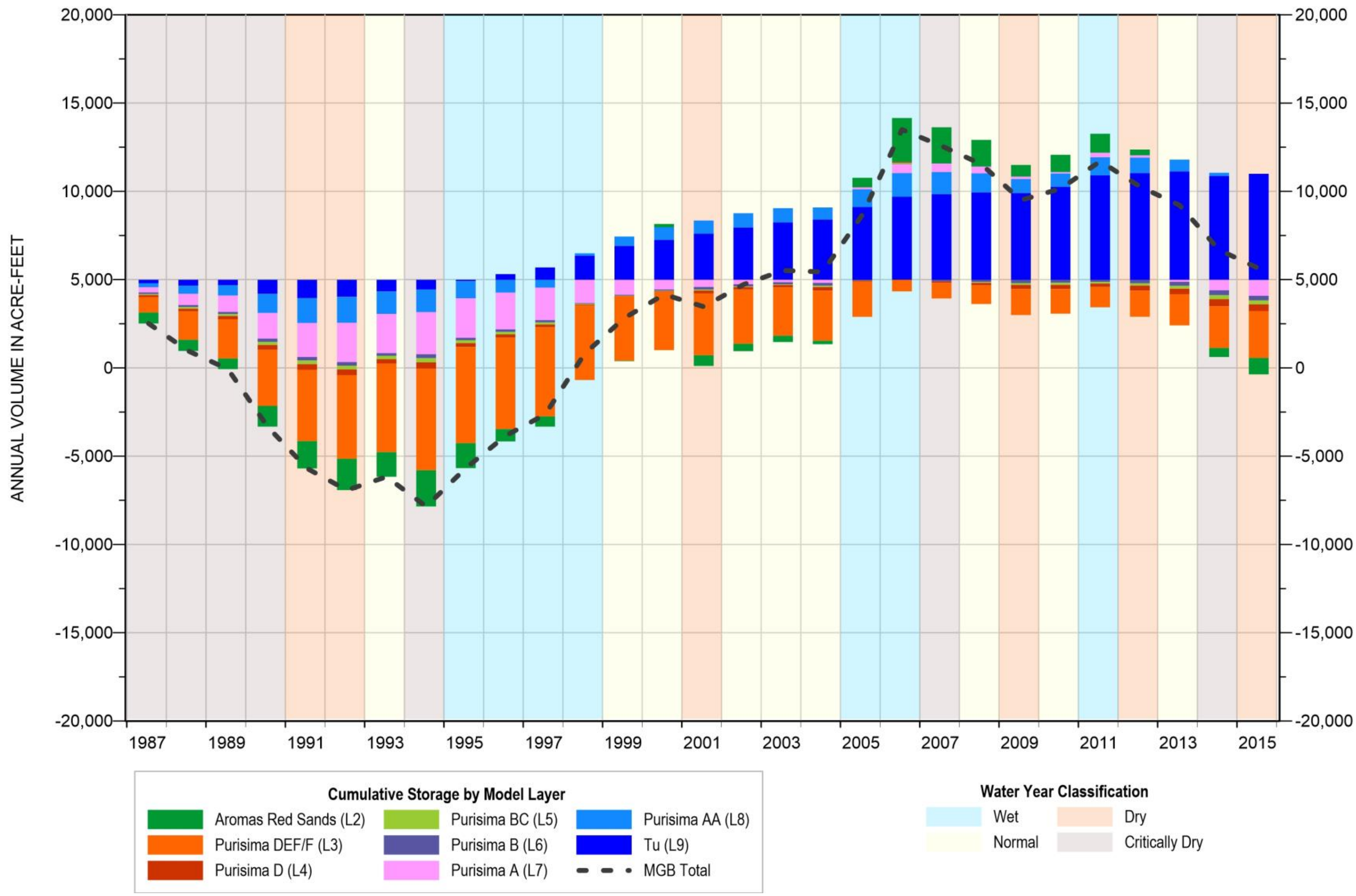


Figure 43. Cumulative Change in Storage in Mid-County Basin; North of HFB for Aptos Faulting

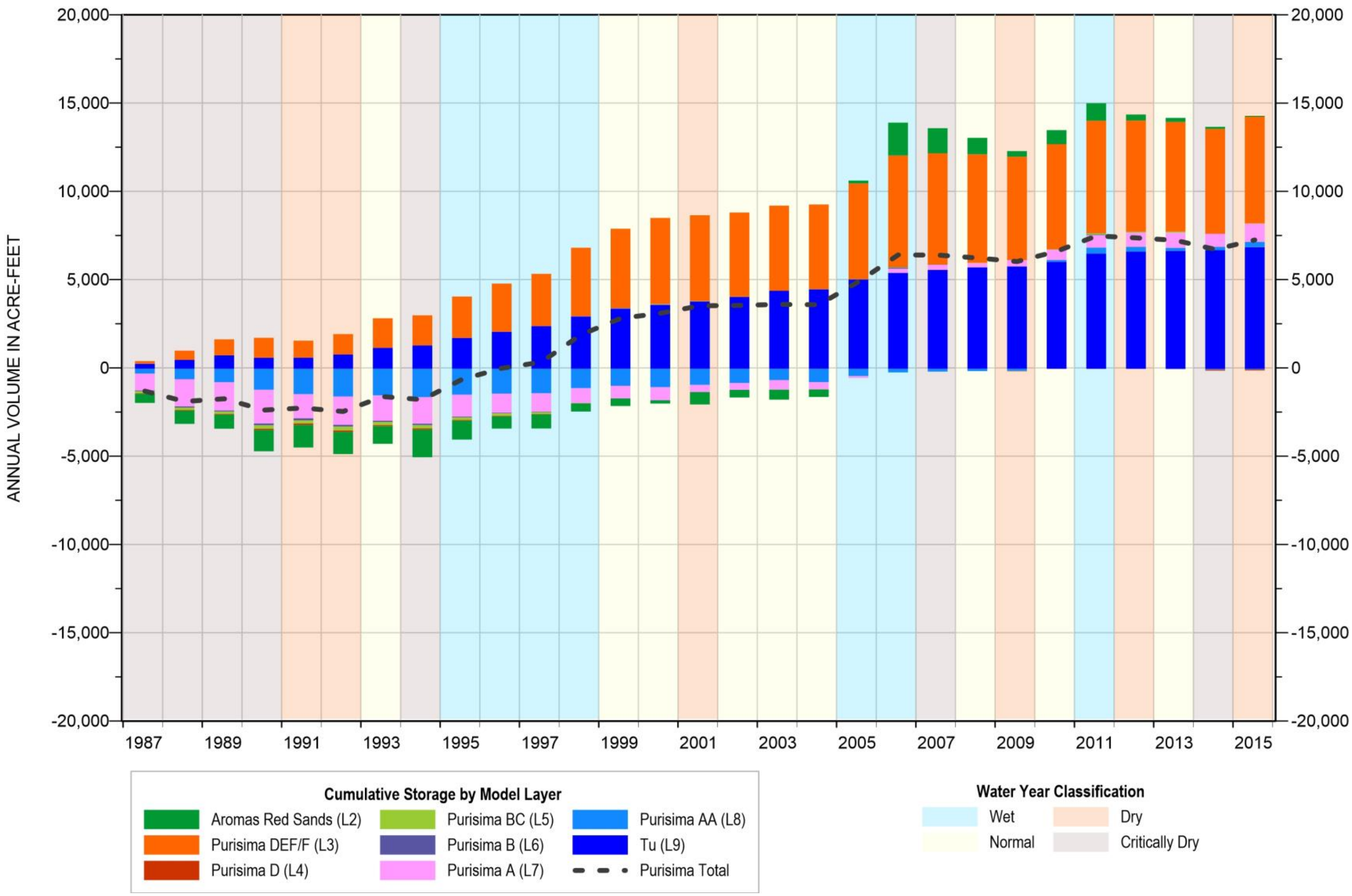


Figure 44. Cumulative Change in Storage in Mid-County Basin, South of HFB for Aptos Area Faulting

8.4 Stream-Aquifer Interactions

The model is used to evaluate stream-aquifer interactions in several ways including identifying where streams are interconnected with groundwater, where shallow pumping may affect streamflows, and estimating groundwater contributions to streamflow. The development of these evaluations were undertaken for Santa Cruz County's Prop 1 grant for stressed basins.

8.4.1 Interconnected Streams with Groundwater

The sustainability indicator in the Groundwater Sustainability Plan (GSP) related to surface water is depletion of interconnected surface water caused by groundwater use. Interconnected surface water is defined in DWR's regulations for GSPs as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer." The model is used to identify how often streams in the Basin are connected with groundwater in the underlying aquifer representing stream alluvium based on output from the model's stream (SFR) package. Figure 45 shows that Soquel Creek is simulated as connected to groundwater more than other streams in the Basin and streams overlying the Purisima F unit and Aromas Red Sands such as Valencia Creek are mostly simulated as not connected to groundwater, which is consistent with the conceptual understanding for the Basin

8.4.2 Depth to Groundwater

In order to identify where shallow pumping wells are more likely to exist and contribute to streamflow depletion in the Basin, Figure 46 shows modeled depth to the water table in March 2015. March 2015 is the representative time for when groundwater levels are high throughout the Basin.

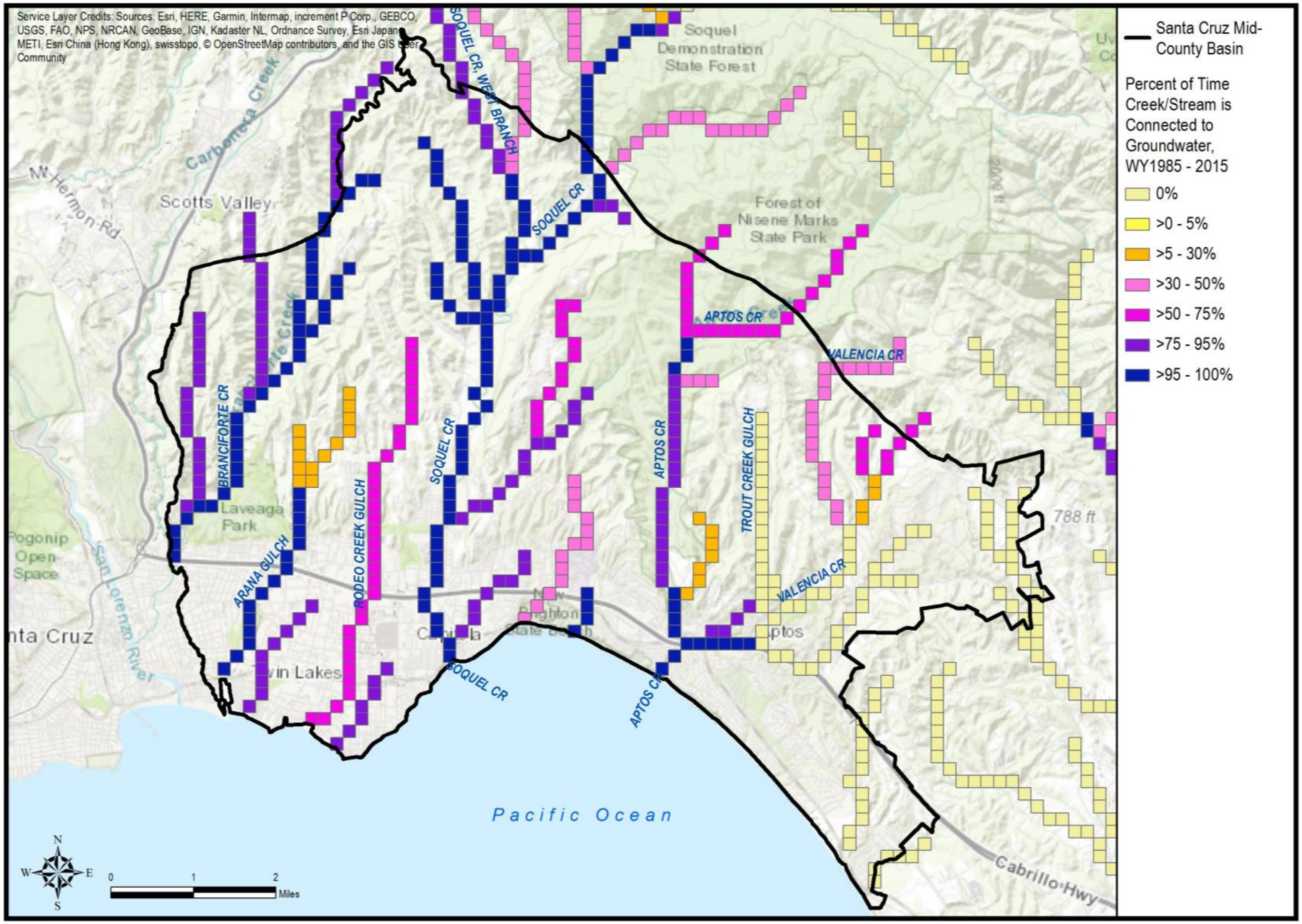
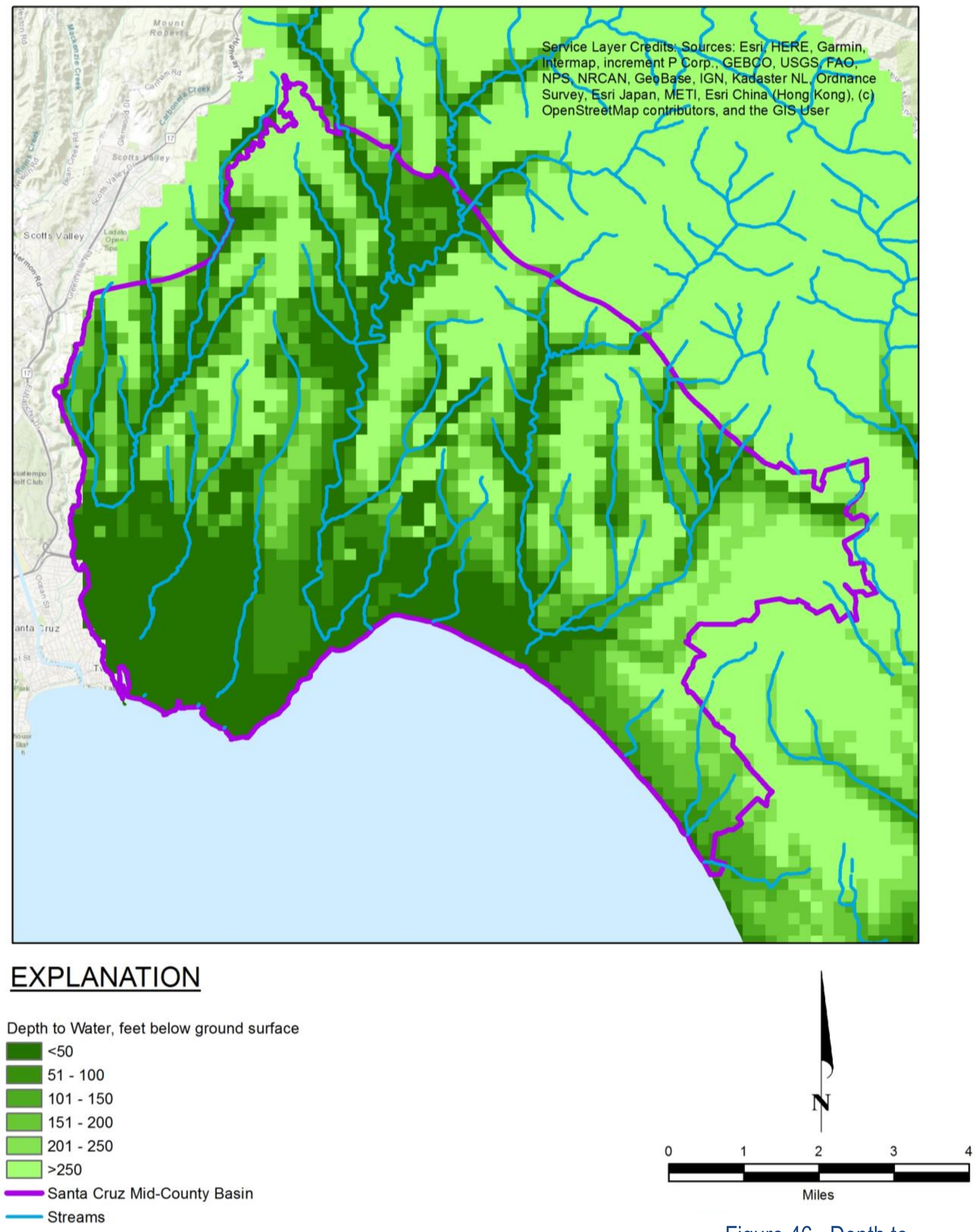


Figure 45. Percent of Time Surface Water and Groundwater are Connected



H:\Santa_Cruz_County\Prop1_StressedBasins\Task6_dtw\GIS\08082019_UPDATE\DTW_TS366_Streams08082019.mxd

Figure 46. Depth to Shallowest Groundwater in March 2015

8.4.3 Groundwater Contribution to Soquel Creek Flow

Based on the calibration of shallow groundwater levels along Soquel Creek (Section 7.3.6), the model is used to estimate groundwater contribution to Soquel Creek where calibration data are available and vertical connection between stream and underlying aquifers is higher than the rest of the model. Figure 47 and Figure 48 show the groundwater contribution to Soquel Creek for the minimum flow month in each year to provide an estimate of the groundwater contribution when streamflow depletions are most likely to result in significant and unreasonable conditions. Figure 47 shows the stretch from Moores Gulch to Bates Creek where the Simons and Balogh shallow wells are located (Figure 21). Figure 48 shows the stretch downstream of Bates Creek where the Main Street, Wharf Road, and Nob Hill shallow wells are located. Most of the streamflow is simulated to come from upstream. Groundwater contribution to streamflow along these stretches is less than 0.5 cfs consistent with estimates from previous studies that streamflow depletion has not been observed because depletion of up to 0.5 cfs cannot be observed from the data (Johnson et al., 2004). As described previously, more precise data for groundwater contribution to streamflow are not available for calibration. Therefore, the model could estimate groundwater contribution of any value from 0 to 0.5 cfs and be consistent with the conclusion from Johnson et al., 2004, which indicates the uncertainty of these groundwater contribution flow estimates.

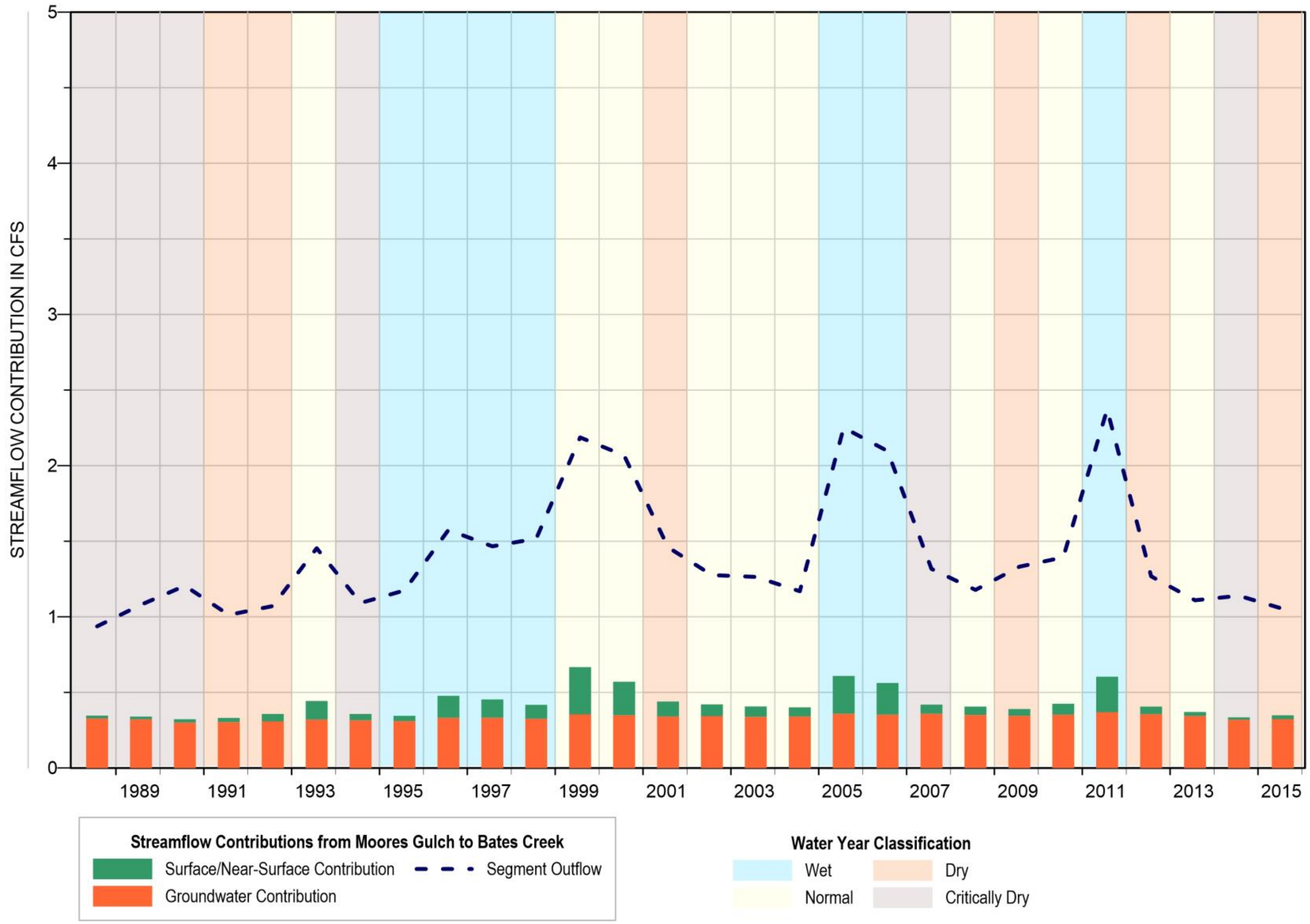


Figure 47. Simulated Minimum Monthly Flows from Moores Gulch to Bates Creek

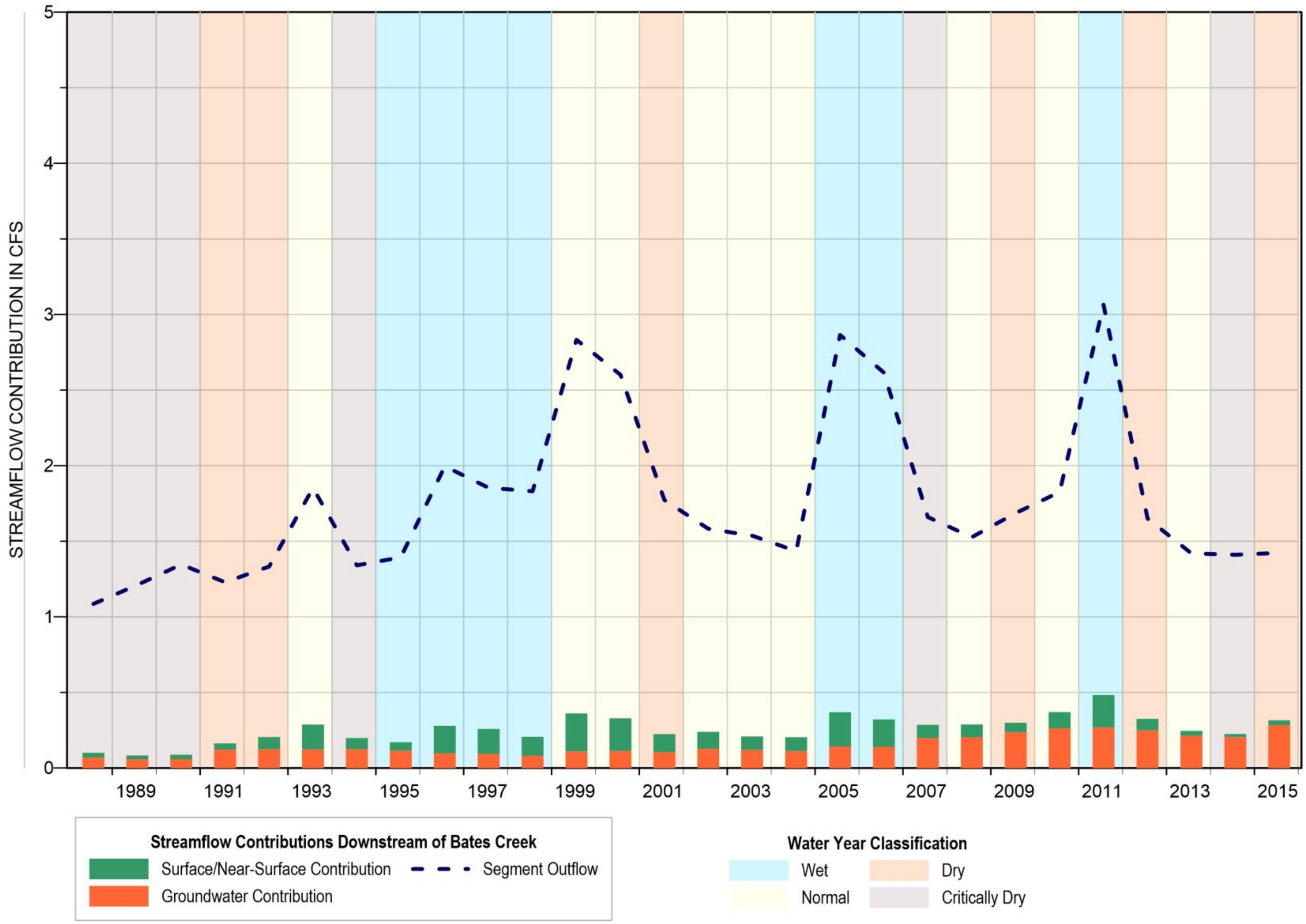


Figure 48. Simulated Minimum Monthly Flows Downstream of Bates Creek

9 SENSITIVITY RUNS

Several sensitivity runs were conducted to evaluate effects of different water use types and assumptions on sustainability for the Basin. The results of these runs are compared to the results of the calibration run described above to evaluate these effects. Sensitivity runs included a run to support development of the streamflow depletion sustainable management criteria:

- Remove all Basin pumping and associated return flow to estimate streamflow depletion in Soquel Creek from Basin groundwater use.

The following sensitivity runs were also performed as part of the scope for Santa Cruz County's Prop 1 grant.

- Remove inland pumping and associated return flow to evaluate effects of inland groundwater use.
- Re-assign non-municipal pumping underneath stream alluvium and Terrace deposit cells to overlying alluvium and Terrace deposit cells to evaluate potential effects of shallow pumping on streamflow.
- Remove non-municipal pumping in lower Soquel Creek and Bates Creek Valleys to evaluate effects of non-municipal pumpers on Soquel Creek streamflow.
- Reduce septic return flow assuming 50% return flow in septic areas instead of 90% currently assumed.

The sensitivity of sustainability to these changes is evaluated by comparing model results to the calibration run. Model results that are compared include:

- Groundwater levels at coastal monitoring wells that are representative monitoring points with groundwater elevation proxies for seawater intrusion in the GSP;
- Groundwater levels at shallow wells along Soquel Creek that are representative monitoring points with groundwater elevation proxies for seawater intrusion in the GSP; and
- Differences in groundwater contribution to streamflow in Soquel Creek watershed during the month with minimum streamflow for each year.

- These sensitivity runs change model output beyond what is calibrated and therefore the results include substantial uncertainty.

9.1 Estimate of Streamflow Depletion from Basin Groundwater Use

In order to establish sustainable management criteria for streamflow depletion, the model is used to estimate historical streamflow depletion in Soquel Creek from Basin groundwater use. This estimate is based on a sensitivity run that removes all Basin pumping and associated return flow over the calibration period. Pumping and return flow simulated for the Basin and removed for this sensitivity run are shown in Figure 12 and Figure 13, respectively. The estimate of streamflow depletion from historical Basin groundwater use is based on the difference in groundwater contributions to streamflow in the Soquel Creek watershed between the sensitivity run and the calibration run. As described previously, the model is not calibrated to precise estimates of flows between groundwater and streams, so estimates of streamflow depletion from the model have high uncertainty. Additionally, sensitivity runs provide estimates of streamflow depletion resulting from groundwater use and incorporating other assumptions. It is important to note that these estimates represent conditions that have not occurred historically and are therefore uncalibrated to any data, which introduces additional uncertainty.

Figure 49 shows the groundwater and surface/near-surface contributions for Soquel Creek watershed in the minimum flow month for each water year of the calibration run. As in Section 8.4.3, the minimum flow month for each year is evaluated because these are the months when streamflow depletions are most likely to result in significant and unreasonable conditions. With all of Basin pumping removed, the increase in total streamflow for the watershed in these minimum flow months are almost all due to higher contributions from groundwater. Removing all Basin pumping in the model results in an increased groundwater contribution to Soquel Creek of up to 1.4 cfs. Therefore, the estimate of historical streamflow depletion based on the model is 1.4 cfs.

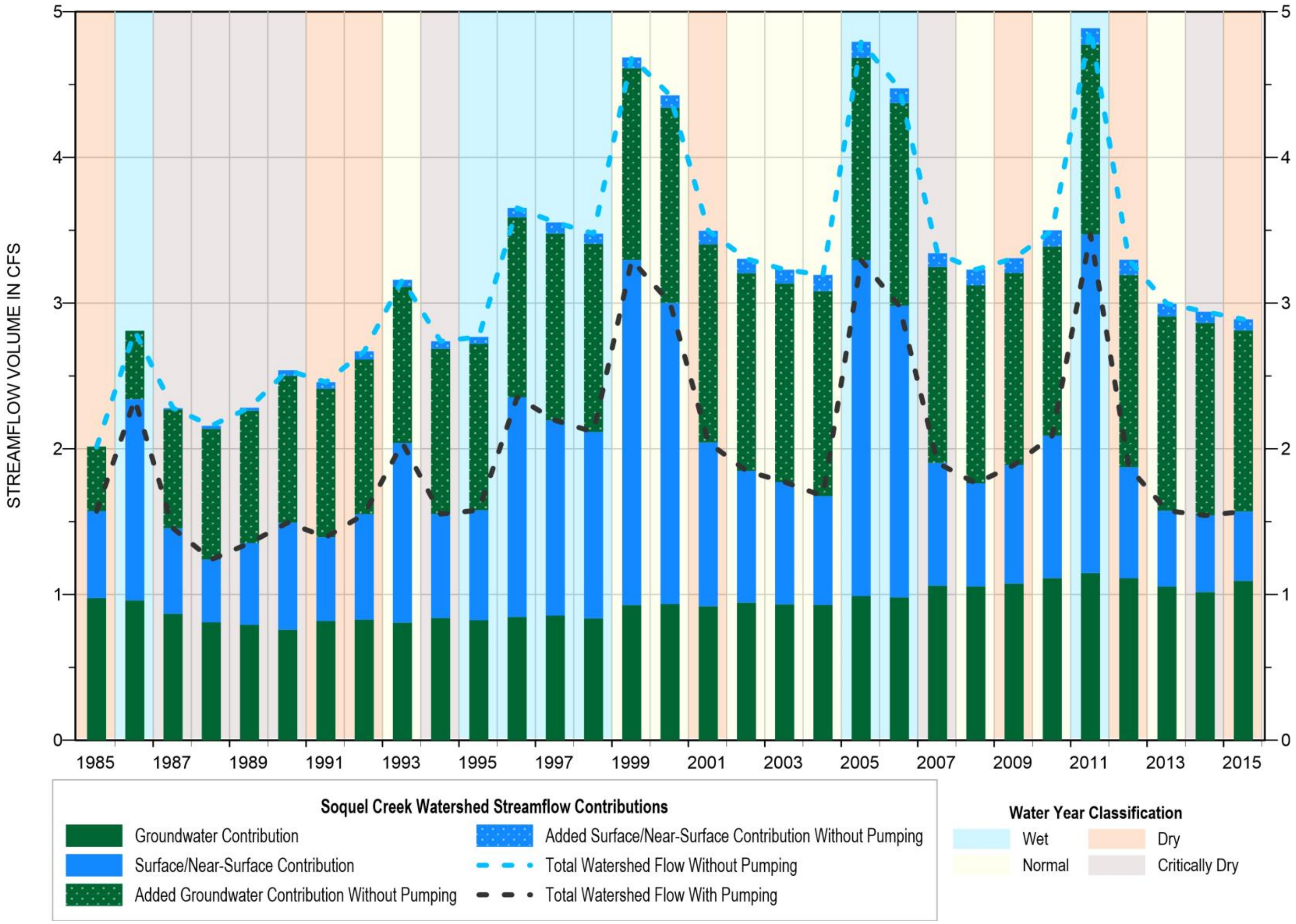


Figure 49. Simulated Contributions to Soquel Creek Watershed Streamflow in Minimum Flow Month with and without Historical Pumping

9.2 Effects of Inland Groundwater Use

For this sensitivity run, inland pumping and associated return flow was removed from the area shown in Figure 50 where groundwater elevations are estimated by the model to be above 50 feet msl. The average decrease in pumping is approximately 1,000 acre-feet per year and the average decrease in return flow is approximately 400 acre-feet per year.

This sensitivity run indicates that inland groundwater use has minimal effect on Basin sustainability. At coastal monitoring wells that are representative monitoring points for seawater intrusion, Figure 51 and Figure 52 show that the increase in groundwater levels resulting from removal of the inland groundwater use is very slight.

Sensitivity of streamflow depletion to inland groundwater use is larger than sensitivity related to seawater intrusion, but still small. At shallow wells along Soquel Creek that are representative monitoring points for streamflow depletion, there are small increases in groundwater levels with removal of the inland groundwater use (Figure 53). Based on the increase in groundwater contribution to streamflow resulting from this groundwater use removal during months with minimum streamflow, the model estimates streamflow depletion effects of this inland pumping as up to 0.1 cfs (Figure 54).

9.3 Effects of Pumping from Shallow Groundwater

In the calibrated model, non-municipal pumping is assumed to occur in the shallowest Basin aquifer unit in the Aromas Red Sands and Purisima Formation, not the stream alluvium and Terrace deposits. For this sensitivity run, non-municipal pumping assumed to occur from Basin aquifer units underlying stream alluvium and Terrace Deposits shown in Figure 40 is moved up to extract from the stream alluvium and Terrace Deposits instead. Approximately 30 acre-feet per year of pumping is moved up to the Terrace Deposits and approximately 250 acre-feet per year is moved up to the stream alluvium.

The run tests the sensitivity of streamflow depletion along Soquel Creek to shallow pumping. Moving pumping to the stream alluvium results in decreases in shallow groundwater levels along Soquel Creek as shown in Figure 53. Based on the decrease in groundwater contribution to streamflow resulting from moving pumping to shallow alluvium and Terrace Deposits during months with minimum streamflow months, the model estimates streamflow depletion effects of potential shallow pumping as approximately 0.1 cfs (Figure 54).

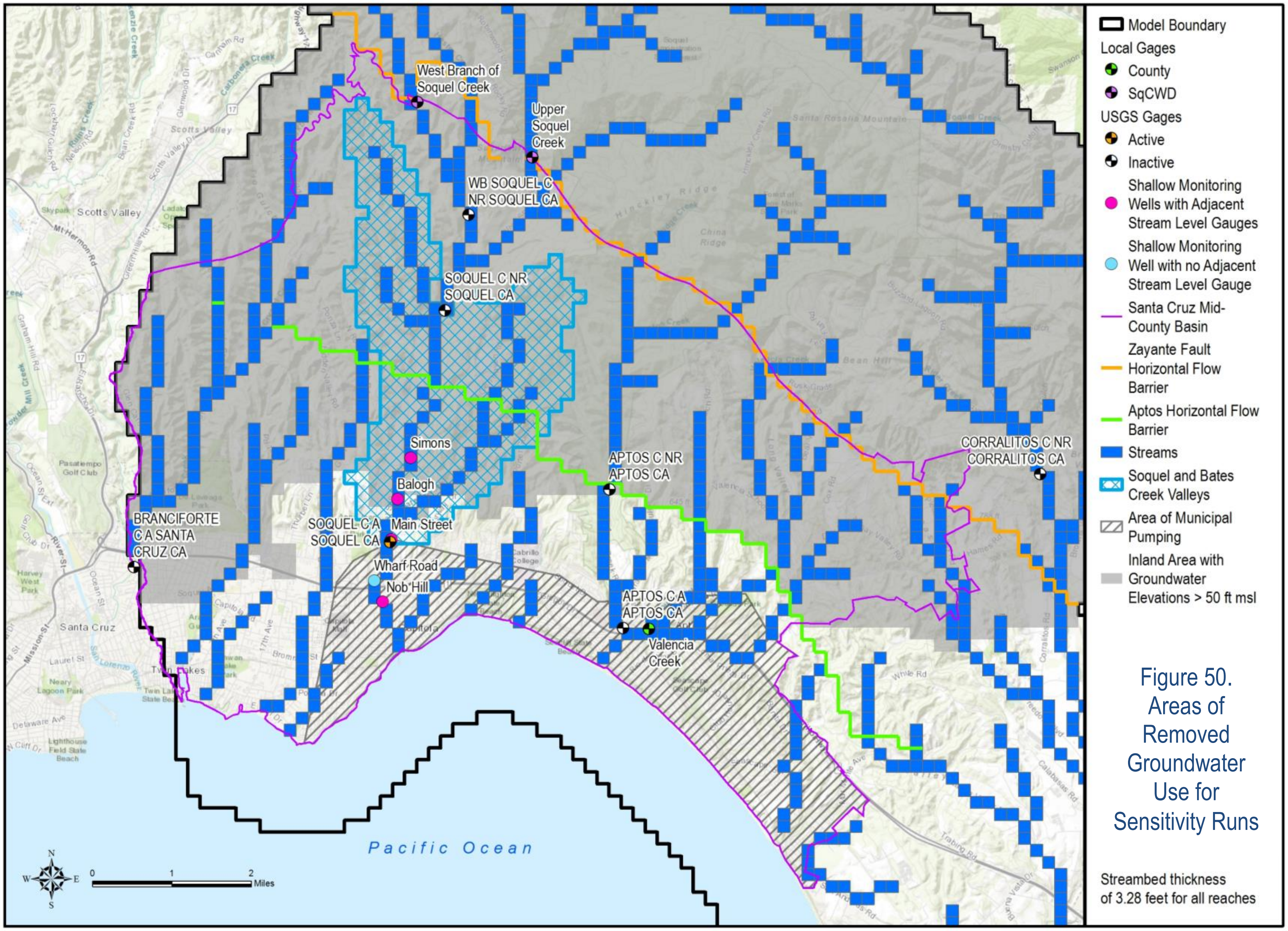


Figure 50. Areas of Removed Groundwater Use for Sensitivity Runs

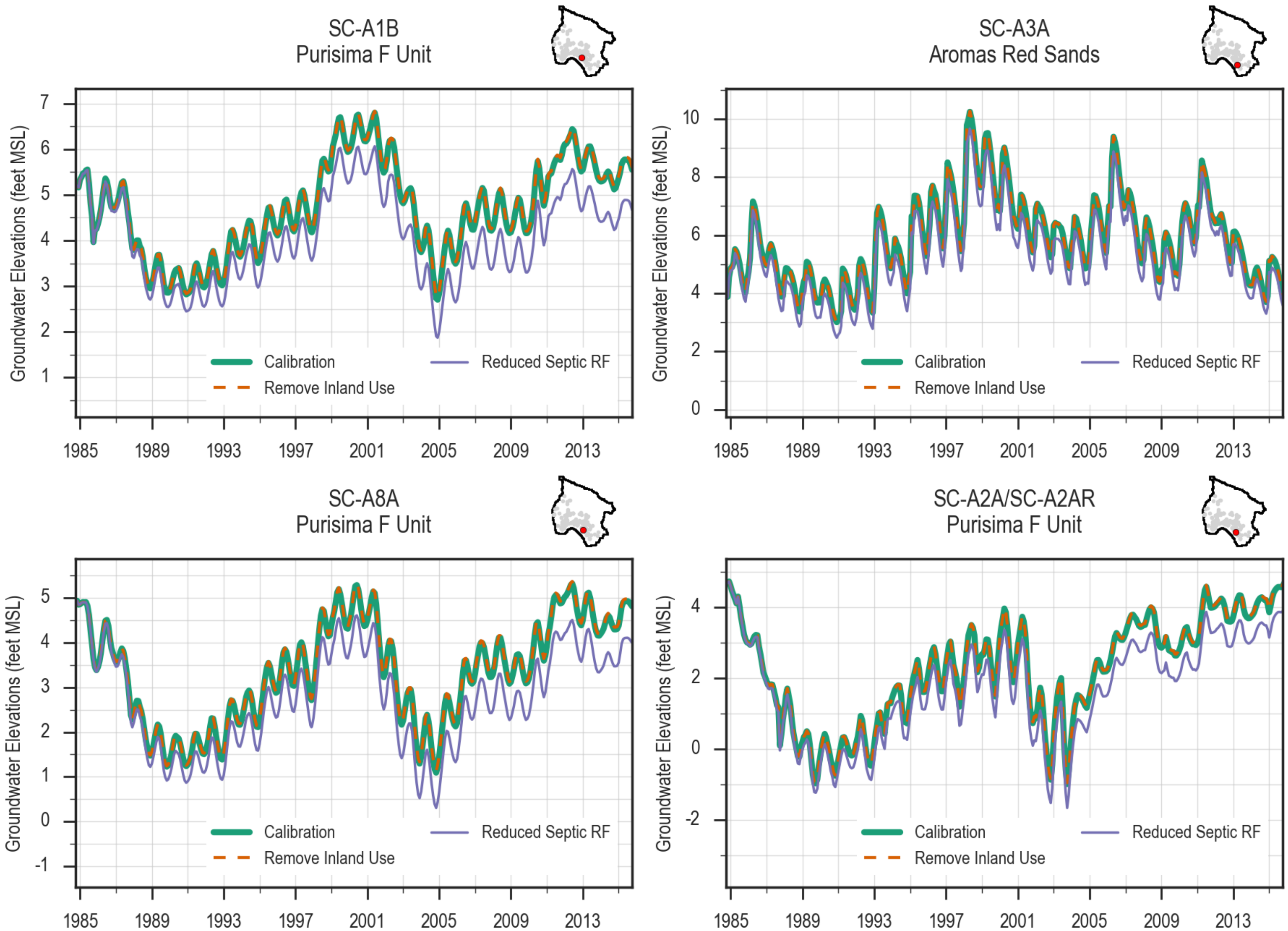


Figure 51. Sensitivity Hydrographs at Coastal Monitoring Wells in Aromas and Purisima F Units

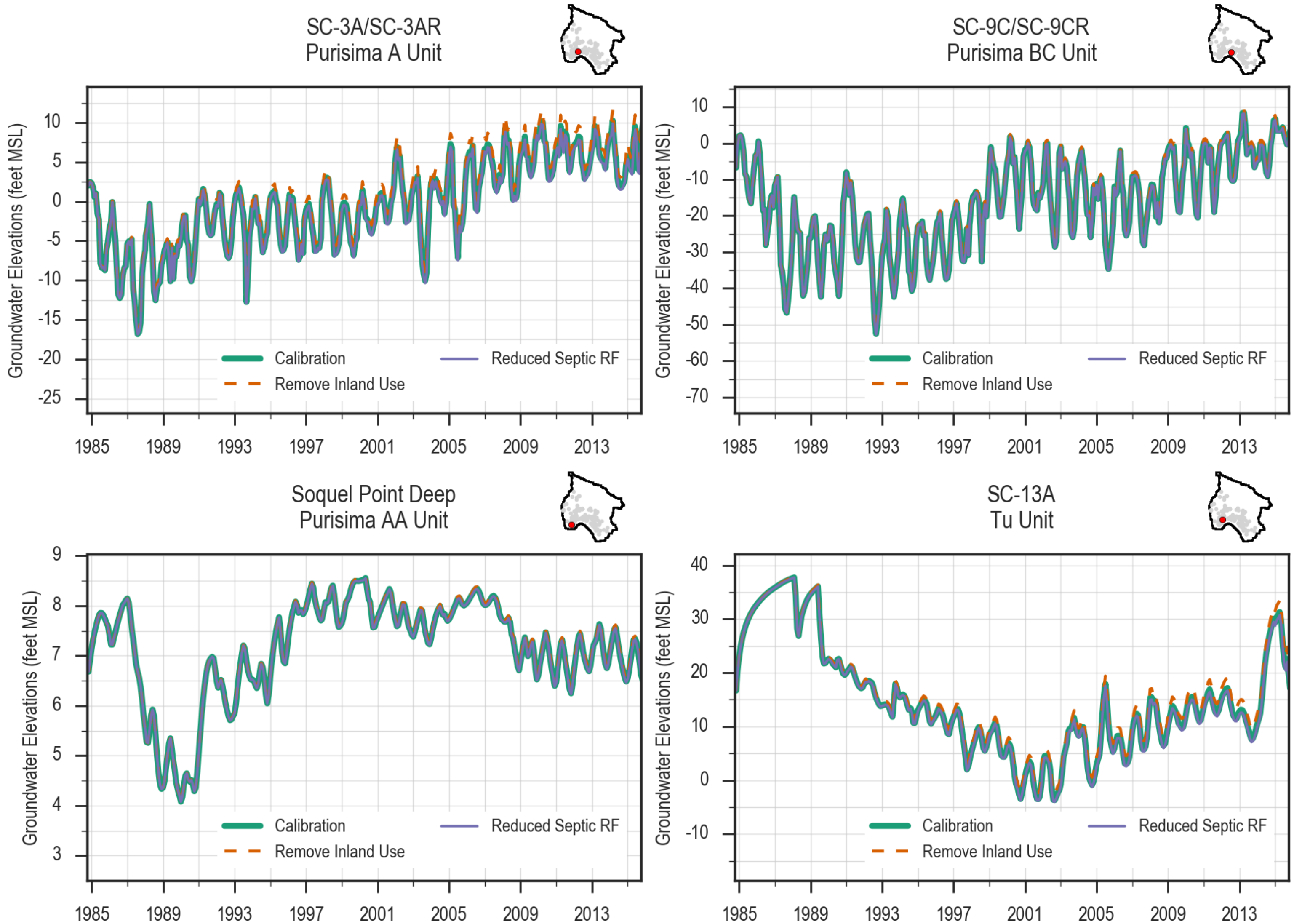


Figure 52. Sensitivity Hydrographs at Coastal Monitoring Wells in Purisima and Tu Units

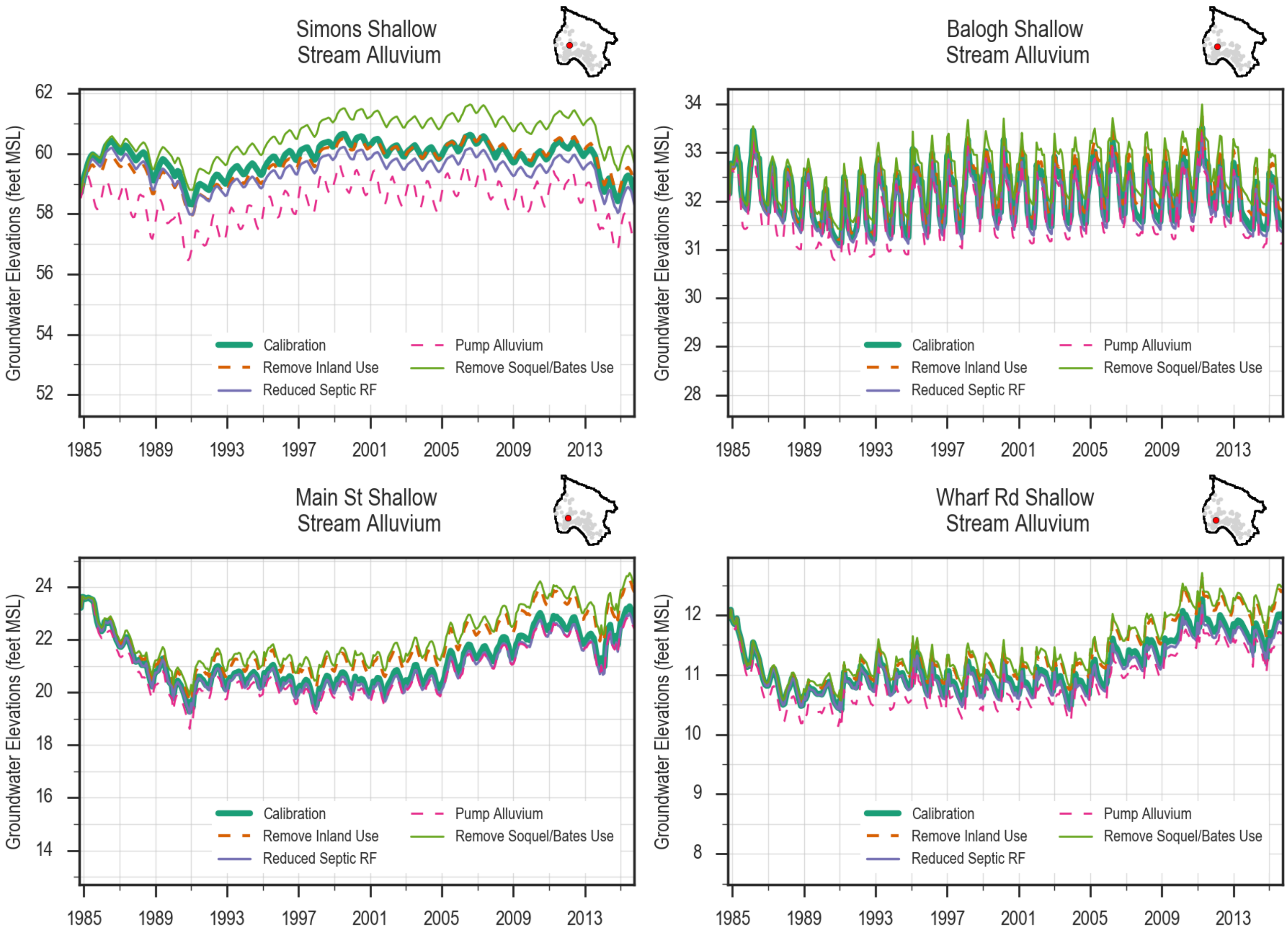


Figure 53. Sensitivity Hydrographs at Shallow Wells along Soquel Creek

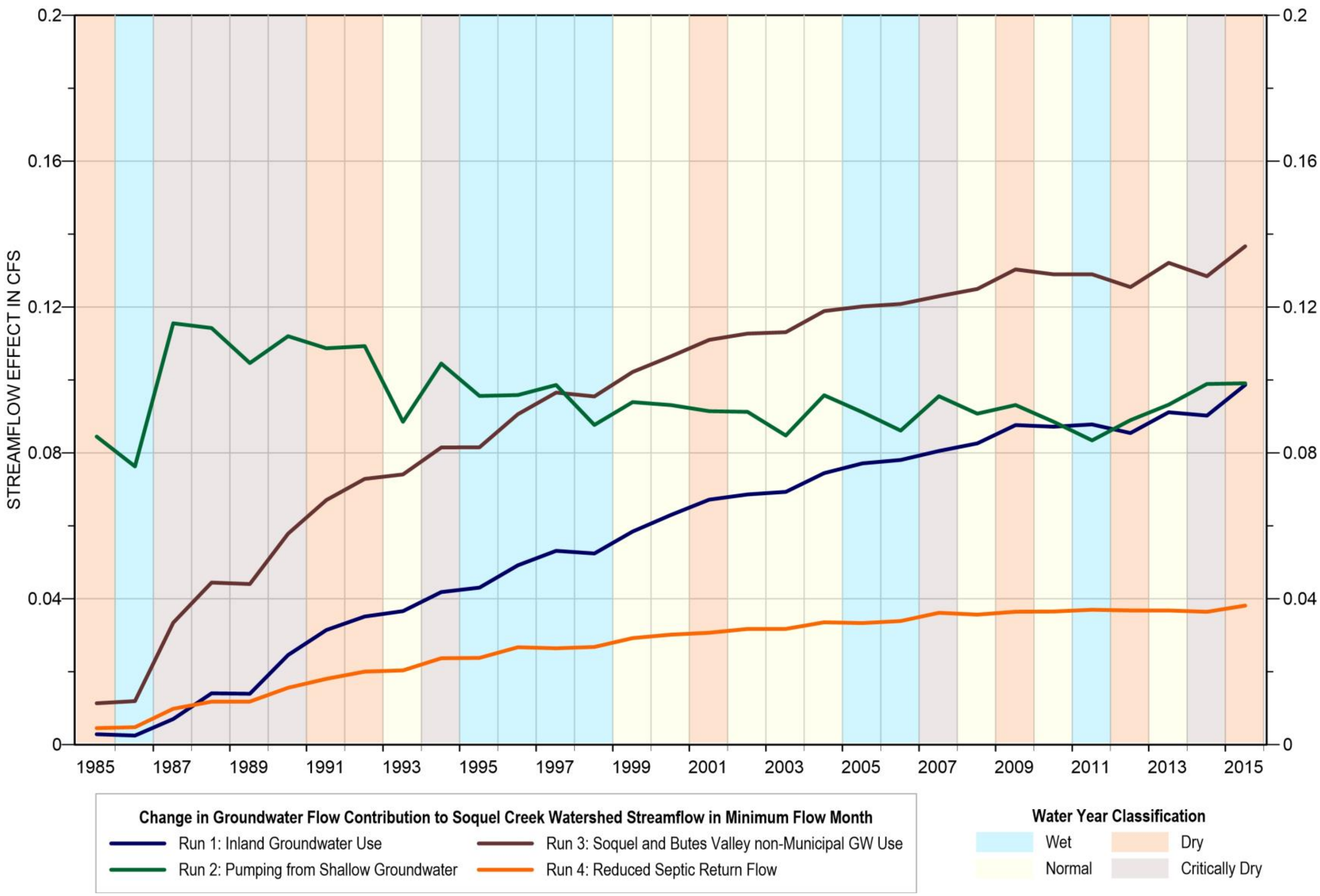


Figure 54. Sensitivity of Stream Depletion Effects

9.4 Effects of Pumping from Soquel Creek and Bates Creek Valleys

For this sensitivity run, non-municipal pumping was removed from Soquel Creek and Bates Creek Valleys, for the area shown on Figure 50. The run tests the sensitivity of streamflow depletion along Soquel Creek to shallow pumping. The average decrease in pumping was approximately 370 acre-feet per year.

As expected, groundwater use in the Soquel Creek and Bates Creek Valleys shows a larger effect on streamflow than other sensitivity runs except the run that removed all Basin groundwater use. At the shallow wells along Soquel Creek, there are small increases in groundwater levels with removal of inland groundwater use (Figure 53). Based on the decrease in groundwater contribution to streamflow resulting from removing pumping in this area during the months with minimum, the model estimates streamflow depletion effects of potential shallow pumping as up to 0.15 cfs (Figure 54).

9.5 Effects of Reduced Septic Return Flow

In the calibrated model, 90% of indoor use in septic areas are assumed to become return flow. The model adds the return flow volumes as recharge below the soil zone to the UZF package. For this sensitivity run, it is assumed that only 50% of indoor use in septic areas are assumed to become return flow to test the effect of the septic return flow assumption. The approximately 45% reduction in septic return flow results in an average decrease in return flow of 300 acre-feet per year.

This sensitivity run indicates that the septic return flow assumption has a small effect on model evaluation of Basin sustainability. At coastal monitoring wells that are representative monitoring points for seawater intrusion, Figure 51 shows the decrease in groundwater levels resulting from reduction of septic return flow is up to 1 foot in the Purisima F unit and Aromas Red Sands where there are septic areas near the coast. There is almost no effect of the assumption in the deeper Purisima and Tu unit.

Sensitivity of streamflow depletion to the assumption for septic return flow is very small. At shallow wells along Soquel Creek that are representative monitoring points for streamflow depletion, there are very small decreases in groundwater levels with reduction of septic return flows. Based on the decrease in groundwater contribution to streamflow during the minimum streamflow months resulting from this removal, the model estimates streamflow depletion effects of this assumption as less than 0.05 cfs.

10 SIMULATING SEAWATER INTERFACE

We previously recommended to implement the MODFLOW SWI2 package (Bakker et al., 2013) in the model to be able to simulate movement of the seawater interface and evaluate potential effects of projects and management actions on the seawater interface. The SWI2 package has not been implemented in the model as it is not necessary for the GSP to simulate the seawater interface because groundwater elevation proxies are being used for the seawater intrusion sustainable management criteria. Model results of groundwater elevations can be used to compare to those groundwater elevation proxies to evaluate the benefits of projects and management actions for preventing undesirable results in seawater intrusion.

We are now recommending that the SWI2 package not be implemented in the model for two reasons.

1. The effort to overcome challenges in implementing the SWI2 package would not be cost-effective given that it is not necessary for evaluating Basin sustainability;

2. Implementing the SWI2 package would not answer the questions from the GSP Advisory Committee about movement of the seawater interface related to the use of five year groundwater elevation averages for seawater intrusion sustainability management criteria.

10.1 Challenges for Implementation of SWI2 package in Santa Cruz Mid-County Basin Model

SWI2 stability and convergence of the solution is highly dependent on having the 3-dimensional representation of the initial salt water interface surface properly and adequately defined over the entire model domain. Defining the current seawater interface configuration poses challenges given current data gaps in the understanding of the interface over the entire model domain. For example, the SKYTEM survey identifying salty water in aquifer units offshore could not be extended onshore over most of the model area and an understanding of how salinity concentrations change with depth in the deeper aquifers is limited both by the lack of deep well data covering the near coastal areas and the limitation on the depth of investigation of the SKYTEM survey. Because the shape of the interface in the lower aquifers is not well understood or constrained, this creates a challenge in representing and modeling the 3-dimensional interface.

10.2 Model Evaluation of Five Year Groundwater Elevation Averages for Seawater Intrusion Sustainability Management Criteria

A GSP Advisory Committee helped develop sustainability management criteria for the GSP. The main questions that arose from the Committee on the movement of the seawater interface were related to the appropriateness of using a five year average as groundwater elevation proxies for seawater intrusion sustainability management criteria. Using a five year average allows for time periods when groundwater elevations are lower than the criteria even if they are offset by times when groundwater elevations are higher than the criteria. The GSP provides sufficient rationale for why the five year average is appropriate, but the MGA may want to evaluate further during GSP implementation.

The SWI2 package cannot be used for this evaluation as it only simulates the movement of a sharp interface. Part of the concern of using the five year average is that time periods of lower groundwater elevations will allow seawater to intrude and even as higher groundwater elevations push out the average location of the interface, salty water will remain inland. Simulating only the sharp interface will not simulate this potential spreading of salty water as groundwater elevations vary.

One potential alternative to implementing the SWI2 package is to use two-dimensional cross-sectional models with the SEAWAT package (Langevin et al., 2008) similar to the models previously used to estimate the protective elevations (HydroMetrics LLC, 2009) used as groundwater level proxies for seawater intrusion sustainable management criteria. SEAWAT represents advection and dispersion of salinity fronts needed to address this issue. In addition, developing a two-dimensional representation of the interface will be simpler than developing a three-dimensional representation. Output from the Mid-County Basin GSFLOW model simulations of projects and management actions can be used as boundary condition inputs to the cross-sectional models to represent expected changes in coastal groundwater elevations over time under the GSP.

11 CONCLUSIONS

This report describes the development and calibration of the integrated surface water-groundwater model of the Santa Cruz Mid-County Basin, which has been used to develop sustainability management criteria and to project future Basin conditions for evaluating water management scenarios during GSP implementation. The GSFLOW model was constructed to evaluate seawater intrusion, simulate groundwater and surface water processes, and is calibrated to groundwater level and streamflow data for the period from Water Year 1984 through 2015.

The PRMS portion of the model is calibrated to measured streamflow and allows for estimation of recharge to Basin aquifers and aquitard units. Groundwater aquifer properties have been calibrated to observed groundwater levels for most coastal groundwater wells. The calibrated model can be used to evaluate groundwater management projects with the primary goal of preventing seawater intrusion. Groundwater level calibration also supports evaluating groundwater level responses to projects in areas where observation data show past responses to municipal pumping (i.e. south of the simulated horizontal flow barrier (HFB) representing Aptos area faulting).

Calibration to shallow groundwater levels along Soquel Creek supports using the model to simulate shallow groundwater level responses to groundwater management projects for evaluating sustainability of streamflow depletion. The model is not calibrated to precise estimates of flows between groundwater and streams, so estimates of streamflow depletion from the model have high uncertainty. Additionally, sensitivity runs provide estimates of streamflow depletion resulting from groundwater use and incorporating other assumptions. It is important to note that these estimates represent conditions that have not occurred historically and are therefore uncalibrated to any data, which introduces additional uncertainty.

The remainder of the model area does not have the benefit of measured shallow groundwater data from which to calibrate the model and therefore the simulation of shallow groundwater and stream-aquifer interactions is much more uncertain than in areas with shallow monitoring wells.

The current model is not recommended for evaluating responses in the Purisima DEF unit due to limitations associated with the current vertical discretization of model layers in this area, which prevents simulation of the observed confined aquifer response. The current model is also not recommended for evaluating responses to pumping or managed recharge north of Aptos area faulting as there lacks measured groundwater level data showing past responses to regional pumping.

The use of the model in evaluating proposed projects should be with respect to protective groundwater elevation for preventing seawater intrusion and whether or not a project recovers and maintains groundwater levels at protective elevations. The model can also be used to evaluate effects of projects on meeting sustainability criteria for streamflow depletion by predicting shallow groundwater levels along Soquel Creek. The model can also be used to evaluate groundwater level effects of projects throughout the area south of the Aptos area faulting, such as at existing or planned well locations.

The model should not be used to define a single number that any project or combination of projects needs to supply to achieve sustainability, as the ability to prevent seawater intrusion and avoid other undesirable results depends on the specifics of each project. The model can be used to define a single number for planning purposes, but it will be based on specific assumptions for projects and management actions to achieve sustainability.

The water budgets calculated by the model can be used for groundwater sustainability planning, but it must be understood that there are significant differences for the portions of the basin north and south of the Aptos area faulting. It is also important to understand that even components of the water budget that make up a small percentage of the total budget, such as offshore outflows which regulate seawater intrusion, can actually have greater importance on basin sustainability than other water budget components with larger volumes.

The following is a list of recommendations for future improvements of the model:

- Consider splitting layer 3 to separately simulate the Purisima DEF and F units which have different observed confined and unconfined aquifer responses in some areas of the model

- Calibrate inland groundwater levels after five years of data become available from representative monitoring points.

- Calibrate shallow groundwater levels along additional creeks after five years of data become available from representative monitoring points.

12 REFERENCES

ASCE-EWRI. (2005). The ASCE standardized reference evapotranspiration equation, Report 0–7844-0805-X, ASCE Task Committee on Standardization of Reference Evapotranspiration, Reston, Virginia., American Society of Civil Engineers. Available at http://www. kimberly.uidaho.edu/water/asceewri/ Accessed June 14, 2014.

Anderson, M.P., and W.W. Woessner, 1992, *Applied Groundwater Modeling: Simulation of Flow and Advective Transport*, Academic Press Inc, San Diego, CA.

Bakker, M., F. Schaars, J.D. Hughes, C.D. Langevin, and A.M. Dausman, 2013, *Documentation of the seawater intrusion (SWI2) package for MODFLOW*: U.S. Geological Survey Techniques and Methods, book 6, chap. A46, 47 p.,

Doherty, J., 2003, Groundwater model calibration using pilot points and regularization, Ground Water, 41(2): 170-177.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000. MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, 121 p.

Henson, W.R, Medina, R.L., Mayers, C.J., Niswonger, R.G., and Regan, R.S., 2013. *CRT -- Cascade Routing Tool to define and visualize flow paths for grid-based watershed models*: U.S. Geological Survey Techniques and Methods 6-D2, 28 p.

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015. *Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information.* Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354

Hughes, J.D., Langevin, C.D., Chartier, K.L., and White, J.T., 2012, *Documentation of the Surface-Water Routing (SWR1) Process for modeling surface-water flow with the U.S. Geological Survey Modular Ground-Water Model (MODFLOW-2005):* U.S. Geological Survey Techniques and Methods, book 6, chap. A40 (Version 1.0), 113 p. https://pubs.er.usgs.gov/publication/tm6A40

HydroMetrics LLC, 2009. *Groundwater Levels to Protect against Seawater Intrusion and Store Freshwater* Offshore, prepared for Soquel Creek Water District, January.

HydroMetrics WRI, 2011. *Estimation of Deep Groundwater Recharge Using a Precipitation-Runoff Watershed Model, Soquel-Aptos, California*, prepared for Soquel Creek Water District, Central Water District, and City of Santa Cruz, August.

HydroMetrics WRI and Kennedy/Jenks, 2014. *Aromas and Purisima Basin Management Technical Study*, Santa Cruz Integrated Regional Water Management Planning Grant Task 4, prepared for Central Water District, March.

HydroMetrics WRI, 2014a, *Proposal for developing groundwater model*, prepared for Soquel Creek Water District, July.

HydroMetrics WRI, 2014b, Task 1.1 Groundwater Model Calibration, Central Water District and Purisima Basin Management, prepared for Central Water District, January 14.

HydroMetrics WRI, 2015, *Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction (Task 3)*, prepared for Soquel Creek Water District, November 24.

HydroMetrics WRI, 2016a, Santa Cruz Mid-County Basin Groundwater Flow Model: Precipitation-Runoff Modeling System Setup (Task 2), prepared for Soquel Creek Water District, August 19.

HydroMetrics WRI, 2016b, *Santa Cruz Mid-County Basin Groundwater Model Boundaries Update*, prepared for Soquel Creek Water District, August 17.

HydroMetrics WRI, 2017a, *Santa Cruz Mid-County Basin Conceptual Model Update*, prepared for Soquel Creek Water District, March 31.

HydroMetrics WRI, 2017b, Shallow Groundwater Evaluation, prepared for Soquel Creek Water District, July 12.

HydroMetrics WRI, 2017c, Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation (Task 2), March 31.

Johnson, N.M., D. Williams, E.B. Yates, G. Thrupp, 2004, Groundwater Assessment of Alternative Conjunctive Use Scenarios, Technical Memorandum 2: Hydrogeologic Conceptual Model, prepared for Soquel Creek Water District, September.

LANDFIRE, 2010. LANDFIRE 1.1.0, Existing Vegetation Type layer, U.S. Department of the Interior, Geological Survey. Accessed online at http://landfire.cr.usgs.gov/viewer.

Langevin, C.D., D.T. Thorne, , Jr., A.M. Dausman, M.C. Sukop, and W. Guo, 2008, *SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport*: U.S. Geological Survey Techniques and Methods Book 6, Chapter A22, 39 p.

Leavesley, G. H., R.W. Lichty, B.M. Troutman, and L.G. Saindon. 1983. *Precipitation-Runoff Modeling System: User's Manual*. U.S. Geological Survey, MS 412, Denver Federal Center, Box 25046, Lakewood, CO 80225. Water Resources Investigation Report 83-4238

Linsley Kraeger and Associates (LKA) and Luhdorff Scalmanini Consulting Engineers (LSCE). 2003.

Markstrom, S.L., R.G. Niswonger, R.S. Regan, D.E. Prudic, and P.M. Barlow, 2008. GSFLOW - Coupled Ground-water and Surface-water FLOW model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1, 240 p.

Markstrom, S.L., R.S. Regan, L.E. Hay, R.J. Viger, R.M.T. Webb, R.A. Payn, J.H. LaFontaine, 2015. *PRMS-IV, the Precipitation-Runoff Modeling System, Version 4.,* U.S. Geological Survey, Techniques and Methods 6-B7.

Milly, P.C.D. and K.A. Dunne, 2011. On the Hydrologic Adjustments of Climate-Model Projections: the Potential Pitfall of Potential Evapotranspiration. Earth Interactions, 15:1-14.

Monteith, J.L., 1965. Evaporation and environment, Proceedings of the 19th Symposium of the Society for Experimental Biology. Cambridge University Press, New York, NY pp. 205–233.

Montgomery & Associates, 2019. *Municipal Return Flow*, technical memorandum to Santa Cruz Mid-County Groundwater Agency, August 28.

Nash, J. E., and J. V. Sutcliffe, 1970. River flow forecasting through conceptual models part I -- A discussion of principles, Journal of Hydrology, 10(3), 282-290.

National Elevation Dataset. 2015. The National Map – Elevation. Available online at http://nationalmap.gov/elevation.html

Priestley, C.H.B., and R.J. Taylor, 1972. On the assessment of surface heat flux and evaporation using large-scale parameters. Mon. Weather Rev., 100:81-82

Ramboll, 2018. *Hydrogeological Investigation Salt-Fresh Water Interface-Monterey*, prepared for Santa Cruz Mid-County Groundwater Agency, February.

Regan, R.S., R.G. Niswonger, S.L. Markstrom, S,R. Maples, and P.M. Barlow, 2018, *GSFLOW version 1.2.2: Coupled Groundwater and Surface-water FLOW model*, U.S. Geological Survey Software Release, http://dx.doi.org/10.5066/F7WW7FS0, February 23.

Thornton, P.E., S.W. Running, and M.A. White, 1997. *Generating surfaces of daily meteorological variables over large regions of complex terrain*. Journal of Hydrology. 190(3-4):214 - 251. http://dx.doi.org/10.1016/S0022-1694(96)03128-9

Thornton; P.E., M.M., Thornton, B.W., Mayer, N., Wilhelmi, Y., Wei, R., Devarakonda, and R.B. Cook, 2014. *Daymet: Daily Surface Weather Data on a 1-km Grid for North America; Version 2*. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center; Oak Ridge; Tennessee; USA. Date accessed: 2016/01/04. Temporal range: 1980/01/01-2014/12/31. http://dx.doi.org/10.3334/ORNLDAAC/1219

U.S. Department of Agriculture (USDA), 2012. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Accessed online at http://websoilsurvey.nrcs.usda.gov/.

U.S. Geological Survey, 2013. National Hydrography Geodatabase: The National Map viewer https://viewer.nationalmap.gov/viewer/nhd.html?p=nhd

13 ACRONYMS & ABBREVIATIONS

AFY................acre-feet per year
ASR................aquifer storage and recovery
amsl................above mean sea level
bgs..................below ground surface
cfs...................cubic feet per second
cfs...................cublic feet per second
COOP.............Cooperative Observer Network
CRT................Cascade Routing Tool
CWD ....Central Water District
DEM...............digital elevation model
GHB ....general head boundary
GIS ....geographic information systems
HFB................horizontal flow barrier
HRU ....hydrologic response unit
Kh...................horizontal hydraulic conductivity
Kv...................vertical hydraulic conductivity
MAE...............mean absolute error
ME..................mean error
MGA ....Mid-County Groundwater Agency
MGB ....Mid-County Groundwater Basin
MNW2 ....Multi-Node Well
NHD...............National Hydrography Dataset
NS ....Nash-Sutcliffe goodness of fit
NWS...............National Weather Service
PET ....potential evapotranspiration
PRMS.............Precipitation-Runoff Modeling System
PVWMA ....Pajaro Valley Water Management Agency
PWS ....Pure Water Soquel
RMSE.............root mean squared error
SFR ....Streamflow-Routing
SWI ....Seawater Interface
SqCWD..........Soquel Creek Water District
SR...................solar radiation
Ss....................specific storage
STD ....standard deviation

Sy ....specific yield
USGS .............U.S. Geological Survey
UZF................Unsaturated-Zone Flow

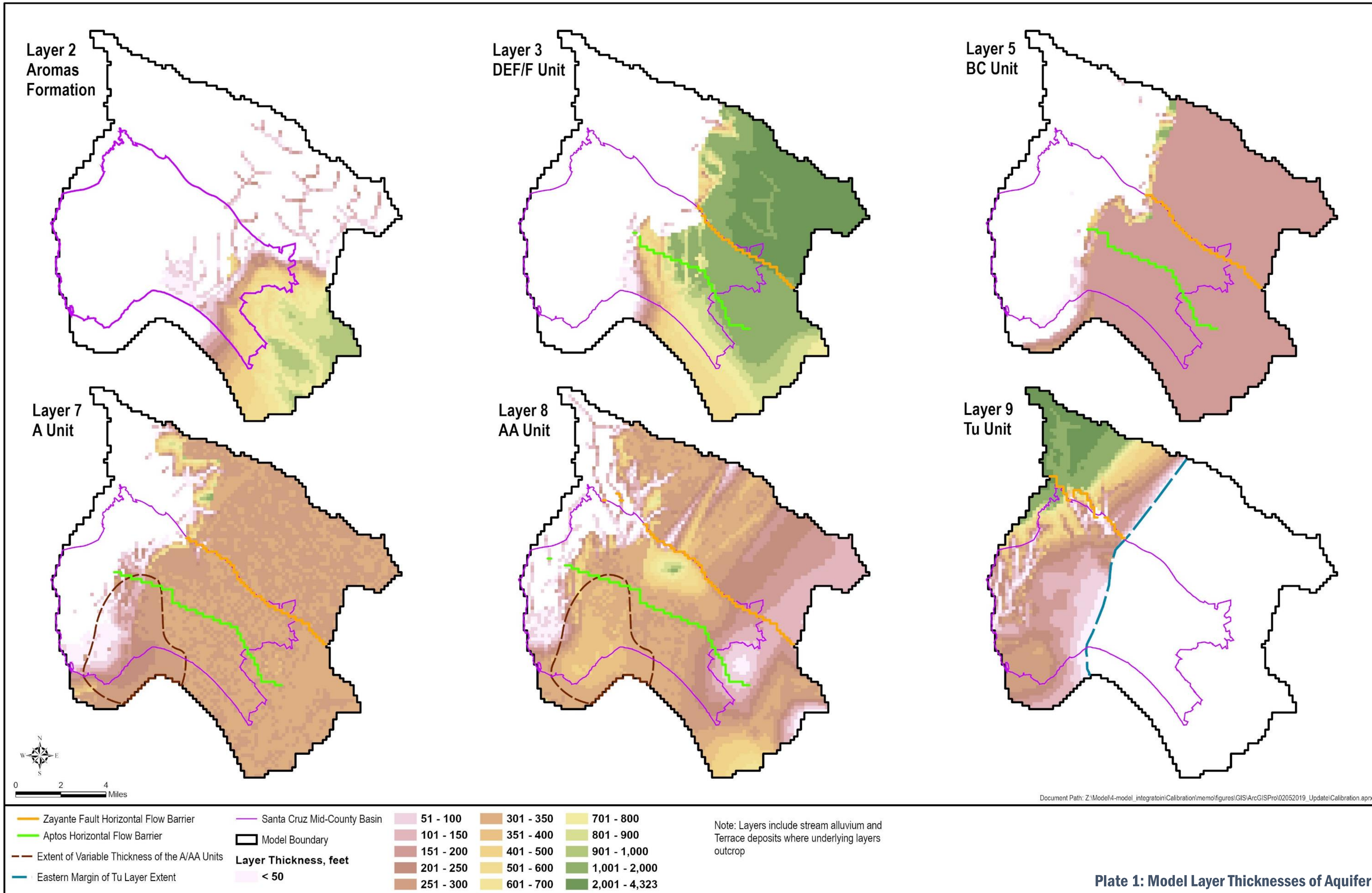


Plate 1: Model Layer Thicknesses of Aquifer

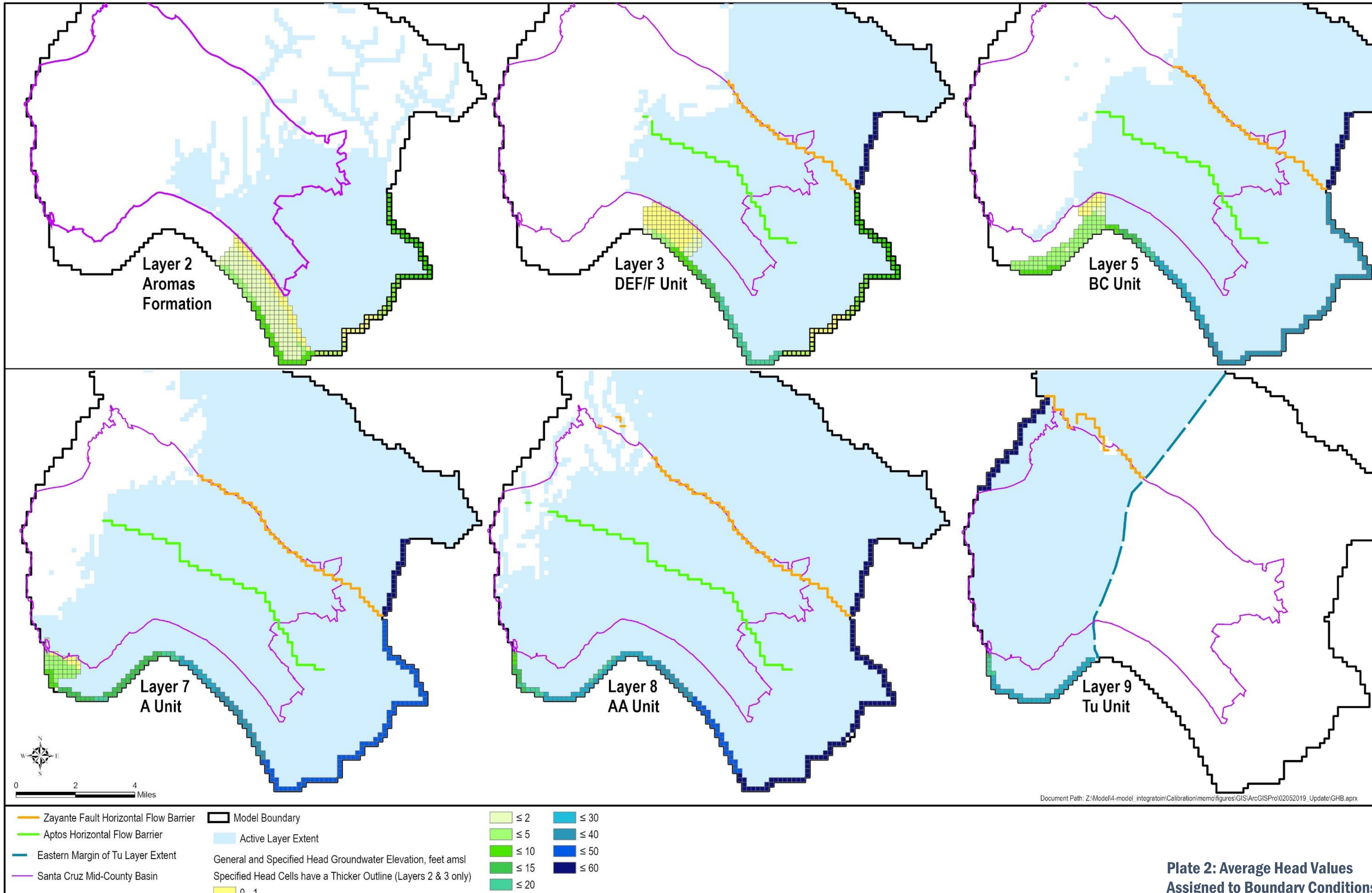


Plate 2: Average Head Values Assigned to Boundary Conditions

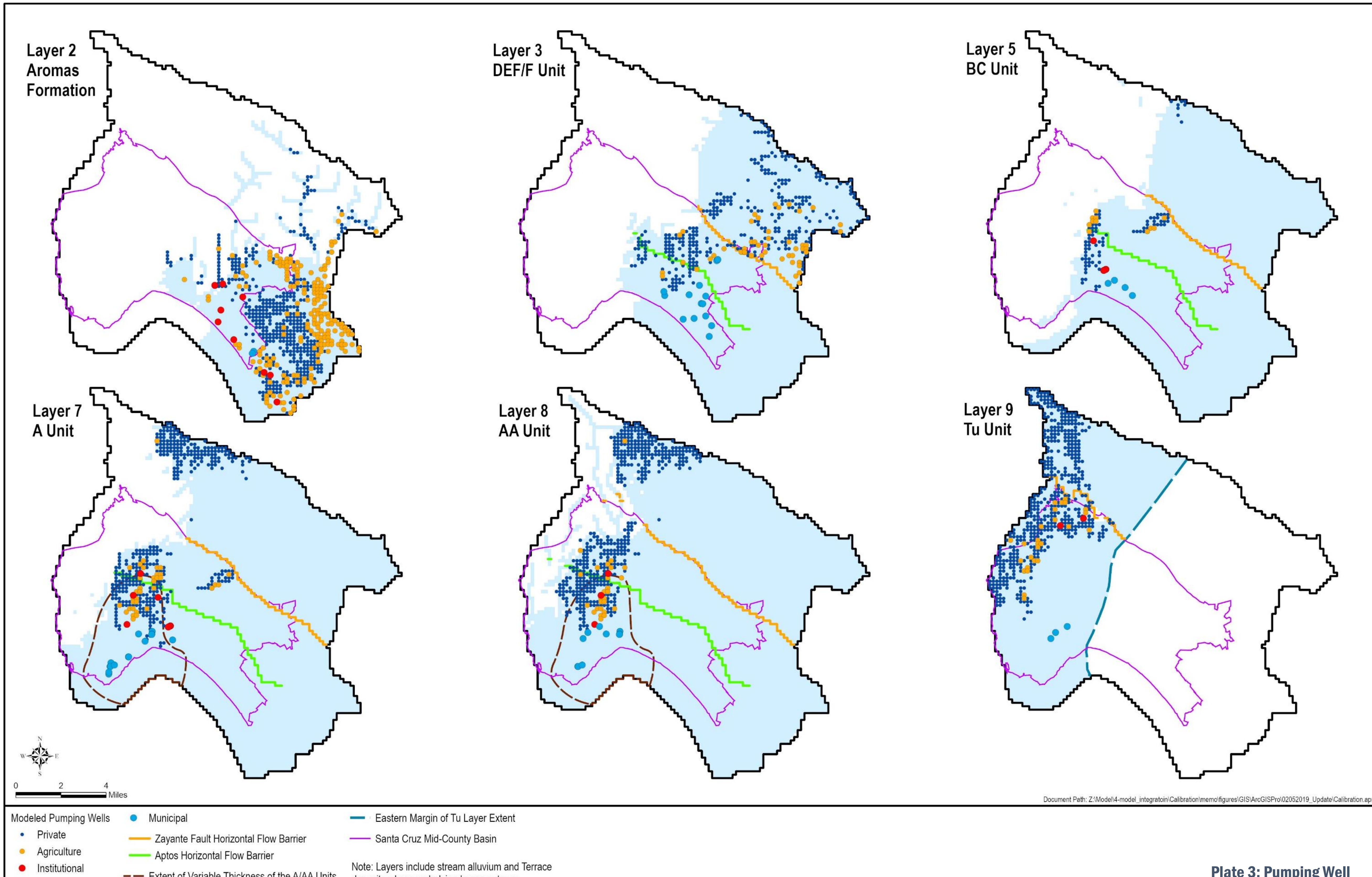


Plate 3: Pumping Well Locations by Model Layer

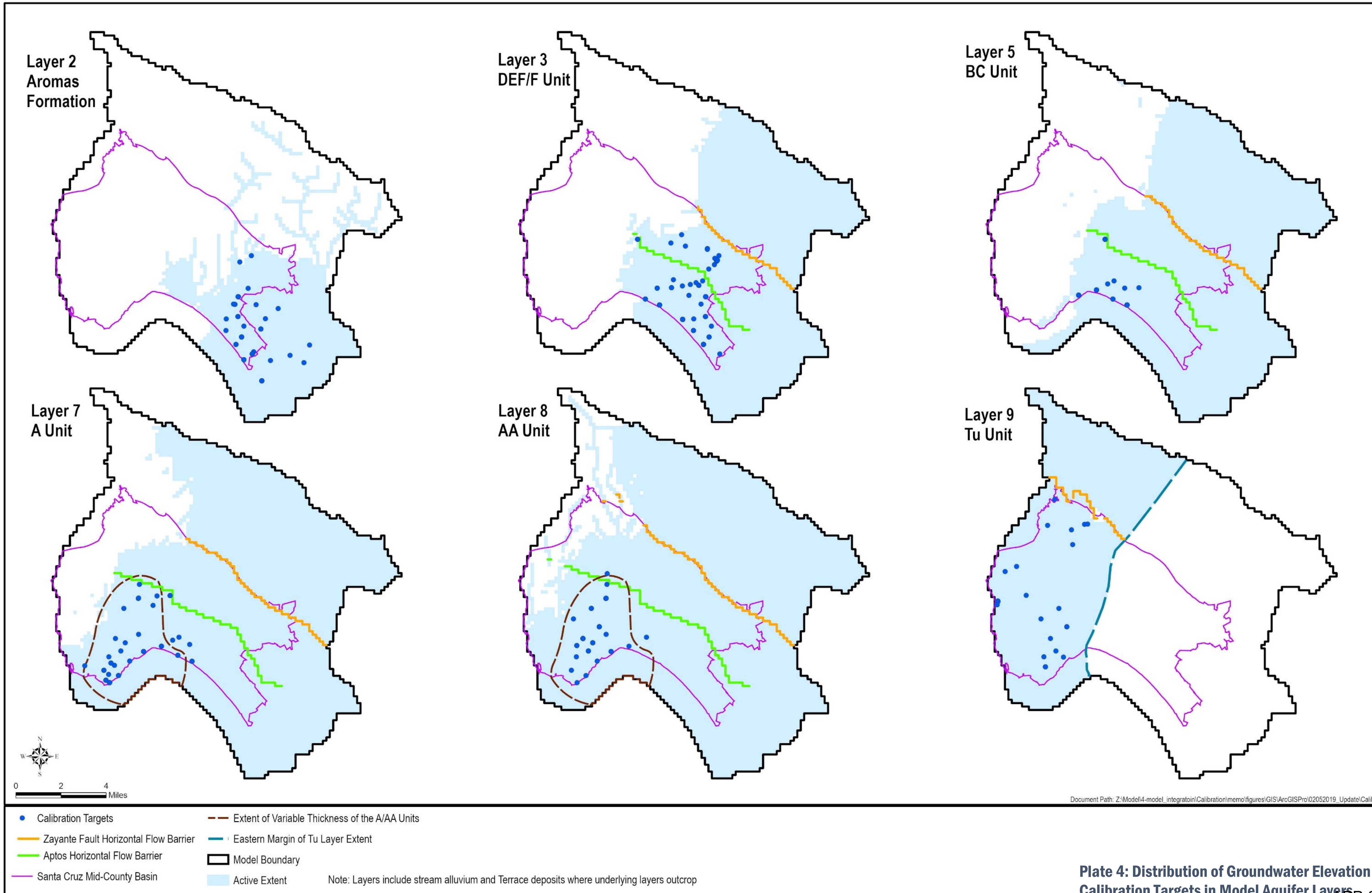
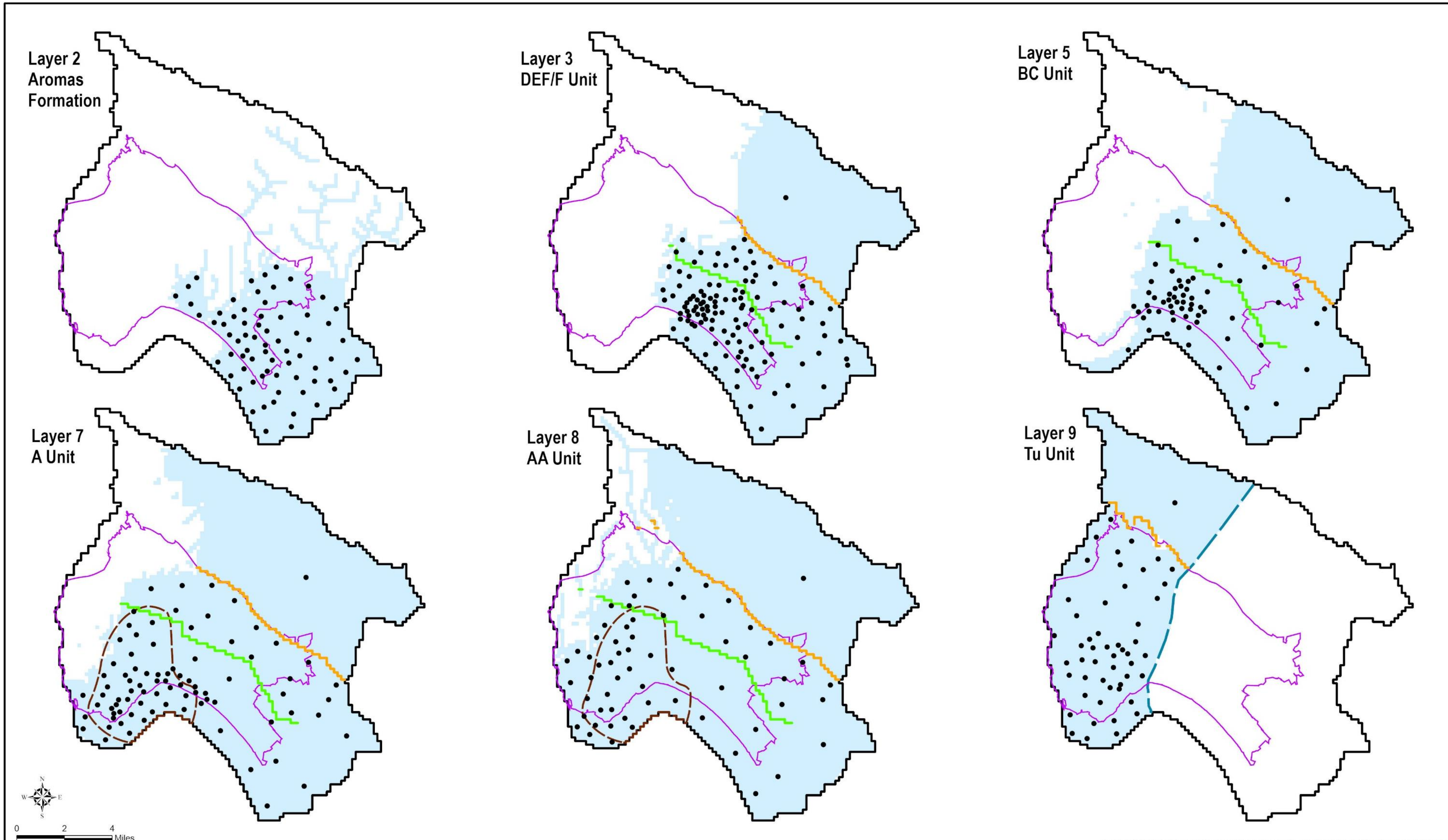


Plate 4: Distribution of Groundwater Elevation Calibration Targets in Model Aquifer Layers



- Pilot Points for Hydraulic Conductivity Calibration
- Zayante Fault Horizontal Flow Barrier
- Aptos Horizontal Flow Barrier
- Extent of Variable Thickness of the A/AA Units
- Eastern Margin of Tu Layer Extent
- Santa Cruz Mid-County Basin
- Model Boundary
- Active Extent

Note: Layers include stream alluvium and Terrace deposits where underlying layers outcrop

Plate 5: Pilot Points by Aquifer Layer

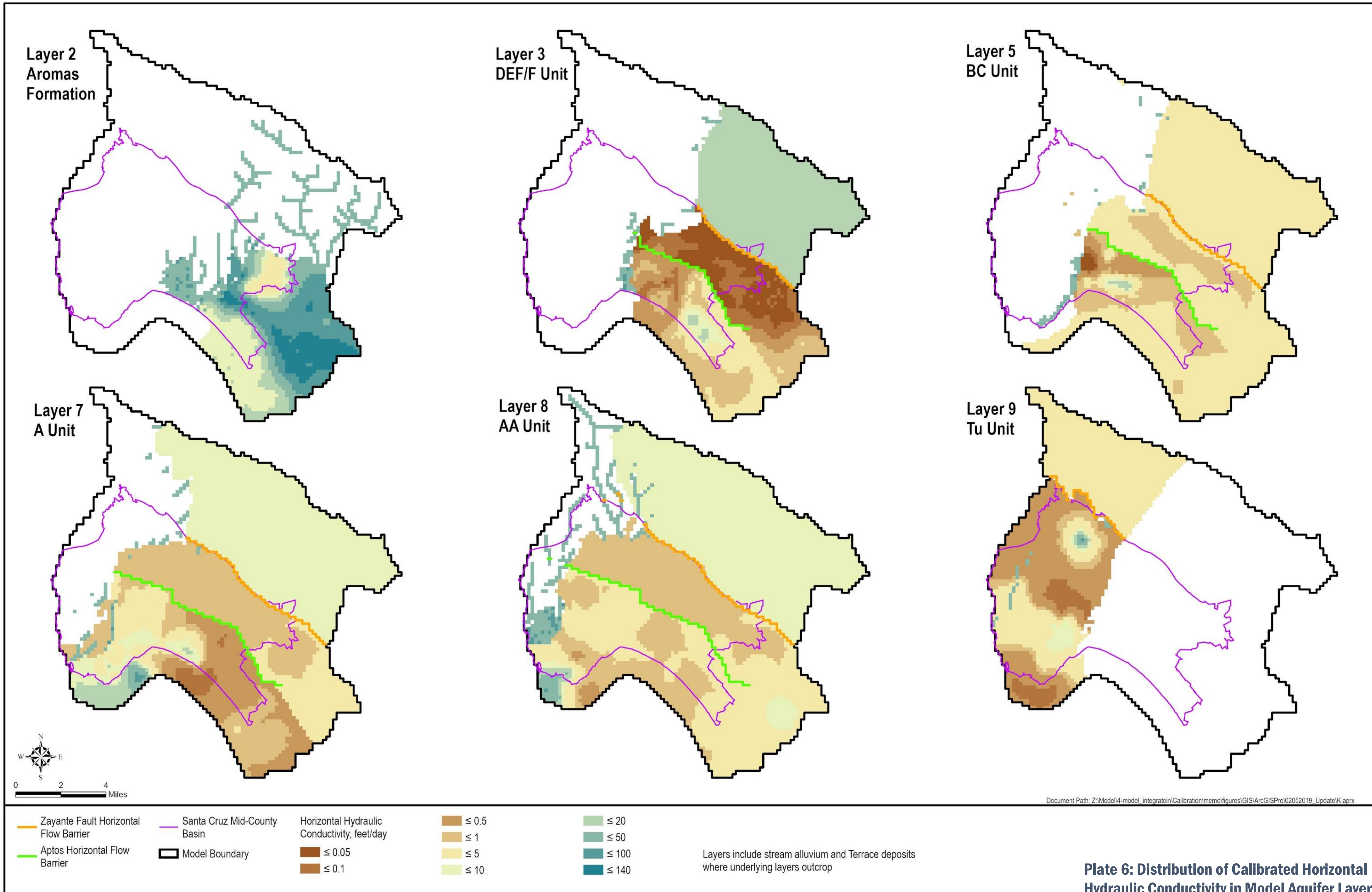


Plate 6: Distribution of Calibrated Horizontal Hydraulic Conductivity in Model Aquifer Layers

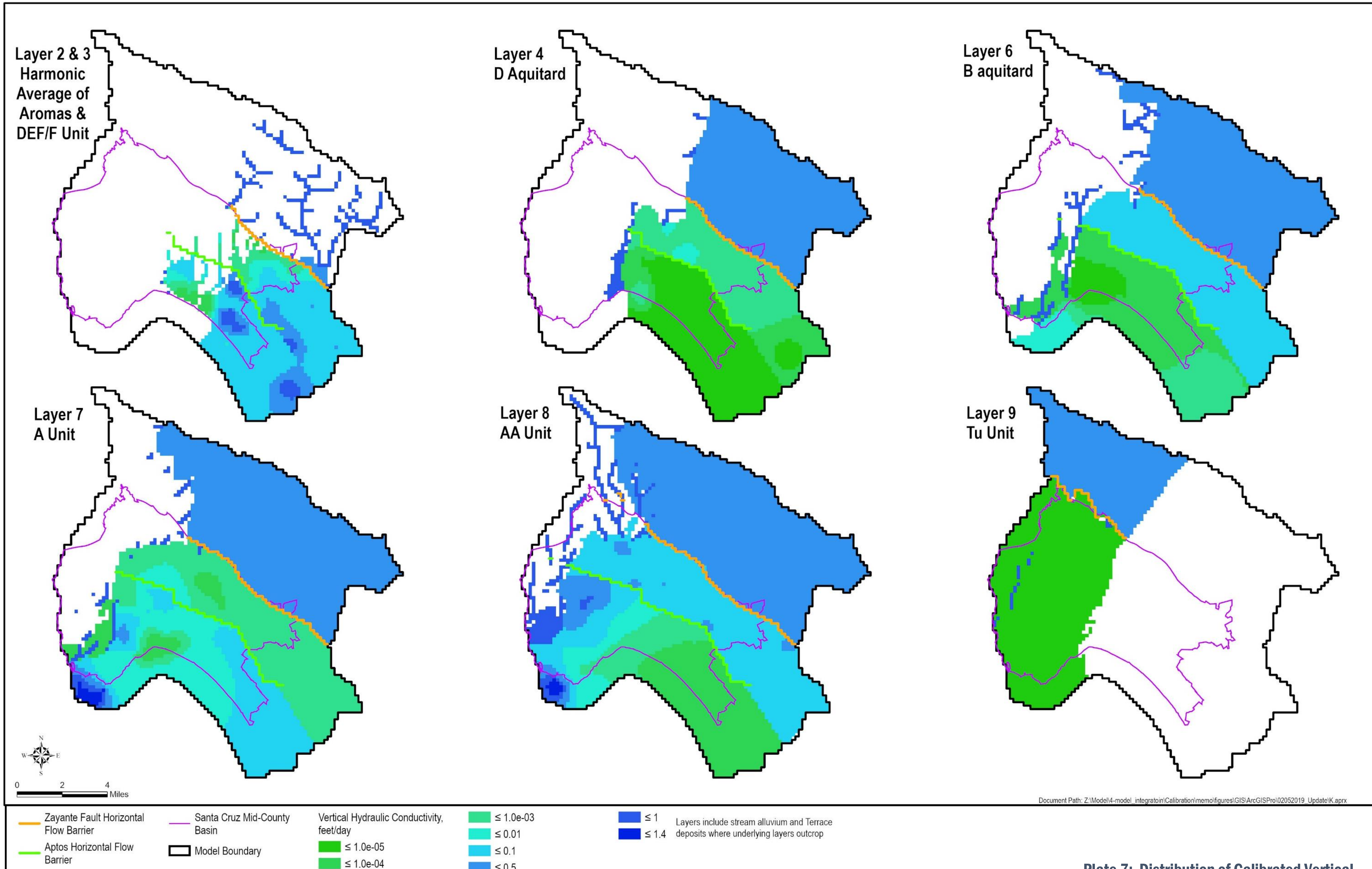
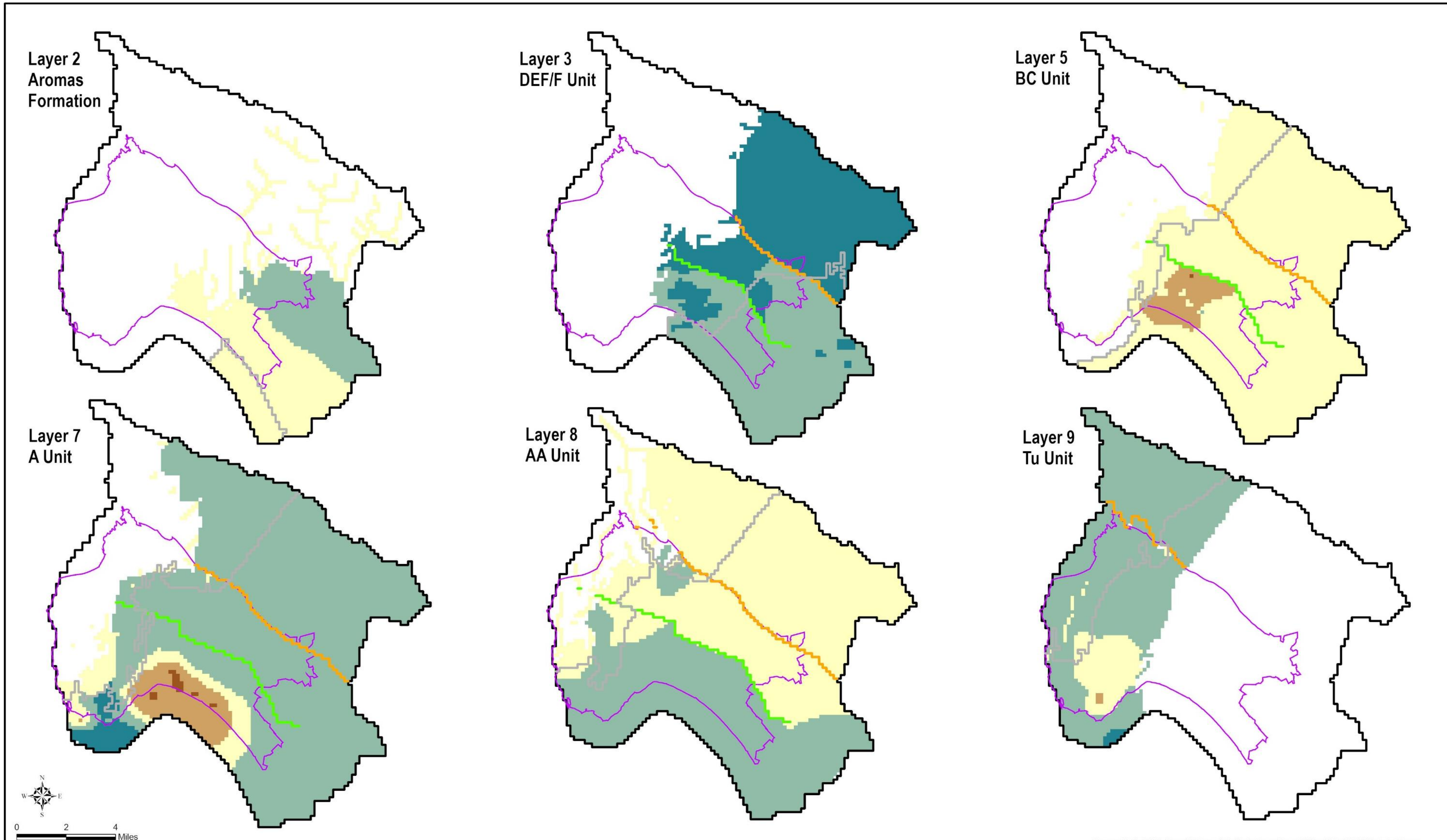


Plate 7: Distribution of Calibrated Vertical Hydraulic Conductivity in Model Aquifer Layers



Zayante Fault Horizontal Flow Barrier
Aptos Horizontal Flow Barrier
Santa Cruz Mid-County Basin
Model Boundary
Confined Boundary, March 2015

Specific Storage, unitless
≤ 2e-007
≤ 2e-006
≤ 2e-005
≤ 2e-004
≤ 2e-003

Layers include stream alluvium and Terrace deposits where underlying layers outcrop

Specific Storage Applies in Confined Area to East of Displayed Approximate Boundary

For Layer 2, it is offshore that is confined and the onshore area is mostly unconfined

Plate 8: Distribution of Calibrated Specific Storage in Model Aquifer Layers

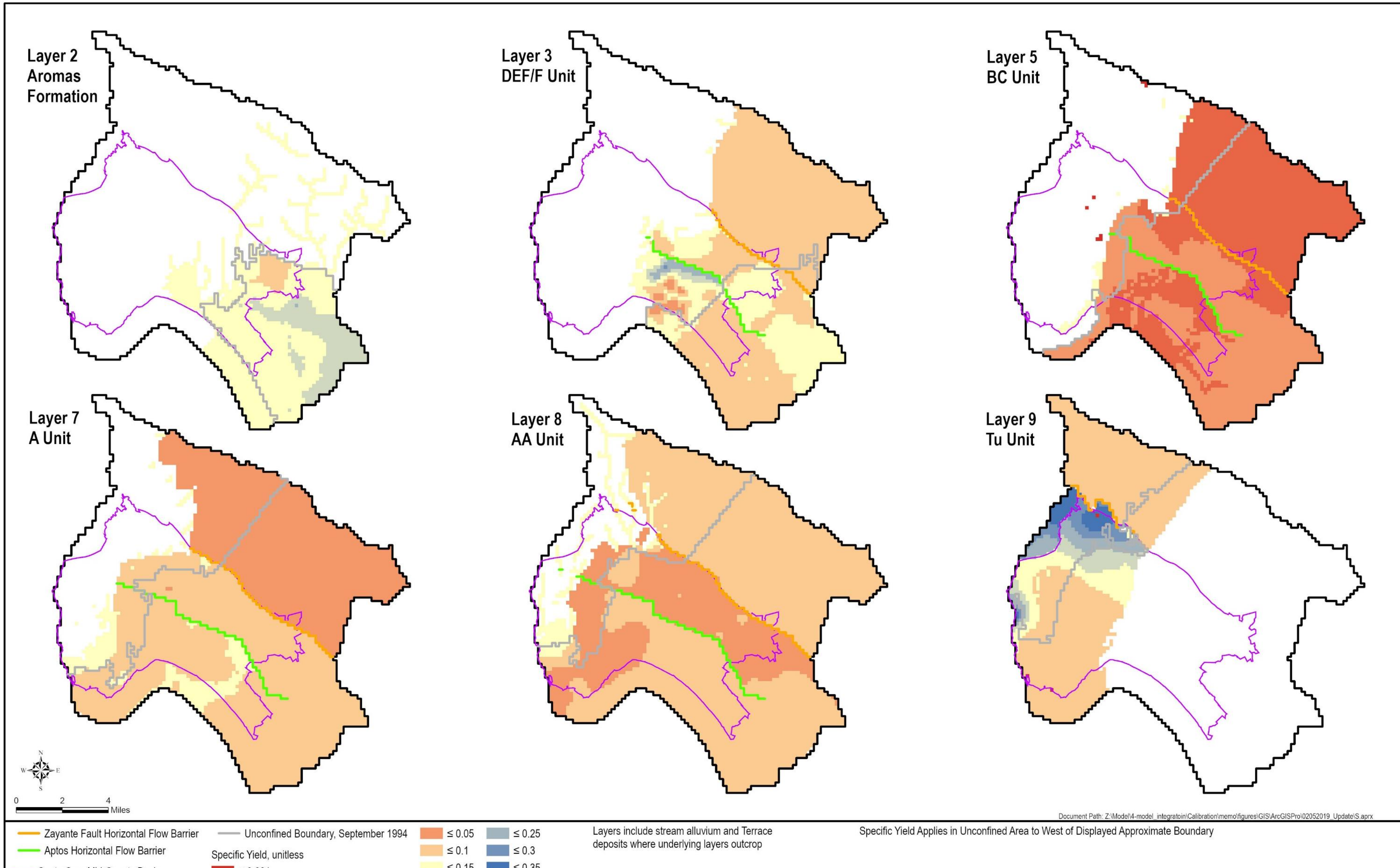


Plate 9: Distribution of Calibrated Specific Yield in Model Aquifer Layers

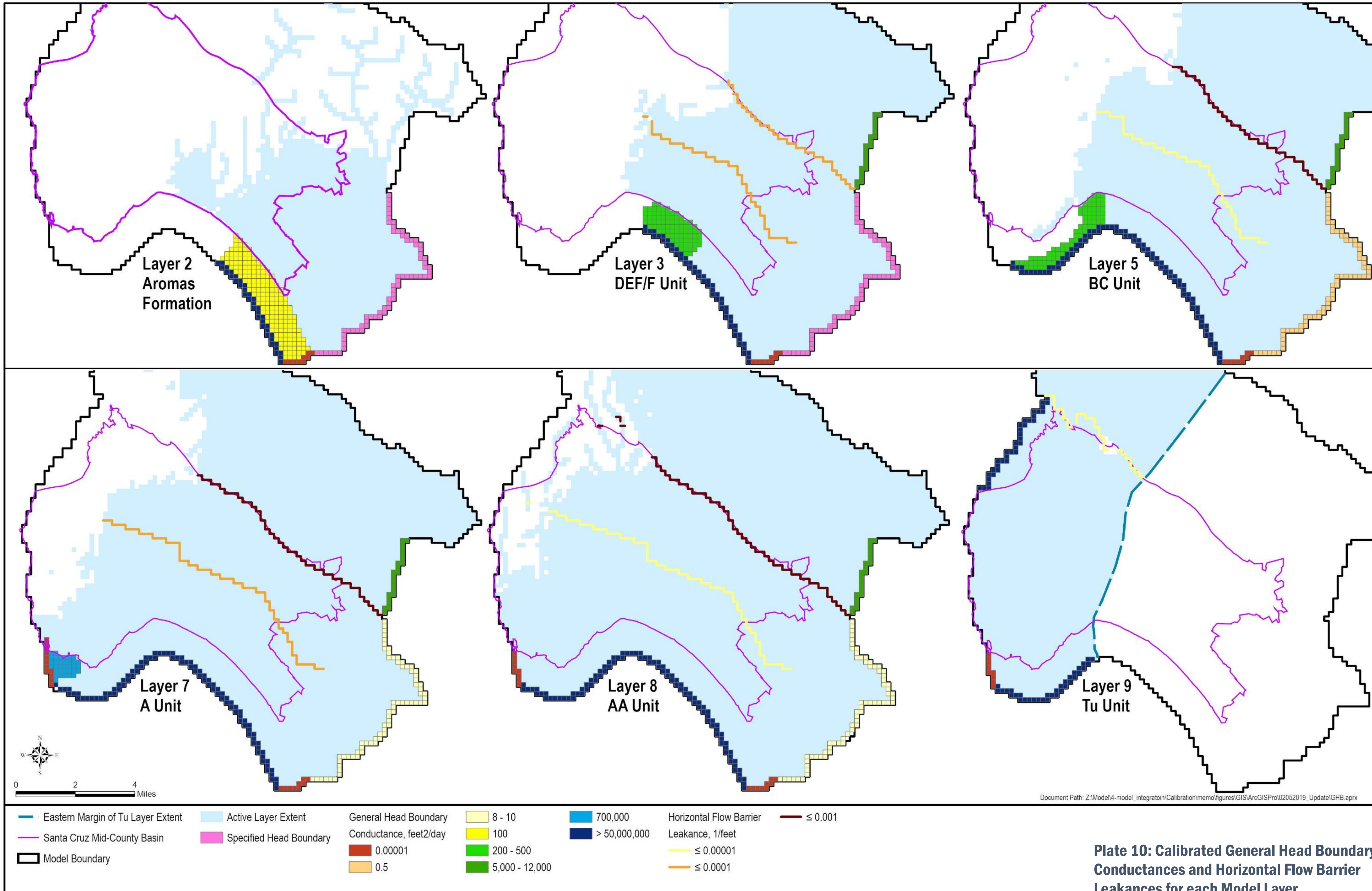


Plate 10: Calibrated General Head Boundary Conductances and Horizontal Flow Barrier Leakances for each Model Layer

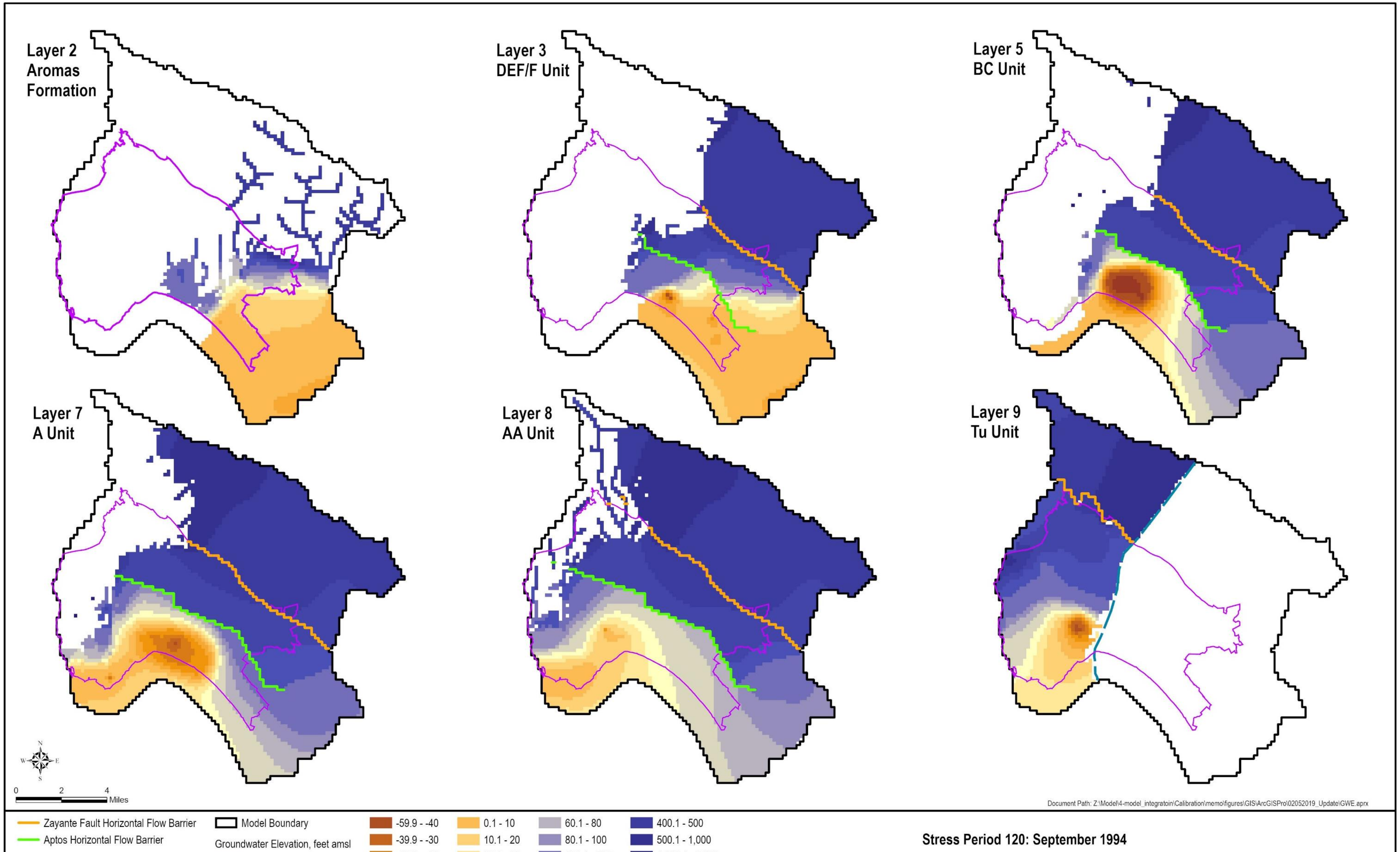


Plate 11: Simulated Groundwater Levels for September 1994

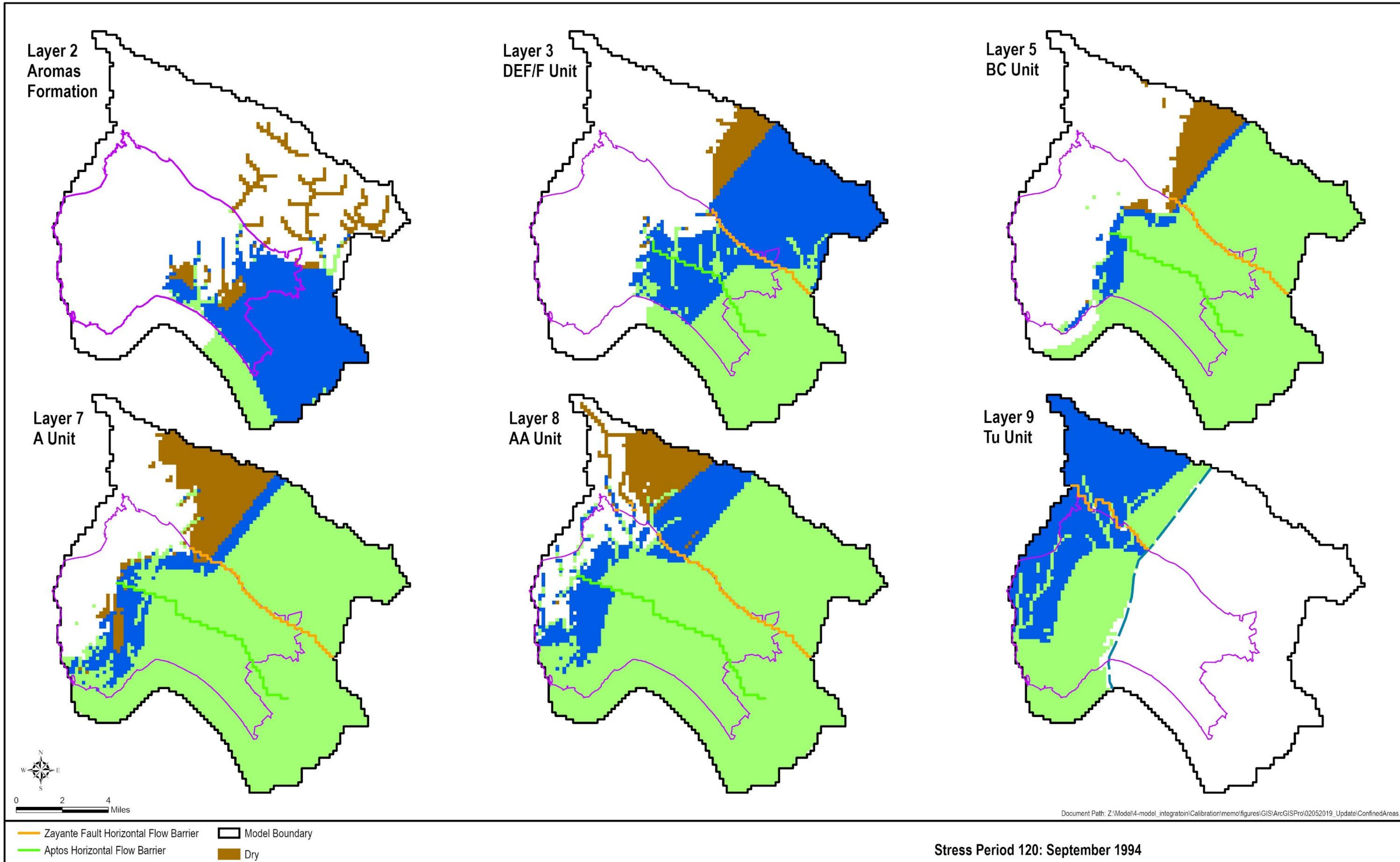


Plate 12: Simulated Dry, Unconfined and Confined Areas for September 1994

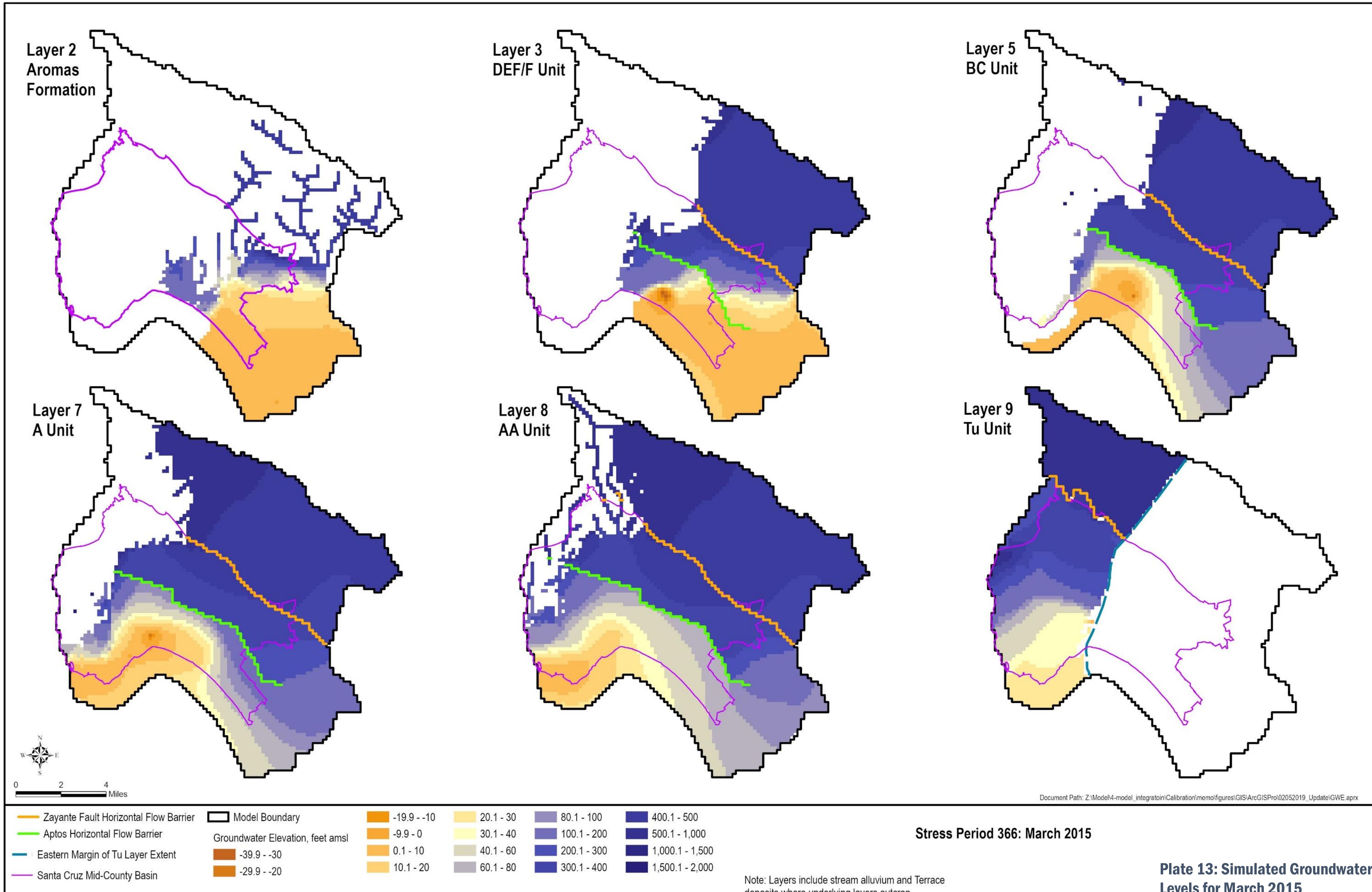
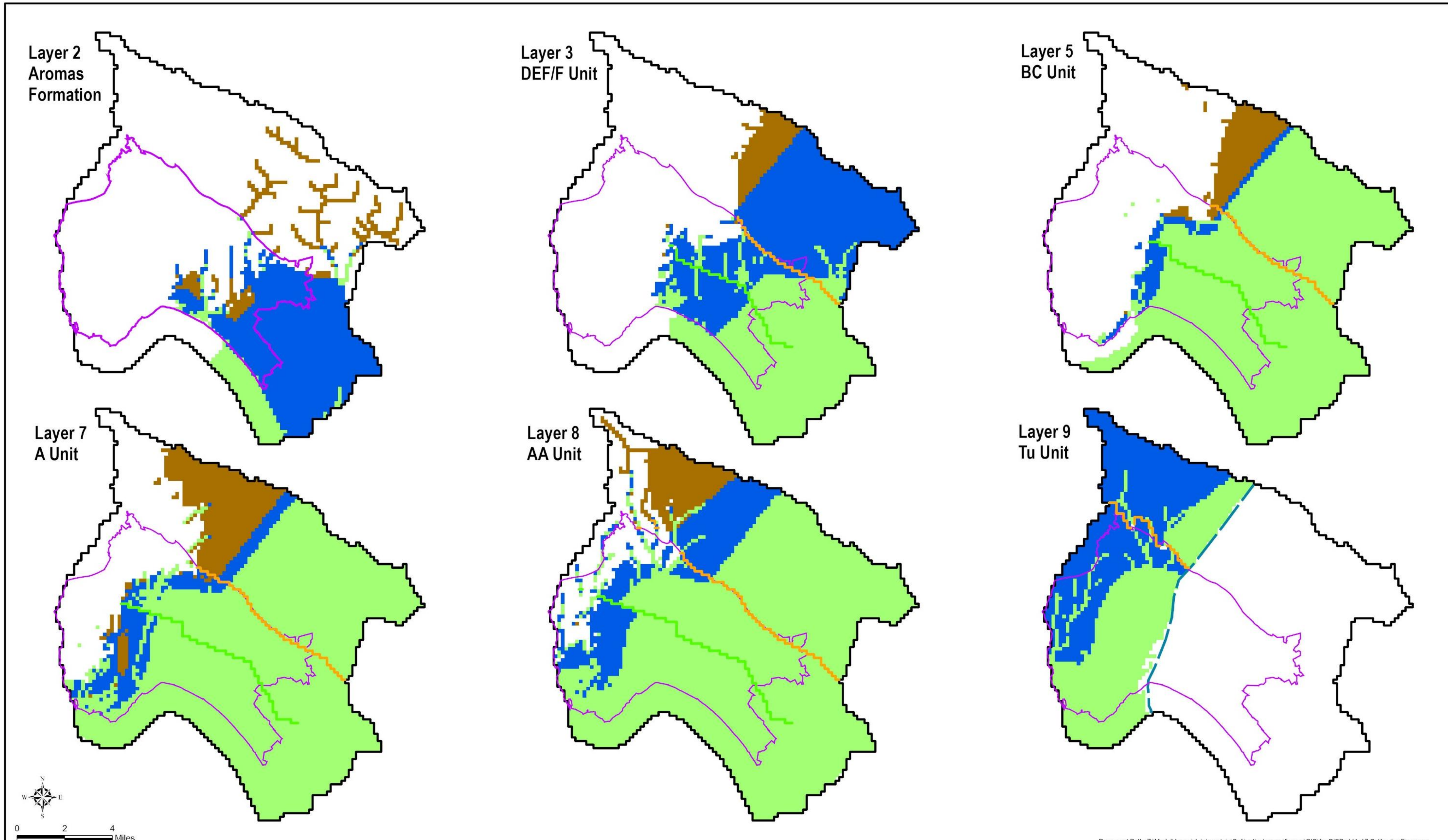


Plate 13: Simulated Groundwater Levels for March 2015



Zayante Fault Horizontal Flow Barrier
Aptos Horizontal Flow Barrier
Eastern Margin of Tu Layer Extent
Santa Cruz Mid-County Basin
Model Boundary
Dry
Unconfined
Confined

Note: Layers include stream alluvium and Terrace deposits where underlying layers outcrop

Stress Period 366: March 2015

Plate 14: Simulated Dry, Unconfined and Confined Areas for March 2015

Appendix A

Municipal Return Flow Estimate Approach

TECHNICAL MEMORANDUM

DATE: August 28, 2019

TO: Santa Cruz Mid-County Groundwater Agency

FROM: Georgina King and Cameron Tana

PROJECT: Santa Cruz Mid-County Basin Groundwater Model

SUBJECT: Municipal Return Flow

SERVICE AREA WATER SUPPLY

Water supplied or delivered to the various municipal service areas in the model is the source of water from which different components of return flow are estimated.

Individual municipal return flow components estimated are:

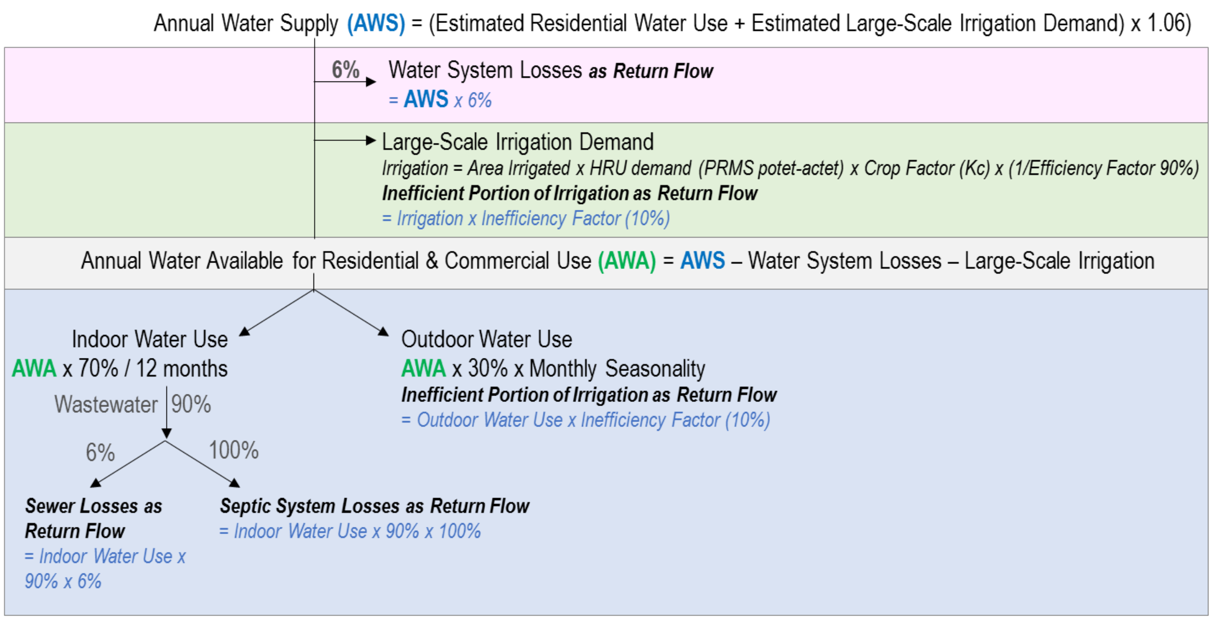
1. Water system losses,
2. Large-scale landscape/field irrigation,
3. Small-scale landscape irrigation (residential and commercial), and
4. Sewer system losses, and septic tank leakage.

The amount of water supplied to each service area is obtained from readily available data provided by the four municipal water agencies in the model area: City of Santa Cruz, Soquel Creek Water District (SqCWD), Central Water District (CWD), and City of Watsonville. If monthly data are not available, annual data are used.

Annual data are used for the Cities of Watsonville and Santa Cruz. Both these municipalities deliver water to customers from both groundwater and surface water sources. Both CWD and SqCWD are able to provide monthly water supply data from well production records as groundwater is their sole source of water.

City of Watsonville

The City of Watsonville was not able to provide readily available water delivery data for the portion of their service area within the model. Their annual water supply (AWS) is estimated as the sum of residential water use and large-scale landscape irrigation, plus 6% to account for water system losses of that water (City of Watsonville, 2016). As an estimate of residential water use, building counts, similar to the approach taken for private water use, are used to estimate annual residential water use to supply areas. The amount of large-scale landscape irrigation is estimated based on irrigated area, water demand, turf crop factor and irrigation inefficiency. The top two rows of Figure 1 show the calculations for estimating AWS for those portions of the City of Watsonville service area within the model.



Monthly Seasonality =Monthly HRU potet-actet / Annual HRU potet-actet

Figure 1: City of Watsonville Return Flow Calculations

City of Santa Cruz

As no delivery data are readily available that are specific to the model area, the City of Santa Cruz provided its entire service area annual consumption data from 1983 – 2015 for its different use types. The amount of water delivered to users in the model area was determined from the percentage of each use type within the model area compared to the entire service area (Table 1). The General Plan land use was used to determine relative land use percentages in the model area. As the City of Santa Cruz's consumption data are generated at meters, 7.5% assumed for water losses (WSC, 2016) was added to the consumption data to estimate AWS within their service area in the model. The top line of Figure 2 shows the calculations to estimate AWS.

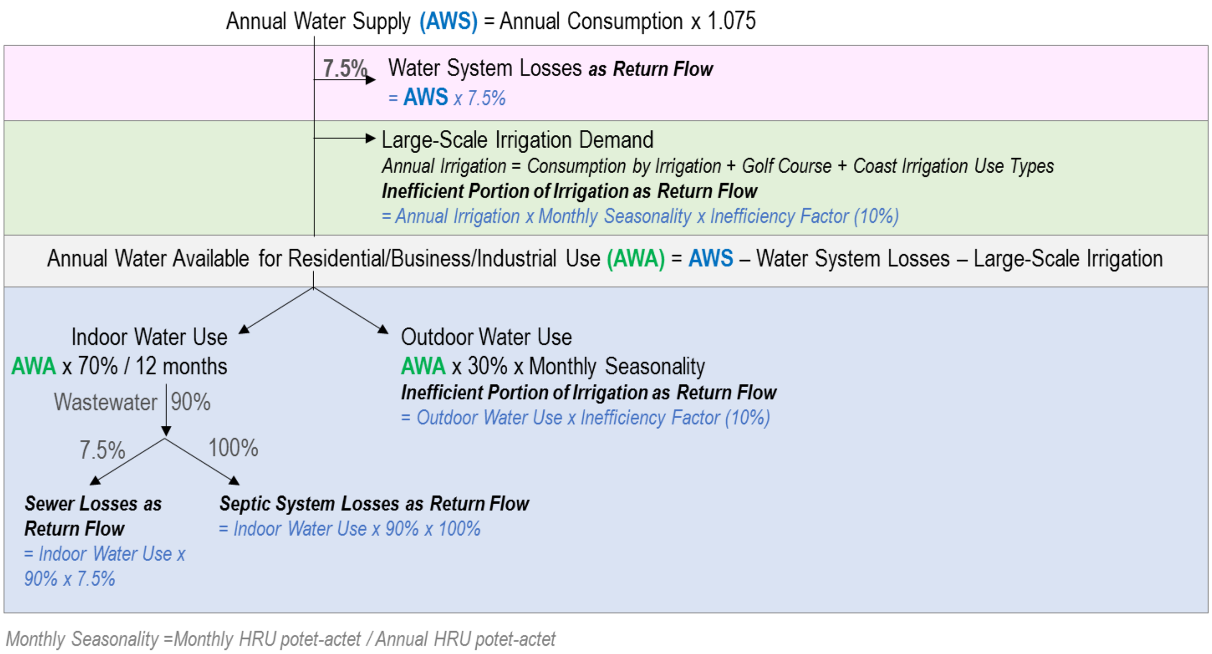


Figure 2: City of Santa Cruz Return Flow Calculations

Table 1: Percentage of All City of Santa Cruz Water Use Types within Model Area

Use Type	Percentage of Total City Land Use within Model Area
Single Family Residential	49%
Multiple Residential	50%
Business	55%
Industrial	34%
Municipal	33%
Irrigation (Large-Scale)	38%
Golf Course Irrigation	100%
Coast Irrigation	55%
Other (Construction & Hydrants)	38% (but negligible return flow assumed)

Central Water District

Groundwater pumped from CWD wells is delivered to both residential/commercial and agricultural customers. The amount of water available for residential/commercial purposes is estimated as the difference between the amount pumped and the amount supplied for agriculture, as shown on Figure 3. Water losses from 1985-1999 are 12%, from 2000-2007 are 7%, and from 2008-2016 are 4%. CWD system loss varies over time based on unaccounted water losses recorded by CWD each fiscal year.

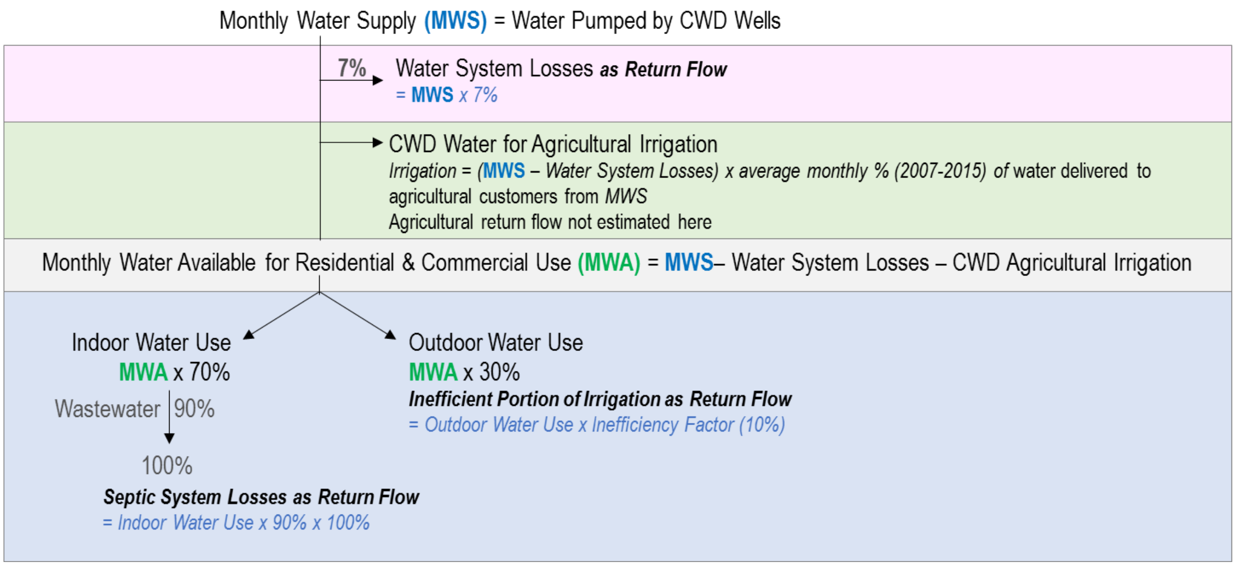


Figure 3: Central Water District Return Flow Calculations

Soquel Creek Water District

Water delivered to each of their four service areas (SA) is determined from the amount of groundwater pumped within each SA plus factoring in transfers that occur between service areas. Delivery data for each SA compared to groundwater pumped within each SA from 2014-2016 was used to estimate the average transfer from SA1 to SA2, SA3 to SA2, and SA3 to SA4. Table 2 summarizes the transfers used to estimate water delivered to each SA that is then used to estimate various components of return flow. The top line on Figure 4 shows the calculation to estimate monthly water supply to each SA. A water loss percentage of 7% is assumed from groundwater pumped (WSC, 2016).

Table 2: Summary of SqCWD Service Area Transfers between 2014 and 2016

Transfer From/To	Percent of Groundwater Produced in Originating Service Area
SA1 to SA2	8.5%
SA 3 to SA2	1.7%
SA3 to SA4	14.3%

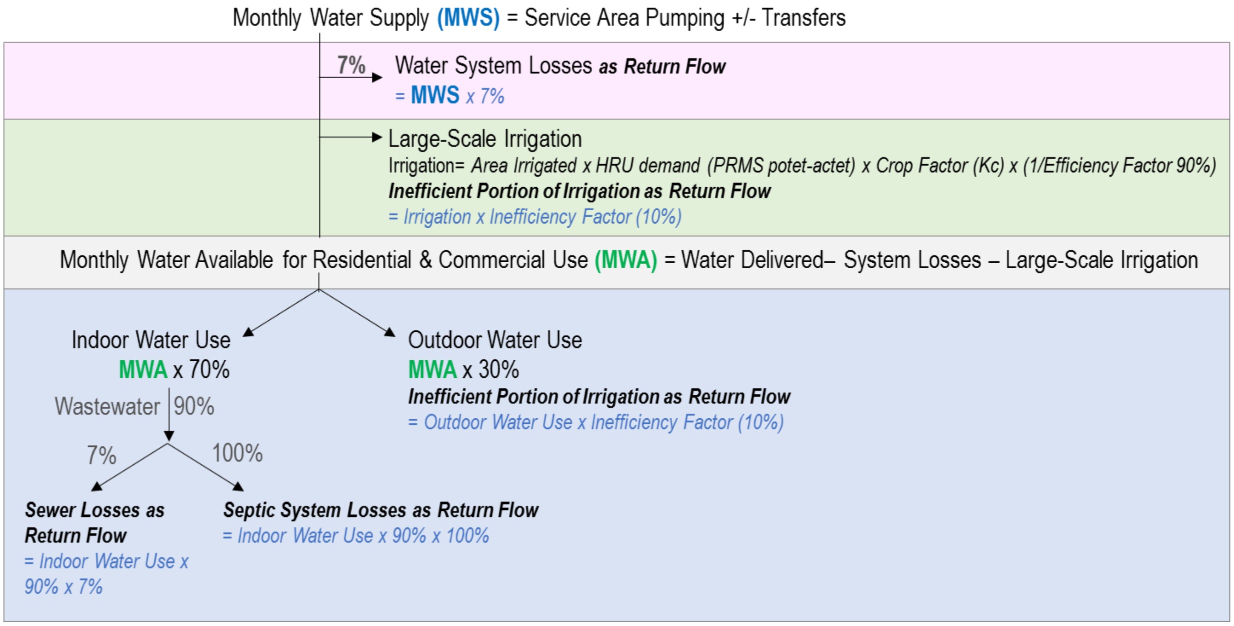


Figure 4: Soquel Creek Water District Return Flow Calculations

RETURN FLOW ESTIMATES

Different municipal water uses have their own proportion of water that percolates into the ground as return flow. Water system losses from both the water distribution and sewer systems are considered return flow. Water system losses are subtracted from water supply and thereafter, any water required to meet large-scale irrigation demand is subtracted from the supply. This leaves an amount of water that can be used for residential/commercial indoor and outdoor use. Assumed indoor and outdoor use is 70% and 30%, respectively. We assume 90% of indoor use becomes wastewater. For areas not connected to sewers, it is further assumed that 100% of wastewater percolates from septic systems into the unsaturated zone as return flow.

Inefficiencies in both residential irrigation (outdoor use) and large-scale irrigation result in an assumed return flow of 10% of the applied water. For the Cities of Santa Cruz and Watsonville, CWD, and SqCWD, Figure 1 through Figure 4, respectively, illustrate the methods for estimating each municipality's return flow estimates. Summaries by water year of each component of return flow are provided in Table 3 through Table 6. The last column of these tables provides the percentage of the total water supply that comprises return flow.

The return flow estimates are applied to the model cells based on the ratio of the area of the model cell that receives municipal water for residential /commercial use compared to the entire service area. Figure 5 shows the location of the residential/commercial and large-landscape irrigation areas within each service area. Figure 6 shows the location of sewered and unsewered (septic tank) areas. Both figures also show model cell boundaries for the municipal water uses.

HOW WATER DELIVERED IS APPLIED TO MODEL CELLS FOR EACH MONTHLY MODEL STRESS PERIOD

For CWD and SqCWD, where monthly data are available, the deliveries to each service area are obtained from the service area pumping +/- any transfers, as described above. For the Cities of Watsonville and Santa Cruz, where annual data are only available, the amount of water applied to each model cell is distributed differently for indoor residential and irrigation use. Monthly indoor use is estimated as 70% of annual water delivered divided by 12 months. Monthly outdoor residential/commercial and large-scale irrigation use are based on irrigation demand (difference between monthly PRMS modeled potential ET (potet) and actual ET (actet)).

- For the City of Santa Cruz, where the water use type was 100% irrigation, the annual volume is distributed to months based on the ratio of monthly to annual irrigation demand for each model cell. For the outdoor portion of residential and commercial water use, the same ratio of monthly to annual irrigation demand for each model cell is used to distribute the annual volumes to monthly volumes.
- For the City of Watsonville, the amount of water to apply to each model cell for either large-scale or residential irrigation is distributed to months based on the ratio of monthly to annual irrigation demand for each model cell.

REFERENCES

City of Santa Cruz Water Department, 2016, City of Santa Cruz Water Department 2015 Urban Water Management Plan. August 2016.

City of Watsonville, 2016 City of Watsonville 2015 Urban Water Management Plan.

Water Systems Consulting, Inc., 2016, Soquel Creek Water District 2015 Urban Water Management Plan. Prepared for Soquel Creek Water District, June 2016.

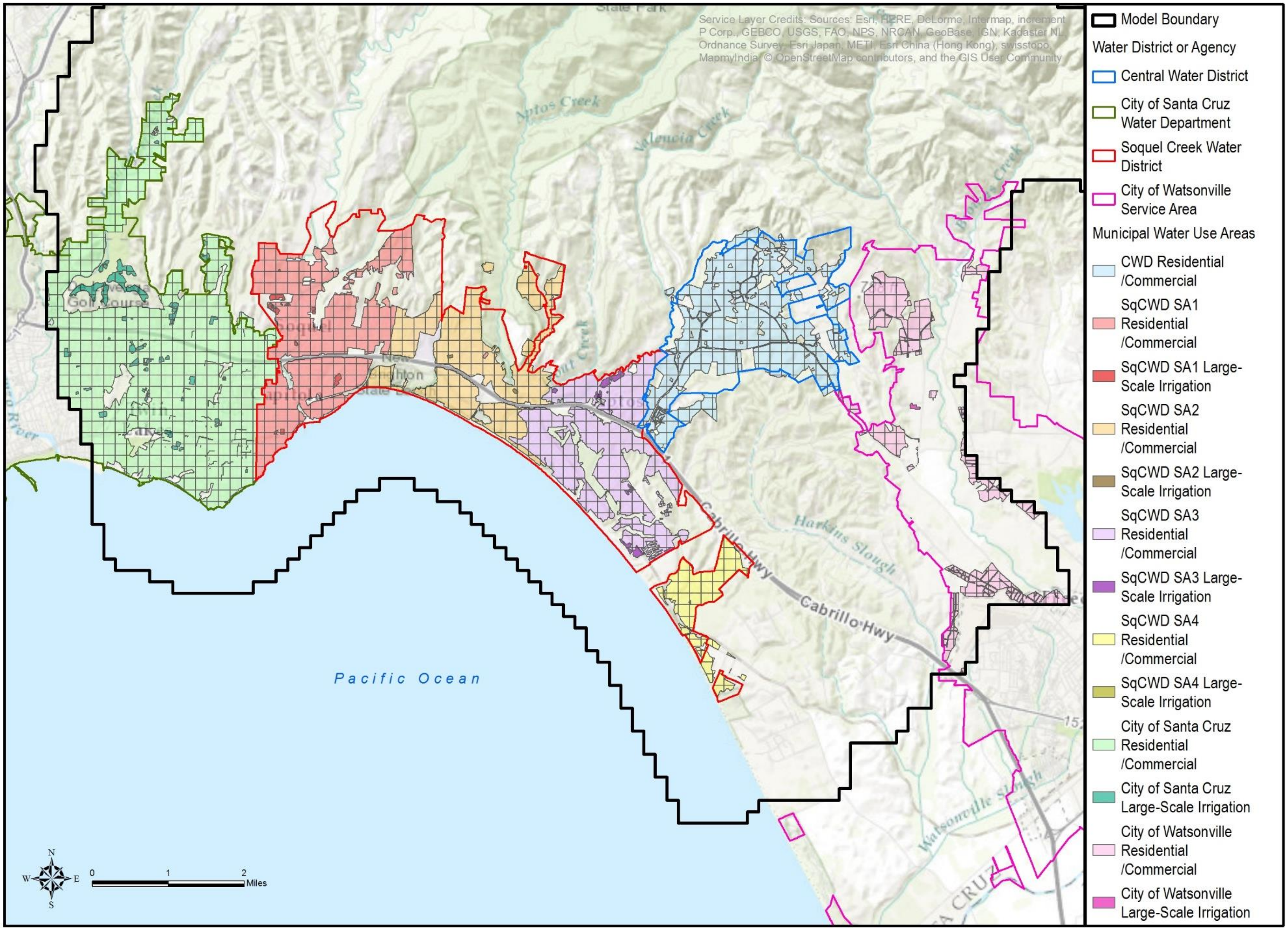


Figure 5: Residential/Commercial and Large-Scale Irrigation Areas within Municipal Service Area

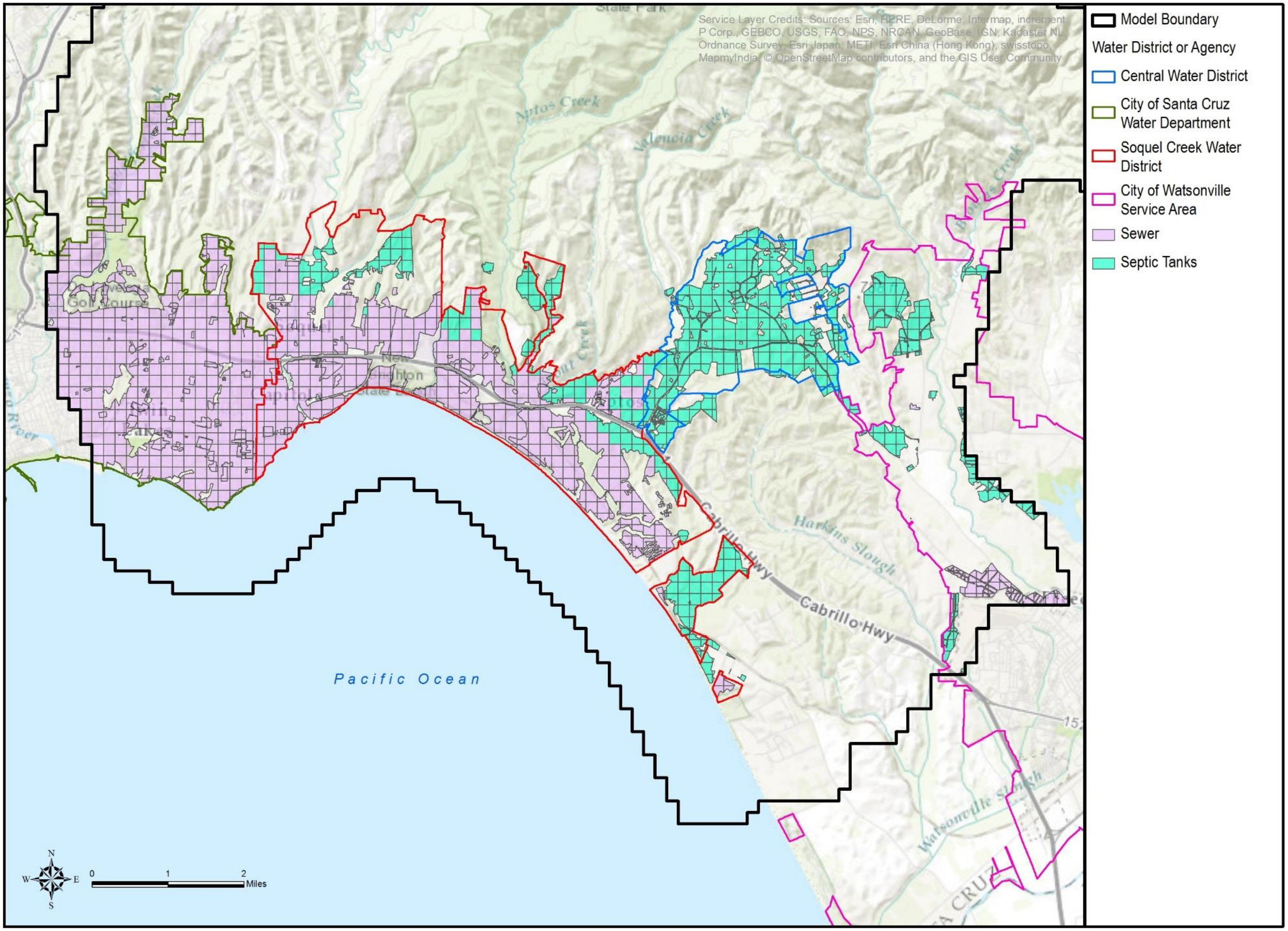


Figure 6: Municipal Sewered and Septic Tank Areas

Table 3: City of Watsonville Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet						Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Septic Systems	Total Return Flow	
1985	478.1	28.7	0.3	14.2	6.5	206.8	227.9	47.7%
1986	497.3	29.8	0.3	14.8	6.7	215.2	237.1	47.7%
1987	511.9	30.7	0.3	15.3	6.9	221.6	244.1	47.7%
1988	529.1	31.7	0.3	15.8	7.2	229.1	252.3	47.7%
1989	543.1	32.6	0.3	16.2	7.4	235.2	259.0	47.7%
1990	561.0	33.7	0.3	16.7	7.6	243.0	267.6	47.7%
1991	577.5	34.6	0.3	17.2	7.8	250.2	275.5	47.7%
1992	596.8	35.8	0.3	17.8	8.1	258.6	284.8	47.7%
1993	614.0	36.8	0.3	18.3	8.3	266.1	293.0	47.7%
1994	633.2	38.0	0.3	18.9	8.6	274.4	302.2	47.7%
1995	650.5	39.0	0.3	19.4	8.8	282.0	310.5	47.7%
1996	708.8	42.5	0.3	21.2	9.6	307.4	338.5	47.7%
1997	724.8	43.5	0.3	21.7	9.8	314.3	346.1	47.7%
1998	742.7	44.6	0.3	22.2	10.1	322.1	354.7	47.8%
1999	766.0	46.0	0.3	22.9	10.4	332.2	365.8	47.8%
2000	816.4	49.0	0.3	24.4	11.1	354.2	390.0	47.8%
2001	823.0	49.4	0.3	24.6	11.2	357.1	393.1	47.8%
2002	819.0	49.1	0.3	24.5	11.1	355.3	391.2	47.8%
2003	828.3	49.7	0.3	24.8	11.2	359.4	395.7	47.8%
2004	850.9	51.1	0.3	25.4	11.5	369.2	406.5	47.8%
2005	843.1	50.6	0.3	25.2	11.4	365.8	402.7	47.8%
2006	860.6	51.6	0.3	25.7	11.7	373.5	411.2	47.8%
2007	868.5	52.1	0.3	26.0	11.8	376.9	414.9	47.8%
2008	872.4	52.3	0.3	26.1	11.8	378.6	416.8	47.8%
2009	850.2	51.0	0.3	25.4	11.5	368.9	406.2	47.8%
2010	852.1	51.1	0.3	25.5	11.6	369.7	407.1	47.8%
2011	858.4	51.5	0.3	25.7	11.6	372.5	410.1	47.8%
2012	861.6	51.7	0.3	25.8	11.7	373.9	411.6	47.8%
2013	866.0	52.0	0.3	25.9	11.8	375.8	413.7	47.8%
2014	798.0	47.9	0.3	23.9	10.8	346.2	381.2	47.8%
2015	744.0	44.6	0.3	22.2	10.1	322.7	355.3	47.8%
Average	727.3	43.6	0.3	21.7	9.9	315.4	347.3	47.7%

Table 4: City of Santa Cruz Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet					Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Total Return Flow	
1985	6,593.7	461.6	72.1	162.3	238.6	934.6	14.2%
1986	6,663.3	466.4	68.7	165.3	243.0	943.4	14.2%
1987	6,941.7	485.9	84.4	168.3	247.4	986.1	14.2%
1988	6,258.3	438.1	77.5	151.3	222.5	889.4	14.2%
1989	5,749.4	402.5	61.8	141.9	208.6	814.7	14.2%
1990	5,209.9	364.7	55.0	126.8	186.4	732.9	14.1%
1991	4,891.0	342.4	53.1	120.3	176.8	692.6	14.2%
1992	5,419.7	379.4	57.6	133.7	196.5	767.2	14.2%
1993	5,455.4	381.9	47.1	137.9	202.8	769.7	14.1%
1994	5,648.9	395.4	47.4	143.2	210.5	796.4	14.1%
1995	5,777.5	404.4	47.1	147.0	216.1	814.6	14.1%
1996	6,143.6	430.1	51.7	155.8	229.0	866.6	14.1%
1997	6,633.3	464.3	64.7	165.5	243.2	937.7	14.1%
1998	5,887.4	412.1	43.9	151.0	221.9	828.9	14.1%
1999	6,192.2	433.5	52.4	156.9	230.7	873.4	14.1%
2000	6,183.4	432.8	51.5	157.0	230.7	872.0	14.1%
2001	6,255.6	437.9	63.6	155.4	228.4	885.2	14.2%
2002	6,072.7	425.1	62.4	150.5	221.3	859.4	14.2%
2003	6,072.7	425.1	69.6	148.4	218.2	861.4	14.2%
2004	6,191.6	433.4	75.0	150.1	220.6	879.2	14.2%
2005	5,780.4	404.6	58.0	143.7	211.3	817.6	14.1%
2006	5,579.3	390.6	62.6	136.8	201.0	790.9	14.2%
2007	5,477.2	383.4	54.7	136.3	200.4	774.8	14.1%
2008	5,537.2	387.6	60.7	136.1	200.1	784.6	14.2%
2009	4,840.5	338.8	44.0	121.7	178.9	683.5	14.1%
2010	4,764.2	333.5	41.4	120.4	177.0	672.4	14.1%
2011	4,569.3	319.8	36.8	116.4	171.1	644.2	14.1%
2012	4,870.7	341.0	47.2	121.7	178.8	688.7	14.1%
2013	5,078.7	355.5	54.5	125.3	184.1	719.4	14.2%
2014	4,083.1	285.8	35.7	103.1	151.6	576.3	14.1%
2015	3,837.2	268.6	42.4	94.3	138.6	543.9	14.2%
Average	5,634.2	394.4	56.3	140.1	206.0	796.8	14.1%

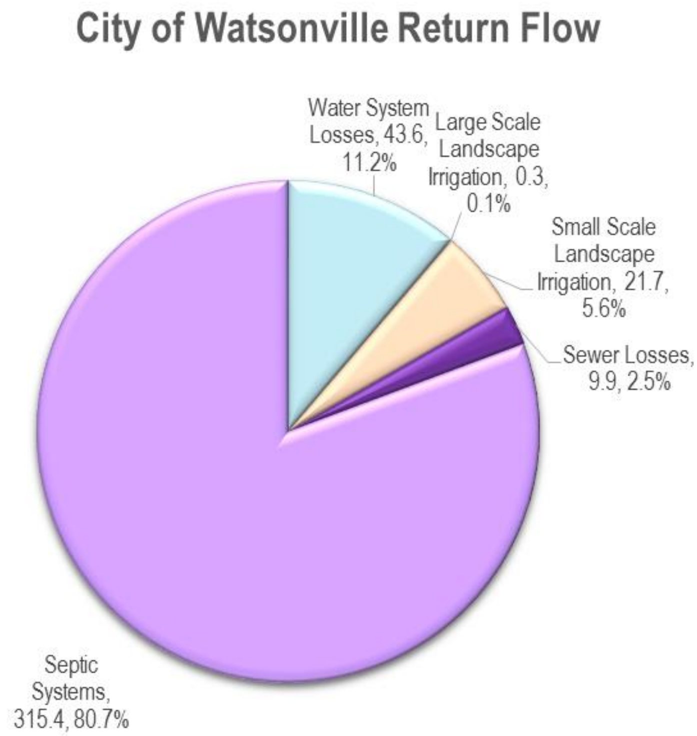
Table 5: Soquel Creek Water District Return Flow Estimates

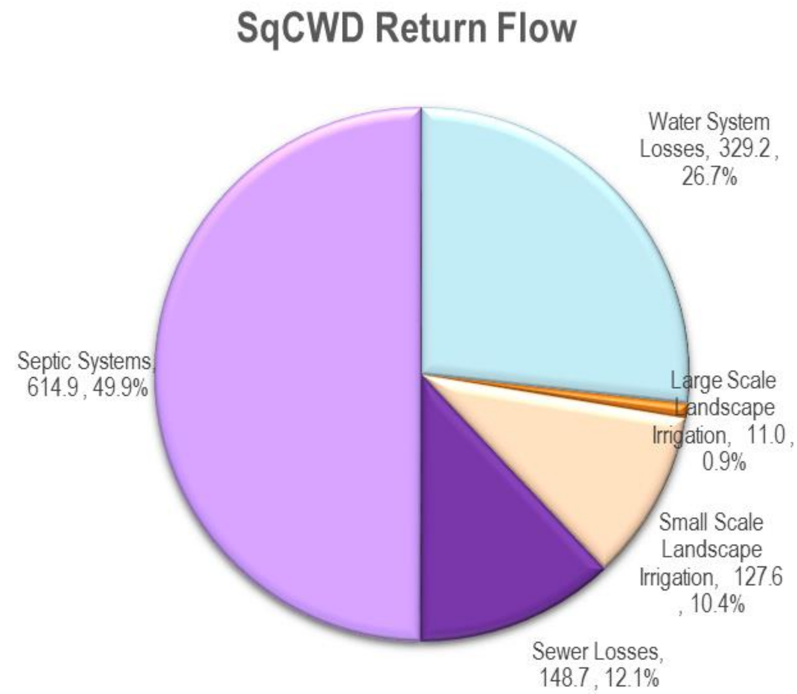
Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet						Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Septic Systems	Total Return Flow	
1985	4,318.5	302.3	13.2	116.5	135.8	559.0	1,126.8	26.1%
1986	4,272.5	299.1	10.3	116.1	137.1	529.0	1,091.6	25.5%
1987	5,234.6	366.4	13.8	141.9	163.7	708.1	1,393.9	26.6%
1988	4,858.7	340.1	14.8	131.1	151.0	658.1	1,295.2	26.7%
1989	4,797.2	335.8	12.7	130.0	149.0	664.8	1,292.3	26.9%
1990	4,818.5	337.3	13.3	130.5	150.6	649.1	1,280.7	26.6%
1991	4,703.0	329.2	10.4	128.1	148.1	634.4	1,250.3	26.6%
1992	4,908.3	343.6	13.9	132.8	152.6	672.0	1,314.9	26.8%
1993	4,863.2	340.4	11.6	132.2	152.2	665.2	1,301.7	26.8%
1994	5,089.3	356.2	10.4	138.9	159.4	706.7	1,371.6	27.0%
1995	4,854.9	339.8	9.9	132.5	153.5	650.6	1,286.3	26.5%
1996	5,183.2	362.8	12.7	140.8	163.4	688.0	1,367.7	26.4%
1997	5,570.8	390.0	14.7	151.0	174.1	755.0	1,484.8	26.7%
1998	4,966.1	347.6	7.8	136.2	157.8	670.0	1,319.4	26.6%
1999	5,211.5	364.8	8.2	142.9	165.0	712.3	1,393.2	26.7%
2000	5,270.8	369.0	9.9	144.1	166.6	712.7	1,402.2	26.6%
2001	5,174.7	362.2	9.7	141.5	164.3	688.2	1,365.9	26.4%
2002	5,375.8	376.3	9.6	147.1	172.6	689.3	1,394.9	25.9%
2003	5,331.8	373.2	11.1	145.4	171.4	667.7	1,368.9	25.7%
2004	5,372.0	376.0	13.0	146.0	172.8	659.2	1,367.0	25.4%
2005	4,543.8	318.1	7.3	124.6	147.2	566.2	1,163.4	25.6%
2006	4,548.6	318.4	10.2	123.9	144.5	591.7	1,188.7	26.1%
2007	4,625.8	323.8	12.0	125.5	144.9	623.6	1,229.7	26.6%
2008	4,557.0	319.0	12.6	123.4	141.7	625.9	1,222.6	26.8%
2009	4,162.1	291.3	12.5	112.4	131.6	529.8	1,077.6	25.9%
2010	3,932.5	275.3	10.3	106.6	127.5	461.6	981.3	25.0%
2011	4,011.2	280.8	8.7	109.3	131.0	467.1	997.0	24.9%
2012	4,159.1	291.1	12.7	112.2	134.0	487.8	1,037.9	25.0%
2013	4,217.5	295.2	19.2	111.9	132.2	509.1	1,067.6	25.3%
2014	3,702.9	259.2	20.0	97.3	115.6	432.6	924.7	25.0%
2015	3,153.9	220.8	22.4	81.3	96.9	355.8	777.2	24.6%
Average	4,702.9	329.2	12.2	127.5	148.6	612.6	1,230.2	26.1%

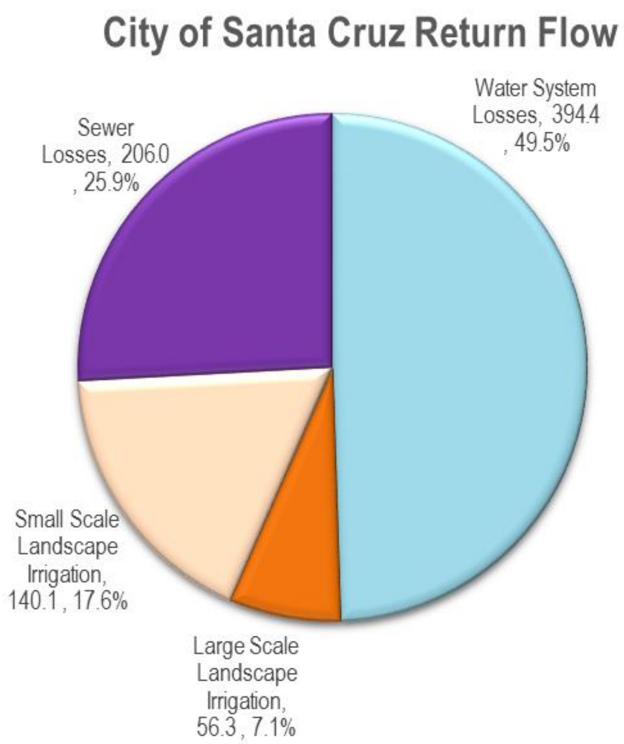
Table 6: Central Water District Return Flow Estimates

Water Year	Water Supply to Service Area in Model*, acre-feet	Return Flow in acre-feet				Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Small-Scale Landscape Irrigation	Septic Systems	Total Return Flow	
1985	352.9	27.5	9.8	205.0	242.3	68.7%
1986	363.0	28.3	10.0	210.9	249.2	68.7%
1987	399.4	31.1	11.1	232.1	274.2	68.6%
1988	393.2	30.6	10.9	228.4	270.0	68.6%
1989	363.2	28.4	10.0	210.9	249.4	68.7%
1990	387.1	30.1	10.7	224.9	265.7	68.6%
1991	383.9	29.8	10.6	223.1	263.5	68.6%
1992	417.5	32.7	11.5	242.5	286.7	68.7%
1993	429.6	33.7	11.9	249.4	295.0	68.7%
1994	431.2	33.7	11.9	250.4	296.1	68.7%
1995	409.5	32.2	11.3	237.7	281.2	68.7%
1996	469.4	36.8	13.0	272.5	322.3	68.7%
1997	539.5	42.3	14.9	313.2	370.4	68.7%
1998	476.0	37.4	13.2	276.3	326.9	68.7%
1999	479.9	37.7	13.3	278.6	329.6	68.7%
2000	489.2	38.3	13.5	284.1	335.9	68.7%
2001	496.7	39.0	13.7	288.4	341.1	68.7%
2002	529.1	41.5	14.6	307.2	363.3	68.7%
2003	519.3	40.8	14.4	301.5	356.7	68.7%
2004	565.6	44.3	15.6	328.4	388.4	68.7%
2005	456.9	36.0	12.6	265.2	313.8	68.7%
2006	483.1	38.1	13.3	280.3	331.8	68.7%
2007	532.3	41.7	14.7	309.1	365.5	68.7%
2008	520.0	40.9	14.4	301.9	357.1	68.7%
2009	530.4	41.6	14.7	307.9	364.2	68.7%
2010	428.8	33.6	11.9	248.9	294.4	68.7%
2011	434.4	34.1	12.0	252.2	298.3	68.7%
2012	479.3	37.5	13.3	278.4	329.1	68.7%
2013	501.2	39.1	13.9	291.1	344.1	68.7%
2014	452.3	35.0	12.5	262.9	310.4	68.6%
2015	352.7	27.4	9.8	204.9	242.1	68.6%
Average	453.8	35.5	12.5	263.5	311.6	68.7%

* This column is water supply for residential/commercial use only, and does not include water delivered for agricultural use.







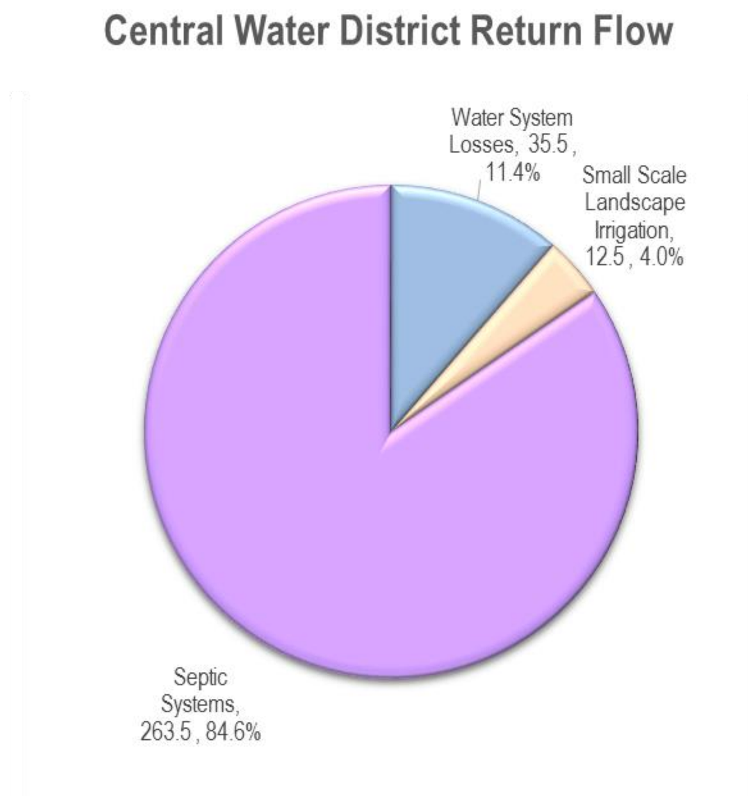
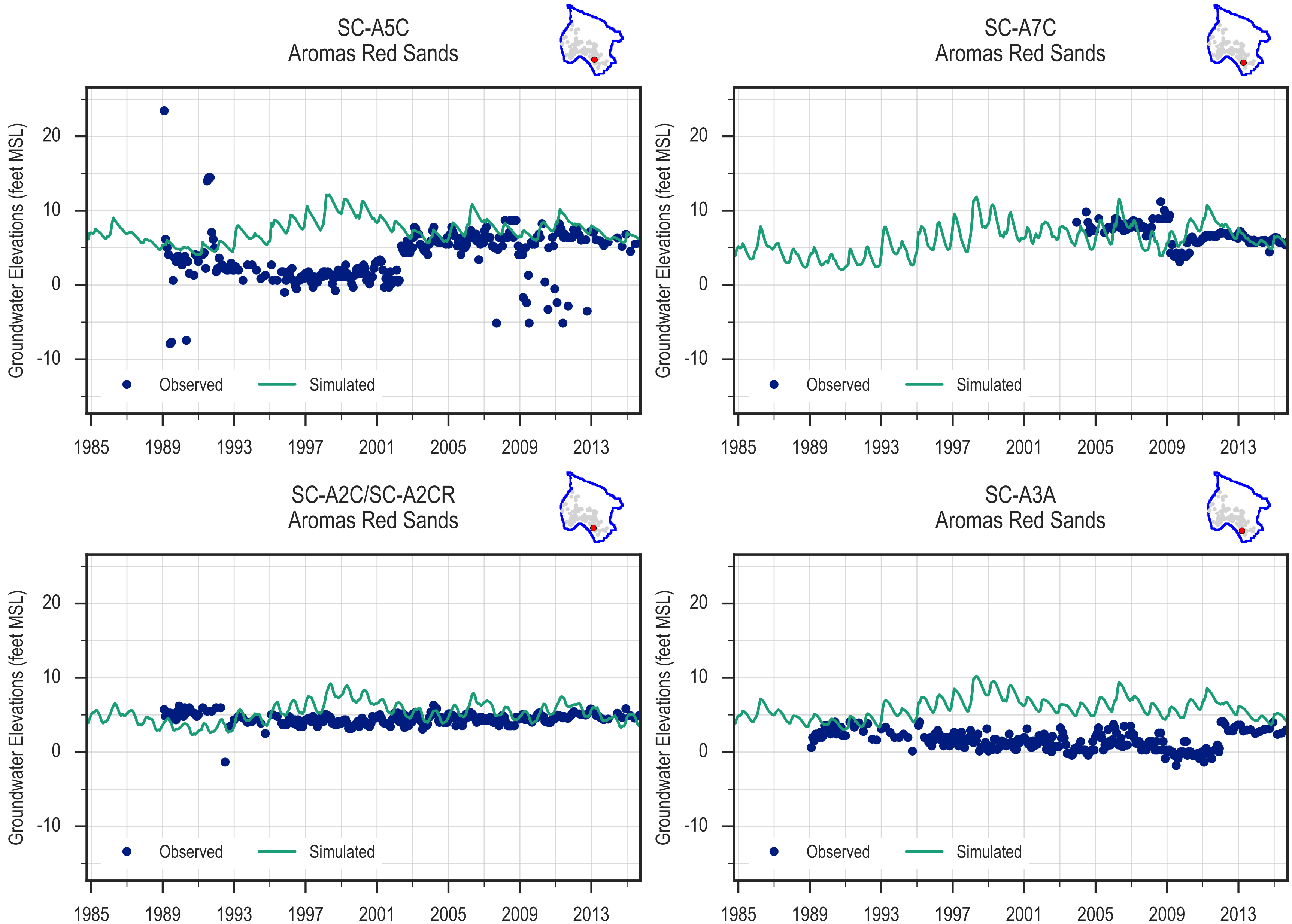
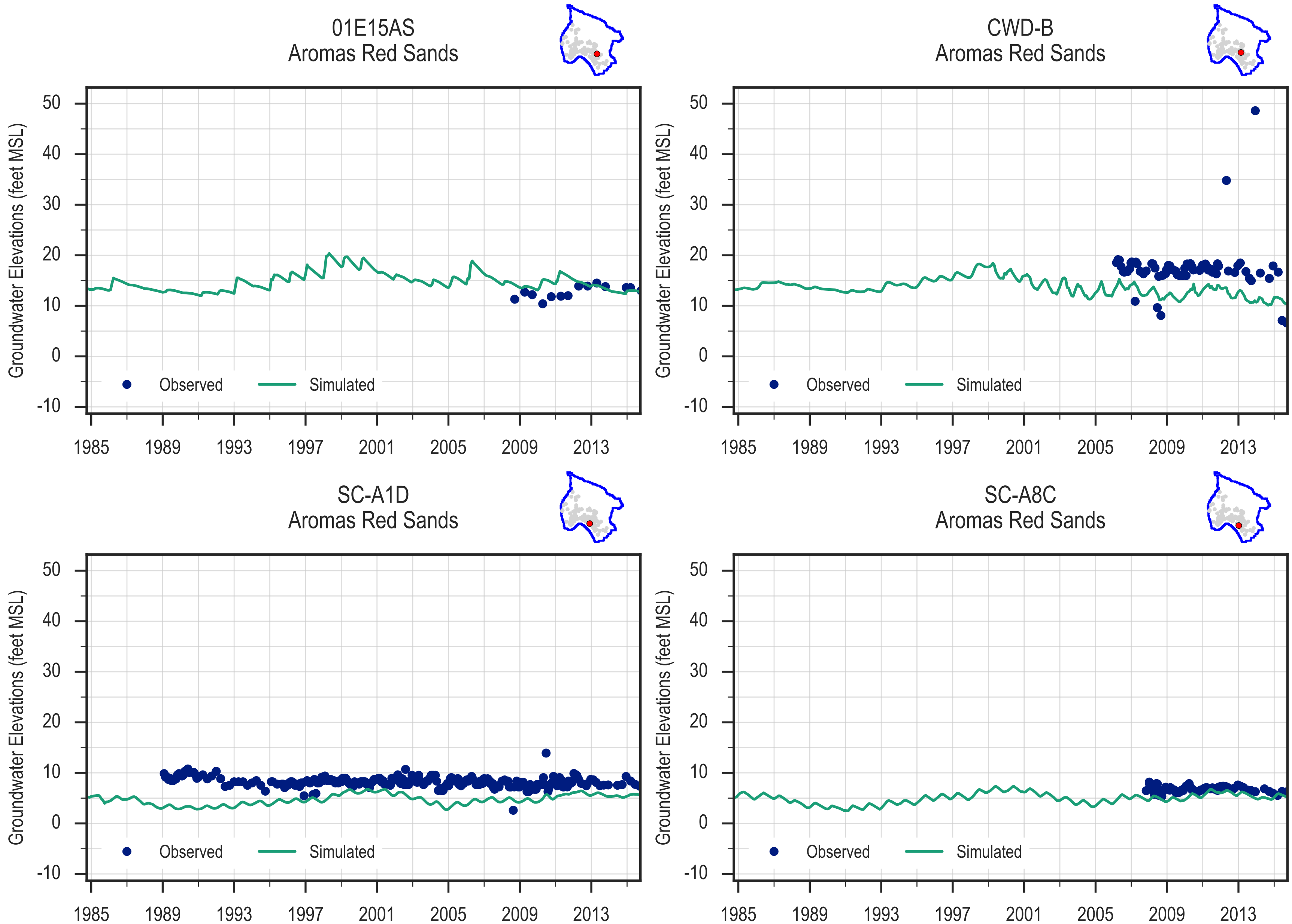


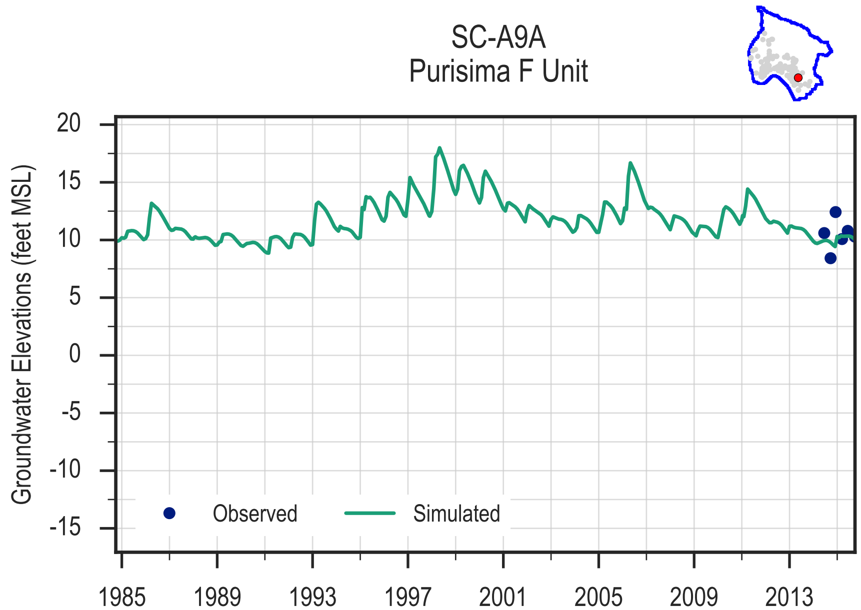
Figure 7: Municipal Return Flow Pie Charts (in acre-feet per year)

Appendix C

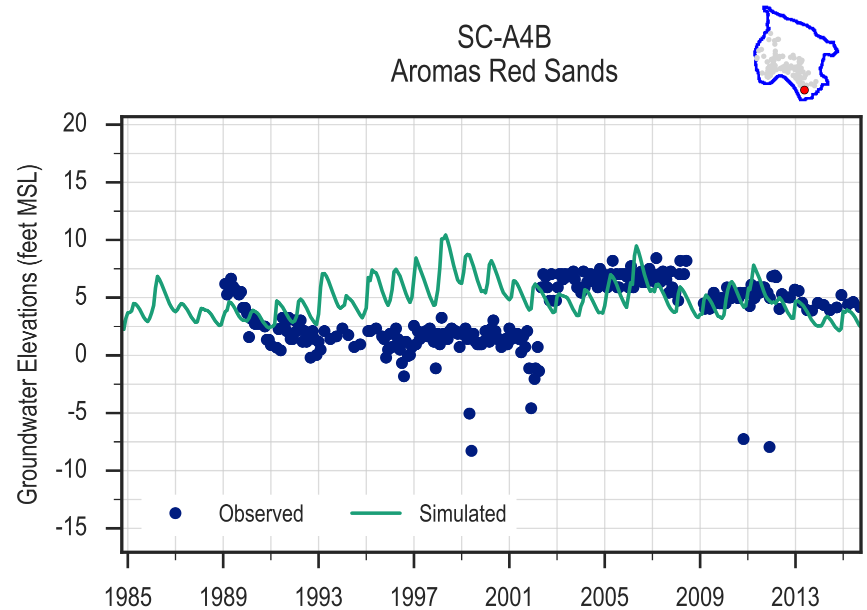
Selected Well Hydrographs


SC-A5C
Aromas Red Sands
SC-A7C
Aromas Red Sands
SC-A2C/SC-A2CR
Aromas Red Sands
SC-A3A
Aromas Red Sands
Groundwater Elevations (feet MSL)
20
10
0
-10
1985
1989
1993
1997
2001
2005
2009
2013
Observed
Simulated

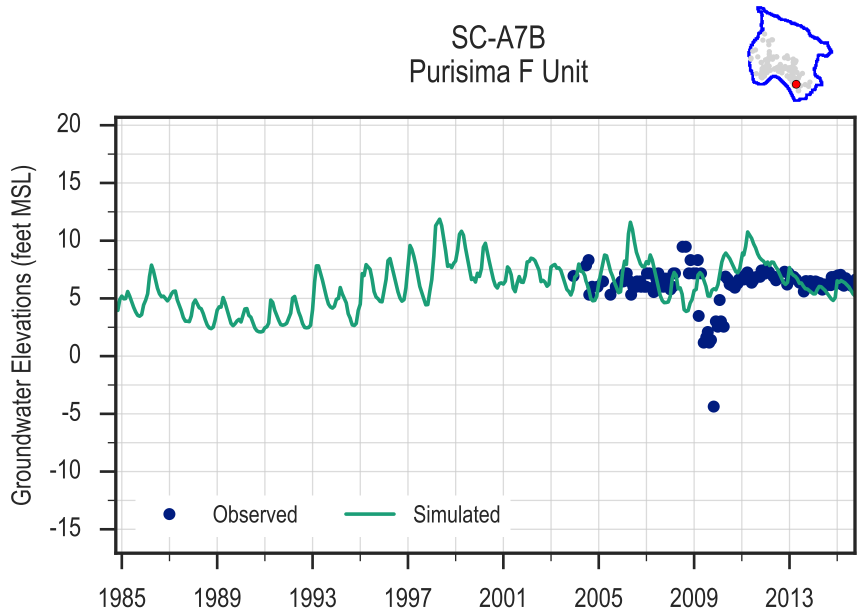

01E15AS
Aromas Red Sands
CWD-B
Aromas Red Sands
SC-A1D
Aromas Red Sands
SC-A8C
Aromas Red Sands
Groundwater Elevations (feet MSL)
Observed
Simulated
50
40
30
20
10
0
-10
1985
1989
1993
1997
2001
2005
2009
2013



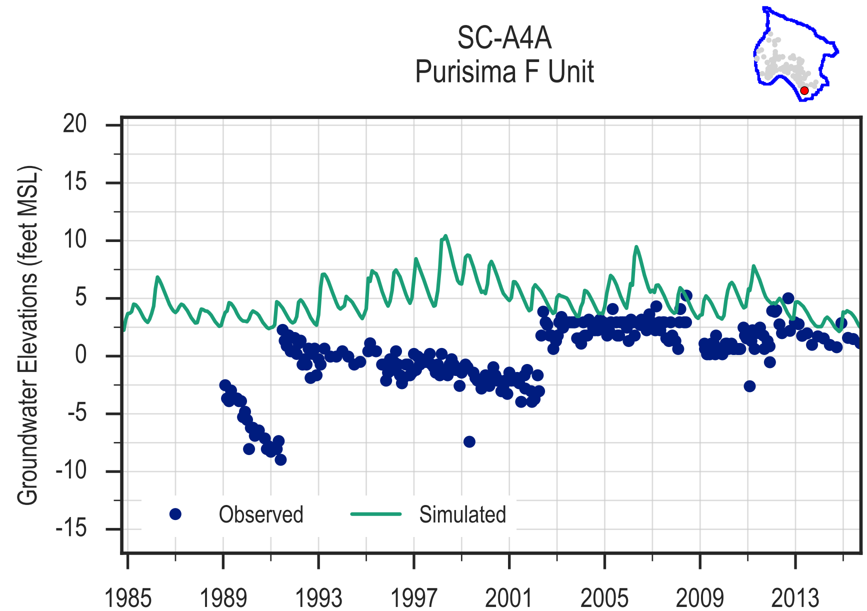
SC-A9A
Purisima F Unit
Groundwater Elevations (feet MSL)
20
15
10
5
0
-5
-10
-15
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013



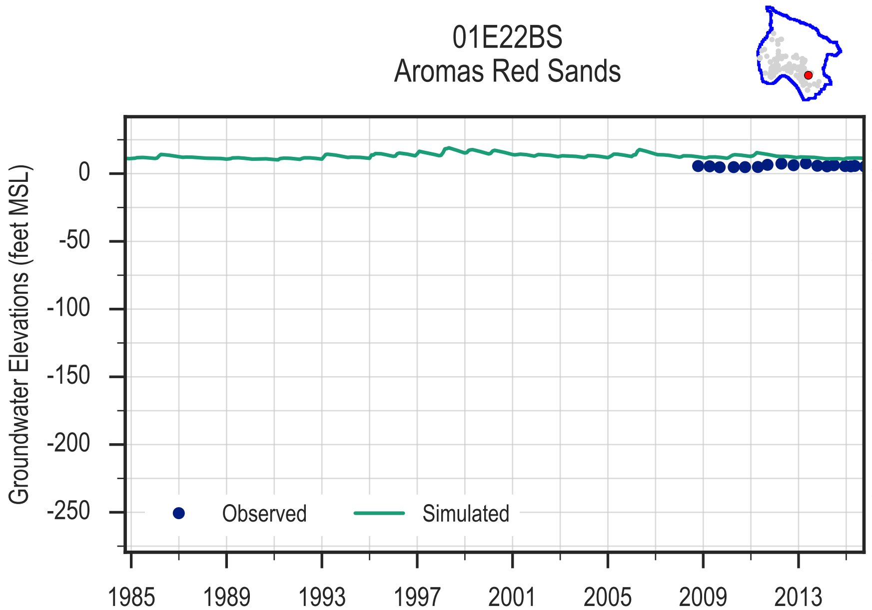
SC-A4B
Aromas Red Sands
Groundwater Elevations (feet MSL)
20
15
10
5
0
-5
-10
-15
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

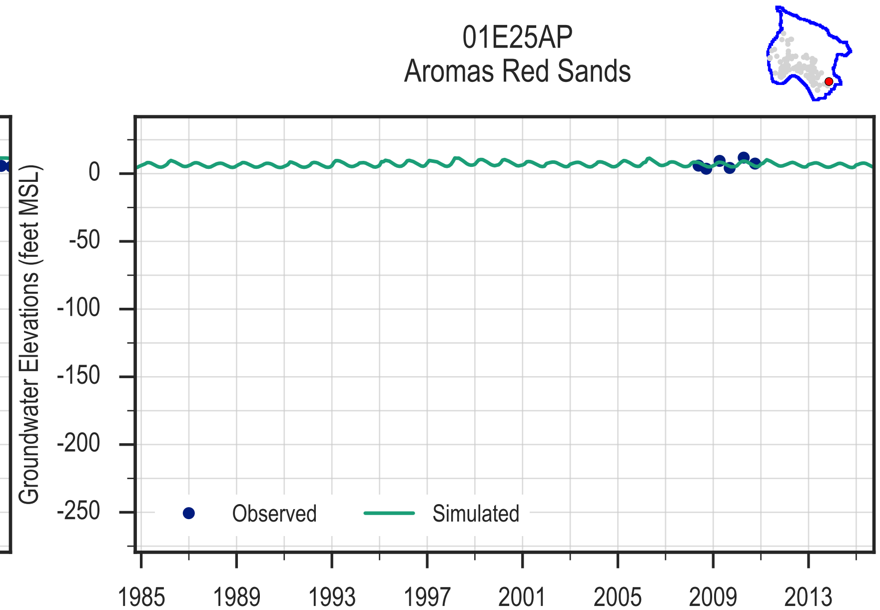


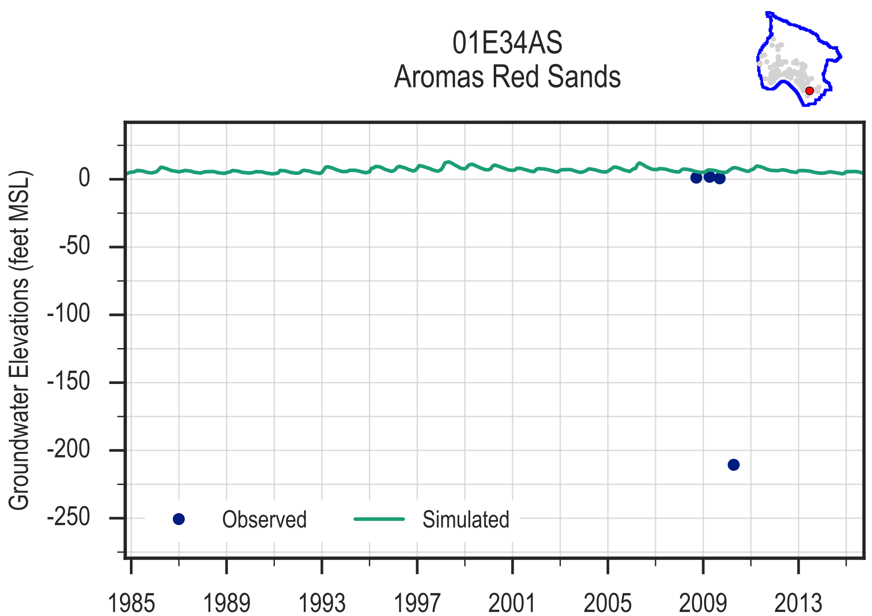
SC-A7B
Purisima F Unit
Groundwater Elevations (feet MSL)
20
15
10
5
0
-5
-10
-15
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

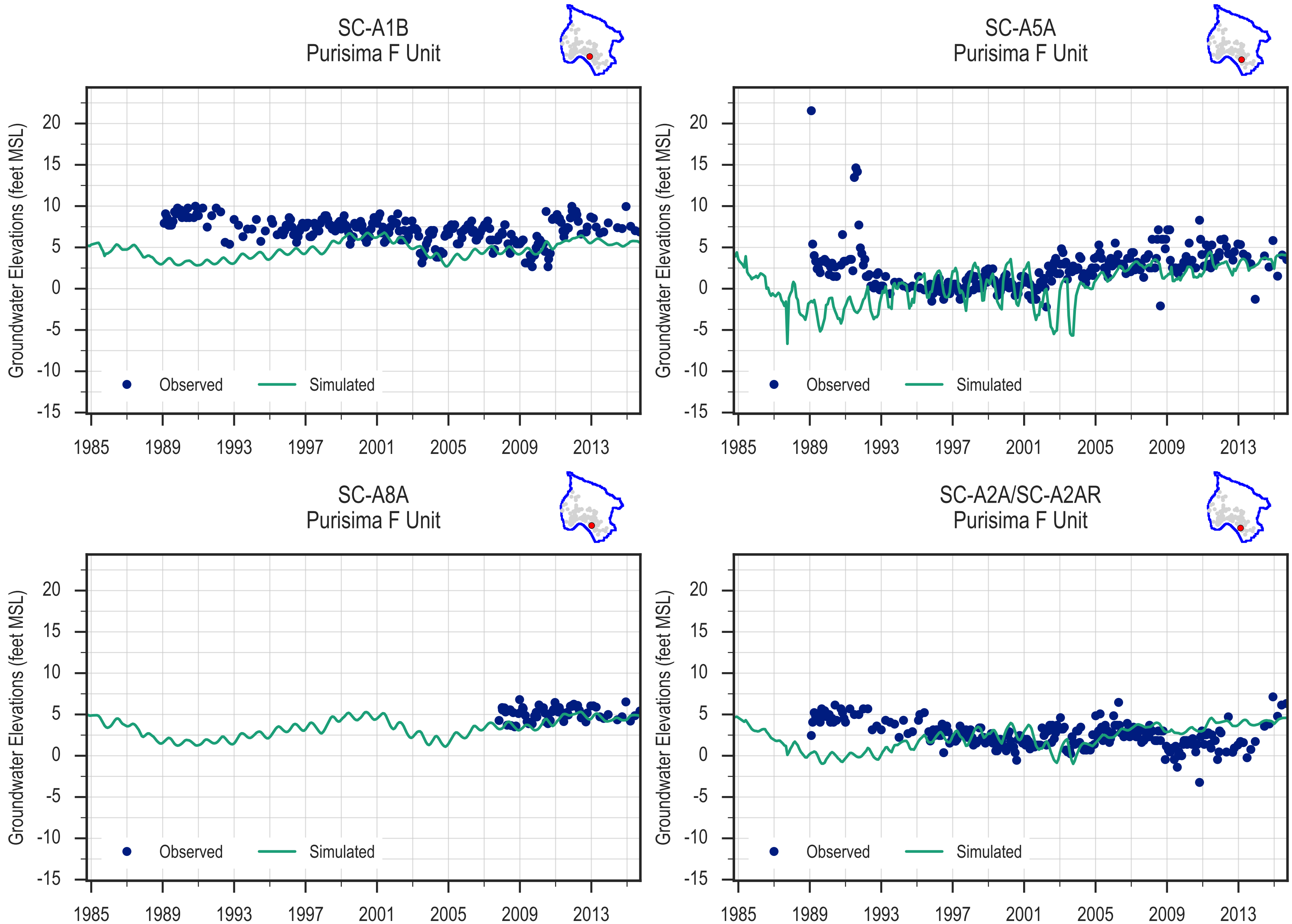


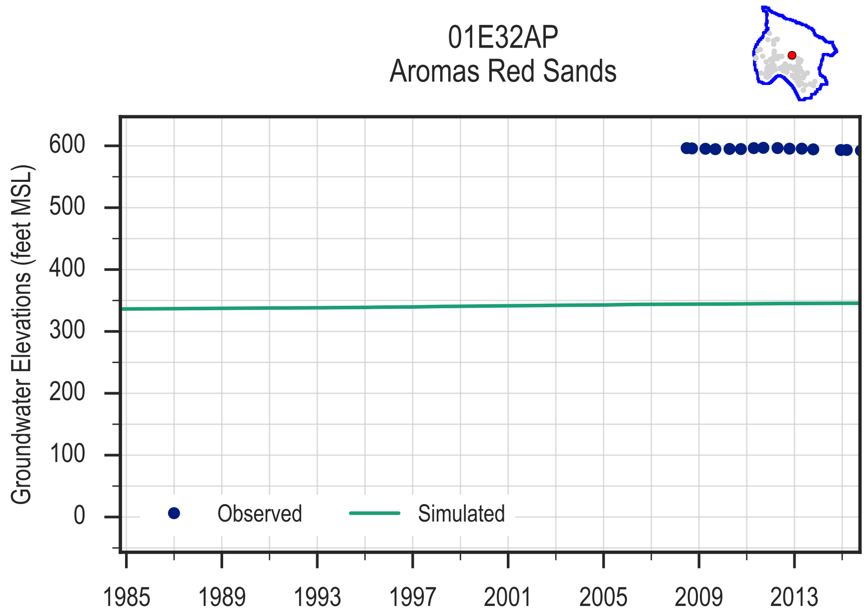
SC-A4A
Purisima F Unit
Groundwater Elevations (feet MSL)
20
15
10
5
0
-5
-10
-15
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

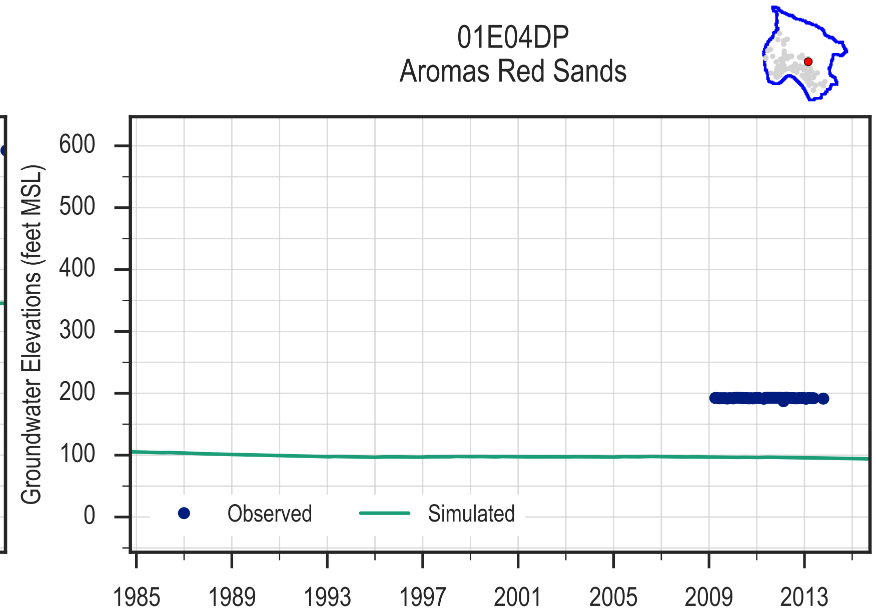

01E22BS
Aromas Red Sands
Groundwater Elevations (feet MSL)
0
-50
-100
-150
-200
-250
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

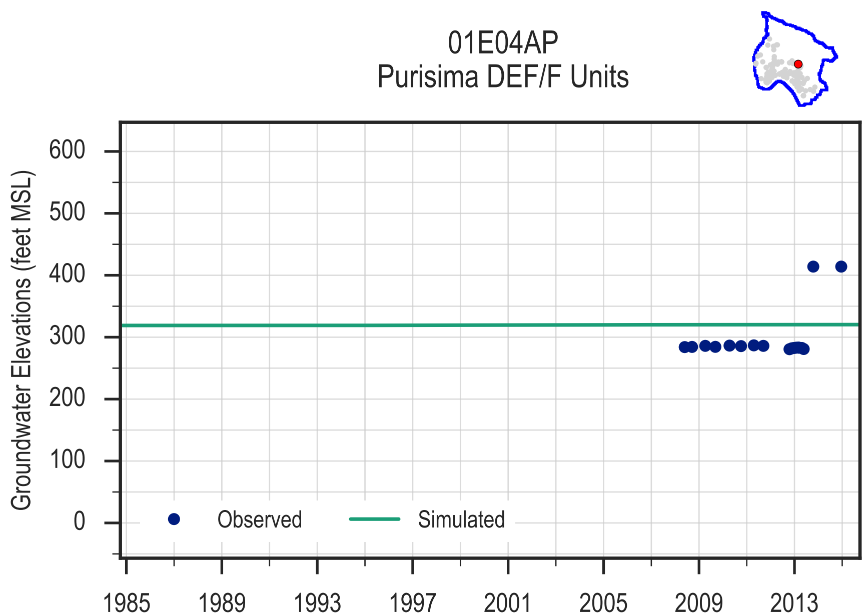

01E25AP
Aromas Red Sands
Groundwater Elevations (feet MSL)
0
-50
-100
-150
-200
-250
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

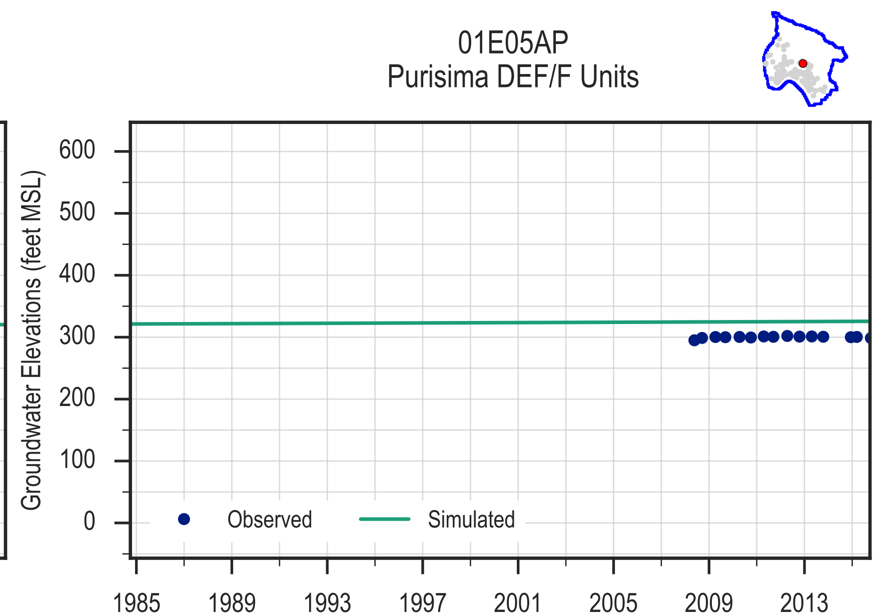

01E34AS
Aromas Red Sands
Groundwater Elevations (feet MSL)
0
-50
-100
-150
-200
-250
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

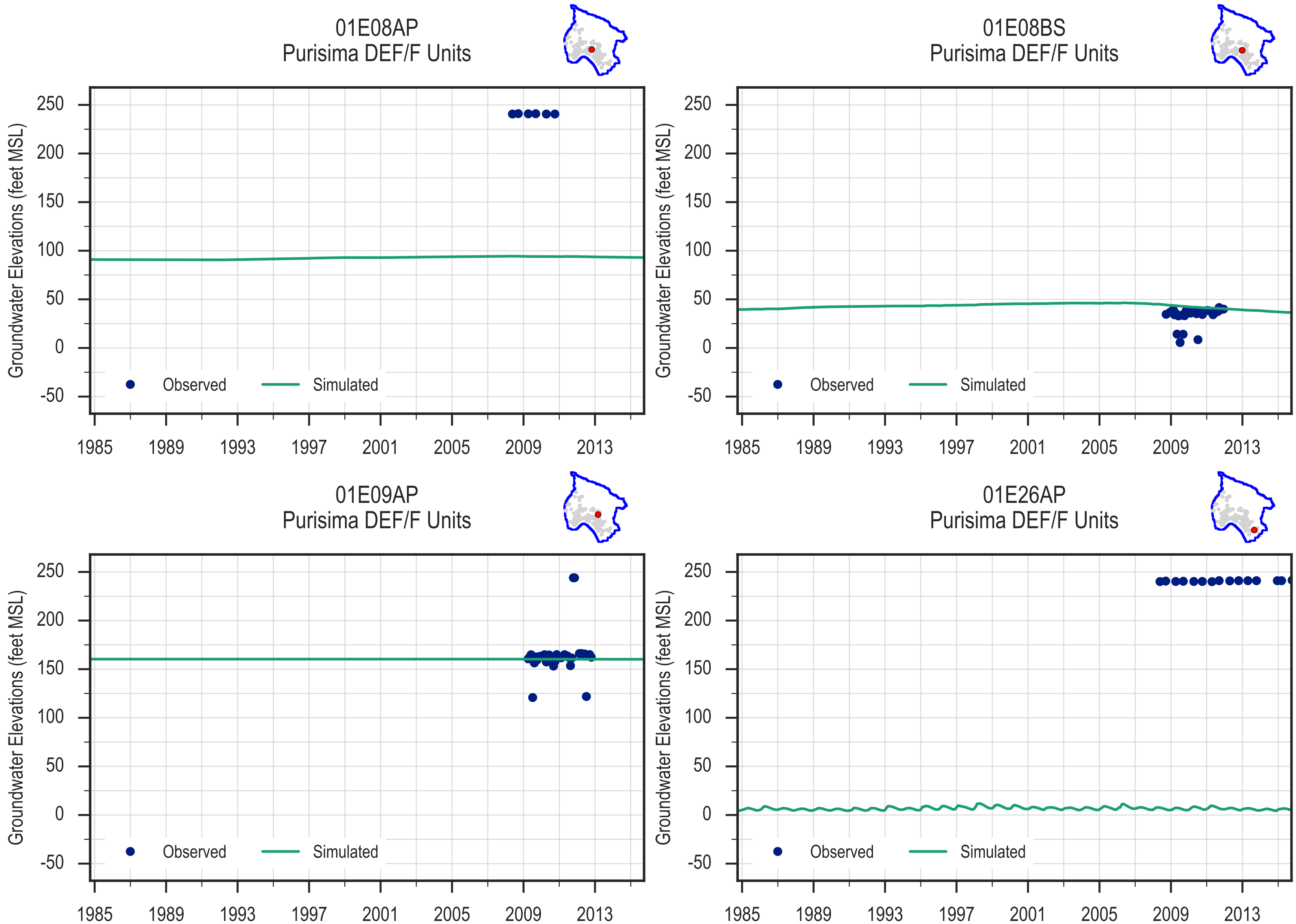

SC-A1B
Purisima F Unit
SC-A5A
Purisima F Unit
SC-A8A
Purisima F Unit
SC-A2A/SC-A2AR
Purisima F Unit
Groundwater Elevations (feet MSL)
20
15
10
5
0
-5
-10
-15
1985
1989
1993
1997
2001
2005
2009
2013
Observed
Simulated

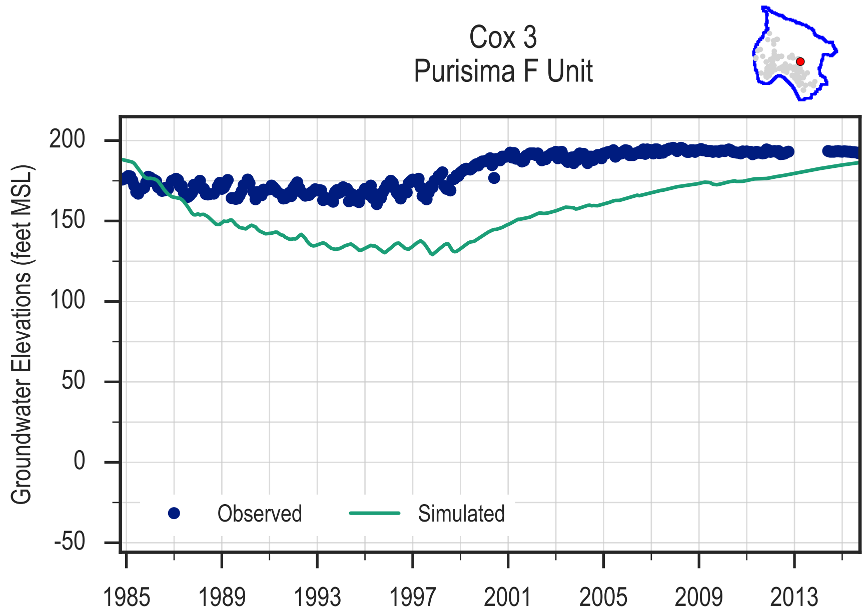

01E32AP
Aromas Red Sands
Groundwater Elevations (feet MSL)
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

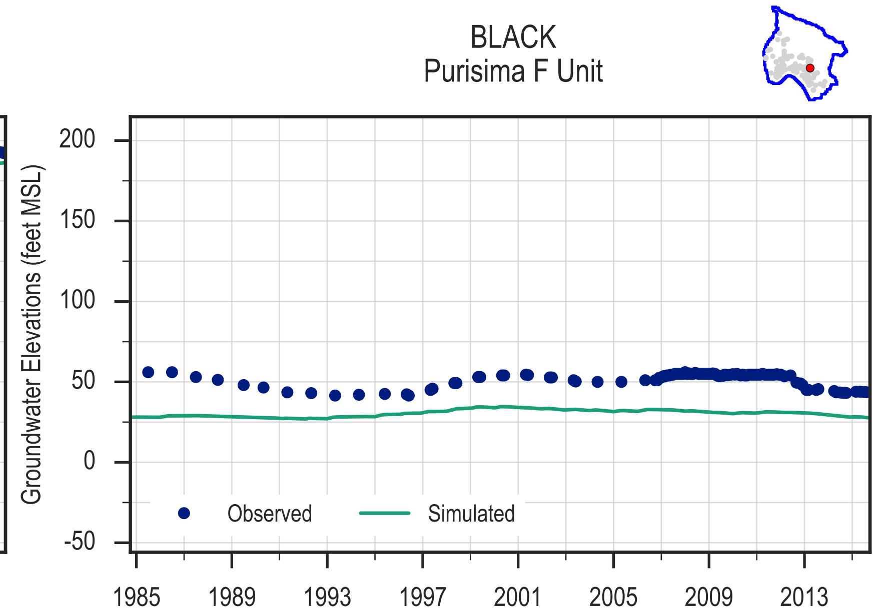

01E04DP
Aromas Red Sands
Groundwater Elevations (feet MSL)
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

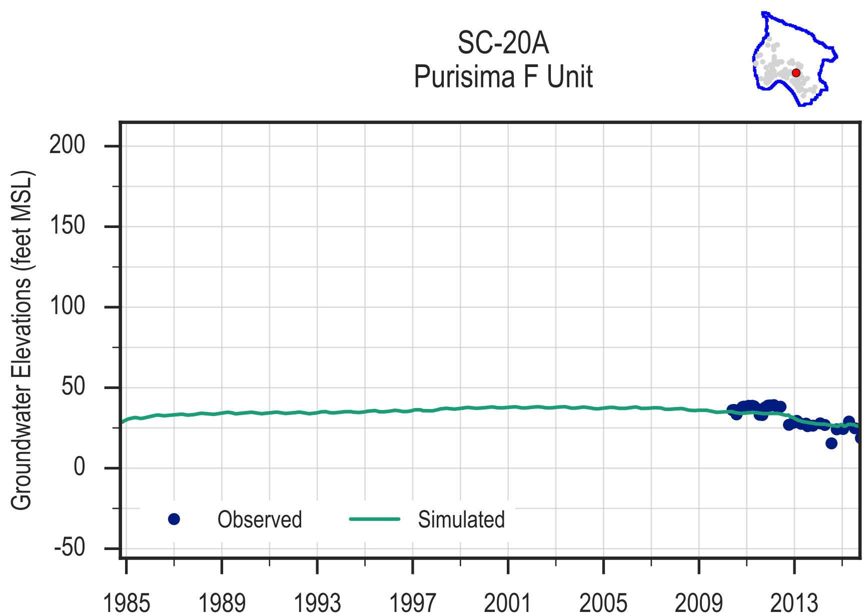

01E04AP
Purisima DEF/F Units
Groundwater Elevations (feet MSL)
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

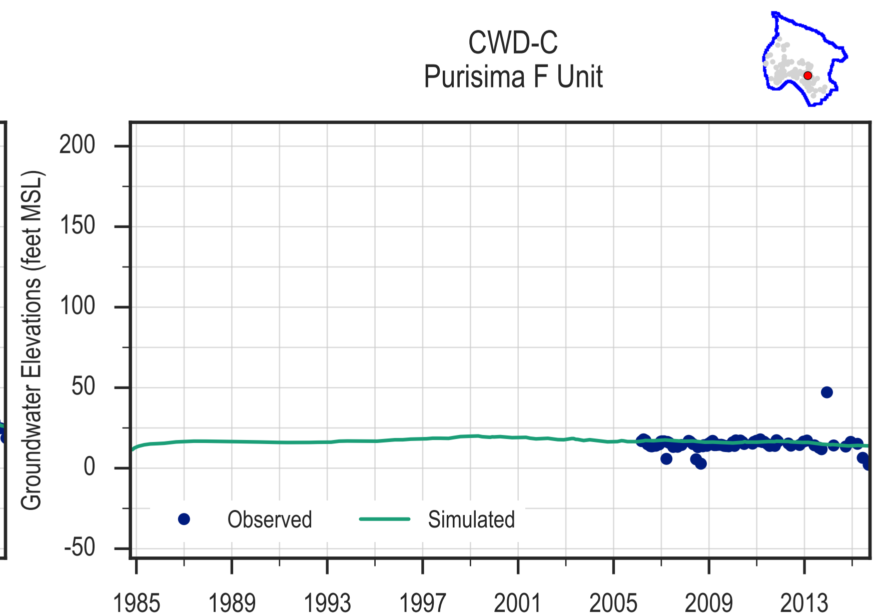

01E05AP
Purisima DEF/F Units
Groundwater Elevations (feet MSL)
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

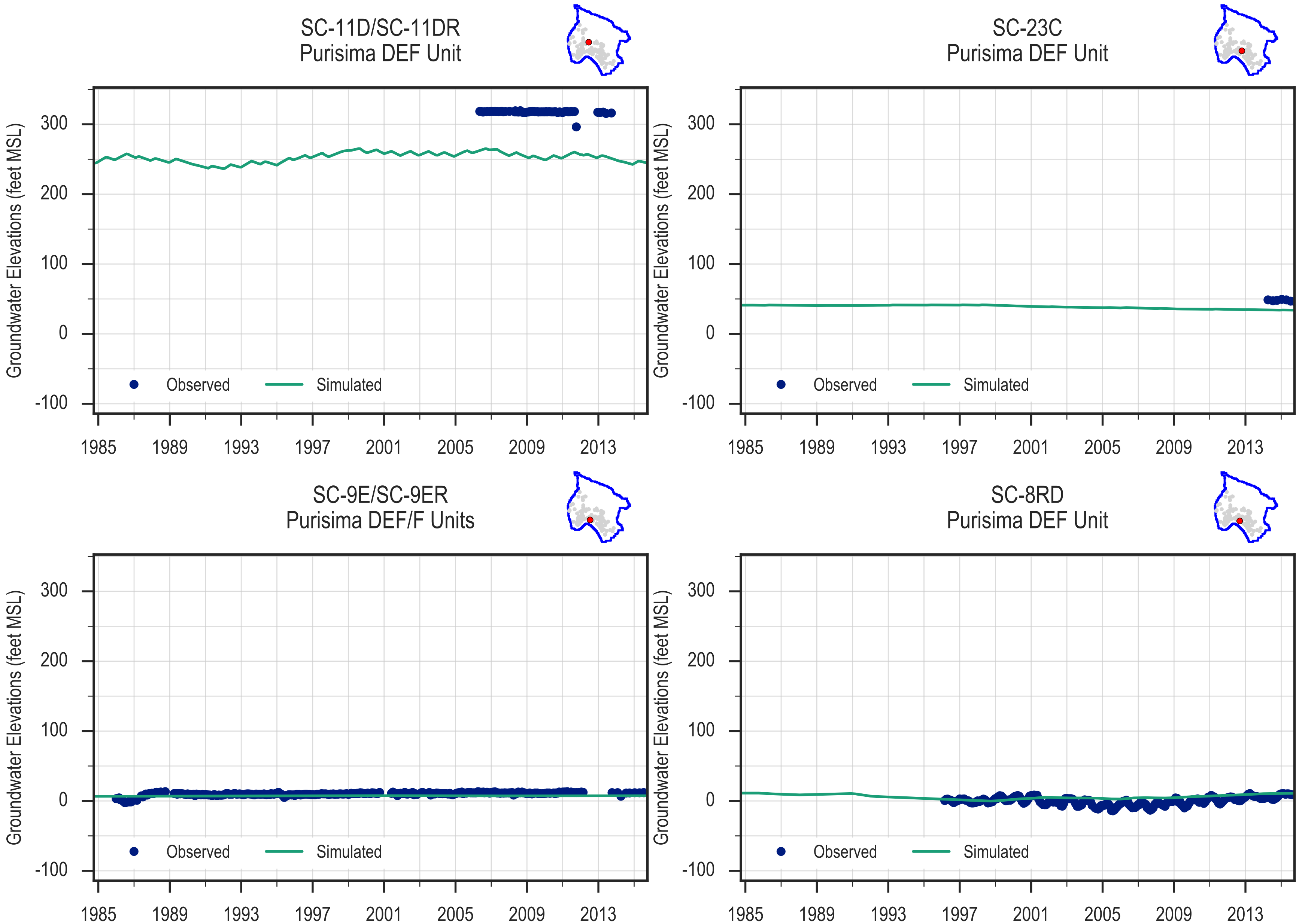

01E08AP
Purisima DEF/F Units
01E08BS
Purisima DEF/F Units
01E09AP
Purisima DEF/F Units
01E26AP
Purisima DEF/F Units
Groundwater Elevations (feet MSL)
250
200
150
100
50
0
-50
1985
1989
1993
1997
2001
2005
2009
2013
Observed
Simulated

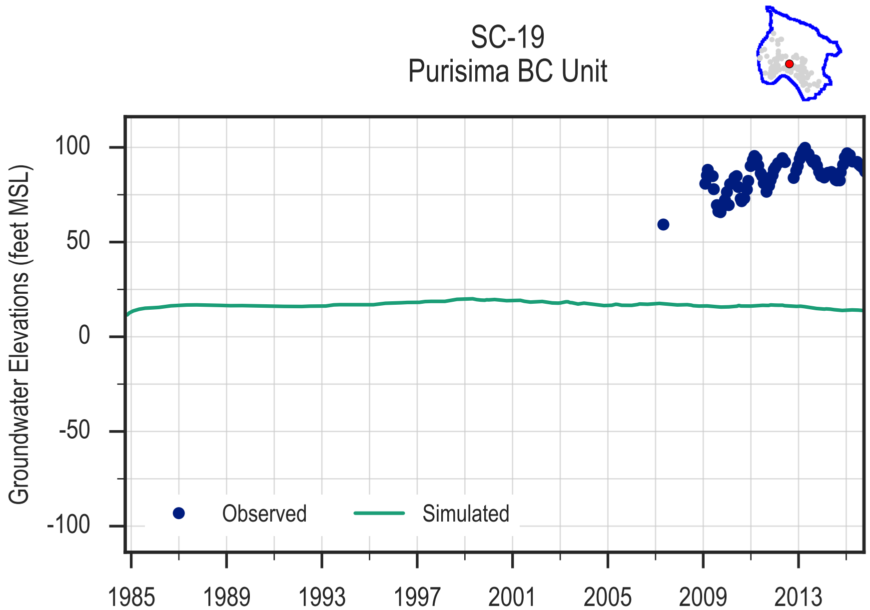

Cox 3
Purisima F Unit
Groundwater Elevations (feet MSL)
200
150
100
50
0
-50
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

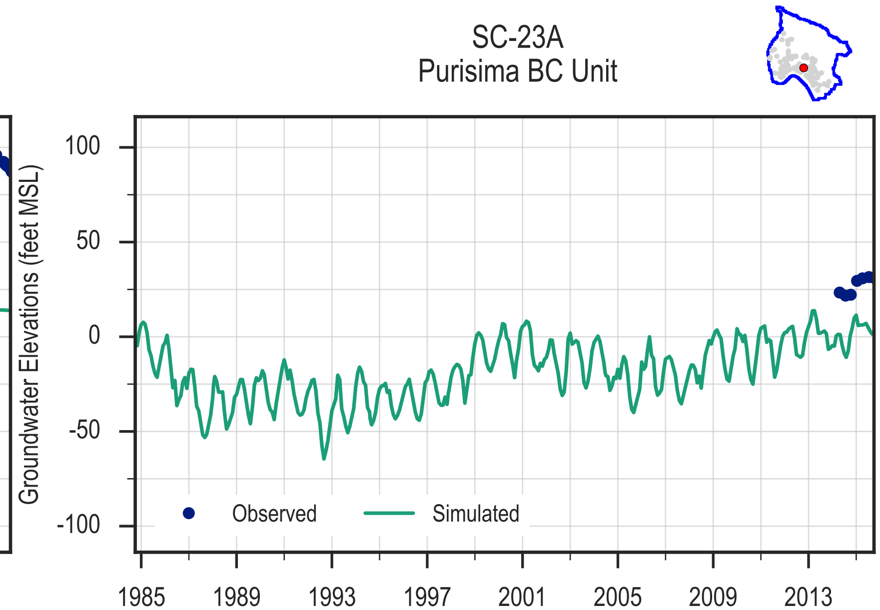

BLACK
Purisima F Unit
Groundwater Elevations (feet MSL)
200
150
100
50
0
-50
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

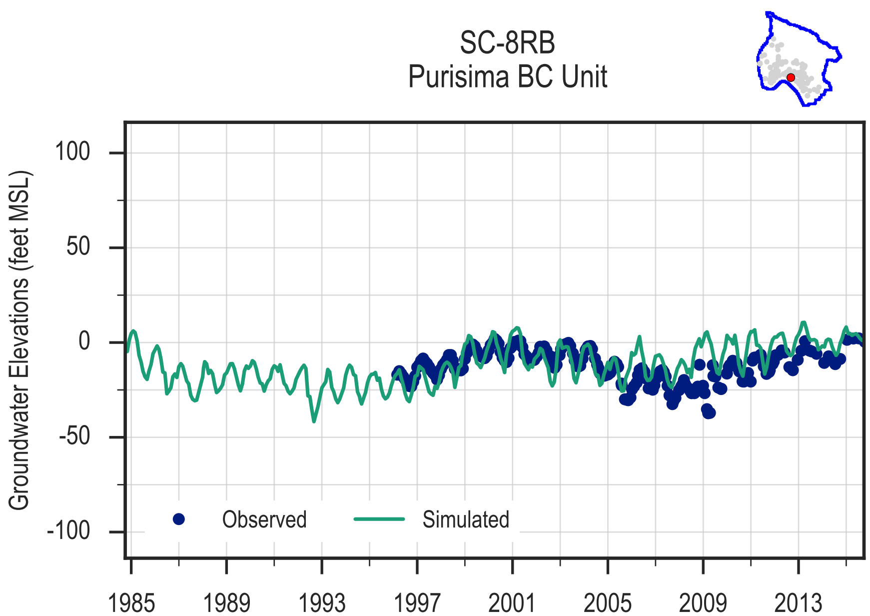

SC-20A
Purisima F Unit
Groundwater Elevations (feet MSL)
200
150
100
50
0
-50
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

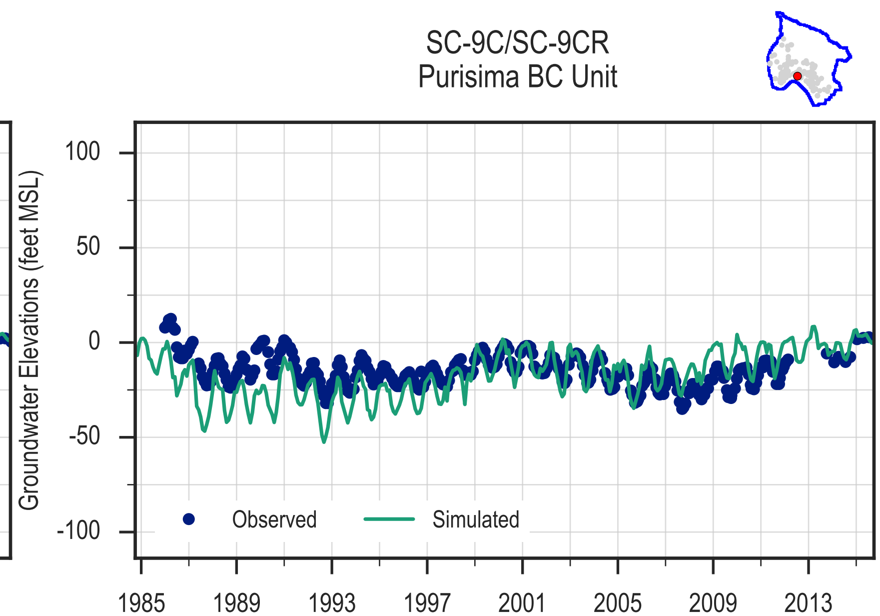

CWD-C
Purisima F Unit
Groundwater Elevations (feet MSL)
200
150
100
50
0
-50
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

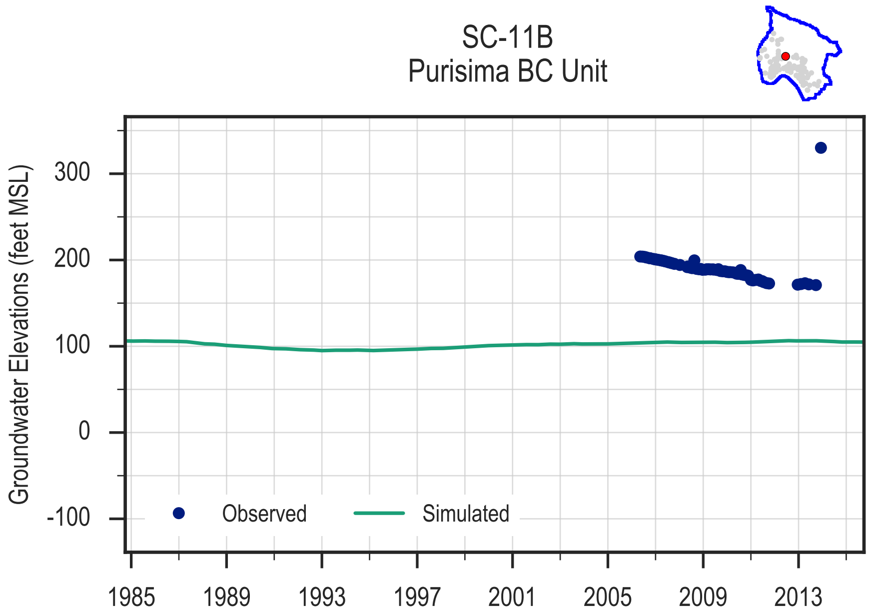

SC-11D/SC-11DR
Purisima DEF Unit
SC-23C
Purisima DEF Unit
SC-9E/SC-9ER
Purisima DEF/F Units
SC-8RD
Purisima DEF Unit
Groundwater Elevations (feet MSL)
300
200
100
0
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

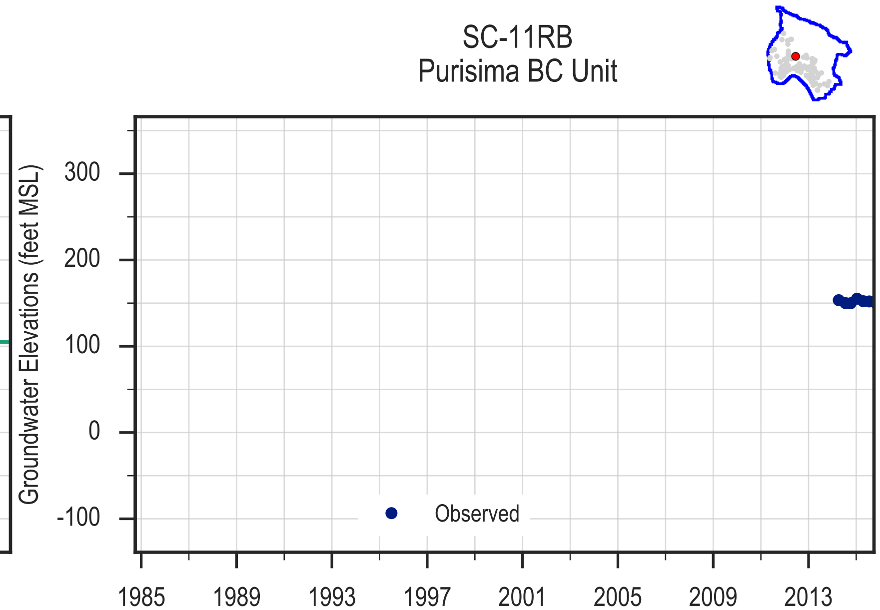

SC-19
Purisima BC Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

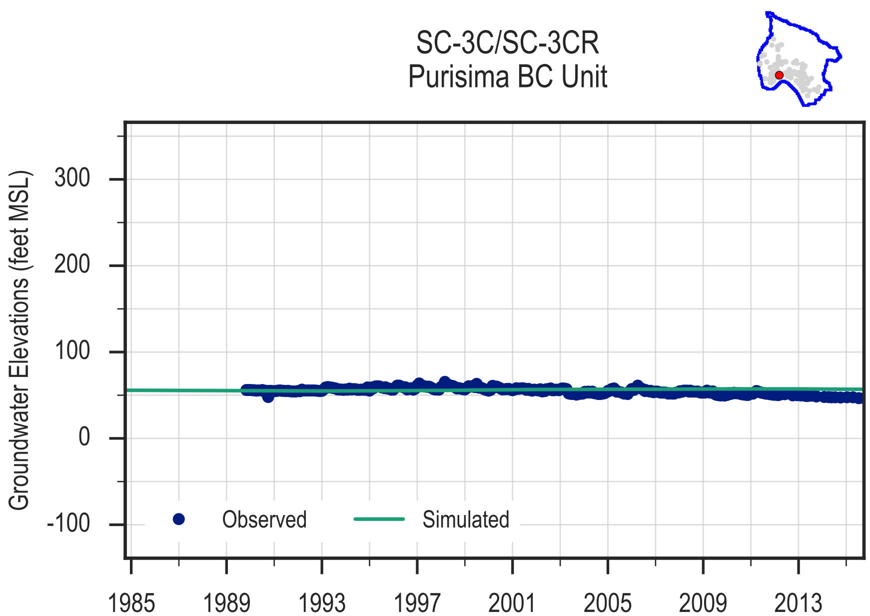

SC-23A
Purisima BC Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

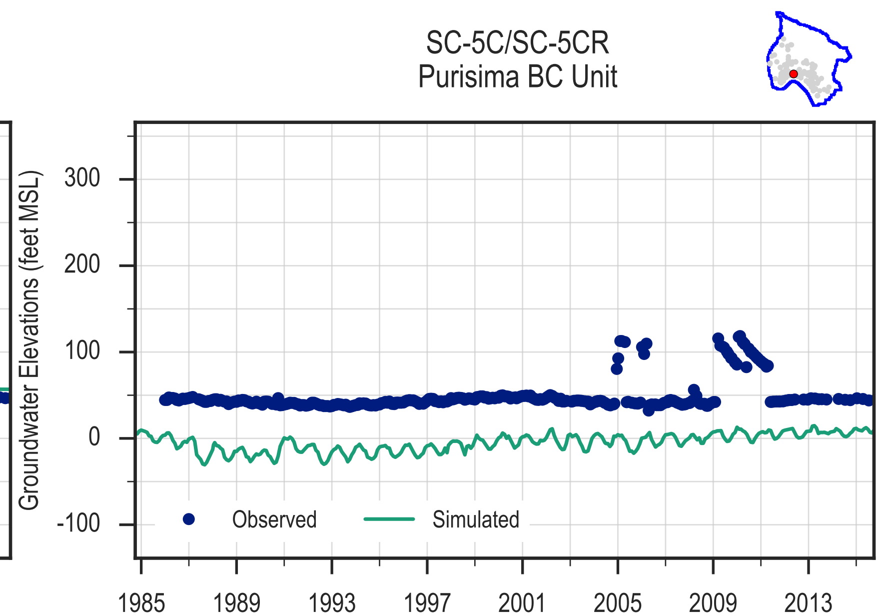

SC-8RB
Purisima BC Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

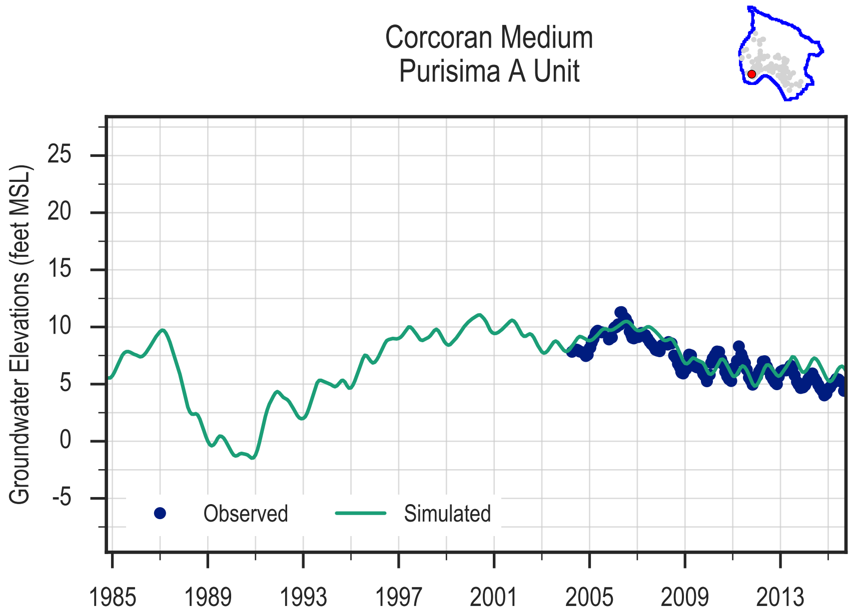

SC-9C/SC-9CR
Purisima BC Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

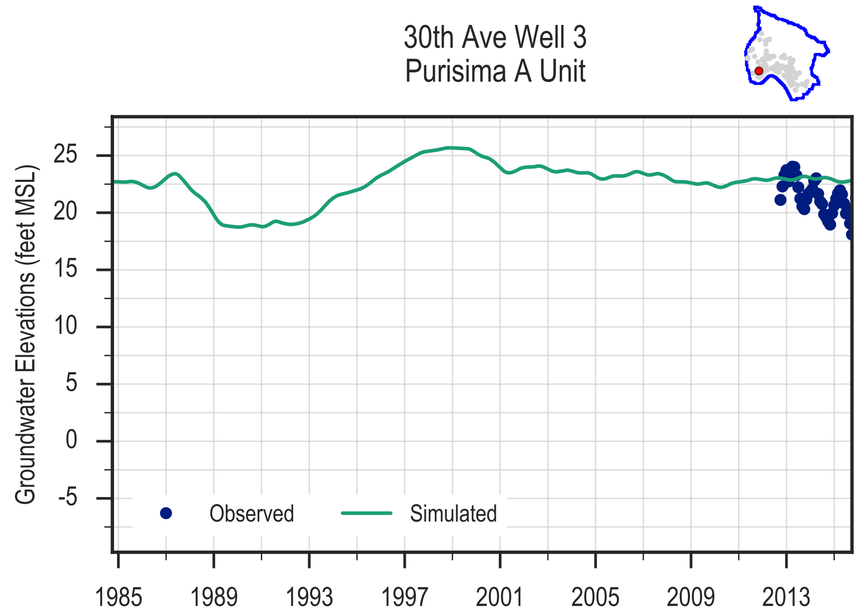

SC-11B
Purisima BC Unit
Groundwater Elevations (feet MSL)
300
200
100
0
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

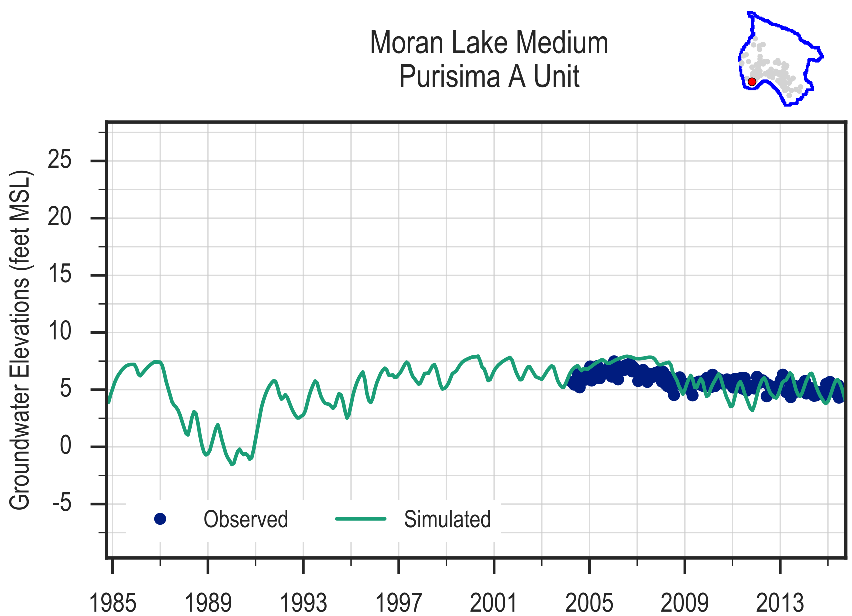

SC-11RB
Purisima BC Unit
Groundwater Elevations (feet MSL)
300
200
100
0
-100
Observed
1985
1989
1993
1997
2001
2005
2009
2013

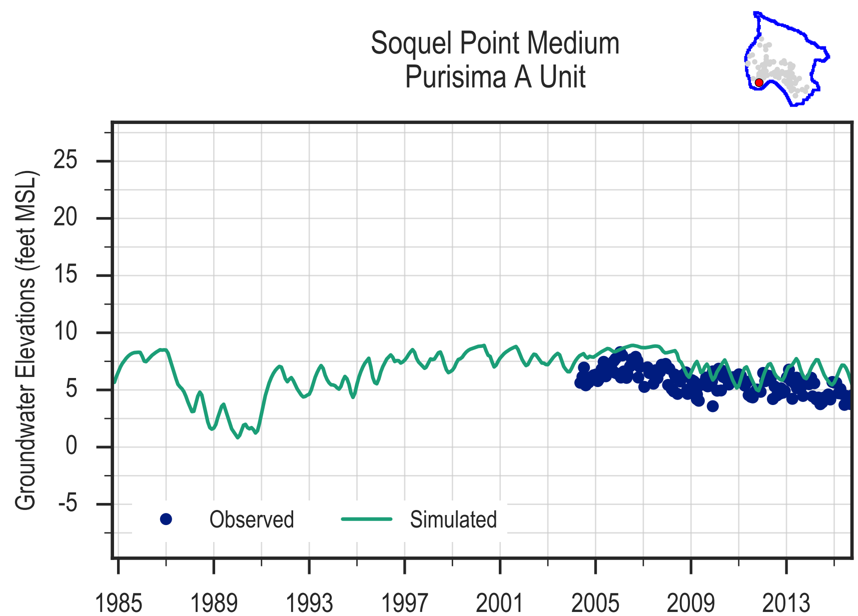

SC-3C/SC-3CR
Purisima BC Unit
Groundwater Elevations (feet MSL)
300
200
100
0
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


SC-5C/SC-5CR
Purisima BC Unit
Groundwater Elevations (feet MSL)
300
200
100
0
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

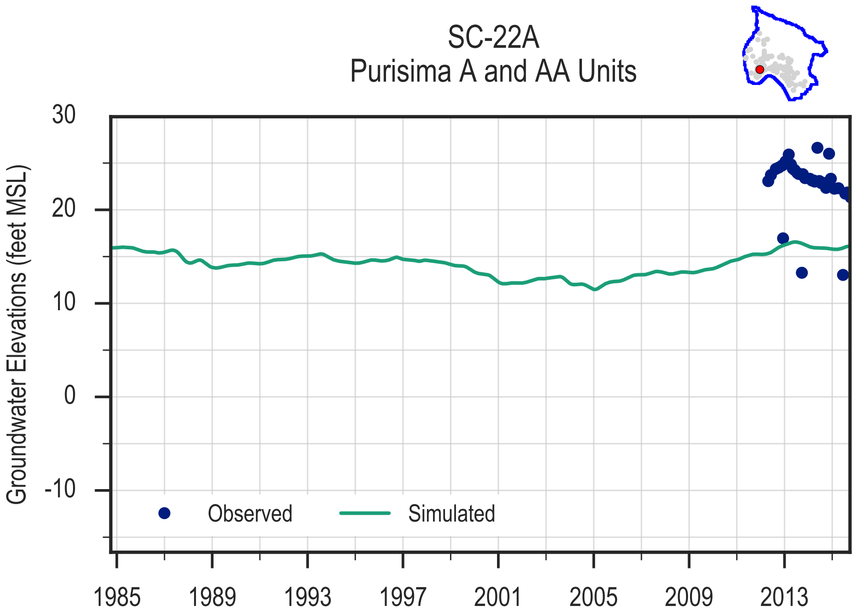

Corcoran Medium
Purisima A Unit
Groundwater Elevations (feet MSL)
25
20
15
10
5
0
-5
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


30th Ave Well 3
Purisima A Unit
Groundwater Elevations (feet MSL)
25
20
15
10
5
0
-5
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

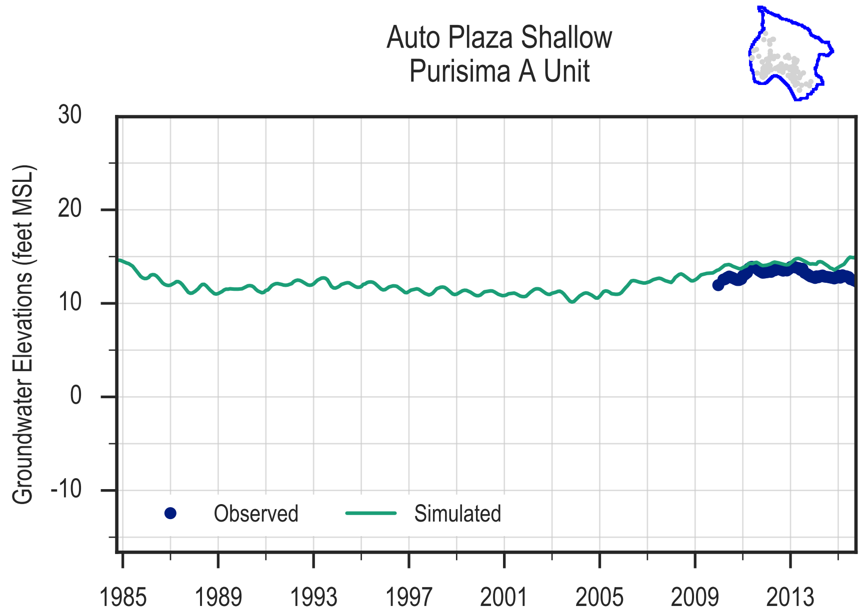

Moran Lake Medium
Purisima A Unit
Groundwater Elevations (feet MSL)
25
20
15
10
5
0
-5
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


Soquel Point Medium
Purisima A Unit
Groundwater Elevations (feet MSL)
25
20
15
10
5
0
-5
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

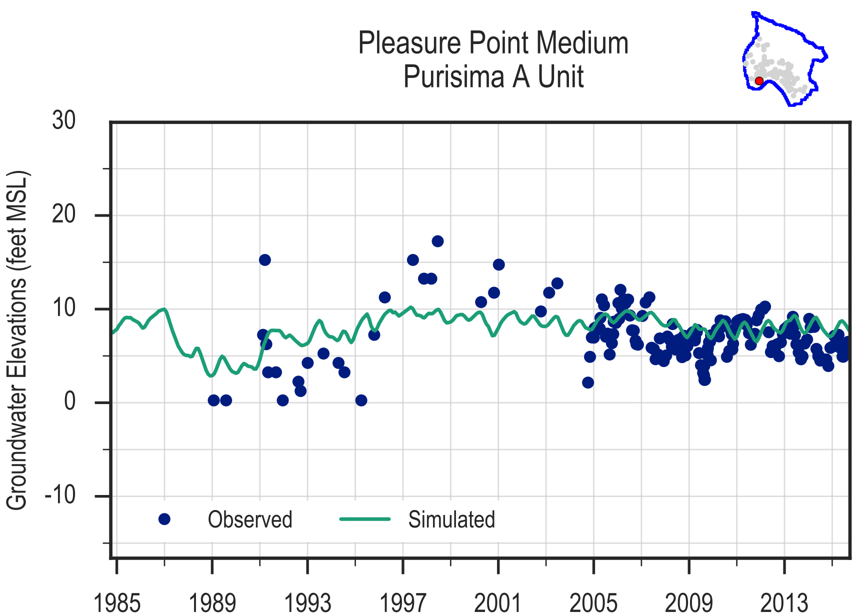
SC-22A
Purisima A and AA Units



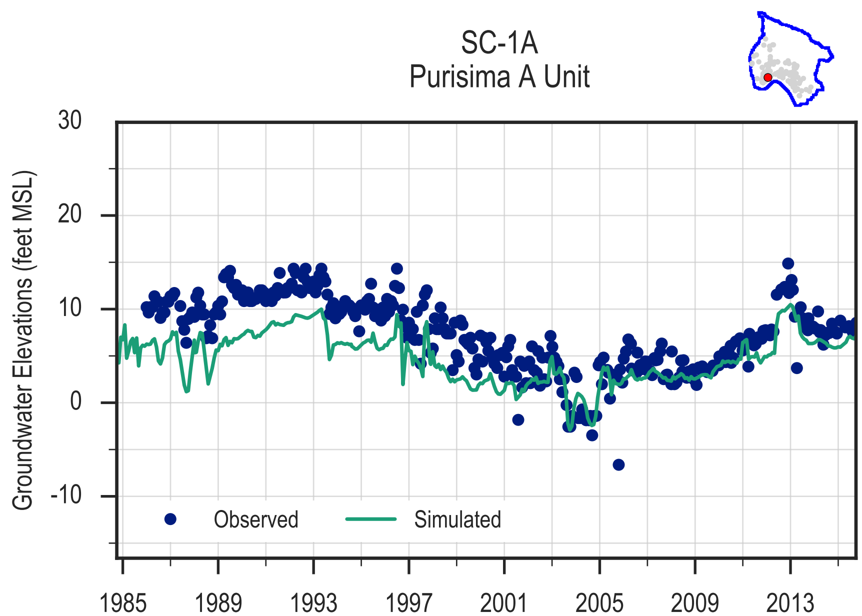
Auto Plaza Shallow
Purisima A Unit



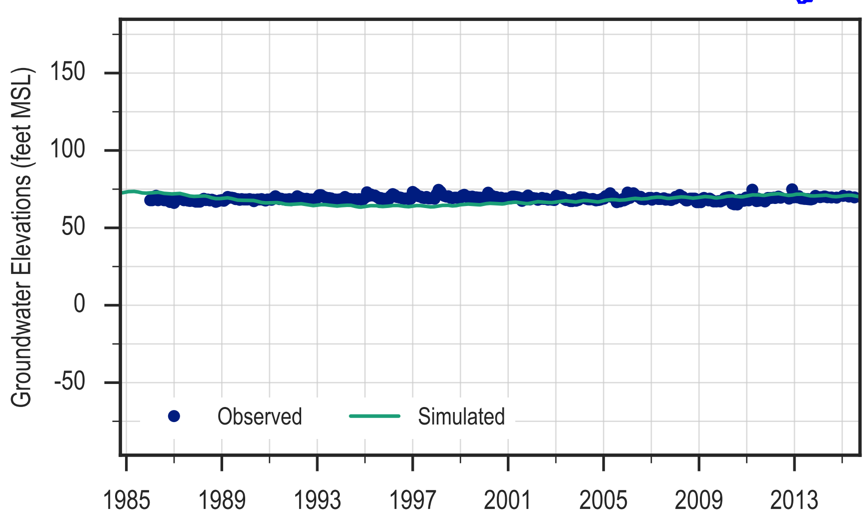
Pleasure Point Medium
Purisima A Unit



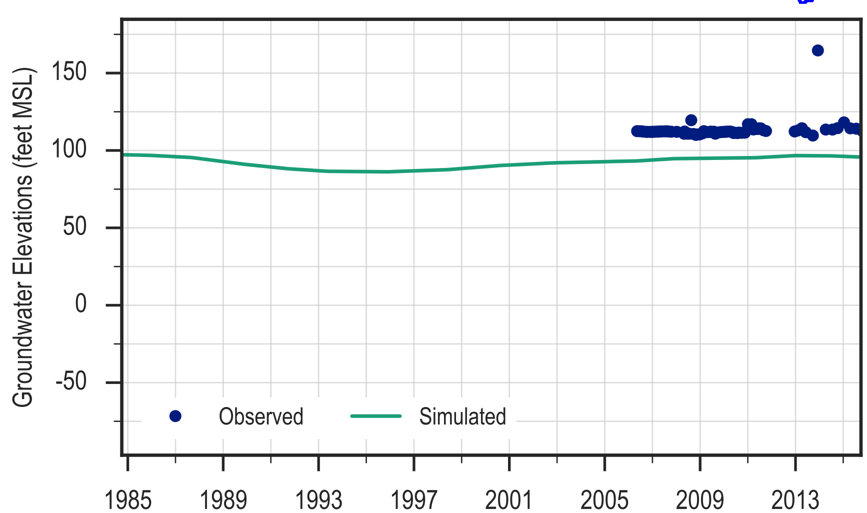
SC-1A
Purisima A Unit



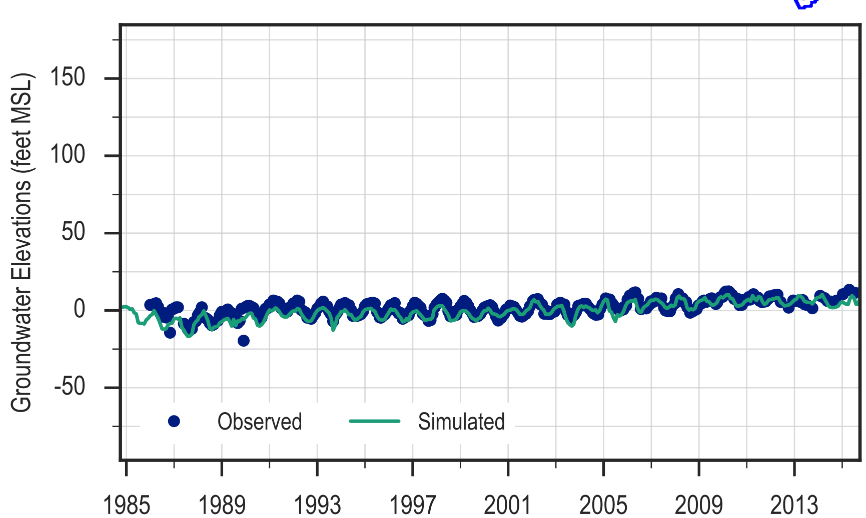
SC-10A/SC-10AR
Purisima A Unit



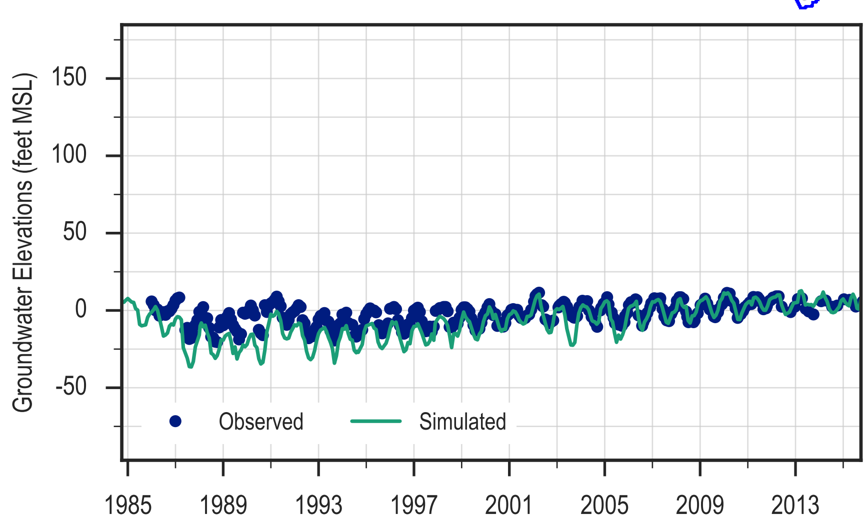
SC-11A/SC-11AR
Purisima A Unit

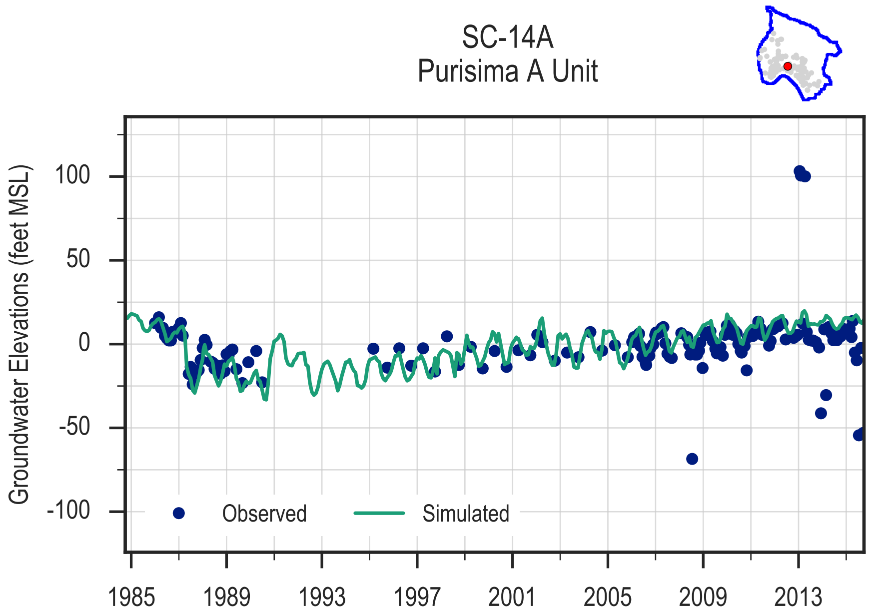


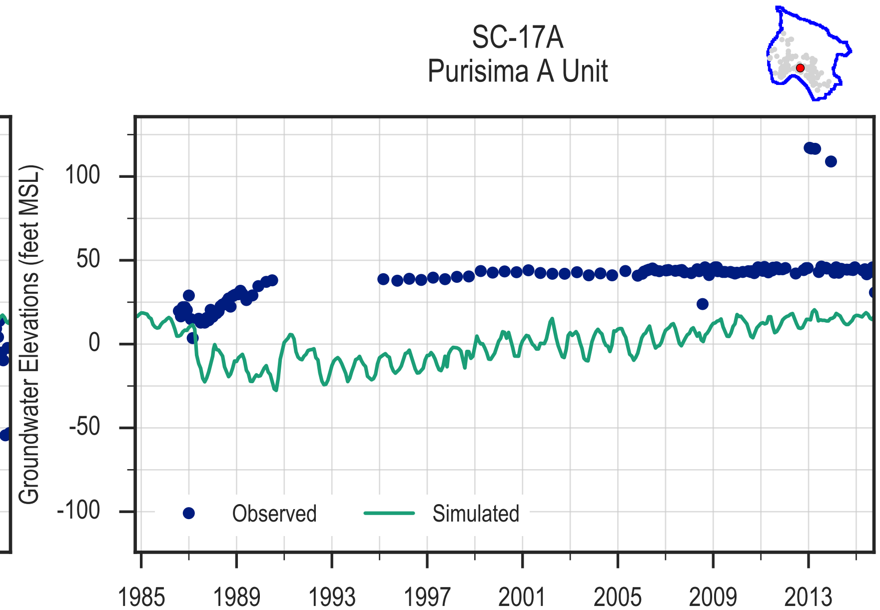
SC-3A/SC-3AR
Purisima A Unit

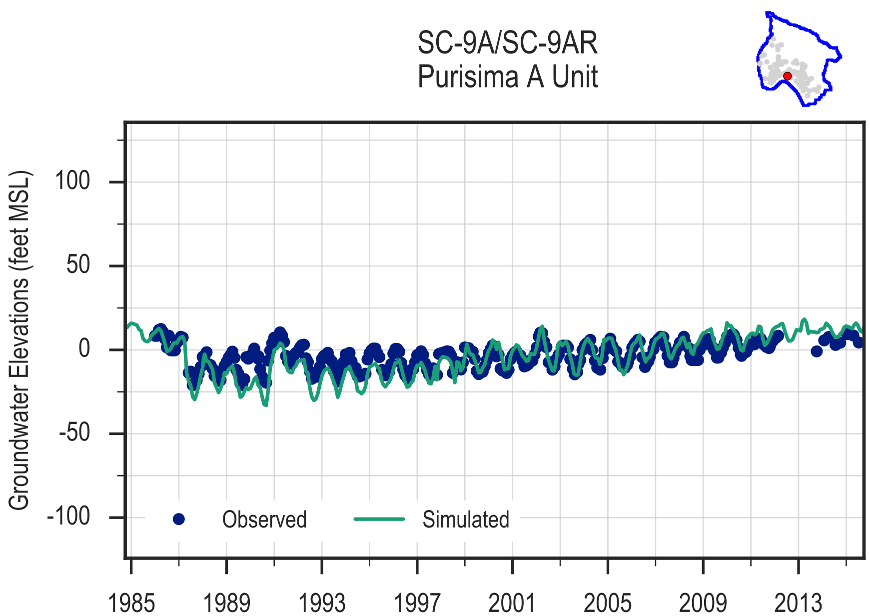


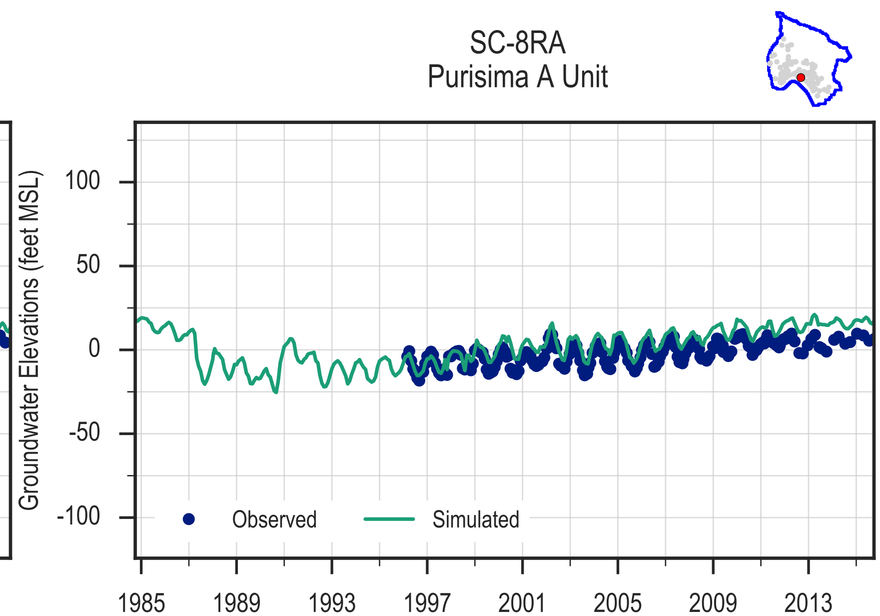
SC-5A/SC-5AR
Purisima A Unit

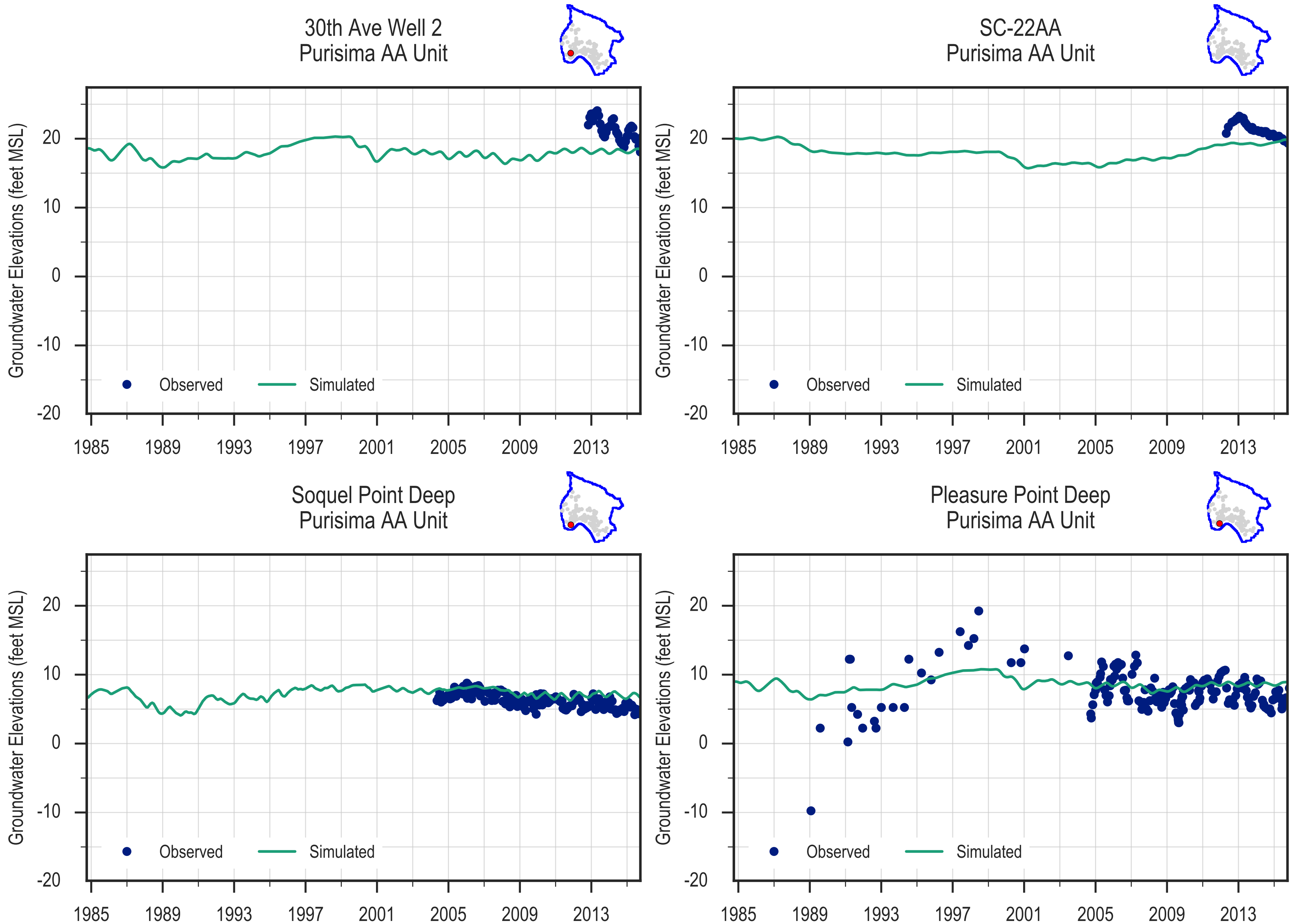


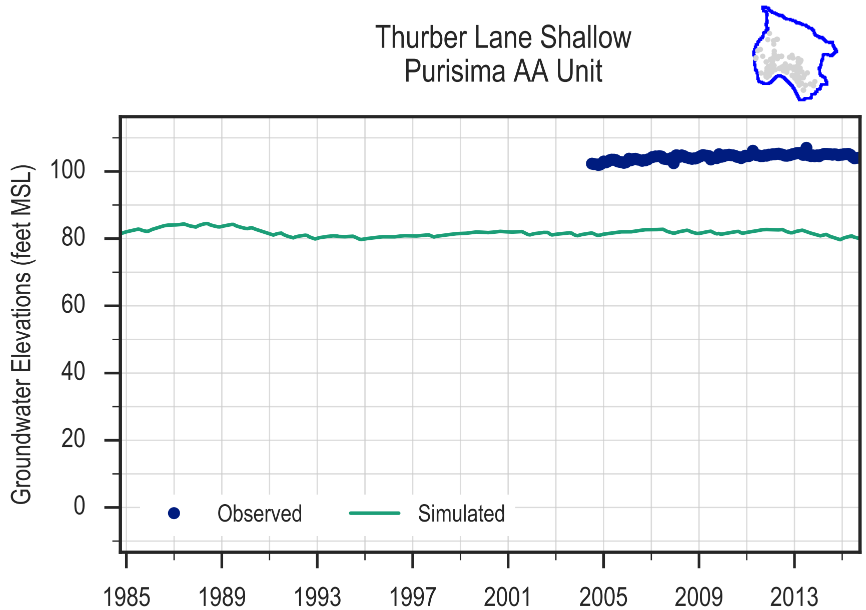

SC-14A
Purisima A Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

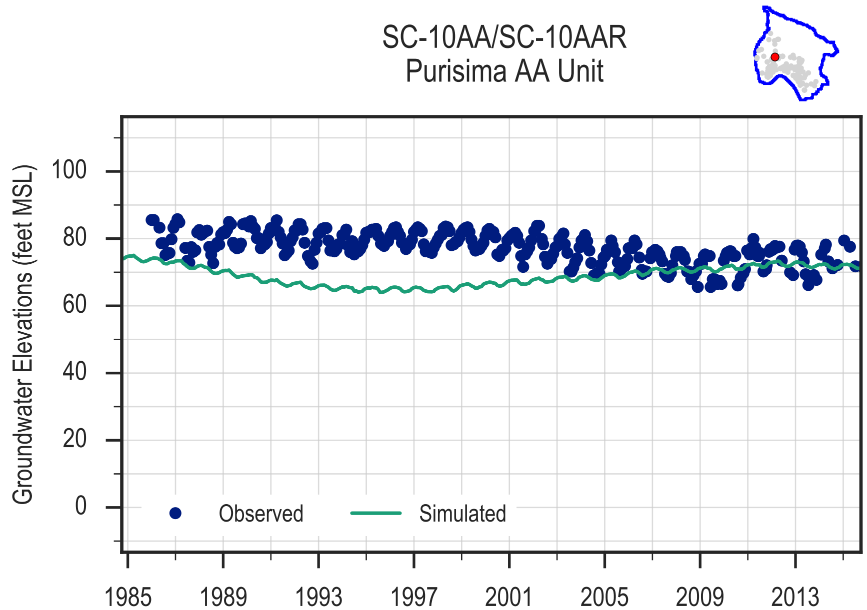

SC-17A
Purisima A Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

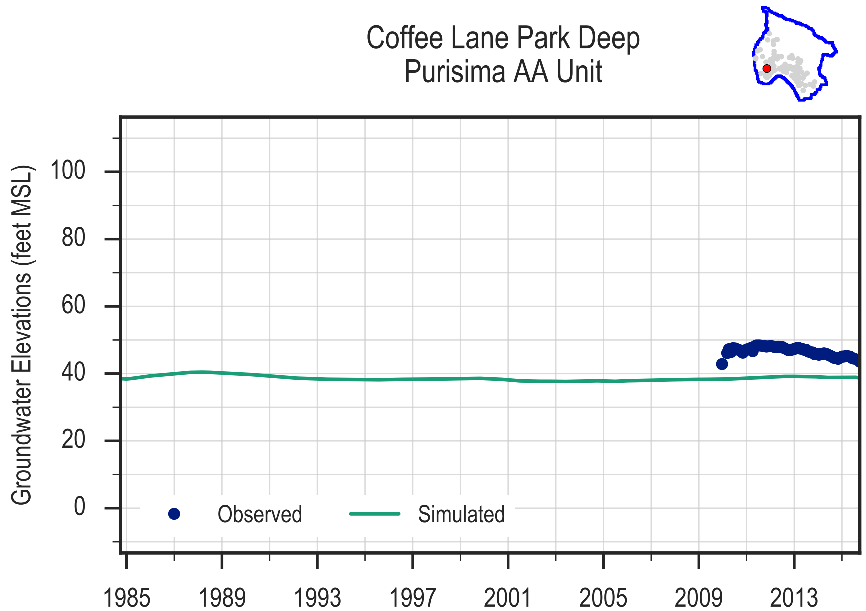

SC-9A/SC-9AR
Purisima A Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

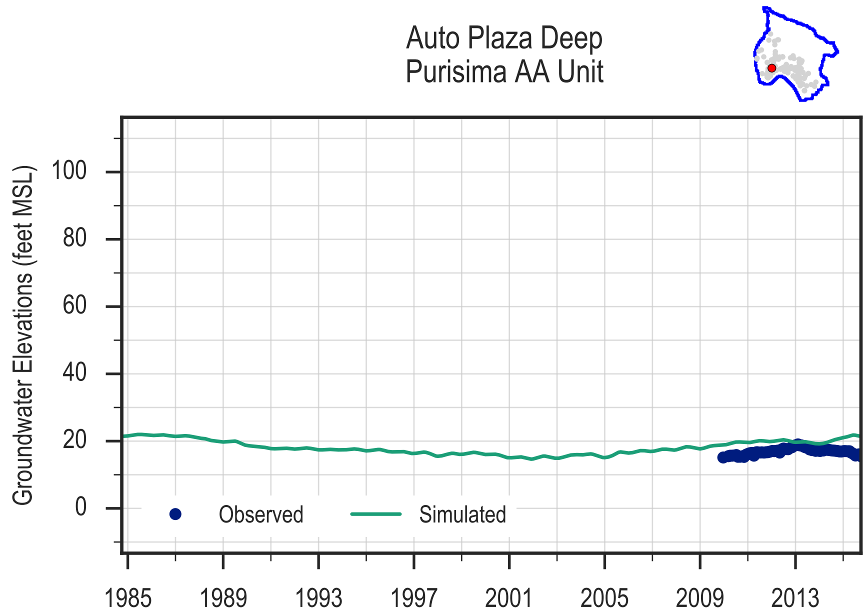

SC-8RA
Purisima A Unit
Groundwater Elevations (feet MSL)
100
50
0
-50
-100
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

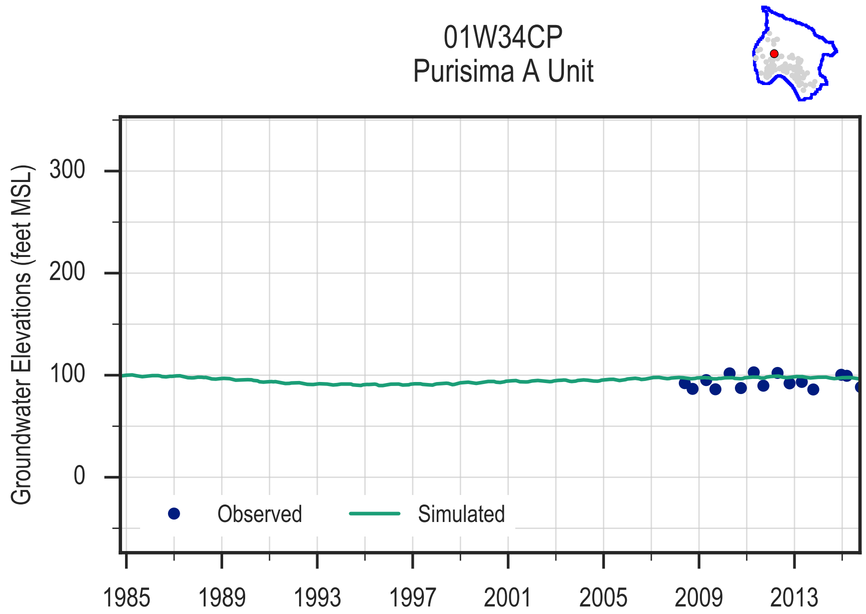

30th Ave Well 2
Purisima AA Unit
SC-22AA
Purisima AA Unit
Soquel Point Deep
Purisima AA Unit
Pleasure Point Deep
Purisima AA Unit
Groundwater Elevations (feet MSL)
20
10
0
-10
-20
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


Thurber Lane Shallow
Purisima AA Unit
Groundwater Elevations (feet MSL)
100
80
60
40
20
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

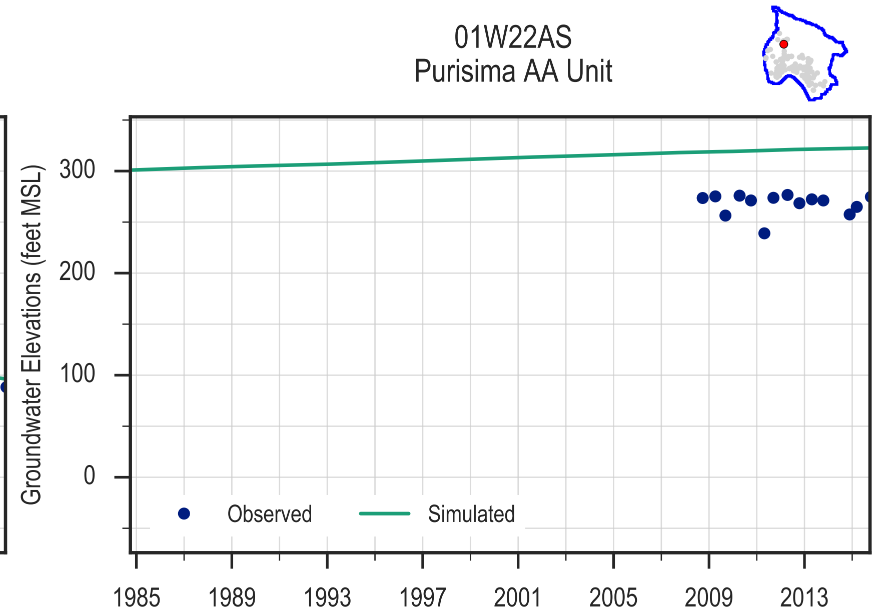

SC-10AA/SC-10AAR
Purisima AA Unit
Groundwater Elevations (feet MSL)
100
80
60
40
20
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


Coffee Lane Park Deep
Purisima AA Unit
Groundwater Elevations (feet MSL)
100
80
60
40
20
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

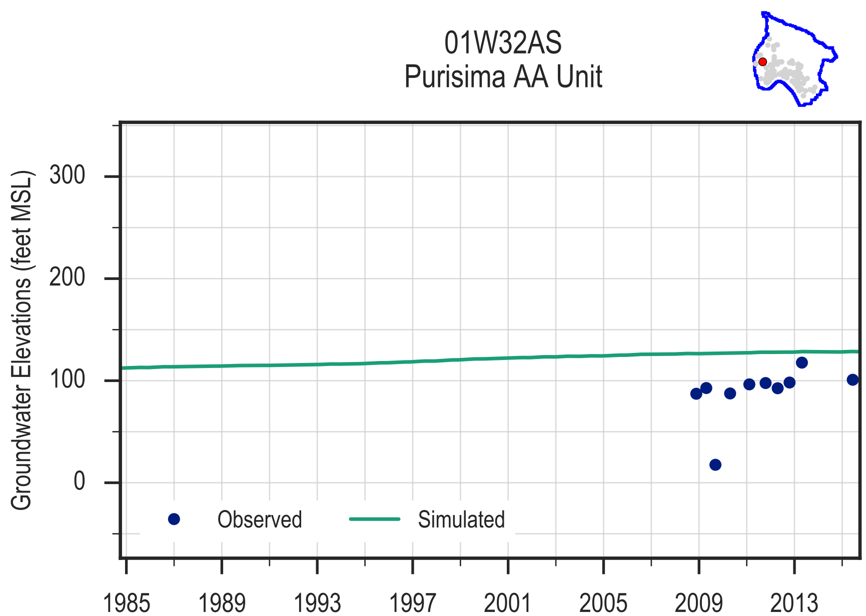

Auto Plaza Deep
Purisima AA Unit
Groundwater Elevations (feet MSL)
100
80
60
40
20
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013



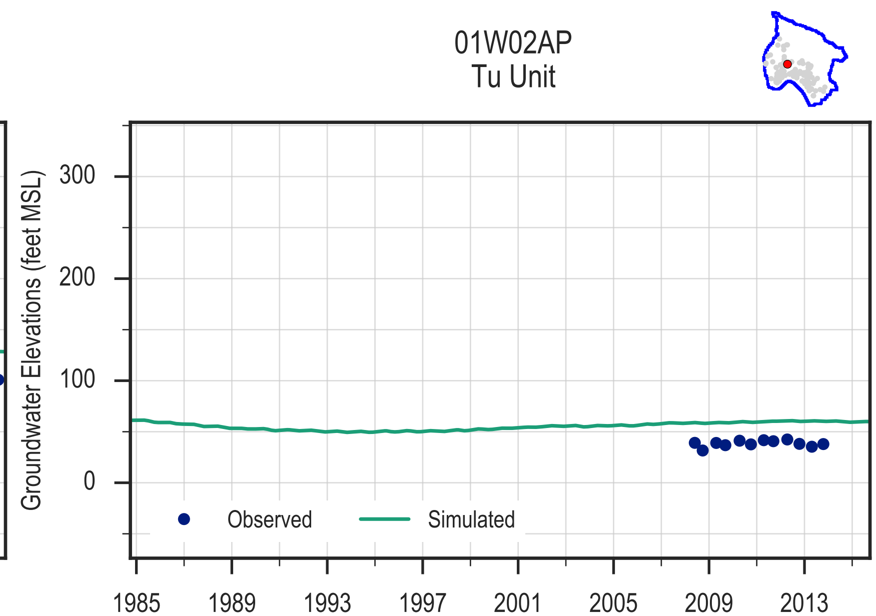
01W34CP
Purisima A Unit
Groundwater Elevations (feet MSL)
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013



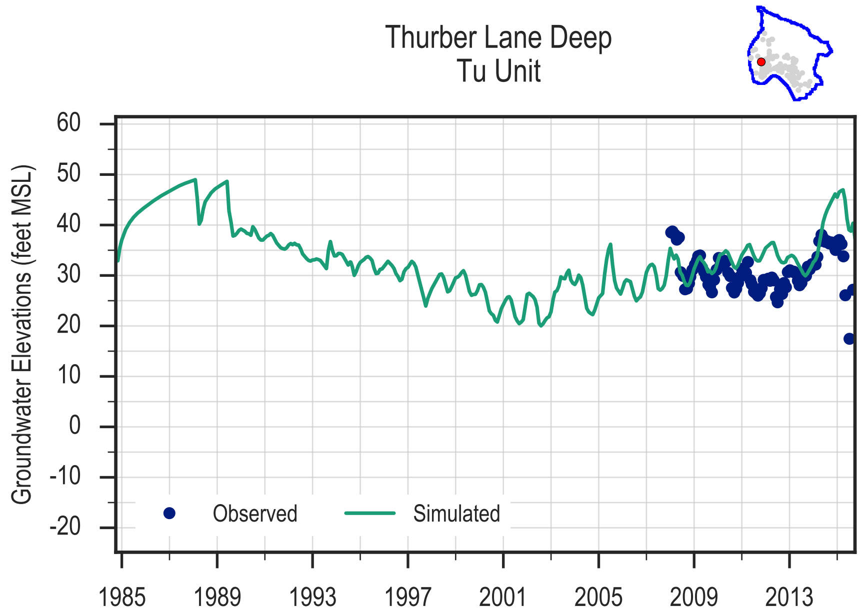
01W22AS
Purisima AA Unit
Groundwater Elevations (feet MSL)
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

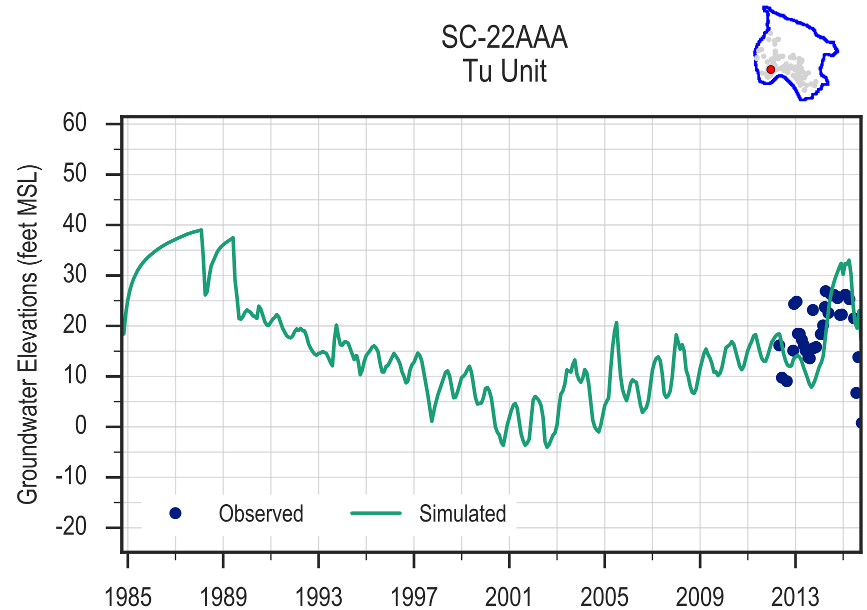


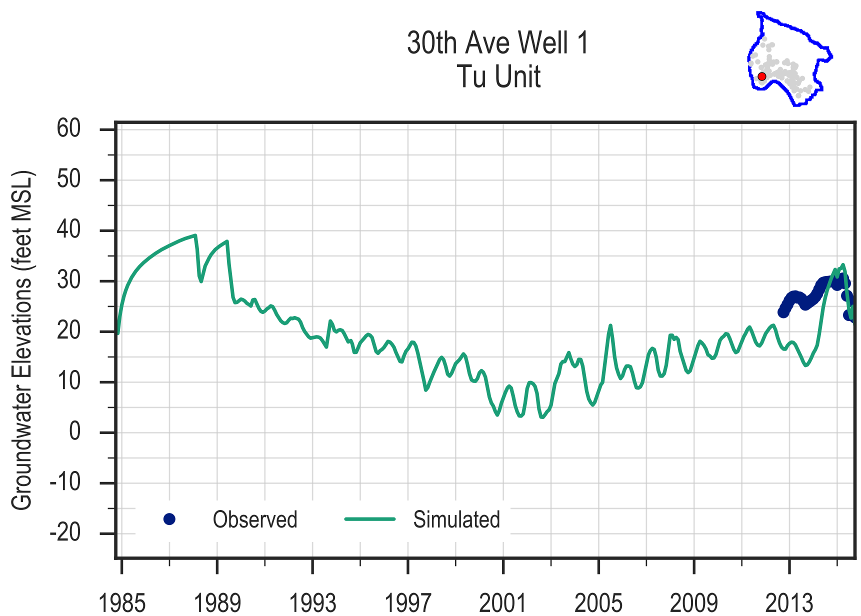
01W32AS
Purisima AA Unit
Groundwater Elevations (feet MSL)
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

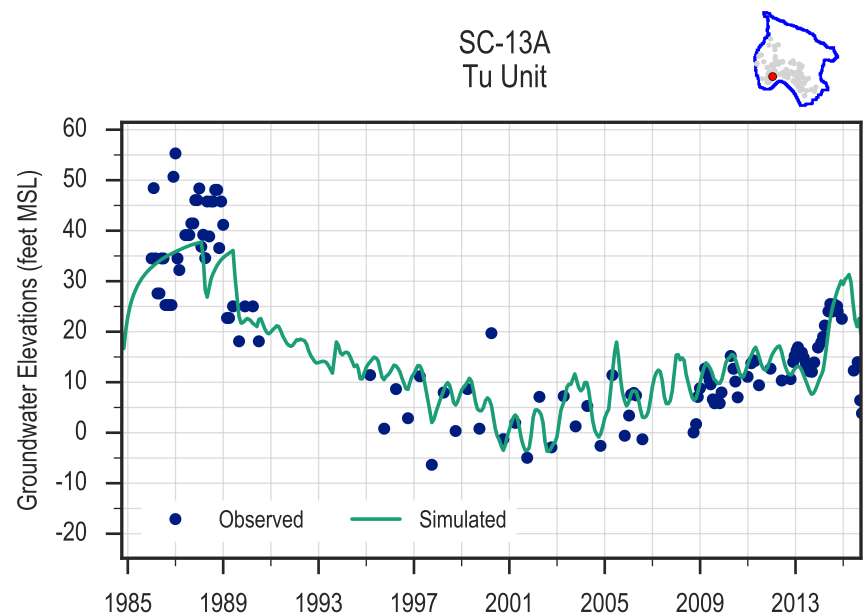


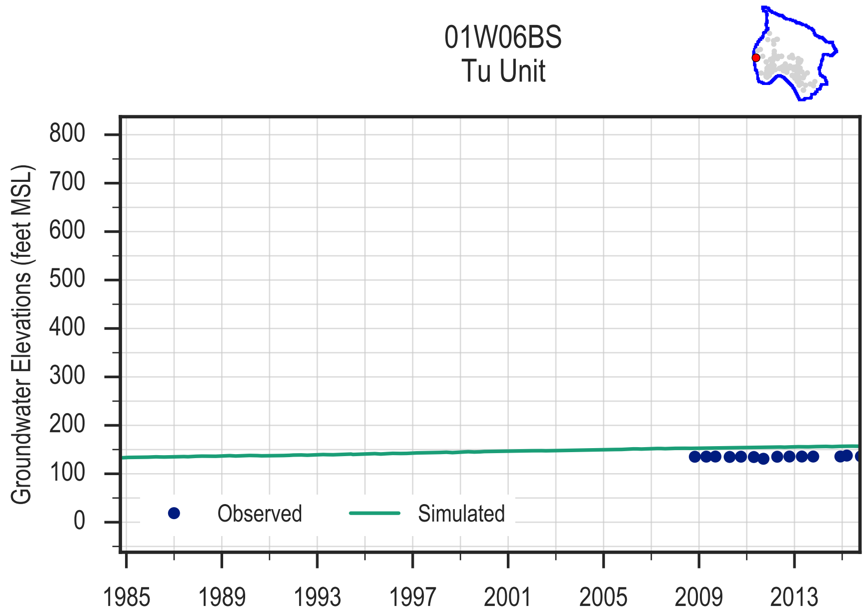
01W02AP
Tu Unit
Groundwater Elevations (feet MSL)
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

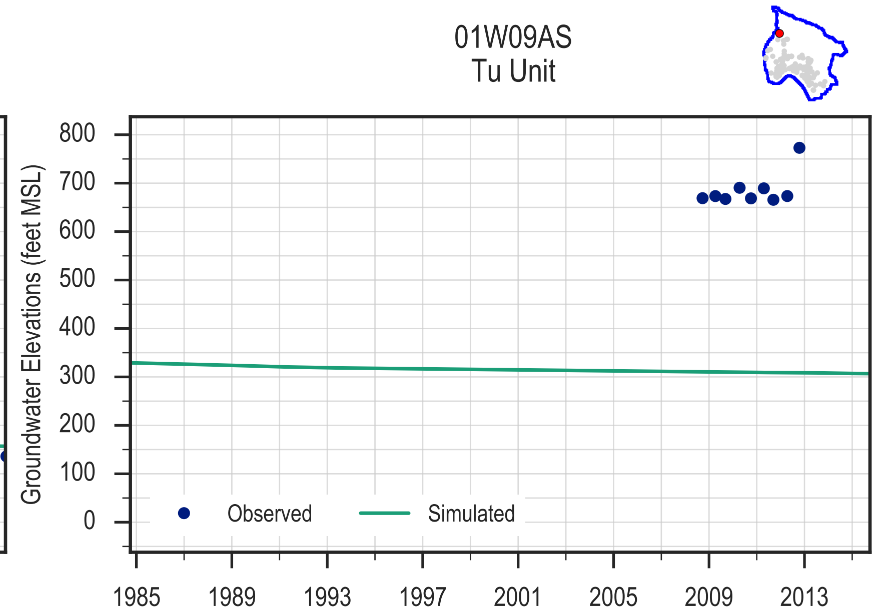

Thurber Lane Deep
Tu Unit
Groundwater Elevations (feet MSL)
60
50
40
30
20
10
0
-10
-20
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

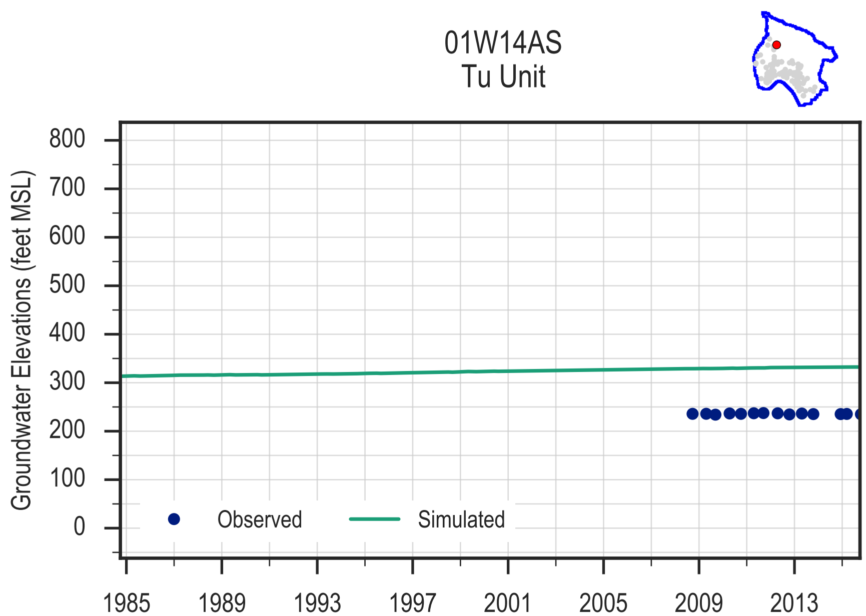

SC-22AAA
Tu Unit
Groundwater Elevations (feet MSL)
60
50
40
30
20
10
0
-10
-20
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

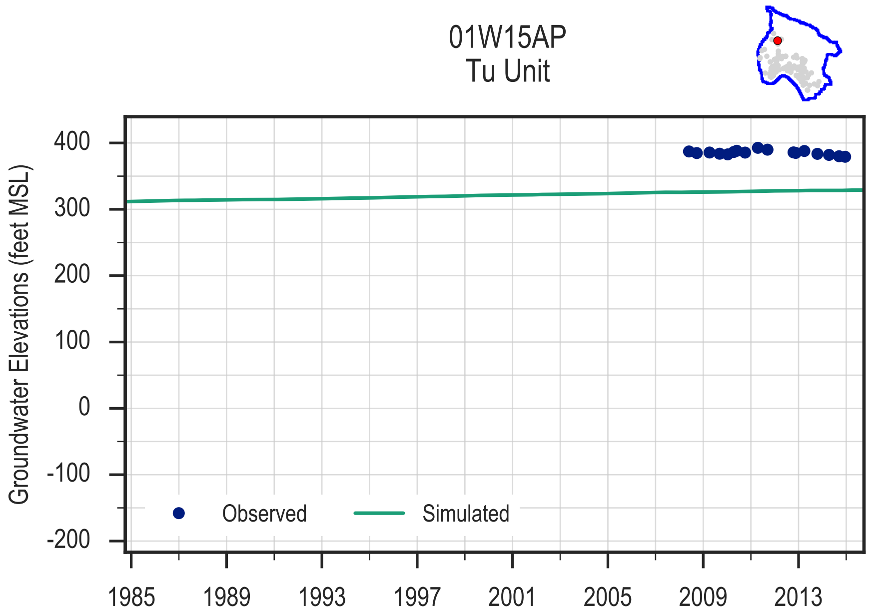

30th Ave Well 1
Tu Unit
Groundwater Elevations (feet MSL)
60
50
40
30
20
10
0
-10
-20
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

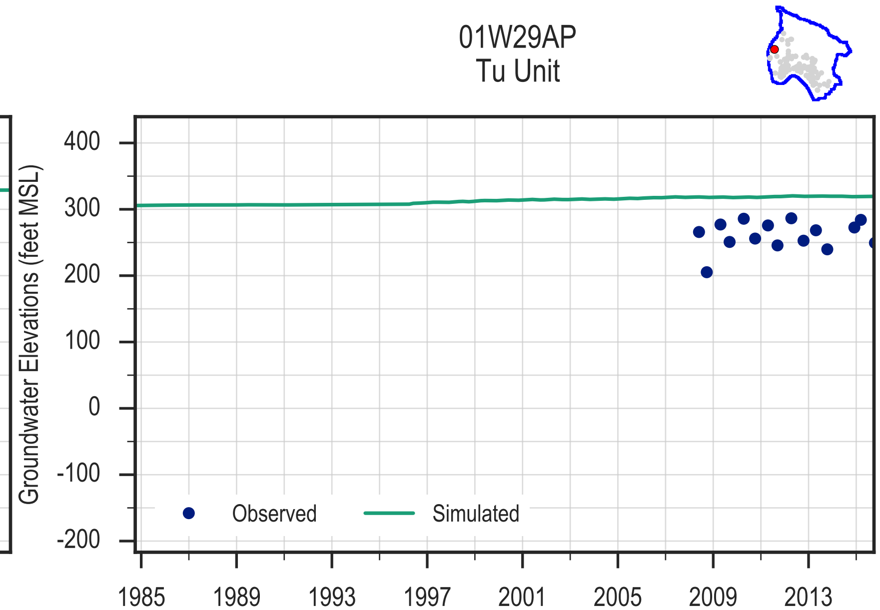

SC-13A
Tu Unit
Groundwater Elevations (feet MSL)
60
50
40
30
20
10
0
-10
-20
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

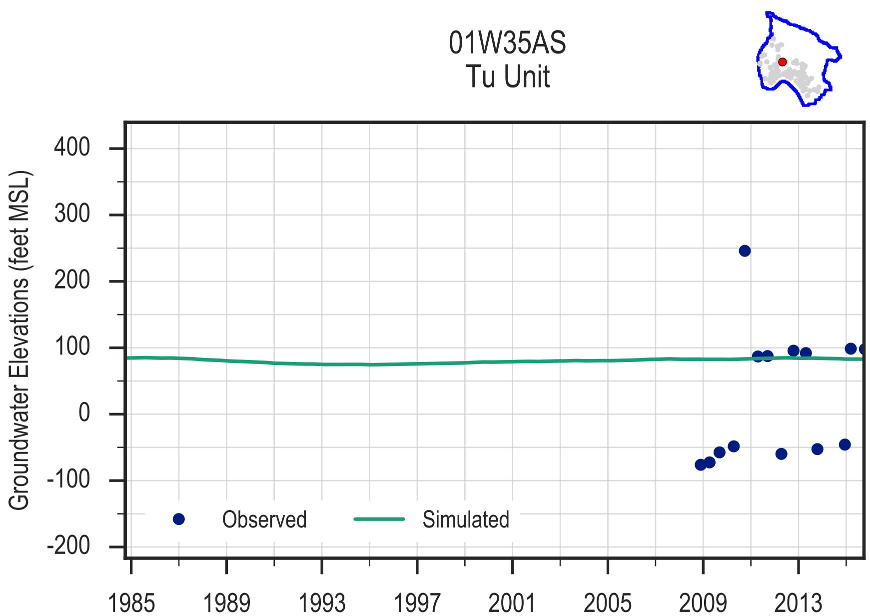

01W06BS
Tu Unit
Groundwater Elevations (feet MSL)
800
700
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


01W09AS
Tu Unit
Groundwater Elevations (feet MSL)
800
700
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


01W14AS
Tu Unit
Groundwater Elevations (feet MSL)
800
700
600
500
400
300
200
100
0
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


01W15AP
Tu Unit
Groundwater Elevations (feet MSL)
400
300
200
100
0
-100
-200
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


01W29AP
Tu Unit
Groundwater Elevations (feet MSL)
400
300
200
100
0
-100
-200
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013


01W35AS
Tu Unit
Groundwater Elevations (feet MSL)
400
300
200
100
0
-100
-200
Observed
Simulated
1985
1989
1993
1997
2001
2005
2009
2013

Appendix B

Comparison of Model Parameters to Parameters Estimated by Pumping Tests

		Thickness [ft]				Horizontal Hydraulic Conductivity [ft/day]						Transmissivity [ft²/day]						Vertical Hydraulic Conductivity [ft/day]					
Well_Name_Data_Type	Aquifer(s)	b_rcl	b_min	b_max	b_am	Kx_rcl	Kx_min	Kx_max	Kx_hm	Kx_gm	Kx_am	T_rcl	T_min	T_max	T_hm	T_gm	T_am	Kz_rcl	Kz_min	Kz_max	Kz_hm	Kz_gm	Kz_am
Aptos Jr High 2 [aquif. tests]	F		246	246	246		9.0	9.0	9.0	9.0	9.0		2,203	2,203	2,203	2,203	2,203		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Aptos Jr High 2 [L3]	F	879	599	1169	832	0.90	0.06	6.5	0.40	0.7	1.1	787	38	5,179	293	579	896	2.7E-02	3.6E-05	1.1E+00	7.9E-04	2.6E-02	1.6E-01
Beltz 07 [aquif. tests]	A/AA		100	100	100		2.5	2.5	2.5	2.5	2.5		125	125	125	125	125		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Beltz 07 [L7]	A	110	7	239	134	10.4	1.0	10	4.8	5.2	5.5	1,154	34	2,067	322	561	783	2.3E-03	1.0E-04	1.8E-02	2.4E-03	3.7E-03	4.6E-03
Beltz 07 [L8]	AA	403	332	406	383	1.67	0.36	24	1.0	1.7	3.5	676	137	8,665	401	633	1,301	1.2E-03	8.4E-04	2.6E-02	1.8E-03	2.3E-03	3.6E-03
Beltz 08 [aquif. tests]	A		90	100	93		37	108	66	70	74	729	3,650	9,690	6,133	6,449	6,767		3.0E-03	5.4E+00	1.5E-02	4.1E-01	1.6E+00
Beltz 08 [L7]	A	163	13	216	145	4.5	3.2	29	5.5	5.9	6.7	838	66	5,769	480	745	1,082		1.1E-03	2.4E-02	3.2E-03	3.7E-03	4.7E-03
Beltz 09 [aquif. tests]	A	A	90	110	100	26	26	68	42	44	47	4,418	2,370	6,830	4,158	4,418	4,658	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01
Beltz 09 [L7]	A	161	39	266	178	5.2	3.2	12.7	6.0	6.4	6.9	838	199	3,350	790	1,046	1,327	2.6E-03	1.6E-03	3.0E-01	3.5E-03	4.9E-03	1.4E-02
Beltz 12 [aquif. tests]	AA/Tu		0	0	#DIV/0!		0.00	0.00	#N/A	#NUM!	#DIV/0!		2,470	2,470	2,470	2,470	2,470		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Beltz 12 [L8]	AA	382	189	428	346	1.37	0.43	4.11	1.17	1.38	1.63	522	163	1,516	397	474	569	5.8E-02	3.8E-03	1.2E-01	1.8E-02	3.2E-02	4.7E-02
Beltz 12 [L9]	Tu	213	124	318	196	5.21	2.44	8.85	4.61	4.81	5.00	1,111	510	1,339	896	916	934	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
Bonita [aquif. tests]	F/Aromas		475	475	475		15	15	15	15	15		7,200	7,200	7,200	7,200	7,200		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Bonita [L2]	Aromas	361	224	616	406	16.2	8.5	114	18	26	40	5,842	2,189	66,971	6,251	10,010	17,370	1.03	0.40	1.07	0.94	0.95	0.96
Bonita [L3]	F	880	737	1041	876	3.93	0.63	11	2.6	3.8	5.1	3,458	563	8,743	2,341	3,273	4,267	1.1E-01	1.0E-02	6.8E-01	3.9E-02	9.5E-02	2.2E-01
Cox #3 [aquif. tests]	DEF/F		143	143	143		3.3000	3.400	3.349	3.350	3.350		470	488	479	479	479						
Cox #3 [L3]	DEF/F	1232	789	1675	1237	0.0525	0.0033	0.071	0.016	0.021	0.027	65	4	85	19	26	35	5.3E-04	7.6E-05	5.7E-03	1.8E-04	2.9E-04	6.5E-04
Estates [aquif. tests]	A/BC		415	615	515		3.90	5.70	4.63	4.71	4.80		2,380	2,400	2,390	2,390	2,390		4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02
Estates [L5]	BC	190	190	190	190	10.68	0.21	12.54	1.07	1.78	3.26	2,030	40	2,382	203	338	620	3.7E-03	9.6E-04	1.2E-02	2.2E-03	2.5E-03	2.9E-03
Estates [L7]	A	307	266	307	299	4.66	0.55	10.00	1.90	2.76	3.89	1,428	163	3,061	570	825	1,164	7.0E-05	1.4E-05	3.3E-03	7.4E-05	2.6E-04	7.3E-04
Garnet [aquif. tests]	A		200	200	200		17.00	19.00	17.62	17.64	17.67		3,350	4,480	3,673	3,705	3,740		4.0E-01	5.0E-01	4.4E-01	4.5E-01	4.5E-01
Garnet [L7]	A	199	93	255	192	5.07	1.83	47.98	4.90	5.99	8.41	1,007	412	9,975	894	1,123	1,674	1.8E-03	6.0E-05	1.1E-01	5.4E-04	2.7E-03	1.2E-02
Granite Way [aquif. tests]	DEF												238	238	238	238	238						
Granite Way [L3]	DEF	593	335	1067	597	0.301	0.048	0.78	0.15	0.20	0.26	178	24	548	88	112	142	1.6E-04	1.1E-05	4.4E-02	8.7E-05	4.5E-04	4.6E-03
Ledyard [aquif. tests]	BC		215	215	215		1.80	1.80	1.80	1.80	1.80		300	300	300	300	300		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Ledyard [L5]	BC	190	190	190	190	17.10	0.34	17.10	1.34	2.08	3.61	3,248	64	3,248	255	394	685	2.0E-03	1.1E-03	3.7E-03	1.9E-03	2.0E-03	2.0E-03
Madeline [aquif. tests]	BC		160	230	195		1.40	1.50	1.45	1.45	1.45		240	300	267	268	270		2.0E-02	2.0E-02	2.0E-02	2.0E-02	2.0E-02
Madeline [L5]	BC	190	190	190	190	5.48	0.11	17.10	0.74	1.69	3.61	1,040	21	3,248	140	321	686	1.7E-03	9.6E-04	1.2E-02	2.1E-03	2.3E-03	2.8E-03
Main St [aquif. tests]	AA/Tu		172	600	399		3.28	14.90	8.70	9.24	9.67		563	4,600	3,040	3,530	3,728		2.0E-03	8.0E-01	1.0E-02	3.2E-02	1.3E-01
Main St [L8]	AA	369	335	404	358	2.33	1.07	4.11	1.79	1.90	2.02	858	378	1,516	636	678	729	2.3E-02	3.1E-03	8.9E-02	1.5E-02	2.2E-02	3.2E-02
Main St [L9]	Tu	110	59	184	116	7.78	0.09	8.85	0.64	1.91	3.71	853	11	1,129	69	215	455	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
Rosedale [aquif. tests]	A		350	350	350		14.00	14.00	14.00	14.00	14.00		4,800	4,800	4,800	4,800	4,800		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Rosedale [L7]	A	255	72	281	223	6.04	1.91	7.64	4.33	4.59	4.84	1,541	194	1,932	845	989	1,102	2.1E-03	1.6E-05	1.1E-01	2.2E-04	3.0E-03	1.8E-02
Rosedale [L8]	AA	345	324	411	360	2.10	1.22	4.11	1.74	1.83	1.94	724	411	1,516	624	658	702	7.9E-03	6.8E-04	8.9E-02	3.5E-03	7.1E-03	1.5E-02
San Andreas [aquif. tests]	F/Aromas		350	450	400		13.00	14.00	13.48	13.49	13.50		4,700	6,300	5,384	5,442	5,500		2.4E+00	2.4E+00	2.4E+00	2.4E+00	2.4E+00
San Andreas [L2]	Aromas	346	215	651	432	9.34	8.47	100.18	13.43	16.64	23.33	3,234	2,061	56,958	5,143	6,978	11,128	1.0	0.8	1.1	1.0	1.0	1.0
San Andreas [L3]	F	886	738	1050	882	6.07	0.99	11.14	3.67	4.70	5.81	5,383	889	8,743	3,369	4,129	4,887	2.0E-01	8.0E-03	6.2E-01	3.3E-02	7.6E-02	1.8E-01
Seascape [aquif. tests]	F/Aromas		420	420	420		29.00	29.00	29.00	29.00	29.00		12,000	12,000	12,000	12,000	12,000		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Seascape [L2]	Aromas	464	198	599	404	10.00	8.47	18.12	9.90	9.97	10.06	4,644	1,982	10,136	3,778	3,928	4,097	1.0	0.5	1.0	0.9	0.9	0.9
Seascape [L3]	F	808	666	964	808	8.90	1.17	11.14	4.86	5.79	6.55	7,186	869	8,743	3,853	4,656	5,266	4.0E-02	7.4E-03	5.6E-01	1.9E-02	3.5E-02	1.0E-01
Sells [aquif. tests]	F/Aromas		330	330	330		210.00	210.00	210.00	210.00	210.00		66,800	73,500	69,990	70,070	70,150		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Sells [L2]	Aromas	478	342	735	503	9.80	9.07	29.95	10.65	10.93	11.34	4,684	3,422	17,716	5,075	5,405	5,928	0.6	0.3	1.1	0.7	0.7	0.8
Sells [L3]	F	769	634	955	777	1.58	0.88	8.24	1.57	1.89	2.40	1,218	557	7,142	1,153	1,457	1,954	9.4E-03	7.5E-03	1.8E-02	9.6E-03	9.7E-03	9.8E-03
Tannery II [aquif. tests]	A		235	235	235		8.80	10.00	9.36	9.38	9.40		2,020	2,060	2,040	2,040	2,040		7.0E-01	7.0E-01	7.0E-01	7.0E-01	7.0E-01
Tannery II [L7]	A	265	231	305	264	5.05	0.55	7.64	2.82	3.61	4.22	1,337	163	1,932	776	950	1,086	2.5E-04	1.2E-05	1.2E-02	7.5E-05	5.5E-04	2.1E-03

Notes:
"Well-Name [aquif. Tests]" denotes parameter summary stats for pumping well based on pumping test results
"Well-Name [LX]" denotes averaged model paramters around each well based on averaging grid cells in Layer X that are within 3200 feet radial distance (4 grid cells) of the grid cell containing the well.
rcl = value at the well grid cell (at row=r, col=c, layer=l)
min = minimum value
max = maximum value
hm = harmonic mean
gm - geometric mean
am = arithmetic mean

MONTGOMERY & ASSOCIATES

		Specifc Storage [1/ft]						Storativity [ft/ft]						Hydraulic Diffusivity (K/Ss) [ft^2/day]					
Well_Name_Data_Type	Aquifer(s)	Ss_rcl	Ss_min	Ss_max	Ss_hm	Ss_gm	Ss_am	S_rcl	S_min	S_max	S_hm	S_gm	S_am	D_rcl	D_min	D_max	D_hm	D_gm	D_am
Aptos Jr High 2 [aquif. tests]	F		1.7E-06	1.7E-06	1.7E-06	1.7E-06	1.7E-06		4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04		5.1E+06	5.1E+06	5.1E+06	5.1E+06	5.1E+06
Aptos Jr High 2 [L3]	F	9.5E-05	9.0E-05	9.9E-04	1.3E-04	1.3E-04	1.6E-04	8.31E-02	6.9E-02	6.1E-01	9.8E-02	1.1E-01	1.3E-01	9.5E+03	6.3E+01	6.5E+04	1.1E+03	5.4E+03	1.1E+04
Beltz 07 [aquif. tests]	A/AA		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Beltz 07 [L7]	A	9.2E-04	9.2E-06	9.2E-04	2.4E-04	2.4E-04	3.6E-04	1.01E-01	5.0E-04	1.2E-01	1.1E-02	2.6E-02	4.0E-02	1.1E+04	3.7E+03	5.7E+05	1.4E+04	2.2E+04	4.5E+04
Beltz 07 [L8]	AA	8.6E-05	6.7E-05	1.1E-04	8.8E-05	8.8E-05	8.9E-05	3.48E-02	2.4E-02	4.3E-02	3.3E-02	3.4E-02	3.4E-02	1.9E+04	5.3E+03	2.5E+05	1.2E+04	1.9E+04	3.7E+04
Beltz 08 [aquif. tests]	A		1.8E-06	4.9E-05	3.7E-06	6.2E-06	1.3E-05		1.6E-04	4.4E-03	3.5E-04	5.8E-04	1.2E-03		1.5E+06	5.6E+07	5.6E+06	1.1E+07	1.9E+07
Beltz 08 [L7]	A	2.7E-04	7.8E-07	9.2E-04	8.6E-05	8.6E-05	2.7E-04	4.43E-02	1.5E-04	1.2E-01	1.8E-03	1.1E-02	3.0E-02	1.6E+04	3.7E+03	8.2E+06	1.8E+04	6.9E+04	8.3E+05
Beltz 09 [aquif. tests]	A	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.40E-02	1.4E-02	1.4E-02	1.4E-02	1.4E-02	1.4E-02	0.0E+00	3.1E+05	3.1E+05	3.1E+05	3.1E+05	3.1E+05
Beltz 09 [L7]	A	5.4E-04	4.3E-05	9.2E-04	2.8E-04	2.8E-04	3.7E-04	8.76E-02	8.7E-03	2.0E-01	3.6E-02	4.6E-02	5.8E-02	9.6E+03	3.7E+03	2.0E+05	1.6E+04	2.3E+04	3.5E+04
Beltz 12 [aquif. tests]	AA/Tu		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03		2.5E+06	2.5E+06	2.5E+06	2.5E+06	2.5E+06
Beltz 12 [L8]	AA	1.0E-04	7.4E-05	1.0E-04	9.3E-05	9.3E-05	9.3E-05	3.90E-02	1.9E-02	3.9E-02	3.1E-02	3.2E-02	3.2E-02	1.3E+04	5.8E+03	4.4E+04	1.3E+04	1.5E+04	1.7E+04
Beltz 12 [L9]	Tu	4.2E-06	2.7E-06	8.0E-06	4.4E-06	4.4E-06	4.6E-06	8.92E-04	6.5E-04	1.2E-03	8.4E-04	8.4E-04	8.5E-04	1.2E+06	5.8E+05	1.6E+06	1.1E+06	1.1E+06	1.1E+06
Bonita [aquif. tests]	F/Aromas		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Bonita [L2]	Aromas	1.0E-05	9.6E-06	1.2E-05	1.0E-05	1.0E-05	1.0E-05	3.61E-03	2.2E-03	7.5E-03	3.8E-03	3.9E-03	4.1E-03	1.6E+06	8.5E+05	1.2E+07	1.8E+06	2.6E+06	4.0E+06
Bonita [L3]	F	1.0E-04	9.8E-05	1.0E-04	1.0E-04	1.0E-04	1.0E-04	8.80E-02	7.4E-02	1.0E-01	8.7E-02	8.7E-02	8.8E-02	3.9E+04	6.3E+03	1.1E+05	2.6E+04	3.8E+04	5.1E+04
Cox #3 [aquif. tests]	DEF/F		7.0E-07	1.7E-06	1.0E-06	1.1E-06	1.2E-06		1.0E-04	2.5E-04	1.4E-04	1.6E-04	1.8E-04		2.0E+06	4.7E+06	2.8E+06	3.0E+06	3.3E+06
Cox #3 [L3]	DEF/F	1.6E-04	1.5E-04	1.1E-03	3.9E-04	3.9E-04	5.0E-04	1.93E-01	1.9E-01	1.5E+00	4.0E-01	4.8E-01	5.8E-01	3.3E+02	3.5E+00	4.5E+02	2.3E+01	5.4E+01	1.2E+02
Estates [aquif. tests]	A/BC		4.8E-07	4.8E-07	4.8E-07	4.8E-07	4.8E-07		2.0E-04	2.0E-04	2.0E-04	2.0E-04	2.0E-04		1.2E+07	1.2E+07	1.2E+07	1.2E+07	1.2E+07
Estates [L5]	BC	5.7E-07	2.0E-07	5.0E-06	7.9E-07	7.9E-07	1.2E-06	1.08E-04	3.8E-05	9.5E-04	1.1E-04	1.5E-04	2.2E-04	1.9E+07	1.0E+05	4.5E+07	9.0E+05	2.3E+06	5.0E+06
Estates [L7]	A	3.4E-07	6.1E-08	3.4E-05	7.7E-07	7.7E-07	3.1E-06	1.03E-04	1.8E-05	1.0E-02	1.0E-04	2.3E-04	9.3E-04	1.4E+07	2.0E+04	1.5E+08	3.6E+05	3.6E+06	1.4E+07
Garnet [aquif. tests]	A		1.0E-06	8.0E-06	1.8E-06	2.8E-06	4.5E-06		2.0E-04	1.6E-03	3.6E-04	5.7E-04	9.0E-04		2.1E+06	1.7E+07	3.8E+06	6.0E+06	9.4E+06
Garnet [L7]	A	7.8E-07	2.0E-07	2.7E-04	3.3E-06	3.3E-06	2.1E-05	1.55E-04	4.6E-05	4.4E-02	2.0E-04	6.2E-04	3.3E-03	6.5E+06	1.6E+04	6.0E+07	2.3E+05	1.8E+06	7.5E+06
Granite Way [aquif. tests]	DEF																		
Granite Way [L3]	DEF	1.8E-04	1.2E-04	9.9E-04	3.3E-04	3.3E-04	3.9E-04	1.04E-01	8.1E-02	6.1E-01	1.7E-01	1.9E-01	2.2E-01	1.7E+03	6.3E+01	6.4E+03	3.6E+02	6.0E+02	9.4E+02
Ledyard [aquif. tests]	BC		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Ledyard [L5]	BC	2.0E-06	2.0E-07	6.4E-06	8.8E-07	8.8E-07	1.1E-06	3.86E-04	3.8E-05	1.2E-03	1.4E-04	1.7E-04	2.1E-04	8.4E+06	1.4E+05	4.5E+07	1.3E+06	2.4E+06	4.7E+06
Madeline [aquif. tests]	BC		2.8E-05	2.8E-05	2.8E-05	2.8E-05	2.8E-05		4.5E-03	4.5E-03	4.5E-03	4.5E-03	4.5E-03		5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Madeline [L5]	BC	6.5E-07	2.0E-07	5.0E-06	8.8E-07	8.8E-07	1.2E-06	1.23E-04	3.8E-05	9.5E-04	1.2E-04	1.7E-04	2.3E-04	8.4E+06	1.0E+05	4.5E+07	7.0E+05	1.9E+06	5.1E+06
Main St [aquif. tests]	AA/Tu		1.1E-07	1.3E-03	7.6E-07	4.6E-06	8.2E-05		3.9E-05	2.3E-01	2.4E-04	1.4E-03	1.5E-02		2.4E+03	1.1E+08	4.5E+04	2.4E+06	1.7E+07
Main St [L8]	AA	9.5E-05	3.1E-05	1.0E-04	8.1E-05	8.1E-05	8.5E-05	3.51E-02	1.1E-02	4.1E-02	2.7E-02	2.9E-02	3.0E-02	2.4E+04	1.4E+04	4.4E+04	2.2E+04	2.3E+04	2.4E+04
Main St [L9]	Tu	8.0E-06	4.4E-06	2.1E-05	8.9E-06	8.9E-06	9.9E-06	8.75E-04	5.8E-04	1.9E-03	9.7E-04	1.0E-03	1.0E-03	9.7E+05	7.0E+03	1.2E+06	5.4E+04	2.1E+05	5.1E+05
Rosedale [aquif. tests]	A		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!		0.0E+00	0.0E+00	#N/A	#NUM!	#DIV/0!
Rosedale [L7]	A	4.1E-06	4.3E-07	1.0E-04	6.2E-06	6.2E-06	2.0E-05	1.05E-03	1.0E-04	1.5E-02	5.0E-04	1.3E-03	3.3E-03	1.5E+06	2.3E+04	1.0E+07	1.7E+05	7.4E+05	2.7E+06
Rosedale [L8]	AA	9.9E-05	6.6E-05	1.1E-04	9.4E-05	9.4E-05	9.4E-05	3.41E-02	2.3E-02	4.1E-02	3.4E-02	3.4E-02	3.4E-02	2.1E+04	1.1E+04	4.4E+04	1.8E+04	1.9E+04	2.1E+04
San Andreas [aquif. tests]	F/Aromas		2.9E-06	2.9E-06	2.9E-06	2.9E-06	2.9E-06		1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03		4.7E+06	4.7E+06	4.7E+06	4.7E+06	4.7E+06
San Andreas [L2]	Aromas	1.0E-05	9.6E-06	1.1E-05	1.0E-05	1.0E-05	1.0E-05	3.46E-03	2.2E-03	7.3E-03	4.1E-03	4.2E-03	4.3E-03	9.3E+05	8.5E+05	9.7E+06	1.3E+06	1.7E+06	2.3E+06
San Andreas [L3]	F	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	8.86E-02	7.4E-02	1.0E-01	8.7E-02	8.8E-02	8.8E-02	6.1E+04	9.9E+03	1.1E+05	3.7E+04	4.7E+04	5.8E+04
Seascape [aquif. tests]	F/Aromas		4.8E-07	4.8E-07	4.8E-07	4.8E-07	4.8E-07		2.0E-04	2.0E-04	2.0E-04	2.0E-04	2.0E-04		6.0E+07	6.0E+07	6.0E+07	6.0E+07	6.0E+07
Seascape [L2]	Aromas	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	4.64E-03	2.0E-03	6.0E-03	3.8E-03	3.9E-03	4.0E-03	1.0E+06	8.5E+05	1.8E+06	9.9E+05	1.0E+06	1.0E+06
Seascape [L3]	F	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	8.08E-02	6.7E-02	9.6E-02	8.0E-02	8.0E-02	8.1E-02	8.9E+04	1.2E+04	1.1E+05	4.9E+04	5.8E+04	6.5E+04
Sells [aquif. tests]	F/Aromas		2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06		8.0E-04	8.0E-04	8.0E-04	8.0E-04	8.0E-04		8.4E+07	9.2E+07	8.7E+07	8.8E+07	8.8E+07
Sells [L2]	Aromas	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	4.78E-03	3.4E-03	7.4E-03	4.9E-03	4.9E-03	5.0E-03	9.8E+05	9.1E+05	3.0E+06	1.1E+06	1.1E+06	1.1E+06
Sells [L3]	F	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	7.69E-02	6.3E-02	9.5E-02	7.7E-02	7.7E-02	7.8E-02	1.6E+04	8.8E+03	8.2E+04	1.6E+04	1.9E+04	2.4E+04
Tannery II [aquif. tests]	A		2.3E-06	2.3E-06	2.3E-06	2.3E-06	2.3E-06		5.5E-04	5.5E-04	5.5E-04	5.5E-04	5.5E-04		3.7E+06	3.7E+06	3.7E+06	3.7E+06	3.7E+06
Tannery II [L7]	A	1.7E-06	1.6E-07	3.2E-05	1.9E-06	1.9E-06	4.8E-06	4.43E-04	4.8E-05	8.0E-03	2.5E-04	5.1E-04	1.3E-03	3.0E+06	1.2E+05	1.1E+07	7.0E+05	1.9E+06	4.1E+06

Notes:
"Well-Name [aquif. Tests]" denotes parameter summary stats for pumping well based on pumping test results
"Well-Name [LX]" denotes averaged model paramters around each well based on averaging grid cells in Layer X that are within 3200 feet radial distance (4 grid cells) of the grid cell containing the well.
rcl = value at the well grid cell (at row=r, col=c, layer=l)
min = minimum value
max = maximum value
hm = harmonic mean
gm - geometric mean
am = arithmetic mean

Appendix D

Water Budgets by Model Layer

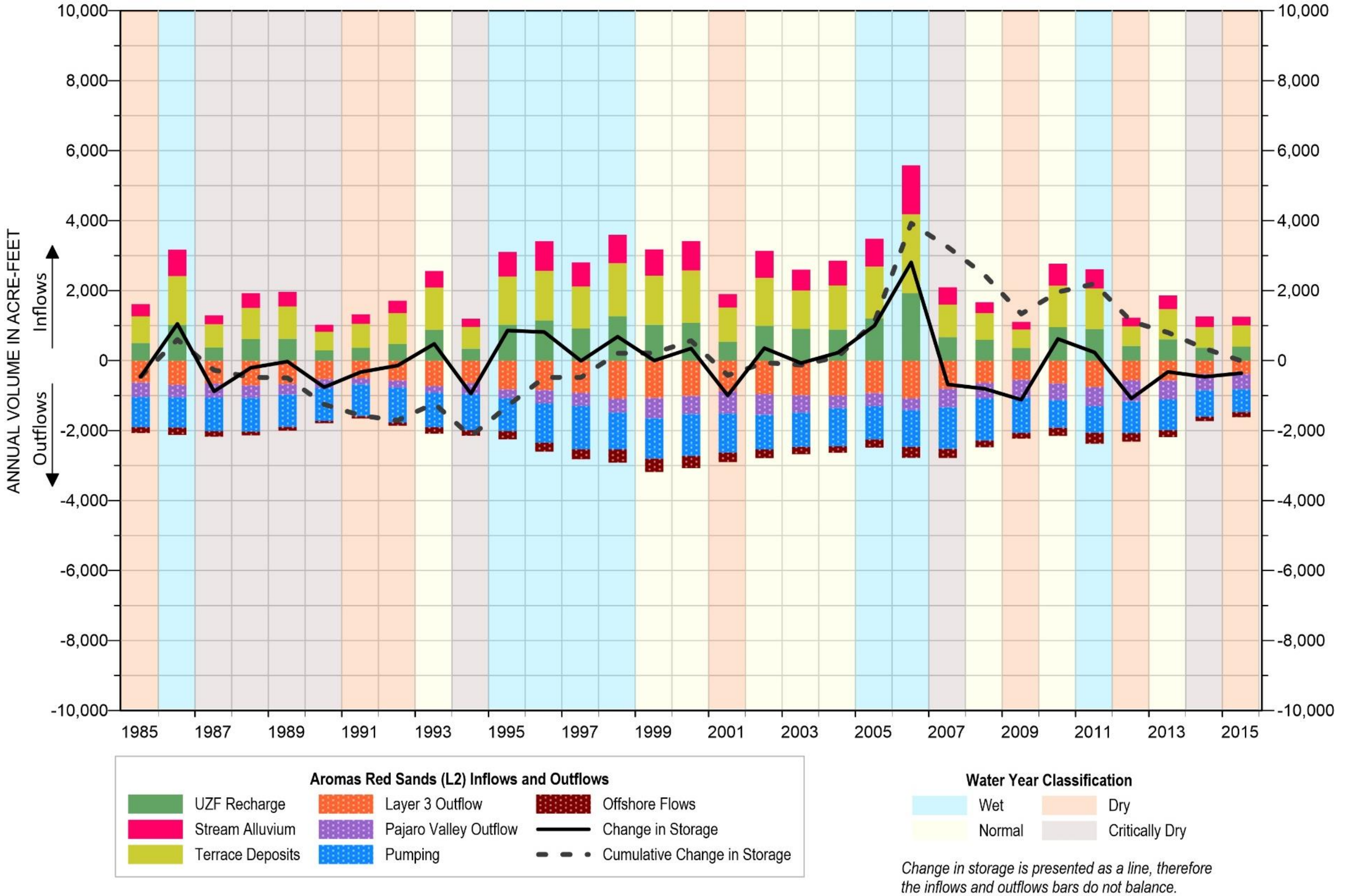


Figure C-1: Detailed Annual Water Budget for Layer 2 (Aromas Red Sands) in Mid-County Basin

MONTGOMERY & ASSOCIATES

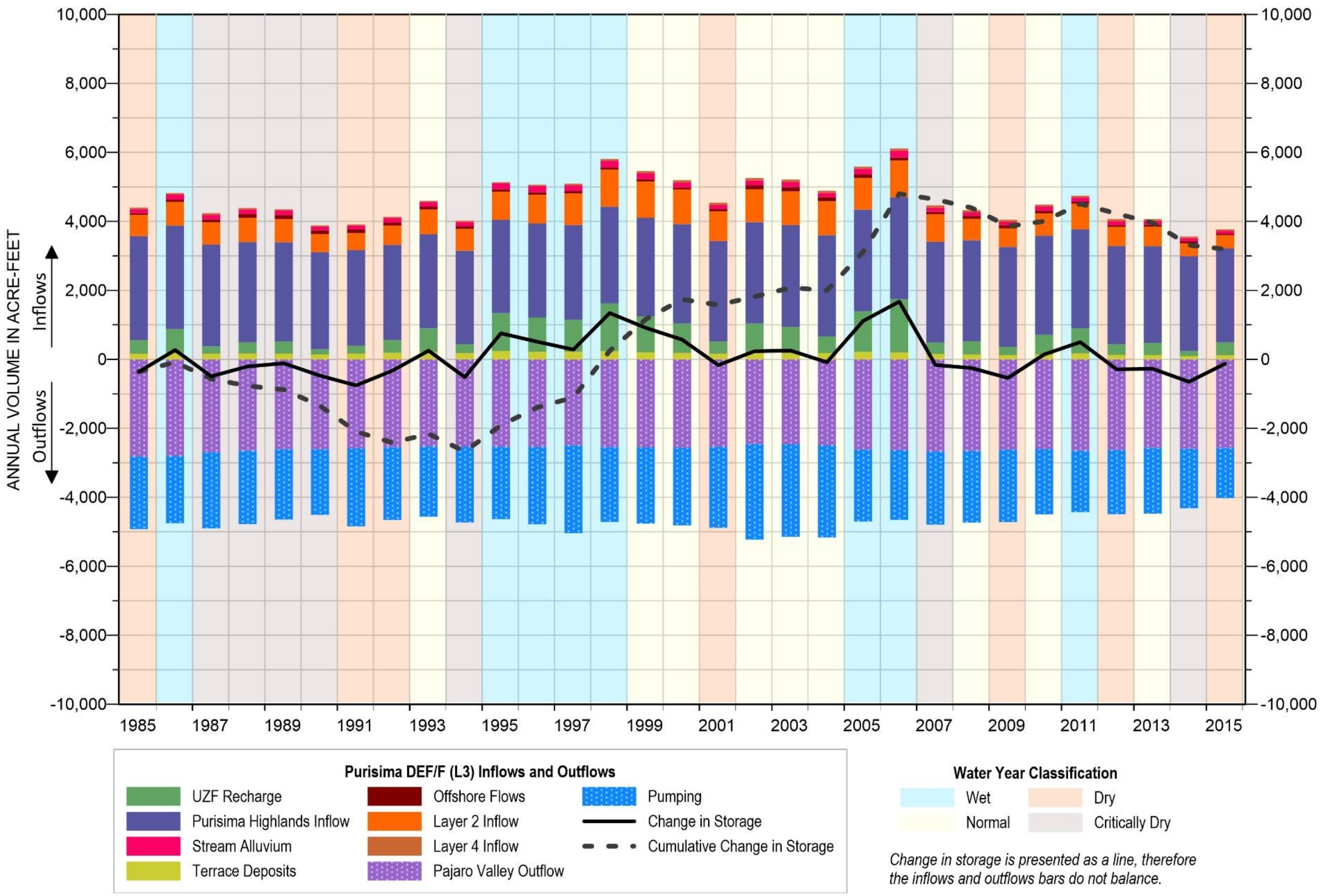


Figure C-2: Detailed Annual Water Budget for Layer 3 (Purisima F/DEF) in Mid-County Basin

MONTGOMERY & ASSOCIATES

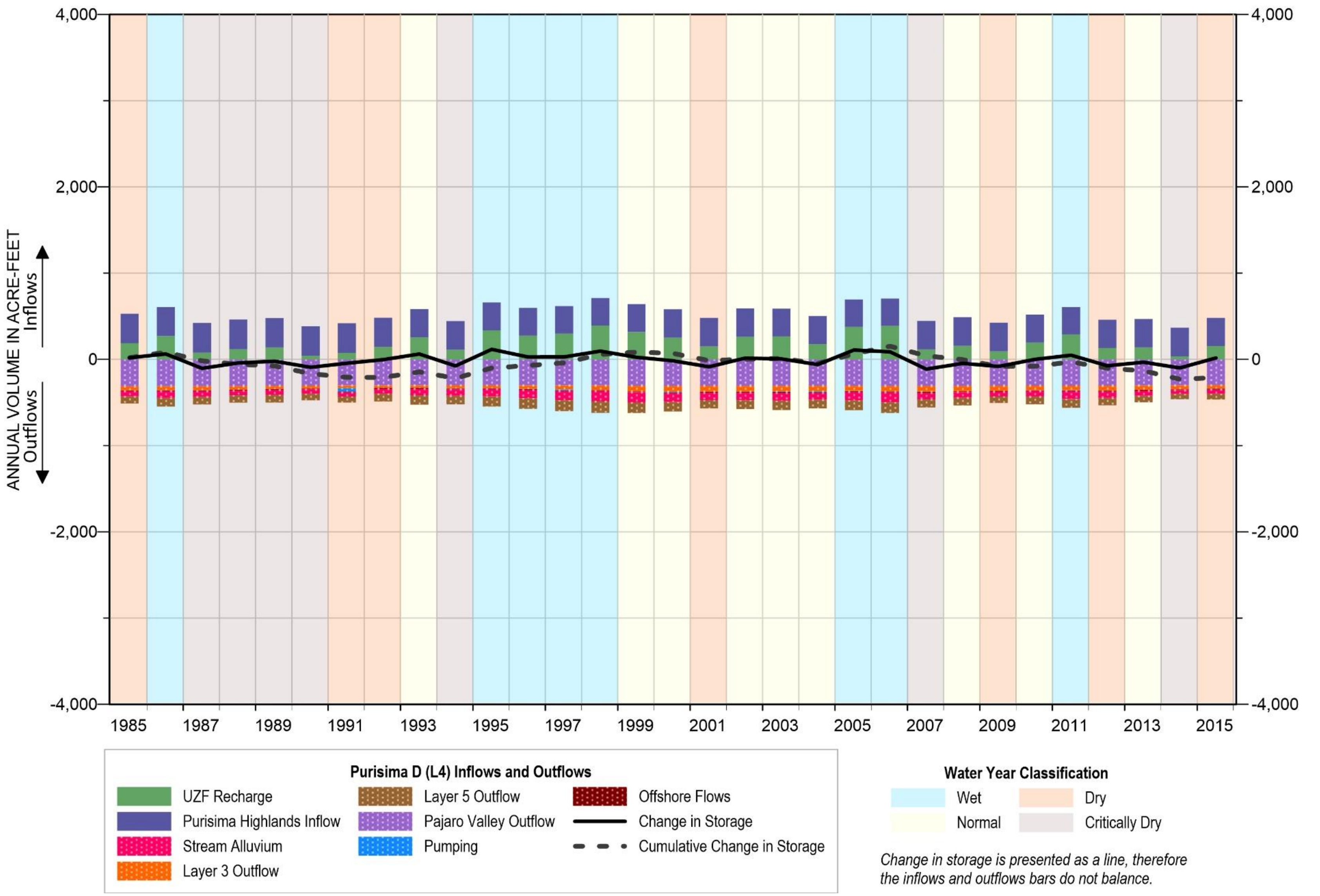


Figure C-3: Detailed Annual Water Budget for Layer 4 (Purisima D) in Mid-County Basin

MONTGOMERY & ASSOCIATES

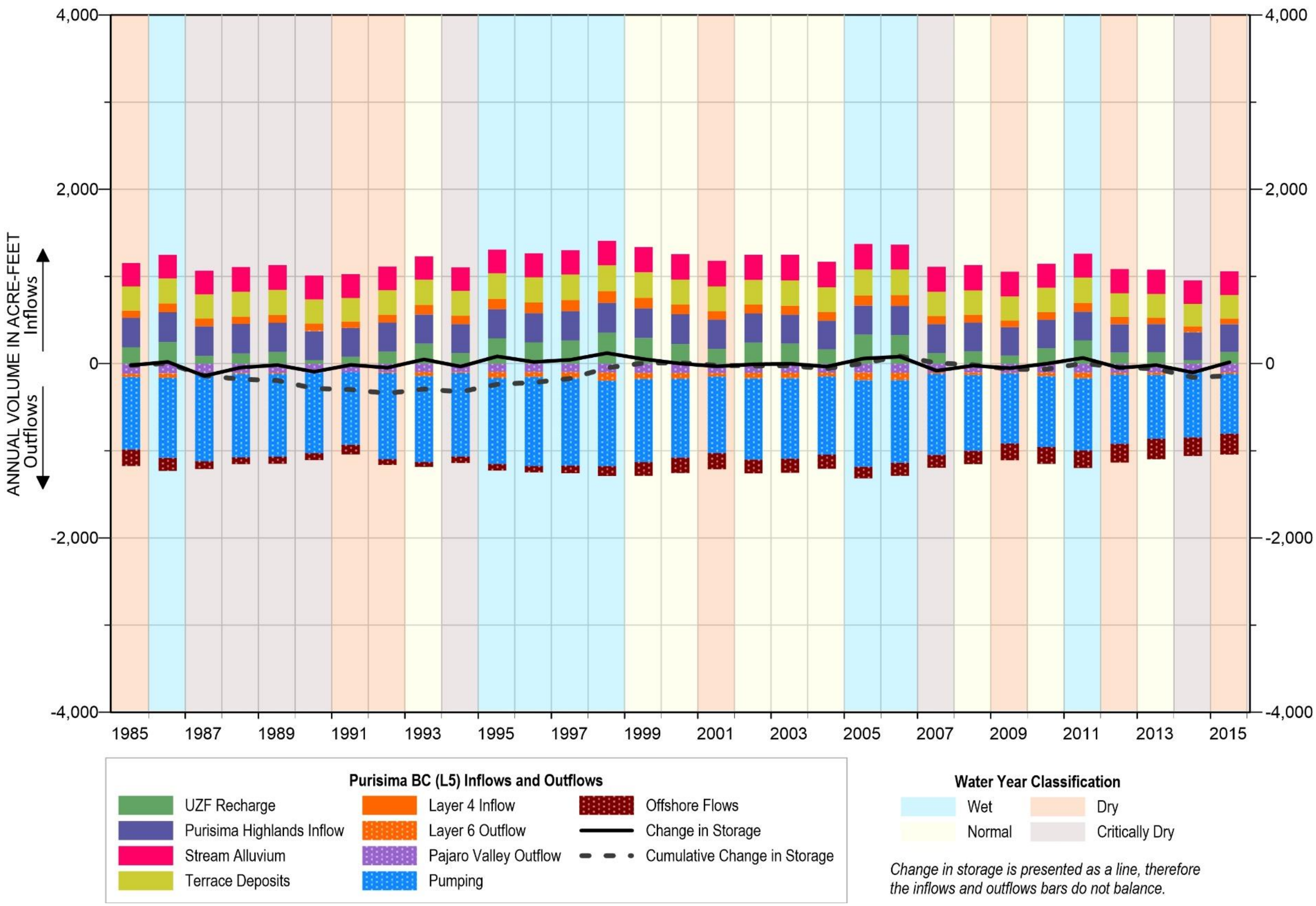


Figure C-4: Detailed Annual Water Budget for Layer 5 (Purisima BC) in Mid-County Basin

MONTGOMERY & ASSOCIATES

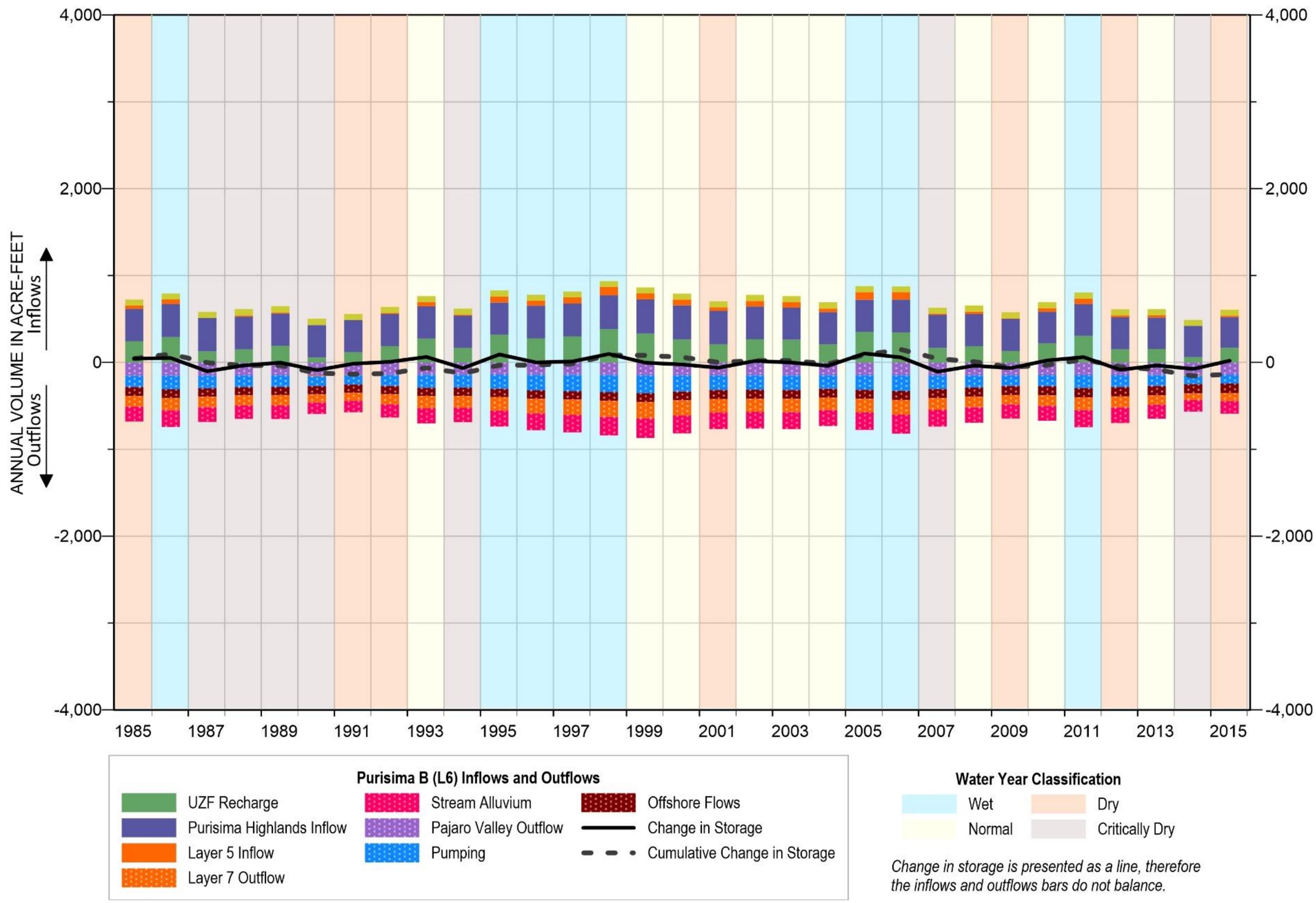


Figure C-5: Detailed Annual Water Budget for Layer 6 (Purisima B) in Mid-County Basin

MONTGOMERY & ASSOCIATES

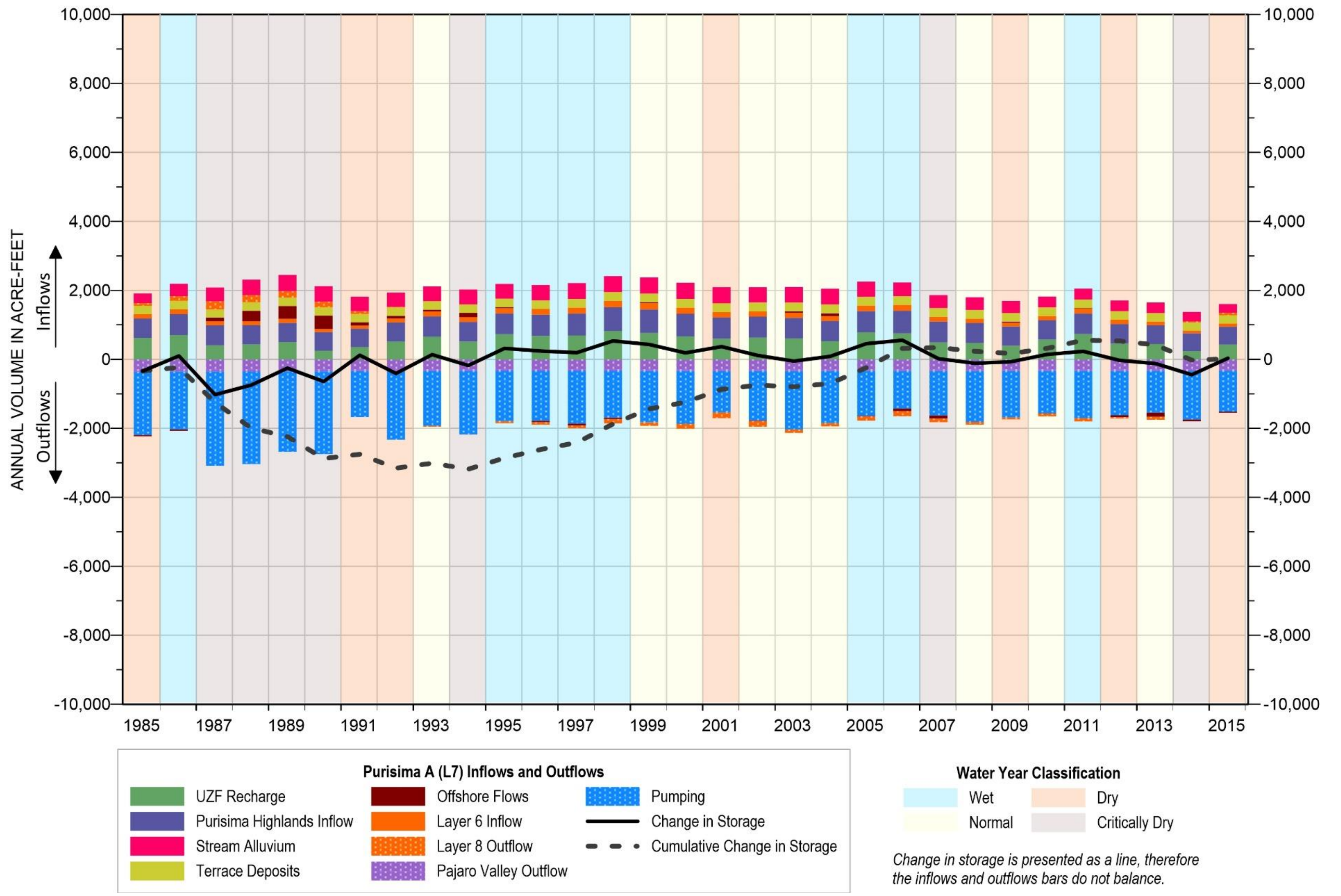


Figure C-6: Detailed Annual Water Budget for Layer 7 (Purisima A) in Mid-County Basin

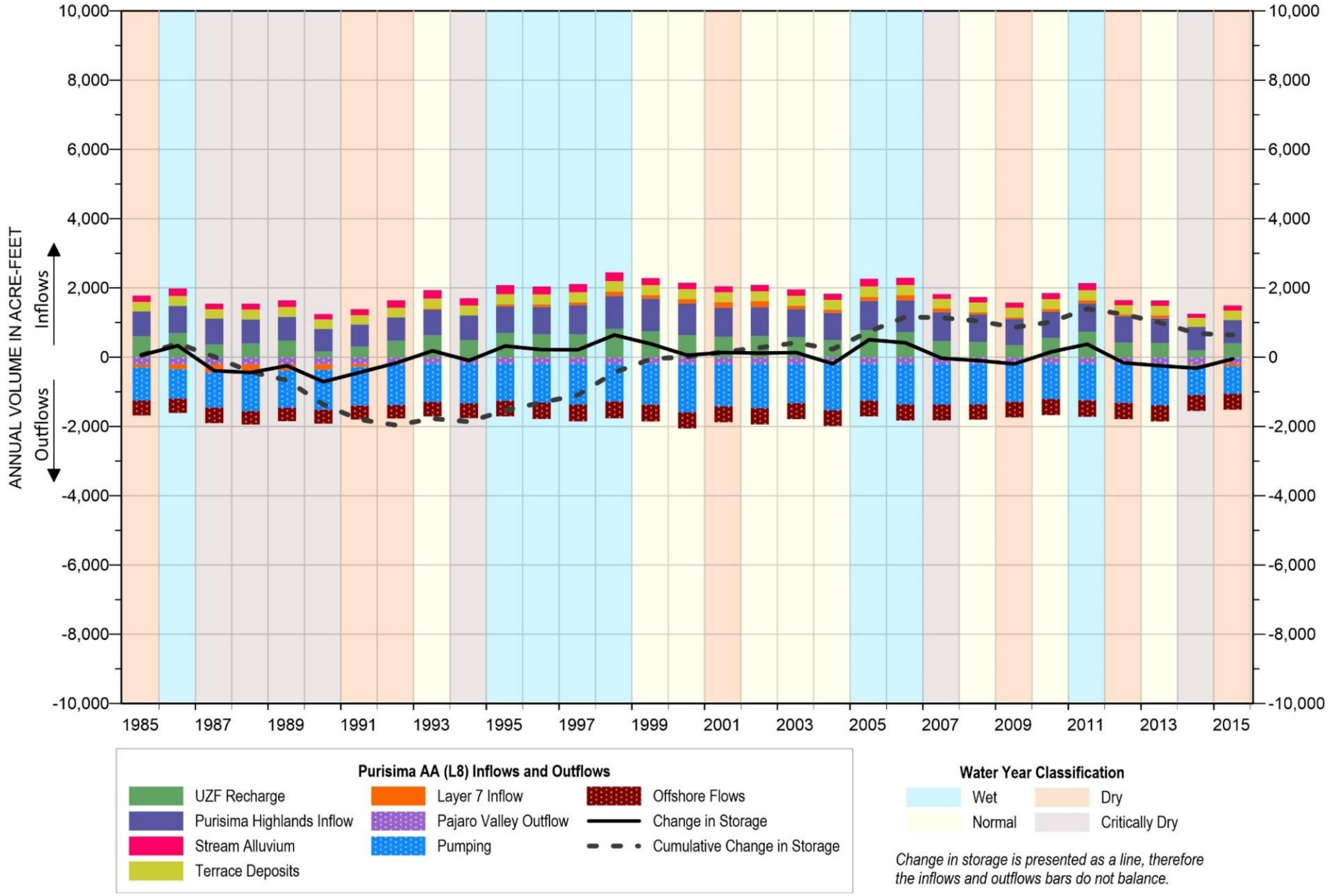


Figure C-7: Detailed Annual Water Budget for Layer 8 (Purisima AA) in Mid-County Basin

MONTGOMERY & ASSOCIATES

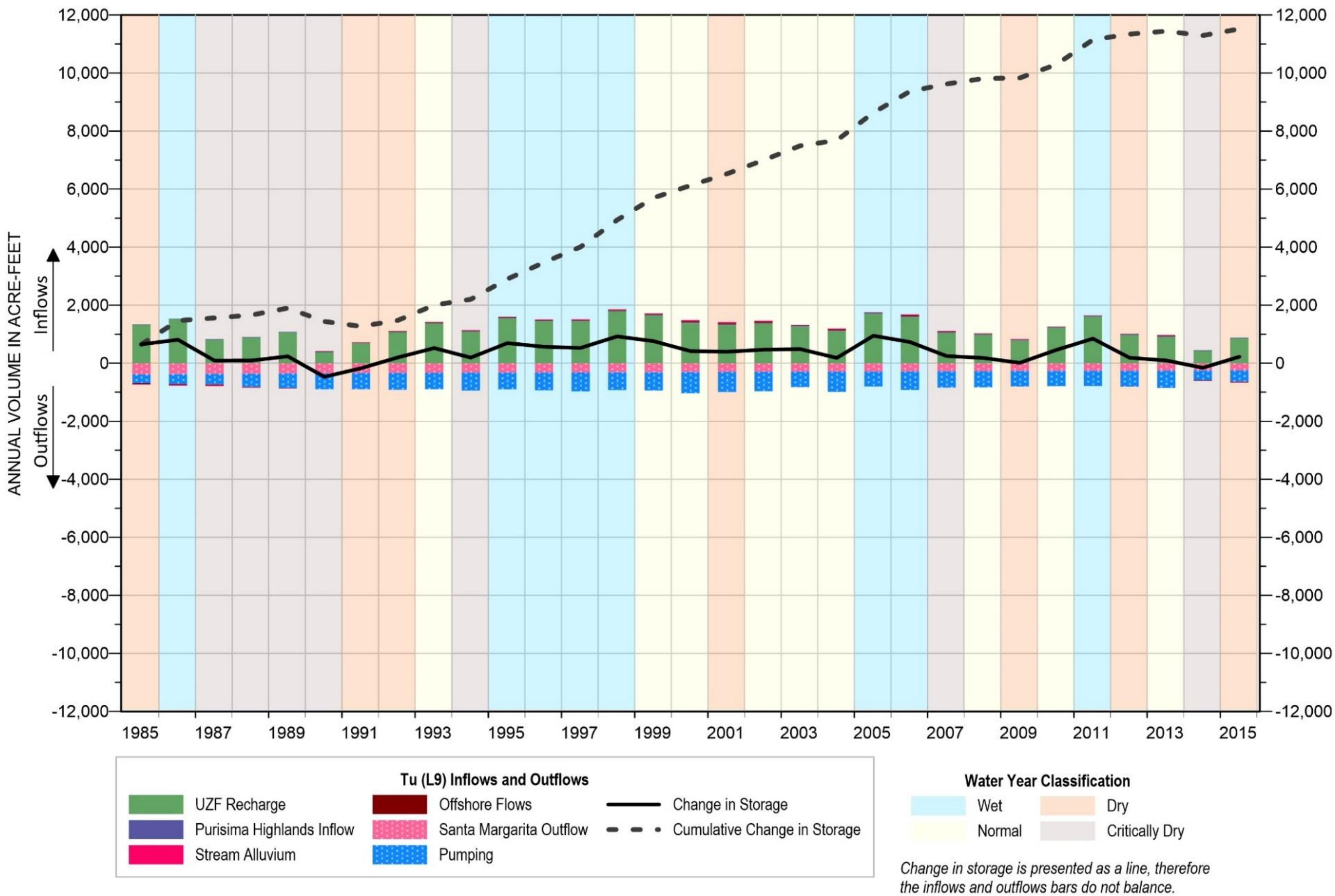


Figure C-8: Detailed Annual Water Budget for Layer 9 (Tu) in Mid-County Basin

MONTGOMERY & ASSOCIATES

APPENDIX 2-G

SANTA CRUZ MID-COUNTY GROUNDWATER FLOW MODEL: FUTURE CLIMATE FOR MODEL SIMULATIONS (TASK 5) MEMORANDUM

1814 Franklin St, Suite 501
Oakland, CA 94612

TECHNICAL MEMORANDUM

To: Mid-County Groundwater Agency Executive Staff

From: Georgina King and Cameron Tana

Date: August 17, 2017

Subject: Santa Cruz Mid-County Basin Groundwater Flow Model: Future Climate for Model Simulations (Task 5)

Contents

1.0 INTRODUCTION

This technical memorandum documents our approach for developing an initial future climate scenario to be implemented with simulations using the GSFLOW model of the Santa Cruz Mid-County Groundwater Basin currently under development, and presents two proposed climate scenarios. Climate data used in GSFLOW includes minimum and maximum temperature, and precipitation at the Santa Cruz Co-op and Watsonville Waterworks stations.

The objective of this subtask is to develop a reasonable climate scenario that adequately represents the warmer temperatures that are being predicted due to global climate change. At the August 24, 2016 TAC meeting, Prof. Andrew Fisher suggested using a catalog of historical annual climate instead of one of the multitude of General Circulation Models (GCM) available for future climate scenarios. The premise of this approach is that we use actual historical climate data representing the warmest years on record and not modeled climate data such as GCM. This approach is appropriate because to retain integrity of the climate data, the future climate scenario must have temperature data that corresponds to precipitation data, which is ensured by using historical data. A similar approach using historical data instead of using future climate predictions is used by Metropolitan Water District of Southern California to evaluate its region's future water supply reliability (MWD, 2016).

As discussed in our revised scope of work for fiscal year 2016-2017 approved by the MGA Board, downscaling one or more GCM scenarios to develop additional climate change scenarios has been re-prioritized for implementation in 2017. This is still recommended because the GCMs predict temperatures warmer than even the warmest years on record.

2.0 CLIMATE DATASETS

2.1 SANTA CRUZ CO-OP STATION

The Santa Cruz Co-op station has climate data available from January 1893 through present. Figure 1 shows the average annual temperature ranges and overall average for Water Years 1894 through 2016. It is visually evident that minimum temperatures have been higher since 1977. Maximum temperatures do not show the same trend, perhaps because of the moderating influence of the ocean. Expectedly, average annual temperatures also show an increase but of a lower magnitude than the minimum temperature increase due to more stable maximum temperatures. Water Years 2013 through 2016 have four of the five hottest average annual temperatures in the record. Table 1 illustrates that post-1977, average annual temperatures at the Santa Cruz Co-op station are 1.3° F warmer than before 1977. The 1985-2015 average for the model calibration period is also shown.

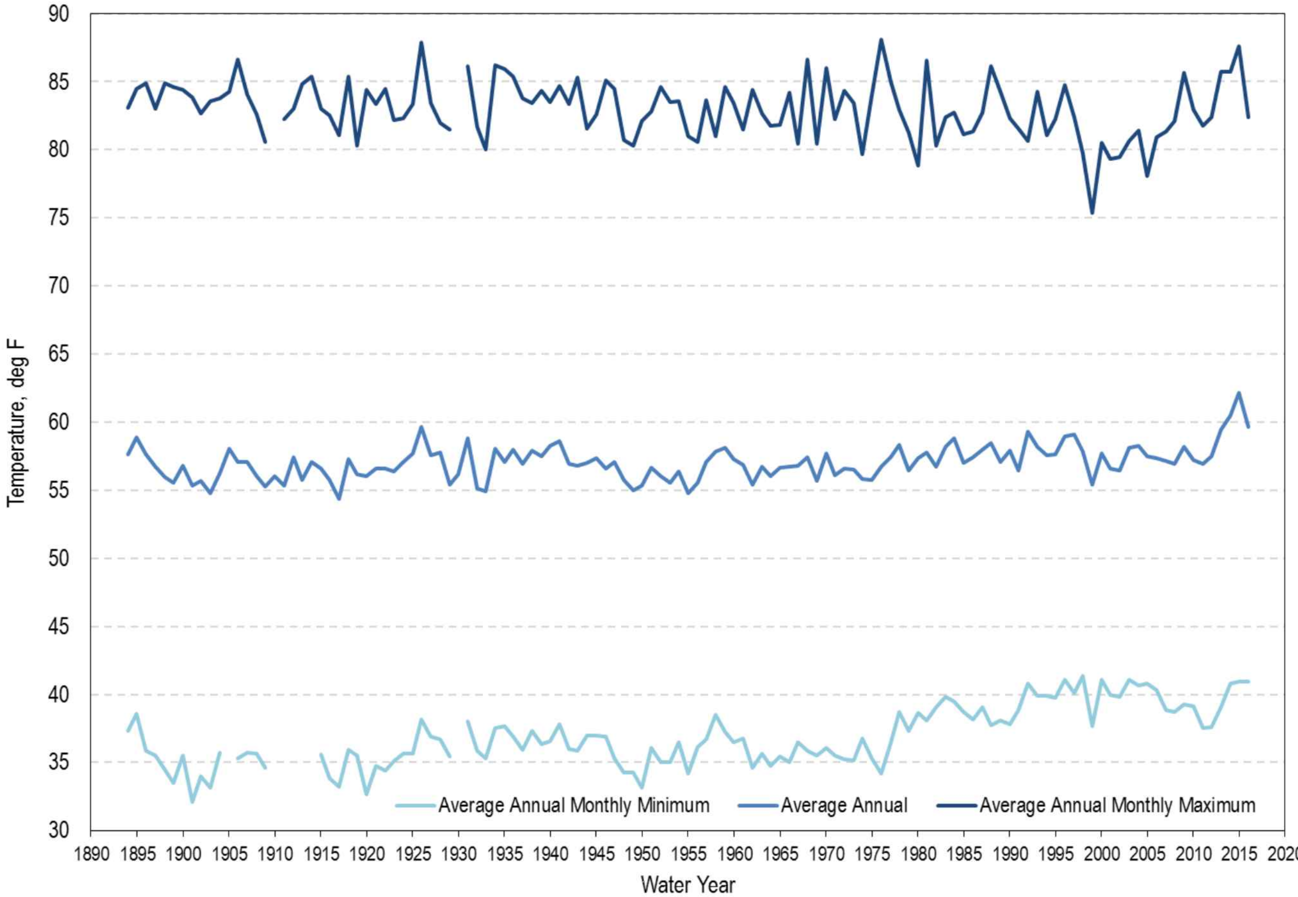


Figure 1: Measured Minimum, Maximum, and Average Annual Temperatures at the Santa Cruz Co-op Station

Table 1: Santa Cruz Co-op Station Average Annual Temperatures for Selected Periods

Annual Temperature, °F	
1985-2015 Average	57.9
1977-2016 Average	57.9
Pre-1977 Average	56.6
1894-2016 Average	57.0

Figure 2 presents the annual precipitation recorded at the Santa Cruz Co-op station. The average annual precipitation for various periods of interest are provided in Table 2. Although the chart on Figure 2 does not show any discernible trends, the averages in Table 2 indicate that pre-1977 precipitation was very slightly lower than that experienced from 1977 onwards. In general however, the data do not show a trend that is visually evident like temperature.

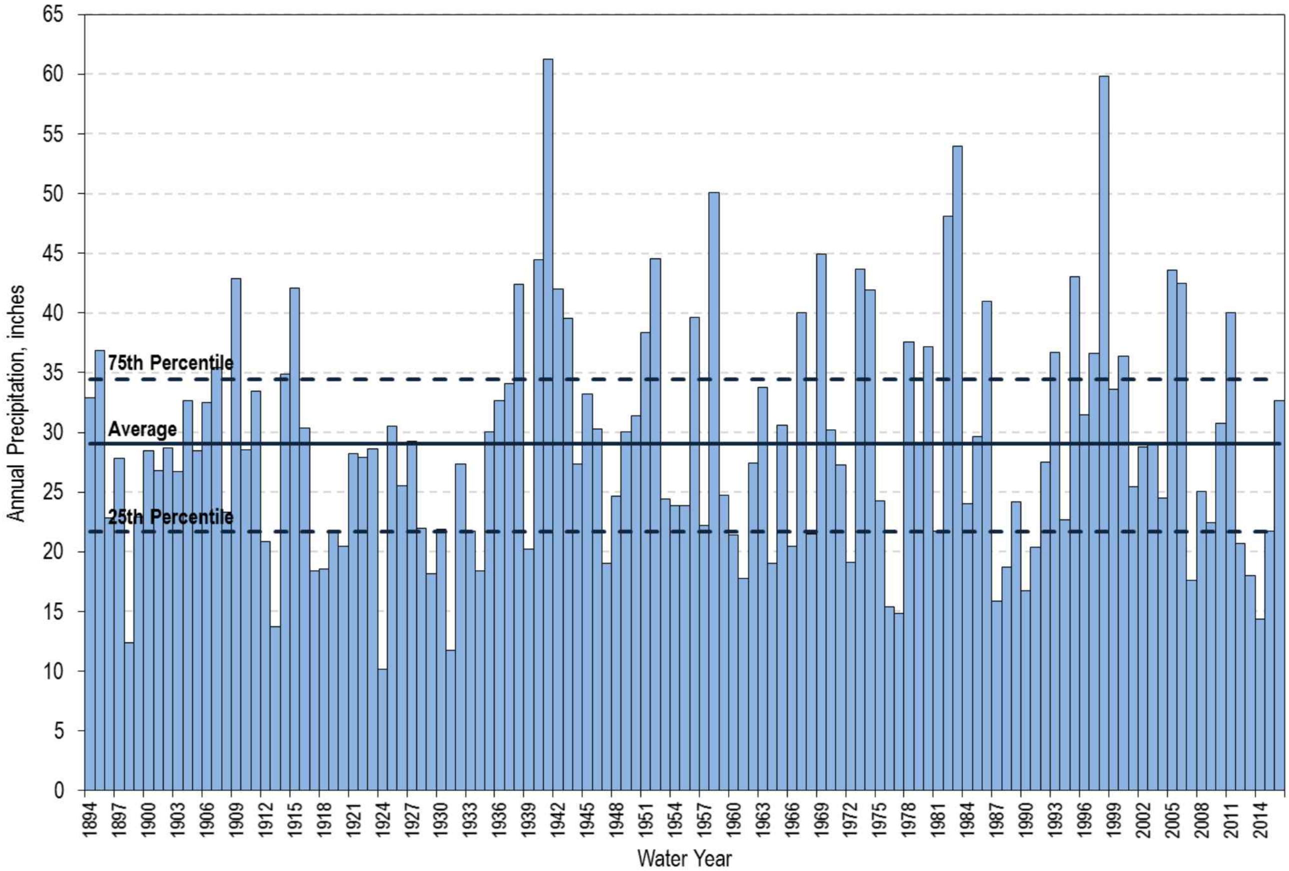


Figure 2: Annual Precipitation at the Santa Cruz Co-op Station

Table 2: Santa Cruz Co-op Station Average Precipitation for Selected Periods

Annual Precipitation, inches	
1985-2015 Average	29.0
1977-2016 Average	30.0
Pre-1977 Average	28.7
1894-2016 Average	29.1

2.2 WATSONVILLE WATERWORKS STATION

The Watsonville Waterworks station has climate data available from January 1908 through present. Figure 3 shows average annual temperature ranges and overall average for Water Years 1909 through 2016; note there were a number of missing records in the monthly data used to generate the annual averages; therefore those years are not included on the chart. The line showing minimum temperatures has a clear increasing trend over the period of record, with a slight jump in temperatures from 1977 onwards where minimum temperatures mostly remain consistently above pre-1977 temperatures. At this station, maximum temperatures also show an increasing trend like minimum temperatures but they are more muted. The Watsonville Waterworks station is 4.5 miles from the ocean compared to the Santa Cruz Co-op station which is two miles from the ocean, and has less effects from the ocean. Average annual temperatures also show a noticeable increase after 1977. Table 4 illustrates that post-1977, average annual temperatures at the Watsonville Waterworks station are 1.7 °F warmer than before 1977.

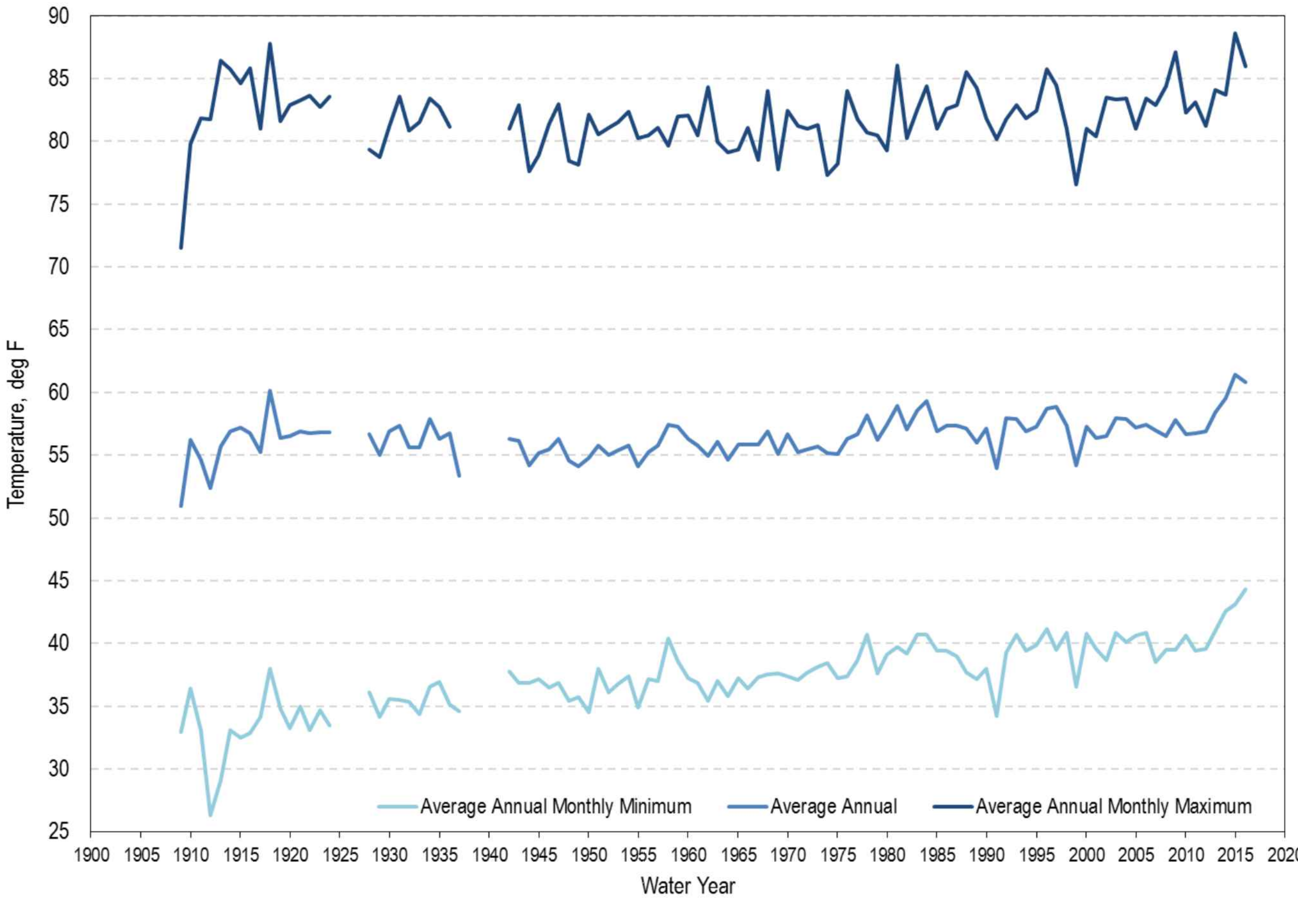


Figure 3: Measured Minimum, Maximum, and Average Annual Temperatures at the Watsonville Waterworks Station

Table 3: Watsonville Waterworks Station Average Annual Temperatures for Selected Periods

Annual Temperature, °F	
1985-2015 Average	57.3
1977-2016 Average	57.5
Pre-1977 Average	55.8
1894-2016 Average	56.5

Figure 4 presents the annual precipitation recorded at the Watsonville Waterworks station. The average annual precipitation for various periods of interest are provided in Table 4. The data suggest that since the 1980s, there has been an increase in the amount of precipitation at this station. This is confirmed in Table 4 where post-1977 precipitation is 2.8 inches more than before 1977.

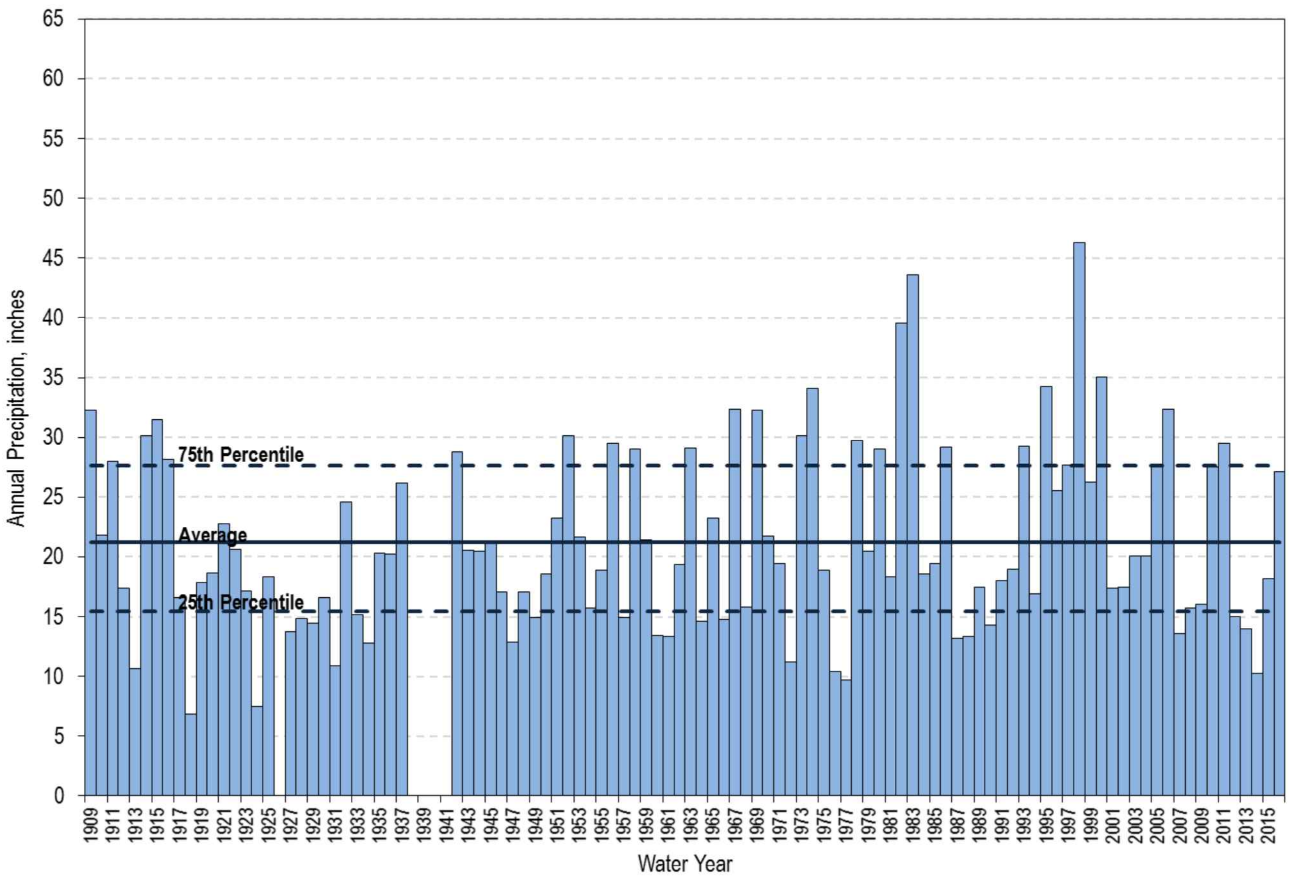


Figure 4: Annual Precipitation at the Watsonville Waterworks Station

Table 4: Watsonville Waterworks Station Average Precipitation for Selected Periods

Annual Precipitation, inches	
1985-2015 Average	21.9
1977-2015 Average	22.9
Pre-1977 Average	20.1
1909-2015 Average	21.2

3.0 APPROACH

3.1 CLIMATE CATALOG

Using the general method for creating a catalog of each historical year suggested by Prof. Andrew Fisher (Young, 2016), exceedance probabilities (p) for both temperature and precipitation are calculated using the following equation for the full dataset on record for the climate station:

$$p = \frac{m}{n+1}$$

where m is the rank based on total precipitation or temperature (from largest to smallest), and n is the total number of years in the dataset. A chart of exceedance probabilities for temperature and precipitation at the Santa Cruz Co-op station is provided on Figure 5. The catalog is based on the Santa Cruz Co-op station because the majority of model cells are assigned to it for rainfall distribution in PRMS, the watershed component of the GSFLOW model.

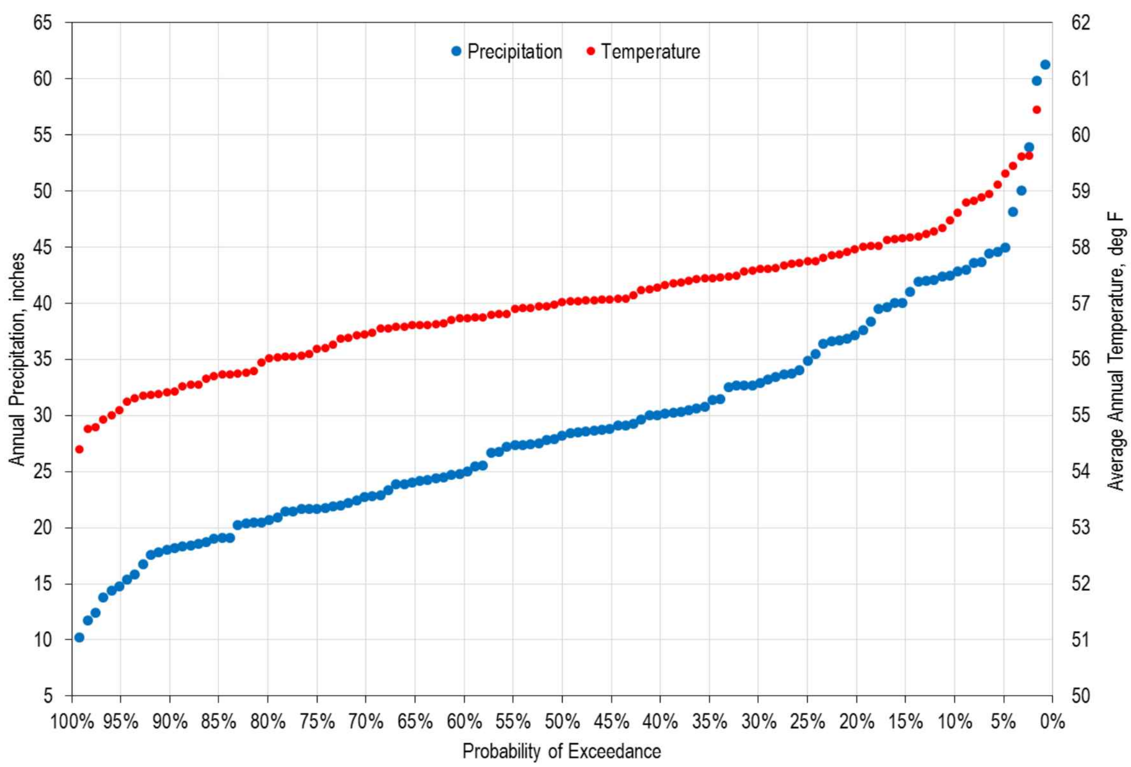


Figure 5: Probability of Exceedance for Annual Precipitation and Average Annual Temperature, Santa Cruz Co-op Station

Figure 6 and Figure 7 graphically show consecutive water years' probabilities of exceedance for temperature and precipitation at the Santa Cruz Co-op Station, respectively. Figure 6, similar to Figure 1, shows that since 1977, there has been an increased number of years that have less than a 50% probability of exceedance, i.e., warmer than the rest of the record. Figure 7 shows no visual trend towards either decreasing or increasing precipitation over time like temperature does.

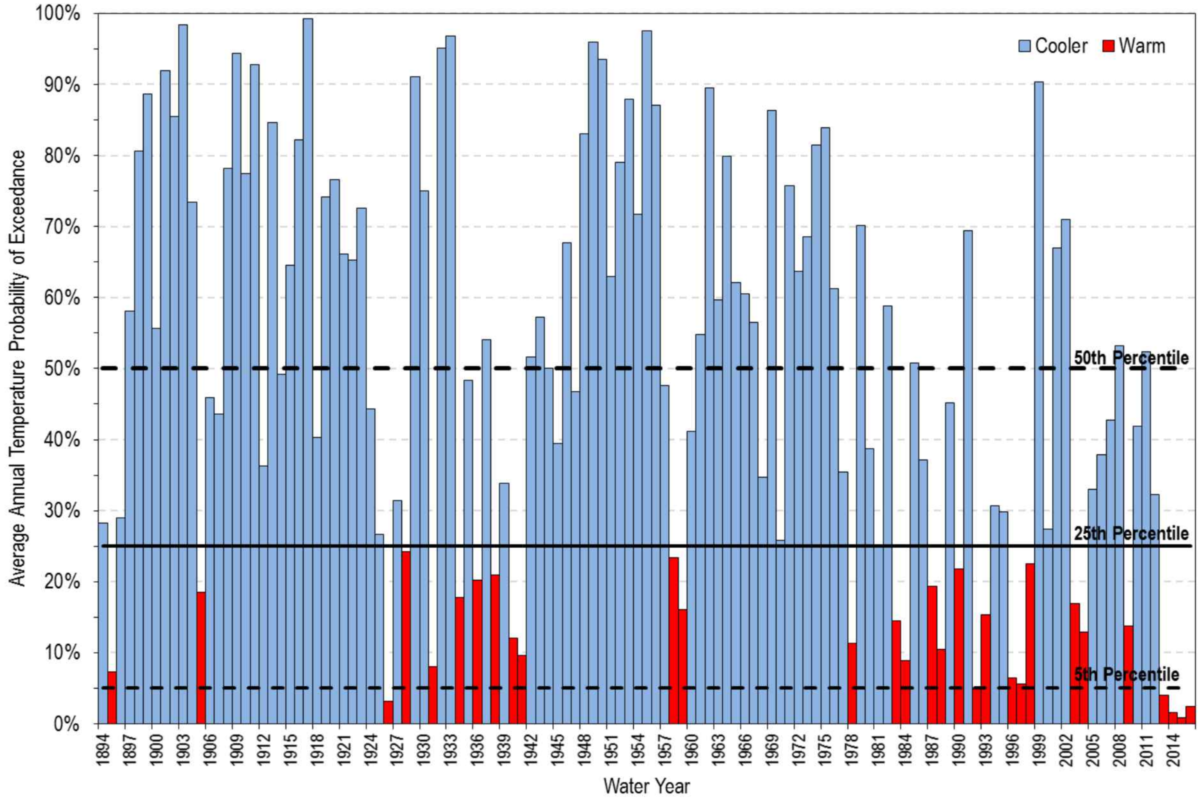


Figure 6: Average Annual Temperature Probability of Exceedance for the Santa Cruz Co-op Station

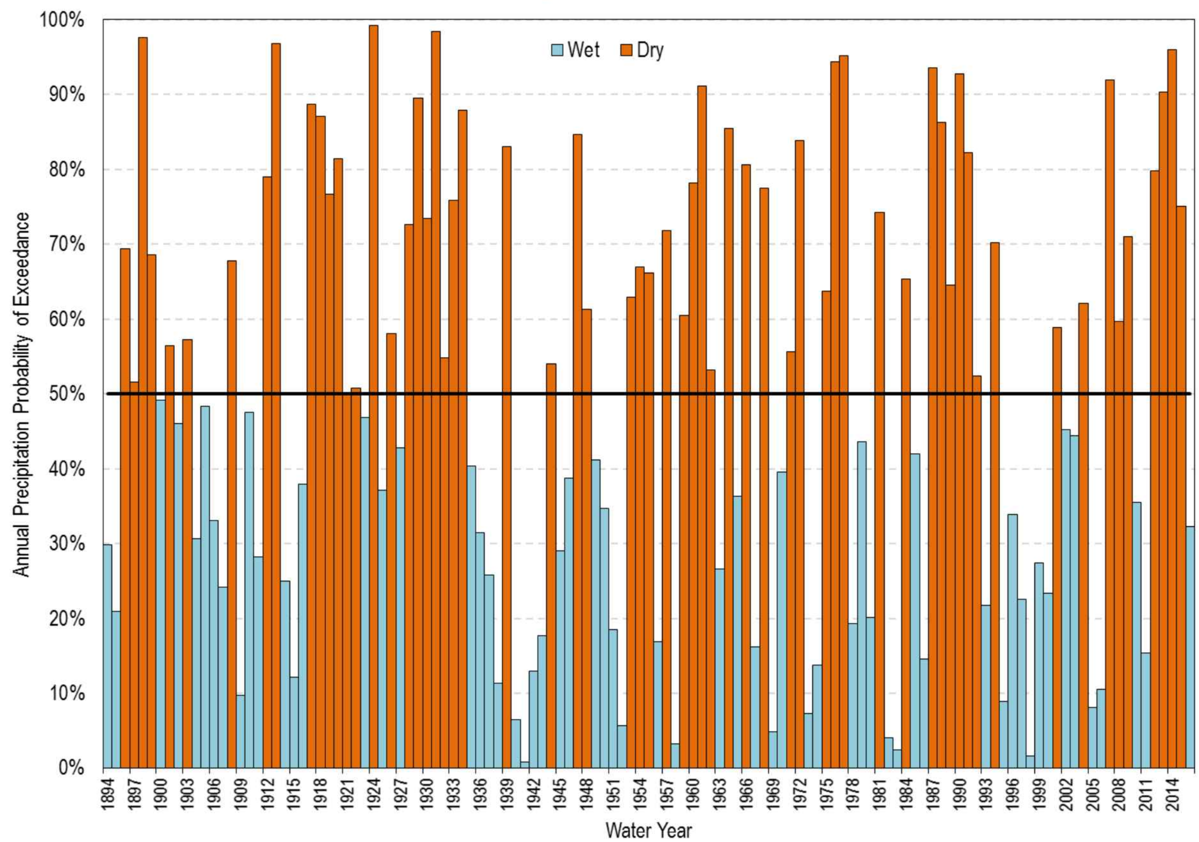


Figure 7: Annual Precipitation Probability of Exceedance for the Santa Cruz Co-op Station

Another way to visualize the climate data based on probabilities of exceedance is to classify each water year according to a combination of temperature and precipitation probabilities shown in Table 5. Appendix A provides the probabilities for all water years on record for the Santa Cruz Co-op Station, and Figure 8 presents the historical data color-coded by classification plotted against precipitation.

Table 5: Classification of Probabilities

Probability of Exceedance		Category
Precipitation	Average Temperature	
>= 50%	< 25%	Warm and Dry
< 50%	< 25%	Warm and Wet
< 50%	>= 25%	Cooler and Wet
>= 50%	>= 25%	Cooler and Dry

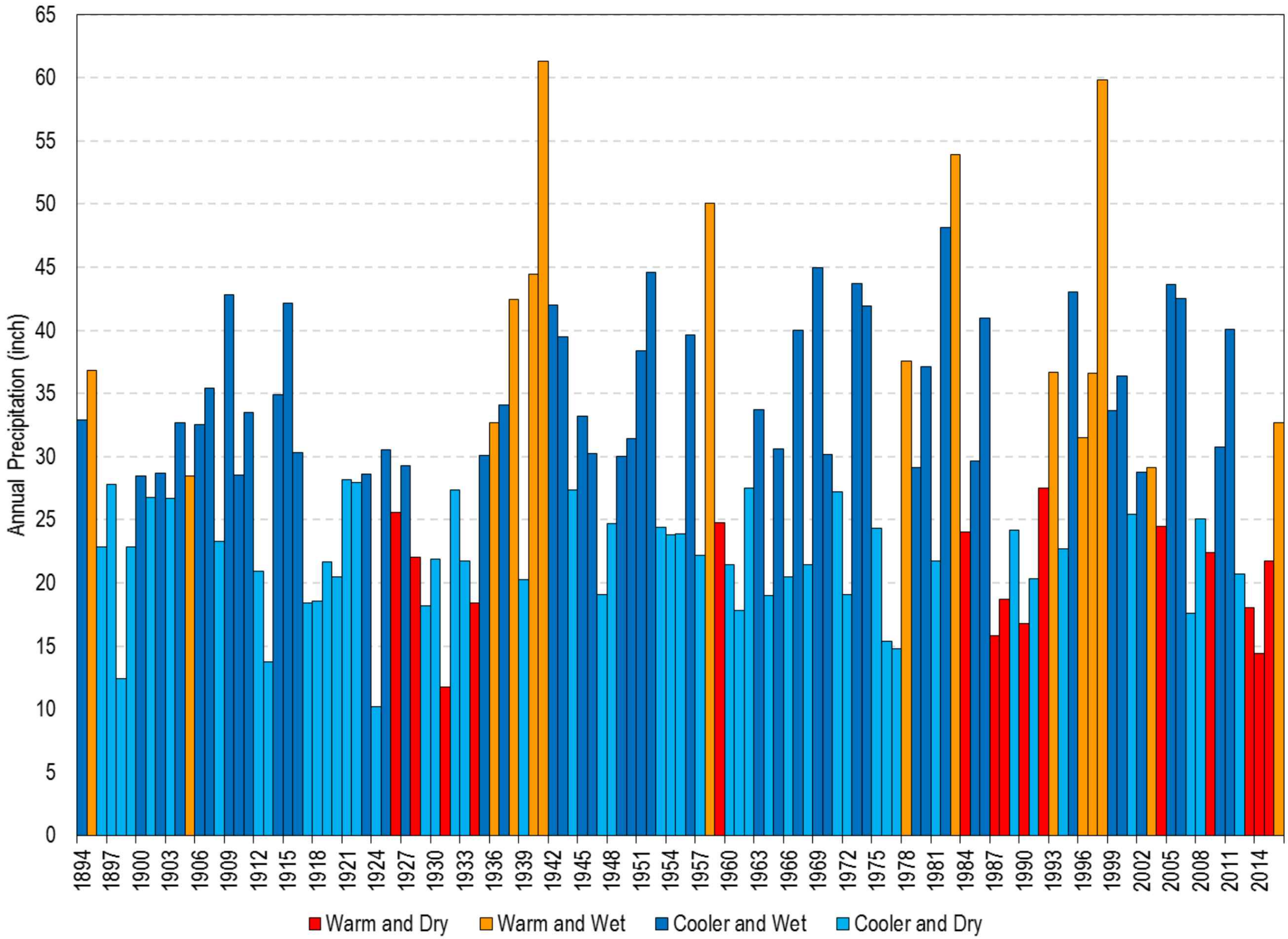


Figure 8: Santa Cruz Co-op Station Classification of Historical Water Years

3.2 FUTURE CLIMATE SCENARIO GENERATION

The future climate scenario will cover Water Years 2016-2069. This time span is selected to meet the requirement in California Department of Water Resources regulations for Groundwater Sustainability Plans (GSP) to evaluate sustainability for future climate over fifty years. Fifty years after the 2020 GSP deadline for the critically overdrafted Santa Cruz Mid-County Groundwater Basin goes through Water Year 2069. Water Year 2016 will be simulated based on recorded climate data using initial conditions from the end of the calibrated model run of Water Years 1985-2015. The 53 water years 2017-2069 will be simulated using the approach described below.

As temperature shows a much more evident trend than precipitation, the catalog of annual average temperature at the Santa Cruz Co-op station is used to generate one future climate scenario. First, a subset of historic climate is selected to form a catalog from which to generate the future climate scenario. The catalog of years selected are all the years from 1977 to 2016 representing the most recent period where warming has been observed, plus six additional years from 1909[1] to 1977 that have a temperature probability of exceedance of 25% or less, i.e., the warmest years and that don't have entire months of missing temperature data in the Watsonville Waterworks station record. See bold records in Appendix A for those years included in the catalog.

The catalog is then randomly ordered using the Random Number Generator in Excel to generate the scenario. The Random Number Generator uses weights applied to each water year to ensure a pre-determined distribution of temperature exceedance probabilities results from the process. Weights are assigned by categories of exceedance probabilities for temperature shown in Table 6. For example, the warmest category (<5% exceedance probability) is given a 50% weight and includes Water Years 1992, and 2013-2016. Warmer years are given greater weights than cooler years to ensure an overall warmer scenario is generated.

[1] Water Year 1909 was selected because this is the first water year for the Watsonville Waterworks station climate records. If we used prior years, there would be no climate data for the Watsonville Waterworks station for the future climate scenario for those years.

Table 6: Weights Assigned to Catalog of Water Years Based on Temperature Exceedance Probabilities

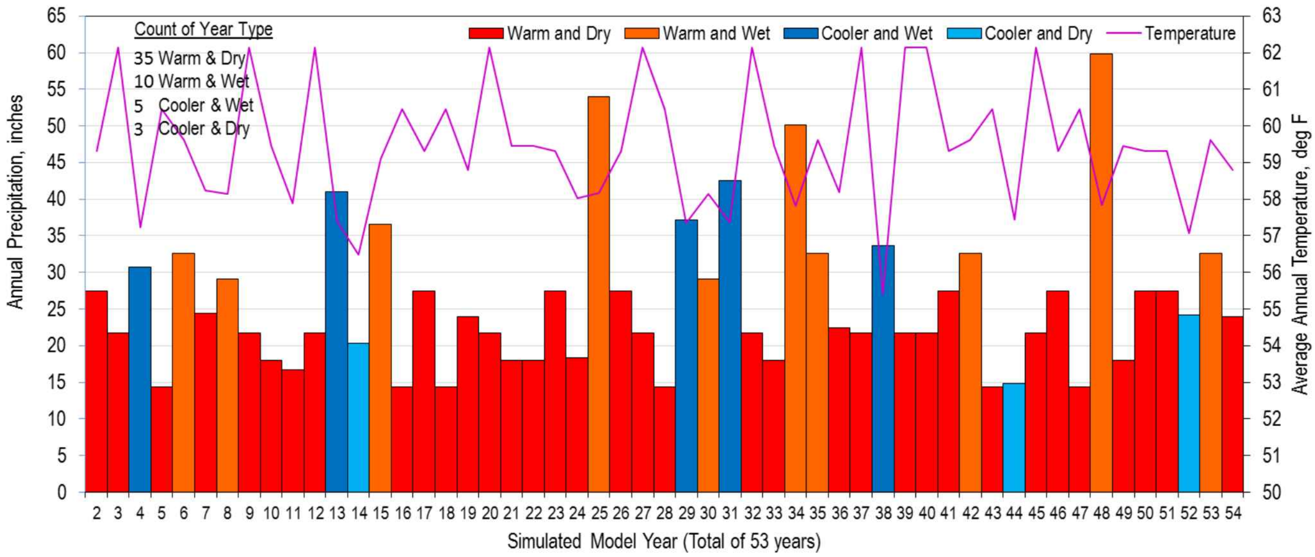
Exceedance Probability Category	Weight
< 5%	0.5
5 – 25%	0.3
>=25 – 50%	0.1
> = 50%	0.1

After the water year sequence is selected based on the Santa Cruz Co-op temperature data, climate data for the future climate scenario for the Watsonville Waterworks station is selected based on the same water year sequence. Climate data for both the Santa Cruz Co-op and Watsonville Waterworks stations are input into the GSFLOW model.

4.0 PROPOSED CLIMATE SCENARIOS

4.1 TEMPERATURE WEIGHTED

The first scenario is generated using the temperature weights shown in Table 6 and the Random Number Generator to arrive at a sequence of 53 water years with an average temperature that is as high as we could get without manually selecting the warmest years. Figure 9 shows the color-coded distribution of water years for the Santa Cruz Co-op station representing a potential future climate scenario that is on average 2.4 °F warmer than the long-term average and 1.6 °F warmer than the average annual temperature from 1977-2016. The scenario also has 3.1 inches less precipitation per year than the long-term historical average as 4 of the 5 hottest years used for 50% of the scenario are dry years. Appendix B provides a list of the randomly selected historic years generated for this scenario.

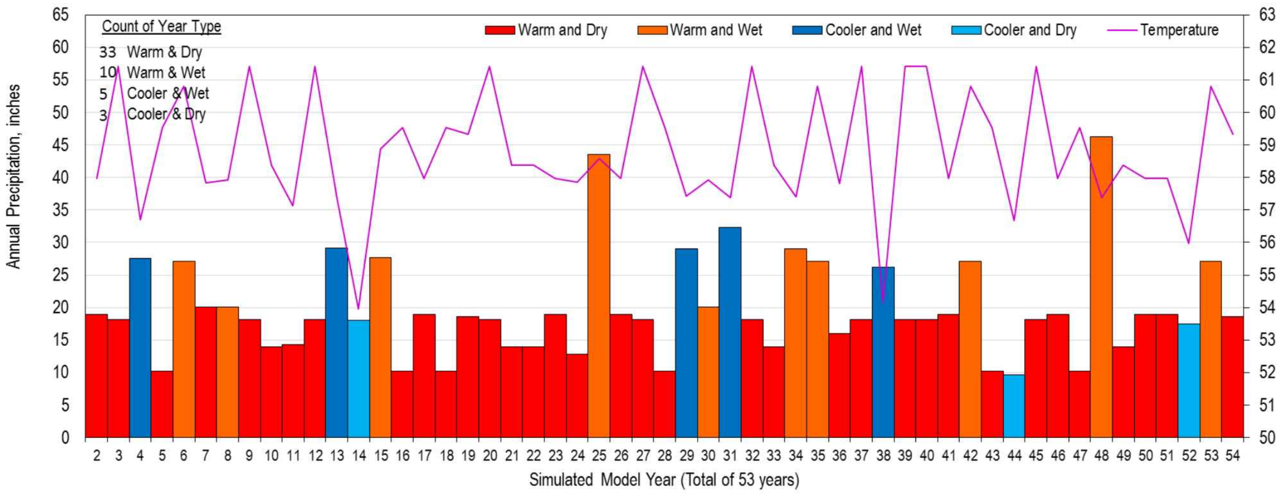


Annual Temperature, deg F	
Scenario Average	59.4
1985-2015 Average	57.9
1977-2016 Average	57.8
Pre-1977 Average	56.6
1894-2016 Average	57.0

Annual Precipitation, inches	
Scenario Average	26.0
1985-2015 Average	29.0
1977-2016 Average	29.9
Pre-1977 Average	28.7
1894-2016 Average	29.1

Figure 9: Temperature Weighted Climate Scenario for Santa Cruz Co-op Station

Using the same sequence of 53 water years used for the Santa Cruz Co-op station temperature weighted climate scenario. Figure 10 shows a potential future climate scenario for the Watsonville Waterworks station that is on average 2.4 °F warmer than the long-term average and 1.4°F warmer than the average annual temperature from 1977-2016. The scenario also has 1.3 inches less precipitation per year than the long-term historical average.



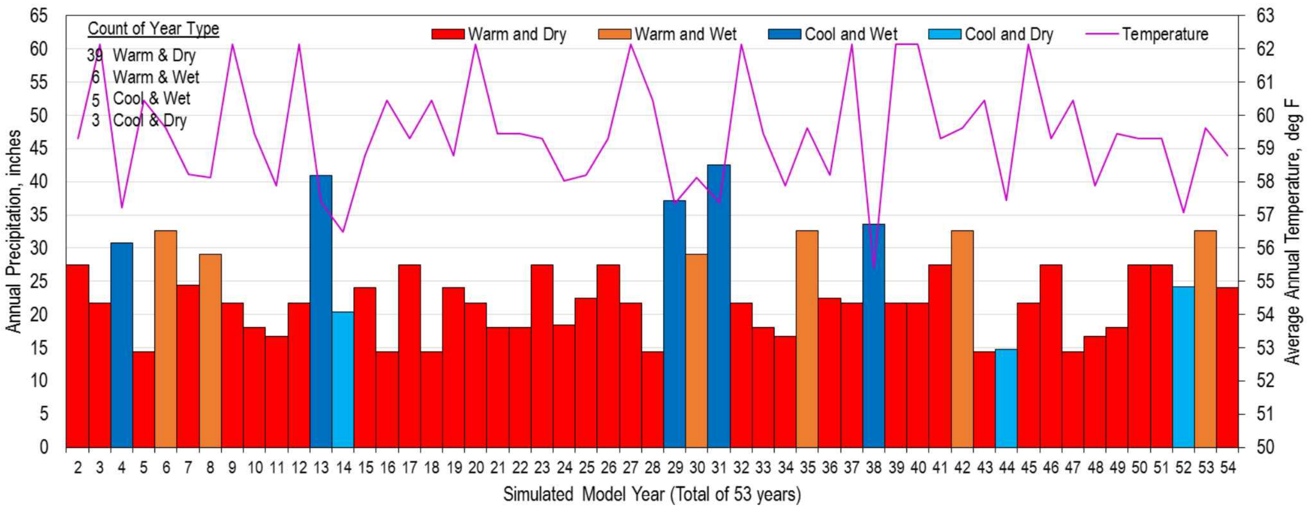
Annual Temperature, deg F	
Scenario Average	58.8
1985-2015 Average	57.3
1977-2016 Average	57.4
Pre-1977 Average	55.8
1894-2016 Average	56.4

Annual Precipitation, inches	
Scenario Average	19.8
1985-2015 Average	21.9
1977-2016 Average	22.8
Pre-1977 Average	20.1
1894-2016 Average	21.1

Figure 10: Temperature Weighted Climate Scenario for Watsonville Waterworks Station

4.2 TEMPERATURE WEIGHTED AND PRECIPITATION ADJUSTED

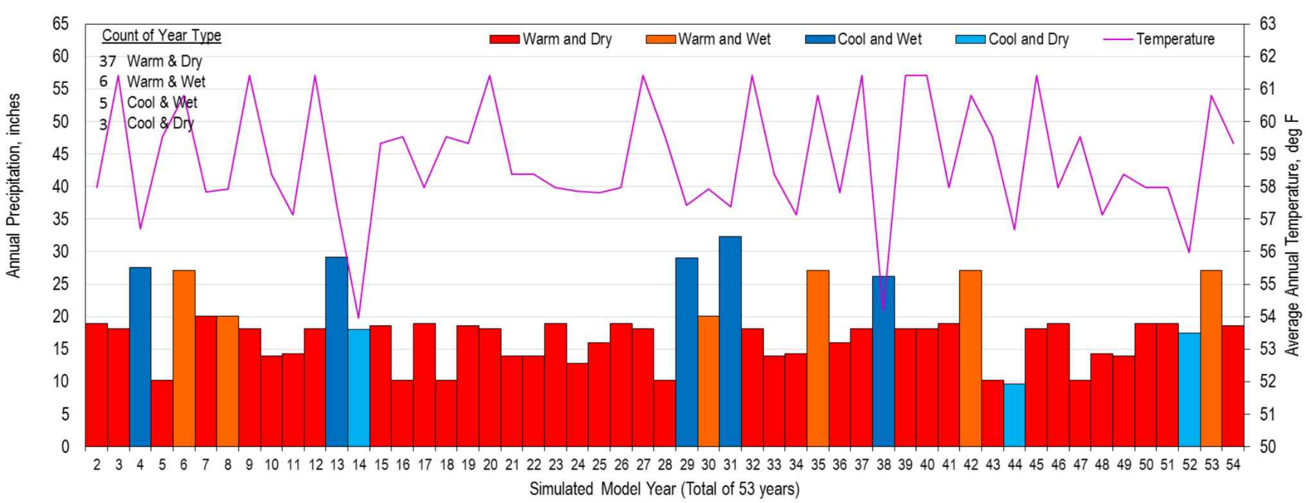
Although there is no trend of decreased precipitation in the Santa Cruz area, a drier scenario than that generated by weighting temperature only is also generated for consideration. We avoided randomly generating a new dataset based on both temperature and precipitation weights as we want a scenario that we can compare with the temperature weighted climate scenario. To arrive at this scenario, we start with the temperature weighted scenario and then adjust the four wettest "Warm and Wet" years to "Warm and Dry" by substituting the "Warm and Wet" years with "Warm and Dry" years with similar temperatures but less precipitation. Figure 11 shows the color-coded distribution of water years for the Santa Cruz Co-op station representing a potential future climate scenario that has the same average temperature as the temperature weighted scenario but has 5.4 inches less precipitation per year than the long-term average. Appendix B provides a list of the randomly selected historic years generated for this scenario. Figure 12 shows this potential future climate scenario applied to the Watsonville Waterworks station that results in the same average temperature as the temperature weighted scenario but has 2.9 inches less precipitation per year than the long-term average.



Annual Temperature, deg F	
Scenario Average	59.4
1985-2015 Average	57.9
1977-2016 Average	57.8
Pre-1977 Average	56.6
1894-2016 Average	57.0

Annual Precipitation, inches	
Scenario Average	23.7
1985-2015 Average	29.0
1977-2016 Average	29.9
Pre-1977 Average	28.7
1894-2016 Average	29.1

Figure 11: Temperature Weighted Climate Scenario for Santa Cruz Co-op Station with Decreased Precipitation Adjustment



Annual Temperature, deg F	
Scenario Average	58.8
1985-2015 Average	57.3
1977-2016 Average	57.4
Pre-1977 Average	55.8
1894-2016 Average	56.4

Annual Precipitation, inches	
Scenario Average	18.2
1985-2015 Average	21.9
1977-2016 Average	22.8
Pre-1977 Average	20.1
1894-2016 Average	21.1

Figure 12: Temperature Weighted Climate Scenario for Watsonville Waterworks with Decreased Precipitation Adjustment

5.0 Discussion and Limitations

One of the two scenarios presented in this memo will be selected to run simulations using the GSFLOW model. The selection will be made based on input from MGA member agency staff, the model Technical Advisory Committee, and possibly the MGA Board.

This approach of using historical climate allows us to generate climate scenarios that are warmer than the past 40 years but it does not increase temperatures to the degree that some of the GCMs predict global warming. For example, GCMs (Flint and Flint, 2014) have been downscaled to the San Lorenzo-Soquel Basin, which includes the Santa Cruz Mid-County Groundwater Basin. The downscaled predictions include warming of up to 4.1 °F (GFDL A2, a moderately warmer, drier future) and 6.2°F (MIROC-esm RCP 8.5, the warmest, driest future) over our simulated model period (54 years from Water Year 2016 – 2069). It is important to note that these GCM predicted temperatures are for minimum temperatures which, as shown above, tend to have a greater increase than average temperatures. We used average temperature in our analysis. Additionally, the GCM downscaled predictions are for the entire San Lorenzo-Soquel Basin which extends much farther inland than the Santa Cruz Co-op and Watsonville Waterworks stations.

Assigning lower weights to the "Cooler and dry" and "Cooler and wet" classifications will raise the scenario's average temperature slightly but still not as high as those in the GCMs described above because the hottest years in the historical record are not as hot as what is projected by the GCMs.

Simulating GCM projections will require downscaling GCM results to the Santa Cruz Co-op and Watsonville Waterworks stations for distribution to the model grid by the PRMS watershed component of GSFLOW. The USGS has recommended that the Jensen-Haise formulation for potential evapotranspiration used in the model be changed to Priestly-Taylor or Penman-Monteith when using hotter GCM projections. The Priestly-Taylor and Penman-Monteith evapotranspiration formulations have only recently been added to PRMS so will take additional work to implement with the likelihood of issues implementing new capabilities. Therefore, we will use one of the scenarios described in this memo to represent future climate to perform the initial evaluation of groundwater management alternatives. Implementation of downscaled GCM projections has been re-prioritized to 2017.

This approach also does not project trends for temporal precipitation patterns as previously evaluated by Daniels (2014)[2]. Daniels identified long-term trends in storm intensity, duration, and pauses between storms and assessed effects on groundwater recharge and streamflow of those trends projected into the future. Since those projections are not part of the historical record, they are not part of the climate scenario described in this memo. However, 83% of historical years randomly selected for the future climate scenario in this memo are from 1990-2016, so the historical trends for these patterns are reflected in the scenario.

[2] Dr. Bruce Daniels is Board President of Soquel Creek Water District, a member of the Santa Cruz Mid-County Agency that is funding development of this GSFLOW model. Dr. Daniels also serves on the Technical Advisory Committee for this model.

6.0 REFERENCES

Daniels, B.K. 2014. *Hydrologic response to climate change in California: observational and modeling studies.* Ph.D. dissertation, University of California, Santa Cruz. December.

Flint L.E. and A.L. Flint. 2014. *California basin characterization model: a dataset of historical and future hydrologic response to climate change*, U.S. Geological Survey Data Release, doi:10.5066/F76T0JPB

Metropolitan Water District of Southern California (MWD). 2016. *Integrated Water Resources Plan, 2015 Update*. Report No. 1518. January.

Young, K. 2016. *A high-resolution, regional-scale analysis of stormwater runoff in the San Lorenzo river basin for managed aquifer recharge decision making*. Masters of Science Thesis, University of California, Santa Cruz. June.

Appendix A

Santa Cruz Co-op Station Exceedance Probabilities with Year Type Classification

Water Year	Temperature			Precipitation			Classification 1 = Warm & dry 2 = Warm & wet 3 = Cooler & dry 4 = Cooler & wet
	Average (°F)	Rank	Probability of Exceedance	Total (inches)	Rank	Probability of Exceedance	
1894	57.6	35	28.2%	32.9	37	29.8%	3
1895	58.9	9	7.3%	36.8	26	21.0%	2
1896	57.6	36	29.0%	22.9	86	69.4%	4
1897	56.8	72	58.1%	27.8	64	51.6%	4
1898	55.9	100	80.6%	12.4	121	97.6%	4
1899	55.5	110	88.7%	22.9	85	68.5%	4
1900	56.8	69	55.6%	28.4	61	49.2%	3
1901	55.4	114	91.9%	26.8	70	56.5%	4
1902	55.7	106	85.5%	28.7	57	46.0%	3
1903	54.8	122	98.4%	26.7	71	57.3%	4
1904	56.3	91	73.4%	32.7	38	30.6%	3
1905	58.0	23	18.5%	28.5	60	48.4%	2
1906	57.1	57	46.0%	32.5	41	33.1%	3
1907	57.1	54	43.5%	35.5	30	24.2%	3
1908	56.0	97	78.2%	23.3	84	67.7%	4
1909	55.2	117	94.4%	42.9	12	9.7%	3
1910	56.1	96	77.4%	28.6	59	47.6%	3
1911	55.3	115	92.7%	33.5	35	28.2%	3
1912	57.4	45	36.3%	20.9	98	79.0%	4
1913	55.7	105	84.7%	13.8	120	96.8%	4
1914	57.0	61	49.2%	34.9	31	25.0%	3
1915	56.6	80	64.5%	42.1	15	12.1%	3
1916	55.8	102	82.3%	30.4	47	37.9%	3
1917	54.4	123	99.2%	18.4	110	88.7%	4
1918	57.3	50	40.3%	18.6	108	87.1%	4
1919	56.2	92	74.2%	21.7	95	76.6%	4
1920	56.1	95	76.6%	20.5	101	81.5%	4
1921	56.6	82	66.1%	28.2	62	50.0%	4
1922	56.6	81	65.3%	27.9	63	50.8%	4
1923	56.4	90	72.6%	28.6	58	46.8%	3
1924	57.1	55	44.4%	10.2	123	99.2%	4
1925	57.7	33	26.6%	30.5	46	37.1%	3
1926	59.6	4	3.2%	25.6	72	58.1%	1
1927	57.6	39	31.5%	29.3	53	42.7%	3

Water Year	Temperature: Average (°F)	Temperature: Rank	Temperature: Probability of Exceedance	Precipitation: Total (inches)	Precipitation: Rank	Precipitation: Probability of Exceedance	Classification 1 = Warm & dry 2 = Warm & wet 3 = Cooler & dry 4 = Cooler & wet
1928	**57.8**	**30**	**24.2%**	**22.0**	**90**	**72.6%**	1
1929	55.4	113	91.1%	18.2	111	89.5%	4
1930	56.2	93	75.0%	21.9	91	73.4%	4
1931	**58.8**	**10**	**8.1%**	**11.7**	**122**	**98.4%**	1
1932	55.1	118	95.2%	27.4	68	54.8%	4
1933	54.9	120	96.8%	21.7	94	75.8%	4
1934	**58.0**	**22**	**17.7%**	**18.4**	**109**	**87.9%**	1
1935	57.0	60	48.4%	30.1	50	40.3%	3
1936	**58.0**	**25**	**20.2%**	**32.7**	**39**	**31.5%**	2
1937	56.9	67	54.0%	34.1	32	25.8%	3
1938	57.9	26	21.0%	42.4	14	11.3%	2
1939	57.5	42	33.9%	20.2	103	83.1%	4
1940	58.3	15	12.1%	44.5	8	6.5%	2
1941	58.6	12	9.7%	61.3	1	0.8%	2
1942	57.0	64	51.6%	42.0	16	12.9%	3
1943	56.8	71	57.3%	39.5	22	17.7%	3
1944	57.0	62	50.0%	27.4	67	54.0%	4
1945	57.3	49	39.5%	33.2	36	29.0%	3
1946	56.6	84	67.7%	30.3	48	38.7%	3
1947	57.1	58	46.8%	19.1	105	84.7%	4
1948	55.7	103	83.1%	24.7	76	61.3%	4
1949	55.0	119	96.0%	30.0	51	41.1%	3
1950	55.3	116	93.5%	31.4	43	34.7%	3
1951	56.6	78	62.9%	38.4	23	18.5%	3
1952	56.0	98	79.0%	44.6	7	5.6%	3
1953	55.6	109	87.9%	24.4	78	62.9%	4
1954	56.4	89	71.8%	23.8	83	66.9%	4
1955	54.8	121	97.6%	23.9	82	66.1%	4
1956	55.6	108	87.1%	39.7	21	16.9%	3
1957	57.0	59	47.6%	22.2	89	71.8%	4
1958	**57.8**	**29**	**23.4%**	**50.1**	**4**	**3.2%**	2
1959	**58.1**	**20**	**16.1%**	**24.8**	**75**	**60.5%**	1
1960	57.3	51	41.1%	21.4	97	78.2%	4
1961	56.9	68	54.8%	17.8	113	91.1%	4
1962	55.4	111	89.5%	27.5	66	53.2%	4
1963	56.7	74	59.7%	33.7	33	26.6%	3
1964	56.0	99	79.8%	19.0	106	85.5%	4
1965	56.6	77	62.1%	30.6	45	36.3%	3
1966	56.7	75	60.5%	20.5	100	80.6%	4
1967	56.8	70	56.5%	40.0	20	16.1%	3

Water Year	Temperature Average (°F)	Temperature Rank	Temperature Probability of Exceedance	Precipitation Total (inches)	Precipitation Rank	Precipitation Probability of Exceedance	Classification 1 = Warm & dry 2 = Warm & wet 3 = Cooler & dry 4 = Cooler & wet
1968	57.4	43	34.7%	21.5	96	77.4%	4
1969	55.7	107	86.3%	44.9	6	4.8%	3
1970	57.7	32	25.8%	30.2	49	39.5%	3
1971	56.1	94	75.8%	27.2	69	55.6%	4
1972	56.6	79	63.7%	19.1	104	83.9%	4
1973	56.5	85	68.5%	43.7	9	7.3%	3
1974	55.8	101	81.5%	42.0	17	13.7%	3
1975	55.7	104	83.9%	24.3	79	63.7%	4
1976	56.7	76	61.3%	15.4	117	94.4%	4
1977	**57.4**	**44**	**35.5%**	**14.8**	**118**	**95.2%**	**4**
1978	**58.3**	**14**	**11.3%**	**37.6**	**24**	**19.4%**	**2**
1979	**56.5**	**87**	**70.2%**	**29.2**	**54**	**43.5%**	**3**
1980	**57.4**	**48**	**38.7%**	**37.1**	**25**	**20.2%**	**3**
1981	**57.7**	**31**	**25.0%**	**21.7**	**92**	**74.2%**	**4**
1982	**56.7**	**73**	**58.9%**	**48.1**	**5**	**4.0%**	**3**
1983	**58.2**	**18**	**14.5%**	**53.9**	**3**	**2.4%**	**2**
1984	**58.8**	**11**	**8.9%**	**24.0**	**81**	**65.3%**	**1**
1985	**57.0**	**63**	**50.8%**	**29.7**	**52**	**41.9%**	**3**
1986	**57.4**	**46**	**37.1%**	**41.0**	**18**	**14.5%**	**3**
1987	**58.0**	**24**	**19.4%**	**15.9**	**116**	**93.5%**	**1**
1988	**58.5**	**13**	**10.5%**	**18.7**	**107**	**86.3%**	**1**
1989	**57.1**	**56**	**45.2%**	**24.2**	**80**	**64.5%**	**4**
1990	**57.9**	**27**	**21.8%**	**16.8**	**115**	**92.7%**	**1**
1991	**56.5**	**86**	**69.4%**	**20.4**	**102**	**82.3%**	**4**
1992	**59.3**	**6**	**4.8%**	**27.5**	**65**	**52.4%**	**1**
1993	**58.2**	**19**	**15.3%**	**36.7**	**27**	**21.8%**	**2**
1994	**57.6**	**38**	**30.6%**	**22.7**	**87**	**70.2%**	**4**
1995	**57.6**	**37**	**29.8%**	**43.0**	**11**	**8.9%**	**3**
1996	**59.0**	**8**	**6.5%**	**31.5**	**42**	**33.9%**	**2**
1997	**59.1**	**7**	**5.6%**	**36.6**	**28**	**22.6%**	**2**
1998	**57.9**	**28**	**22.6%**	**59.8**	**2**	**1.6%**	**2**
1999	**55.4**	**112**	**90.3%**	**33.7**	**34**	**27.4%**	**3**
2000	**57.7**	**34**	**27.4%**	**36.4**	**29**	**23.4%**	**3**
2001	**56.6**	**83**	**66.9%**	**25.5**	**73**	**58.9%**	**4**
2002	**56.4**	**88**	**71.0%**	**28.8**	**56**	**45.2%**	**3**
2003	**58.1**	**21**	**16.9%**	**29.1**	**55**	**44.4%**	**2**
2004	**58.2**	**16**	**12.9%**	**24.5**	**77**	**62.1%**	**1**
2005	**57.5**	**41**	**33.1%**	**43.6**	**10**	**8.1%**	**3**
2006	**57.4**	**47**	**37.9%**	**42.5**	**13**	**10.5%**	**3**
2007	**57.1**	**53**	**42.7%**	**17.6**	**114**	**91.9%**	**4**

Water Year	Temperature Average (°F)	Temperature Rank	Temperature Probability of Exceedance	Precipitation Total (inches)	Precipitation Rank	Precipitation Probability of Exceedance	Classification 1 = Warm & dry 2 = Warm & wet 3 = Cooler & dry 4 = Cooler & wet
2008	**56.9**	**66**	**53.2%**	**25.0**	**74**	**59.7%**	**4**
2009	**58.2**	**17**	**13.7%**	**22.4**	**88**	**71.0%**	**1**
2010	**57.2**	**52**	**41.9%**	**30.8**	**44**	**35.5%**	**3**
2011	**57.0**	**65**	**52.4%**	**40.1**	**19**	**15.3%**	**3**
2012	**57.5**	**40**	**32.3%**	**20.7**	**99**	**79.8%**	**4**
2013	**59.4**	**5**	**4.0%**	**18.0**	**112**	**90.3%**	**1**
2014	**60.5**	**2**	**1.6%**	**14.4**	**119**	**96.0%**	**1**
2015	**62.2**	**1**	**0.8%**	**21.7**	**93**	**75.0%**	**1**
2016	**59.6**	**3**	**2.4%**	**32.6**	**40**	**32.3%**	**2**

Bold records denote water years included in the catalog for future climate scenario generation

Appendix B

Proposed Climate Scenarios

The Weighted Temperature Scenario with Precipitation Adjustment columns only show those water years where records are manually adjusted to be drier. For the remaining years, data from the Weighted Temperature Scenario apply.

	Weighted Temperature Scenario					Weighted Temperature Scenario with Precipitation Adjustment (Drier)				
		Temperature		Precipitation			Temperature		Precipitation	
Model Water Year	Historic Water Year	Average (°F)	Probability of Exceedance	Average (inches)	Probability of Exceedance	Historic Year if changed	Average (°F)	Probability of Exceedance	Average (inches)	Probability of Exceedance
1	2016	59.6	2.4%	32.6	32.3%					
2	1992	59.3	4.8%	27.5	52.4%					
3	2015	62.2	0.8%	21.7	75.0%					
4	2010	57.2	41.9%	30.8	35.5%					
5	2014	60.5	1.6%	14.4	96.0%					
6	2016	59.6	2.4%	32.6	32.3%					
7	2004	58.2	12.9%	24.5	62.1%					
8	2003	58.1	16.9%	29.1	44.4%					
9	2015	62.2	0.8%	21.7	75.0%					
10	2013	59.4	4.0%	18.0	90.3%					
11	1990	57.9	21.8%	16.8	92.7%					
12	2015	62.2	0.8%	21.7	75.0%					
13	1986	57.4	37.1%	41.0	14.5%					
14	1991	56.5	69.4%	20.4	82.3%					
15	1997	59.1	5.6%	36.6	22.6%	1984	58.8	8.9%	24.0	65.3%
16	2014	60.5	1.6%	14.4	96.0%					
17	1992	59.3	4.8%	27.5	52.4%					
18	2014	60.5	1.6%	14.4	96.0%					
19	1984	58.8	8.9%	24.0	65.3%					
20	2015	62.2	0.8%	21.7	75.0%					
21	2013	59.4	4.0%	18.0	90.3%					
22	2013	59.4	4.0%	18.0	90.3%					
23	1992	59.3	4.8%	27.5	52.4%					
24	1934	58.0	17.7%	18.4	87.9%					
25	1983	58.2	14.5%	53.9	2.4%	2009	58.2	13.7%	22.4	71.0%
26	1992	59.3	4.8%	27.5	52.4%					
27	2015	62.2	0.8%	21.7	75.0%					
28	2014	60.5	1.6%	14.4	96.0%					

Model Water Year	Weighted Temperature Scenario					Weighted Temperature Scenario with Precipitation Adjustment (Drier)				
	Historic Water Year	Temperature		Precipitation		Historic Year if changed	Temperature		Precipitation	
		Average (°F)	Probability of Exceedance	Average (inches)	Probability of Exceedance		Average (°F)	Probability of Exceedance	Average (inches)	Probability of Exceedance
29	1980	57.4	38.7%	37.1	20.2%					
30	2003	58.1	16.9%	29.1	44.4%					
31	2006	57.4	37.9%	42.5	10.5%					
32	2015	62.2	0.8%	21.7	75.0%					
33	2013	59.4	4.0%	18.0	90.3%					
34	1958	57.8	23.4%	50.1	3.2%	1990	57.9	21.8%	16.8	92.7%
35	2016	59.6	2.4%	32.6	32.3%					
36	2009	58.2	13.7%	22.4	71.0%					
37	2015	62.2	0.8%	21.7	75.0%					
38	1999	55.4	90.3%	33.7	27.4%					
39	2015	62.2	0.8%	21.7	75.0%					
40	2015	62.2	0.8%	21.7	75.0%					
41	1992	59.3	4.8%	27.5	52.4%					
42	2016	59.6	2.4%	32.6	32.3%					
43	2014	60.5	1.6%	14.4	96.0%					
44	1977	57.4	35.5%	14.8	95.2%					
45	2015	62.2	0.8%	21.7	75.0%					
46	1992	59.3	4.8%	27.5	52.4%					
47	2014	60.5	1.6%	14.4	96.0%					
48	1998	57.9	22.6%	59.8	1.6%	1990	57.9	21.8%	16.8	92.7%
49	2013	59.4	4.0%	18.0	90.3%					
50	1992	59.3	4.8%	27.5	52.4%					
51	1992	59.3	4.8%	27.5	52.4%					
52	1989	57.1	45.2%	24.2	64.5%					
53	2016	59.6	2.4%	32.6	32.3%					
54	1984	58.8	8.9%	24.0	65.3%					

APPENDIX 2-H
COMPARISON OF CLIMATE CHANGE SCENARIOS MEMORANDUM

TECHNICAL MEMORANDUM

DATE: July 17, 2018

TO: Ron Duncan, Santa Cruz Mid-County Groundwater Agency

FROM: Georgina King, John Mejia, and Cameron Tana

PROJECT: Santa Cruz Mid-County Basin Groundwater Model

SUBJECT: Comparison of Climate Change Scenarios

1. BACKGROUND

For the Santa Cruz Mid-County Basin (Basin) Groundwater Flow Model using GSFLOW, we plan to run predictive simulations of groundwater management alternatives for the Santa Cruz Mid-County Groundwater Agency (MGA) using future climate change scenarios. One future climate change scenario based on a catalog of historical climate years has already been developed for the MGA (HydroMetrics WRI, 2016) but we are scoped to also run simulations using projections of climate change downscaled to the Basin. Simulations based on climate change projections are considered important for planning because projections generally have warmer temperatures than the historical record which could have a significant effect on the water resources of the Basin. There are a number of options available for climate change projections. This technical memorandum compares the suite of projections available.

Climate change projections are made primarily on the basis of coupled atmosphere-ocean Global Circulation Model (GCM) simulations under a range of future emission scenarios. Currently, climate projections used in climate change analysis are based on climate model simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5). The predecessor to CMIP5 was CMIP3.

Climate models in the CMIP5 use a set of emission scenarios called representative concentration pathways (RCPs) to reflect possible trajectories of greenhouse gas (GHG) emissions throughout this century. Each RCP defines a specific emissions trajectory and subsequent radiative forcing (a radiative forcing measures the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system).

For purposes of quantifying benefits or adverse impacts that could result from water storage projects proposed for the Water Storage Investment Program (WSIP) in California (California Water Commission, 2016), technical assistance included recommendations for the use of climate change projections. Twenty climate scenario-model combinations were selected based on recommendations by the California Department of Water Resources' (DWR) Climate Change Technical Advisory Group that they are the most appropriate for California water resources. The climate scenario-model combinations compose 10 global circulation models run with two emission scenarios: one optimistic (RCP 4.5) that stabilizes shortly after 2100 and one pessimistic (RCP 8.5) that is characterized by continuing increased GHG emissions over time.

Included in our comparison is the City of Santa Cruz's (City) climate change projection. The City, since 2008, uses CMIP3 GCM data adopted and made available by the CalAdapt program as the basis for their hydrologic and climate change modeling (Stratus, 2015). Specifically, they have selected the GFDL2.1 GCM for the A2 emissions scenario, which is the worst-case climate change dataset in the CalAdapt dataset. Under a subcontract to Pueblo Water Resources Inc., we have performed bias corrected spatial downscaling (Mejia et al., 2012) of the GFDL2.1-A2 projections to the climate stations in the Basin for use as input to represent climate for Water Years 2020-2069. We are currently using this climate input to simulate City of Santa Cruz Aquifer Storage and Recovery (ASR) preliminary alternatives.

A comparison of climate change projections will lead to a decision on what GCM projections should be used by the MGA for its simulations, including those simulations to guide the Basin's Groundwater Sustainability Plan (GSP). One option is the GFDL2.1-A2, which has already been downscaled to the Basin. If different GCM(s) are deemed appropriate, downscaling of those GCM(s) to climate stations in the Basin will be required to use with the Basin GSFLOW model.

2. COMPARISON OF DATASETS

Downscaling is commonly used to refine the coarse scale of GCM data to local regions. The CMIP5 ensemble of CGMs area available as downscaled projections using local constructed analogs (LOCA) for California on a 6 kilometer grid (Pierce, Cayan, and Dehann, 2016). WSIP used these downscaled projections for its set of 20 climate scenario-model combinations. Although further downscaling from LOCA, similar to what has been done for the GFDL2.1-A2 projection used by the City of Santa Cruz, will be required for the Basin GSFLOW model, we evaluated data from the LOCA cell in which the Santa Cruz Co-Op climate station is located, to compare climate change projections for the Basin region (Figure 1).

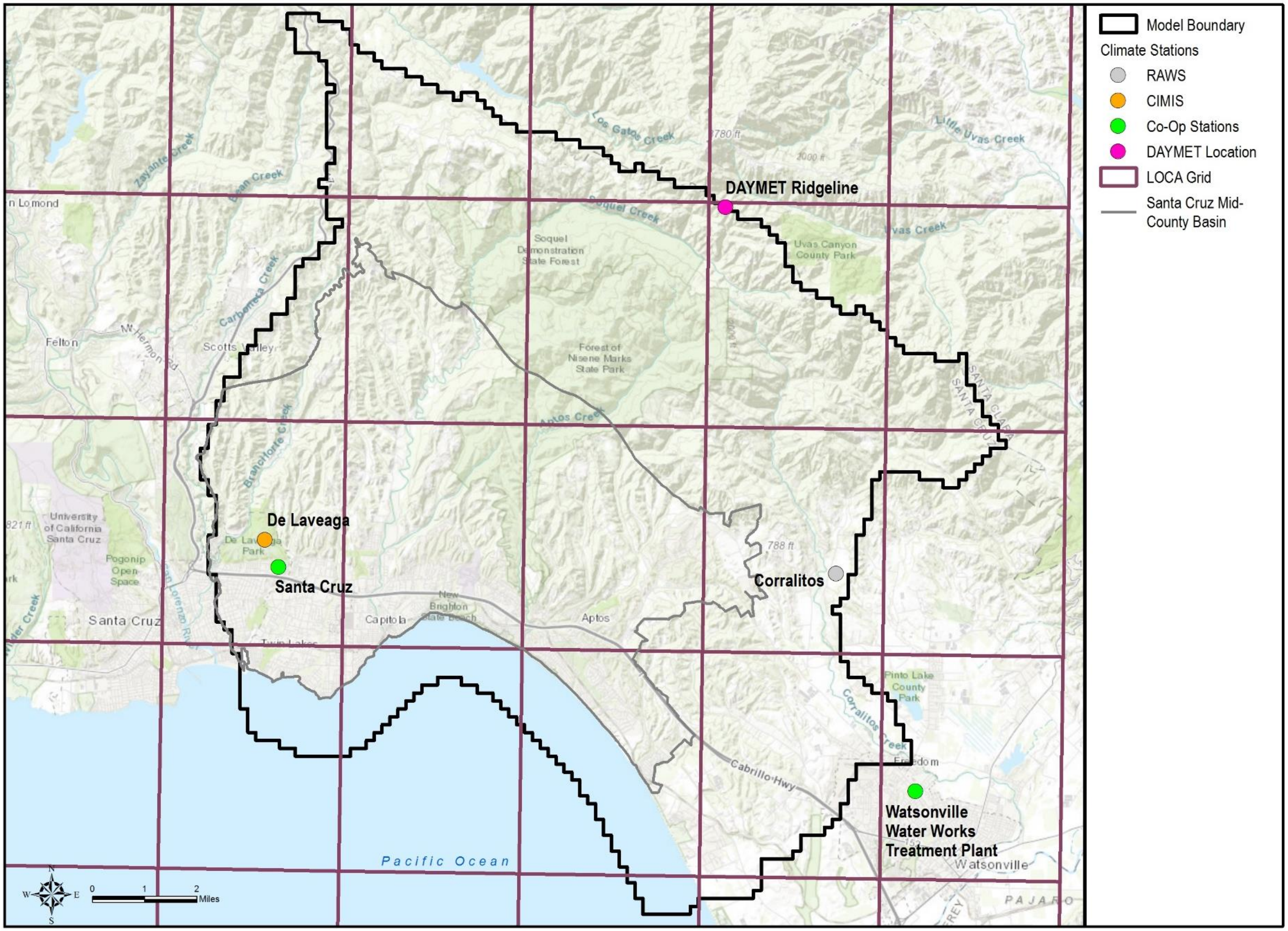


Figure 1. LOCA Grids in the Santa Cruz Area

Our comparison includes all available CMIP5 scenarios. The two different RCPs are compared separately, as are the 20 WSIP emission scenarios. Change in average precipitation, and minimum and maximum temperatures comparisons are summarized in Table 1. The values in the table represent changes between average projected 2020-2069 GCM climate and average reference historical 1984-2015 GCM climate for the grid cell. Comparing modeled results for these time periods are meant to represent the expected change in downscaled climate for a future period versus the Basin GSFLOW model calibration period of 1985-2015. Figure 2 plots the individual scenarios with a line connecting the average minimum and maximum temperature changes against a percentage change in average precipitation for each emission scenario.

Table 1: Climate Change 2020-2069 Compared to Reference Historical 1984-2015 Period

Scenario	Average Precipitation (%)	Average Minimum Temperature (°F)	Average Maximum Temperature (°F)
CMIP5 all	3.16	2.68	2.59
CMIP5 all RCP4.5	1.68	2.35	2.26
CMIP5 all RCP8.5	4.66	3.02	2.91
CMIP5 WSIP	1.79	2.82	2.74
CMIP5 WSIP RCP4.5	0.47	2.48	2.45
CMIP5 WSIP RCP8.5	3.11	3.16	3.04
CMIP3-GFDL-CM-A2 downscaled at Santa Cruz Co-op Station	-1.46	1.2	2.2
Catalog at Santa Cruz Co-op Station	-10.2	0.78	2.29

Notes: Historical Reference for CMIP5 is GCM results for 1984-2015
Historical reference for GFDL and Catalog is 1984-2015 dataset at Santa Cruz Co-op station.

The California Department of Water Resources (DWR) has stated they will use the ensemble of WSIP scenarios as the basis for climate change projections provided to local Groundwater Sustainability Agencies for sustainable groundwater management planning (Hatch, 2017). Personal communication with Tyler Hatch of DWR’s Sustainable Groundwater Management Branch, indicated that for sustainable groundwater planning, DWR will accept a climate change scenario that was more conservative than the WSIP ensemble, i.e., hotter and drier.

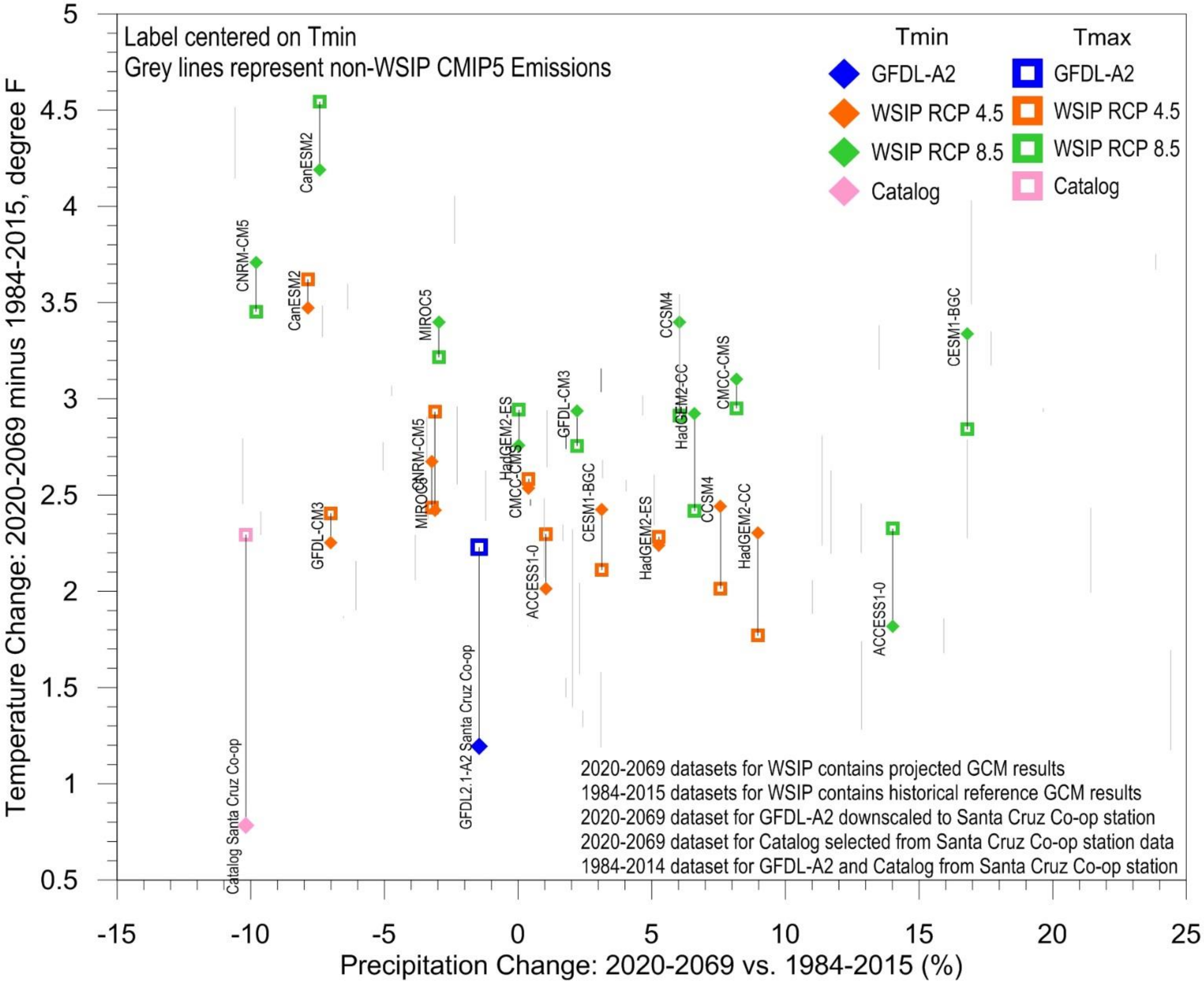


Figure 2. Climate Change 2020-2069 with Respect to Reference Period 1984-2015 for All CMIP5 Emissions

2.1. Precipitation Comparison

Average precipitation increases over 1984 – 2015 precipitation in all groups of CMIP5 scenarios (Table 1). The RCP 4.5 scenarios have lower precipitation increases than the RCP 8.5 scenarios. The WSIP scenarios have lower precipitation increases than the combined CMIP5 scenarios. Median daily precipitation plotted for each year (Figure 3) shows an increasing trend in the precipitation to 2069. Monthly averages of precipitation changes between 2020-2069 and 1984-2015 show only little change or increases every month for medians of all groups of CMIP5 scenarios. December through March precipitation increases in the WSIP scenarios is generally higher than the combined CMIP5 scenarios (Figure 4). The other months have similar daily precipitation changes.

Daily precipitation from the City's GFDL-A2 scenario compared to the full combination of WSIP scenarios is slightly wetter, with 2.04% more precipitation than 1984-2015 reference precipitation (Table 1). There is a notable reduction in precipitation after 2069, which is after our planned GSFLOW model period (Figure 3). GFDL-A2 precipitation from March through May has less precipitation than the reference historical period and less than the CMIP5 scenarios, however September, October, and February precipitation has greater increases than the CMIP5 scenarios (Figure 4).

2.2. Minimum Temperature Comparison

As expected, all RCP 8.5 scenarios are warmer than RCP 4.5 scenarios because of the projected increasing emissions that characterize those scenarios. The combined 20 WSIP scenarios' minimum temperature increases are overall greater than the full complement of CMIP5 scenarios, and more noticeably so in the RCP 8.5 group (Table 1). Figure 5 shows that the median RCP 8.5 minimum temperatures depart from temperatures in the other groups of scenarios around 2056 with an increasing trend.

GFDL-A2 average annual projections of minimum temperature are lower than median CMIP5 temperatures around 2038 and 2060 (Figure 5). Overall, this results in average minimum temperature increases than are lower than all other CMIP5 groups of scenarios (Table 1). Monthly averages for minimum temperatures are higher in all months for median RCP 8.5 emission scenarios than median RCP 4.5 emission scenarios. The average monthly minimum temperatures show less temperature increase in the GFDL-A2 scenario than the CMIP5 scenarios, except from May to August where they are more comparable to the RCP 4.5 scenarios (Figure 6).

2.3. Maximum Temperature Comparison

Similar to minimum temperatures, the combined 20 WSIP scenarios' maximum temperatures are overall slightly warmer than the full complement of CMIP5 maximum temperatures (Table 1). The months of June through October are when the WSIP scenario maximum temperature increases are noticeably greater than the combined CMIP5 scenarios (Figure 8).

Figure 7 shows that the GFDL-A2 scenario maximum temperatures follows the general trend of the WSIP RCP 8.5 emission scenarios better than other scenarios. However, similar to minimum temperature, around 2038 and 2060, the projection of maximum temperature falls below most CMIP5 scenarios (Figure 7). Overall, the average maximum temperature increases for the GFDL-A2 scenario are lower than the WSIP maximum temperatures increases. Monthly averages for maximum temperatures are higher in all months for median RCP 8.5 emission scenarios than median RCP 4.5 emission scenarios. The monthly distribution of average maximum monthly temperatures also show higher temperature increases in the GFDL-A2 scenario than the CMIP5 scenarios from May through August, and generally lower temperature increases in the other months (Figure 8).

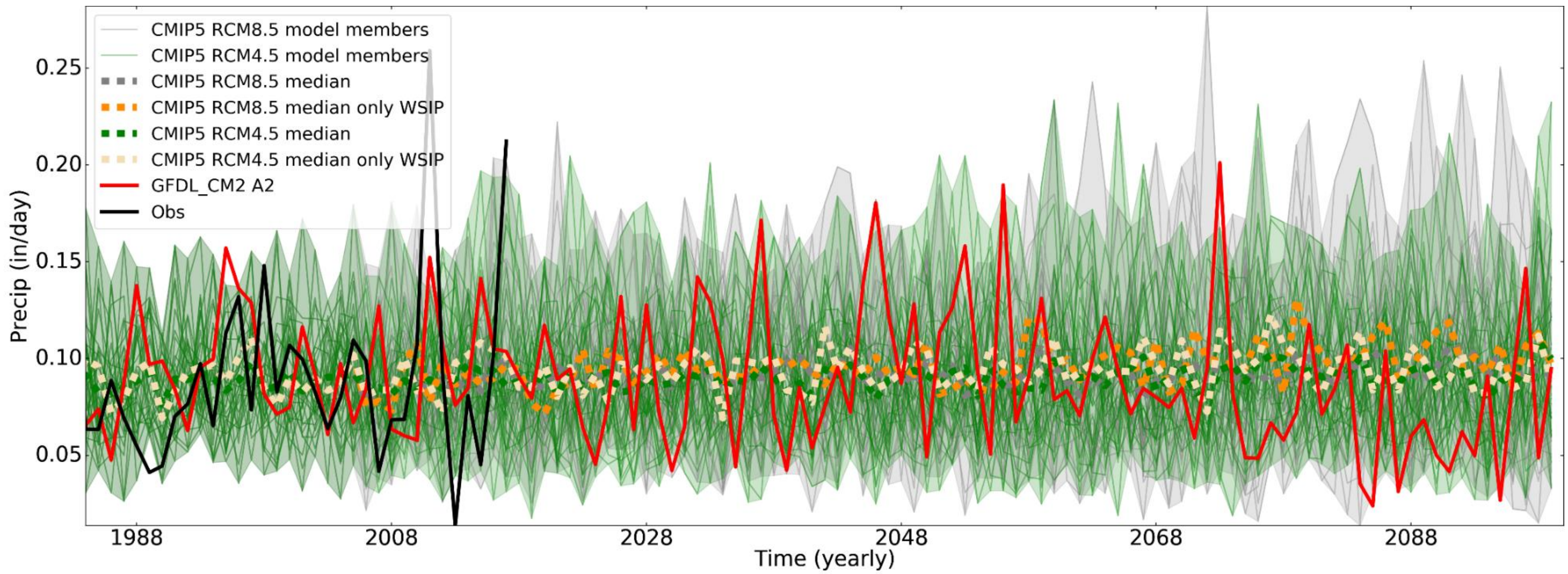


Figure 3. Average Annual Daily Projections for Precipitation

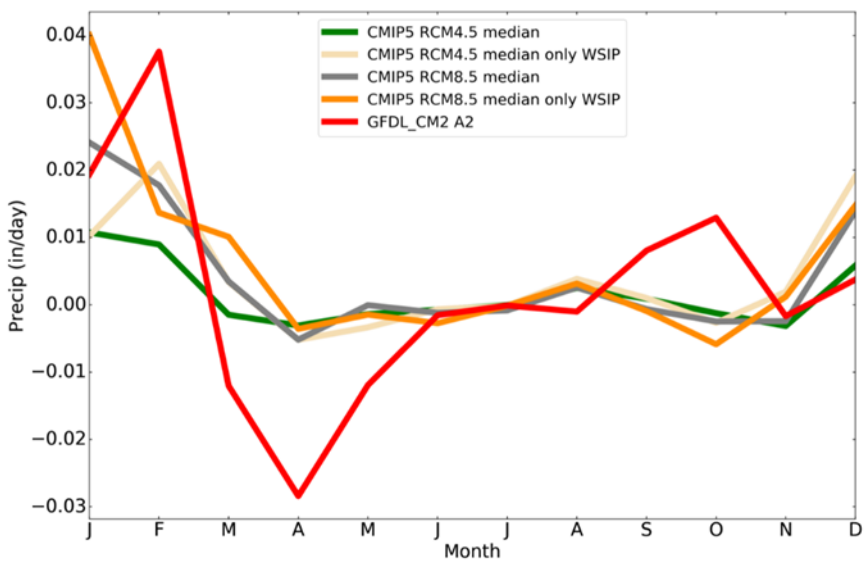


Figure 4. Average Monthly Projections for Precipitation Changes between 2020-2069 and 1985-2015

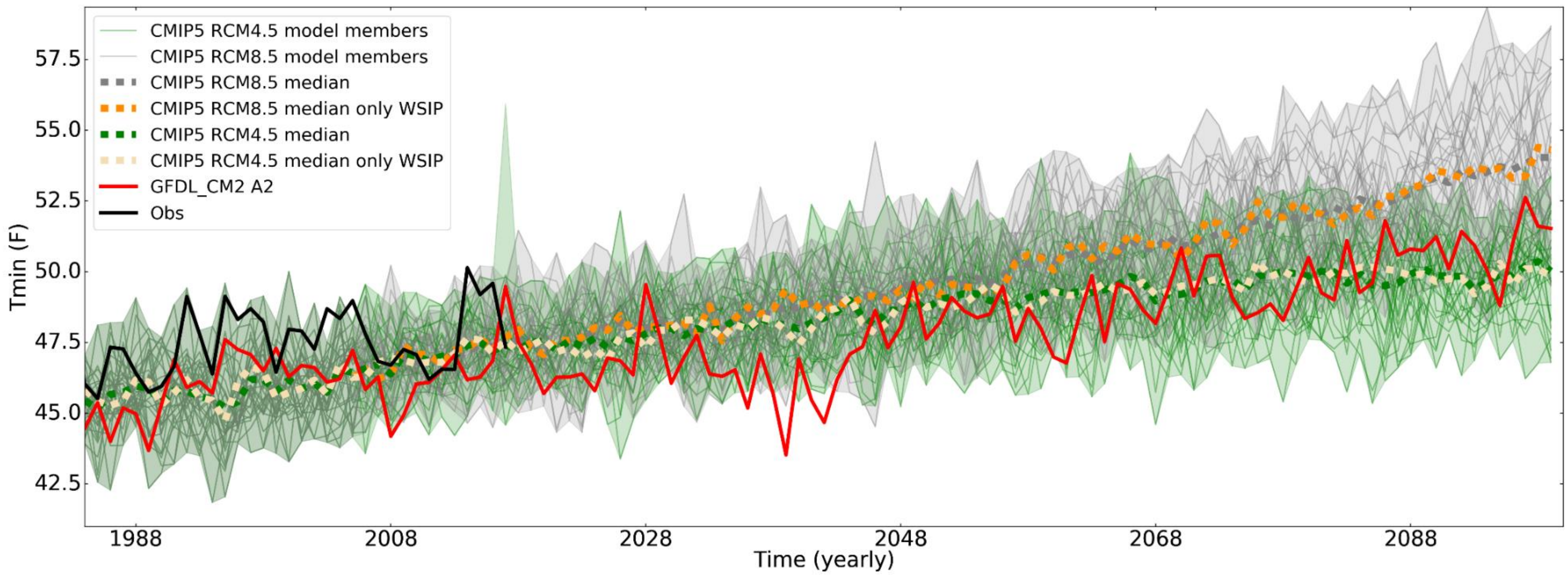


Figure 5. Average Annual Daily Projections for Minimum Temperature (Tmin)

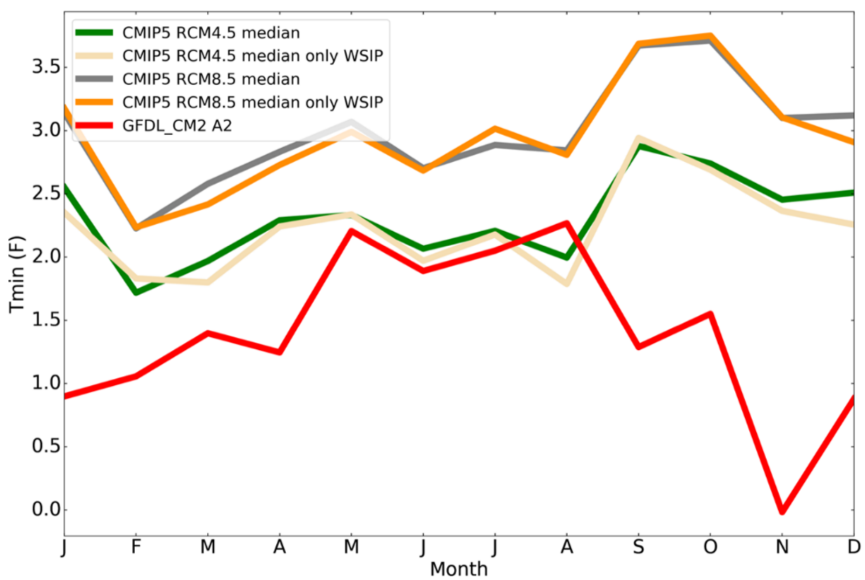


Figure 6. Average Monthly Projections for Minimum Temperature (Tmin) Changes between 2020-2069 and 1985-2015

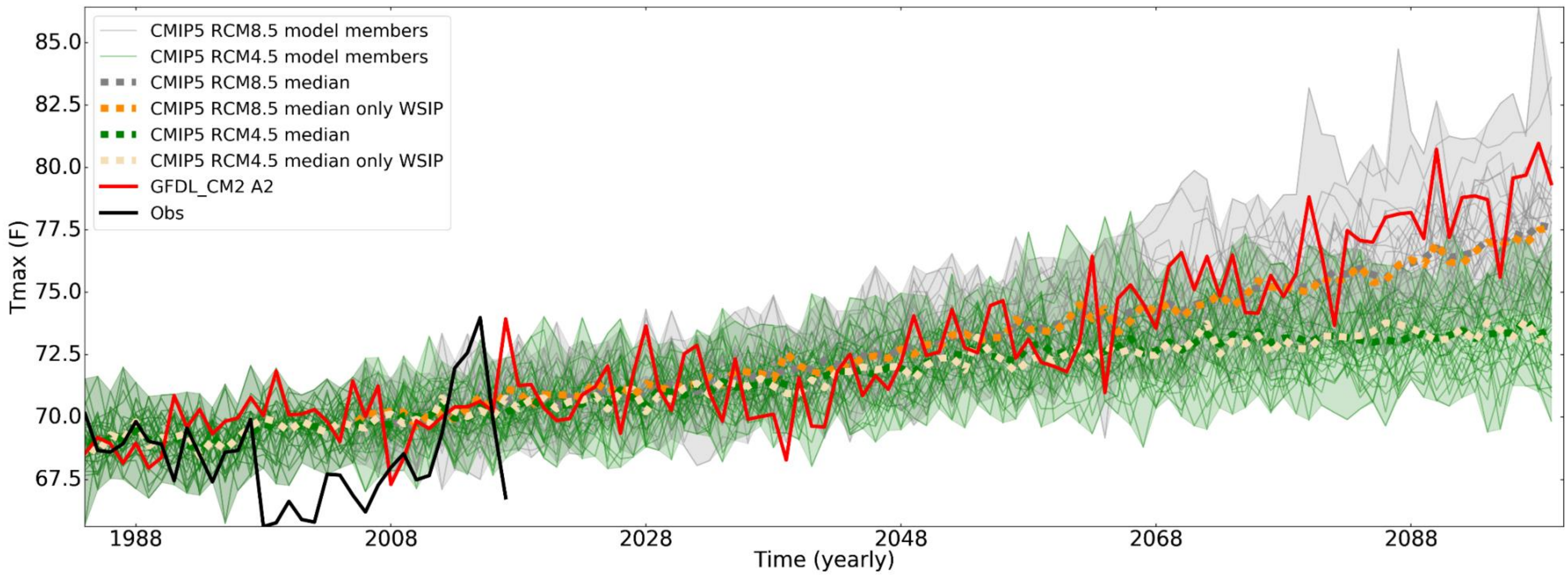


Figure 7. Average Annual Daily Projections for Maximum Temperature (Tmax)

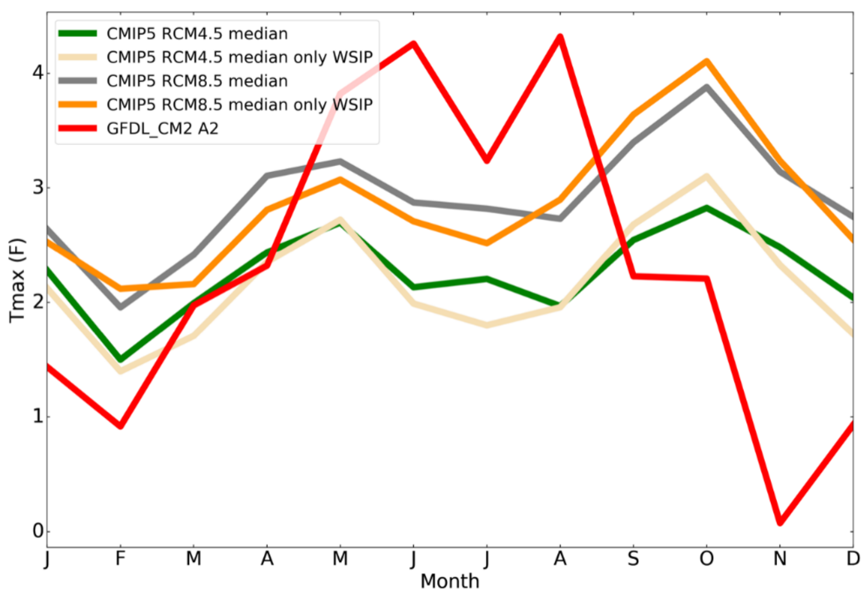


Figure 8. Average Monthly Projections for Maximum Temperature (Tmax) Changes between 2020-2069 and 1985-2015

3. CONCLUSIONS AND RECOMMENDATIONS

3.1. Conclusions

1. All projected average scenario ensembles (CMIP5 and WSIP) are wetter than the reference historical period.
2. The WSIP emission scenarios are drier and warmer than the combined CMIP5 scenarios.
3. The City's GFDL-A2 scenario is both wetter and cooler than many WSIP scenarios, although its maximum temperatures are warmer than WSIP RCP 4.5 scenarios.

3.2. Recommendations

It is expected that for groundwater sustainability planning, DWR will accept a climate change scenario that is more conservative than the WSIP ensemble, i.e., hotter and drier. Since the City's GFDL-A2 scenario does not fulfill this condition, a potential alternative needs to be selected. Although most projections show an increase in precipitation, we recommend selecting a projection that shows a decrease in precipitation. This will contribute to the robustness of groundwater sustainability planning by taking into account the possibility that water supply is reduced. Any projection that shows higher than average increases in temperature than the WSIP ensemble should also meet the requirements for groundwater sustainability planning.

We recommend selecting a scenario from the one of the 20 WSIP scenarios. WISP scenarios that are potential candidates are: MIROC5 RCP 8.5, CanESM2 RCP 4.5, CanESM2 RCP 8.5, and CNRM-CM5 RCP 8.5. These are shown on to have lower projected average precipitation than the reference historical period and higher temperatures than most other CMIP5 scenarios.

- CanESM2 RCP 8.5, CanESM2 RCP 4.5, and CNRM-CM5 RCP 8.5 are extreme scenarios that have over 7% less precipitation and some of the highest temperatures of all projections (Figure 2); such an extreme selection may not be justified.
- A fourth less extreme option is MIROC5 RCP 8.5 has 3% less precipitation than the reference historical period, and average temperatures that are higher than the majority of other scenarios.

4. REFERENCES

California Water Commission, 2016. Water Storage Investment Program Technical Reference. November. Accessed online at: https://cwc.ca.gov/Documents/2017/WSIP/TechnicalReference.pdf

Hatch, 2017. Presentation from GRA-UC Davis Hydrology course.

HydroMetrics WRI, 2016. Santa Cruz Mid-County Basin Groundwater Flow Model: Future Climate for Model Simulations (Task 5), to MGA Executive Staff. November.

Mejia, J.F., J. Huntington, B. Hatchett, D. Koracin, and R.G. Niswonger, 2012. Linking Global Climate Models to an Integrated Hydrologic Model: Using an Individual Station Downscaling Approach. Universities Council on Water Resources Journal of Contemporary Water Research & Education Issue 147, Pages 17-27, March 2012.

Pierce, D.W., D.R. Cayan, and L. Dehann, 2016. Creating Climate projections to support the 4th California Climate Assessment, Division of Climate, Atmospheric Sciences, and Physical Oceanography, La Jolla, CA. Accessed online at http://loca.ucsd.edu/~pierce/IEPR_Clim_proj_using_LOCA_and_VIC_2016-06-13b.pdf

Stratus Consulting, 2015. Technical Memorandum: Background information on climate change effects on local hydrology. Prepared for Santa Cruz Advisory Committee (WSAC). March.

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

Prepared for:

Santa Cruz Mid-County Groundwater Agency

Prepared by:

Montgomery & Associates

1970 Broadway, Oakland, California

Contents

Tables

Figures

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.

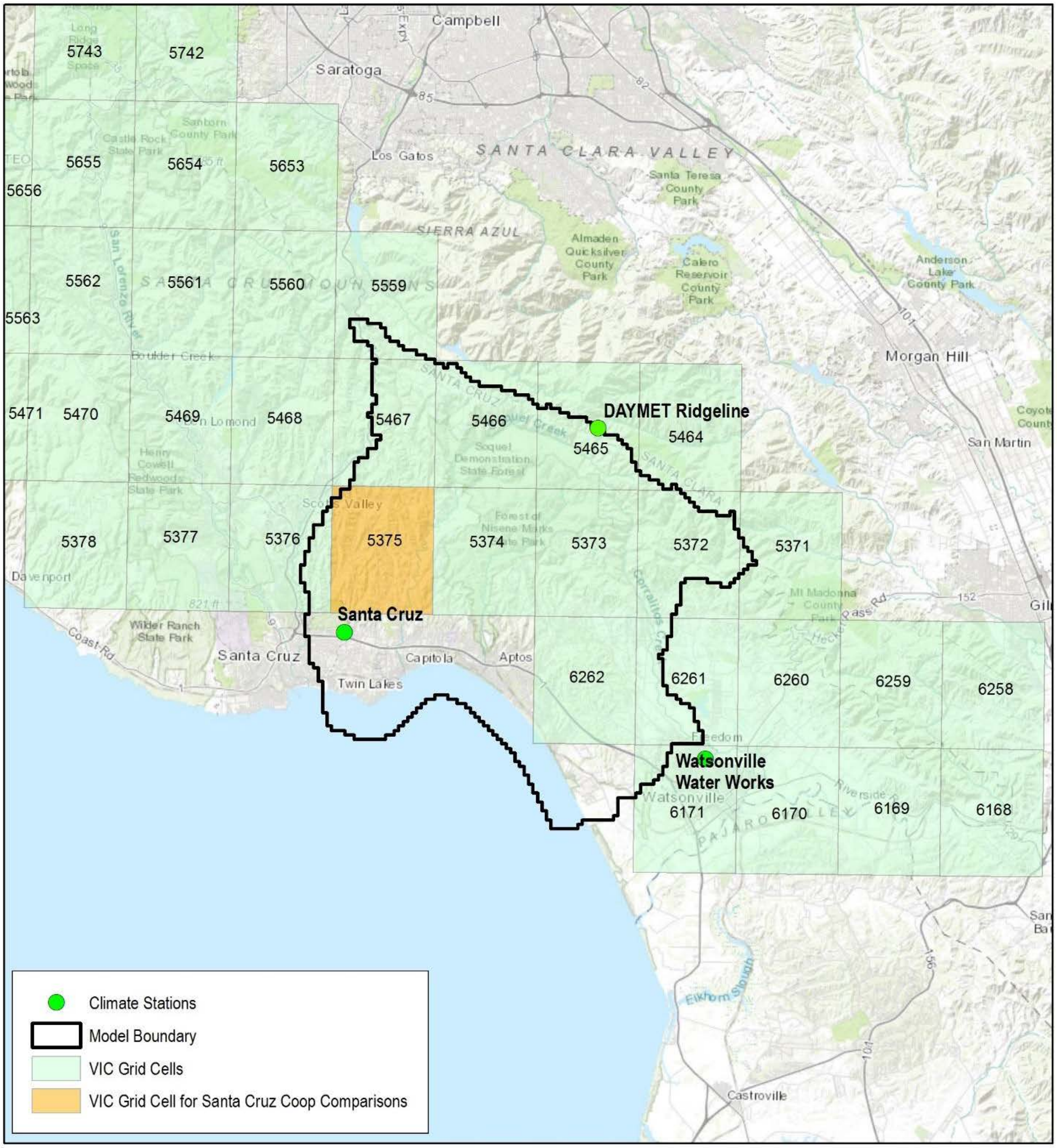


Figure 1. Climate Stations used in Model and Grid Cells for DWR Climate Datasets near Basin

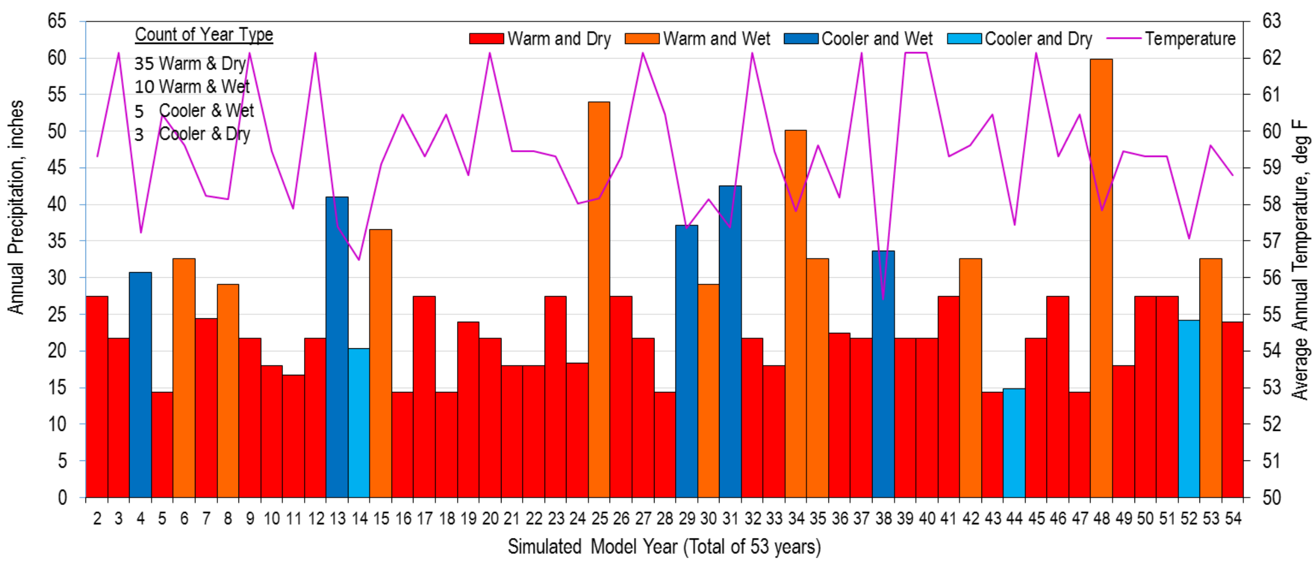


Figure 2. Simulated Future Precipitation and Temperature at Santa Cruz Co-op Station based on Catalog Climate

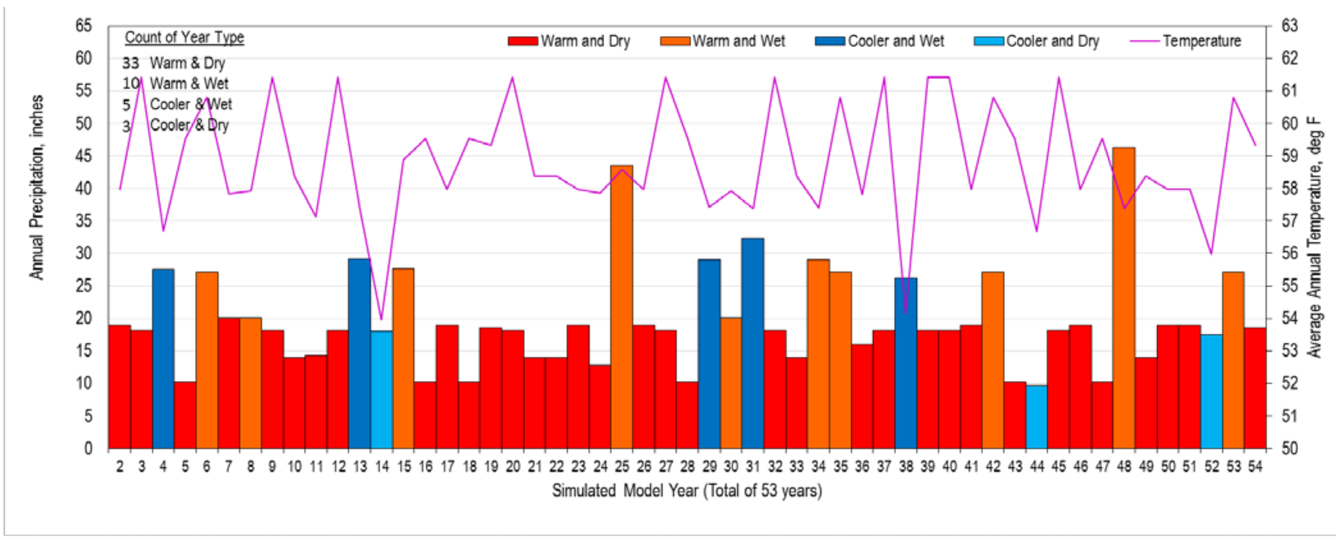


Figure 3. Simulated Future Precipitation at Watsonville Waterworks Station based on Catalog Clima

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

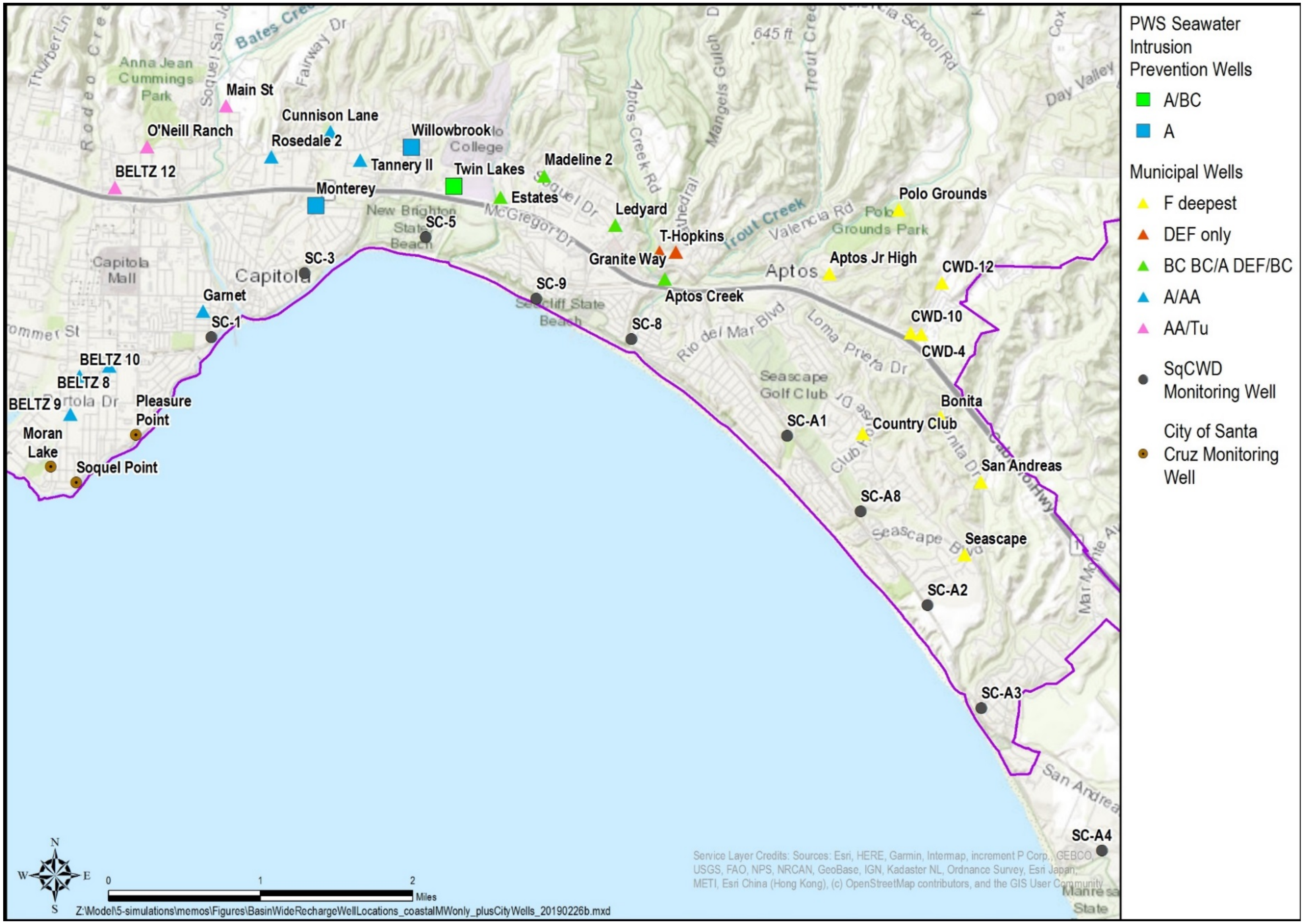


Figure 4. Locations of Existing and Planned Wells for Baseline and Projects Simulation

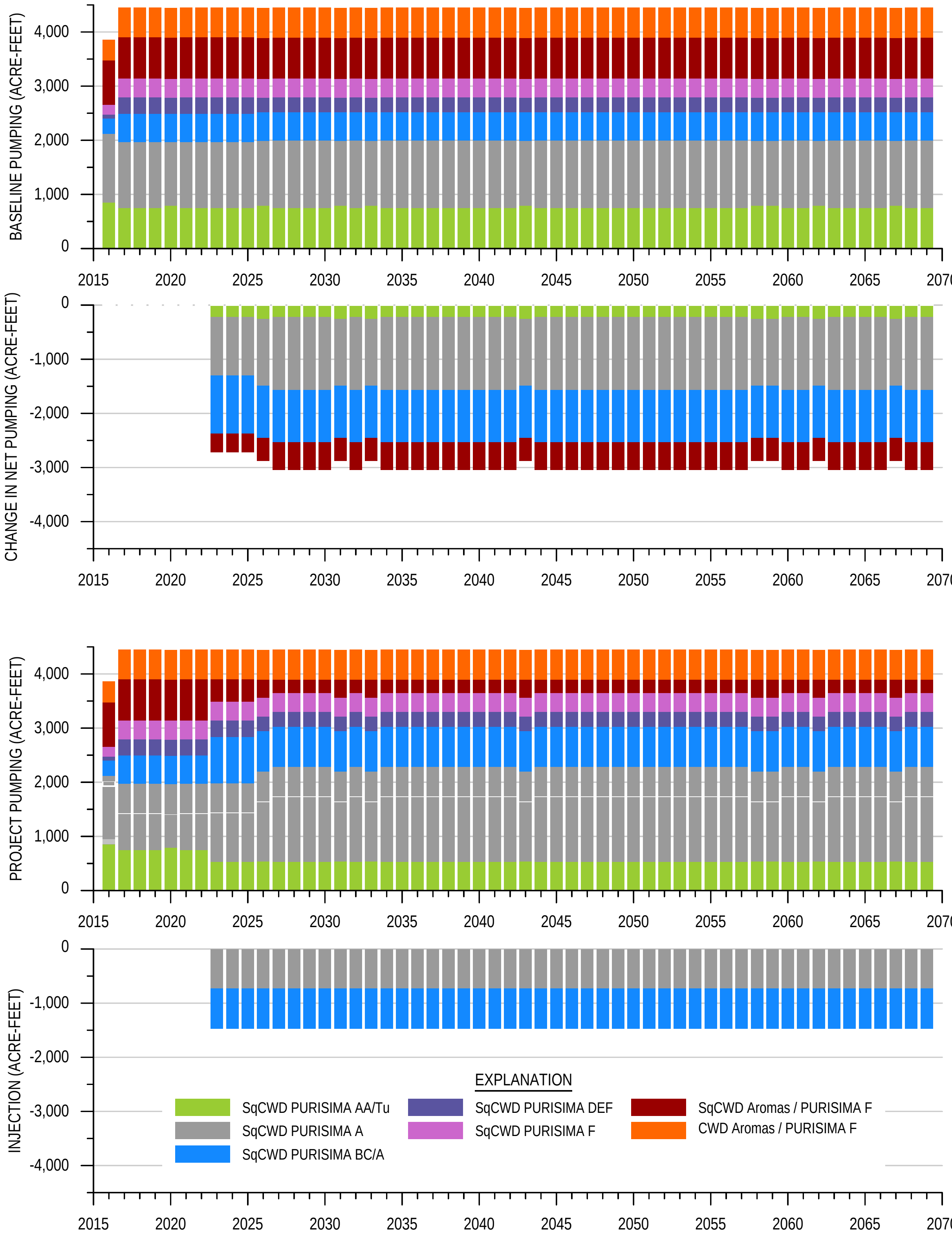


Figure 5. Central Water District and Soquel Creek Water District Pumping Distribution by Aquifer Unit for Baseline and Projects Simulation

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

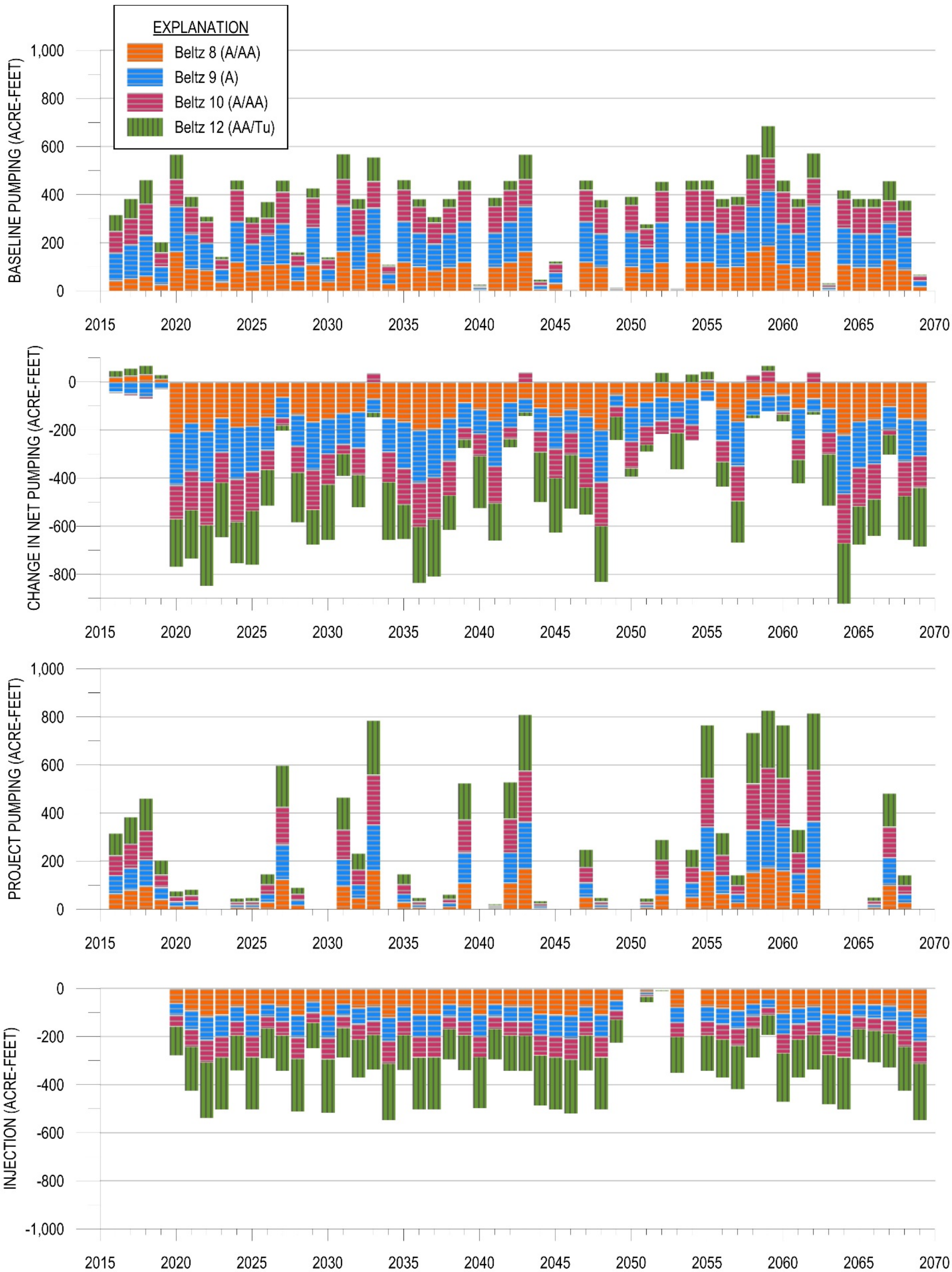


Figure 6. City of Santa Cruz Pumping and Injection for Baseline and Projects Simulations

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.

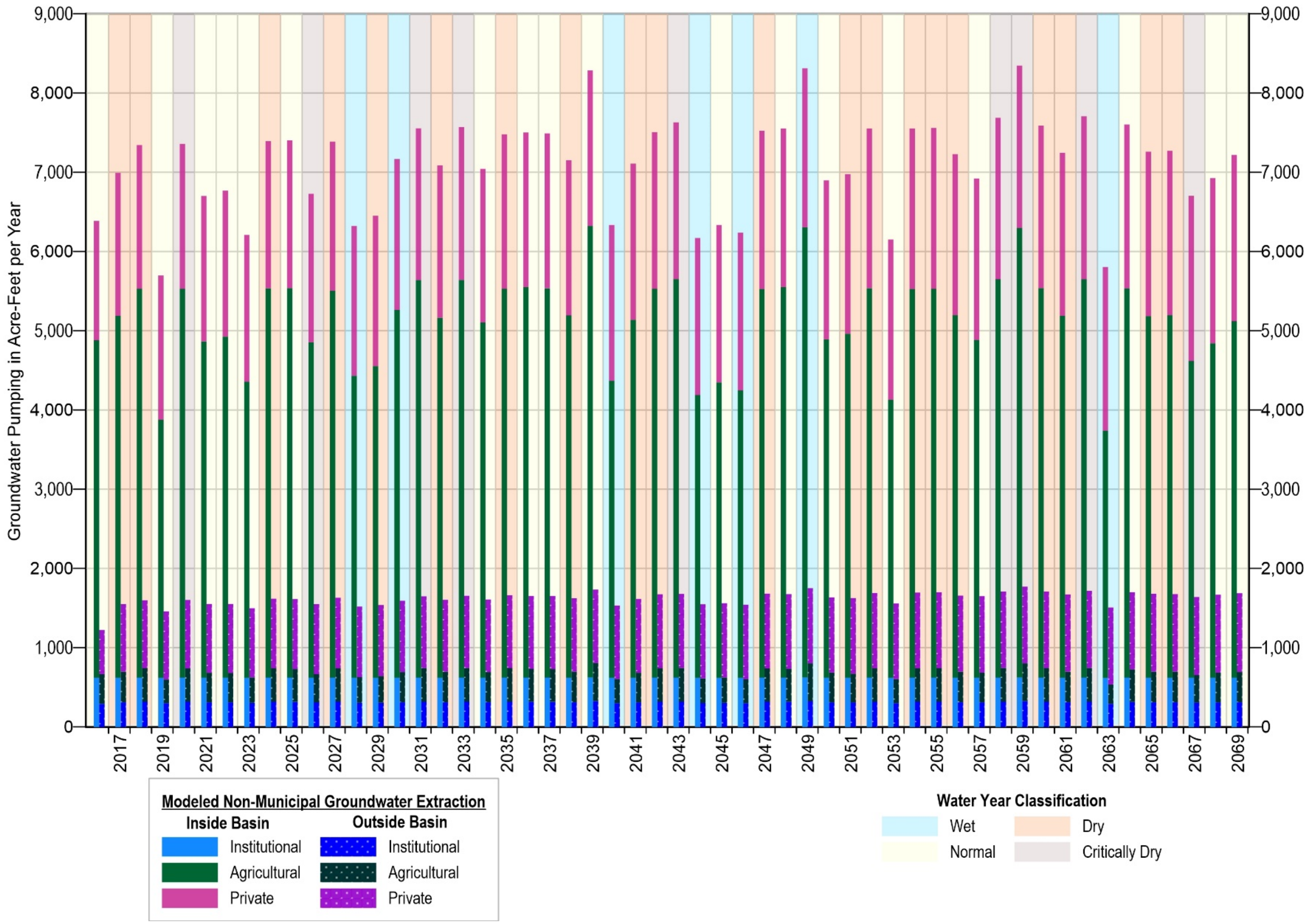


Figure 7. Non-Municipal Pumping for Baseline and Projects Simulation

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.

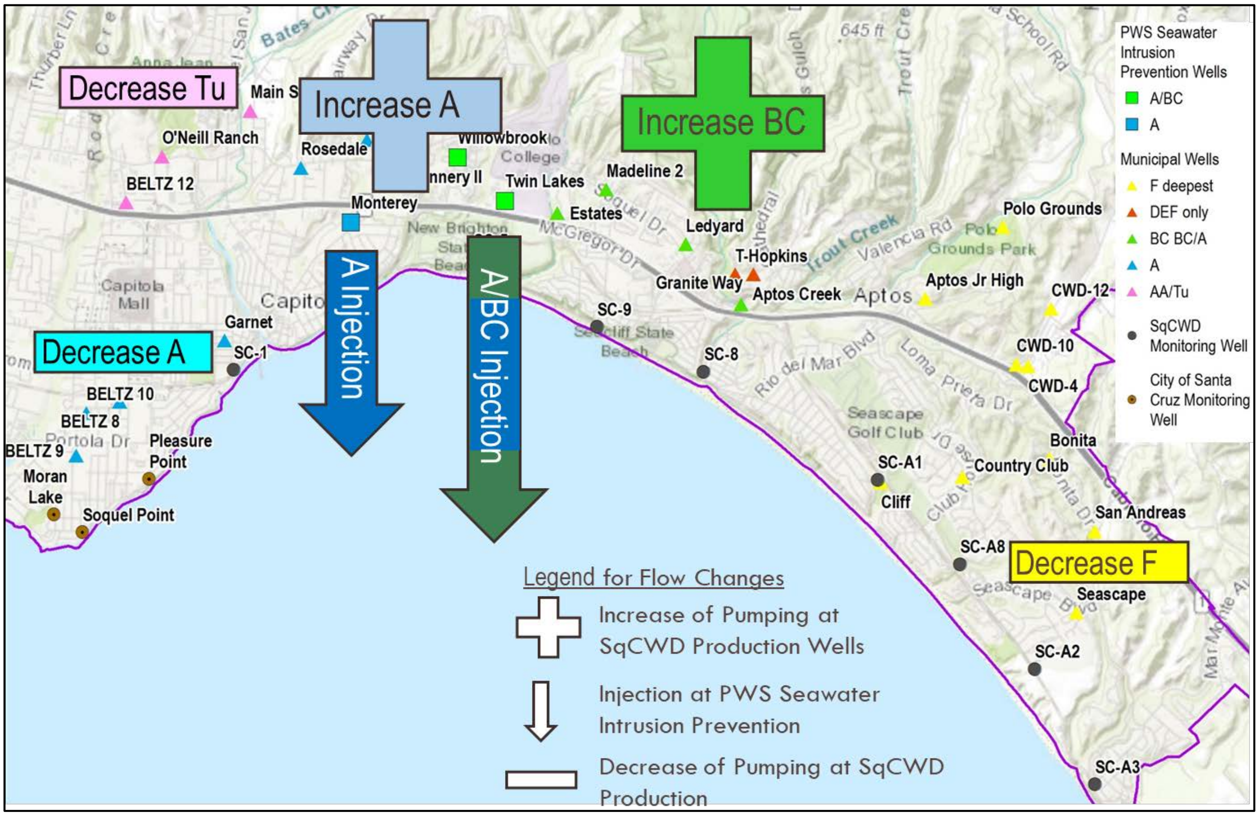


Figure 8 Map Schematic of Changes in Pumping Distribution from Pure Water Soquel Injection

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.

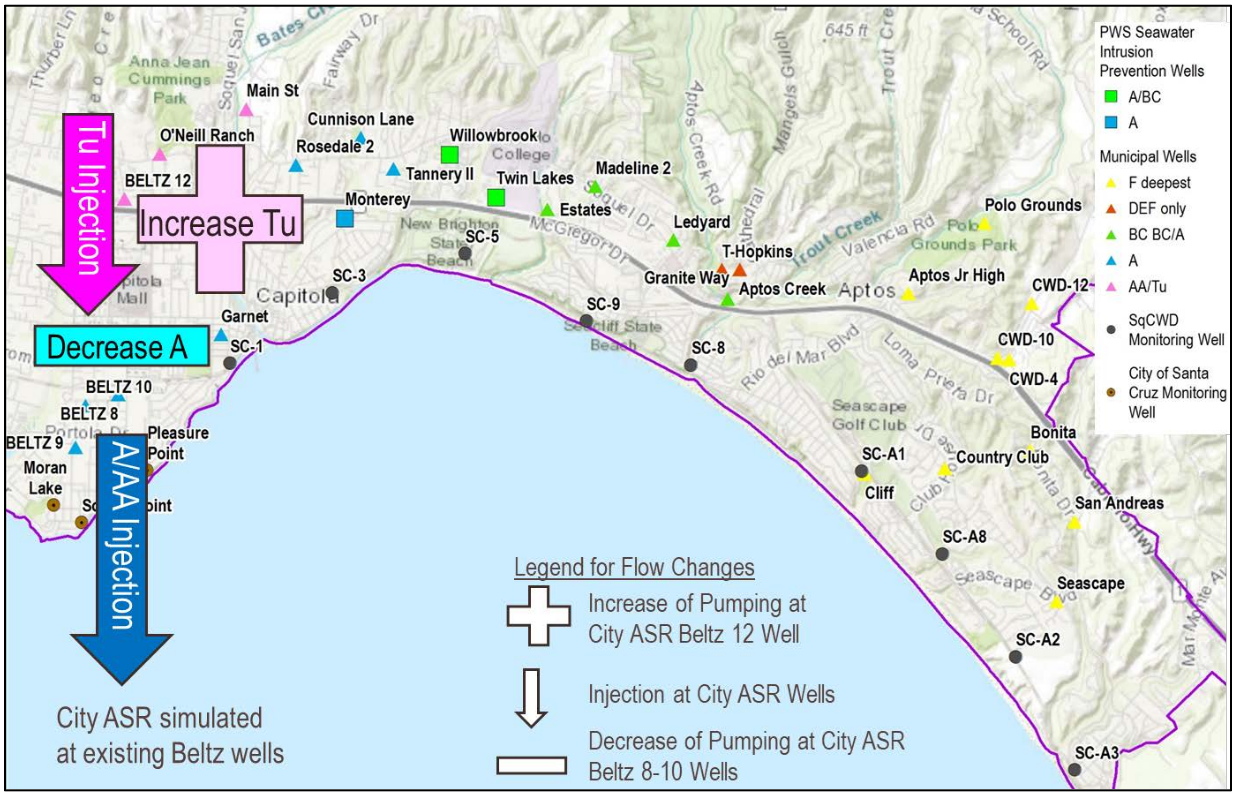


Figure 9 Map Schematic of Changes to ASR Injection and Pumping Distribution

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.

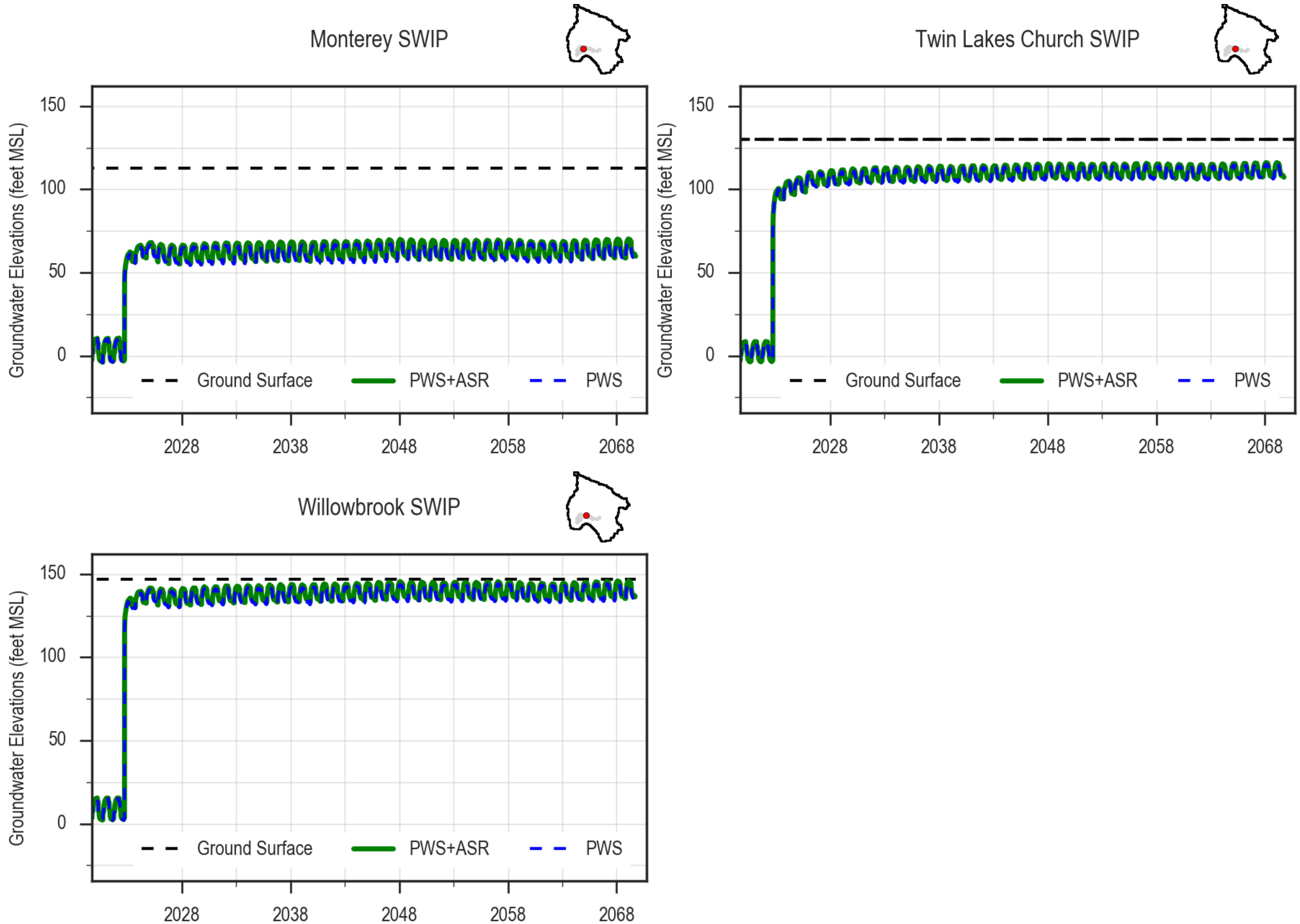


Figure 10. Simulated Well Heads at PWS Seawater Intrusion Prevention Wells versus Ground Surface

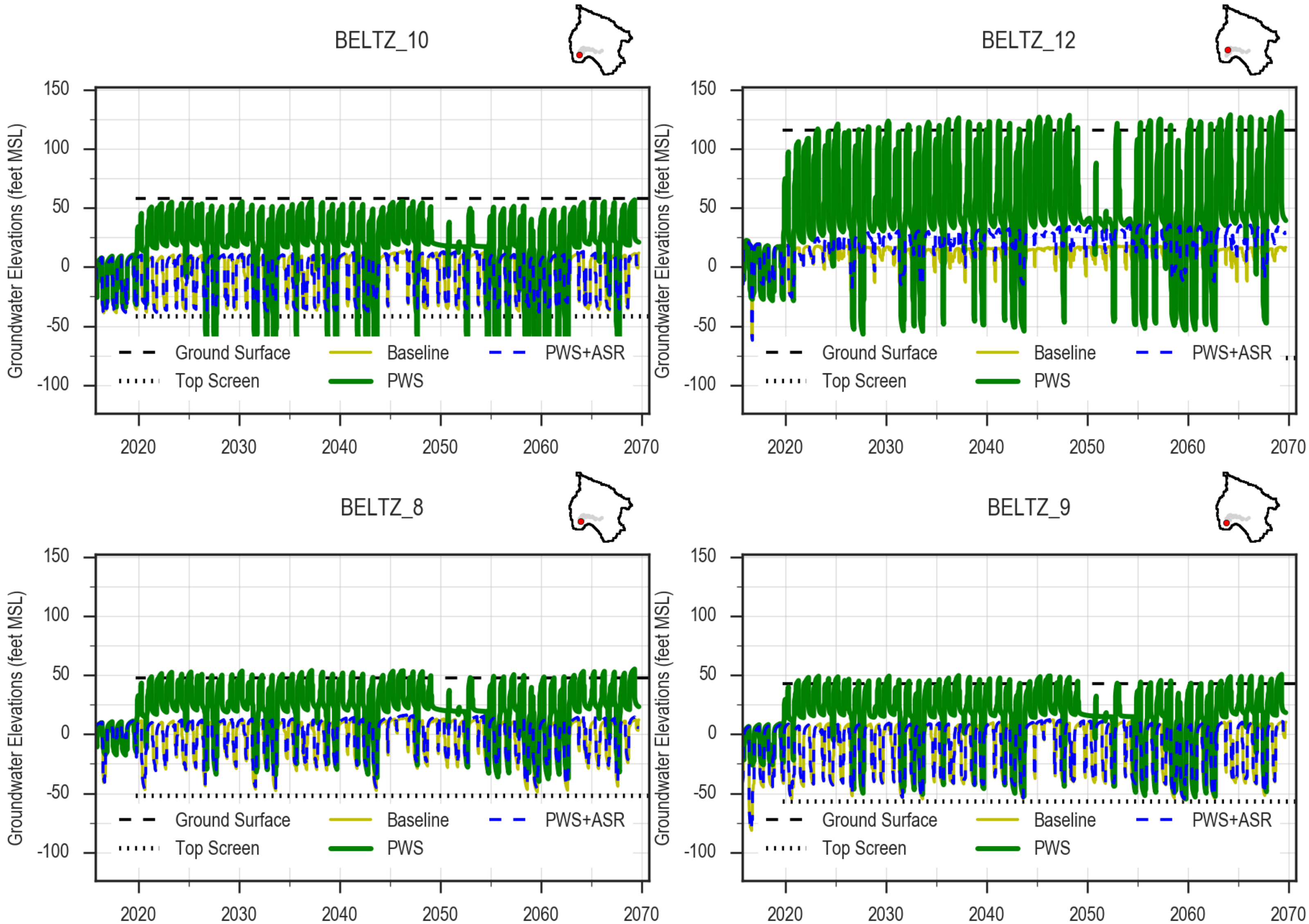


Figure 11. Simulated Well Heads at Beltz ASR Wells vs. Ground Surface

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.

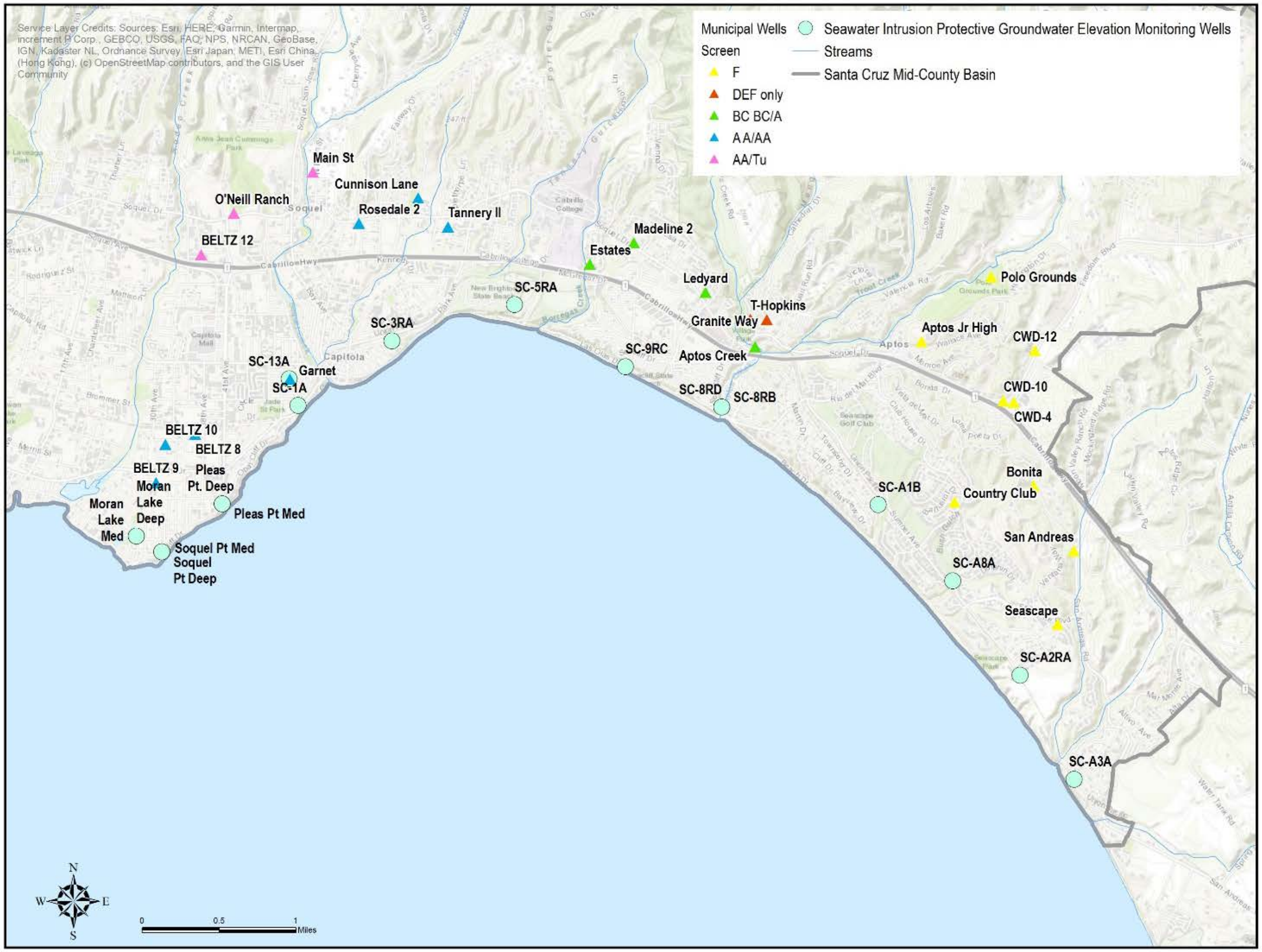


Figure 12. Locations of Representative Monitoring Points with Groundwater Elevation Proxies for Seawater Intrusion in Relation to Municipal Production Wells

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.

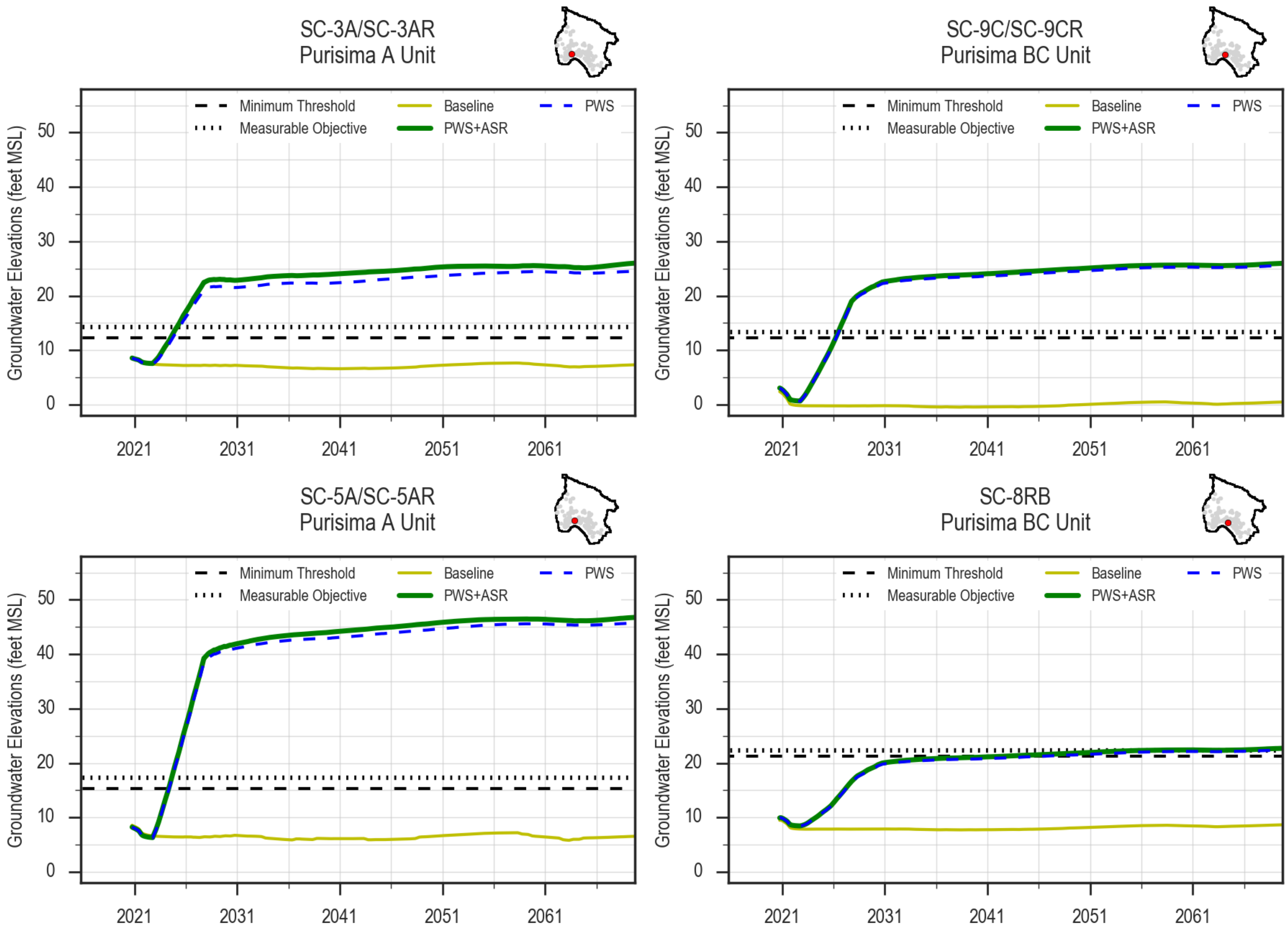


Figure 13. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima A and BC Units

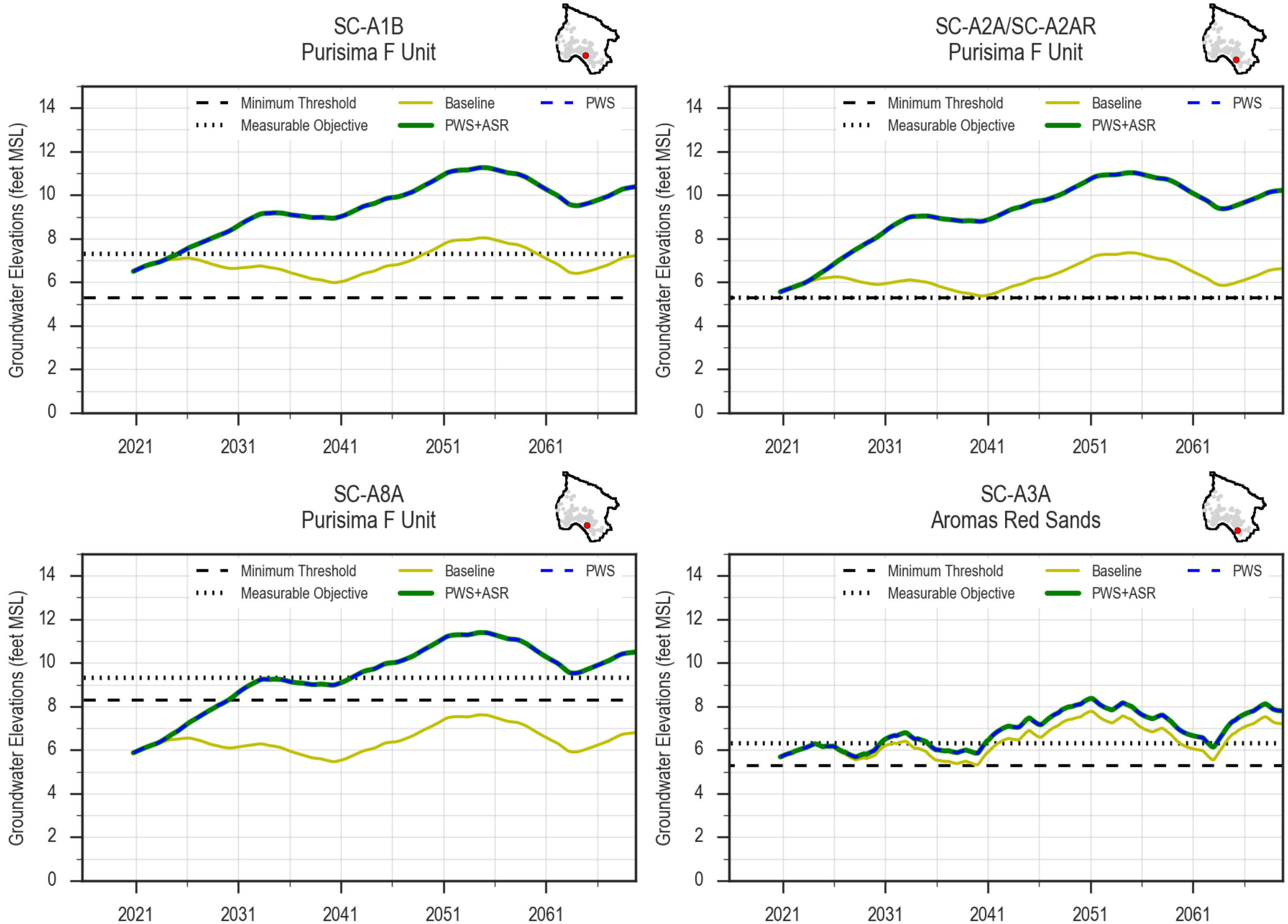


Figure 14. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima F and Aromas Red Sands Units

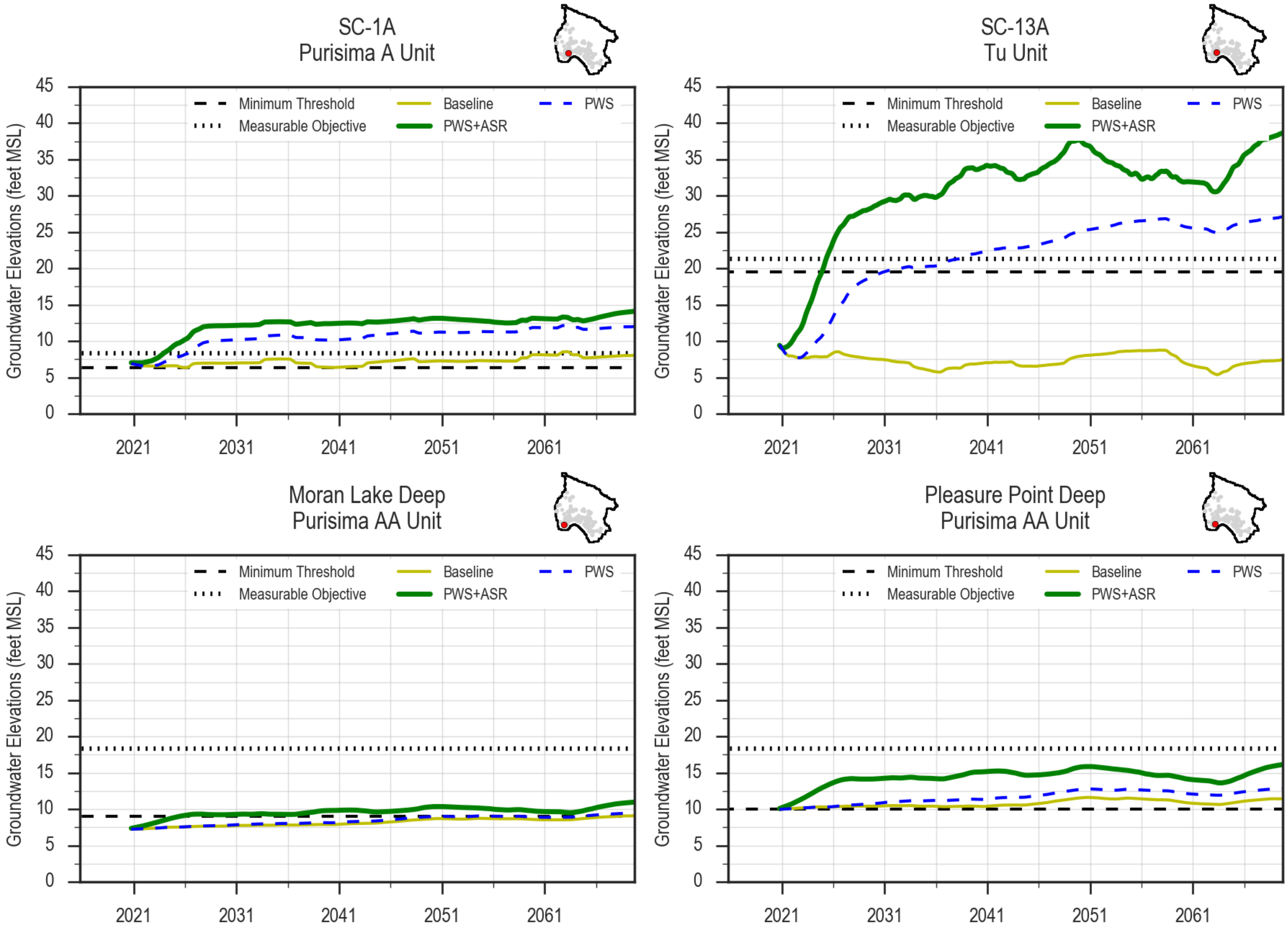


Figure 15. Running Five-Year Average Groundwater Elevations at Coastal Monitoring Wells in Tu and Purisima AA and A Units

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.

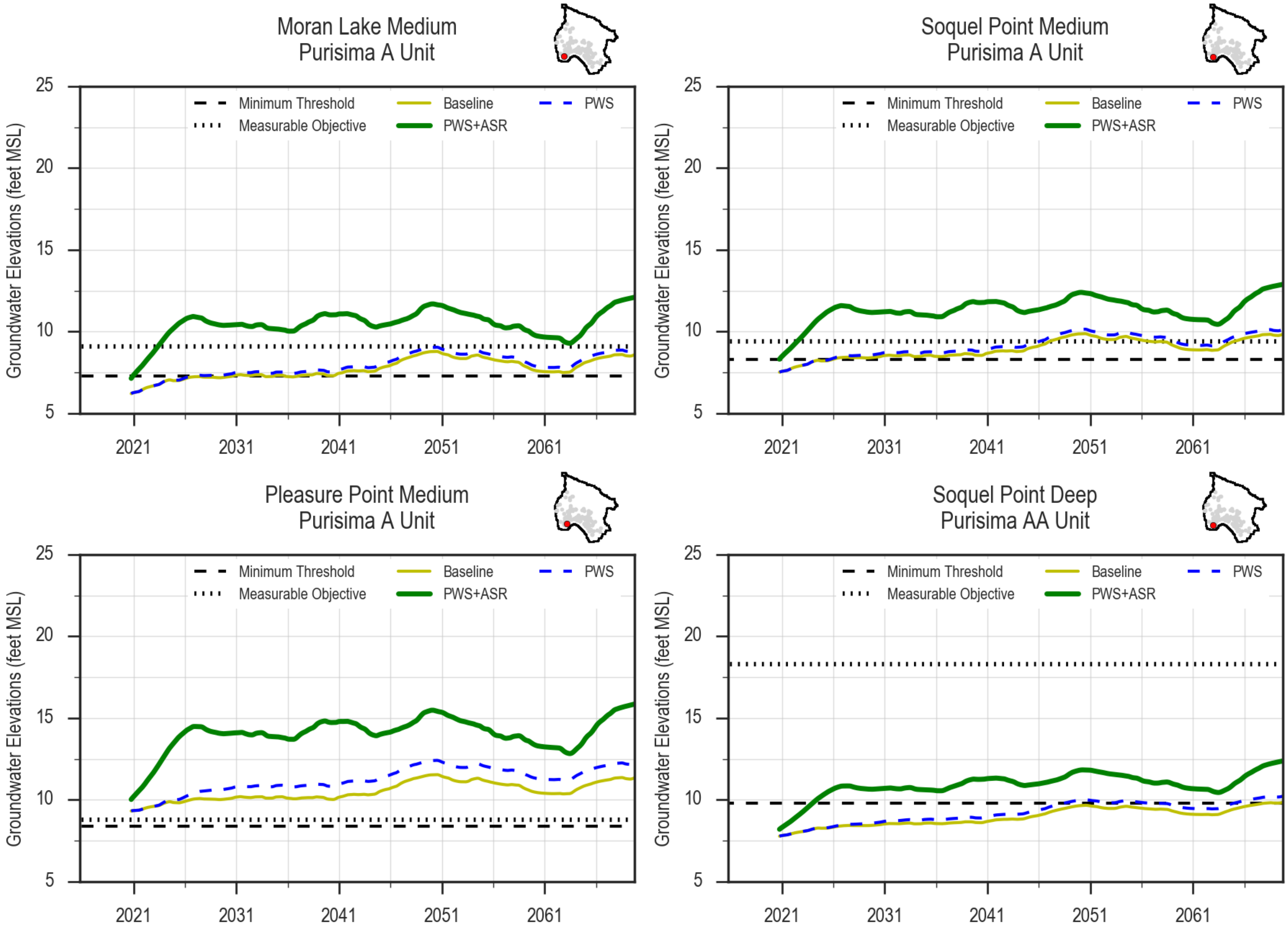


Figure 16. Running Five-Year Average Groundwater Elevations at Coastal Monitoring Wells in Purisima AA and A Units

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.

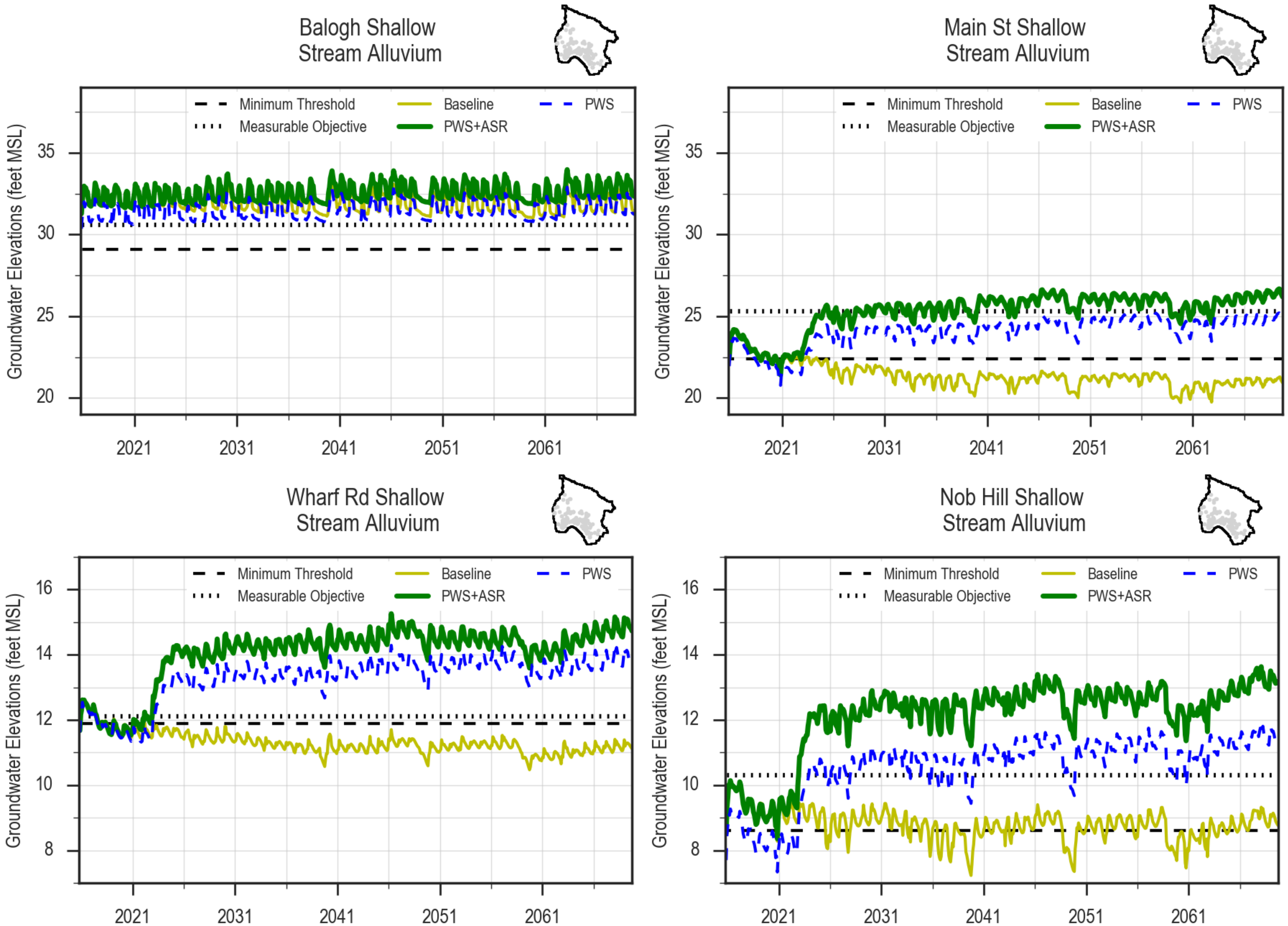


Figure 19. Simulated Groundwater Elevations at Shallow Monitoring Wells along Soquel Creek

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.

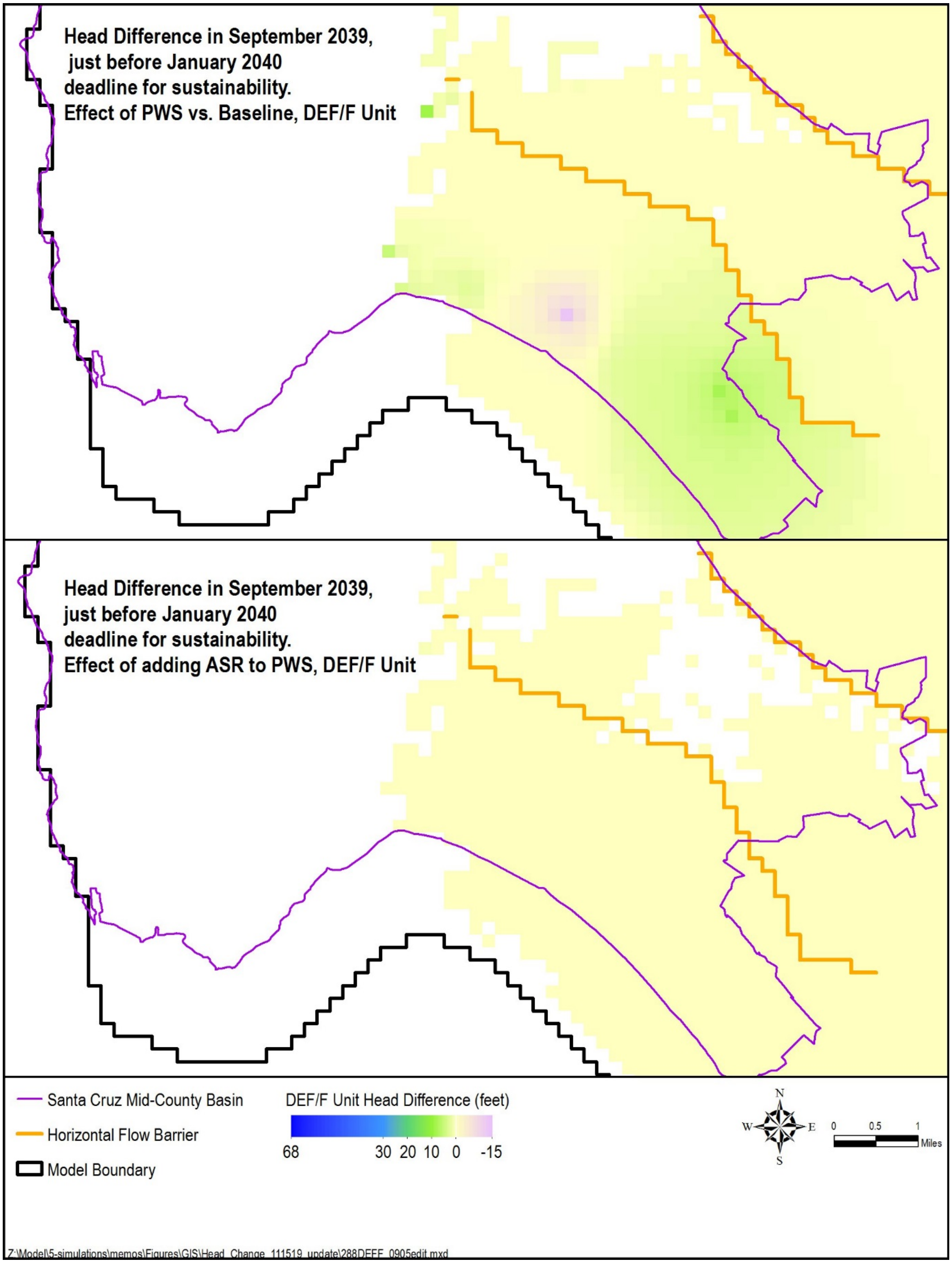


Figure 20. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations, DEF/F Unit

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.

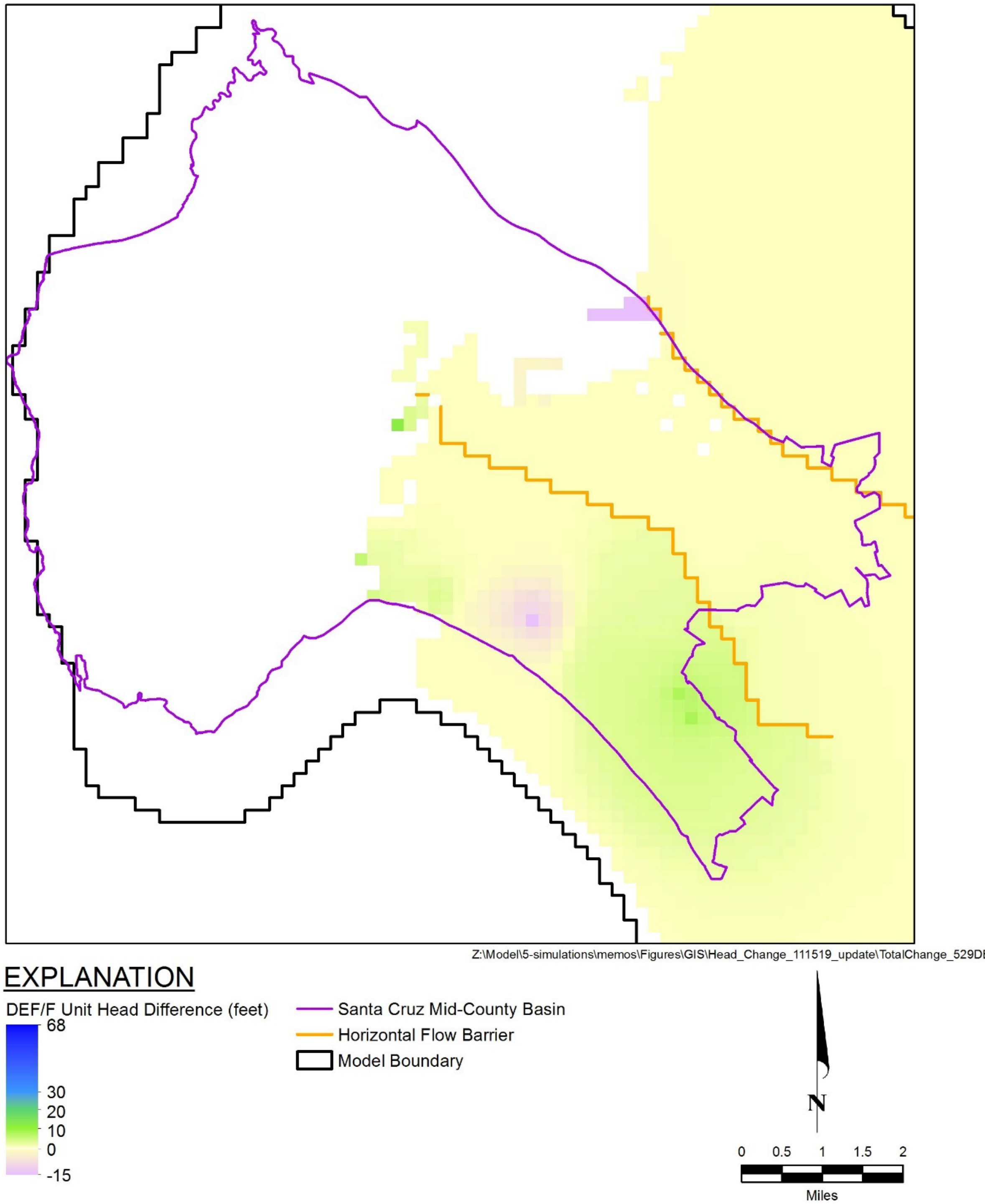


Figure 21. Simulated Effect of ASR and PWS on Groundwater Elevations on October 2059, DEF/F Unit

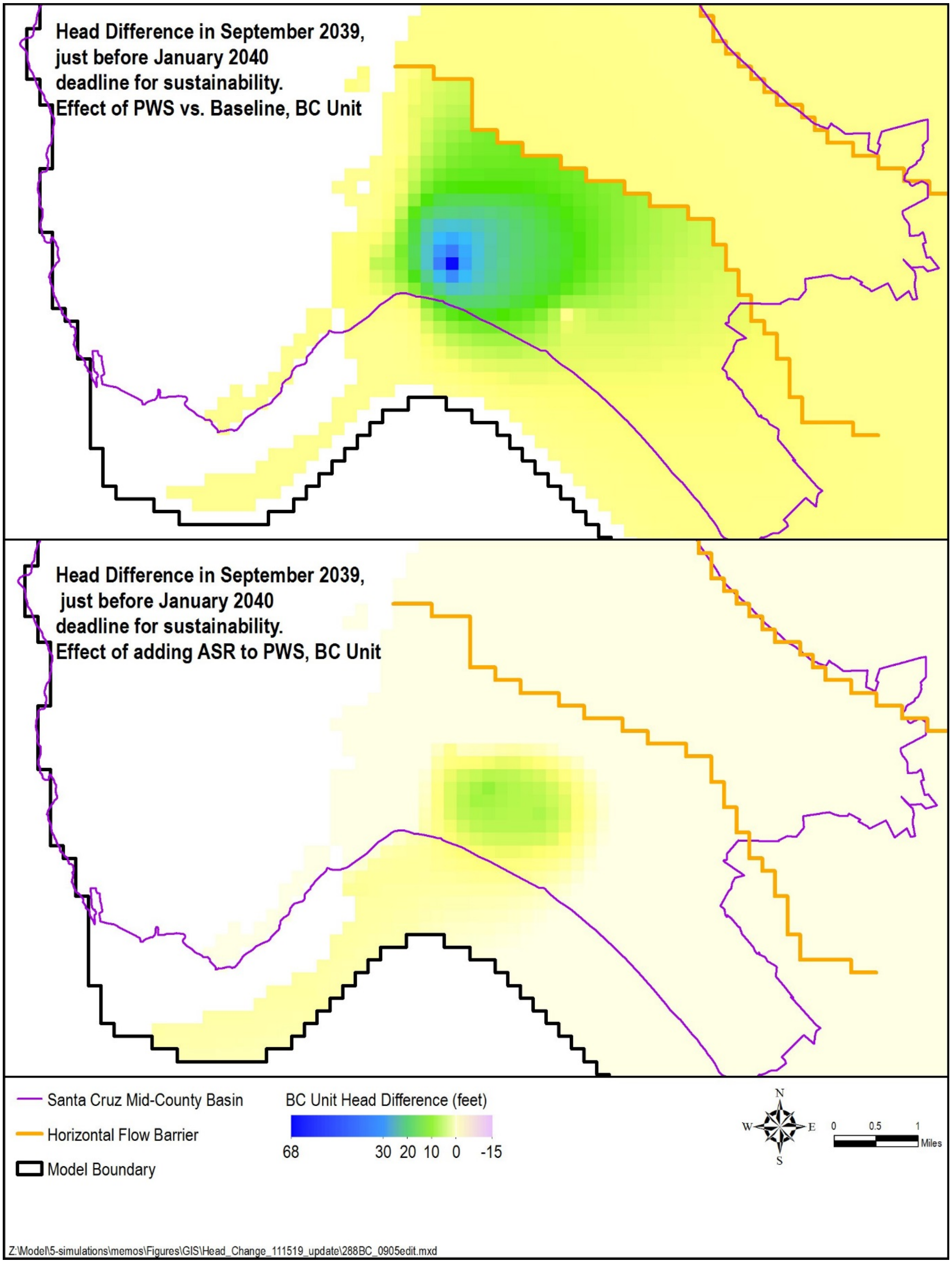


Figure 22. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations , BC Unit

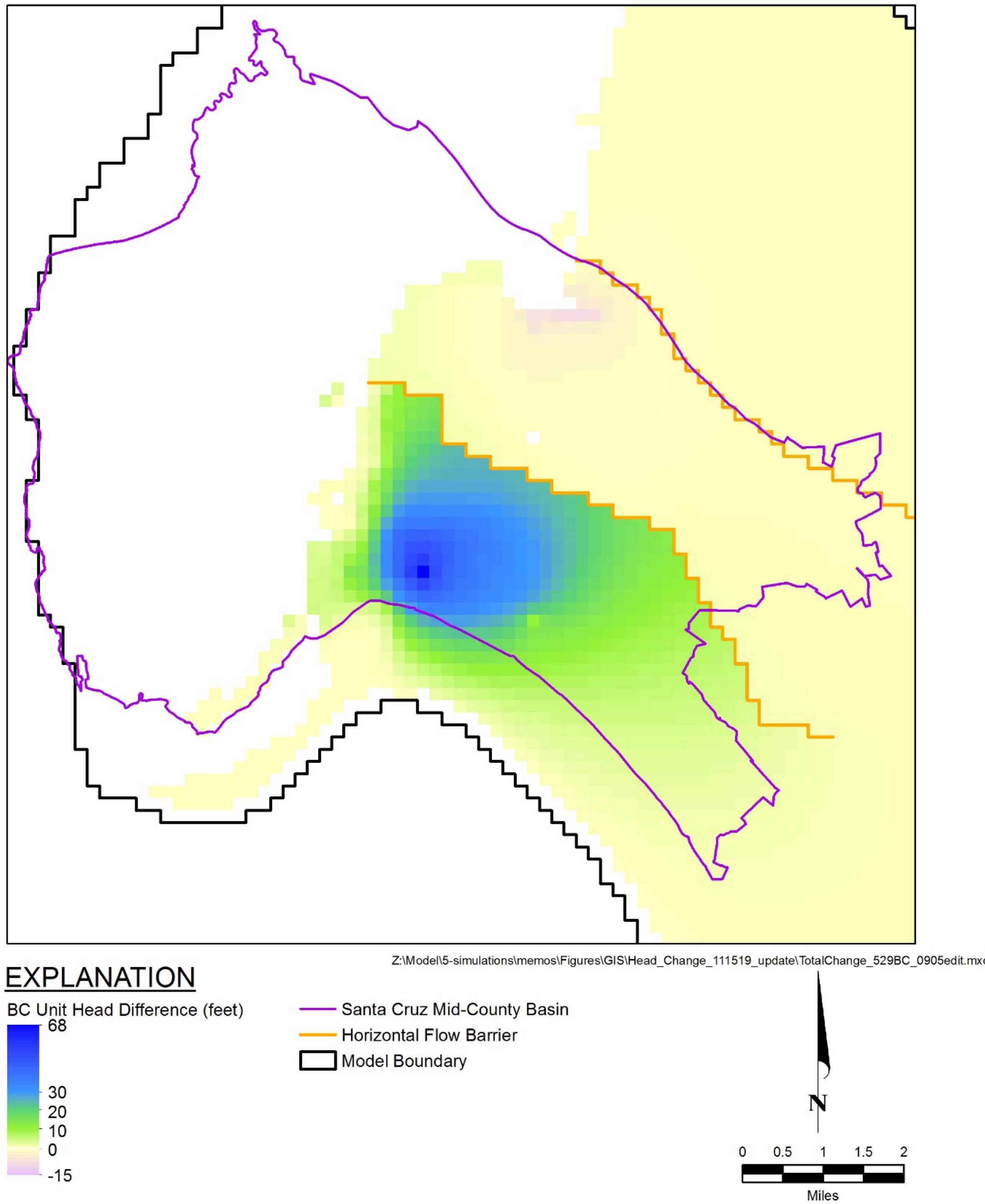


Figure 23. Simulated Effect of ASR and PWS on October 2059 Groundwater Elevations, BC Unit

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.

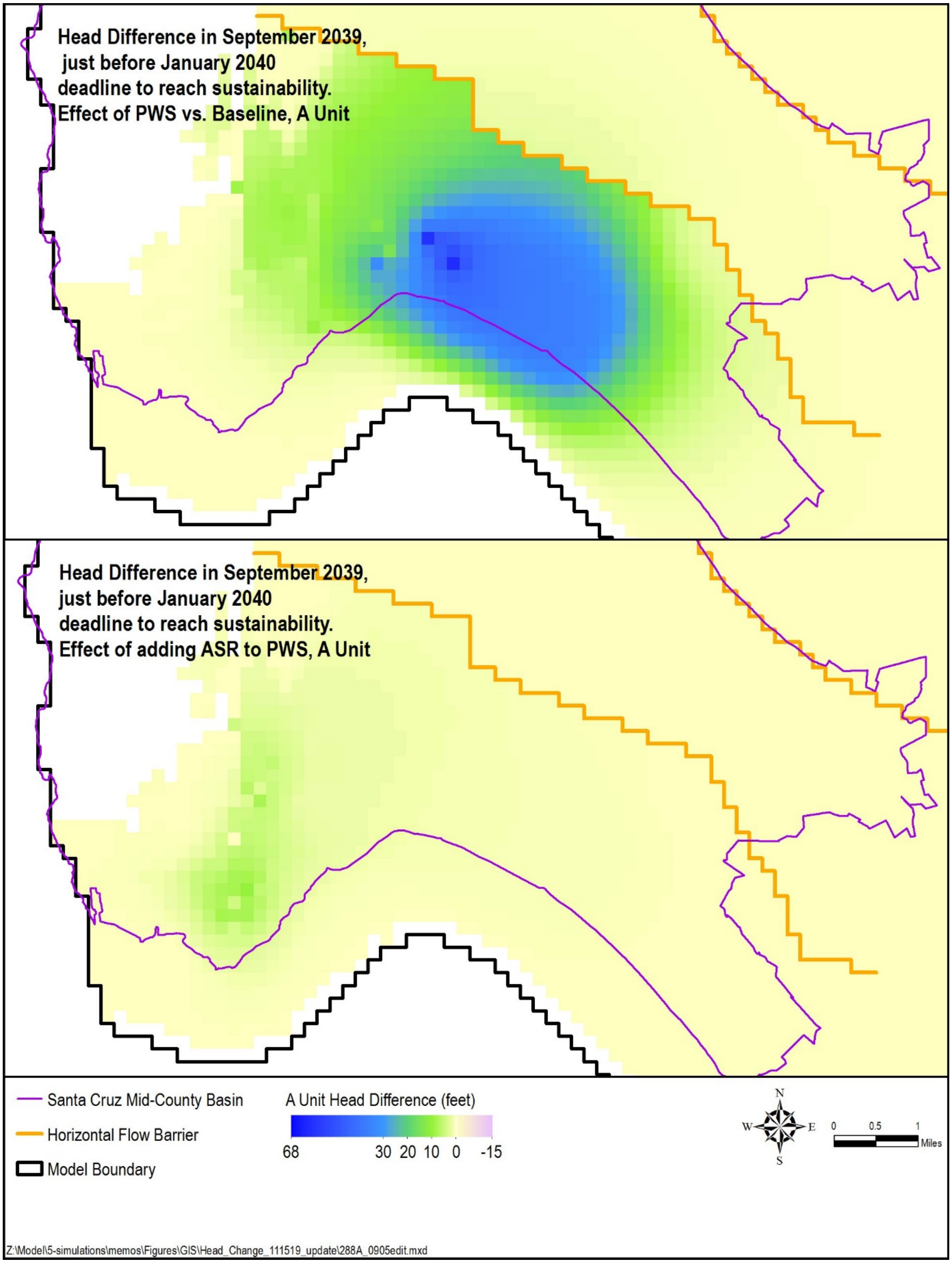


Figure 24. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations, A Unit

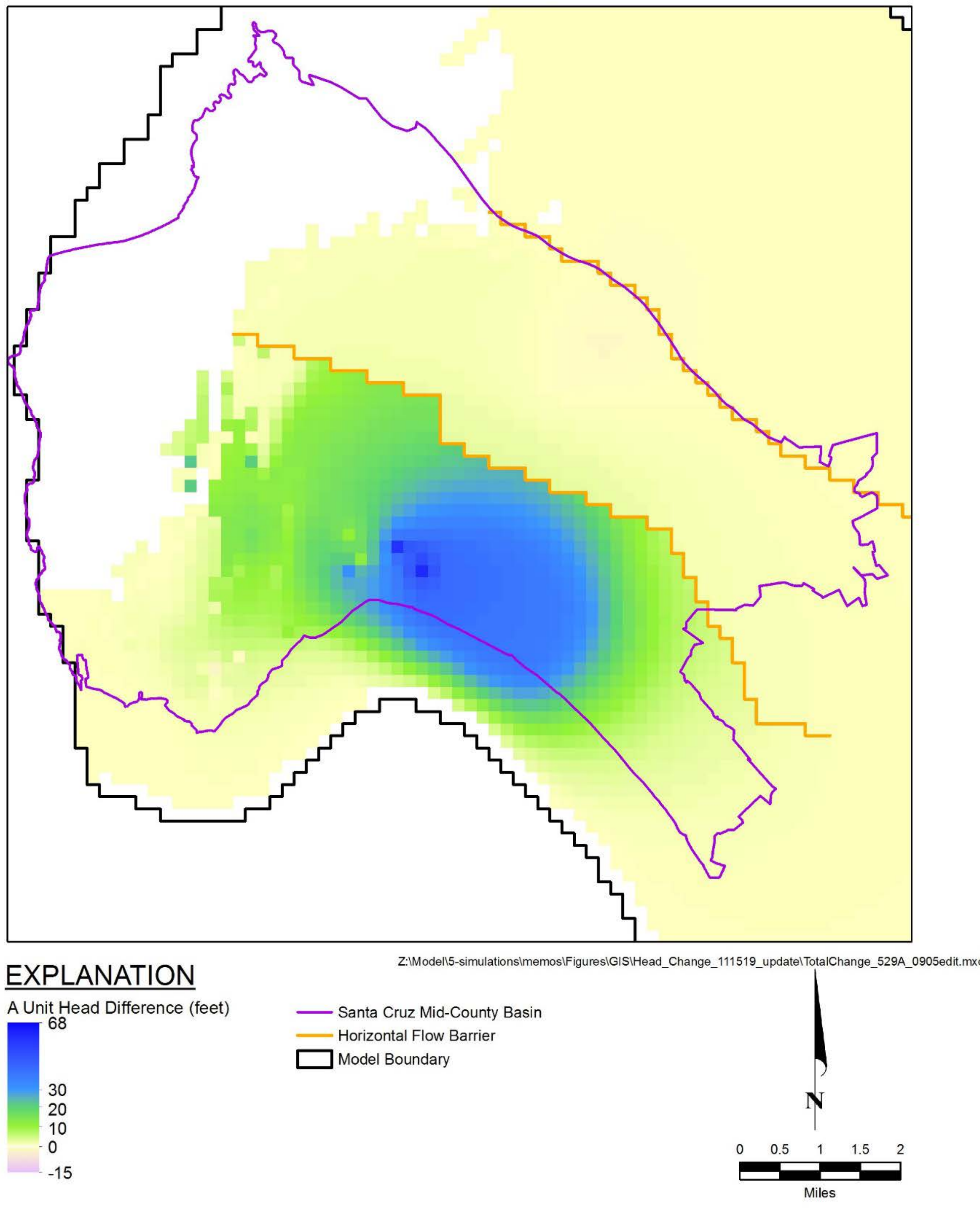


Figure 25. Simulated Effect of ASR and PWS on October 2059 Groundwater Elevations A Unit

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.

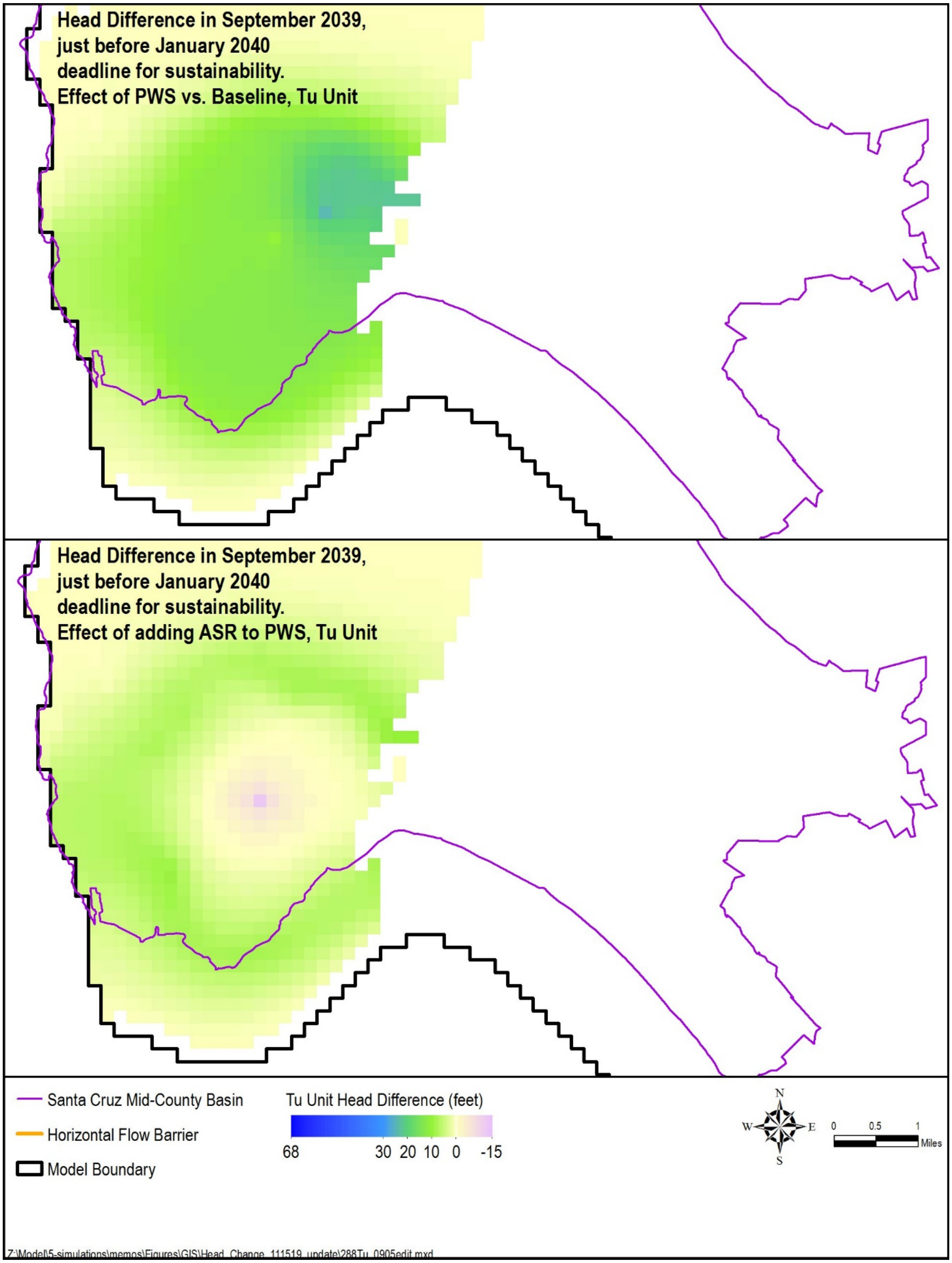


Figure 26. Simulated Effect of ASR and PWS on September 2039 Groundwater Elevations, Tu Unit

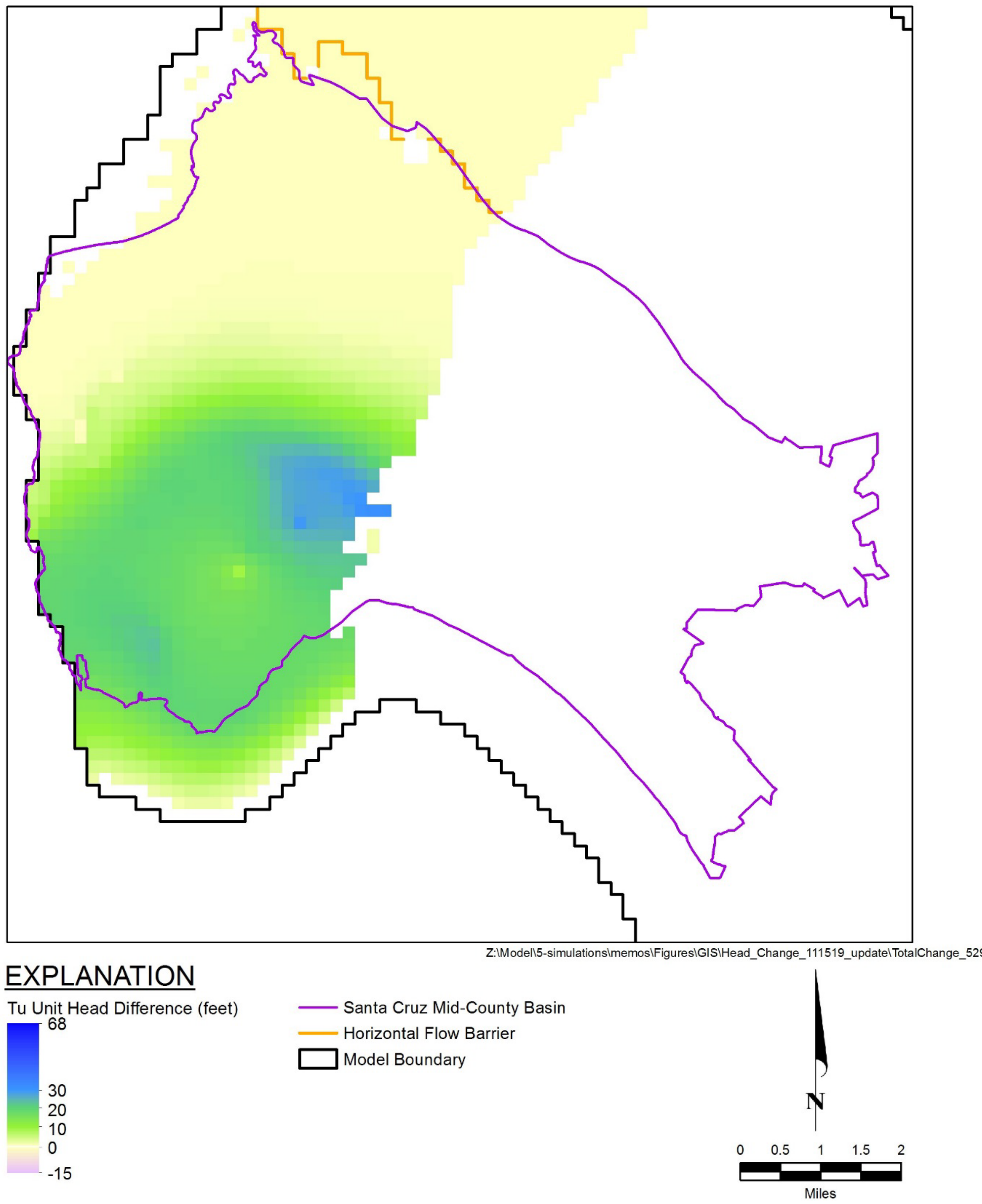


Figure 27. Simulated Effect of ASR and PWS on October 2059 Groundwater Elevations, Tu Unit

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.

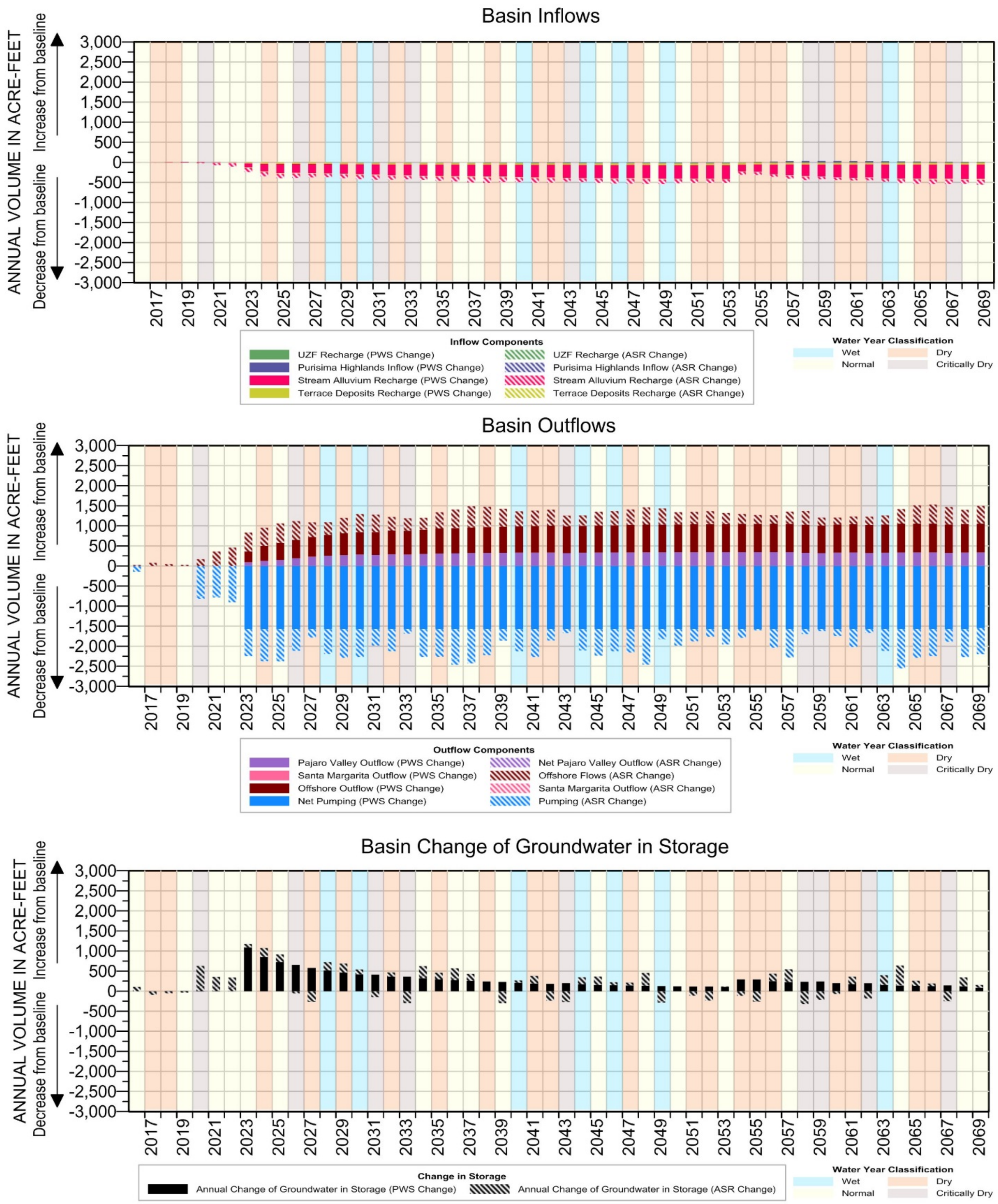


Figure 28. Overall Groundwater Budget, Comparison Between Baseline and Project Scenarios

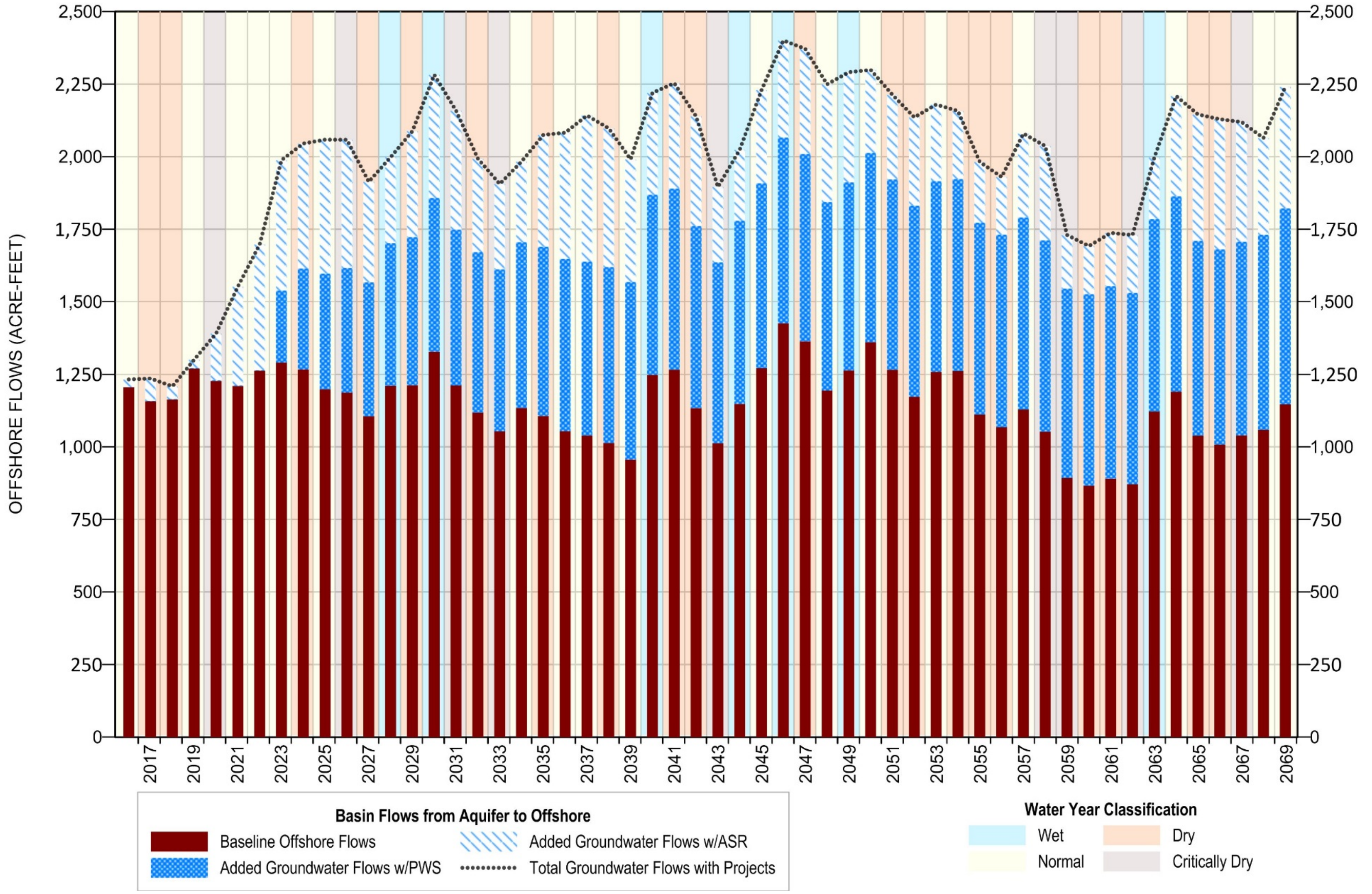


Figure 29. Offshore Flows, Comparison Between Baseline and Project Scenario

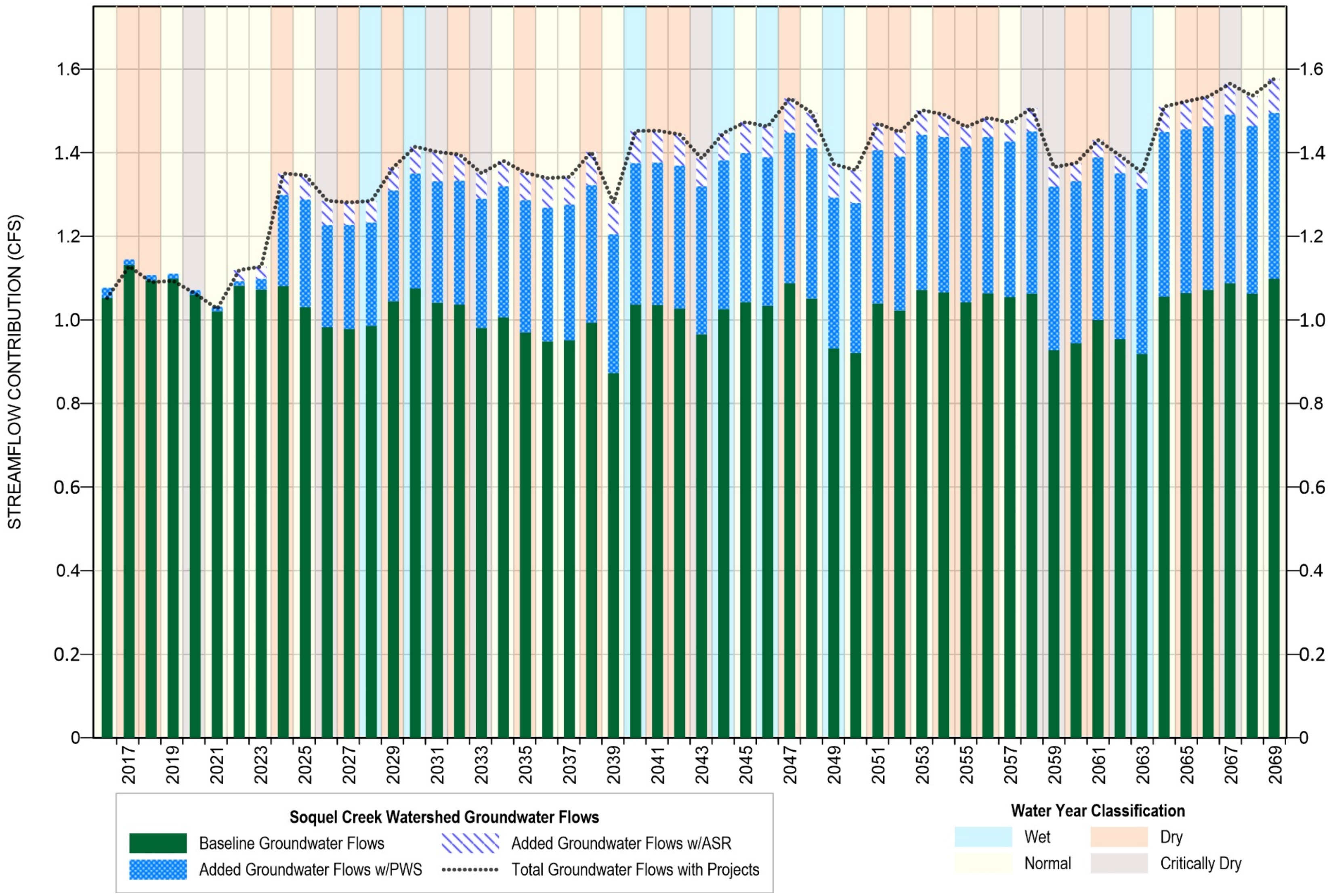


Figure 30. Soquel Creek Watershed Groundwater Flows during Minimum Flow Month Each Year, Comparison between Baseline and Project Scenarios

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.

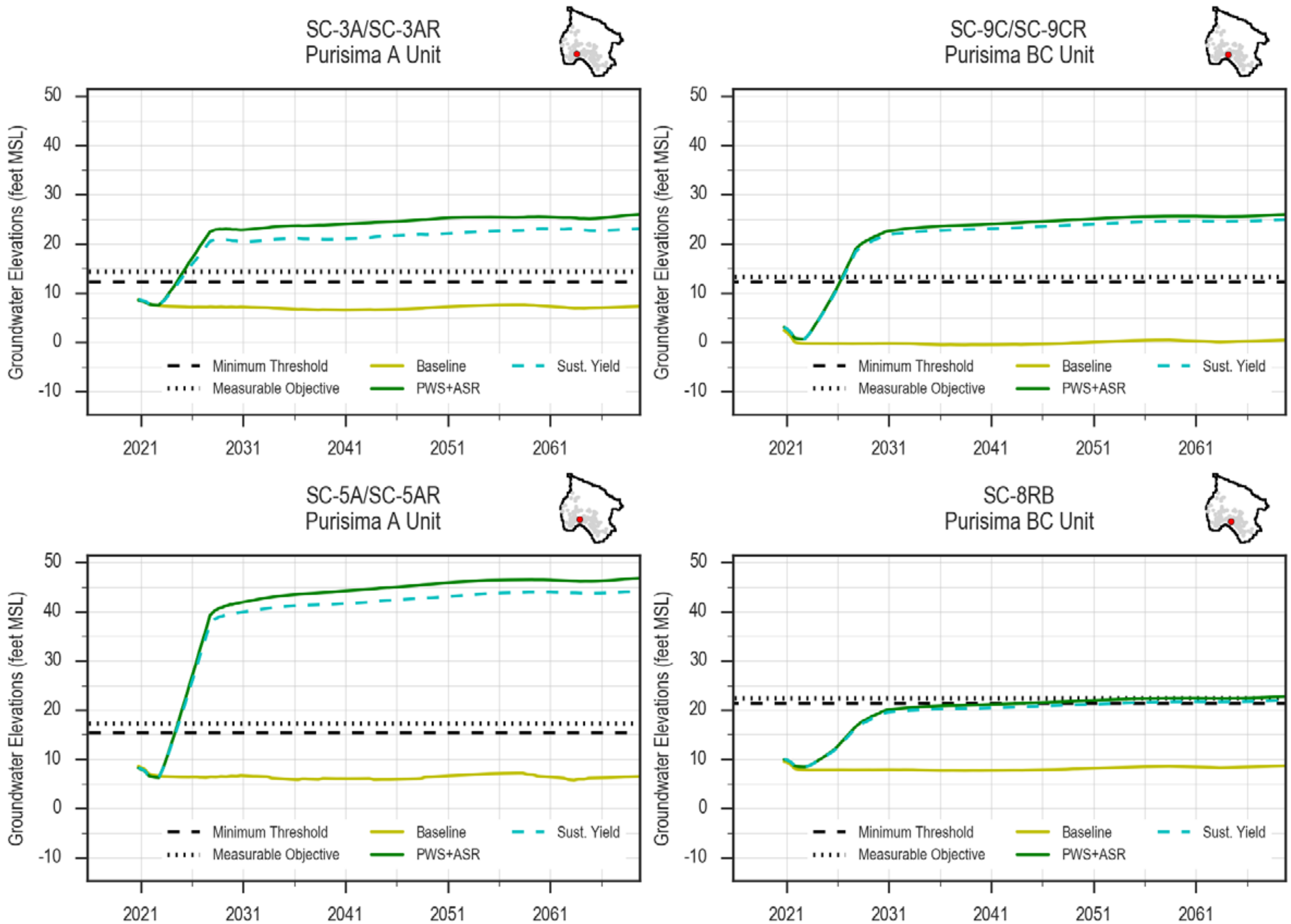


Figure 31. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima A and BC Units for Sustainable Yield Estimate

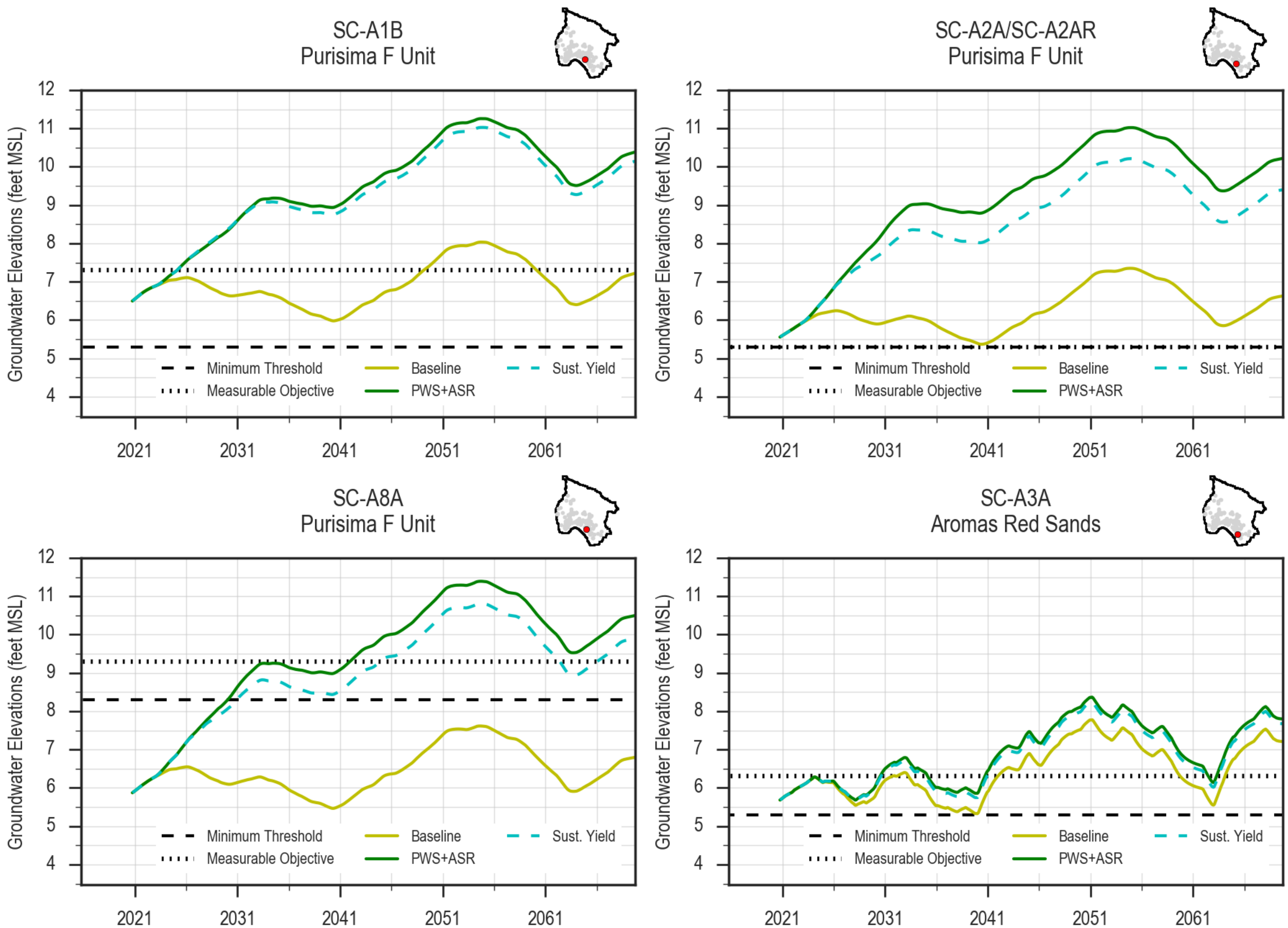


Figure 32. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Purisima F and Aromas Red Sands Units for Sustainable Yield Estimate

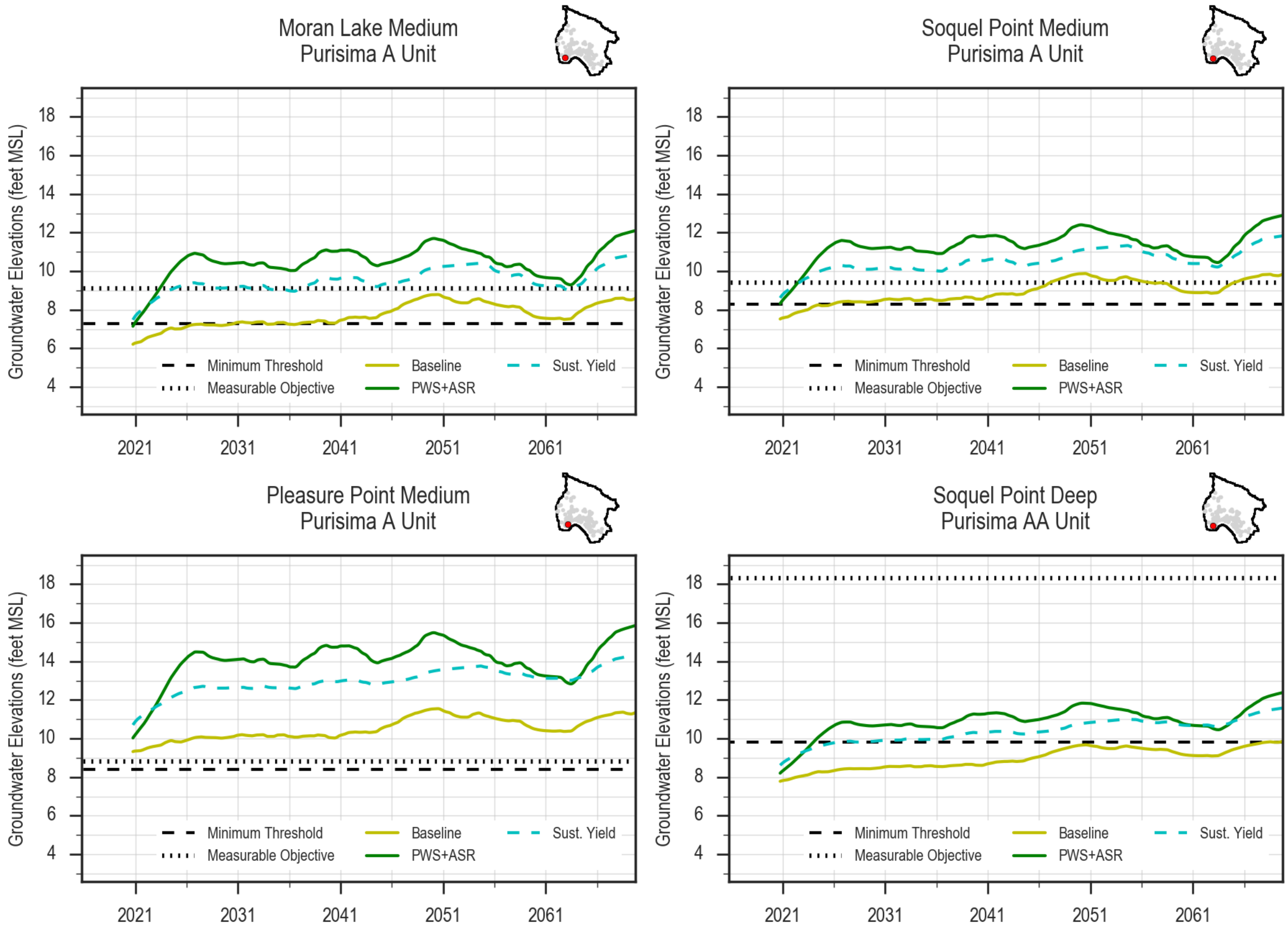


Figure 33. Running Five-Year Average Model Simulated Groundwater Elevations at Coastal Monitoring Wells in Tu and Purisima AA and A Units for Sustainable Yield Estimate

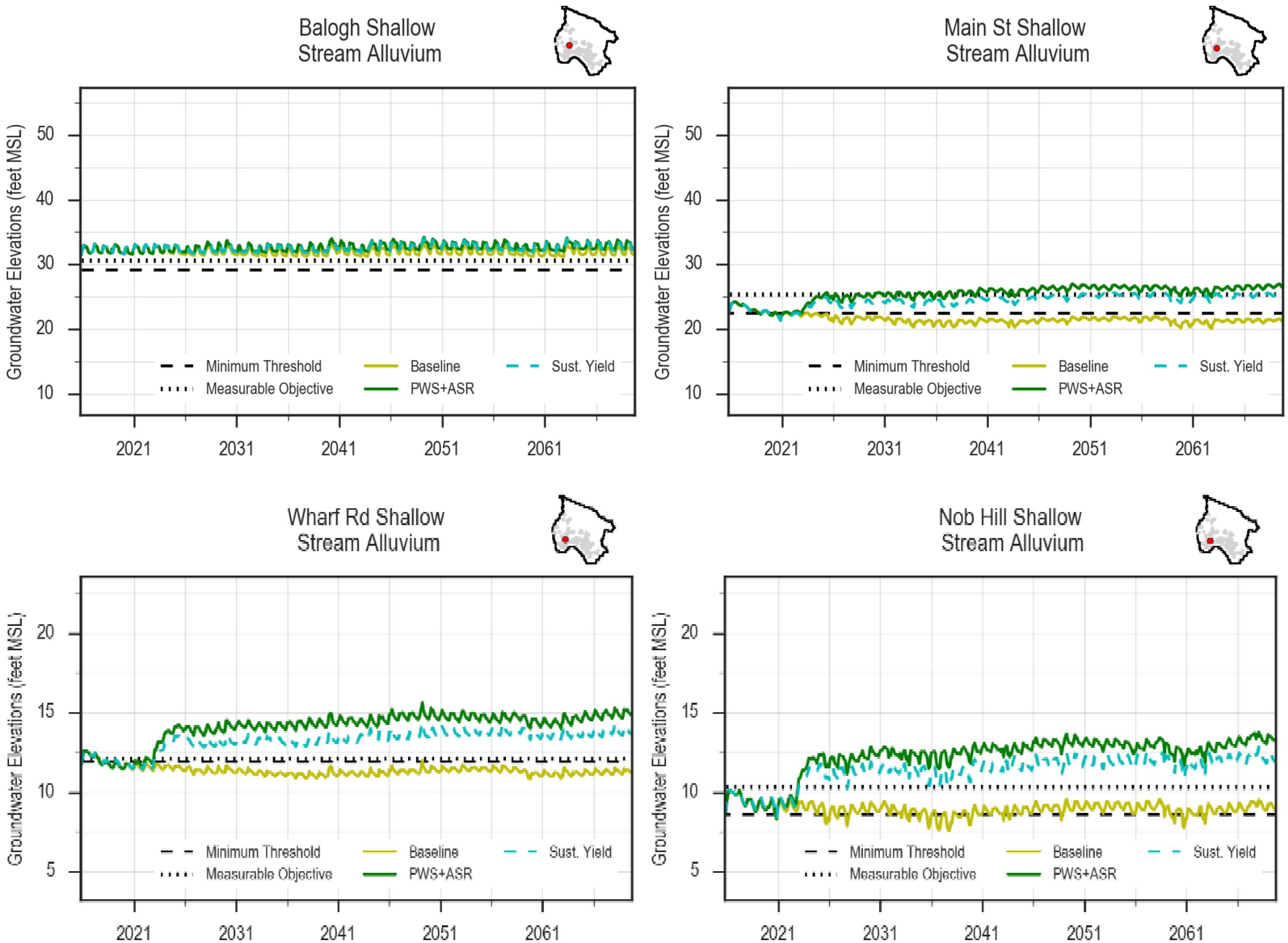


Figure 34. Simulated Groundwater Elevations at Shallow Wells along Soquel Creek for Sustainable Yield Estimate

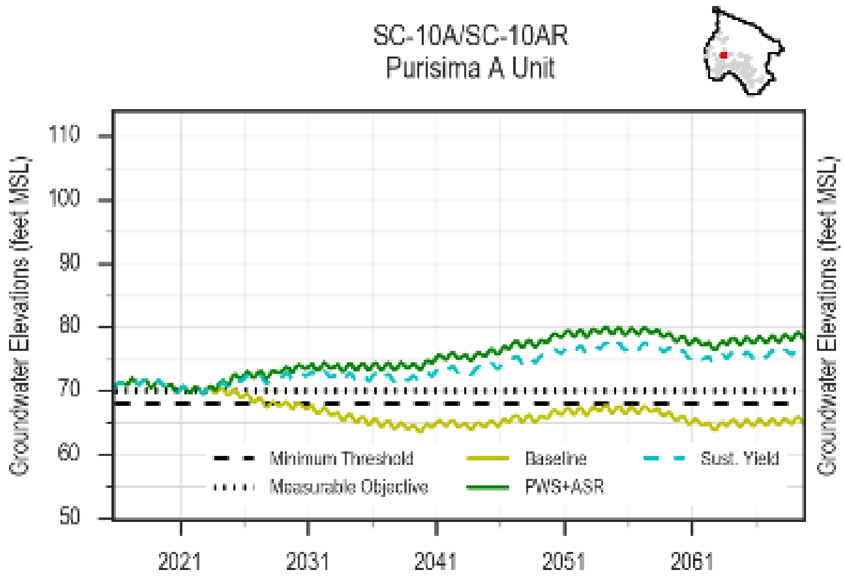


Figure 35. Simulated Groundwater Elevations at Purisima A Unit Well along Soquel Creek for Sustainable Yield Estimate

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.

7 REFERENCES

California Department of Water Resources (DWR), 2018, *Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development*, Sustainable Groundwater Management Program, July.

California Natural Resources Agency and California Ocean Protection Council, 2018, *State of California Sea-Level Rise Guidance: 2018 Update.*

Carollo Engineers, 2016, *Supplemental Groundwater Investigations (From Hopkins Consultants, Inc. and HydroMetrics WRI)*, project memorandum to Soquel Creek Water District, Appendix G of Groundwater Replenishment Feasibility Study, February 3.

City of Santa Cruz, 2019, *Water Demand – how it's changing*, Attachment 2 to Water Commission Information Report for Joint Workshop with Former Water Supply Advisory Committee, April 1.

HydroMetrics WRI, 2017a, *Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation (Task 2)*, Technical Memorandum to Santa Cruz Mid-County Groundwater Agency, March 31.

HydroMetrics WRI, 2017b, *Santa Cruz Mid-County Basin Groundwater Flow Model: Future Climate for Model Simulations (Task 5)*, Technical Memorandum to Santa Cruz Mid-County Groundwater Agency, August 17.

Montgomery & Associates (M&A), 2018, *Comparison of Climate Change Scenarios*, Technical Memorandum to Santa Cruz Mid-County Groundwater Agency, July 17.

Montgomery & Associates (M&A), 2019a. *Municipal Return Flow*, Technical Memorandum to Santa Cruz Mid-County Groundwater Agency, August 28.

Montgomery & Associates (M&A), 2019b. *Santa Cruz Mid-County Basin Model Integration and Calibration*, prepared for Santa Cruz Mid-County Groundwater Agency, GSP Review Draft, August 30.

Thornton; P.E., M.M., Thornton, B.W., Mayer, N., Wilhelmi, Y., Wei, R., Devarakonda, and R.B. Cook, 2014. *Daymet: Daily Surface Weather Data on a 1-km Grid for North America; Version 2*. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center; Oak Ridge; Tennessee; USA. Date accessed: 2016/01/04. Temporal range: 1980/01/01-2014/12/31. http://dx.doi.org/10.3334/ORNLDAAC/1219

Water Systems Consulting (WSC), 2016, *2015 Urban Water Management Plan*, prepared for Soquel Creek Water District, June.

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

APPENDIX 3-A

TECHNICAL APPROACH FOR DETERMINING GROUNDWATER ELEVATION MINIMUM THRESHOLD FOR CHRONIC LOWERING OF GROUNDWATER LEVELS IN REPRESENTATIVE MONITORING WELLS

Technical Approach for Determining Groundwater Elevation Minimum Threshold for Chronic Lowering of Groundwater Levels in Representative Monitoring Wells

The general premise for determining Minimum Thresholds for chronic lowering of groundwater levels is that groundwater levels cannot go below a level which prevents overlying groundwater users from meeting their typical water demand. Overlying water demand is determined from land use and by the well use indicated on well driller logs in the vicinity of the RMP.

The saturated thickness of an aquifer is an important factor that can limit well yields. When groundwater levels decline, the saturated thickness of the aquifer decreases. The saturated thickness may decrease to a point at which the aquifer can no longer produce water to the well at the minimum rate of pumping needed to meet typical demands.

The pump rate and aquifer properties control how much saturated aquifer thickness (distance between the bottom of the well and the groundwater level) is needed to meet water demands. Water demands by municipal wells are known as municipal agencies have detailed records of each well's pump capacity and volumes pumped. Private domestic and agricultural well users generally do not have this information, and therefore assumptions are made to estimate their water usage. For domestic use, average rates of 10 gpm were provided by a local pump contractor. For purposes of estimating the minimum saturated thickness (MST) needed, a more conservative rate of 15 gpm was used as this needs more saturated thickness than a well pumping at 10 gpm (i.e. the groundwater level needs to be higher for 15 gpm). For agricultural wells, the estimated capacity provided on the well driller's logs available indicated 250 gpm is typical.

A theoretical MST for each RMP is estimated using a spreadsheet tool developed by the Kansas Geological Survey based on the overlying water demand (Brookfield, 2016). The tool considers well efficiency, nearby pumping wells, and drawdown in the well due to pumping at a given rate. To consider uncertainties in the MST estimation, a 20% safety factor is added to the MST obtained from the spreadsheet tool. It is also assumed that a well pump can be placed no deeper than 20 feet from the bottom of the well to prevent the pump from being damaged by settled sediment in the bottom of the well. This is the typical depth well pumps are set in domestic wells according to a local pump installer. To account for this, a further 20 feet is added to the estimated MST. Figure 1 provides a generalized schematic that illustrates the method described above. The resultant adjusted MST is the minimum thickness of saturated aquifer that is needed for overlying groundwater users to meet their typical demand. In some areas, there may be two overlying uses, such as agricultural and domestic, or municipal and domestic. For these cases, the adjusted MST of the use type that results in the shallowest groundwater level is used.

As a conservative measure, the approach assumes the RMP has a depth equal to the shallowest nearby well screened in the same aquifer as the RMP. This results in a shallower groundwater elevation than if the actual depth of the RMP is used (if it is deeper than nearby wells).

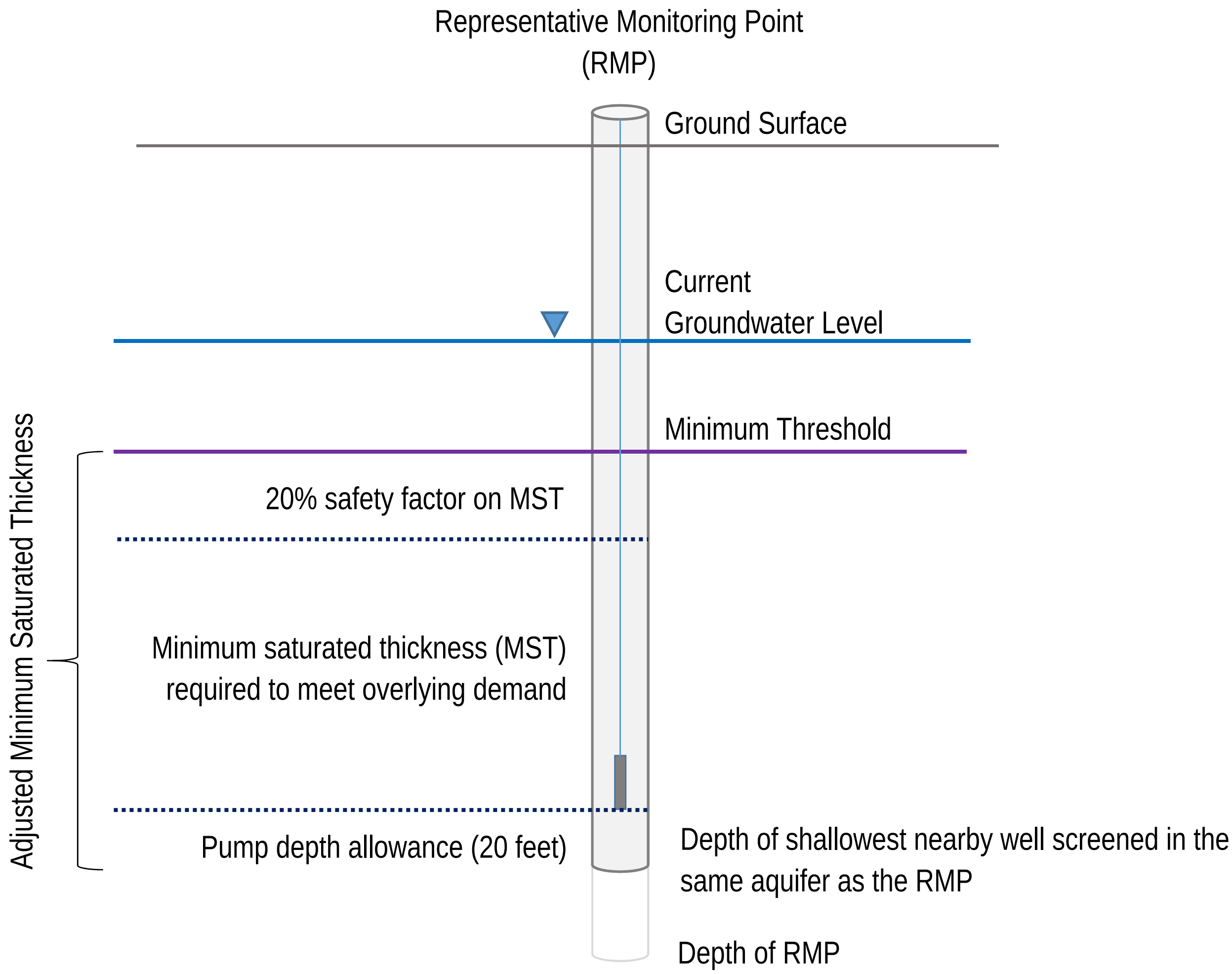


Figure 1. Schematic of Minimum Saturated Thickness Approach

Table 1 summarizes the minimum thresholds for 17 RMPs selected as representative across the Basin. There are five RMPs that had adjusted MSTs that are greater than 30 feet below historic low groundwater levels. For these RMPs, the minimum threshold was raised to 30 feet below historic low groundwater levels. This was done because, although the wells could meet their demand with a much lower groundwater level, having groundwater levels drop to these depths may influence other sustainability indicators. The rationale for selecting a maximum of 30 feet below historic low is that the majority of the RMPs have adjusted MSTs less than 30 feet below historic low levels as shown on Figure 2.

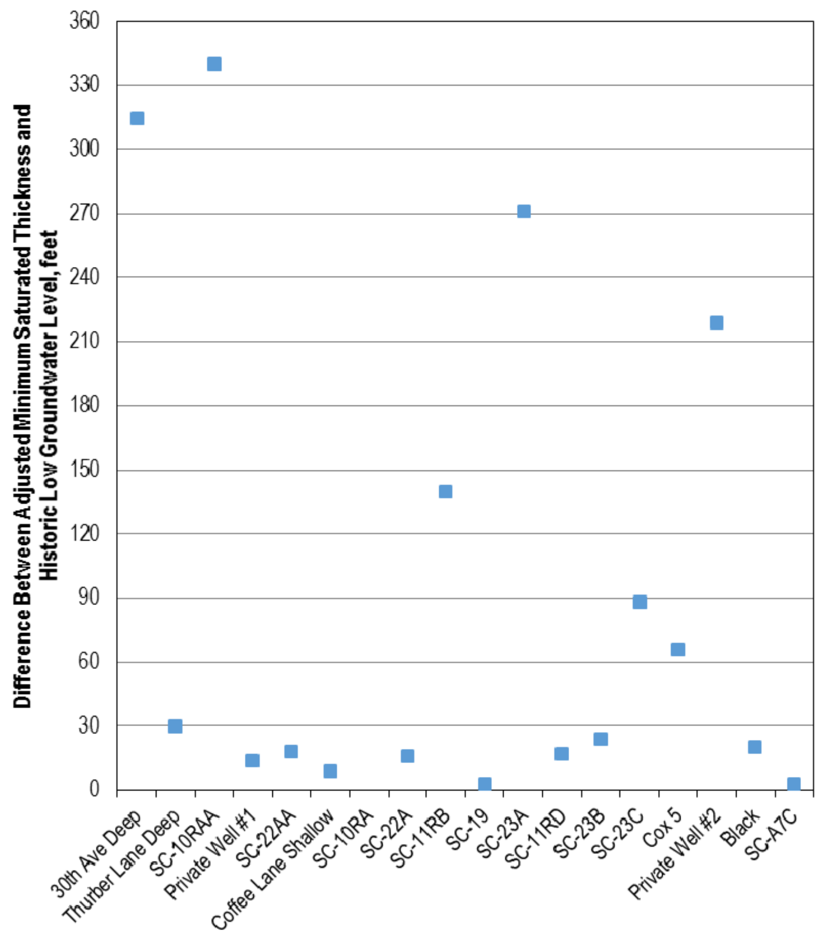


Figure 2. Representative Monitoring Points Difference between Adjusted Minimum Saturated Thickness and Historic Low Groundwater Level

There are four wells where the minimum thresholds were raised to sea level as these are close to protective elevation coastal monitoring wells and having groundwater levels below sea level will make it difficult to achieve protective elevations at the coast. Other reasons for raising elevations from the MST levels are provided in Table 1.

References

Brookfield, A. 2016. Minimum Saturated Thickness Calculator, Method Overview and Spreadseet Description. Kansas Geological Survey Open---File Report 2016---3, pp 6.

Table 1. Summary of Representative Monitoring Points with Minimum Threshold Groundwater Elevations

RMP Name	Overlying Demand Type	Aquifer	Minimum Threshold Elevation (feet amsl)	Minimum Saturated Thickness (MST) Assumptions and Adjustments made to Minimum Thresholds (MT)
30th Ave Deep	Municipal	Tu	0	No private wells screened in this very deep aquifer. There are some municipal wells screened in this aquifer > 0.8 mile to the north. Shallowest municipal well depth results in a minimum elevation of -324 ft amsl based on the MST. However, well screens are typically at 200 ft below ground so the MT is adjusted upwards to sea level which is typically above well screens.
Thurber Lane Deep	Private Domestic	Purisima AA/Tu	-10 Upward	Shallowest domestic well depth results in a minimum elevation of -33 ft amsl that still meets demands. Increase the elevation to -10 ft amsl so that there is not such a steep gradient between this RMP and the coast where there are higher protective groundwater elevations.
SC-10RAA	Private Domestic	Purisima AA/Tu	35 30 ft below low	There are no deep domestic wells in the area of this RMP that are screened in the Pur AA/Tu similar to the RMP. They are screened shallower in Pur A/AA and in the alluvium. Even using the shallowest domestic well depth (not screened in the same aquifer), adjusted MST is at -275 ft amsl, MT is therefore set to 30 ft below historic low levels.
Private Well #1	Private Domestic	Purisima AA/Tu	362	Shallowest domestic well depth in same aquifer as RMP.
SC-22AA	Municipal	Purisima AA	0	Shallowest municipal well depth and municipal well MST. The adjusted MST is --3 ft amsl, MT is therefore increased to sea level.
Coffee Lane Shallow	Municipal	Purisima A/AA	27	Shallowest domestic well depth in same aquifer as RMP.
SC-22A	Municipal/Private Domestic	Purisima A	2	Shallowest domestic well depth, adjusted MST at muni well MST is -3 ft amsl. MT set at 2 ft above SC-22AA MT because groundwater levels in SC-22A are typically 2 ft higher than SC-22AA levels, which has a minimum threshold of 0 ft amsl.
SC-11RB	Private Domestic	Purisima BC	120	Not many domestic wells are deep enough in this location to go down through the Purisima DEF and D units into the underlying Purisima BC unit. Shallowest domestic well depth in same aquifer as RMP (555 ft). MT set to 30 ft below historic low because adjusted MST results in > 30 ft below historic low level.
SC-19	Municipal/Private Domestic	Purisima BC	56	Not many private wells nearby. Municipal wells are shallower than private wells with County records. Used shallowest municipal well depth

RMP Name	Overlying Demand Type	Aquifer	Minimum Threshold Elevation (feet amsl)	Minimum Saturated Thickness (MST) Assumptions and Adjustments made to Minimum Thresholds (MT)
				in same aquifer as RMP.
SC-23A	Municipal	Purisima BC	0	No domestic wells at this depth in the area. Shallowest municipal well depth, adjusted MST >30 ft below historic low. Raise MT to sea level 0 ft amsl which is 21 ft below historic low.
SC-11RD	Private Domestic	Purisima DEF	295	Shallowest domestic well depth in same aquifer as RMP.
SC-23B	Small Water System/ Private	Purisima DEF	50	Shallowest domestic well depth results in a minimum elevation of -137 ft amsl that still meets demands. Increase the elevation to 50 ft amsl. Difference in groundwater levels between SC-23B and SC-23A is 50 ft during historic low levels on hydrograph.
SC-23C	Municipal	Purisima F	15	Shallowest domestic well depth results in a minimum elevation of -14 ft amsl that still meets demands. Increase the elevation to 15 ft amsl. This is both 30 ft lower than historic low and equal to the average depth below SC-23B elevation.
CWD-5	Private Domestic	Purisima F	133	Shallowest domestic well depth results in a minimum elevation of 97 ft amsl that still meets demands. Increase the MT elevation to 30 ft below average historic lows.
Private Well #2	Private Domestic	Purisima F	562	Shallowest domestic well depth results in a minimum elevation of 433 ft amsl that still meets demands. Increase the elevation to 562 ft amsl, which is 30 ft below historic lows.
Black	Private Domestic	Purisima F	21	Other domestic wells in the area are screened in both the Aromas and Purisima F, while this RMP is screened in only the Purisima F. The MT is set at a level less than 30 ft below the historic low.
SC-A7C	Ag/Municipal	Aromas	0	Shallowest Ag well depth results in a minimum elevation of --20 ft amsl that still meets demands. MT is therefore set at sea level.

APPENDIX 3-B

HYDROGRAPHS OF REPRESENTATIVE MONITORING POINTS FOR CHRONIC LOWERING OF GROUNDWATER LEVELS

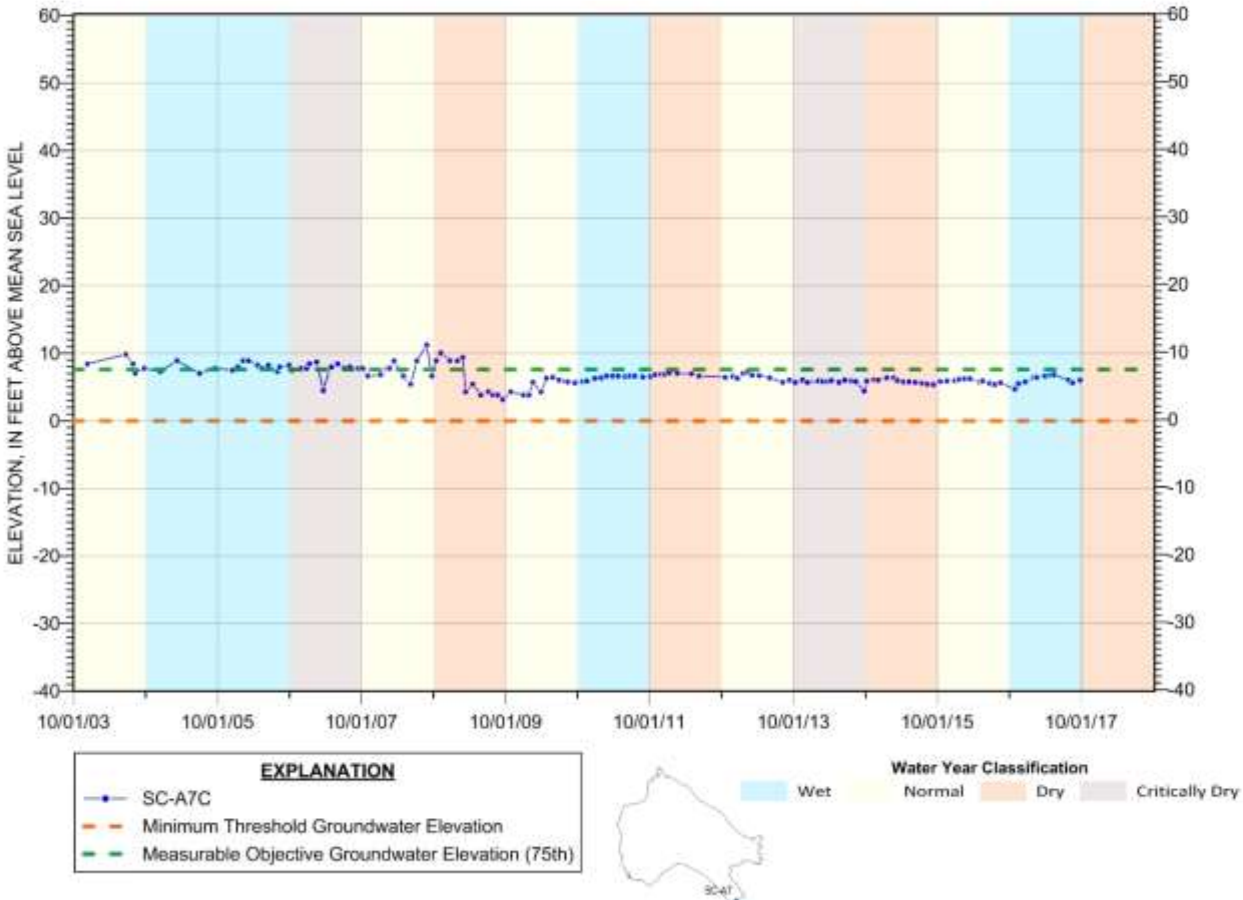


Figure 3-B.1. SC-A7C Hydrograph with Minimum Threshold and Measureable Objective

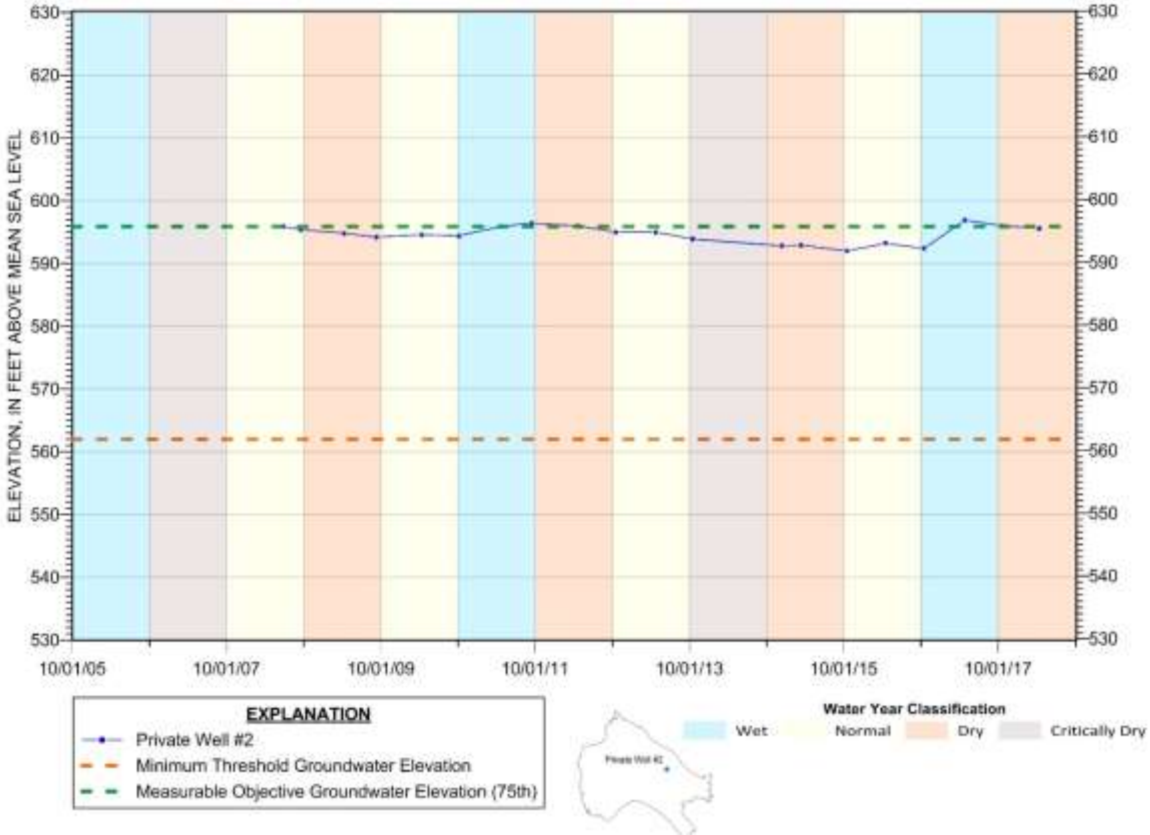


Figure 3-B.2. Private Well #2 Hydrograph with Minimum Threshold and Measureable Objective

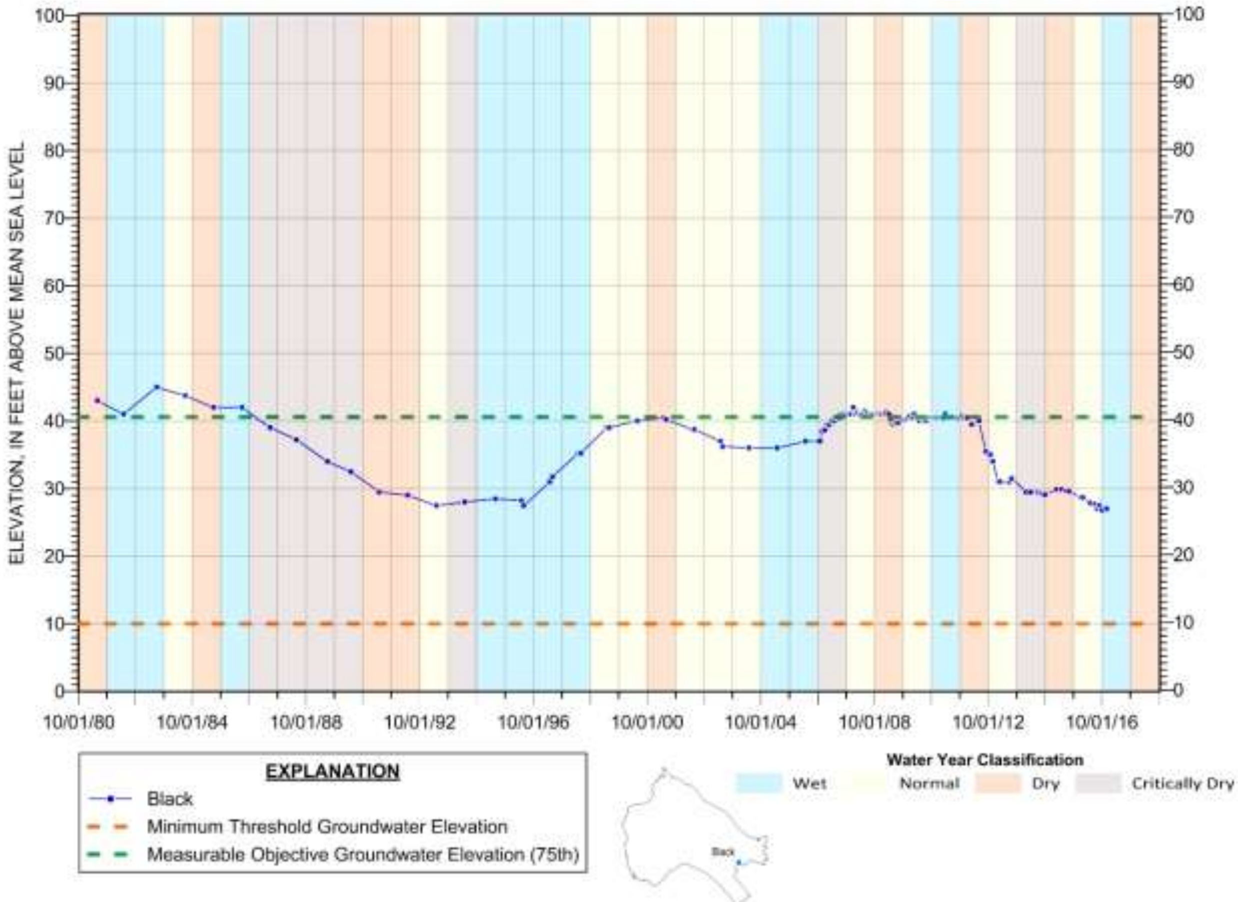


Figure 3-B.3. Black Hydrograph with Minimum Threshold and Measureable Objective

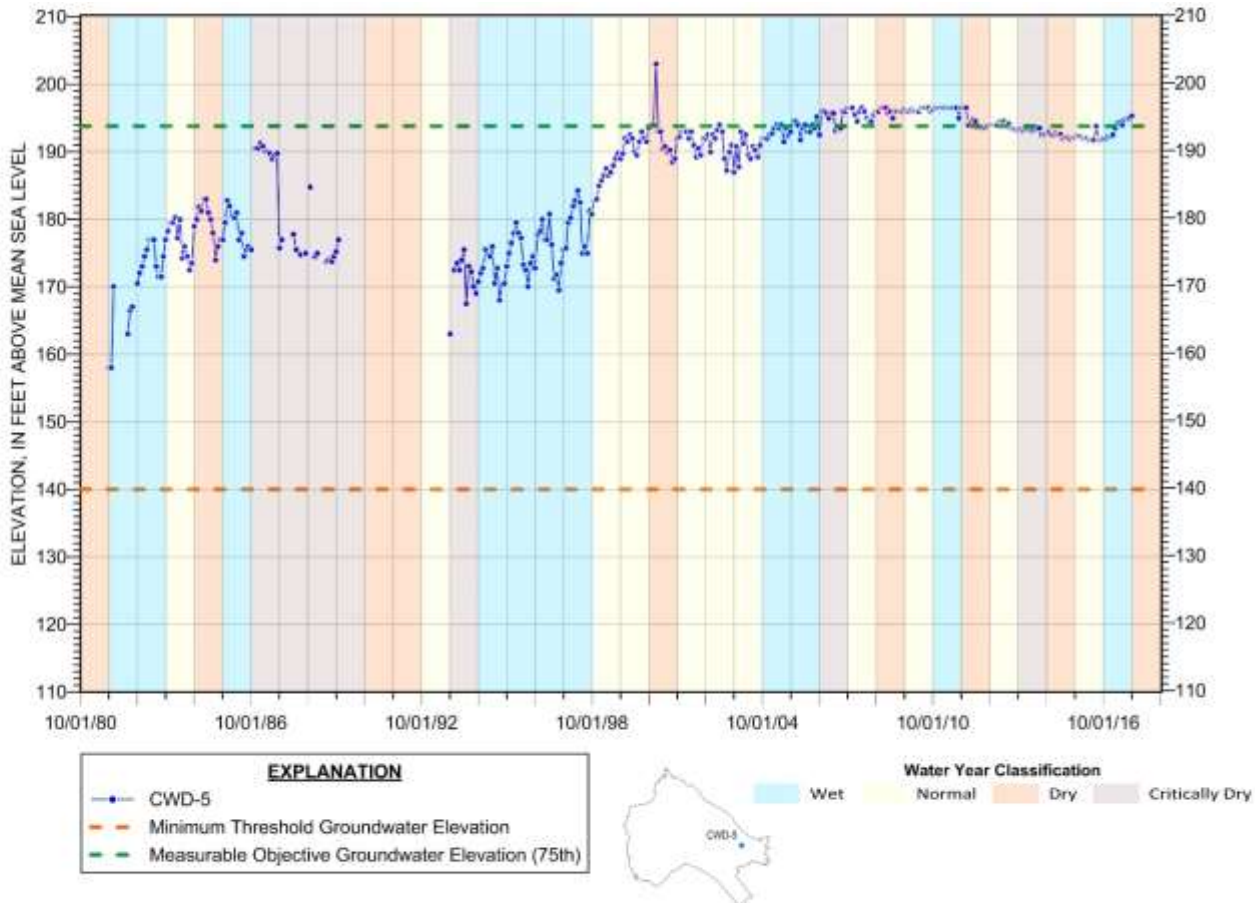


Figure 3-B.4. CWD-5 Hydrograph with Minimum Threshold and Measureable Objective

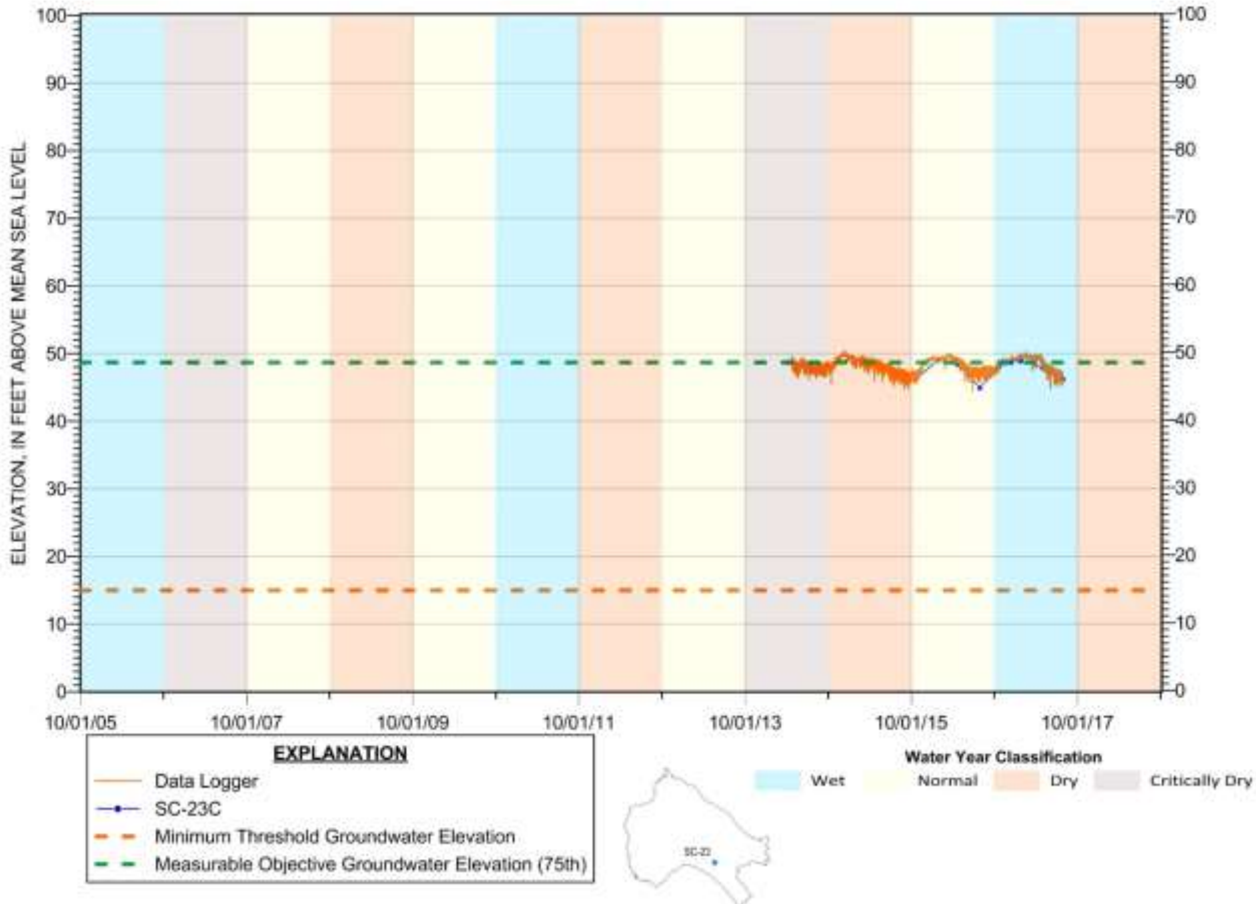


Figure 3-B.5. SC-23C Hydrograph with Minimum Threshold and Measureable Objective

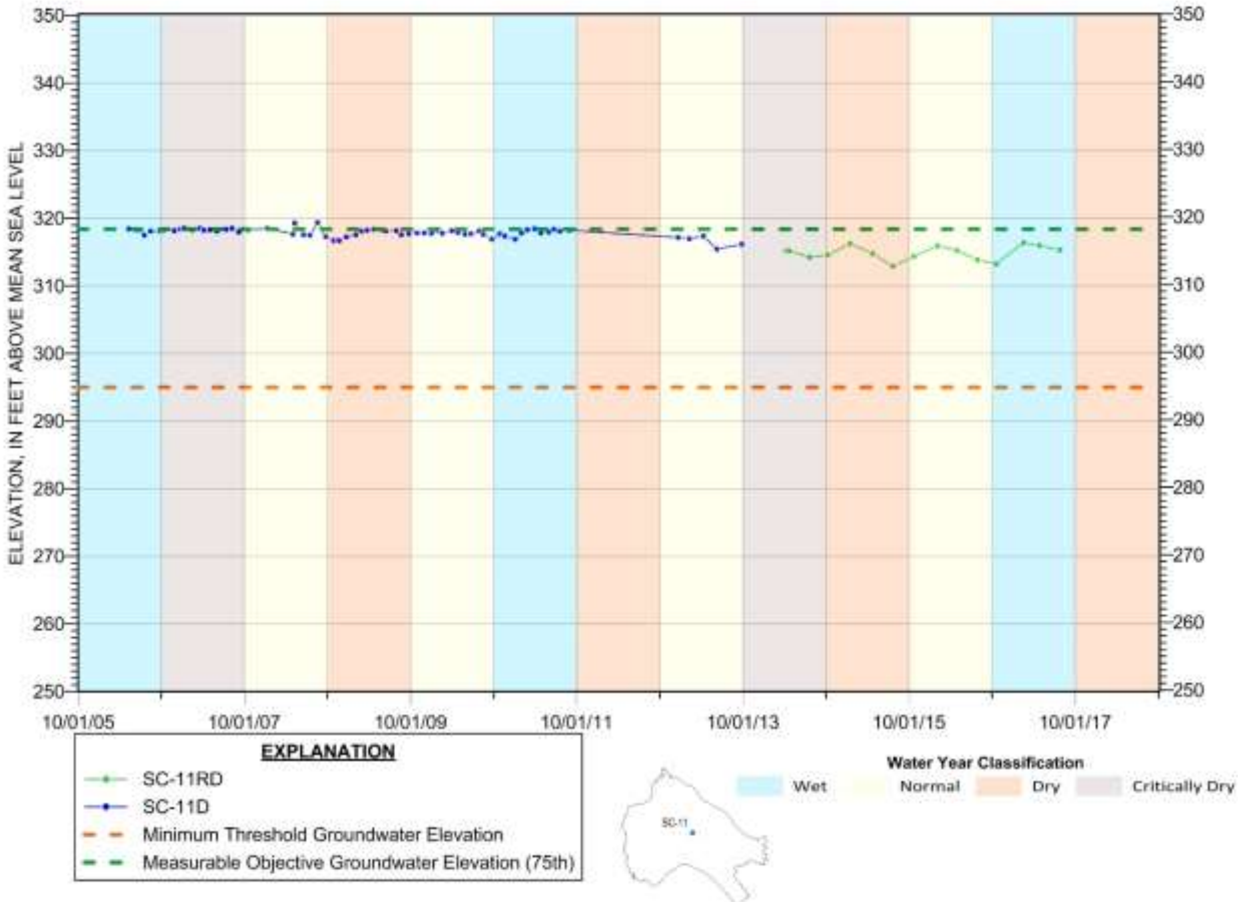


Figure 3-B.6. SC-11RD Hydrograph with Minimum Threshold and Measureable Objective

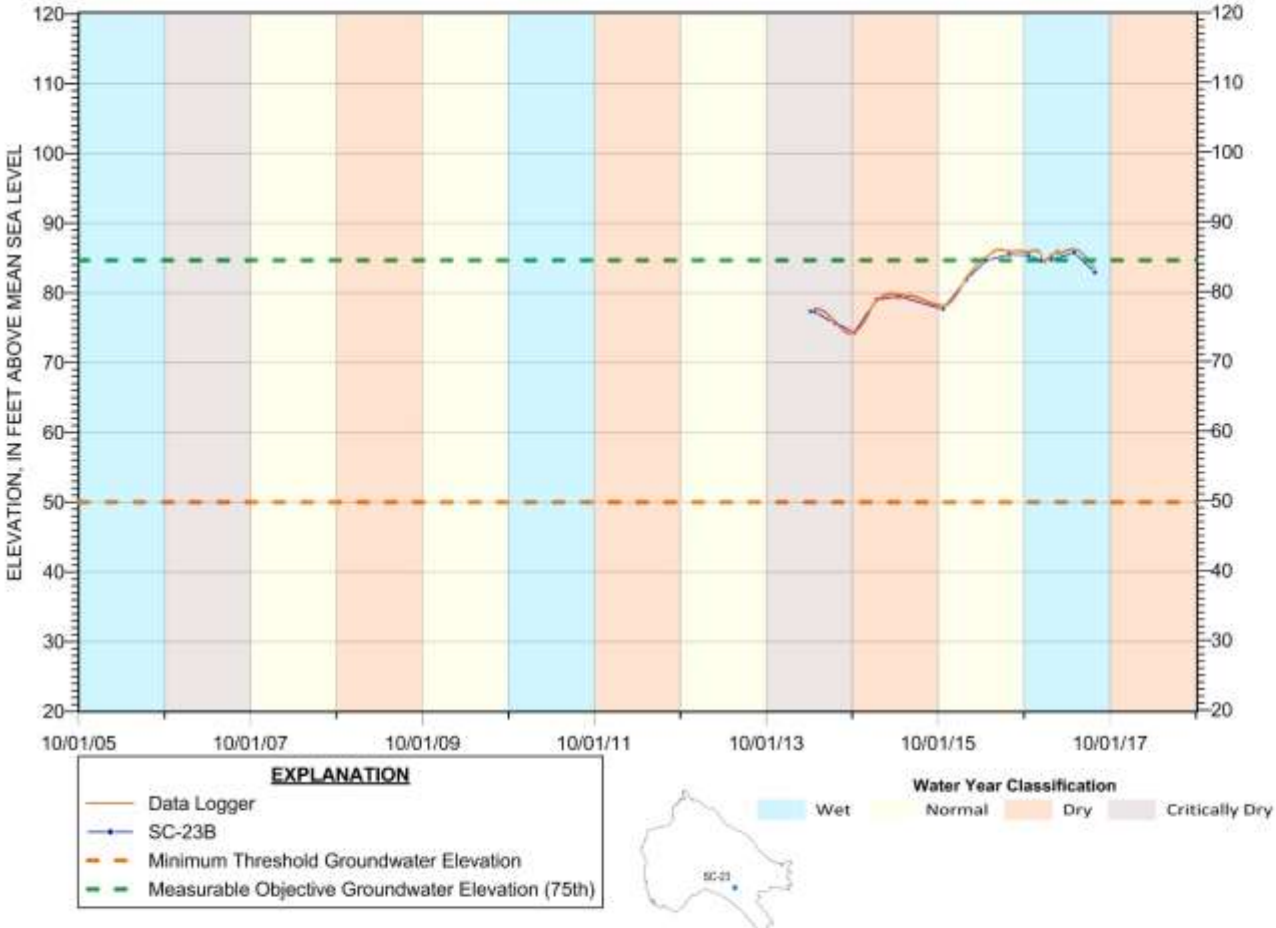


Figure 3-B.7. SC-23B Hydrograph with Minimum Threshold and Measurable Objective

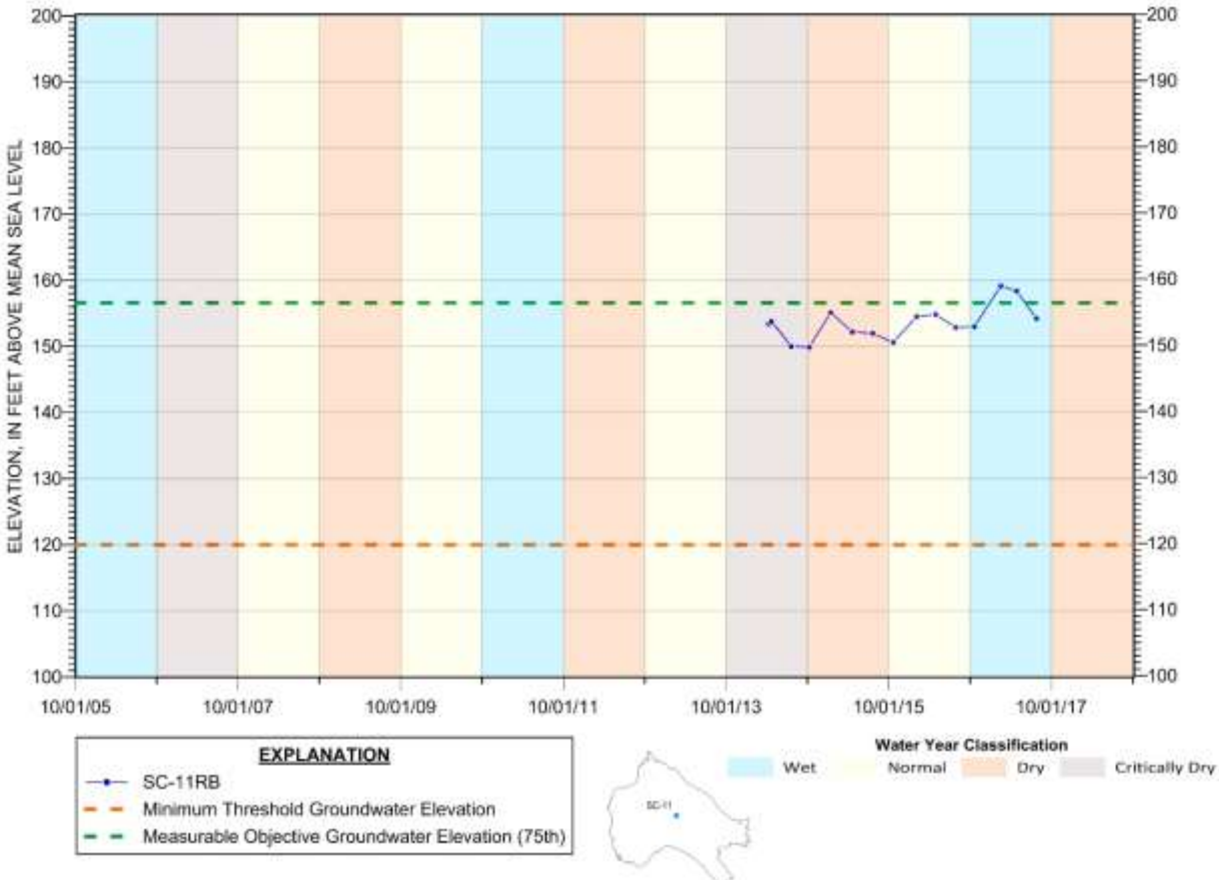


Figure 3-B.8. SC-11RB Hydrograph with Minimum Threshold and Measureable Objective

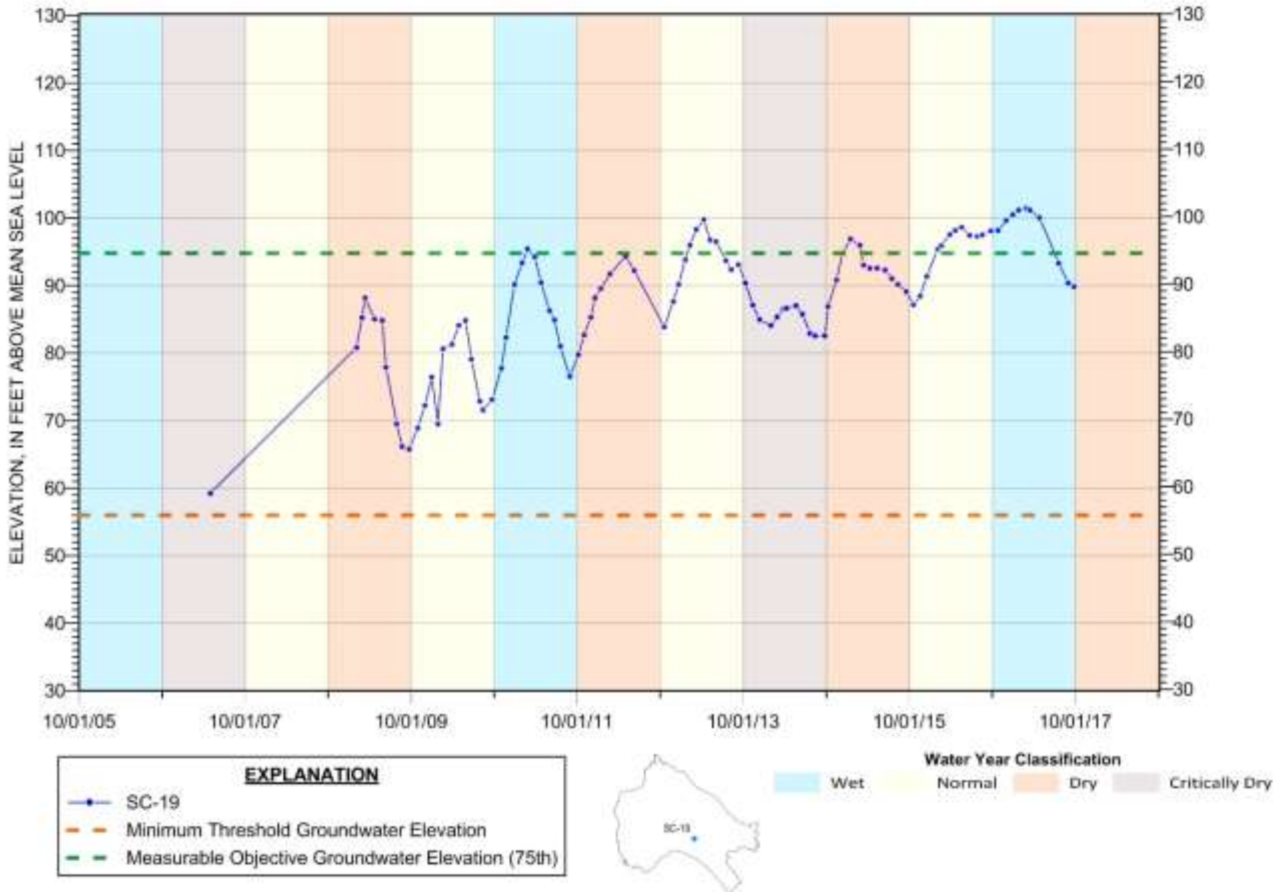


Figure 3-B.9. SC-19 Hydrograph with Minimum Threshold and Measureable Objective

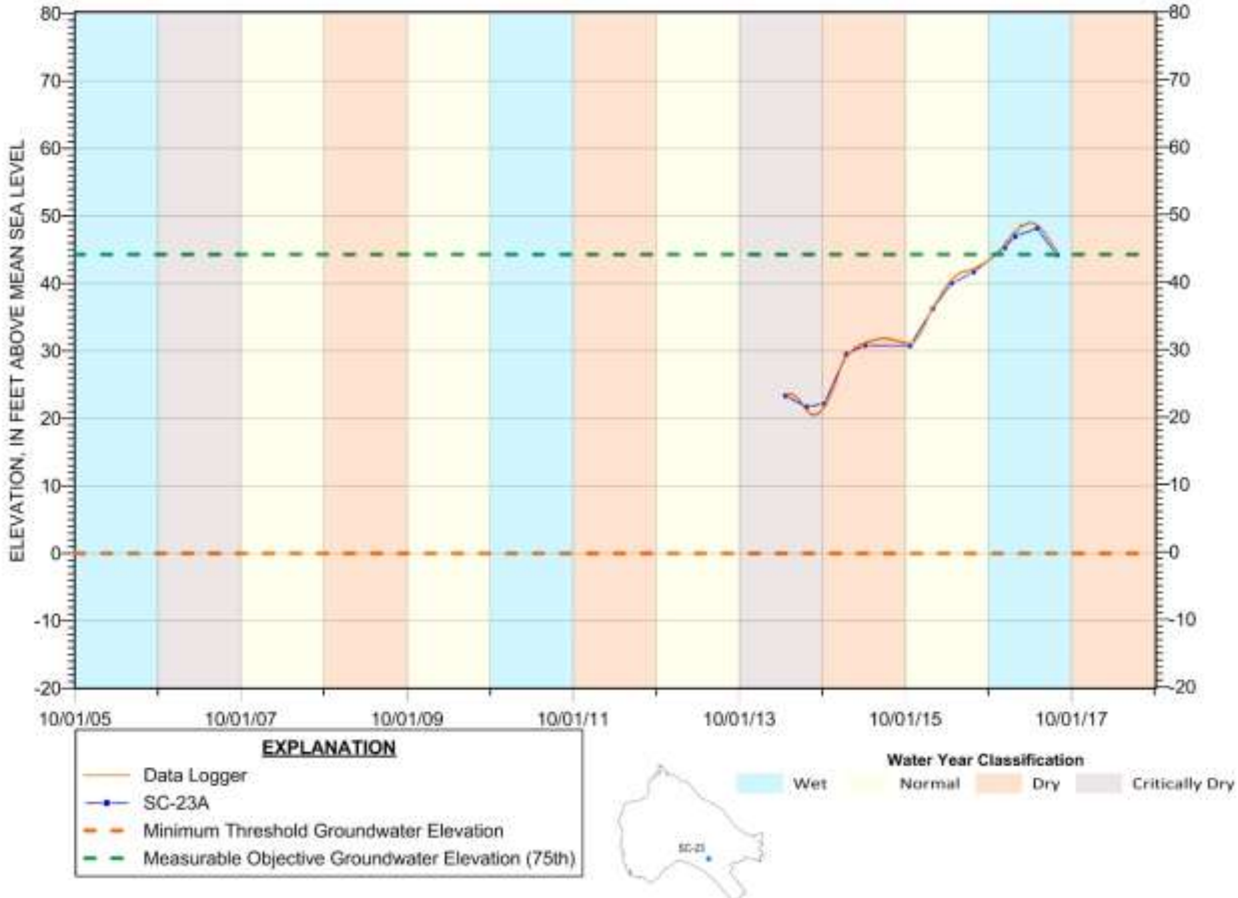


Figure 3-B.10. SC-23A Hydrograph with Minimum Threshold and Measureable Objective

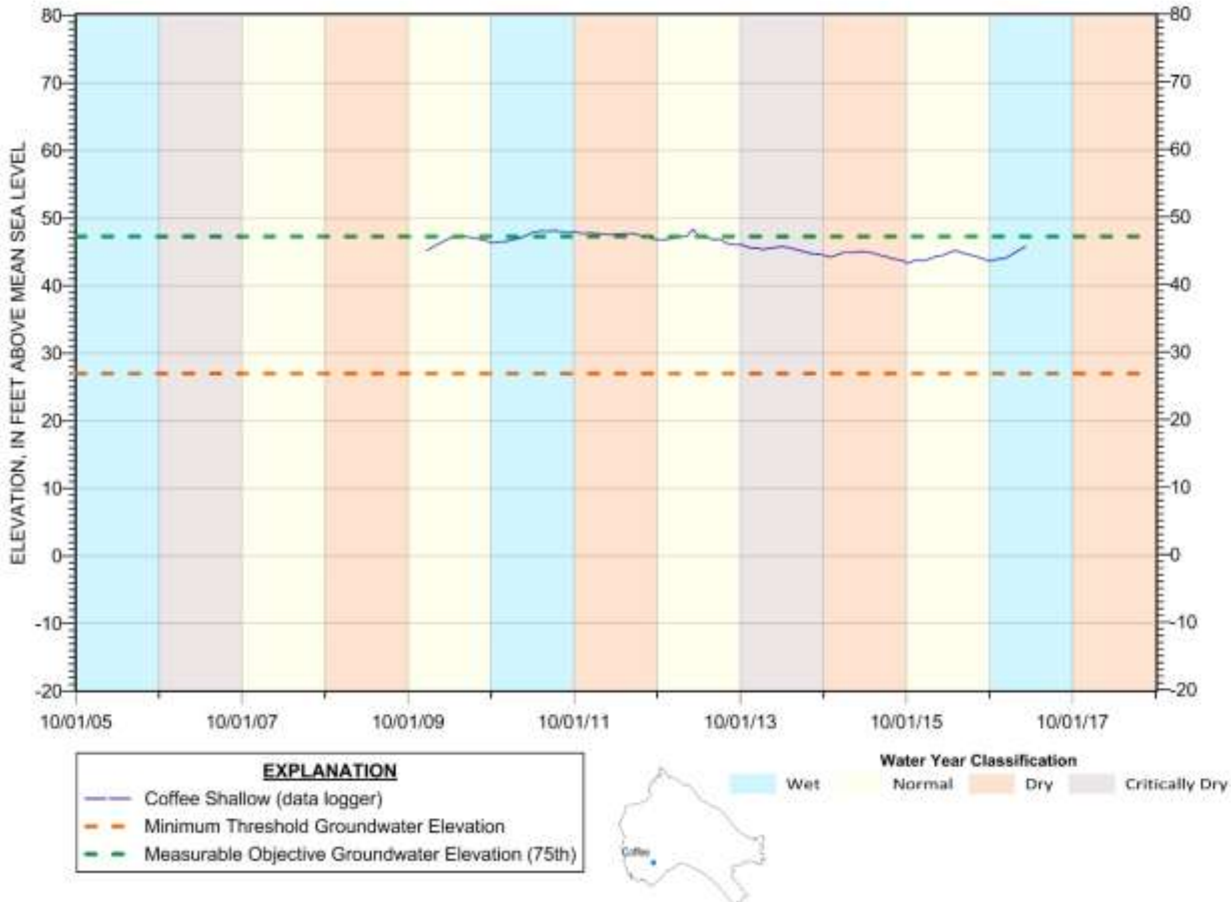


Figure 3-B.11. Coffee Lane Shallow Hydrograph with Minimum Threshold and Measureable Objective

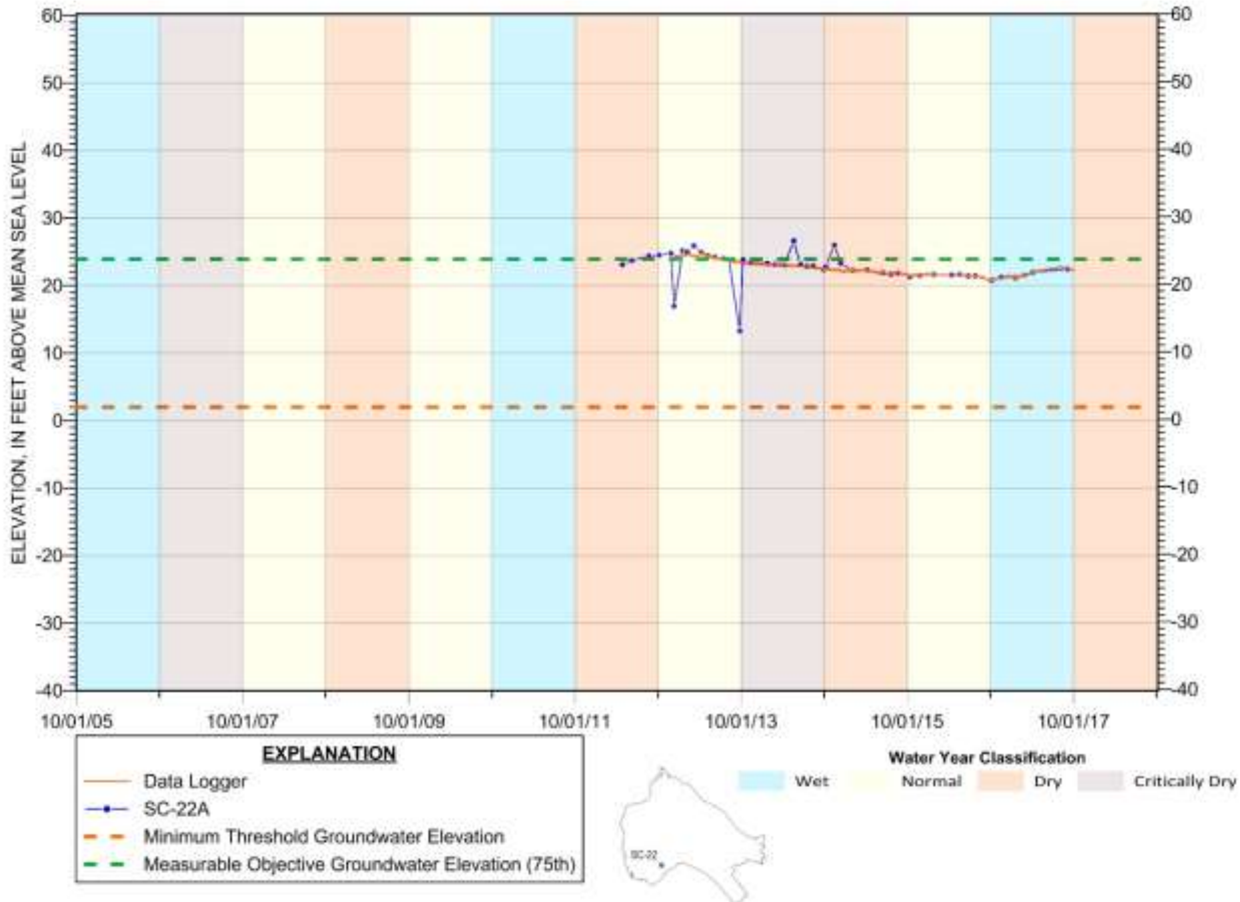


Figure 3-B.12. SC-22A Hydrograph with Minimum Threshold and Measureable Objective

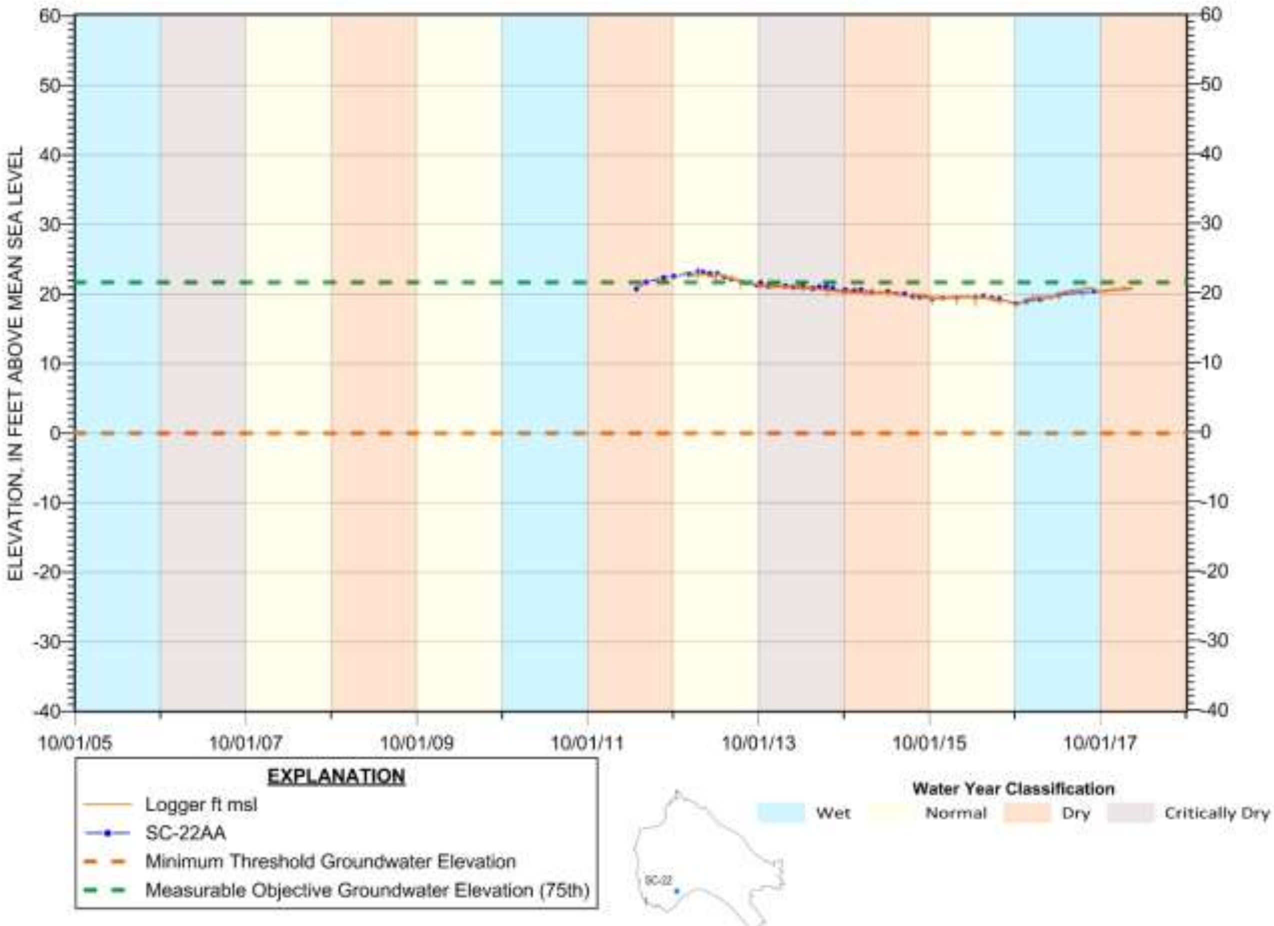


Figure 3-B.13. SC-22AA Hydrograph with Minimum Threshold and Measureable Objective

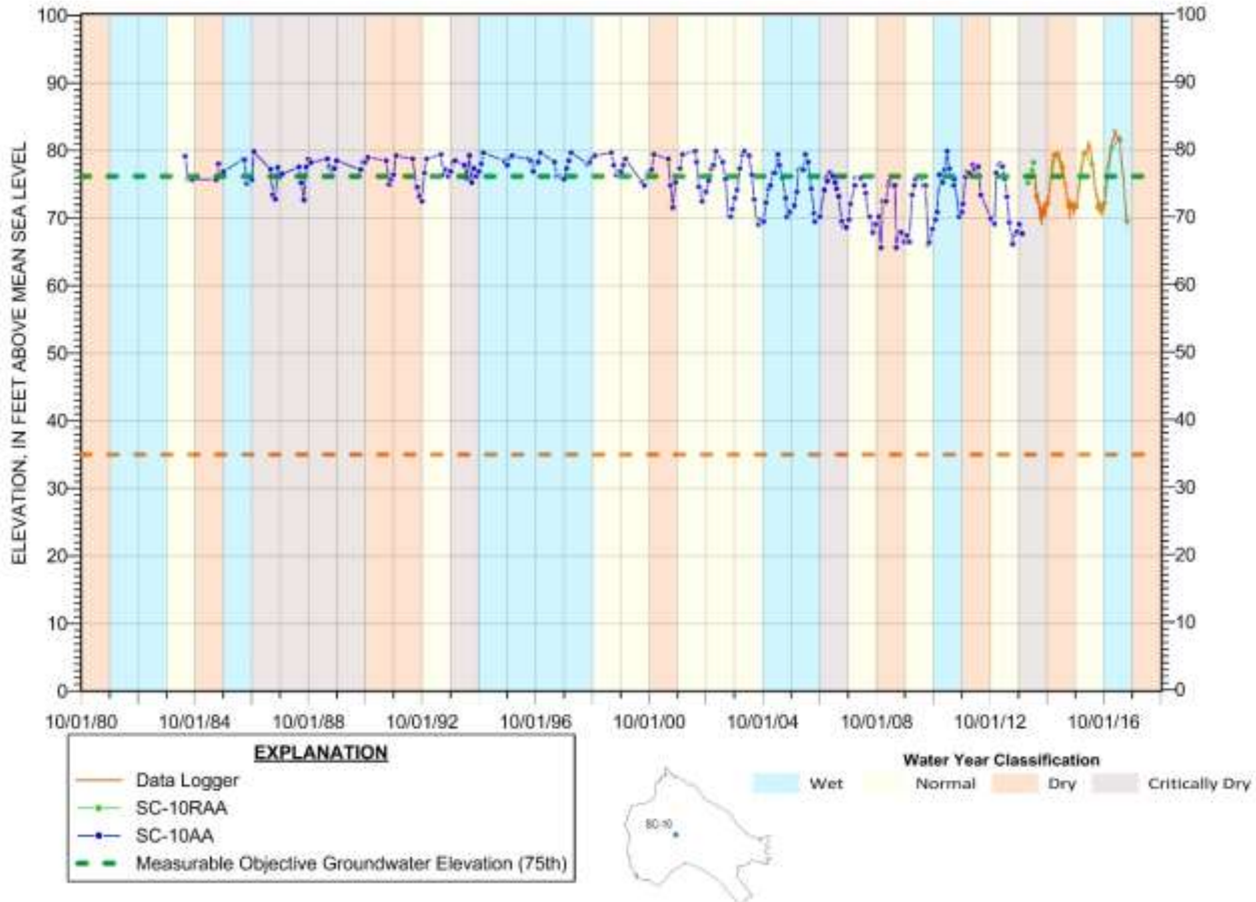


Figure 3-B.14. SC-10RAA Hydrograph with Minimum Threshold and Measureable Objective

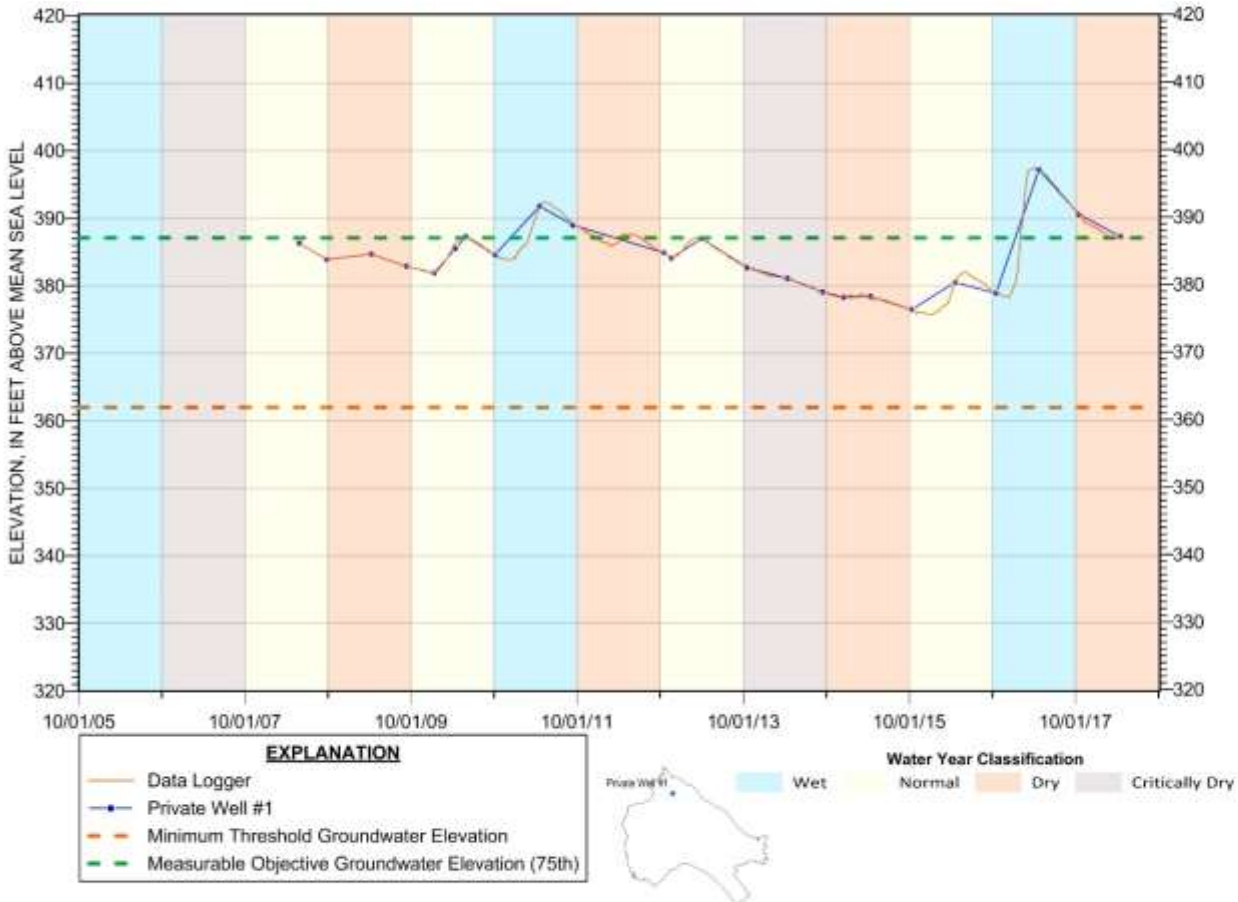


Figure 3-B.15. Private Well #1 Hydrograph with Minimum Threshold and Measureable Objective

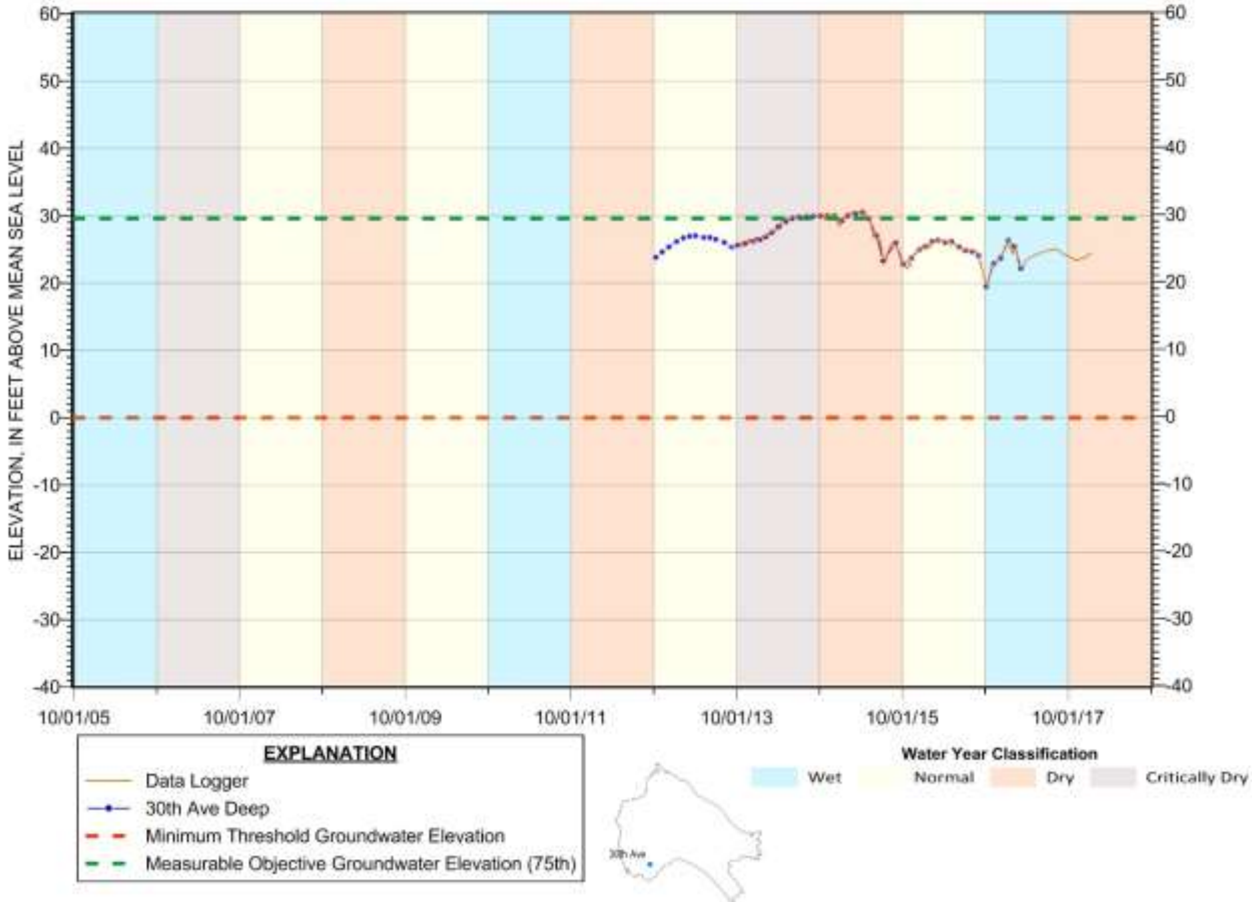


Figure 3-B.16. 30th Ave Deep Hydrograph with Minimum Threshold and Measureable Objective

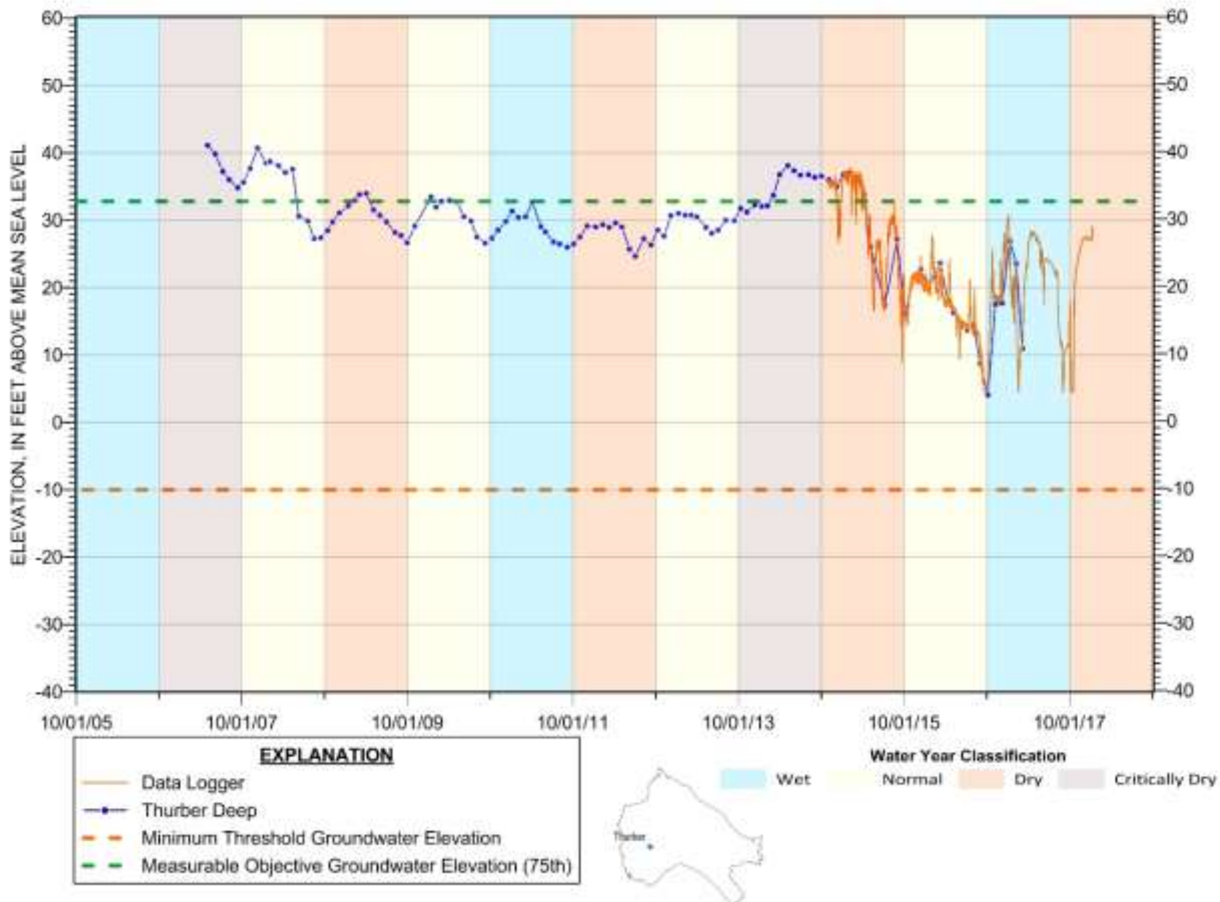


Figure 3-B.17. Thurber Lane Deep Hydrograph with Minimum Threshold and Measureable Objective

APPENDIX 3-C

SUMMARY OF FEDERAL, STATE, AND LOCAL WATER QUALITY REGULATIONS

Existing Regulatory Policies Related to Groundwater

This appendix provides an overview of federal, state, and local environmental laws, policies, plans, regulations, and guidelines (referred to generally as "regulatory requirements") relevant to groundwater resources and applicable to the MGA member agencies. The text is almost entirely from Pure Water Soquel's Draft Environmental Impact Report (EIR). The full Draft EIR document can be found at: https://www.soquelcreekwater.org/PWS-CEQA.

Federal and State Regulations

CLEAN WATER ACT (1972)

The federal Clean Water Act (CWA) of 1972's primary objective is to restore and maintain the integrity of the nation's waters. The objective translates into two fundamental national goals:

- to eliminate the discharge of pollutants into the nation's waters, and
- to achieve water quality levels that are fishable and swimmable.

To achieve the second objective, Designated Uses have been established for individual water bodies (e.g., lake, stream, creek, river) with typical designated uses including:

- Protection and propagation of fish, shellfish and wildlife;
- Recreation;
- Public drinking water supply; and
- Agricultural, industrial, navigational and other purposes.

The Clean Water Act includes an Antidegradation Policy (40 CFR 131.12).

Federal Antidegradation Policy

Section 303 of the Clean Water Act (CWA) (33 U.S.C. § 1313) requires that states adopt water quality standards for waters of the United States within their applicable jurisdiction. Such water quality standards must include, at a minimum, (1) designated uses for all waterbodies within their jurisdiction, (2) water quality criteria necessary to protect the most sensitive of the uses, and (3) antidegradation provisions. Antidegradation policies and implementing procedures must be consistent with the regulations in 40 C.F.R. § 131.12. Antidegradation is an important tool that states use in meeting the CWA requirement that water quality standards protect public health and welfare, enhance water quality, and meet the objective of the Act to "restore and maintain the chemical, physical and biological integrity" of the nation's waters. The CWA requires that states adopt antidegradation policies and identify implementation methods to provide three levels of water quality protection to maintain and protect (1) existing water uses and the level of water quality, (2) high quality waters, and (3) outstanding national resource waters.

SAFE DRINKING WATER ACT (1972)

The Safe Drinking Water Act (SDWA) is the federal law that is intended to protect public drinking water supplies throughout the nation (see: https://www.epa.gov/sdwa). Under the SDWA, EPA sets standards for drinking water quality and, with its partners (e.g., states), implements various technical and financial programs to ensure drinking water safety.

State agencies accepting primacy[1] authority from EPA implement drinking water regulations that are no less stringent than federal standards. Federal regulations and standards also apply to underground injections including Aquifer Storage and Recovery wells (see: https://www.epa.gov/uic/class-v-wells-injection-non-hazardous-fluids-or-above-underground-sources-drinking-water).

STATE WATER RESOURCES CONTROL BOARD RESOLUTION 68-16 ANTI-DEGRADATION POLICY

In 1968, the State Water Resources Control Board (SWRCB) adopted an anti-degradation policy (policy) aimed at maintaining the high quality of waters in California through the issuance of Resolution No. 68-16 ("Statement of Policy with Respect to Maintaining High Quality Waters in California"). They apply to both surface waters and groundwaters (and thus groundwater replenishment projects), protect both existing and potential beneficial uses of surface water and groundwater, and are incorporated into Regional Water Quality Control Board (RWQCB) Water Quality Control Plans (e.g., Basin Plans).

The policy requires that existing high water quality be maintained to the maximum extent possible, but allows lowering of water quality if the change is "consistent with maximum benefit to the people of the state, will not unreasonably affect present and anticipated use of such water (including drinking), and will not result in water quality less than prescribed in policies." The policy also stipulates that any discharge to existing high quality waters will be required to "meet waste discharge requirements which will result

[1] States accepting primacy are delegated authority by EPA to implement the regulation for which they have accepted primacy. The SDWA and CWA programs are typically delegated to states via primacy agreements.

in the best practicable treatment or control of the discharge to ensure that (a) pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained."

The policy prohibits actions that tend to degrade the quality of surface and groundwater. The RWQCBs oversee this policy (SWRCB, 1968). The anti-degradation policy states that:

- Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies.

- Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters must meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained.

SWRCB has interpreted Resolution No. 68-16 to incorporate the federal anti-degradation policy, which applies if a discharge that began after November 28, 1975 would lower existing surface and groundwater quality. This policy would apply to any project that brings in supplemental sources of water into the Basin because the projects would be required to comply with the state resolution maintaining the existing water quality.

Furthermore, one of the requirements for any recycled water project is that it must be compatible with State Board Resolution 68-16 and the Recycled Water Policy (see below). This can be evaluated on a project-specific localized impacts basis or can be evaluated in terms of the utilization of basin-wide groundwater assimilative capacity. Utilization of more than 10% of basin-wide assimilative capacity for compliance with anti-degradation policy has typically required a Salt and Nutrient Management Plan for the basin or a similar level of evaluation (Brown and Caldwell, 2018).

PORTER-COLOGNE WATER QUALITY CONTROL ACT

The Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code) provides the basis for water quality regulation within California and defines water quality objectives as the limits or levels of water constituents established for the reasonable protection of beneficial uses. The SWRCB administers water rights, water pollution control, and water quality functions throughout California, while the Central Coast RWQCB (CCRWQCB) conducts planning, permitting, and enforcement activities. The Porter-Cologne Act requires the RWQCB to establish a regional Basin Plan with water quality objectives, while acknowledging that water quality may be changed to some degree without unreasonably affecting beneficial uses. Beneficial uses, together with the corresponding water quality objectives, are defined as standards, per federal regulations. Therefore, the regional basin plans form the regulatory references for meeting state and federal requirements for water quality control. Changes in water quality are allowed if the change is consistent with the maximum beneficial use of the State waters, it does not unreasonably affect the present or anticipated beneficial uses, and it does not result in water quality less than that prescribed in the water quality control plans. The basin plan regulations also apply to groundwater. The Basin Plan for this location is discussed below in the local regulations subsection.

This Act would apply to any project where any supplemental sources of water are brought into the Basin because they would have potential to affect water quality and beneficial uses in the Basin. Thus, it is likely that most supplemental water supply projects would be required to comply with the Basin Plan water quality objectives established by the CCRWQCB to protect the beneficial uses of groundwater. This is discussed in the Local Regulations subsection below.

STATE WATER RESOURCES CONTROL BOARD POLICIES RELATED TO GROUNDWATER

Sources of Drinking Water Policy

The Sources of Drinking Water Policy (adopted as Resolution 88-63) designates the municipal and domestic supply (MUN) beneficial use for all surface waters and groundwater except for those waters: (1) with total dissolved solids exceeding 3,000 mg/L, (2) with contamination that cannot reasonably be treated for domestic use, (3) where there is insufficient water supply, (4) in systems designed for wastewater collection or conveying or holding agricultural drainage, or (5) regulated as a geothermal energy producing source. Resolution 88-63 addresses only designation of water as drinking water source; it does not establish objectives for constituents that threaten source waters designated as MUN.

Recycled Water Policy

The Recycled Water Policy, adopted by the SWRCB in February 2009, and amended in 2013 to include monitoring for CECs (discussed below) for groundwater replenishment projects. The Recycled Water Policy was a critical step in creating uniformity in how RWQCBs were individually interpreting and implementing the Anti-degradation Policy in Resolution 68-16 for water recycling projects, including groundwater replenishment projects. The critical provisions in the Policy related to groundwater replenishment projects are discussed in the following subsections.

Constituents of Emerging Concern

As defined in the SWRCB Recycled Water Policy, CECs are chemicals in personal care products, pharmaceuticals including antibiotics, antimicrobials, agricultural and household chemicals, hormones, food additives, transformation products and inorganic constituents. These chemicals have been detected in trace amounts in surface water, wastewater, recycled water, and groundwater. The Recycled Water Policy includes monitoring requirements for six CECs for subsurface application groundwater replenishment projects using recycled water, four of which are used as health-based indicators and others serving as performance-based indicators. In addition to the Recycled Water Policy CECs, as part of the SWRCB regulations for groundwater replenishment projects with recycled water, a project sponsor must recommend CECs for monitoring in recycled water and potentially in groundwater in the project's Engineering Report. For recharge projects that use recycled water that has been treated using reverse osmosis (RO) and an advanced oxidation process (AOP), the monitoring requirements in the Recycled Water Policy only apply to recycled water prior to and after RO/AOP treatment (i.e., no groundwater sampling). None of the CECs currently have regulatory limits. The Recycled Water Policy includes monitoring trigger levels (MTLs) for the four health-based CEC indicators and response actions to be taken by groundwater replenishment project sponsors based on monitoring results compared to the MTLs. The MTLs were based on Drinking Water Equivalent Levels. A Drinking Water Equivalent Level represents the amount of a CEC in drinking water that can be ingested daily over a lifetime without appreciable risk (MRWPCA and MPWMD, 2016). The following CECs from the Recycled Water Policy are those with health-based indicators, treatment/performance- based indicators, or both as indicated below in parentheses.

- 17-β-estradiol - steroid hormone (health-based indicator)
- Caffeine – stimulant (health-based and performance-based indicator)
- N-nitrosodimethylamine (NDMA) – disinfection byproduct (health-based and performance- based indicator) [Note: NDMA's current California NL is 0.01μg/L]
- Triclosan – antimicrobial (health-based indicator)
- N,N-diethyl-metatoluamide (DEET) – ingredient in personal care products (performance- based indicator)
- Sucralose – food additive (performance-based indicator)

Salt and Nutrient Management Plans

In recognition that some groundwater basins in the state contain salts and nutrients that exceed or threaten to exceed Basin Plan groundwater objectives, and that some Basin Plans do not have adequate implementation measures to achieve compliance, the Recycled Water Policy includes provisions for managing salts and nutrients on a regional or watershed basis through development of Salt and Nutrient Management Plans (SNMP) rather than imposing requirements on individual recycled water projects (which had been the practice prior to adoption of the Recycled Water Policy). Unfavorable groundwater salt and nutrient conditions can be caused by natural soils, discharges of waste, irrigation using surface water, groundwater, or recycled water, and water supply augmentation using surface or recycled water (although treating the recycled water through RO prior to application would typically prevent this from occurring). The Recycled Water Policy recognizes that regulation of recycled water alone will not address these conditions. SNMPs are to be developed for every groundwater basin/sub-basin by May 2014 (May 2016 with a RWQCB-approved extension). SNMPs were not prepared for the Santa Cruz Mid-County Basin because it does not contain salts and nutrients in excess of Basin Plan objectives. If a SNMP is not prepared for a basin underlying a project or a project is using a limited amount of be available assimilative capacity (described below), the recycled water policy requires the preparation of a dedicated anti-degradation evaluation.

Antidegradation and Assimilative Capacity

Assimilative capacity is the ability for groundwater to receive contaminants without detrimental effects to human health or other beneficial uses. It is typically derived by comparing background ambient chemical concentrations in groundwater to the concentrations of the applicable Basin Plan groundwater quality objectives. The difference between the ambient concentration and groundwater quality objective is the available assimilative capacity.

The Recycled Water Policy establishes two assimilative capacity thresholds in the absence of an adopted SNMP. A groundwater replenishment project that utilizes less than 10% of the available assimilative capacity in a groundwater basin/sub-basin (or multiple projects utilizing less than 20% of the available assimilative capacity in a groundwater basin/subbasin) are only required to conduct an anti-degradation analysis verifying the use of the assimilative capacity. In the event a project or multiple projects utilize more than the designated fraction of the assimilative capacity (e.g., 10% for a single project or 20% for multiple projects), the project proponent must conduct a RWQCB-deemed acceptable (and more elaborate) anti-degradation analysis.

A RWQCB has the discretionary authority to allocate assimilative capacity to groundwater replenishment projects. There is a presumed assumption that allocations greater than the Recycled Water Policy thresholds would not be granted without concomitant mitigation or an amendment to the Basin Plan groundwater quality objective to create more assimilative capacity for allocation. Groundwater replenishment projects that utilize advanced treated recycled water will use very little to essentially none of the available assimilative capacity because of the high quality of the water.

Regional Water Quality Control Board Groundwater Requirements

The Recycled Water Policy does not limit the authority of a RWQCB to impose more stringent requirements for groundwater replenishment projects to protect designated beneficial uses of groundwater, provided that any proposed limitations for the protection of public health may only be imposed following regular consultation with the California SWRCB Division of Drinking Water (DDW). The Recycled Water Policy also does not limit the authority of a RWQCB to impose additional requirements for a proposed groundwater replenishment project that has a substantial adverse effect on the fate and transport of a contaminant plume (for example those caused by industrial contamination or gas stations), or changes the geochemistry of an aquifer thereby causing the dissolution of naturally occurring constituents, such as arsenic, from the geologic formation into groundwater. These provisions require additional assessment of the impacts of groundwater replenishment projects on areas of contamination in a basin and/or if the quality of the water used for replenishment causes constituents, such as naturally occurring arsenic, to become mobile and impact groundwater.

SWRCB DIVISION OF DRINKING WATER (DDW)

California's drinking water program was originally created in 1915, when the California State Board of Health established the Bureau of Sanitary Engineering. In 1976, two years after the Safe Drinking Water Act was passed, California adopted its own safe drinking water act (contained in the Health and Safety Code) and adopted implementing regulations (contained in Title 22 California Code of Regulation). The state's act had two main goals: (1) to continue the state's drinking water program, and (2) to be the delegated authority (referred to as the "primacy") by the EPA for enforcement of the federal Safe Drinking Water Act. As required by the federal act, California's program must set drinking water standards that are at least as stringent as the EPA's standards. Each public water system also must monitor for a specified list of contaminants, and the findings must be reported to the state.

The DDW regulates public water systems, oversees water recycling projects, permits water treatment devices, supports and promotes water system security, and performs a number of other functions. DDW has adopted enforceable primary and secondary maximum contaminant levels (MCLs). The MCLs are either based on the federal MCLs or as part of DDW's own regulatory process. For example, California has an MCL for perchlorate while there is no federal MCL. The MCLs account for not only chemicals' health risks, but also factors such as their detectability and treatability, as well as costs of treatment. Health and Safety Code Section116365(a) requires a contaminant's MCL to be established at a level as close to its Public Health Goal (PHG) as is technologically and economically feasible, placing primary emphasis on the protection of public health. The Office of Environmental Health Hazard Assessment (OEHHA) established PHGs. They are concentrations of drinking water contaminants that pose no significant health risk if consumed for a lifetime, based on current risk assessment principles, practices, and methods. OEHHA establishes PHGs pursuant to Health and Safety Code Section116365(c) for contaminants with MCLs, and for those for which MCLs will be adopted. Public water systems use PHGs to provide information about drinking water contaminants in their annual Consumer Confidence Reports. Certain public water systems must provide a report to their customers about health risks from a contaminant that exceeds its PHG and about the cost of treatment to meet the PHG, and hold a public hearing on the report. Action levels (AL) are included in CCRs for certain constituents where no MCLs have been established, i.e., under the lead and copper rule. If a constituent exceeds its AL, this triggers treatment or other requirements.

There are also a variety of chemicals of health concern whose occurrence is too infrequent in conventional drinking water sources to justify the establishment of national standards, but are addressed using advisory levels. The DDW, with the assistance of OEHHA, has established notification levels (NL) and Response Levels (RL) for that purpose. If a chemical is present in drinking water that is provided to consumers at concentrations greater than the RL (10 to 100 times greater than the NL depending on the toxicological endpoint of the constituent), DDW recommends that the source be taken out of service. If the source is not taken offline and a chemical concentration is greater than its NL in drinking water that is provided to consumers, DDW recommends that the utility inform its customers and consumers about the presence of the chemical, and about health concerns associated with exposure to it.

Final Groundwater Replenishment with Recycled Water Regulations hereafter, referred to as "Groundwater Replenishment Regulations," went into effect June 18, 2014 (SWRCB, 2014). The overarching principles taken into consideration by DDW in developing the Groundwater Replenishment Regulations were:

- Groundwater replenishment projects are replenishing groundwater basins that are used as sources of drinking water.
- Control of pathogenic microorganisms should be based on a low tolerable risk that was defined as an annual risk of infection from pathogen microorganisms in drinking water of one in 10,000 (10-4). This risk level is the same as that used for the federal Surface Water Treatment Rule for drinking water.
- Compliance with drinking water standards for regulated chemicals.
- Controls for unregulated chemicals.
- No degradation of an existing groundwater basin used as a drinking water source.
- Use of multiple barriers to protect water quality and human health.
- Projects should be designed to identify and respond to a treatment failure. A component of this design acknowledges that groundwater replenishment projects inherently will include storage in a groundwater aquifer and include some natural treatment.

CENTRAL COAST REGIONAL WATER QUALITY CONTROL PLAN (BASIN PLAN)

The CCRWQCB, under the authority of the California Water Code, is responsible for authorizing and regulating activities that may discharge wastes to surface water or groundwater resources.

This authority includes adoption of Basin Plans (Section 13240) with beneficial uses and water quality objectives (both narrative and numeric) to reasonably protect those uses (Section 13050). The Basin Plan also establishes guidelines for water used for irrigation. The Basin Plan for the Central Coast was originally adopted in 1971 and was last amended in 2011.

Groundwater beneficial uses for the Basin are listed as agricultural water supply (AGR), municipal and domestic water (MUN). The Basin Plan has:

- For MUN beneficial uses – groundwater criteria for bacteria and DDW primary and secondary MCLs.
- For AGR beneficial uses – objectives to protect soil productivity, irrigation, and livestock watering and guidelines to interpret a general narrative objective to prevent adverse effects on the beneficial use.

Permit limits for groundwater replenishment projects are set to ensure that groundwater does not contain concentrations of chemicals in amounts that adversely affect beneficial uses or degrade water quality. For some specific groundwater sub-basins, the Basin Plan establishes specific mineral water quality objectives for total dissolved solids, chloride, sulfate, boron, sodium, and nitrogen.

WATER WELL STANDARDS

Under California Water Code Section 231, enacted in 1949, California Department of Water Resources (DWR) is responsible for developing standards for the protection of well water quality. Authority for enforcing the standards as they apply to the construction, destruction, and modification of water wells rests with the Santa Cruz County Environmental Health Services, which also implements additional local requirements. The California Water Code requires contractors that construct or destruct water wells to have a C-57 Water Well Contractor's License, follow DWR well standards, and file a completion report with DWR (Water Code Sections 13750.5 et seq.).

WELL COMPLETION REPORTS

DWR is responsible for maintaining a file of well completion reports (DWR Form 188), which must be submitted whenever a driller works on a water well. Well completion reports must be filed with DWR within 60 days from the date of the work and must also be filed with the County. Well completion reports may be used by public agencies conducting groundwater studies, and may also be made available to the public as long as the owner's name is not made public (Water Code Sections 13751 and 13752).

GROUNDWATER RIGHTS

In California, water rights involve the right to use water, not the right to own water. While the Water Code implies the existence of groundwater rights, their doctrinal bases and characteristics are essentially the product of the decisions of the courts. There are three types of groundwater rights:

Overlying Rights. All property owners above a common aquifer possess a mutual right to the reasonable and beneficial use of a groundwater resource on land overlying the aquifer from which the water is taken. Overlying rights are correlative (related to each other) and overlying users of a common water source must share the resource on a pro rata basis in times of shortage. A property overlying use takes precedence over all non-overlying uses.

Appropriative Rights. Non-overlying uses and public uses, such as municipal uses, are called appropriative uses. Among groundwater appropriators, the "first in time, first in right" priority system applies. Appropriative users are entitled to use the surplus water available after the overlying user's rights are satisfied.

Prescriptive Rights. Prescriptive rights are gained by trespass or unauthorized taking that can yield a title because it was allowed to continue longer than the five year statute of limitations. Claim of a prescriptive water right to non-surplus water by an appropriator must be supported by many specific conditions, including a showing that the pumpage occurred in an open manner, was continuous and uninterrupted for five years, and was under a claim of right.

From a water law standpoint, rights of public agencies to store water via in-lieu recharge and to recapture water in the Santa Cruz Mid-County Basin can be summarized by the following general rules:

- The agencies have the right to recapture water that has been added to the groundwater supply as a result of in-lieu recharge;
- The agencies have the right to prevent other groundwater producers from extracting the replenished supply, although this could require litigation, and in some cases, adjudication of all rights to the groundwater basin may be necessary to determine rights to the total supply; and
- The underground storage and recovery of the groundwater basin cannot substantially interfere with the basin's native or natural groundwater supply.

Material Injury. Groundwater case law has generally adopted the threshold that "…material injury… turns on the existence of an appreciable diminution in the quantity or quality of water…" (District, 2010) A reasonable definition of "appreciable" would render a nearby well incapable of meeting its:

1. Historically measured maximum daily production level;
2. Historically measured dry-season production levels; or
3. Historically measured annual production levels under drought conditions.

Local Regulations

California Government Code Section 53091 (d) and (e) provides that facilities for the production, generation, storage, treatment, or transmission of water supplies are exempt from local (i.e. city and county) building and zoning ordinances. However, they would not be exempt from the requirements of Local Coastal Programs.

COASTAL ZONE MANAGEMENT ACT FEDERAL CONSISTENCY REVIEW

The federal consistency requirement set forth in Section 307 of the Coastal Zone Management Act (CZMA) requires that activities approved or funded by the federal government (e.g., the federally-funded California Clean Water State Revolving Fund Program) that affect any land or water use or natural resource of a state's coastal zone, must be consistent with the enforceable policies of the state's federally approved coastal management program.

California's federally approved coastal management program consists of the California Coastal Act, the McAteer-Petris Act, and the Suisun Marsh Protection Act. The California Coastal Commission implements the California Coastal Act and the federal consistency provisions of the CZMA for activities affecting coastal resources outside of San Francisco Bay. Subparts D and F of the federal consistency regulations govern consistency review for activities involving a federal permit and federal funding, respectively. These sections generally require the applicant to provide the subject state agency (e.g., the Coastal Commission) with a brief assessment of potential coastal resources impact and project conformity with the enforceable policies of the management program.

The Coastal Commission considers an application for a coastal development permit to satisfy the Subpart D and F conformity assessment requirements. Typically, the Coastal Commission will provide its response (concurrence, conditional concurrence, or objection) in its staff report for the coastal development permit. In cases where the coastal development permit is issued by a local government with a certified local coastal program (LCP), the Coastal Commission will typically provide its response in a letter, following the permit issuance and the completion of any appeals process.

California Coastal Act

The California Coastal Act (Public Resources Code Section 30000 et seq.) provides for the long-term management of lands within California's coastal zone boundary. The Coastal Act includes specific policies for management of natural resources and public access within the coastal zone. Of primary relevance to groundwater and water quality are Coastal Act policies concerning protection of the biological productivity and quality of coastal waters. For example, Article 4 of the Act details policies related to the marine environment, such as biological productivity and water quality. Specifically, and relevant to groundwater hydrology and water quality, the Act requires the quality of coastal waters, streams, wetlands, estuaries appropriate to maintain optimum populations of marine organisms and for the protection of human health, to be maintained and, where feasible, restored through, among other means, preventing depletion of groundwater supplies (Cal. Pub. Res. Code §§ 30231).

SANTA CRUZ COUNTY ENVIRONMENTAL HEALTH SERVICES

At the local level, the Santa Cruz County Environmental Health Services enforces the well drilling and reporting requirements of the California Water Code (Sections 13750.5 et seq.) through enforcement of Title 7, Chapter 7.70, Water Wells, of the Santa Cruz County Code. The Santa Cruz County Environmental Health Services well program provides permitting for the construction, destruction, and repair/modification of all wells, including geothermal heat exchange wells, cathodic protection wells, test wells, and monitoring wells.

Summary of Key Points

1. There are strong federal and state statutes and regulations governing water quality that will apply to implementation of management actions and/or projects that become part of the GSP;
2. Federal and state anti-degradation policies are particularly important in considering how projects and/or management actions might be used to support basin sustainability; and
3. Federal and state policy and regulations are not static but are continuously evolving based on new information and experience.

APPENDIX 3-D

HYDROGRAPHS OF REPRESENTATIVE MONITORING POINTS FOR DEPLETION OF INTERCONNECTED SURFACE WATER

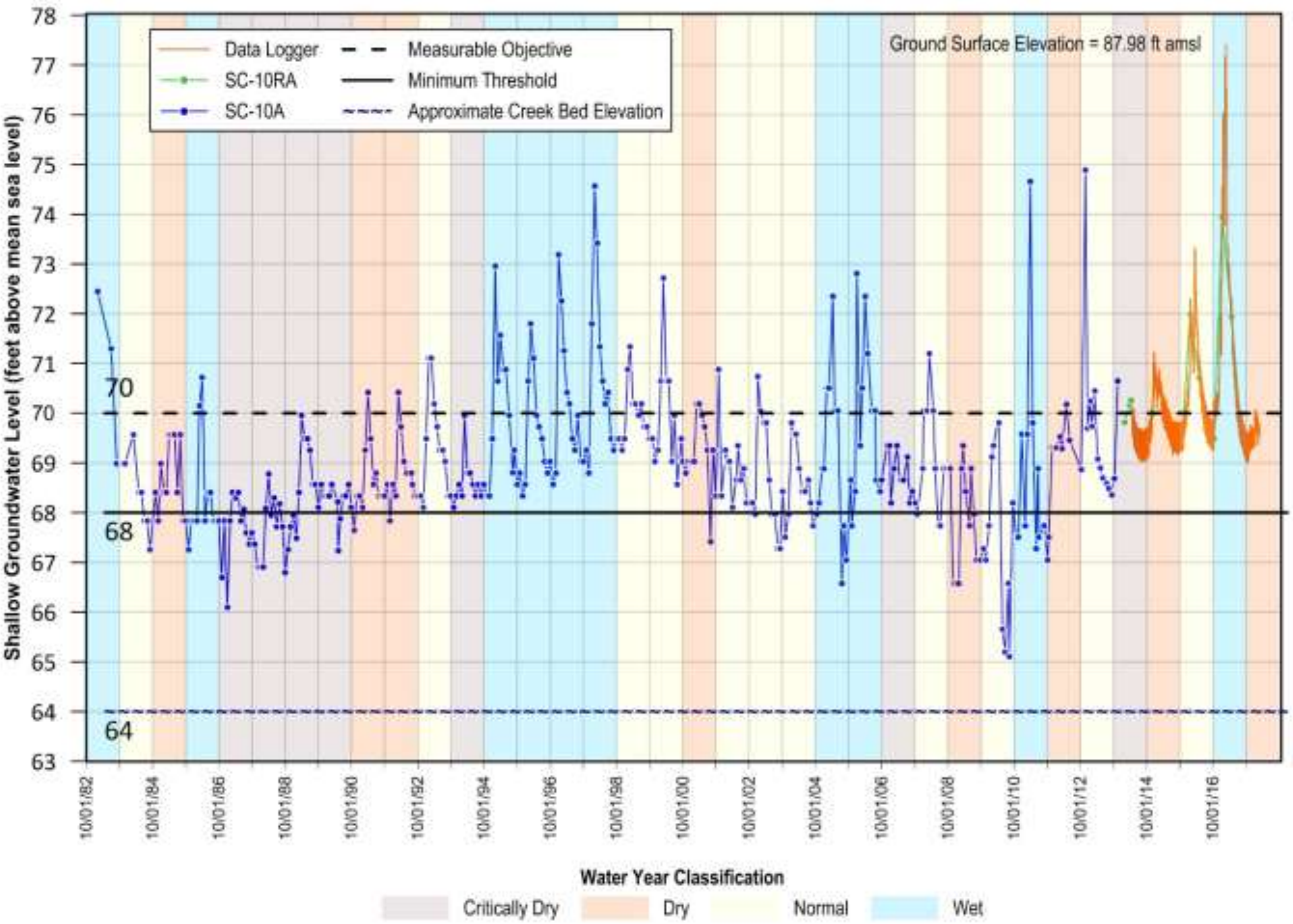


Figure 3-C.1. SC-10RA Hydrograph with Minimum Threshold and Measureable Objective

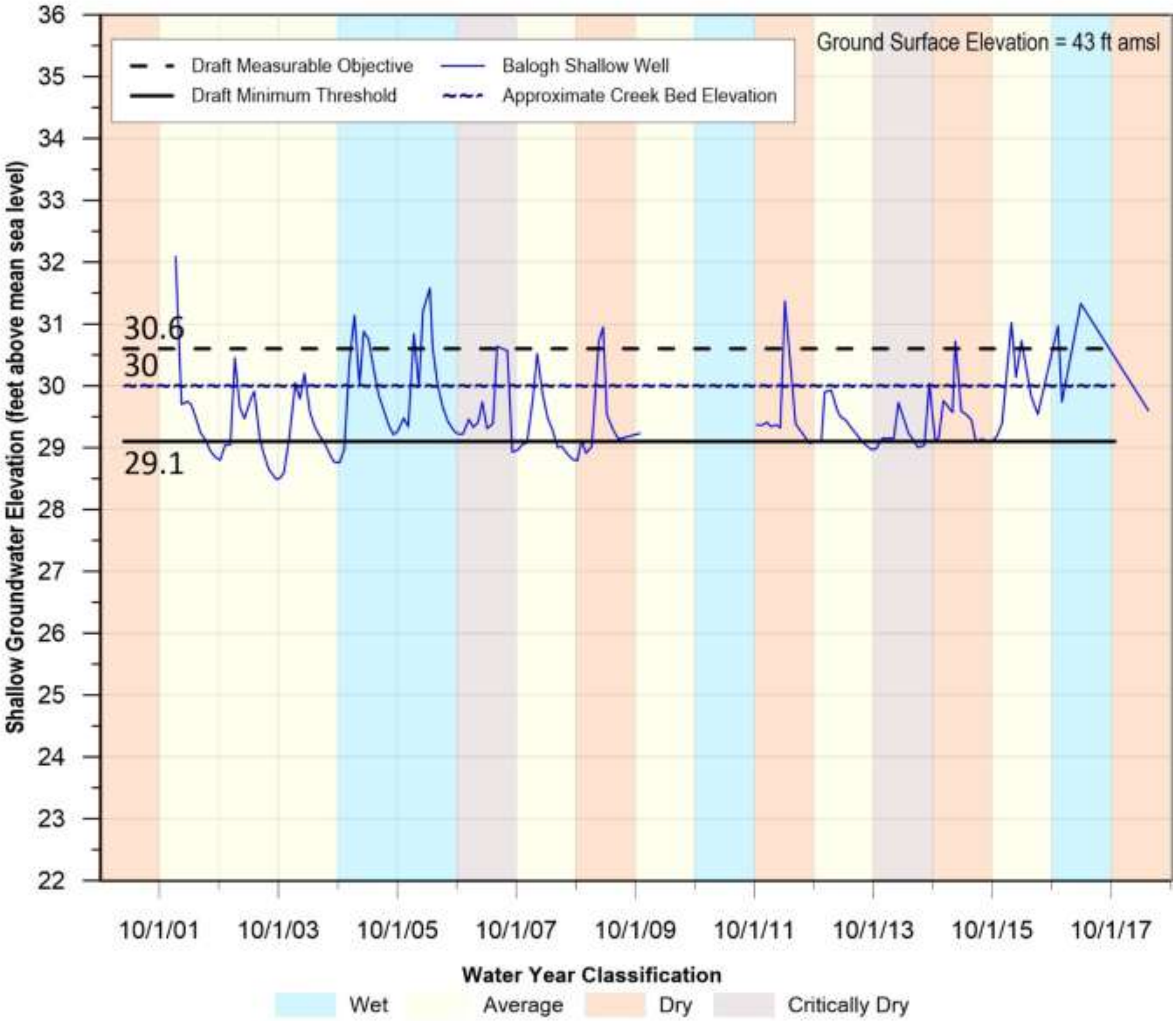


Figure 3-C.2. Balogh Shallow Monitoring Well Hydrograph with Minimum Threshold and Measureable Objective

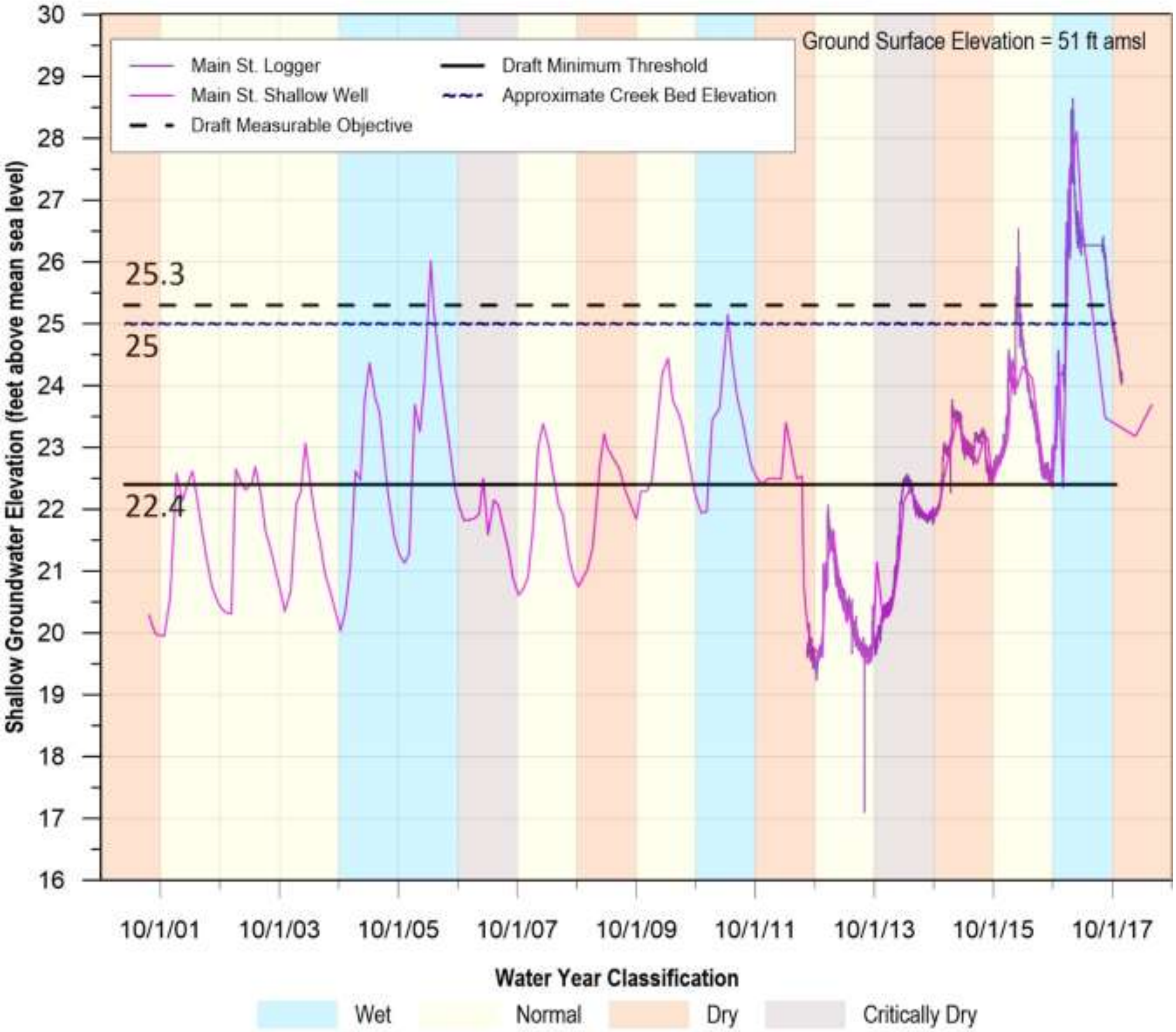


Figure 3-C.3. Main Street SW 1 Shallow Monitoring Well Hydrograph with Minimum Threshold and Measureable Objective

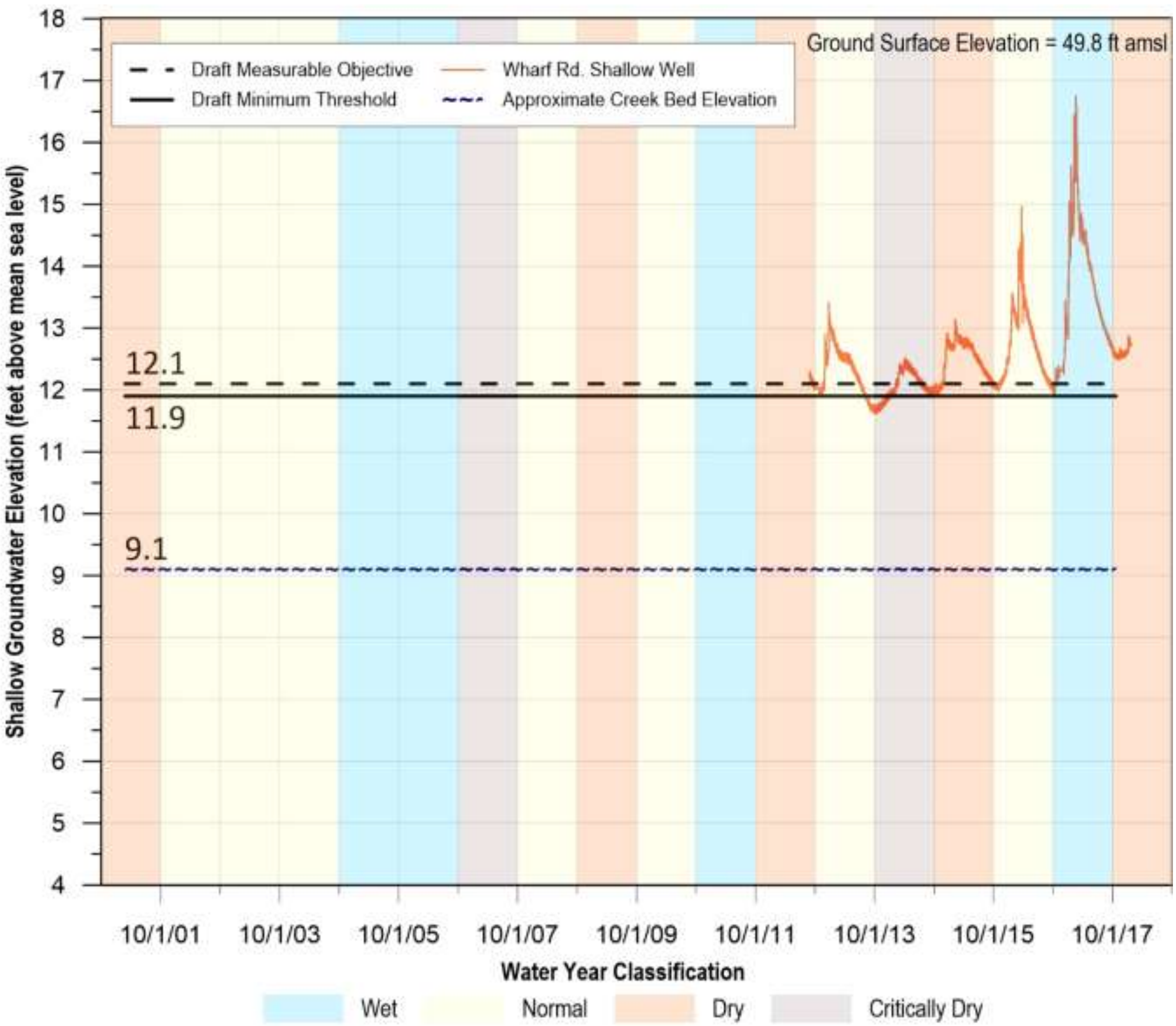


Figure 3-C.4. Wharf Road SW Shallow Monitoring Well Hydrograph with Minimum Threshold and Measureable Objective

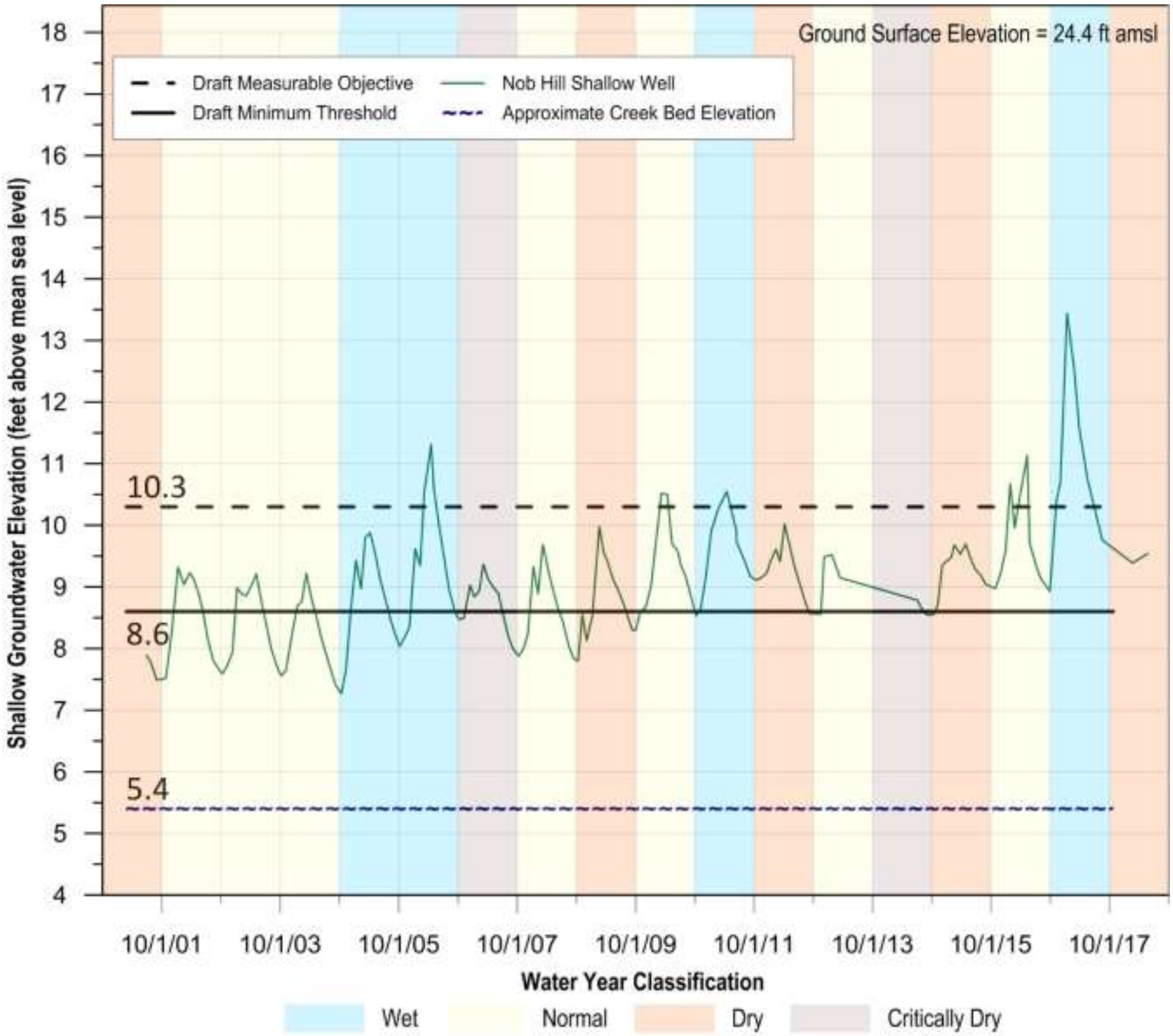


Figure 3-C.5. Nob Hill SW 2 Shallow Monitoring Well Hydrograph with Minimum Threshold and Measureable Objective

APPENDIX 5-A

SANTA CRUZ MID-COUNTY GROUNDWATER AGENCY EVALUATION OF PRIVATE PUMPER FUNDING MECHANISMS AND FEE CRITERIA, RAFTELIS, MAY 2019

SANTA CRUZ

MID-COUNTY GROUNDWATER AGENCY

Evaluation of Private Pumper Funding Mechanisms and Fee Criteria

May 2019

RAFTELIS

May 3, 2019

John Ricker
Water Resources Division Director
County of Santa Cruz
701 Ocean Street, Room 312
Santa Cruz, CA 95060

Subject: Private Non-de minimis Funding Options and Fee Criteria

Dear Mr. Ricker:

This memorandum identifies opportunities for the Santa Cruz Mid-County Groundwater Agency (MGA) to recover costs of Groundwater Sustainability Plan (GSP) administration and management. The criteria, necessary policies, and data required for charging non-de minimis pumpers are explained in detail as well as estimated charges based on preliminary cost estimates and groundwater user data. Development of a funding mechanism is critical to facilitate successful implementation of the GSP consistent with the requirements of the Sustainable Groundwater Management Act (SGMA). A key success factor is preparing a cost allocation that is equitable to GSA members and basin users.

This White Paper includes discussion on the following items:

- Preliminary GSA Budget
- Fee basis options
- Criteria for including/excluding users from cost recovery
- Calculation of hypothetical non-de minimis private pumper charges
- Costs and benefits of various types of charges
- Proposition 218 and 26 requirements in the context of SGMA

The tasks identified to prepare the White Paper include:

1. Determine the suite of options to recovery GSA costs from non-de minimis pumpers based on geographic location, proximity to surface water and the coast, volume of water pumped, and other criteria
2. Calculate fees using preliminary data based on parcels, acreage, and volumetric production of water
3. Assess the costs and benefits of each fee structure and mechanism for implementing each fee
4. Relate the implications of each fee type to the requirements of Proposition 218 and Proposition 26
5. Describe the conditions, if any, whereby de minimis users can be charged for a fair share of MGA costs

Table of Contents

List of Tables

List of Figures

1. Introduction and Study Background

1.1 Santa Cruz Mid-County Groundwater Agency

The Santa Cruz Mid-County Groundwater Agency (MGA) is a Joint Powers Authority (JPA)[1] formed by the Central Water District, the City of Santa Cruz, the Soquel Creek Water District, and the County of Santa Cruz to oversee groundwater management activities in the Mid-County Basin of Santa Cruz County. The MGA is governed by an eleven-member board consisting of two officials each from the agencies named in the JPA as well as three private well owner representatives. The MGA is charged with implementing the requirements of the Sustainable Groundwater Management Act (SGMA) of 2014 which consists of developing a Groundwater Sustainability Plan (GSP) and implementation of the adopted GSP over a long horizon.

Due to chronic over-pumping and impending seawater intrusion into the aquifer, the Mid-County Basin has been designated a critically overdrafted basin by the Department of Water Resources (DWR) in Bulletin 118. Basins designated as “critical” must submit sustainability plans to DWR by January 2020 and achieve “sustainability” over a 20-year period. Sustainability is defined as mitigation of the following six undesirable results[2]:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable reduction of groundwater storage.
- Significant and unreasonable seawater intrusion.
- Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses.
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

1.2 Study Purpose

The MGA has acquired grant funds to develop and submit the GSP. This paper concerns the long-term costs of managing, administering, and regulating the basin after GSP adoption, otherwise referred to as GSP implementation. More specifically, this paper addresses options in regulating and recovering plan implementation costs from private groundwater users not affiliated with the three municipal water agencies who are party to the JPA. Plan implementation costs include regulatory activities associated with groundwater monitoring, administration of the GSP, periodic reporting, outreach, and fee collection, among other activities. The following sections detail the estimated plan implementation costs (budget), identify several fee setting mechanisms for

[1] Joint Exercise Powers Agreement signed March 17, 2016
[2] Water Code §10721(x)

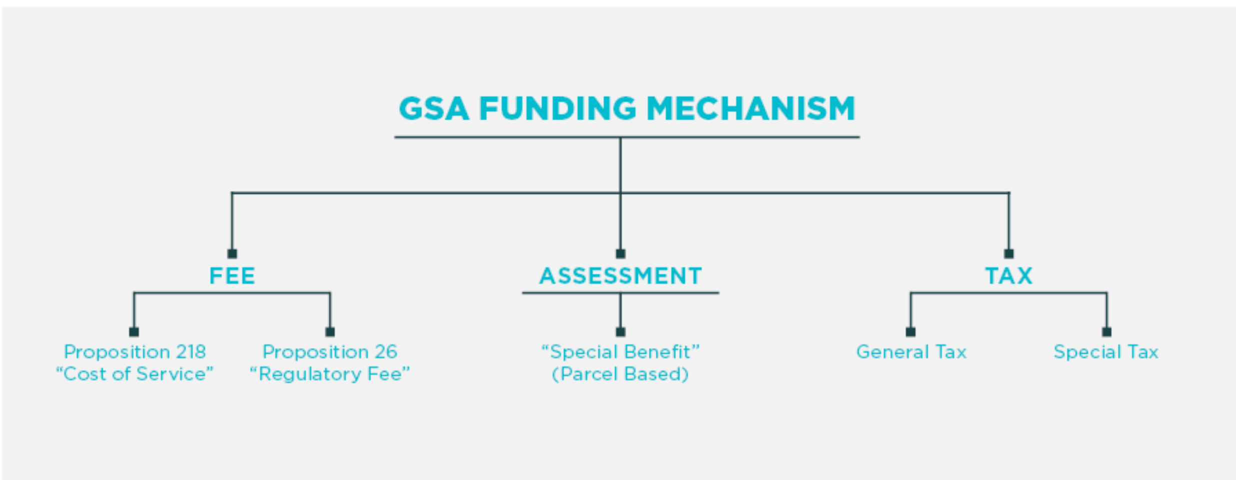
evaluation, discuss different measurement options for determining a regulatory fee, and considers the MGA's authority to charge non-de minimis[3] private groundwater users for groundwater management activities.

[3] SGMA defines de minimis users as those that are residential *and* extract less than two acre-feet of water per year. All other extractors are considered non-de minimis.

2. Funding Mechanisms

Due to Constitutional limitations imposed through California's Propositions 13, 218, and 26, there are strict distinctions between, and regulations associated with, fees and taxes. Taxes and assessments require voter approval. Water rates passed under Proposition 218 are subject to mandatory noticing and a potential majority protest. Regulatory fees are identified as an exemption from taxes under Proposition 26 and can be passed by majority vote of the governing body of the Agency imposing the fee[4]. An example is a dollar per acre foot ($/AF) pumping charge levied by a groundwater management agency. Other fees require protest proceedings for individuals who are paying the fees, for example water rates of a public utility. Figure 1 is a graphical illustration of the broad options available to MGA. What follows in this section is a primer on the various funding mechanisms available for exploration and considerations for the use of each as they relate to future MGA charges.

Figure 1- Funding Options



Raftelis is not a law firm and does not purport to give legal advice or make any recommendation on the legality of individual options in the context of SGMA. The aim is to illustrate the universe of funding mechanisms that may be available to the MGA. The legality of various funding options in the context of GSA fees and charges is fluid. The most recent meaningful case for MGA to consider is the *City of San Buenaventura versus United Water Conservation District* decision (Cal. Supreme Court Case No. S226036). Ultimately the GSA Counsel must opine on the legality of the funding mechanisms and MGA must choose what it believes to be most appropriate for the basin and its groundwater users. The following section introduces four potential funding mechanisms, including the statutory authorization and adoption procedures of each.

2.1 Regulatory Fee (Proposition 26)

The Agency can assess regulatory fees governed by Proposition 26 (Prop 26). This Proposition, passed in 2010, states that everything is a tax under the California Constitution Article XIII C, section 1(e), except:

[4] Proposition 26 and 218 Implementation Guide, League of California Cities, Sacramento, California, 2017

- **A charge imposed for a specific benefit** conferred or privilege granted directly to the payor that is not provided to those not charged, and which does not exceed the reasonable costs to the local government of conferring the benefit or granting the privilege.
- **A charge imposed for a specific government service** or product provided directly to the payor that is not provided to those not charged, and which does not exceed the reasonable costs to the local government of providing the service or product.
- **A charge imposed for the reasonable regulatory costs** to a local government for issuing licenses and permits, performing investigations, inspections, and audits, enforcing agricultural marketing orders, and the administrative enforcement and adjudication thereof.
- **A charge imposed for entrance to or use of local government property**, or the purchase, rental, or lease of local government property.
- **A fine, penalty, or other monetary charge** imposed by the judicial branch of government or a local government, as a result of a violation of law.
- **A charge imposed as a condition of property development**.
- **Assessments and property-related fees** imposed in accordance with the provisions of Article XIII D.

Property-related fees and special benefit assessments levied under Article XIII D are an exemption (number 7) from the requirements of Proposition 26. Additionally, every exaction must bear a fair or reasonable relationship to the payer's burden on, or benefits received from, the governmental activity.

Example: City of San Buenaventura (Ventura) Decision, 2017[5]
United Water Conservation District (District) imposes groundwater pumping fees. The District charges non-agricultural users three times that of agricultural uses. The City of Ventura challenged that the difference in pumping charges represented an illegal subsidy to agricultural users and violated Article XIII D, section 6(b) (Proposition 218) because the fees exceeded the cost of service. The appellate court held that the charges are not property related fees because they are based on the pumping activity and not property ownership (Ventura Water customers do not have their own wells). The court determined that the pumping charges are regulatory fees meeting the first two exceptions of Article XIII C, section 1(e): fee imposed for a specific benefit and does not exceed the reasonable cost of the service. Further the court stated that the reasonableness of costs is not to be measured on an individual basis, but on a collective basis. Since the total cost recovery across all users is reasonable, so is the fee.

MGA may argue that the fee imposed on users is for the reasonable regulatory costs related to managing the groundwater basin. This would presumably comply with Section 1(e)(3) "*A charge imposed for the reasonable regulatory costs…"* The calculated fees charged by MGA should not exceed the reasonable costs of administering and managing the GSP and the basin, and the fees should be proportional to the benefits.

[5] City of San Buenaventura v. United Water Conservation Dist. (2017) 3 Cal.5th 1191, 1198 (City of San Buenaventura)

Key Considerations
Cost to develop: Low
Cost to implement: Low
Collected by: Direct billing or County Assessor
Limitations on use of funds: Reasonable costs of managing the basin
Ease of protest: Not applicable

2.2 Rate/Fee for Service (Proposition 218)

Proposition 218 (Prop 218), passed by the voters in 1996, governs property related fees including water, wastewater, and solid waste. The measure created an amendment to the California Constitution: Article XIII D, Section 6. Proposition 218 was enacted to ensure in part that fees and charges imposed for ongoing delivery of a service to a property are proportional to, and do not exceed, the cost of providing service. Proposition 218 defines property related fees for service and the criteria for achieving the amendment's requirements. The principal requirements, as they relate to public water service fees and charges are as follows:

- Revenues derived from the fee or charge shall not exceed the costs required to provide the property-related service.
- Revenues derived by the fee or charge shall not be used for any purpose other than that for which the fee or charge was imposed.
- The amount of the fee or charge imposed upon any parcel shall not exceed the proportional cost of service attributable to the parcel.
- No fee or charge may be imposed for a service unless that service is actually used or immediately available to the owner of property.
- A written notice of the proposed fee or charge shall be mailed to the record owner of each parcel not less than 45 days prior to a public hearing, when the Agency considers all written protests against the charge.

Procedurally, Prop 218 requires noticing of all affected properties with each property allowed to protest the proposed rates. Absent a majority protest, rates can be adopted by majority vote of the governing body at a public hearing. SGMA makes explicit that fees imposed on the extraction of groundwater "shall be adopted in accordance with subdivisions (a) and (b) of Section 6 of Article XIII D of the California Constitution" (Water Code 10730.2(c)). This section is commonly referred to as Proposition 218.

As it exists, the section of the Water Code created by SGMA requires that fees charged by a GSA comply with Proposition 218 as a water service fee. It is Raftelis' understanding that there may be attempts to amend Water Code Section 10730.2(c) and adopt a lower standard. It is also our understanding that water law practitioners have varying opinions of the requirements of Section 10730.2 as it relates to fee adoption and "extraction of groundwater from the basin." The language in the Water Code is clear, however, and the issue will surely be litigated in the courts in the years to come.

The noticing and majority protest requirements of Proposition 218 presents challenges and questions in the context of GSA fees. If only private non-de minimis pumpers are noticed, it would be easy to foresee a majority protest as the groups are generally few and organized. Including de minimis users in the noticing may reduce the likelihood of a protest, however, it is unclear to Raftelis if such noticing would be considered legal since users classified as de minimis would receive a notice but no charge for service. More, if only private users are noticed it is unclear if the substantive requirements of Proposition 218 would be met. Consider for example that all residential, commercial, and irrigation users within a municipal agency boundary are also users of groundwater, albeit with service from municipal wells. Is it legally defensible to exclude these users from noticing even if their water service provider is paying their proportional share of MGA management costs? Inclusion of municipal users to notice the entirety of the management area would almost certainly guarantee no majority protest of the fee, but again if these users were not assessed a fee in the notice it is unknown if this action would be legal. More, if municipal users are de-minimis in their water use (residential with annual consumption below two-acre feet per year (AFY)) is it lawful to charge these parcels if MGA is not "regulating" them at the time of fee adoption? These questions require further exploration by MGA's legal team.

Key Considerations
Cost to develop: Low-Moderate – Cost of Service Study Report
Cost to implement: Low
Collected by: Direct billing or County Assessor
Limitations on use of funds: Only for those costs identified in the Cost of Service Study
Ease of protest: Moderate to high

2.3 Assessment (Special Benefit Nexus)

Special assessments have been redefined over the years. Assessments for special benefit are also governed by Proposition 218 and are exempted from Prop 26; nor are they subject to a 2/3 vote like a special tax. Property owners can be assessed to pay for a public improvement or service if it provides a special benefit to the property. To assess, local government bodies must:

- Develop a Special Benefit methodology to determine each parcel's assessment
- Ensure that each owner's assessment does not exceed its proportional share of total costs when compared to total project costs
- Ensure only special benefits are assessable
- Ensure all parcels which benefit are assessable (with no government property exemptions)
- Prepare an engineer's report that determines the amount of special benefit to each property
- Notify all affected property owners by mail with mail-in protest ballot form

The Agency must then hold a Public Hearing to determine if a majority protest exists. Protest ballots are tabulated and weighted based on the *amount* of each assessment. Assessments have a similar implementation timeline to utility rates and the Agency has complete control over the timeline (unlike taxes). Once the Engineer's Report is approved, notices must be mailed at least 45 days prior to the public hearing. The notice must include the affected parcel's protest ballot. An average project timeline from start to finish is six months.

Like a possible majority protest under Proposition 218, the Agency runs the risk of protest by assessment if a few large users exercise their disproportionate power to protest the special assessment, and if only private non-de minimis pumpers are included. MGA could consider a special assessment for all users basin-wide to reduce the chance of protest, however, the lawfulness of assessing fees to de minimis users who are not "regulated" at the time of adoption is unclear. Further, an assessment may be challenged post-formation by any property owner under the premise that the special benefit is invalid.

Key Considerations

Cost to develop: Moderate – Outreach and special benefit nexus report
Cost to implement: Low
Collected by: County Assessor
Limitations on use of funds: Only for those costs identified in the Engineer's Report
Ease of protest: Moderate to high

2.4 General and Special Taxes (approval from electorate)

Everything that does not meet the exceptions defined in Proposition 26, and is not a special assessment, is considered a tax and must be approved by the voters. The Agency is still required to develop a reasonable relationship between the tax and affected parcels. The tax could potentially be spread based on acreage, parcel, or by estimated pumping. These are not the only options but are the most likely given data availability. General taxes require a simple majority vote; however, the charges required to manage the basin and administer the GSP would most likely be considered a special tax. Article XIII D, Section 2(a) states that "Special purpose districts or agencies, including school districts, shall have no power to levy general taxes." Special taxes require a two-thirds (2/3) approval from the electorate (i.e. registered voters); and with a special tax, government properties are exempt from the tax.

A special tax would need to be placed on a ballot for either a general election or special election. There are specific tasks and a firm timeline that must be followed to include a tax measure on an election ballot. The minimum time required prior to election day to fulfill the requirements is approximately 90 days. A special tax is the option with the highest risk of failure as unlike Proposition 218 fees and assessments that require majority protest, a special tax would fail with any less than a 2/3 majority.

Key Considerations

Cost to develop: Low-Moderate
Cost to implement: High compared to other options
Collected by: County Assessor
Limitations on use of funds: None
Ease of protest: Moderate for General Tax; High (super-majority threshold failure) for Special Tax

2.5 Contract

A novel approach in recovering costs and charging non-de minimis extractors is to sign contracts with each based on individual pumping. Depending on the number of extractors and their agreeability, or lack thereof, negotiation costs may be high. Individual contracts may help to avoid political landmines related to the protest of fees and assessments or the high threshold of a special tax, however, it is Raftelis' recommendation that all non-de minimis users (any residential extractor greater than two AFY or any non-residential extractor) have a contract with MGA.

The Agency could face legal challenge if it was determined that low volume extractors were excluded from a contract because it was cost effective and politically expedient to do so.

Key Considerations

Cost to develop: Unknown

Cost to implement: depends on number of extractors and timeliness of negotiations

Collected by: Direct billing by MGA

Limitations on use of funds: Unknown

Ease of protest: Not applicable

Table 1 - Funding Mechanism Matrix

Basis	Development Cost	Implementation Cost	Collection	Funds Limitation	Ease of Protest
Prop 26 Regulatory Fee	Low	Low	Direct or Assessor Billing	Reasonable Costs	N/A
Prop 218 Fee for Service	Low-Moderate	Low	Direct or Assessor Billing	Cost of Service	Moderate to High
Special Assessment	Moderate	Low	Assessor Billing	Special Benefit Parcels	Moderate to High
Special Tax	Low-Moderate	High	Assessor Billing	None	High
Contract	Unknown	Unknown	Direct	Unknown	N/A

3. GSA Charges

3.1 GSA Budget

The GSA will incur costs in implementing the GSP. These include administrative costs, monitoring costs, and other interim costs. MGA has estimated a preliminary annual and five-year budget (annualized) for these activities including administration and personnel, data management, monitoring and management, and reporting. These costs are summarized in Table 2. The estimated annualized budget in 2019 dollars is $350,000.

3.1.1 ADMINISTRATIVE COSTS

These costs include dedicated MGA staff support, internal reporting, managing Agency information, public outreach, legal retainer, and program coordination.

3.1.2 MONITORING COSTS

There are several costs associated with monitoring groundwater in the basin. These are discussed in further detail below.

1. **Water Quality**

   Includes collection, testing, and analysis of groundwater samples from designated monitoring wells on a semi-annual basis. A trained professional will visit designated wells, perform field testing of select water quality parameters, collect samples, and send samples to a laboratory for water quality testing. Test results will be tabulated and reported per the GSP guidelines. Management of data, as well as annual preparation of a water quality monitoring summary.

   The water budget and numeric groundwater model will be updated and calibrated to incorporate the previous 5 years of applicable data.

2. **Stream Flow Monitoring**

   Inspection and monitoring of streams within the basin on a semi-annual basis. Tasks may include measuring flow rates, visual inspection of streams, noting changes in geomorphology, and preparation of a stream monitoring summary.

3. **Groundwater Monitoring and Shallow Groundwater Elevation**

   Monitoring of groundwater levels conducted semi-annually throughout the well network within the Basin. This may consist of multiple days of field monitoring annually in which a trained professional will manually measure depth to water, or, collect data from transducer data loggers. Management of data, as well as annual preparation of groundwater level monitoring summary.

4. **SkyTEM Offshore Surveys**

Monitoring of the change in the saltwater interface offshore is vital to the assessment of ongoing risk to the basin of saltwater intrusion. The SkyTEM geotechnical survey will be conducted approximately every 5 years.

5. Model Updates

As needed, the numeric groundwater model will be updated and calibrated with the data collected through the monitoring, and will in-turn inform additional data collection gaps.

6. Data Management System

Collected monitoring data will be included in a data management system.

3.1.3 FIVE YEAR ADDITIONAL SCOPE OF WORK

Every 5th year of GSP implementation and whenever the GSP is amended, the GSA is required to prepare and submit an Agency Evaluation and Assessment Report to the Department of Water Resources together with the annual report for that year. The assessment and report will be prepared as described in CWC § 356.10. Five-year costs are annualized to determine the amount of revenue required to fund Five Year activities on an annual basis.

1. Updated Water Budget and Sustainable Yield Value

The water budget will be updated and calibrated to incorporate the previous 5 years of applicable data. Using the updated model, MGA will generate a refined estimate of the sustainable yield of the basin.

2. Five Year Plan Evaluation and Assessment Report

Every 5th year of GSP implementation and whenever the GSP is amended, the GSA is required to prepare and submit an Agency Evaluation and Assessment Report to the Department together with the annual report for that year. The assessment and report will be prepared as described in California Water Commission (CWC) § 356.10.

3.1.4 COST CONTINGENCY

MGA is a new entity and is budgeting from the ground up. The cost estimate should account for a contingency between estimated and actual expenses. Cost contingencies provide a buffer for the variance in costs, particularly in the early years. Most frequently contingencies are estimated as a percentage of the total budget, or with better information, an expected dollar value. Comparable agencies budget for a contingency of 10 to 20 percent of expenditures. As the budgets in Sections 3.1.1, 3.1.2, and 3.1.3 are rough estimates using staff and consultant judgment and best available data, the cost estimate accounts for a $25,000 contingency.

3.1.5 RESERVES

In addition to covering the operations budget, the GSA should consider adoption of a reserves policy which is expressly authorized by SGMA (Section 10730(a) and 10730.2(a)(1)). Reasonable and achievable reserves are a prudent financial tool to aid in cash flow timing and unforeseen expenditures. Generally, a reserve for operations targets a specific percentage of annual operating costs or days of cash on hand. The reserve target is influenced by several factors including the frequency of billing and the recurrence of expenses. Comparable reserve percentage is 50% of operating budget if billing semi-annually and less if billing more frequently (monthly, bi-monthly, or quarterly). For this evaluation no reserve funding is assumed in the first year.

3.1.6 TOTAL REVENUE REQUIRED

The estimated Administrative, Monitoring, Five-year Update, and Contingency is combined to determine the annual revenue required to fund MGA. The total annual budget in 2019 dollars is $350,000 per year. This total includes the annualized amount of Five-year Update costs and does not account for any reserve funds.

Table 2 – MGA Budget Estimate

Task	Expense Items	Cost ($)
Administration	Personnel, Outreach, Program Coordination, Legal, Finance	$200,000
Monitoring and modeling	Water Quality, Stream Flow, Groundwater Elevation, SkyTEM. Model updates, Data Management System	$85,000
Reporting (annual and 5-year)	Updated Water Budget, , Reports	$40,000
Contingency		$25,000
Reserves		$0
Total		**$350,000**

3.2 Unit of Service/Measure Options

The GSA budget discussed in the previous section represents the numerator in developing GSA charges and recovering costs. The denominator must be determined from a suite of options. Each option to define the "unit" has certain advantages and disadvantages, data requirements, and policy and legal considerations. Additionally, specific options relate to possible funding mechanisms in different ways. Raftelis has identified eight preliminary unit options, with certain options having multiple variations. This list is not necessarily exhaustive and is provided to present potential units of measurement for the basin. From a data availability and data quality standpoint, the six main options rank as follows, with those listed earlier having fewer data requirements: well count, parcel count (total parcels and total non-de minimis parcels[6]), acreage, well capacity, irrigated acreage, and pumping (gross extraction). The data requirements of the contract option are unknown.

[6] SGMA defines de minimis use in Section 10721(e) as extraction for domestic use of less than 2 AFY. Non-de minimis use is for any water use greater than 2 AFY. The GSA has evaluated groundwater extractions by de minimis users and determined that they represent approximately 10 percent of total basin withdrawals.

3.2.1 WELL COUNT (TOTAL NON-DE MINIMIS WELLS)

Advantages: Simple to understand and to administer. Data available to MGA.

Disadvantages: Complete dataset may not be available at the start of the GSP. Uncertainty regarding timing of data availability. Not related to actual extraction amount and burden on the basin.

Data requirements: Basin-wide count of non-de minimis wells subject to the GSP.

Other/Policy Requirements: None identified.

Internally Raftelis discussed active versus total (active and non-active) wells and determined that total is appropriate given the non-de minimis threshold of 2 AFY. Additionally, GSA action would be required to clearly define active, non-active, and abandoned wells.

3.2.2 WELL CAPACITY (NON-DE MINIMIS WELLS)

Advantages: All wells are not equal, they have different capacities and ability to extract water.

Disadvantages: More data is required than simple well count.

Data requirements: Need well head/well meter size for all active wells or wells subject to the GSP.

Other/Policy Requirements: Requires adoption of a metering plan, or similar way to validate well head size.

3.2.3 PARCEL COUNT (TOTAL PARCELS)

Advantages: Parcel based approaches are generally simple to understand and to administer. Few data requirements with the data from the County Assessor readily available.

Disadvantages: Approach assumes a broad benefit of groundwater, or a "general benefit logic." Requires a voter approval process to put on an election ballot.

Data requirements: County Assessor's parcel database.

Other/Policy Requirements: None identified.

3.2.4 PARCELS COUNT (NON-DE MINIMIS)

Advantages: Generally simple to understand and to administer. Few data requirements. Requires a good data set of parcel owners and non-de diminish classification.

Disadvantages: Inequitable among non-de minimis users. No relation to groundwater extraction.

Data requirements: Basin-wide count of non-de minimis parcels.

Other/Policy Requirements: None identified.

3.2.5 ACREAGE (TOTAL)

Advantages: Simple to understand and to administer. Minimal data requirements. Data is readily available. Acts as a proxy for potential extraction.

Disadvantages: Assumes a general benefit but with a stronger nexus than parcel count. Not related to actual water extraction.

Data requirements: County Assessor's parcel database.

Other/Policy Requirements: None identified.

3.2.6 ACREAGE (IRRIGATED)

Advantages: Absent another source of supply, irrigated usage is directly tied to groundwater extraction. More equitable than parcel or acreage. Proxy for actual water extraction by land area and land cover data.

Disadvantages: Data intensive. Will require regular updates. May be prone to challenges and manual surveys for confirmation. Will require plant/crop type being irrigated.
Data requirements: Accurate geospatial land cover data and independent estimation.
Other/Policy Requirements: None identified.

3.2.7 PUMPING (GROSS EXTRACTION)

Advantages: Greatest equity since fee based on actual extraction. Easy to understand. Easy to administer provided metering plan adoption.
Disadvantages: Requires flow meter installation to implement. If not, more time, effort, and cost than other options (i.e., wells, parcels, or acreage options).
Data requirements: Validated metered data.
Other/Policy Requirements: Requires adoption of metering plan.

3.2.8 CONTRACT

Advantages: Simple, potentially cost effective, avoids adoption and implementation hurdles and limits legal risk associated with Prop 218/26, taxes, and assessments. Based on negotiation of parties.
Disadvantages: Not necessarily related to past, present, or future extraction. Potential inequity.
Data requirements: None identified.
Other/Policy Requirements: Requires formal agreement/signed contract between basin non-de minimis extractors and MGA.

3.2.9 MEASUREMENT OPTION SELECTION

Raftelis makes no recommendation with regards to the unit of service. Rather, it should be the decision of the MGA Board to select the unit of service approach that is most appropriate for the Agency given the policy objectives, basin characteristics, data availability, and types of costs incurred. There are varying degrees of equity, user flexibility, and ease of administration with each option. These decisions will require input from MGA staff, the Advisory Committee, and the MGA Board.

While Raftelis makes no single recommendation, given the characteristics of the basin's non-de minimis private users and data available at this time, we recommend narrowing down the options to the following three: parcels (non-de minimis), acreage, and estimated gross pumping. Narrowing the options allows a deeper dive into each and an easier comparison across options. In the following sub-section, we have calculated preliminary charges based on these three options and the estimated annual costs of MGA identified in Section 3.1.

3.3 GSA Charge Calculations

Raftelis calculated preliminary charges using the cost estimates in the prior sub-sections and the following units of service: irrigated acreage, estimated pumping volume, and parcel count. Charges are shown in both dollars per year and dollars per month. All rates are rounded up to the nearest whole penny.

The first step is to allocate the total costs (revenue requirement) of MGA between the municipal users and the non-de minimis users based on pumping estimates. The table below shows the class, specific user, estimated pumping, and share of total pumping. Charges developed in this section for non-de minimis users include Small Water

Systems, Institutional, and Agriculture. In total this class accounts for roughly 18 percent of total basin pumping and approximately 20 percent of regulated basin pumping (exclusive of de-minimis pumping which is not included in the cost allocation).

Table 3 – MGA Cost Allocation

Class	Water pumper	2016 Estimate (AF)	Percent of Total GW	2016 Estimate - Regulated (AF)	Percent of Regulated GW	Share of MGA Costs
Municipal	Santa Cruz	480	8.74%	480	9.71%	$34,001
Municipal	Soquel Creek	3,090	56.25%	3090	62.54%	$218,883
Municipal	Central	381	6.94%	381	7.71%	$26,988
Non-de Minimis	Small Water Systems	85	1.55%	85	1.72%	$6,021
Non-de Minimis	Institutional	190	3.46%	190	3.85%	$13,459
de Minimis	Private wells	552	10.05%	0	0.00%	$0
Non-de Minimis	Agriculture	715	13.02%	715	14.47%	$50,648
Total		**5,493**	**100%**	**4,941**	**100%**	**$350,000**

The summation of costs allocated to the three Non-de minimis user classifications - Small Water Systems, Institutional, and Agriculture – yields the total costs required to be recovered from non-de minimis users. The total revenue recovery required from non-de minimis users is $70,128.

Table 4 – Non-de Minimis Cost Allocation to User Classes

Class	Share of MGA Costs
Municipal	$279,872
Non-de Minimis	$70,128
De Minimis	$0
Total Costs Recovered	**$350,000**

3.3.1 PARCEL FEE

Table 5 shows the total count of parcels subject to a fee and Table 6 shows the calculated fee based on the count of non-de minimis parcels. Total costs are divided by the number of parcels to derive the fee. The estimated fee is shown both on an annual and monthly basis. The estimated fee for small water systems does not include the number of parcels served by each system. Therefore, each system is treated as one parcel. Depending upon the actual number of parcels served by small water systems it is possible that there could be a large variance in the calculated parcel fee. Any addition of parcels will reduce the fee as the costs allocable to the class (non-de minimis users) remains fixed.

Table 5 – Non-de Minimis Parcel Count

User Type	Parcel Count
Private Non-de Minimis Users	135
Small Water Systems	22
Total Parcels	**157**

Table 6 – Parcel Fee

Costs	Parcel Count	$ Per Parcel Per Year	$ Per Parcel Per Month
$70,128	157	$446.67	$37.23

3.3.2 IRRIGATED ACREAGE FEE

Table 7 shows the sum of acres subject to the fee and Table 8 shows the calculated fee based on non-de minimis irrigated acreage. Total costs are divided by each class's irrigated acreage to derive the fee per acre. The estimated fee is shown both on an annual and monthly basis. The estimated acreage fee is high as the data for small water systems considers all acreage, not just the total number of irrigated acres served by each system. To be more conservative, Raftelis accounted for the small water systems' total pumping in the acreage estimate, effectively assuming water use at a rate of one acre foot per acre per year. Depending upon the actual acreage of small water systems it is possible there will be a significant variance in the calculated acreage fee. Any additional acreage above what is assumed in the calculation will reduce the fee as the costs allocable to the class remain fixed.

Table 7 – Non-de Minimis Irrigated Acreage

User Type	Acreage
Private Non-de Minimis Users	838.5
Small Water Systems	275.1
Total Parcels	**1,114**

Table 8 – Irrigated Acreage Fee

Costs	Acreage	$ Acre Per Year	$ Per Acre Per Month
$70,128	1,114	$62.97	$5.25

3.3.3 VOLUMETRIC FEE

As previously discussed, MGA may choose to assess charges on all non-de minimis pumpers or at a minimum threshold, yet to be determined. Raftelis calculated fees at the following minimum extraction thresholds: 0 AFY, 2 AFY, 5 AFY, and 10 AFY. For reference 0 AFY represents all 135 identified private non-de minimis users and 100 percent of private non-de minimis pumping (exclusive of small water systems); 2 AFY represents 58 private non-de minimis users and 93 percent of private pumping; 5 AFY represents 31 users and 80 percent of private pumping; 10 AFY represents 15 users and 62 percent of private pumping. The top nine private users pump half of the water in the class. Table 9 summarizes the volume of pumping among private non-de minimis users at these various thresholds. In all scenarios small water systems are charged for all their pumping.

Table 9 – Volumetric Fee Thresholds

User Type	AFY
Private Non-de Minimis User (0 AFY Minimum)	659.74
Private Non-de Minimis User (2 AFY Minimum)	611.05
Private Non-de Minimis User (5 AFY Minimum)	523.64
Private Non-de Minimis User (10 AFY Minimum)	408.86
Small Water System	275.1
Total Acre Feet	**1,113.6**

The following four tables show the calculated volumetric pump charge at each threshold of 0 AFY, 2 AFY, 5 AFY, and 10 AFY. Fees are presented in dollars per acre foot and range from a low of $75.02 per acre foot to a high of $102.53 per acre foot.

Table 10 – 0 AFY Threshold

Costs	Acre Feet per Year	$ acre foot
$70,128	935	$75.02

Table 11 – 2 AFY Threshold

Costs	Acre Feet per Year	$ Per Acre Foot
$70,128	886	$79.14

Table 12 – 5 AFY Threshold

Costs	Acre Feet per Year	$ acre foot
$70,128	799	$87.80

Table 13 – 10 AFY Threshold

Costs	Acre Feet per Year	$ acre foot
$70,128	684	$102.53

3.4 Other GSA Charges

In addition to fees and charges imposed to recover the costs of implementing the GSP and operating MGA, the Agency will assess other charges in cases of pumping over allocations (should allocations be adopted), non-compliance charges, and/or penalties. Non-extraction and over-pumping charges are outlined in the following subsections.

3.4.1 PUMPING OVERAGE CHARGES

Groundwater extractions exceeding the amount that a groundwater user is authorized to pump under regulations adopted by the Agency may be subject to fines or penalties under Water Code section 10732(a). The fine may not exceed $500 per acre-foot extracted in excess of their authorized amount (Water Code §10732 (a)(1)). Implementation of fines or penalties assumes that MGA will adopt a metering plan and develop individual pumping allocations for each non-de minimis user in the basin. Given the nature of the Sub-basin, the Water Code maximum fine of $500/AF appears warranted. Justification for this value is as follows:

- Supplemental water costs (Indirect Potable Reuse (IPR)) – Soquel Creek Water District is designing and constructing a supplemental supply project using tertiary treated wastewater, advanced purification, and groundwater injection. While the project will be wholly owned and funded by an MGA member agency, it will assist in achieving Mid-County Basin sustainability goals. The estimated cost of finished water (operating and capital costs included) will far exceed $500 per AF so it is appropriate for the Agency to charge the maximum fine defined in the Water Code.

- Supplemental water costs (Water Transfers) – High flow events may be captured on the San Lorenzo River and transferred for consumption by municipal users or groundwater recharge within the Mid-County Basin. The costs of water transfers have been estimated to exceed $500 per AF so it is appropriate for the Agency to charge the maximum fine defined in the Water Code.

An argument may be made that the requirements of Article XIII D, section 6(b) (Proposition 218) supersede the maximums presented in the Water Code. Simply, the cost of service based on supplemental supplies through IPR and water transfers trumps the Water Code maximum of $500/AF. Additional legal review by MGA counsel would be required to explore this argument.

Overage Charges (Surcharge Rates) Example – Fox Canyon Groundwater Management Agency

Tier I: One to 25.000 AF = $1,461.00 per AF
Tier II: 25.001 AF to 99.999 AF = $1,711.00 per AF
Tier III: 100 AF or more = $1,961.00 per AF

From the Fox Canyon Ordinance: *Extraction surcharges are necessary to achieve safe yield from the groundwater basins within the Agency and shall be assessed annually when annual extractions exceed the historical and/or baseline allocation for a given extraction facility or the combined sum of historical allocation and baseline allocation for combined facilities. The extraction surcharge shall be fixed by the Board and shall be based upon (1) the cost to import potable water from the Metropolitan Water District of Southern California, or other equivalent water sources that can or do provide non-native water within the Agency jurisdiction; and (2) the current groundwater conditions within the Agency jurisdiction. The Board shall fix the surcharge by Resolution at a cost sufficiently high to discourage extraction of groundwater in excess of the approved allocation when that extraction will adversely affect achieving safe yield of any basin within the Agency. In circumstances where an individual or entity extracts groundwater from* *a facility(s) having no valid extraction allocation, the extraction surcharge shall be applied to the entire quantity of water extracted. Surcharges are assessed annually.*

Deficit Accounting - GSAs can allow unused groundwater extraction allocations to be carried over and transferred only "if the total quantity of groundwater extracted in any five-year period is consistent with the provisions of the [GSP]." § 10726.4(a)(4). If the GSA adopts a carryover policy then deficit pumping may be allowable with sufficient carryover water. However, the policy should be specific and should not allow borrowing from future allocations.

3.4.2 NON-COMPLIANCE CHARGES

If the fine or penalty is for non-compliance with regulations adopted by the GSA (e.g., failing to install a meter), then it is subject to the limitations in Water Code section 10732(b) and the fine or penalty may not exceed $1,000 plus $100 per day additional charges if the violation continues for longer than 30 days after the notice of the violation has been provided. A list of anticipated non-compliance charges is below, including examples identified by Raftelis:

Non-metered use (non-de minimis): The fee is equal to double the current groundwater extraction charge for all estimated water used (Fox Canyon GMA 2013).

Failure to provide access: No known guidance on reasonable costs but may be tied to reasonable staff labor costs.

Failure to report: No known guidance on reasonable costs but may be tied to reasonable staff labor costs.

State Non-Compliance Charges: In the event that a GSA is unwilling or unable to manage the groundwater basin the State will intervene with a schedule of fees set by the State Water Resources Control Board. Fees would be imposed on all users of the "probationary" basin and extractors would be required to file a groundwater extraction report. In probationary basins non-de minimis users may be required to file an extraction report, due by December 15 of each year for the prior water year. For reference, the table below shows the 2017 fee schedule for unmanaged and probationary basins.

Table 14 – SWRCB Non-Compliance Charges

Fee Category	Fee Amount	Applicable Parties
Base Filing Fee	$300 per well	All extractors required to report
Unmanaged Area Rate (metered)	$10/AF	Extractors in unmanaged areas
Unmanaged Area Rate (unmetered)	$25/AF	Extractors in unmanaged areas
Probationary Plan Rate	$40/AF	Extractors in probationary basins
Interim Plan Rate	$55/AF	Extractors in probationary basins where the Board determines an interim plan is required
De minimis Fee	$100 per well	Parties that extract, for domestic purposes, two acre-feet or less per year from a probationary basin, If the Board decides the extractions will likely be significant.
Late Fee	25% of total fee per month late	Extractors that do not file reports by the due date

3.4.3 PENALTIES

If the GSA has adopted an ordinance, it may levy an administrative civil fine or penalty (Government Code §53069.4). The fine or penalty may not exceed $100 for the first violation, $200 for the second violation, and $500 for each additional violation within 12 months of the first (§25132(b) and §36900(b)).

Section 10730.6(a) outlines the authority of a GSA to collect management fees and the remedies available to the Agency for failure to pay. These remedies include collection of interest on late payments at a maximum of one percent per month[7]; assessing penalties "in the same manner as it would be applicable to the collection of delinquent assessments, water charges, or tolls[8]"; or even the cessation of pumping[9] until the outstanding fees are paid and the user is no longer delinquent on payments.

Alternatively, and only if MGA was to adopt individual pumping allocations, in place of monetary penalties the GSA could impose a penalty that results in a percent of volume loss of a following year pumping allocation, or similar allocation reduction penalty.

A series of examples follows from Fox Canyon Groundwater Management Agency (MGA):

Late Statements

Statements submitted after the due date incur a Civil Penalty of $50 per day.

Late fee on extraction

An Extraction Interest Charge of 1.5% is charged for every month the statement and/or payment is overdue. (Extraction charge x 1.5% x month(s) overdue).

Late fee on overage/surcharge[10]

A Surcharge Late Penalty of 1.5% is charged for every month the statement and/or payment is overdue. (Surcharge x 1.5% x month(s) overdue).

Late fee on non-metered water use

Any delinquent Non-Metered Water Use Fee obligations shall also be charged interest at the rate of 1.5% per month on any unpaid balances.

3.5 Other Considerations

3.5.1 METERING PLAN

[7] Water Code Section 10730.6(b)
[8] Water Code Section 10730.6(d)
[9] Water Code Section 10730.6(e) requires a public hearing with at least 15 days' notice to the owner of operator of the well
[10] Greater than an extractors pumping allocation

Aerial survey for landcover data is an accurate method of estimating the irrigation demands of a parcel. However, challenges arise due to timing and frequency of updated crop cover, validating parcel boundaries, and identifying the parcel(s) served by an individual well, among other challenges. A remedy is to require installation of meters on individual non-de minimis wells for precise pumping volumes rather than estimations. However, there are tradeoffs for precision. It is costly to install meters on wells and the cost is greater for small volume users, particularly if the fee amount is low. Consequently, MGA may impose a significant financial burden on the pumper and increase the effort on MGA staff for a relatively small benefit. Conversely, large users have a greater impact on the basin and the cost of meter compliance is low relative to their fee. Additionally, if the fee is based on actual pumping, and a metering plan is not adopted by the MGA Board, a larger user will have an incentive to report lower pumping to reduce the fee. If actual gross pumping is selected as the method of fee-setting, metering should be required along with regular reporting and verification.

3.5.2 PUMPING ALLOCATIONS

MGA may choose to adopt individual pumping allocations for all non-de minimis users. These allocations would be based, at least initially, on estimated pumping from aerial survey and land cover/crop type data. Each extractor will know their allocation which would could become the basis for their pumping fee. MGA should determine if individual allocations are prudent if no pumping reductions are required by individual non-de minimis pumpers. Further, if estimated pumping (and therefore allocation) is greater than actual extraction the private pumper would have an incentive to pump *more* so that their pumping is in line with their allocation.

3.5.3 PUMPING REDUCTIONS AND NON-DE MINIMIS USER FEE THRESHOLD:

The sustainable yield of the Mid-County Basin will be achieved predominantly by using supplemental supply projects from the MGA's Municipal entities. Still, approximately 18 percent of total basin pumping (20% of non-de minimis pumping) comes from non-de minimis private pumpers. Approximately 15 of these users extract greater than 10 AFY. Given the significant pumping of the largest private users, MGA should consider developing pumping reductions for these individuals by identifying the costs and benefits of curtailment. They would effectively be treated as a separate sub-class of private pumper, unique from the de-minimis users and small non-de minimis users.

3.5.4 EXTRACTION THRESHOLD FOR FEE ASSESSMENT

Given that the majority of non-residential, non-de minimis users are estimated to use less than 2 AFY, the question of extraction threshold should be considered. What should the threshold for assessing charges on these users be and why? SGMA and the Water Code give MGA the authority to assess these users however minimal their extraction; however, the burden on staff and administrative costs may not cover the literal dollars, in some cases, of assessing an annual volumetric fee on a user extracting one-tenth of an acre foot per year. Still, MGA would require a sound argument as to why a specific threshold was selected. While a statistical analysis, or some other analytical assessment, could be used to determine an appropriate threshold we would recommend MGA use 2 AFY as the threshold. This volume corresponds to the definition of a de minimis user, were they a residential user. Further a review of MGA's data on non-de minimis users shows that 77 of 135 identified extract less than 2 AFY. In total these 77 extractors amount to 49 AF of pumping relative to 660 AF for the class in total. In other words, the remaining 58 users account for 93 percent of pumping among the user group. Removing the 77 users from the charge calculation has an immaterial effect on the resulting fees to other users (in fee recovery by acreage or pumping volume). Additionally, it reduces the demands on MGA staff and potential for contentious public meetings. Raftelis reviewed our work in the Sonoma GSAs and Borrego GSA, as well as the draft report in the neighboring

SVBGSA, and found no mention of minimum thresholds for non-de minimis users at which they will or will not be assessed management charges. The Borrego Valley GSA is considering a de-minimis threshold of 5 AFY because after long term reductions these users would approach 2 AFY in 2040.

2 AFY identified as de minimis in SGMA seems appropriate even when the user is not Residential in nature. The cost-benefit of charging a private irrigator who uses less than 2 AFY versus a private residential pumper who uses less than 2 AFY may not pan out.

3.5.5 ACTIONS IN OTHER BASINS

Borrego Valley GSA plans to adopt a metering a plan and are currently identifying individual allocations which will then need to be reduced over time (interim and final reductions) to achieve the long-term sustainable yield. The Borrego basin requires a greater than 70 percent reduction in pumping and no supplemental/alternative water supply projects are feasible. Achieving sustainable yield will be achieved with reduced pumping, fallowing of agricultural lands, and conservation. In Sonoma County GSAs there is no plan for metering or reductions for large private pumpers. Groundwater users will be assessed a volumetric charge per acre foot of water based on estimated extractions from the basin (using spatial data analysis). The Salinas Valley Basin GSA (SVBGSA) has released a draft report with non-de minimis users (which are almost exclusively commercial agricultural users) assessed charges based on estimated irrigated acreage (estimates from spatial data analysis). It should be noted that Borrego GSA actions are for GSA fees (GSP implementation) while the Sonoma GSAs and SVBGSA actions are to fund GSP development activities prior to implementation.

4. Fee Recovery Methods

Below are two bill collection options for MGA groundwater users.

4.1 Direct Billing

Direct billing requires more staff, has higher administrative costs (printing, postage, customer service, collections), and has a higher rate of late payments and delinquencies. It requires the Agency maintain its own customer information system and internal accounting. If the existing County system or member agency system is not readily available for use there may be significant one-time costs to purchase, configure, integrate, and train staff on the software. Direct billing results in greater cash flow assuming regular monthly or bi-monthly billing. This results in lower cash reserve requirements.

4.2 Property Tax Roll

Billing users through the County Assessor results in less overhead, lower billing and customer service costs, and a lower rate of late payments and delinquencies. Setup costs should be lower as the Agency relies on the County Assessor. The Agency is still required to maintain accurate parcel data and associated data for charges that may be based on volumetric pumping, well count, or well capacity. Revenue is only received twice per year, so cash flow may be a concern depending on timing. Property Tax Roll billing requires greater cash reserves than direct billing. Additional fees will be incurred by the County to place a charge on the property tax roll.

As it relates to the available funding mechanisms presented in Section 2, assessments and special taxes are always recovered on a parcel's property tax bill. Fees for service are more likely to be directly billed but many agencies find it advantageous to collect fees on the property tax roll. As previously mentioned, the collection rate is frequently higher, and the collected revenue is then transferred to the charging agency twice per year.

5. Management Area Designation

If MGA determines it to be beneficial to differentiate the basin into Management Areas, Raftelis recommends the Agency identify and document the rationale for doing so. In traditional rate and fee setting, costs should be matched to benefits to ensure equity among and between different users, as well as to ensure each user group pays its fair share. In utility rate setting costs are allocated to classes of customers commensurate with their service requirements. In fee setting costs are allocated proportional to the benefits gained through the fee.

Considering that any capital project costs will be borne by the three municipal water service partner agencies, the costs recovered by MGA are for management only. In a certain sense, management zones have unintentionally been derived between coastal municipal users and all other non-de minimis users. Coastal zone users will pay fees, additional to the MGA management fees, through their water rates and charges as customers of Soquel Creek Water District, the City of Santa Cruz, or Central Water District; all other non-de minimis users within the Basin in County areas will only pay the management fee.

If MGA wishes to further designate management zones it may be appropriate to different impact zones using long term monitoring costs. If monitoring costs in coastal zones versus inland zones, or stream adjacent zones versus non-adjacent zones, or high elevation zones versus low elevation zones, can be demarcated with a sound rationale it may be justifiable. However, consider the following analogy: Property A is inland and adjacent to a creek. Property B is near the coast but not creek adjacent. The two properties pay different management fees due to long term monitoring costs with Property A paying a higher fee. However, Property B, the coastal parcel, benefits from the monitoring taking place inland. The exercise leads back to the fact that the fees derived to fund MGA are for basin-wide management, which is an implicit objective of SGMA: all current, future, or potential users benefit from basin management and the benefit of management is general to all.

If MGA decides to differentiate management areas it will need to ensure that specific benefits are identified for users in different areas. Initial questions that arise when hypothesizing include:

- Can we identify all non-de minimis users inside and outside a proposed impact zone?
- Is the "impact" just seawater intrusion, or is it also basin elevation, basin storage reduction, etc?
- What about connectivity with surface water?
- Can we identify and differentiate management, monitoring, and other costs between two or more impact zones?
- What other information would be required to develop separate fees for coastal and creek impact zones that would be *additional to* general basin management fee?
- Would MGA adopt a metering plan for non-de minimis users? This would be beneficial so that charges could be related to impact based on water extraction, and recovered proportionally
- Can creek monitoring costs be used to differentiate? For example, an instream flow fee and a coastal impact fee, etc. Again, a specific benefit would need to be identified for those having the fee imposed.

6. De Minimis Users

SGMA defines a "de minimis extractor" as "a person who extracts, for domestic purposes, two acre-feet or less per year[11]." De minimis "extractors" or de minimis groundwater users cannot be charged fees "unless the agency has regulated the users pursuant to this part[12]." The key operating phrase is "has regulated" and unfortunately the term *regulated* is undefined leaving the meaning up to legal interpretation. Does *has regulated* imply past regulation and management? Or can the new sustainability agency "regulate" de minimis users prior to fee adoption to be able to charge them for basin management over the long-term? At least one GSA that Raftelis consults for is considering the act of noticing de minimis groundwater extractors as "regulating" them. By corresponding with a de minimis user and requesting basic information, the agency *has regulated* the de minimis user and can legally impose a fee.

Beyond the legal gray area and semantics of the Water Code language, a GSA should consider the cost-benefit analysis of recovering management costs from de minimis users. For example, consider a hypothetical groundwater basin experiencing critical overdraft where greater than 95 percent of extraction is from large non-de minimis agricultural interests and a single municipal entity. Are the real costs of management, and the potential costs of litigation, worth the benefit of revenues deriving from users responsible for five percent of water extraction? Or, should the Agency instead focus resources on the 95 percent of extraction which is almost certainly responsible for the required mitigation of the six undesirable results? Conversely, consider a basin experiencing critical overdraft where 75 percent of extraction is from de minimis extractors and the remainder from three municipal agencies. It may be considered unreasonable to expect 100 percent of funding required to mitigate impacts to come from three agencies (and their customers) when they are responsible for only 25 of extraction. In this situation the risk may be in *not* regulating and imposing a fee on de minimis users.

MGA should consider their own cost-benefit analysis with the Advisory Committee and GSA Board. Considerations should include the gross and net extraction by de minimis extractors, their geographical and hydrological location within the basin, and the likely amount of total cost recovery from the group, relative to the whole. Raftelis has developed a Pricing and Policy Objectives exercise for the Board to use to evaluate the decision to regulate and charge de minimis extractors, or not. The Raftelis exercise is attached as an appendix to this paper.

[11] Water Code Section 10721(e)
[12] Water Code Section 10730(a)

7. Appendices

7.1 Comparative Agency Administrative and Management Budgets

Raftelis has researched management and administrative costs of five similar agencies, which represent three GSAs, a groundwater management agency, and a Watermaster in an adjudicated basin. Details of each comparative agency are presented in the subsequent sub-sections. The table below presents a comparison of the five agencies with measurements that may be useful to MGA in identifying long-term management and administrative costs. Where available, the first fiscal year of GSP implementation costs are used; otherwise the most recently available values are used.

	Borrego Valley GSA	Mojave Watermaster	Fox Canyon GMA	North Fork Kings GSA[2]	Kings River East GSA[4]	Southwest Kings GSA
Personnel Costs		$634,955	$735,831	$75,400	$45,000	$50,000
Legal Costs				$27,400	$10,000	$11,139-20,000
Total Admin Budget	$574,566	$759,855	$1,431,744	$156,750	$68,400	$85,884-99,000
Staff Level (FTEs)	2	4	6.5[1]			Time and Materials
Staff Hours			11,700[1]	458[3]		
Management	Borrego Water District	Mojave Water Agency	Ventura County Public Works	Kings River Conservation District	Alta Irrigation District	Provost & Pritchard Consulting
Basin	Borrego	Mojave	Oxnard Plain, etc.	Kings	Kings	Tulare
Water Production (AFY)	20,000	120,000	134,000	TBD	TBD	TBD
Predominant User Groups	Single Municipal & Agriculture	Private Pumpers & Single Municipal	Municipal & Agriculture	Municipal	Municipal	Municipal

[1]Staff levels and hours assume contracted labor from the County of Ventura using 1,800 annual hours per FTE

[2]Estimates based on fiscal year 2020-2021, the first full year of GSP implementation

[3]Extrapolated using January through June 2018 costs

[4]Administrative budget for GSP Development and not GSP implementation

7.1.1 MOJAVE BASIN AREA WATERMASTER

The Mojave Basin Area Watermaster (Mojave Watermaster) is administered as a unit of the Mojave Water Agency (MWA). As Watermaster, the agency's main responsibilities include monitoring, reporting, and verification of water extraction for all parties of the adjudication, collection of assessments, production of annual reports, and facilitating water transfers between parties. In many respects the watermaster of an adjudicated basin and the GSA for a basin subject to SGMA are similar in duties and commitments.

The Budget Summary for the Mojave Watermaster from FY 2015-16 through budget year FY 2019-2020 is presented below. The overwhelming majority of expenses relate to wages and benefits, expected to cost $653,884 in FY 2019-2020. Secondary costs relate to engineering services of $93,500 in FY 2019-2020. The remaining costs of approximately $34,000 relate to travel, training, supplies, and other miscellaneous expenses.

The Mojave Watermaster consists of four staff including two technicians, a database administrator, and a services manager. Assuming four full-time employees (FTEs) and the wages and benefits in the FY 2019-2020 budget, the cost per FTE is approximately $163,500 per year.

Watermaster (WM) – Dept #90

Department Budget Summary

	ADMINISTRATIVE EXPENSES:	FY 15/16 Actual	FY 16/17 Actual	FY 17/18 Budget	Actual YTD as of 03/31/2018	FY 17/18 Projected	FY 18/19 Budget	FY 19/20 Budget
5600	Dept Wages	374,484	409,735	408,253	300,111	409,764	427,645	440,474
5612	Dept Overtime	5,646	3,936	4,000	2,257	859	4,000	4,000
5613	Health Insurance - Medical	54,609	48,960	48,960	36,249	48,960	55,455	57,119
5614	Payroll Taxes	12,048	12,659	13,259	9,667	13,439	14,010	14,430
5615	Misc Benefit	-	-	-	-	-	-	-
5616	Workers Compensation Expense	2,149	2,005	2,602	2,116	2,804	2,554	2,631
5618	Health Insurance - Dental/Vision	9,576	9,524	9,675	5,684	7,979	8,525	8,781
5620	Health Ins Reimb - FSA	6,879	5,949	10,400	4,386	6,000	10,600	10,918
5621	Deferred Comp Contributions	-	-	-	-	-	21,382	22,023
5623	PERS Retirement	67,897	72,908	98,679	81,214	105,656	90,784	93,508
	TOTAL WAGES & BENEFITS	**533,288**	**565,676**	**595,828**	**441,684**	**595,461**	**634,955**	**653,884**
5702	Safety Supplies	-	-	500	-	-	500	500
5710	Small Tools	-	-	100	-	-	250	250
5711	Books & Subscriptions	-	37	50	-	-	50	50
5713	Printing	-	-	500	-	-	500	500
5725	Auto Expenses	2,842	368	500	228	400	500	500
5726	Travel Expenses	-	-	500	-	1,850	8,800	9,000
5728	Education & Training	-	-	1,500	-	1,000	5,800	8,000
5736	Engineering, General	144,370	72,981	73,500	43,930	73,500	93,500	93,500
5741	Aerial Photos	19,750	10,875	12,500	10,875	12,500	15,000	15,000
	NON-LABOR EXP	**166,962**	**84,261**	**89,650**	**55,033**	**89,250**	**124,900**	**127,300**
	TOTAL DEPT EXPENSES	**700,250**	**649,937**	**685,478**	**496,717**	**684,711**	**759,855**	**781,184**
5610	Labor & Benefits from Watermaster	(350,125)	(276,286)	(297,914)	(152,750)	(297,731)	(317,478)	(326,942)
	Total Capital Labor & OH Out	**(350,125)**	**(276,286)**	**(297,914)**	**(152,750)**	**(297,731)**	**(317,478)**	**(326,942)**
	TOTAL NET DEPT EXPENSES:	**350,125**	**373,651**	**387,564**	**343,967**	**386,980**	**442,377**	**454,242**

7.1.2 FOX CANYON GROUNDWATER MANAGEMENT AGENCY (FCGMA)

FCGMA is a special district which governs the extraction of water in southern Ventura County and serves five municipalities and agricultural users in unincorporated areas of the county. While a special district since 1982 FCGMA will also be the GSA for the local groundwater basins including Arroyo Santa Rosa, Oxnard Plain, Pleasant Valley, and Las Posas Valley. The agency is staffed by contract with Ventura County Public Works overseeing technical, legal, financial, and administrative services. Total expenses in FY 2014-2015 were $1,088,951 with 60 percent of expenses ($645,975) towards County staff charges. Another 14 percent was spent on Groundwater Supply Enhancement Assistance Program (GSEAP) funding to assist local agencies with local groundwater projects that increases groundwater supply. 21 percent of costs were associated with professional services.

Per communications with Fox Canyon management, the County of Ventura utilizes 6.5 FTEs at assumed annual hours of 1,800 hours per FTE for a total of 11,700 hours. The fully burdened labor rate is approximately $115 per hour for an average annual cost of $1,345,500.

FOX CANYON GROUNDWATER MANAGEMENT AGENCY
Statements of Revenues, Expenses, and Changes in Net Position
For the Years Ending
June 30, 2016 and 2015

	2016	2015
OPERATING REVENUES		
Extraction charges and surcharges	$ 2,129,739	$1,373,904
Groundwater sustainability fee	274,544	-
Interest and penalties on delinquent accounts	75,969	33,946
Total Operating Revenues	2,480,252	1,407,850
OPERATING EXPENSES		
Ventura County Public Works Agency charges	735,831	645,975
Professional specialty services	603,816	227,410
Management and administrative services	19,580	7,197
Supplies and minor equipment	300	600
Liability insurance	4,707	4,498
Depreciation expense	51,908	51,908
GSEAP spending	-	148,269
Miscellaneous	15,602	3,094
Total Operating Expenses	1,431,744	1,088,951

7.1.3 NORTH FORK KINGS GSA

Located in the Central San Joaquin Valley, North Fork Kings GSA consists of 15 member agencies in the Kings Subbasin. Kings River Conservation District (KRCD) will administer the GSA including data collection and reporting, financial and accounting services, engineering services, and public outreach and education. The cost for administrative services by KRCD in FY 2020-2021 (the first full year of GSP implementation) is estimated at $75,400.

Table 3-2. Projected 5-Year Annual Budget

Category	Prior to 6/30/17	FY[a] 2017-2018	FY[a] 2018-2019	FY[a] 2019-2020	FY[a] 2020-2021	FY[a] 2021-2022	FY[a] 2022-2023	TOTAL
GSA Administration								
KRCD Staffing / Public Outreach		$ 69,000	$ 71,100	$ 73,200	$ 75,400	$ 77,700	$ 80,000	$ 377,400
Office Supplies / Postage / Outreach Materials		$ 6,000	$ 6,200	$ 6,400	$ 6,600	$ 2,000	$ 2,100	$ 23,300
Insurance		$ 2,000	$ 2,100	$ 2,200	$ 2,300	$ 2,400	$ 2,500	$ 11,500
Annual Audit		$ -	$ 4,000	$ 4,100	$ 4,200	$ 4,300	$ 4,400	$ 21,000
Miscellaneous Overhead		$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 7,500
Start-up Costs	$ 188,628		$ -	$ -	$ -	$ -	$ -	$ -
SUBTOTAL	$ 188,628	$ 78,500	$ 84,900	$ 87,400	$ 90,000	$ 87,900	$ 90,500	$ 440,700
Professional Services								
Project Management		$ 20,000	$ 20,600	$ 21,200	$ 21,800	$ 22,500	$ 23,200	$ 109,300
Funding Mechanism Assessment		$ 8,000	$ -	$ -	$ -	$ -	$ -	$ -
Prop 218 Engineer's Report/Elections		$ 30,000	$ 2,000	$ -	$ -	$ -	$ -	$ 2,000
Groundwater Sustainability Plan Preparation[b]		$ 150,000	$ 285,770	$ 80,000	$ -	$ -	$ -	$ 365,770
Legal, Litigation Reserve		$ 25,000	$ 25,800	$ 26,600	$ 27,400	$ 28,200	$ 29,000	$ 137,000
Lobbyist		$ 3,000	$ 3,100	$ 3,200	$ 3,300	$ 3,400	$ 3,500	$ 16,500
Grant Writing		$ 7,000	$ -	$ -	$ -	$ -	$ -	$ -
SUBTOTAL	$ -	$ 243,000	$ 337,270	$ 131,000	$ 52,500	$ 54,100	$ 55,700	$ 630,570
~10% Contingency/Reserve		$ 19,296	$ 42,220	$ 21,840	$ 14,250	$ 14,200	$ 14,620	$ 107,130
Reimbursement to Member Agencies			$ 264,712	$ 264,712	$ -	$ -	$ -	$ 529,424
Total Estimated GSA Administration & Professional Services Cost	$ 188,628	$ 340,796	$ 729,102	$ 504,952	$ 156,750	$ 156,200	$ 160,820	$ 1,707,824
Enterprise Fund for GSP Implementation - Project Development / Groundwater Monitoring			$ 907,435	$ 1,131,585	$ 1,479,787	$ 1,480,337	$ 1,475,717	$ 6,474,861
Total Estimated Cost			**$ 1,636,537**	**$ 1,636,537**	**$ 1,636,537**	**$ 1,636,537**	**$ 1,636,537**	**$ 8,182,685**

Raftelis contacted KRCD which provided a detail of staff hours by function. It is estimated that KRCD will spend approximately 458 staff hours across all functions on GSA administration in calendar year 2018 in support of GSP development. KRCD disclosed that May 2018 hours were higher than normal due to a special assessment hearing.

Employee Description	January-June 2018	Calendar Year 2018 (extrapolated)
Coordinator	72.5	145
Public Relations	50.5	101
Assistant	2	4
Finance	35	70
GIS	22.75	45.5
Accounting	0	0
Minutes	20.25	40.5
Admin	16	32
General Labor	10	20
Total	**229**	**458**

7.1.4 KINGS RIVER EAST GSA

Kings River East GSA is southeast of Fresno and west of the Sierra foothills. The GSA is a MOU between 14 municipalities and special districts in the basin. The total three-year budget is presented below. The administrative budget in each year is $68,400. The budget presented is only for GSP development and not GSP implementation and ongoing administration and management of the GSA. Administrative services are provided by contract with Alta Irrigation District, a party to the MOU. Staff time is billed hourly for costs incurred in servicing the GSA with an estimate of $45,000 per year.

Table 3: Projected Budget
Kings River East Groundwater Sustainability Agency
Groundwater Fee Study

Budget Item	Year 1	Year 2	Year 3	Total
Administration	**$68,400**	**$68,400**	**$68,400**	**$205,200**
Board Members (Per Diem)	$8,400	$8,400	$8,400	$25,200
Insurance	$5,000	$5,000	$5,000	$15,000
Legal	$10,000	$10,000	$10,000	$30,000
Administration Services	$45,000	$45,000	$45,000	$135,000
Grants/Outreach	**$3,500**	**$28,500**	**$3,500**	**$35,500**
Grant Application	$0	$25,000	$0	$25,000
Grower/Landowner Outreach	$3,500	$3,500	$3,500	$10,500
Groundwater Sustainability Plan	**$206,800**	**$235,350**	**$214,350**	**$656,500**
Sub-basin Coordination	$64,600	$64,600	$64,600	$193,800
Coordination Agreement	$0	$7,550	$7,550	$15,100
Data Management System	$0	$21,000	$0	$21,000
Hydrogeology	$75,000	$75,000	$75,000	$225,000
Legal Assistance	$7,800	$7,800	$7,800	$23,400
Monitoring Network	$14,600	$14,600	$14,600	$43,800
Projects & Management Actions	$17,800	$17,800	$17,800	$53,400
Sustainable Management Criteria	$18,700	$18,700	$18,700	$56,100
Report Compilation	$8,300	$8,300	$8,300	$24,900
Other	**$5,000**	**$5,000**	**$5,000**	**$15,000**
Miscellaneous Costs	$5,000	$5,000	$5,000	$15,000
Subtotal	**$283,700**	**$337,250**	**$291,250**	**$912,200**
Contingency (15%)	$42,600	$50,600	$43,700	$136,900
Total	**$326,300**	**$387,850**	**$334,950**	**$1,049,100**

7.1.5 SOUTHWEST KINGS GSA

Located in the Tulare Lake Subbasin, GSA day-to-day management will be provided by a consultant including financial management, reporting to the Board of Directors, and legal functions among others. The proposed five-year budget for on-going management is $85,884 in FY 2018-2019 and is presented below. The budget is drawn from the GSA's Engineer's Report dated June, 2017.

Description	2017	2018	2019	2020	2021
ON-GOING MANAGEMENT					
On-Going Management					
Communications, general administration	$ 12,000	$ 12,360	$ 12,731	$ 13,113	$ 13,506
Insurance	3,000	3,090	3,183	3,278	3,377
Website maintenance	5,000	5,150	5,305	5,464	5,628
Financial management	6,000	6,180	6,365	6,556	6,753
Administrative support	6,000	6,180	6,365	6,556	6,753
Assessments, collections	4,000	4,120	4,244	4,371	4,502
Printing, supplies, travel	12,000	12,360	12,731	13,113	13,506
Audit	0	5,000	5,150	5,305	5,464
	$ 48,000	$ 54,440	$ 56,073	$ 57,755	$ 59,488
SWKGSA board meetings (4)					
Board packages, attend, minutes	$ 8,000	$ 8,240	$ 8,487	$ 8,742	$ 9,004
Legal: attend, resolutions, agreements	8,000	8,240	8,487	8,742	9,004
	$ 16,000	$ 16,480	$ 16,974	$ 17,484	$ 18,008
Subbasin meetings (Monthly)					
Management: attend (12)	$ 9,600	$ 9,888	$ 10,185	$ 10,490	$ 10,805
Legal: attend (2)	2,500	2,575	2,652	2,732	2,814
	$ 12,100	$ 12,463	$ 12,837	$ 13,222	$ 13,619
Total On-Going Management	**$ 76,100**	**$ 83,383**	**$ 85,884**	**$ 88,461**	**$ 91,115**

A more recent FY 2018 Budget presented at the Southwest Kings GSA Board Meeting on May 9, 2018 shows a slightly different amount for management and legal costs. The FY 2018 Budget total for on-going management is $79,000 with $50,000 in management and $20,000 in legal representing the overwhelming majority of costs.

SWKGSA
2018 Budget

Description	Proposed 2018 Budget
Management	50,000
Legal	20,000
Clerical	6,000
Insurance	-
Website	2,000
Audit	1,000
GSP	115,000
Contingency	20,000
Total Expenses	214,000
Projected Income	
Assessments	455,906
Reimbursements	(97,939)
Delinquent Assessments	-
Interest	-
Total Income	357,967

7.2 Pricing Objectives Exercise

1. OVERVIEW

Fee structures are best designed when formulated to collect the appropriate amount of revenue while addressing unique characteristics of the Agency and the needs of its locale, basin users, and other stakeholders. Policy objectives for pricing are specifics that support broad policies, such as equity and conservation, and serve as discussion points when designing a fee structure.

Raftelis developed a list of policy objectives, and sub-objectives, according to the specific characteristics of the Santa Cruz Mid-County Groundwater Agency (MGA) and the suite of possible fee structures identified to implement the Groundwater Sustainability Plan (GSP) as part of the Sustainable Groundwater Management Act (SGMA) of 2014. Each pricing objective is defined herein.

2. BACKGROUND

The policy objectives in Table 1 – Administration, Equity, Rate and Revenue Stability, Affordability, and Conservation – were developed by Raftelis and will help guide the selection of an appropriate fee structure and fee recovery mechanism. Each policy objective includes several sub-objectives.

To inform the Board, each policy objective includes a policy statement, discussion notes and advantages and disadvantages of the policies. The seventeen pricing objectives were determined as most relevant to the possible fee structures identified and the characteristics of the groundwater basin.
The ranking of these policy objectives by the GSA Board will be used to develop a framework for the most appropriate fee structure(s) and fee recovery mechanism for the MGA. Recommended fee structure(s) may include a hybrid approach based on management and extraction and/or may include fixed and variable components.

Table 15: Policy Objectives and Associated Sub-Objectives for Fee Structure Evaluation

Administration	Equity	Rate and Revenue Stability	Affordability	Conservation
•Ease of Understanding •Easy of Implementation and Administration (Simplicity) •Defensibility	•Equitable among property owners •Equitable among pumpers •Equity across all basin users (beneficiaries) •Equity across management areas •Inter-generational equity	•Revenue Stability •Rate Stability •Minimize financial impacts	•Shared burden •Affordability for Essential Use	•Rewards past conservation •Tool for GSP implementation •Promotes future conservation •Scientific

Policy Objective 1 –Administration

Policy Statement: Recognizes the advantages of designating a structure and fee recovery mechanism that is easily understood by fee-payers, is simple to implement and administer by staff, and which is most defensible under applicable laws including the water code and the State Constitution.

Discussion: This objective highlights the importance of keeping structures and the process of administering them simple. Basin user education and clarity of bills should be considered as part of this principle.

Advantages of the Policy Objective: Creating structures that are easy for fee payers to understand will minimize fee-related user related administrative issues. If basin users understand the basis of their bills, they will have a greater ability to comprehend their calculated charges and conclude that it is fair.

Disadvantage of the Policy Objective: Simplifying the rate structure does not generally provide a maximum degree of fairness and equity across user groups and may limit conservation and affordable outcomes.

Sub-Objectives:

- **Ease of Understanding** – The ability for the fee structure to be explained in a manner that can be understood by basin users and other stakeholders that will have a positive impact on the ability to build acceptance of fees.
- **Ease of Implementation and Administration (Simplicity)** – Implementing a new fee structure merits careful consideration as fee structure implementation requires upfront (one-time) costs such as data gathering or billing system changes. An easy-to-administer structure does not negatively impact the ongoing costs of administration, which are predominately staffing costs.
- **Defensibility** – Producing a fee structure perceived to be fair, well documented, and well explained reduces the likelihood of legal challenge. This leads to more efficient and less costly administration.

Policy Objective 2 –Equity

Policy Statement: In compliance with the State Constitution (Article XIII D) and governing statutes of State Law (including Water Code §10720-10737.8 (SGMA)), fees should be cost-based, fairly apportioned among basin users, and account for the substantive provisions of law through a sound, technically defensible methodology.

Discussion: This principle highlights the importance of basin users' perception of fairness and equity, while also recognizing that an absolute equity among all basin users and user classes may not be achieved. Rates should generally be perceived as fair, reasonable, and equitable for all basin users.

Advantages of the Policy Objective: This principle reinforces the priority of treating all basin users fairly. Also, it acknowledges the practical obstacles that may prevent perfect equity, such as, excessive administrative costs or technical costs incurred solely to achieve additional equity.

Disadvantages of the Policy Objective: "fairness" and "equity" can be subjective and requires the Board to apply its discretion and judgment. More, equity can be interpreted at the basin-wide level or among and between different user groups or stakeholders.

Sub-Objectives:

- **Equity Among Property Owners** – States that a fee structure achieves equity by allocating costs fairly and proportionally across property owners whose parcels overlay the basin.
    - Example argument for: An impaired groundwater basin may diminish property values while an improved basin may increase land values

- **Equity Among Pumpers -** States that a fee structure achieves equity by allocating costs fairly and proportionally across well owners who extract from the basin.
    - Example argument for: Pumpers, or those owning wells, should pay because they are the actual extractors of groundwater from the basin
- **Equity Across All Basin Users (Beneficiaries) -** States that a fee structure achieves equity by allocating costs fairly and proportionally across all water users in the basin. Considers basin groundwater a general benefit across all users of groundwater.
    - Example argument for: Access to local groundwater benefits all and therefore all should pay
- **Equity Across Management Areas** - Considers specific regions within the basin boundaries that contribute to groundwater replenishment and specific regions which contribute to intrusion, depletion, and/or impairment.
    - Example argument for: It is fair and appropriate for MGA to incorporate natural sub-basin characteristics across the groundwater basin into a fee structure
- **Inter-Generation Equity –**States that a fee structure achieves equity by matching the costs of existing basin impacts to those who have caused the impacts. The objective aims to protect current and future users from disproportionately bearing costs related to groundwater management due to past activities.
    - Example argument for: It is fair and appropriate to recoup mitigation and restoration costs based on past users and their uses

Policy Objective 3 –Rate and Revenue Stability

Policy Statement: There are advantages to an agency in increasing revenue certainty and stabile rates to users. These policies are achieved by selecting specific funding mechanisms or incorporating specific cost components into a fee structure.

Discussion: This principle highlights the importance of ensuring adequate revenue generation for maintaining a self-sustaining agency. Revenues must be adequate to fund technical, personnel, and other operational costs. Revenue generation, and the rates charges to users, should be predictable.

Advantages of the Policy Objective: The practice of ensuring revenue sufficiency and stability generates additional gains in financial health.

Disadvantages of the Policy Objective: While pursuing a rate structure that promotes revenue stability is advantageous, setting user charges in a fashion that fixes a user's bill may be perceived as unfair and inequitable. In addition, the public may perceive the need as unnecessary and that the agency has little incentive to be judicious with operating and management costs.

Sub-Objectives:

- **Revenue Stability** – The ability of the fee structure to generate stable and predictable revenues from month to month or year to year. Specific types of fee structures are more effective at maintaining revenue stability than others. Adequate revenues ensure, for example, that technical studies can be conducted, qualified personnel can be retained, and that operational costs of the agency are covered.
- **Rate Stability** – To reasonably ensure that user fees are predictable from over billing cycles and without sharp fluctuations in magnitude or structure year over year. Similar to the revenue stability objective, certain fee structures are more effective at guarding against fee spikes and highly fluctuating user bills.
- **Minimize Financial Impacts** – Fees imposed by MGA on basin users will be the first of its kind. This objective aims to minimize the financial burden on users to the greatest extent possible. The objective overlaps with the shared burden objective in Policy Objective 4.

Policy Objective 4 –Affordability

Policy Statement: It is important to establish rates that generate adequate revenues from year to year, regardless of climate cycles or variation in basin extractions. Large and unexpected rate changes may impose financial hardships on users large and small. This may negatively affect public opinion of the MGA in terms of revenue management, fiscal responsibility, and rate equity.

Discussion: Affordable fees require a balance between generating stable and sufficient revenue for operations and providing flexibility in user charges. Any new fee structure may result in different impacts to different basin users.

Advantages of the Policy Objective: Flexibility in bills allows users a degree of choice and control over their charges. More, lower income and/or those facing financial hardship are more likely to stay current on their charges with fees deemed affordable by the community.

Disadvantages of the Policy Objective: Affordability is relative to each individual fee payer and can be difficult to define. What may be affordable for one user is unaffordable to another. Additionally, affordability efforts generally present a tradeoff with revenue stability to the agency.

Sub-Objectives:

- **Shared Burden** – Recognizes that the Mid-County Basin benefits all current, future, and potential users of groundwater. In essence, each overlying property benefits from a sustainable groundwater basin and the burden of ensuring basin health should be distributed as broadly as possible.
- **Affordability for Essential Use** – This objective addresses the importance of maintaining the price - i.e. that which is used for health and safety – at the lowest cost possible while considering the needs of the Agency and regulatory conditions.

Policy Objective 5 – Conservation

Policy Statement: The critical condition of the groundwater basin, and the mandate of sustainability as defined by SGMA, should be reflected in the fees and charges. The fee structure should encourage a reduction in basin-wide use and empower necessary water management efforts by the GSA.

Discussion: This principle recognizes the limited water availability of the basin, as well as the environmental and financial impact of mitigation activities. The fees should encourage reduced use of a limited resource to the greatest extent under the law.

Advantages of the Policy Objective: This policy attempts to align the costs of reducing basin extraction with the users causing basin overdraft and seawater intrusion. The fee structure assigns a tangible value on the costs of critical overdraft.

Disadvantages of the Policy Objective: Typically, fee structures emphasizing efficiency, conservation, and reduced water use pose increased costs in implementation, administration, technical services, and outreach.

Sub-Objectives:

- **Reward Past Conservation Efforts** –Recognizes the value either of rewarding individuals for reduced and efficient use according to their needs, or at minimum, not penalizing those users for their conservation efforts prior to SGMA.
- **Tool for Implementing the Groundwater Sustainability Plan (GSP)** –Aims to develop a fee structure that is most likely to achieve the goals of the GSP over the long term. Advocates for a mechanism to allocate costs and incentivize activities to avoid or mitigate undesirable results as defined by SGMA.

- **Promotes Future Conservation** –Aims to reduce total water use through a focus on reduced pumping. The objective may include increased efficiency of basin water use to include development of benchmark standards associated with the appropriate amount of water use based on local characteristics.
- **Scientific Method** – Use of best available science, models, and empirical data-based standards and guidelines should be employed to develop the fee structure. The scientific method is applied to pumping for indoor and outdoor water use, such as the specific amount of water estimated for outdoor requirements given parcel land cover as well as the estimated return of water to the basin based on geology and other hyper-local characteristics.

3. Pricing objectives Exercise

Santa Cruz Mid-County Groundwater Agency

Pricing Objectives Exercise

Please rank each of the objectives from 1 to 17 with
1 being most important and 17 being least important
See Appendix A for the definitions of each Objective

	Objectives	Ranking
Administration	Ease of Understanding	
	Easy of Implementation and Administration	
	Defensibility	
Equity	Equity Among Property Owners	
	Equity Among Pumpers	
	Equity Across All Basin Users (Beneficiaries)	
	Equity Across Geographic Areas	
	Inter-Generational Equity	
Rate and Revenue Stability	Revenue Stability	
	Rate Stability	
	Minimize Financial Impacts	
Affordability	Shared Burden	
	Affordability for Essential Use	
Conservation	Rewards Past Conservation Effort	
	Tool for Implementing the GSP	
	Promotes Future Conservation	
	Scientific Method	

Participant's name ____

4. Sub-Objective Definitions

Affordability for Essential Use: This objective addresses the importance of maintaining the price - i.e. that which is used for health and safety – at the lowest cost possible while considering the needs of the Agency and regulatory conditions.

Defensibility: Producing a fee structure perceived to be fair, well documented, and well explained reduces the likelihood of legal challenge. This leads to more efficient and less costly administration.

Ease of Implementation and Administration (Simplicity): Implementing a new fee structure merits careful consideration, as rate structure implementation requires upfront (one-time) costs such as data gathering or billing system changes. An easy-to-administer structure does not negatively impact the ongoing costs of administration, which are predominately additional staffing costs.

Ease of Understanding: The ability for the fee structure to be explained in a manner that can be understood by basin users and other stakeholders will have a positive impact on the ability to build acceptance of fees.

Equity Across All Basin Users (beneficiaries): This objective states that a fee structure achieves equity by allocating costs fairly and proportionally across all water users in the basin. Considers basin groundwater a general benefit across all users of groundwater.

Equity Across Management Areas: Considers specific regions within the basin boundaries that contribute to groundwater replenishment and specific regions which contribute to intrusion, depletion, and/or impairment.

Equity Among Property Owners: This objective states that a fee structure achieves equity by allocating costs fairly and proportionally across property owners whose parcels overlay the basin.

Equity Among Pumpers: This objective states that a fee structure achieves equity by allocating costs fairly and proportionally across well owners whose parcels overlay the basin.

Inter-Generational Equity: This objective states that a fee structure achieves equity by matching the costs of existing impacts to the basin to those who have caused the impacts. The objective aims to protect current and future users from bearing all costs related to groundwater management due to past activities.

Minimize Financial Impacts: Fees imposed on basin users will be the first of its kind. This objective aims to minimize the financial burden on users to the greatest extent possible. The objective overlaps with the shared burden objective.

Promotes Future Conservation: The objective aims to reduce total water use through a focus on reduced pumping. The objective may include increased efficiency of basin water use to include development of benchmark standards associated with the appropriate amount of water use based on local characteristics.

Rate Stability: The objective is to reasonably ensure that user fees are predictable from billing cycle to billing cycle and without sharp fluctuations in magnitude or structure year over year. Similar to the revenue stability objective, certain fee structures are more effective at guarding against fee spikes and highly fluctuating user bills.

Revenue Stability: The ability of the fee structure to generate stable and predictable revenues from month to month or year to year. Specific types of fee structures are more effective at maintaining revenue stability than others. Adequate revenues ensure, for example, that technical studies can be conducted, qualified personnel can be retained, and that operational costs of the agency are covered.

Reward Past Conservation Efforts: This objective recognizes the value either of rewarding individuals for efficient use according to their needs, or at minimum, not penalizing those users for their conservation efforts prior to SGMA.

Scientific Method: Use of best available science, models, and empirical data-based standards and guidelines should be employed to develop the fee structure. The scientific method is applied to pumping for indoor and outdoor water use, such as the specific amount of water estimated for outdoor requirements given parcel land cover, as well as the estimated return of water to the basin based on geology and other hyper-local characteristics.

Shared Burden: This objective recognizes that the Mid-County Basin benefits all current, future, and potential users of groundwater. In essence each overlying property benefits from a sustainable groundwater basin and the burden of ensuring basin health should be distributed as broadly as possible.

Tool for Implementing the Groundwater Sustainability Plan (GSP): This objective aims to develop a fee structure that is most likely to achieve the goals of the GSP over the long term. Advocates for a mechanism to allocate costs and incentivize activities to avoid or mitigate undesirable results as defined by SGMA.

Appendix B

Part 2.74 of Division 6 of the Water Code contains 12 chapters on Sustainable Groundwater Management. Below are five important sub-sections of Chapter 8: Financial Authority that are pertinent to MGA's ability to develop a fee structure that is most appropriate for the basin and the authority and technical requirements to charge fees. The language that follows is direct from the sub-sections in Chapter 8 of Part 2.74 of the Water Code. Bolded font is emphasis added by Raftelis.

10730.2(d): Fees imposed pursuant to this section may include **fixed fees** and **fees charged on a volumetric basis**, including, but not limited to, fees that increase based on the quantity of groundwater produced annually, the year in which the production of groundwater commenced from a groundwater extraction facility, and impacts to the basin.
10730.8(a): Nothing in this chapter shall affect or interfere with the authority of a groundwater sustainability agency to levy and collect **taxes, assessments, charges**, and tolls as otherwise provided by law.
10730.2(c): Fees imposed pursuant to this section shall be adopted in accordance with subdivisions (a) and (b) of **Section 6 of Article XIII D** of the California Constitution. (*Proposition 218*)
10730(a): A groundwater sustainability agency may impose fees, including, but not limited to, **permit fees** and **fees on groundwater extraction** or other regulated activity, to fund the costs of a groundwater sustainability program, including, but not limited to, preparation, adoption, and amendment of a groundwater sustainability plan, and investigations, inspections, compliance assistance, enforcement, and program administration, including a prudent reserve.
10730.2(a): …may impose fees on the extraction of groundwater from the basin to fund costs of groundwater management, including:

- Administration, operation, and maintenance, including a prudent reserve.
- Acquisition of lands or other property, facilities, and services.
- Supply, production, treatment, or distribution of water.
- Other activities necessary or convenient to implement the plan.