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.

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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.

Deep Wells: 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.

Shallow Wells: 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

<u>Initial GSP Implementation Phase (2020 – 2025)</u>

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.

<u>Ongoing GSP Implementation (2026 – 2040)</u>

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.

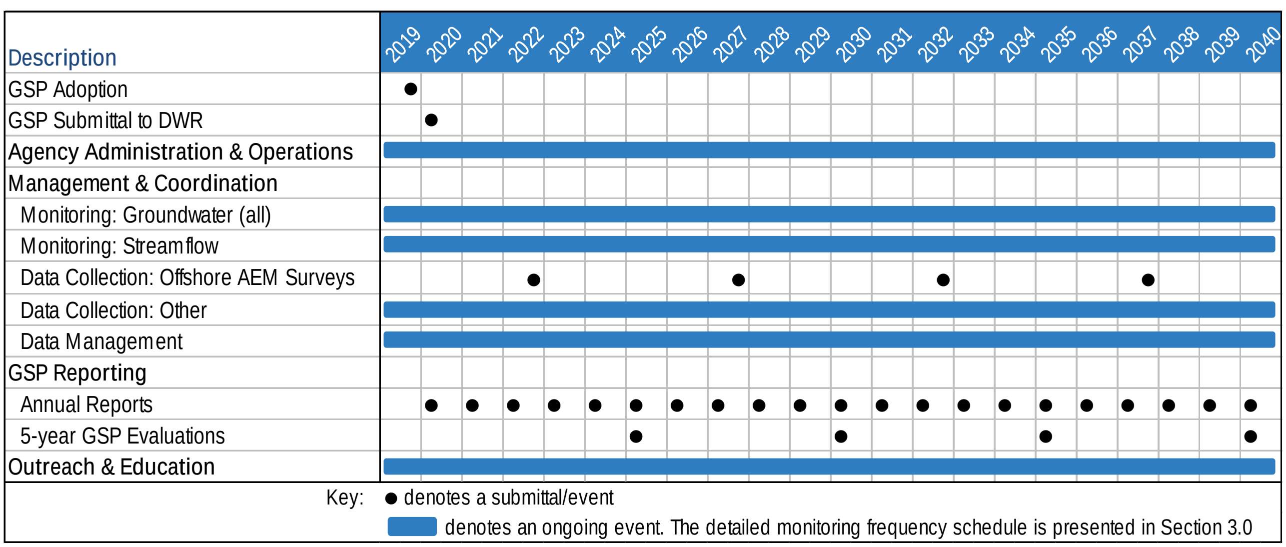

Figure 5-1. GSP Implementation Schedule

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.

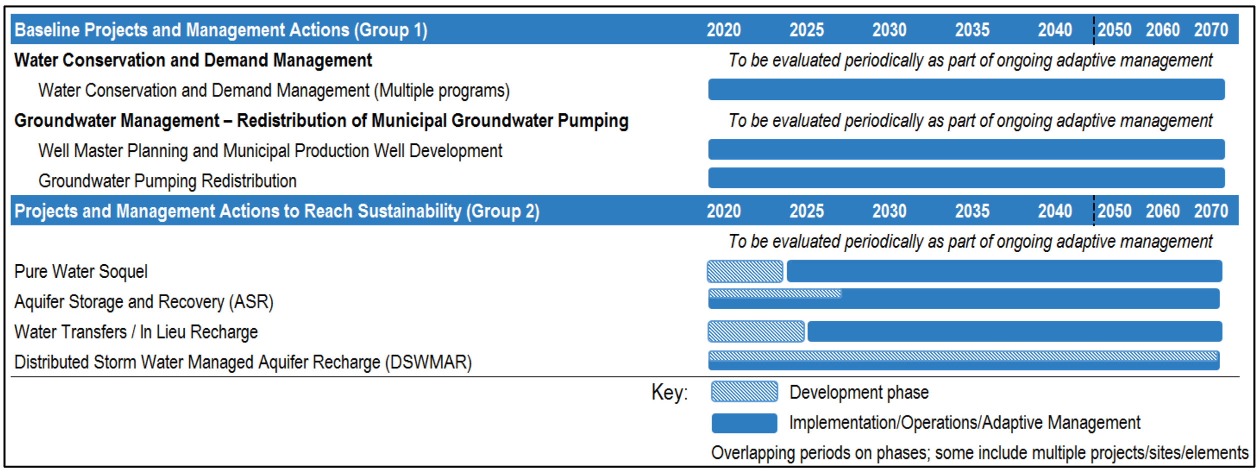

Figure 5-2. Member Agency Projects and Management Actions Estimated Timeline

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.

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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

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Appendix 2-B. Santa Cruz Mid-County Basin Groundwater Flow Model: Water Use Estimates and Return Flow Implementation (Task 2) Memorandum

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Appendix 2-D. Soquel-Aptos Groundwater Flow Model: Subsurface Model (Task 3) Memorandum

Appendix 2-E. Santa Cruz Mid-County Basin Conceptual Model Update Memorandum

Appendix 2-F. Santa Cruz Mid-County Basin Model Integration and Calibration

Appendix 2-G. Santa Cruz Mid-County Groundwater Flow Model: Future Climate for Model Simulations (Task 5) Memorandum

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Appendix 3-B. Hydrographs of Representative Monitoring Points for Chronic Lowering of Groundwater Levels

Appendix 3-C. Summary of Federal, State, and Local Water Quality Regulations

Appendix 3-D. Hydrographs of Representative Monitoring Points for Depletion of Interconnected Surface Water

Appendix 5-A. Santa Cruz Mid-County Groundwater Agency Evaluation of Private Pumper Funding Mechanisms and Fee Criteria, Raftelis, May 2019

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

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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 30^{th}. 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: ______________________

Title: Board President -CWD

APPROVED AS TO FORM:

By: ______________________

Title: District Counsel

CITY OF SANTA CRUZ

By: ______________________

Title: City Manager

2-23-16

APPROVED AS TO FORM:

By: ______________________

Title: Anthony P. Condotti City Attorney

COUNTY OF SANTA CRUZ

By: ______________________

Title: County Administrative Officer

APPROVED AS TO FORM:

By: ______________________

Title: County Counsel

SOQUEL CREEK WATER DISTRICT

By: ______________________

Title: President, Board

APPROVED AS TO FORM:

By: ______________________

Title: District Counsell

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?:*
    1. *Local daily/weekly newspapers (please name)*
    2. *Radio (please name)*
    3. *Websites (please name)*
    4. *Social Media (please name)*
    5. *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

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)

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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**

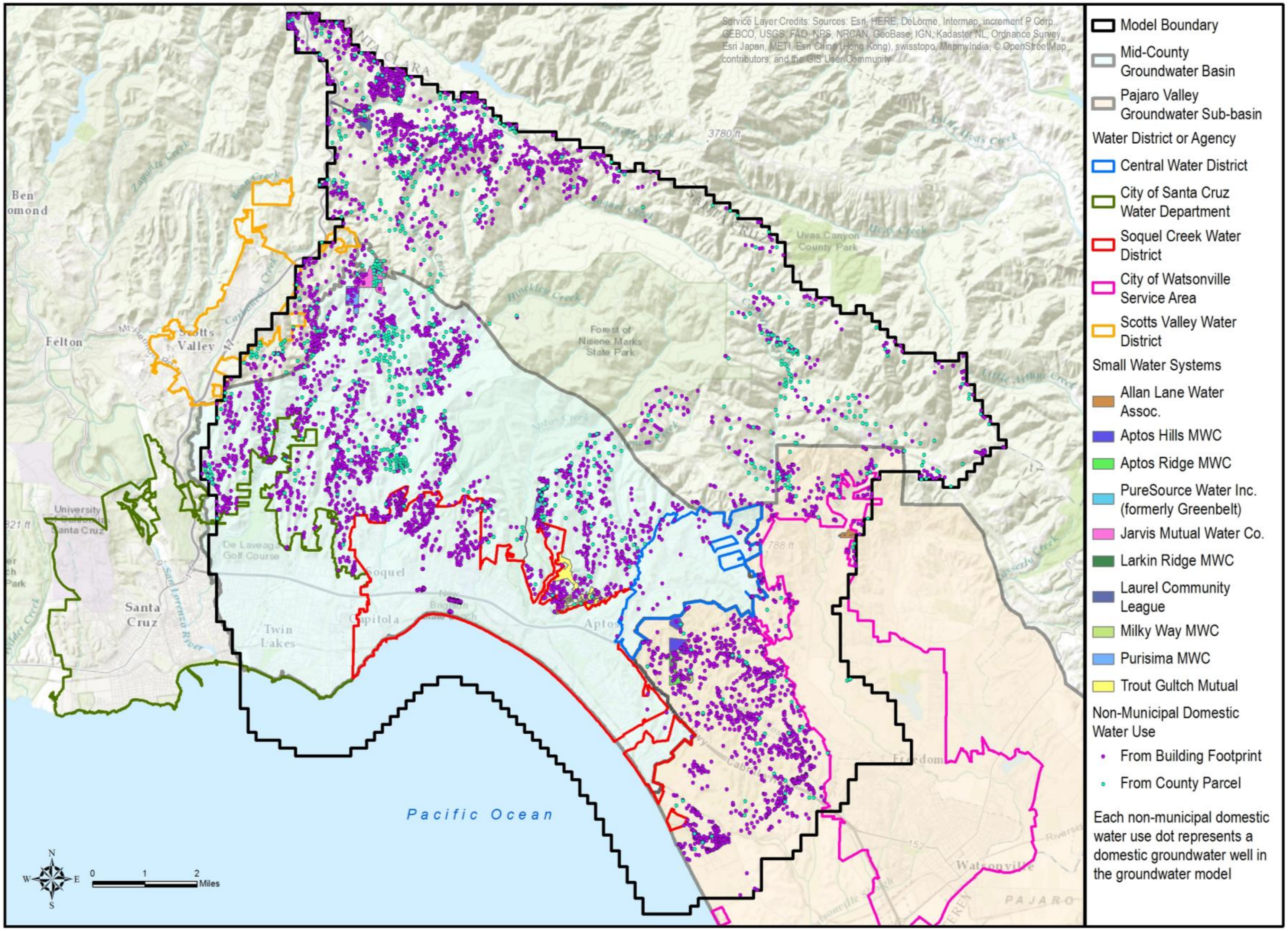

Figure 1: Non-Municipal Water Use Building Footprints and Residential Parcels

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

Water Year	Unincorporated Population % of 2014	Estimated Number of Non-Municipal Supplied Residential Buildings Model Area	Estimated Number of Non-Municipal Supplied Residential Buildings Mid-County Groundwater Basin	Non-Municipal Domestic Water Use (AFY) Model Area	Non-Municipal Domestic Water Use (AFY) 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

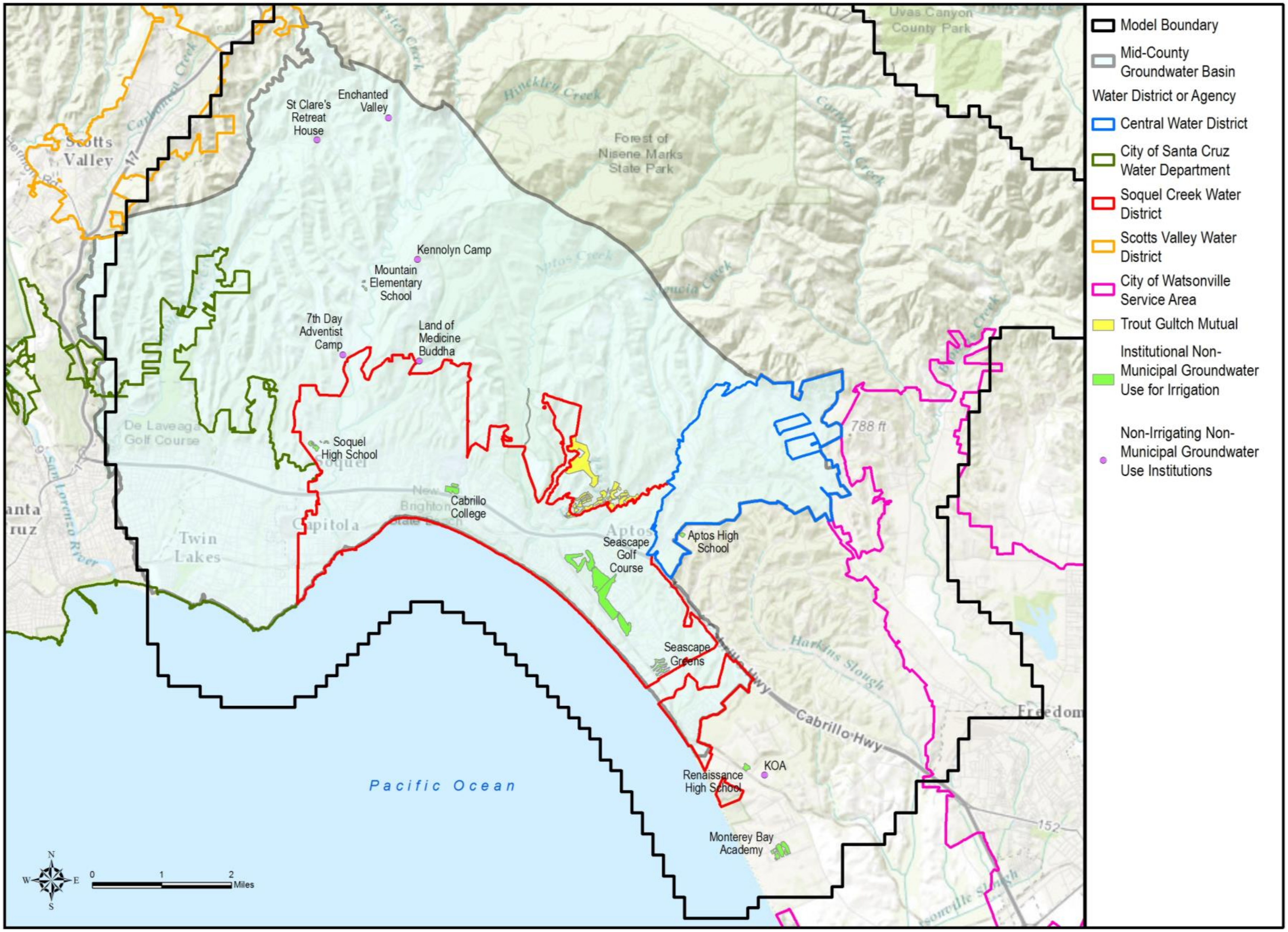

Figure 2: Non-Municipal Groundwater Use Institutions

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**

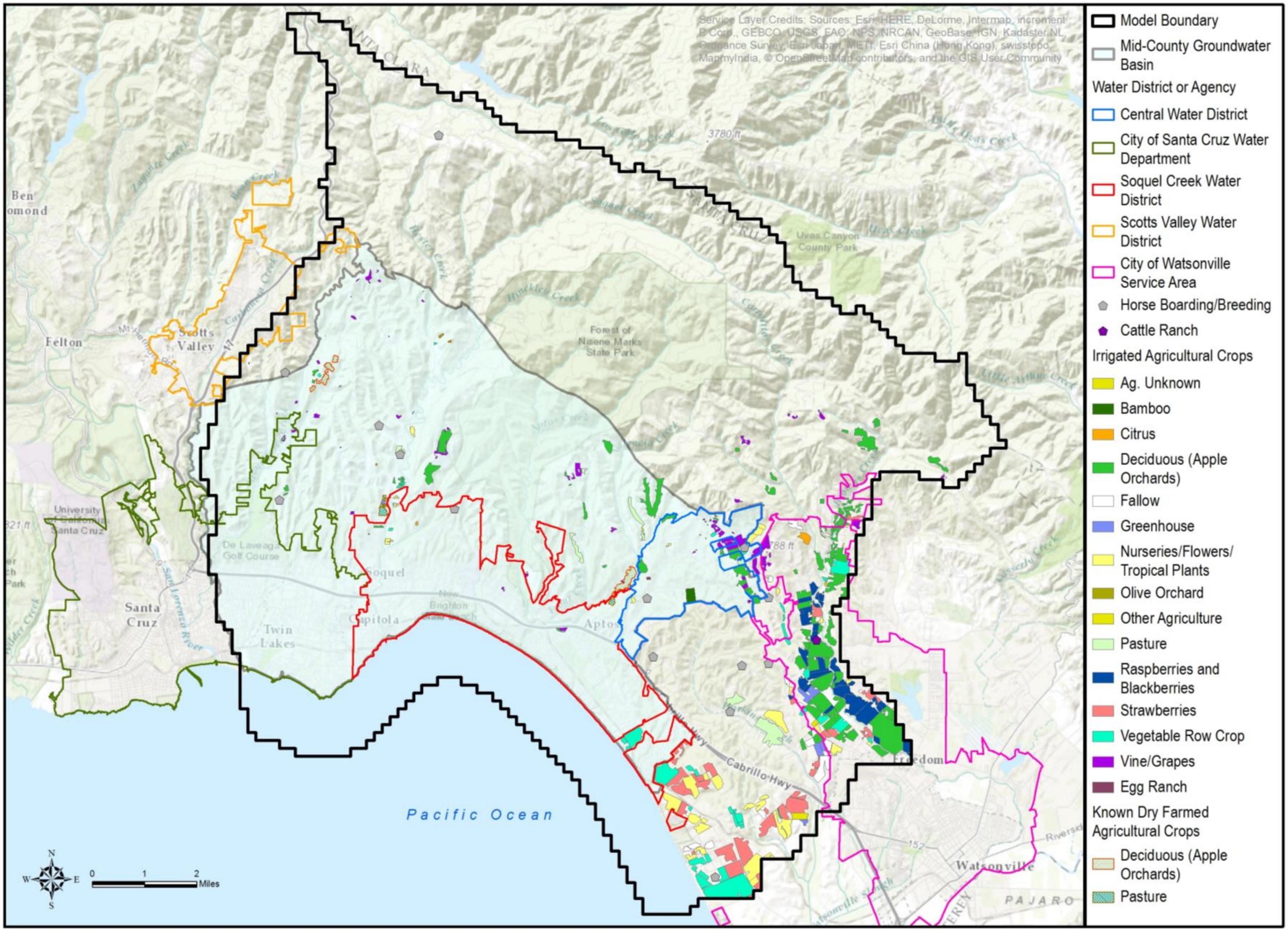

Figure 3: 2014 Agriculture in the Model Area

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.

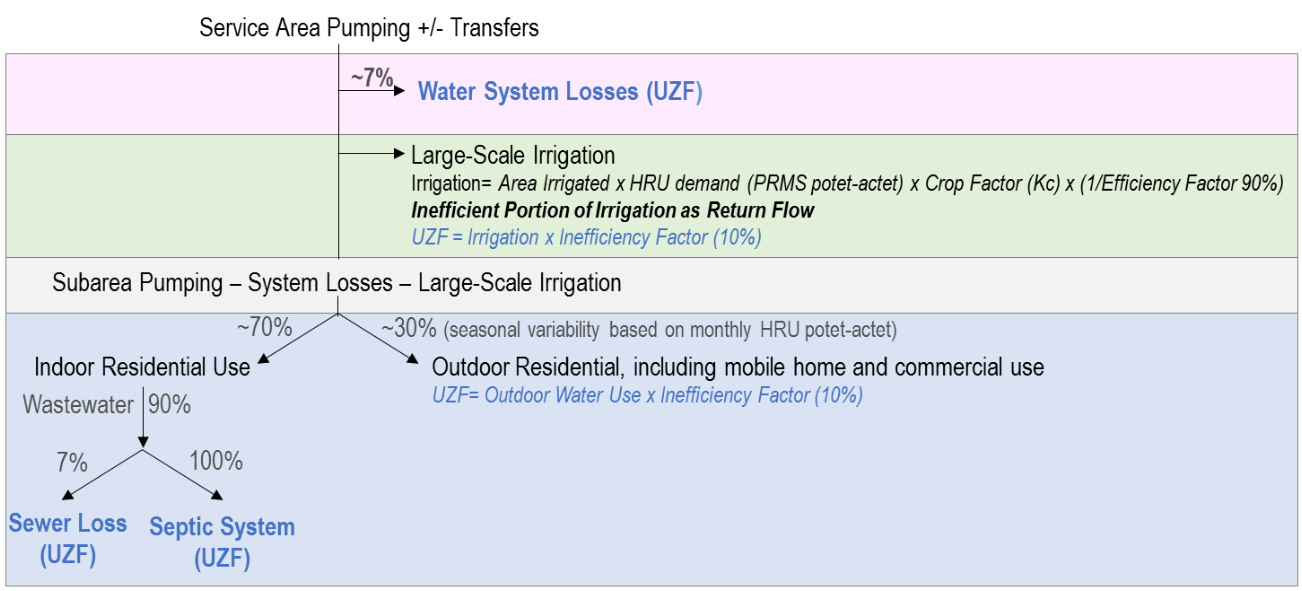

Figure 4: Approach to Estimating Municipal Return Flow

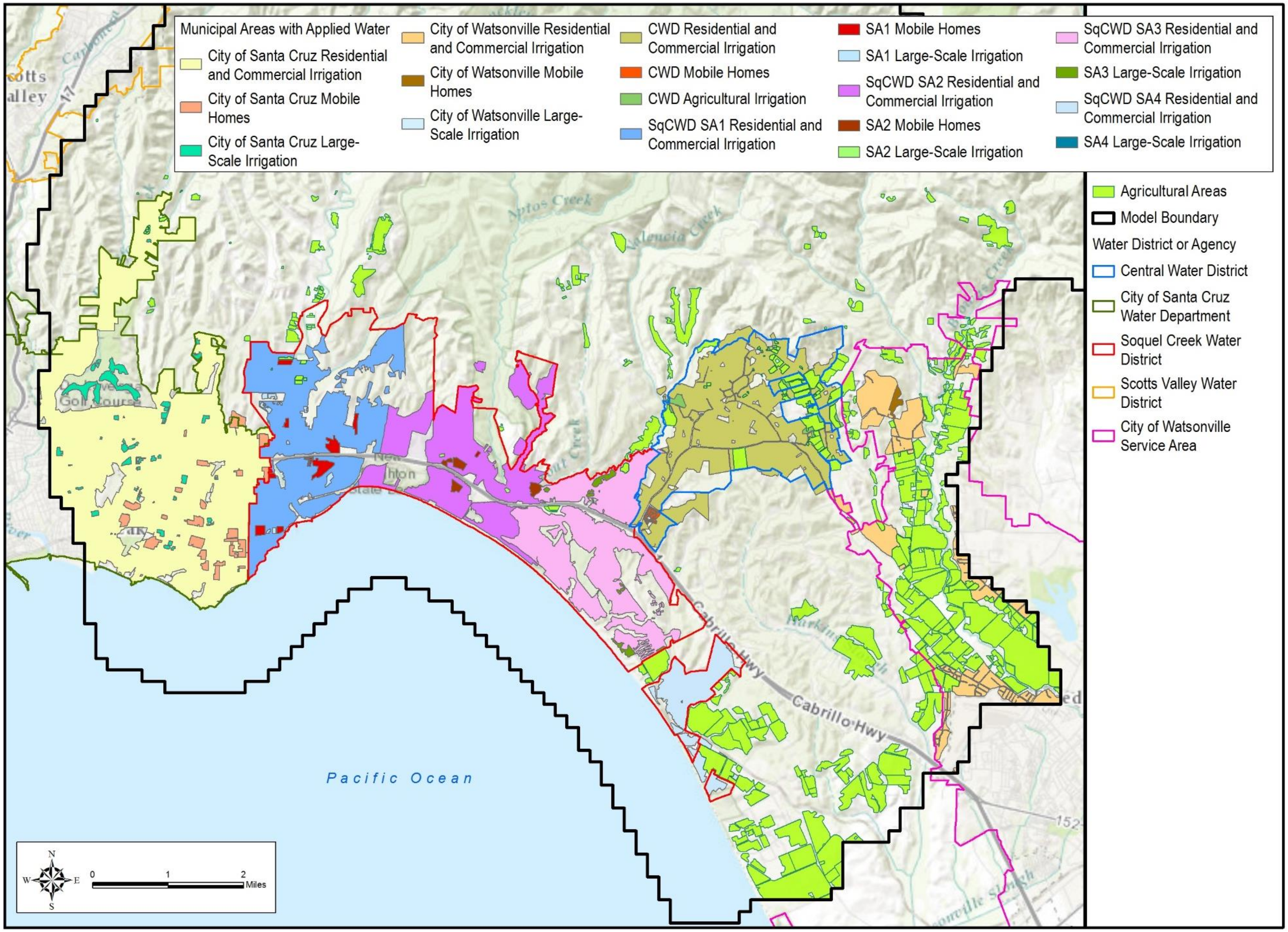

Figure 5: Municipal Applied Water Areas

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.

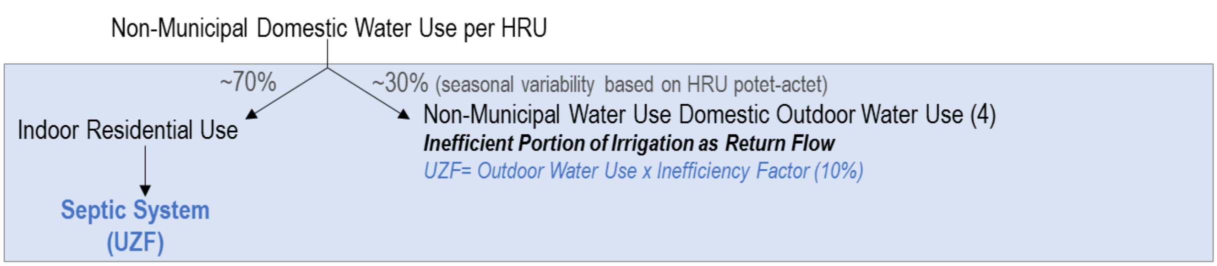

Figure 6: Approach for Estimating Non-Municipal Domestic Return Flow

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).

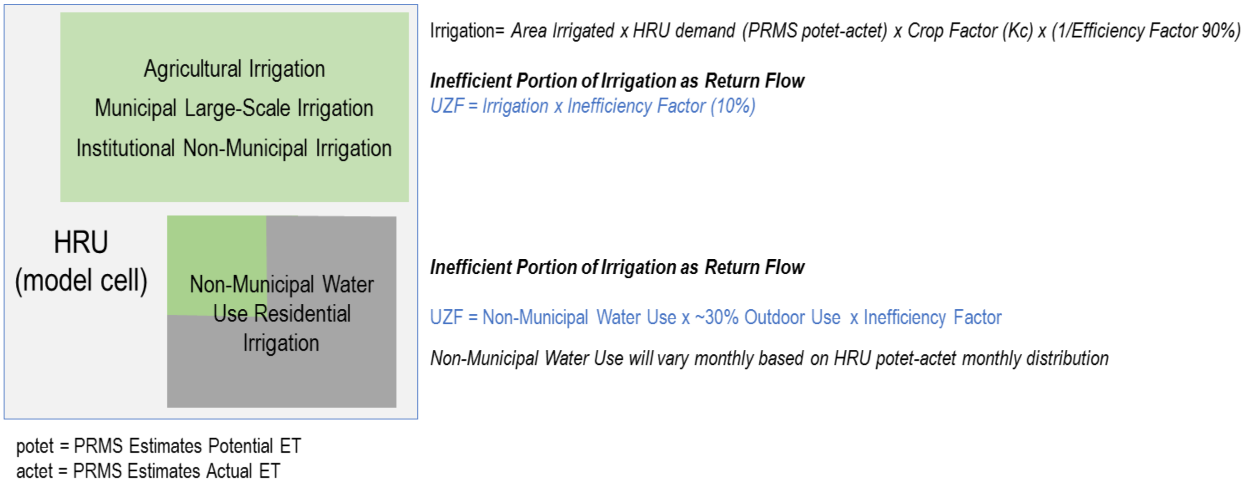

Figure 7: Return Flow Estimate Approach from Irrigation per Model Cell

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.

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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.

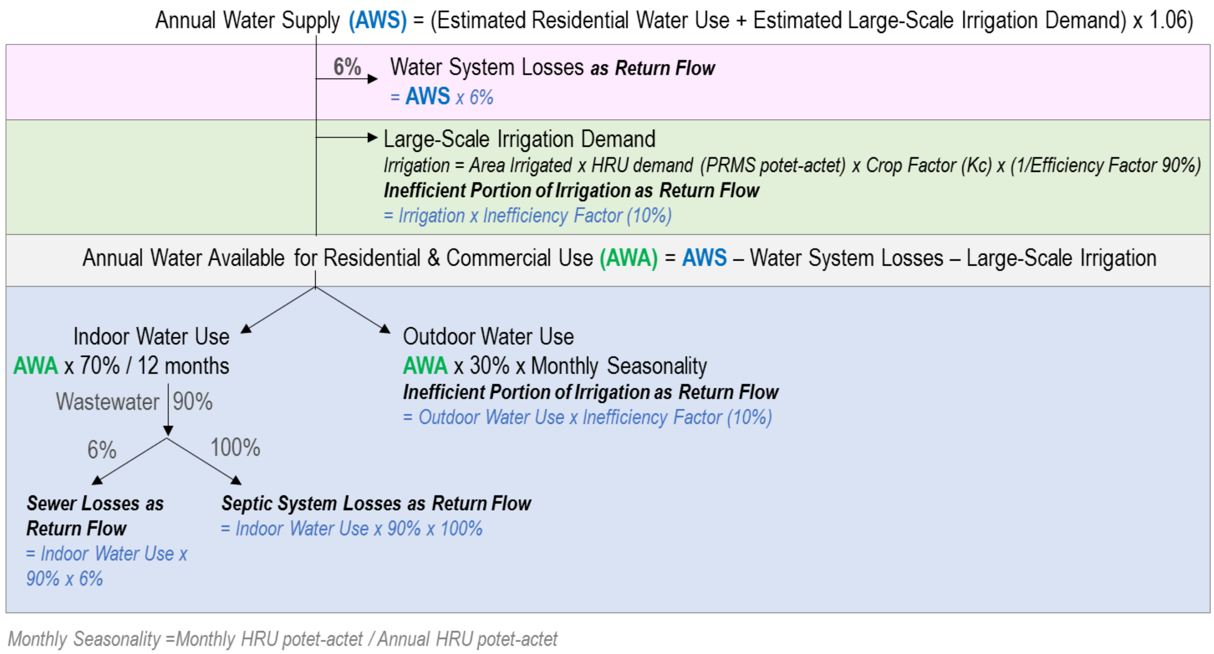

Figure 1: City of Watsonville Return Flow Calculations

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.

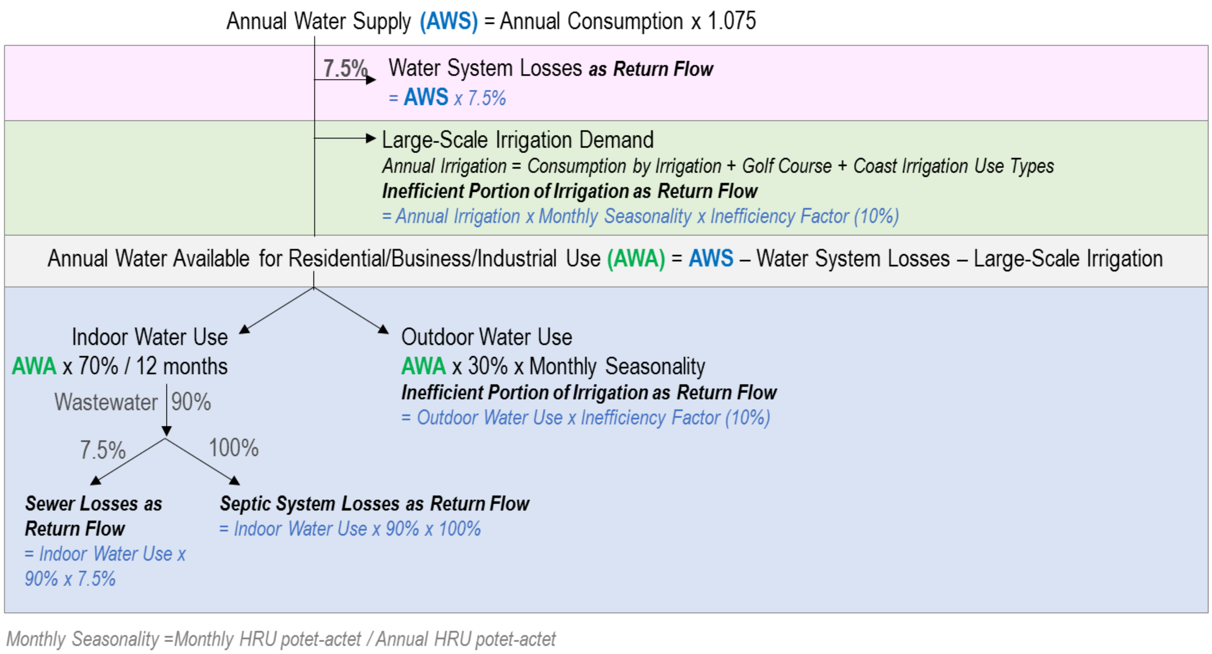

Figure 2: City of Santa Cruz Return Flow Calculations

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.

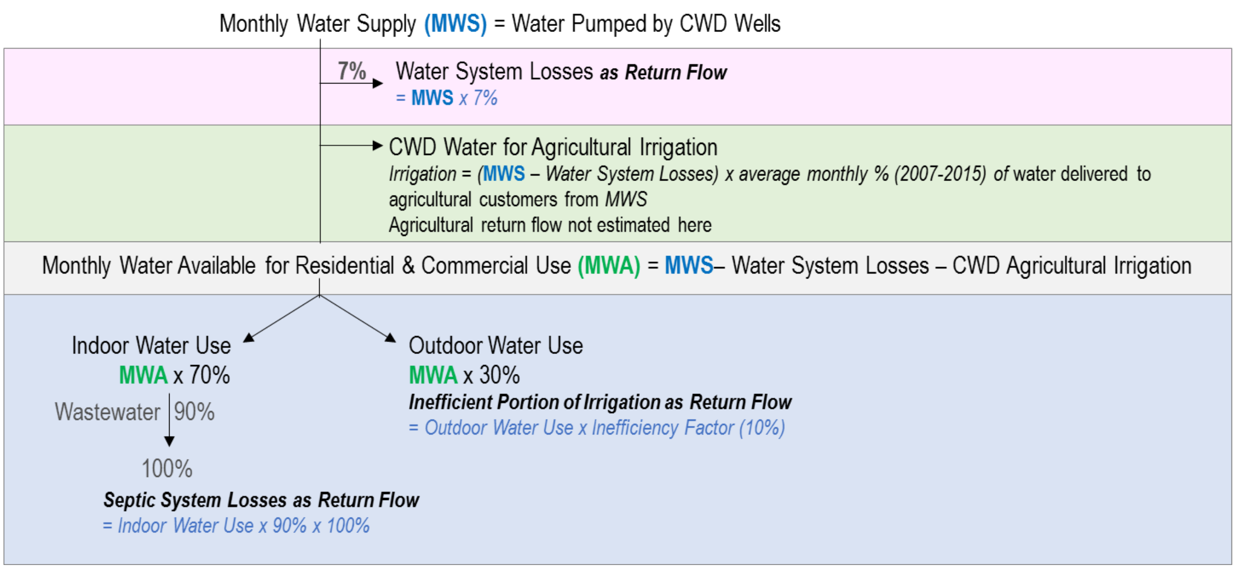

Figure 3: Central Water District Return Flow Calculations

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%

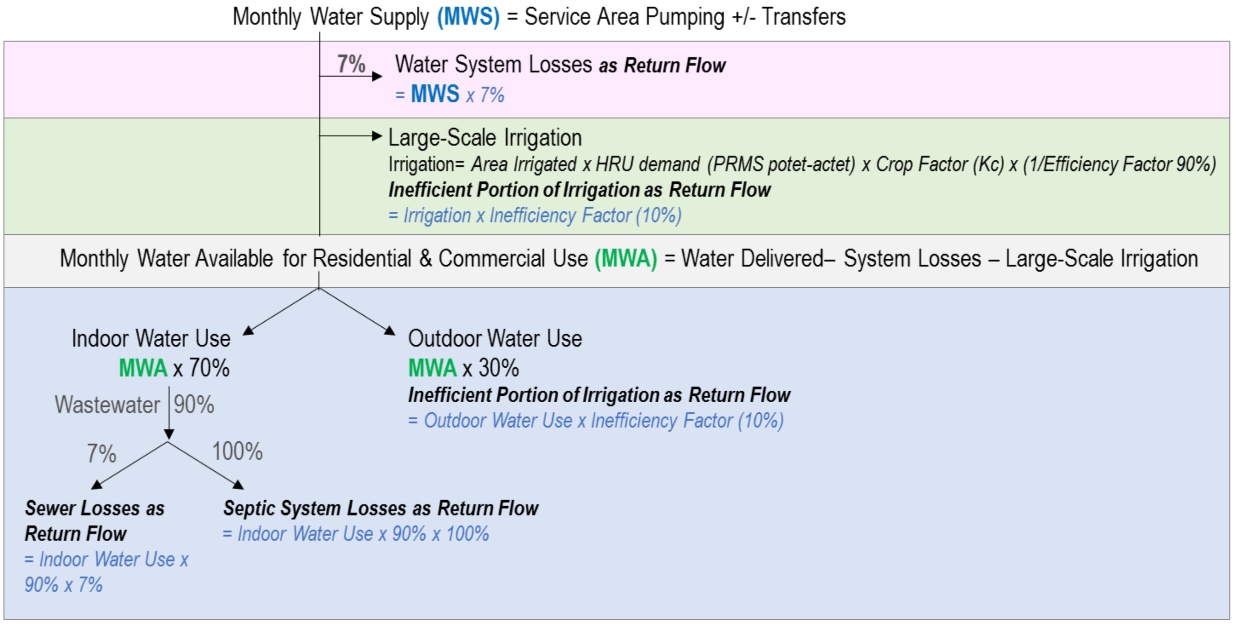

Figure 4: Soquel Creek Water District Return Flow Calculations

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.

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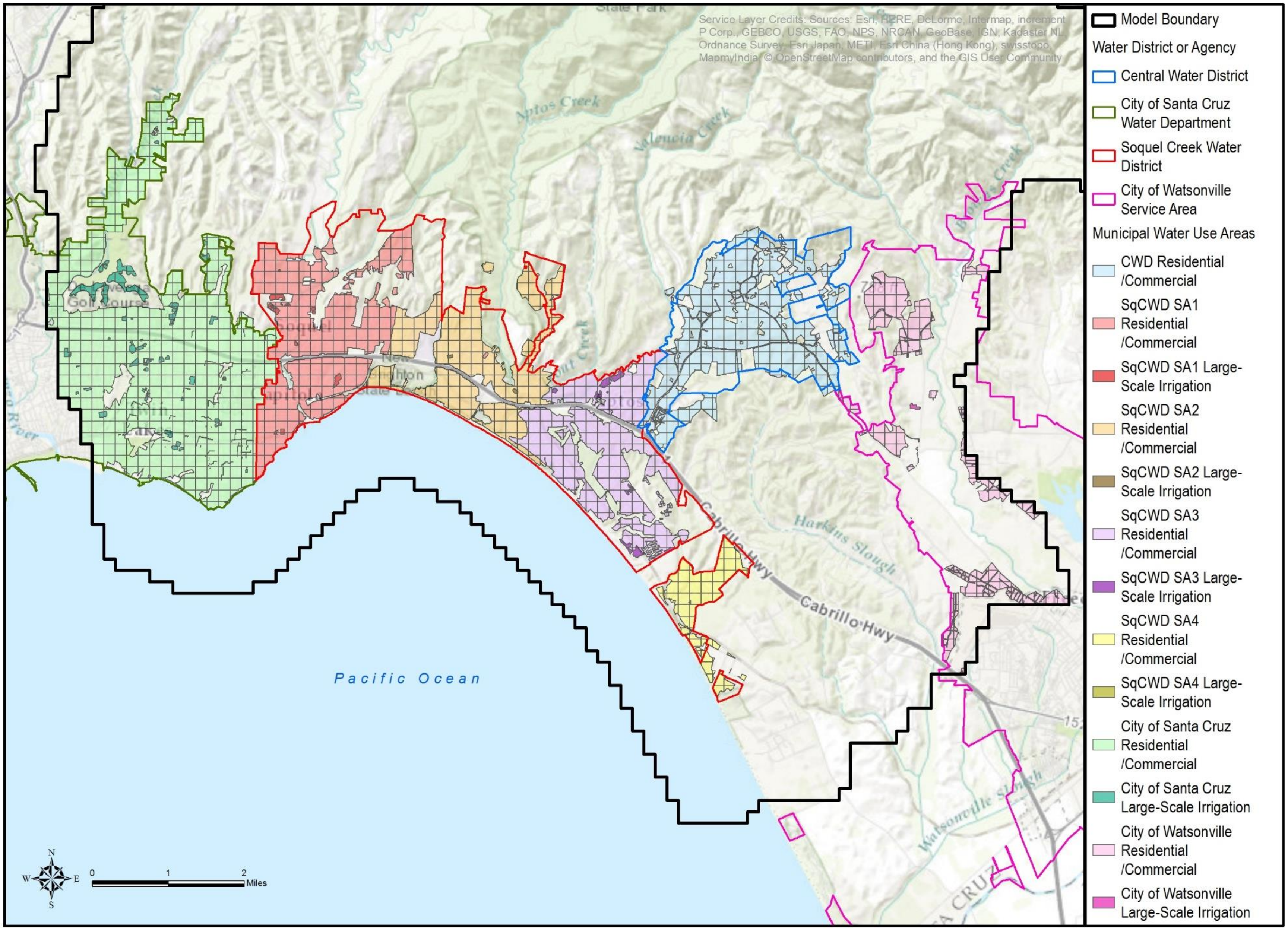

Figure 5: Residential/Commercial and Large-Scale Irrigation Areas within Municipal Service Area

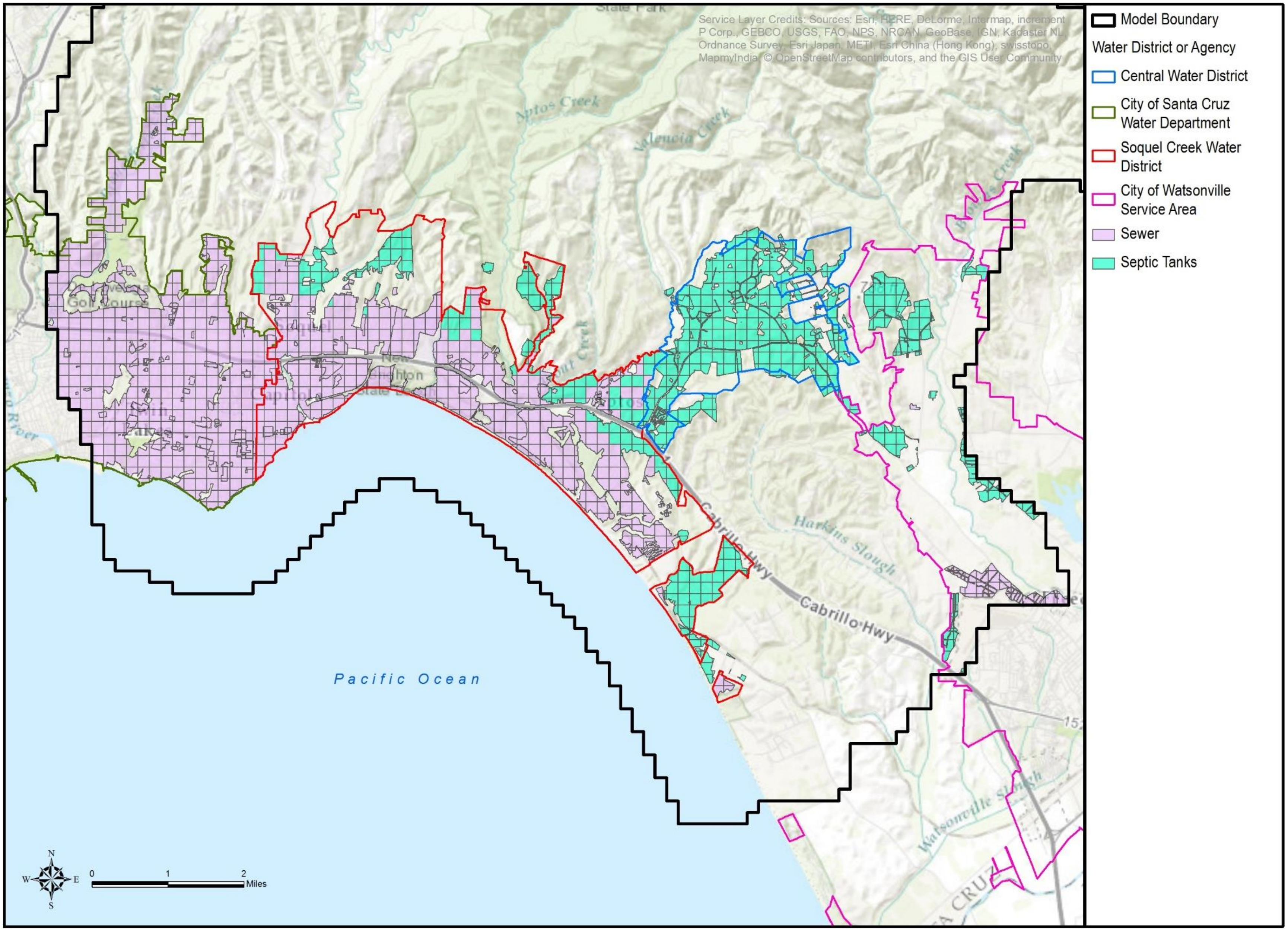

Figure 6: Municipal Sewered and Septic Tank Areas

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.

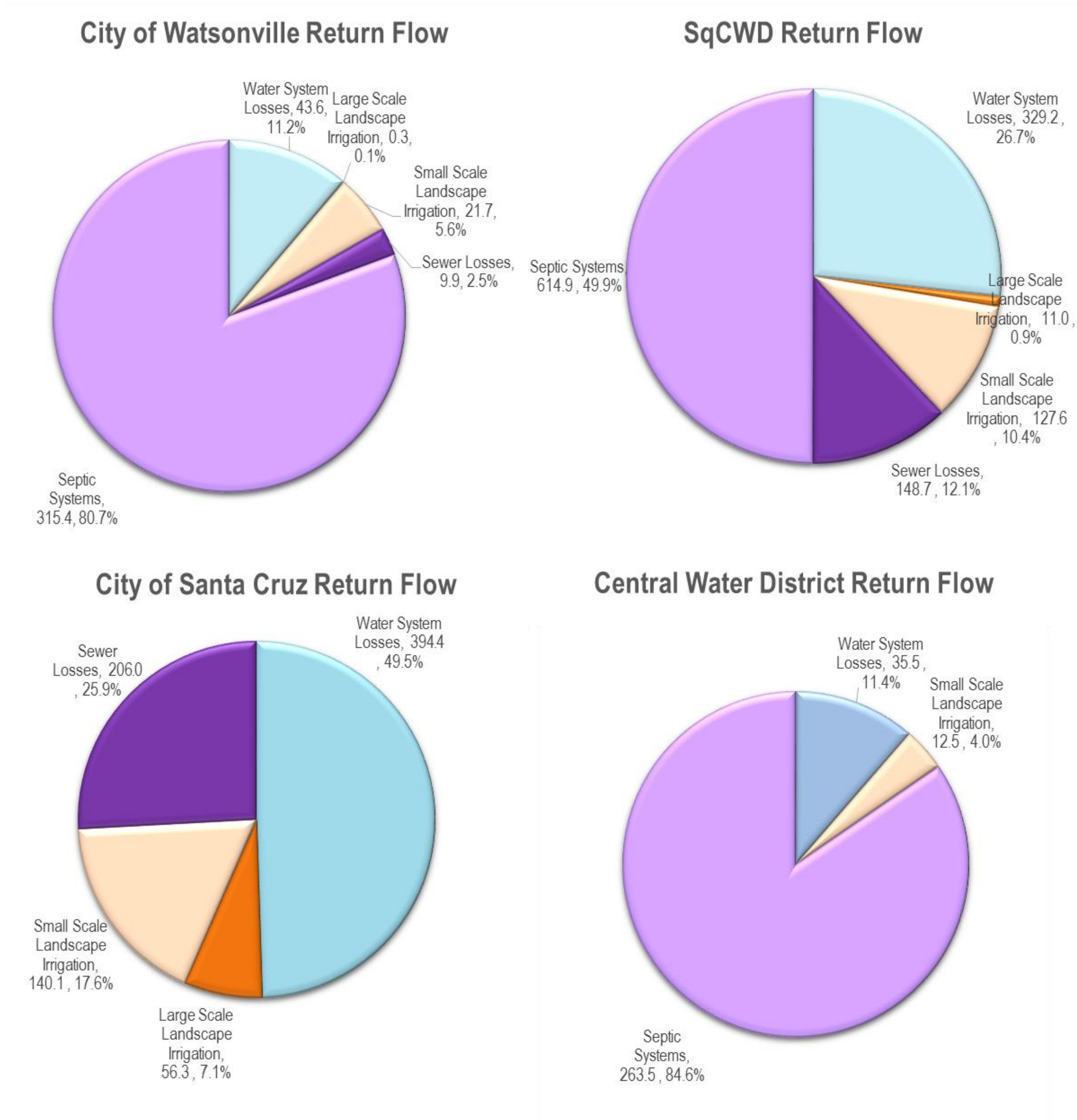

Figure 7: Municipal Return Flow Pie Charts (in acre-feet per year)

APPENDIX 2-D

SOQUEL-APTOS GROUNDWATER FLOW MODEL: SUBSURFACE MODEL (TASK 3) MEMORANDUM

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

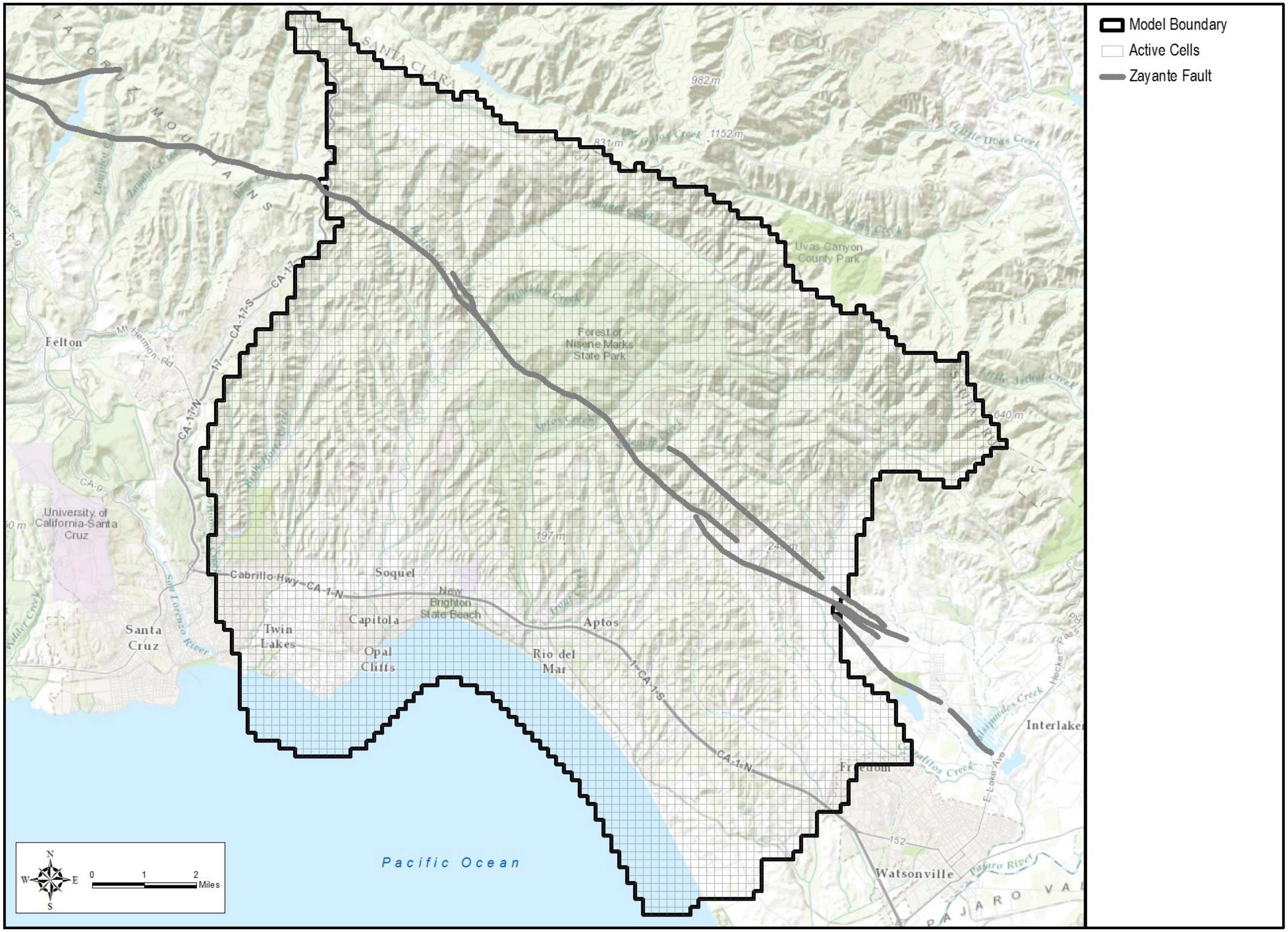

Figure 1: Basin Model Domain Extent

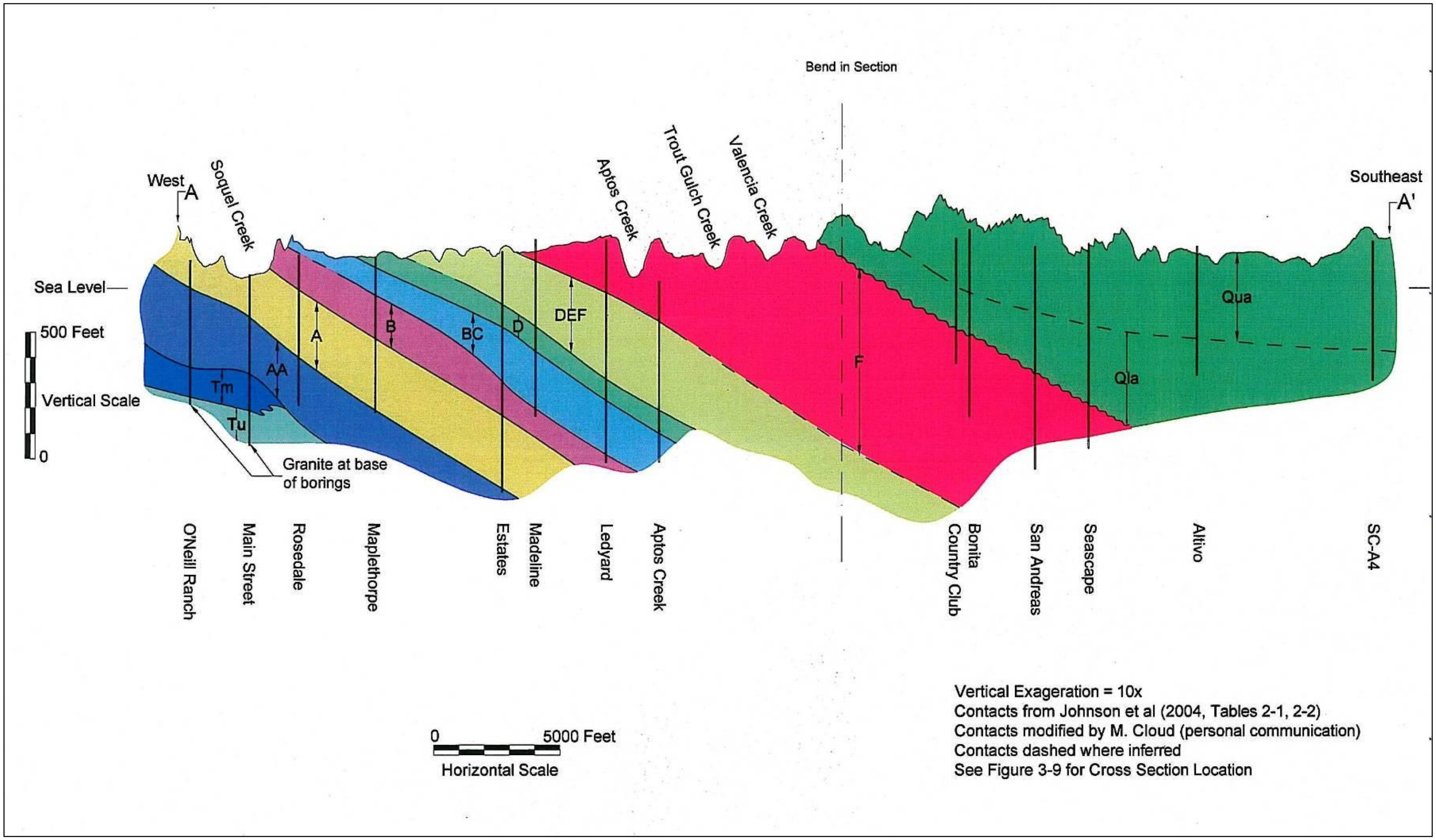

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Figure 2: Generalized Hydrostratigraphic Cross-Section

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.

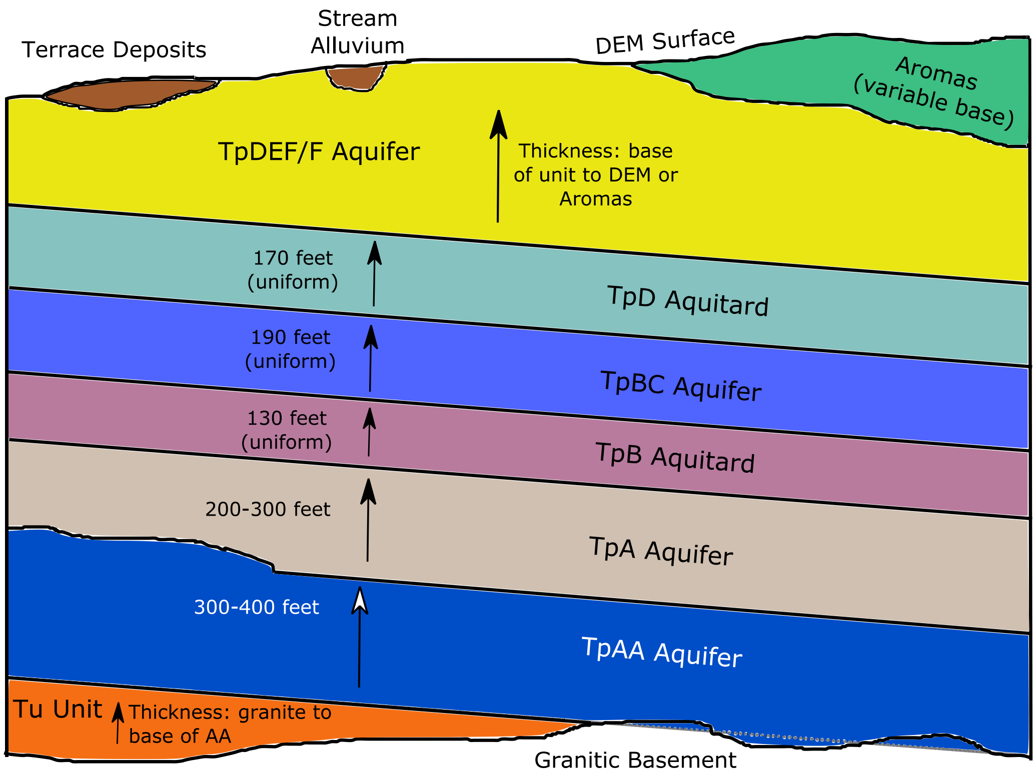

Figure 3: Example Stratigraphic Column of Model Hydrostratigraphy

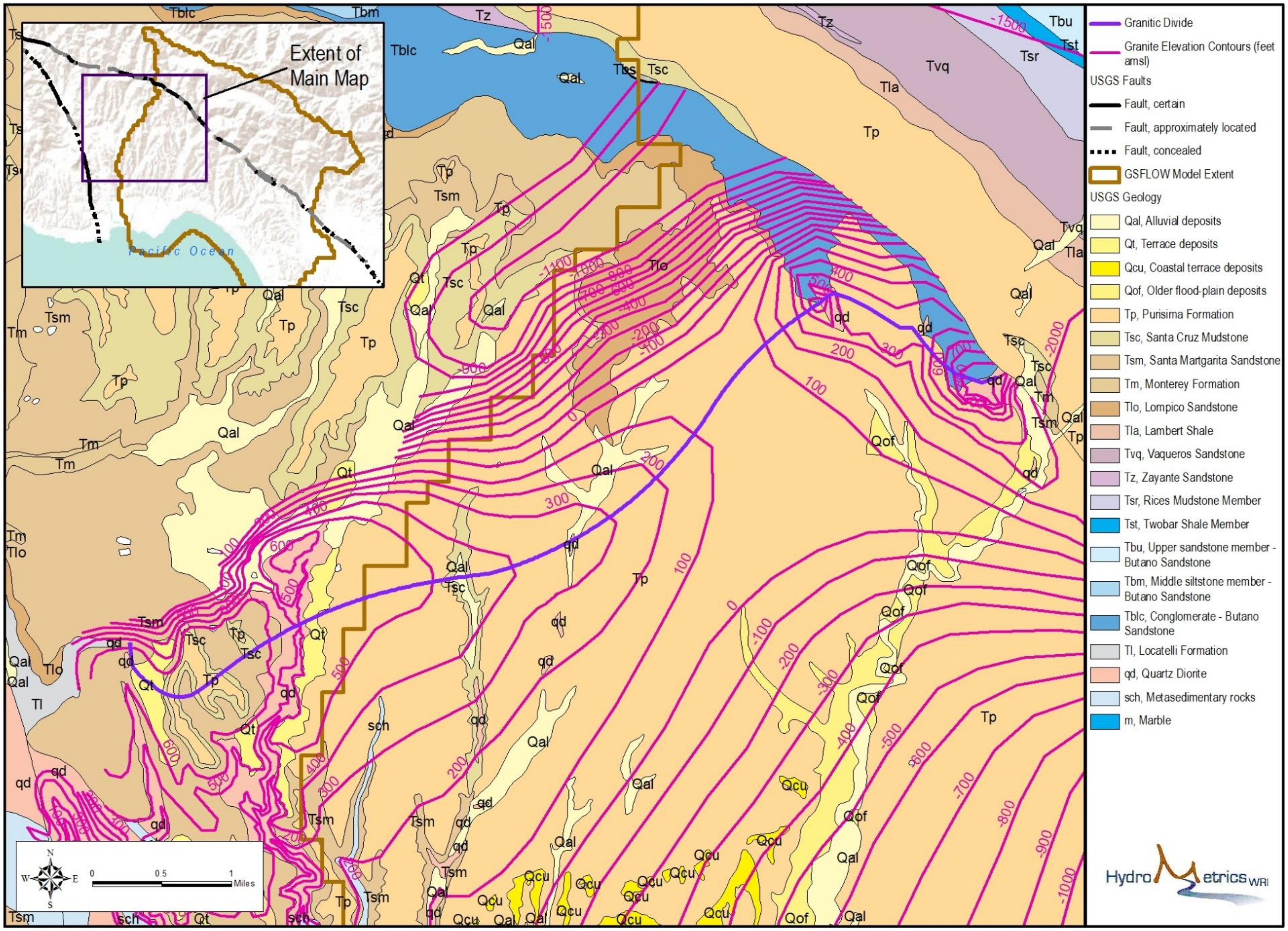

Figure 4: Structure of Granitic Basement Elevation, Western Area of Model Domain

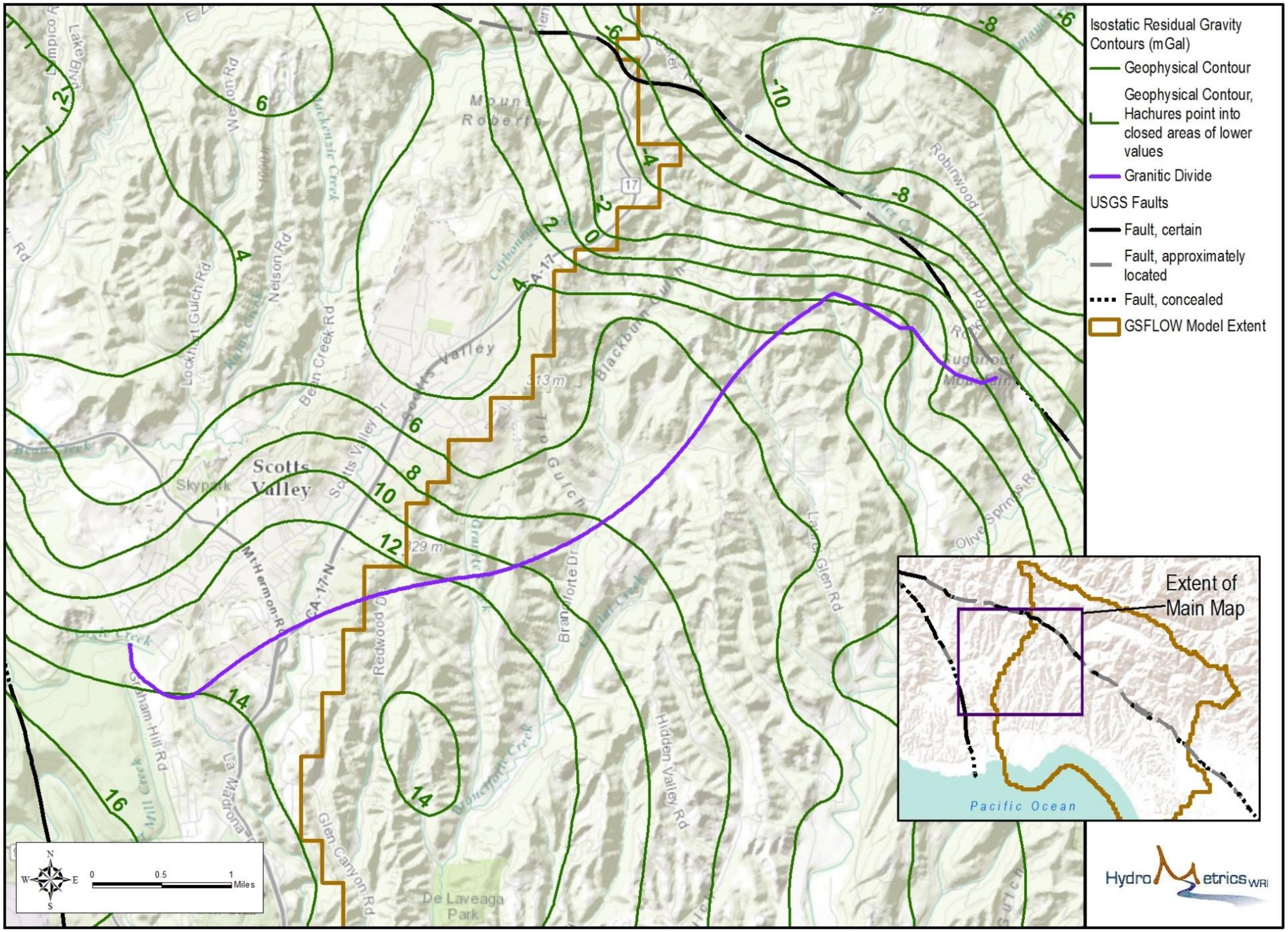

Figure 5: Gravity Anomaly Contours, Western Area of Model Domain

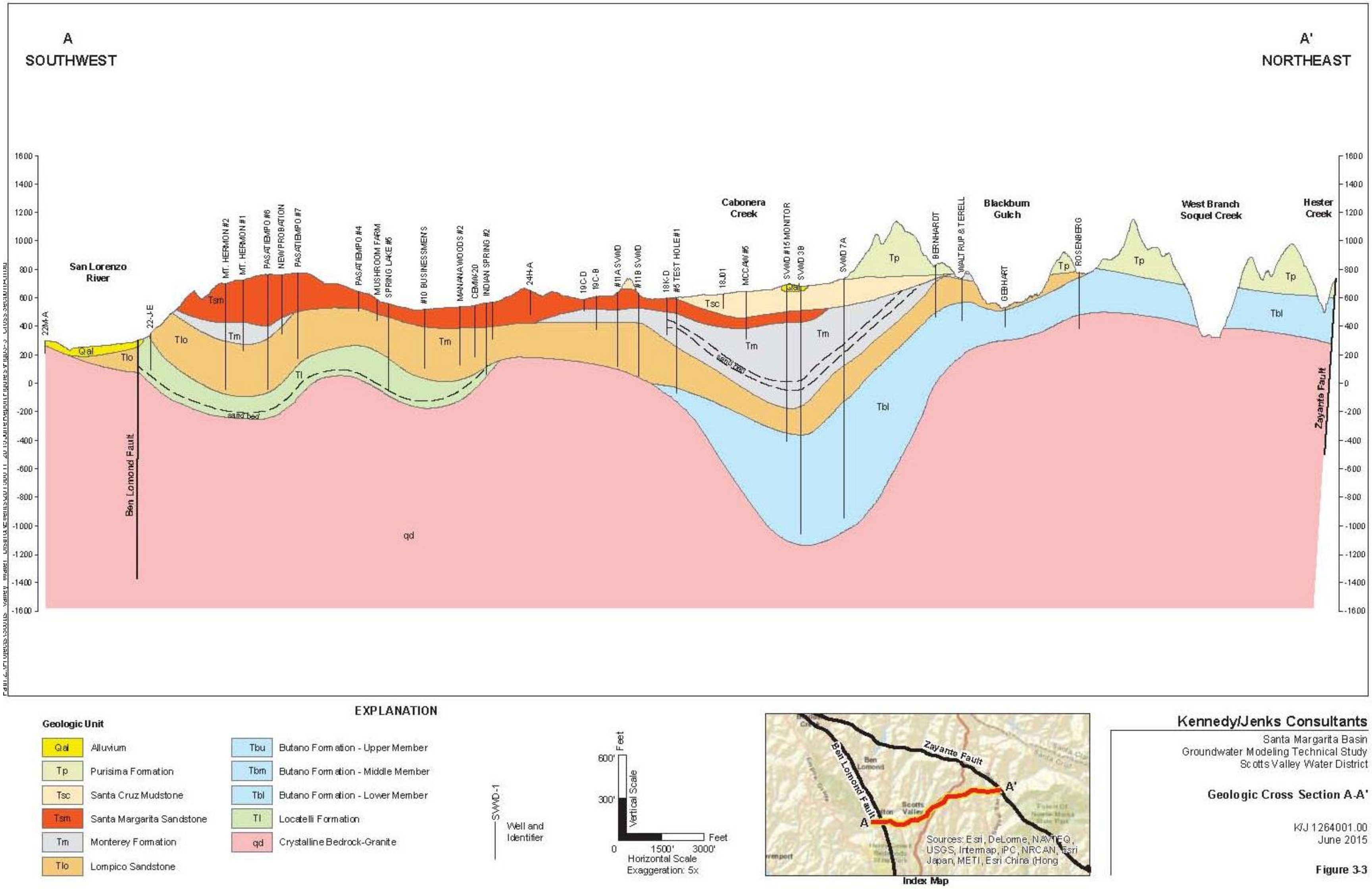

Figure 6: Cross-Section Near Western Boundary of Model Domain (from Kennedy/Jenks Consultants, 2015)

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.

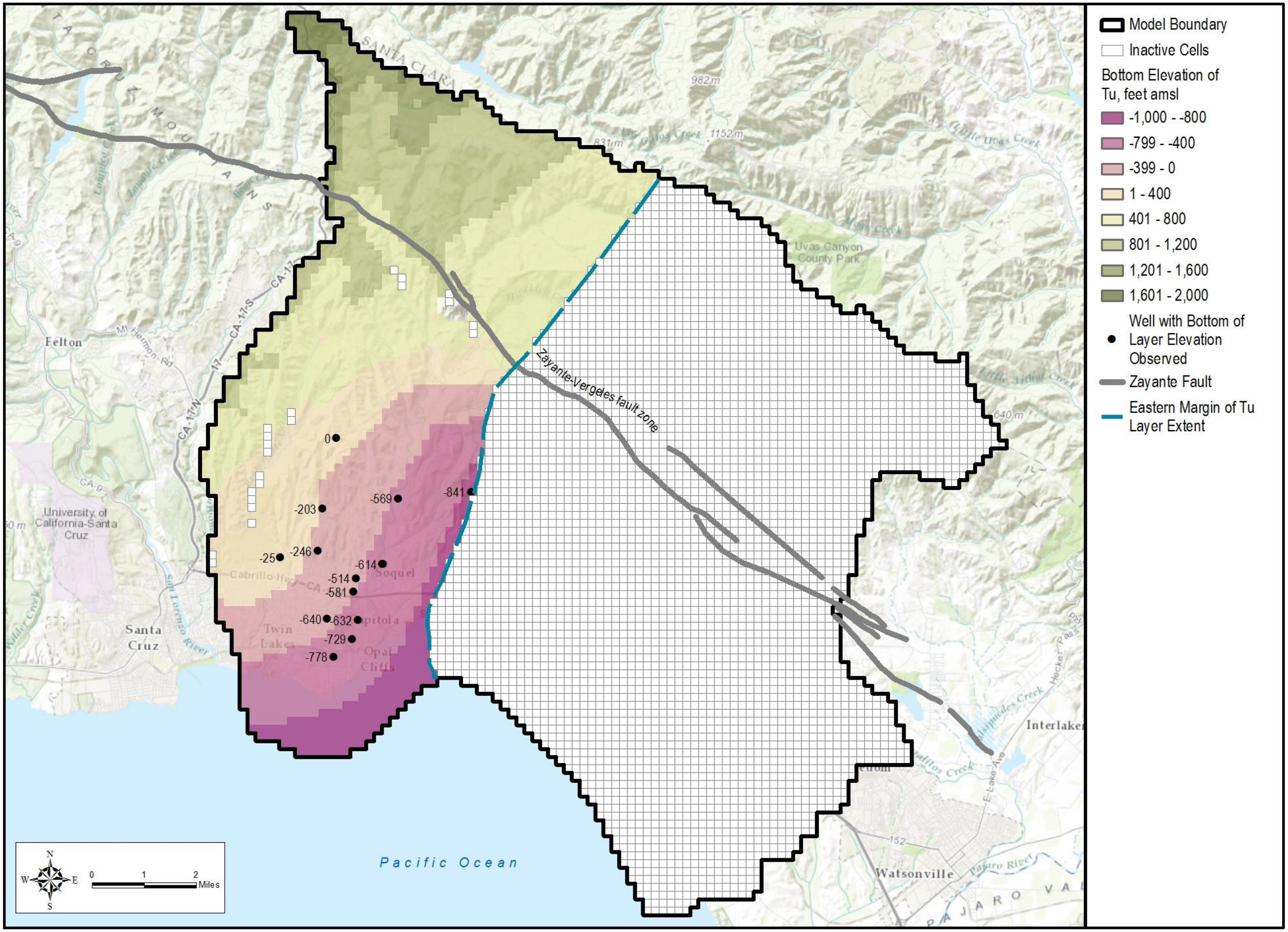

Figure 7: Base of Tu Unit Elevations in Model

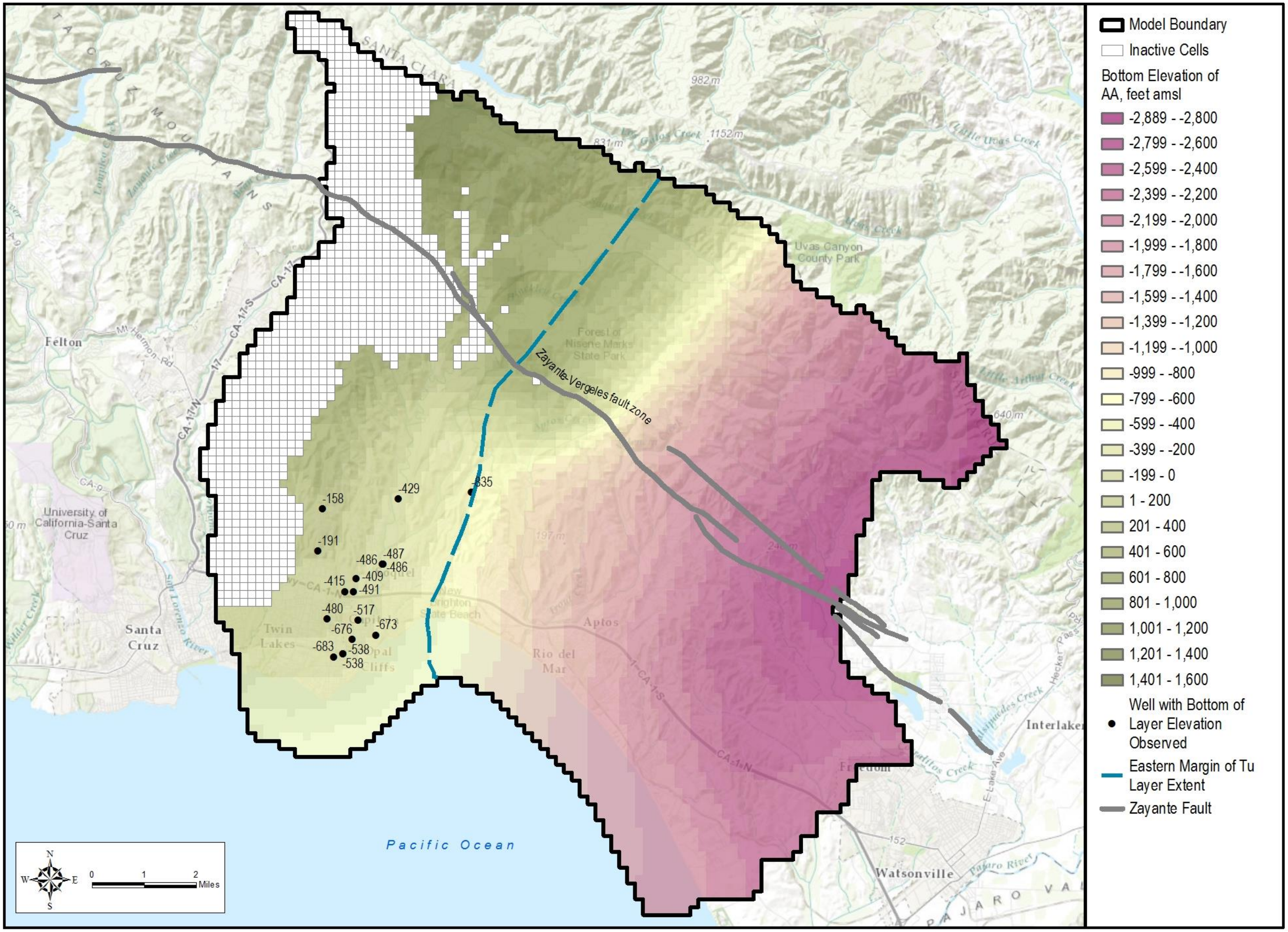

Figure 8: Base of TpAA Unit Elevations in Model

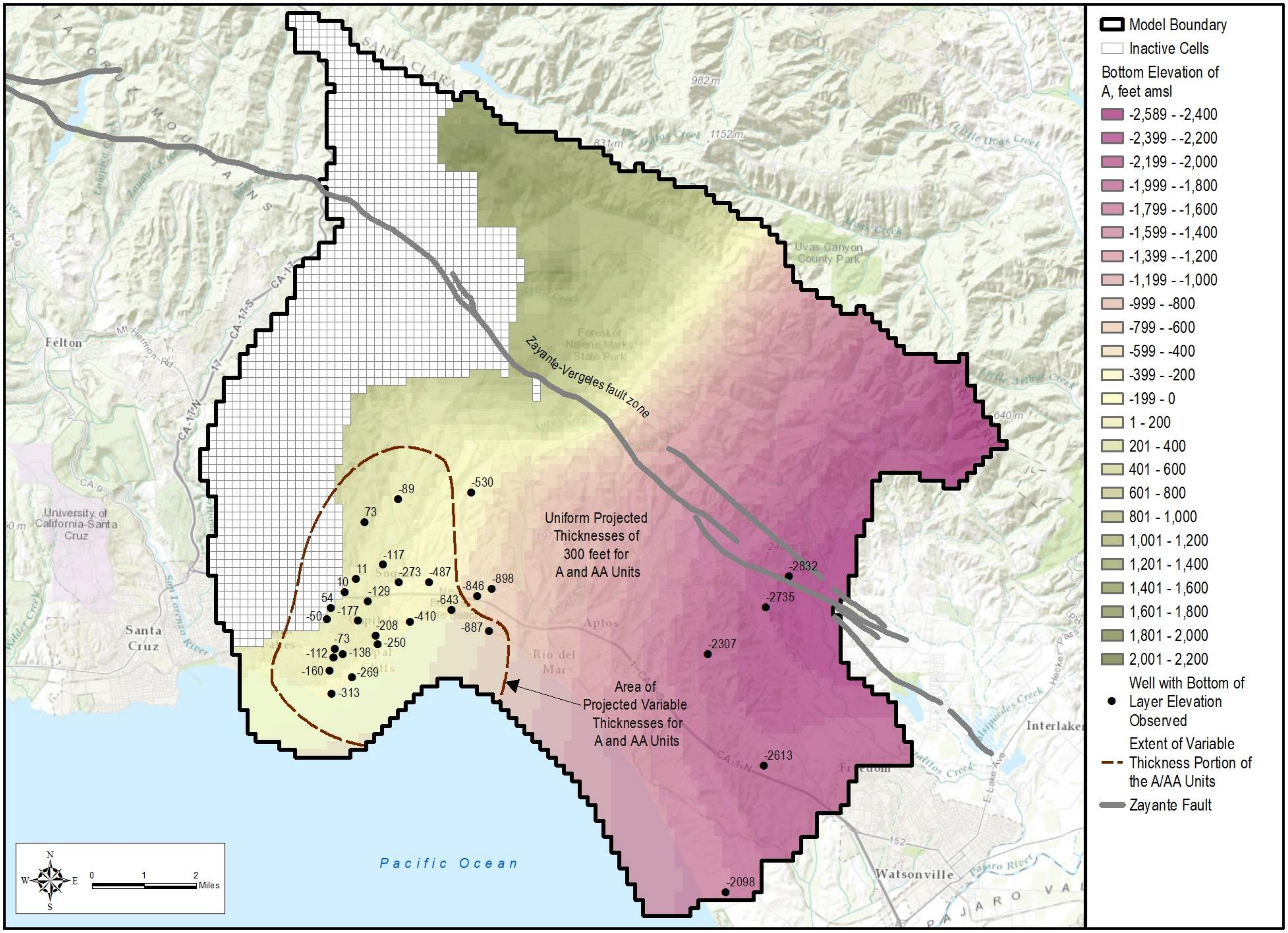

Figure 9: Base of TpA Unit Elevations in Model

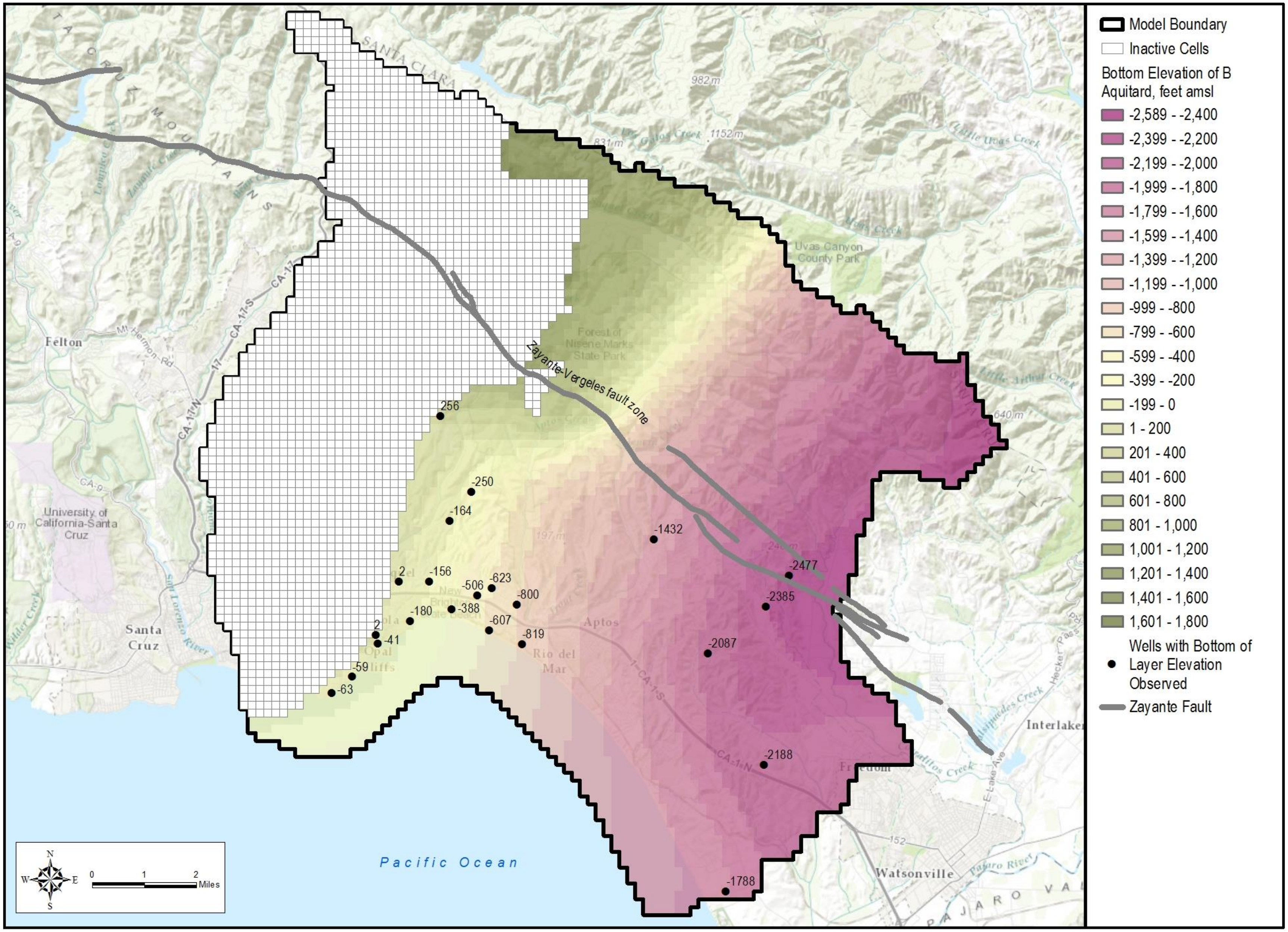

Figure 10: Base of TpB Aquitard Elevations in Model

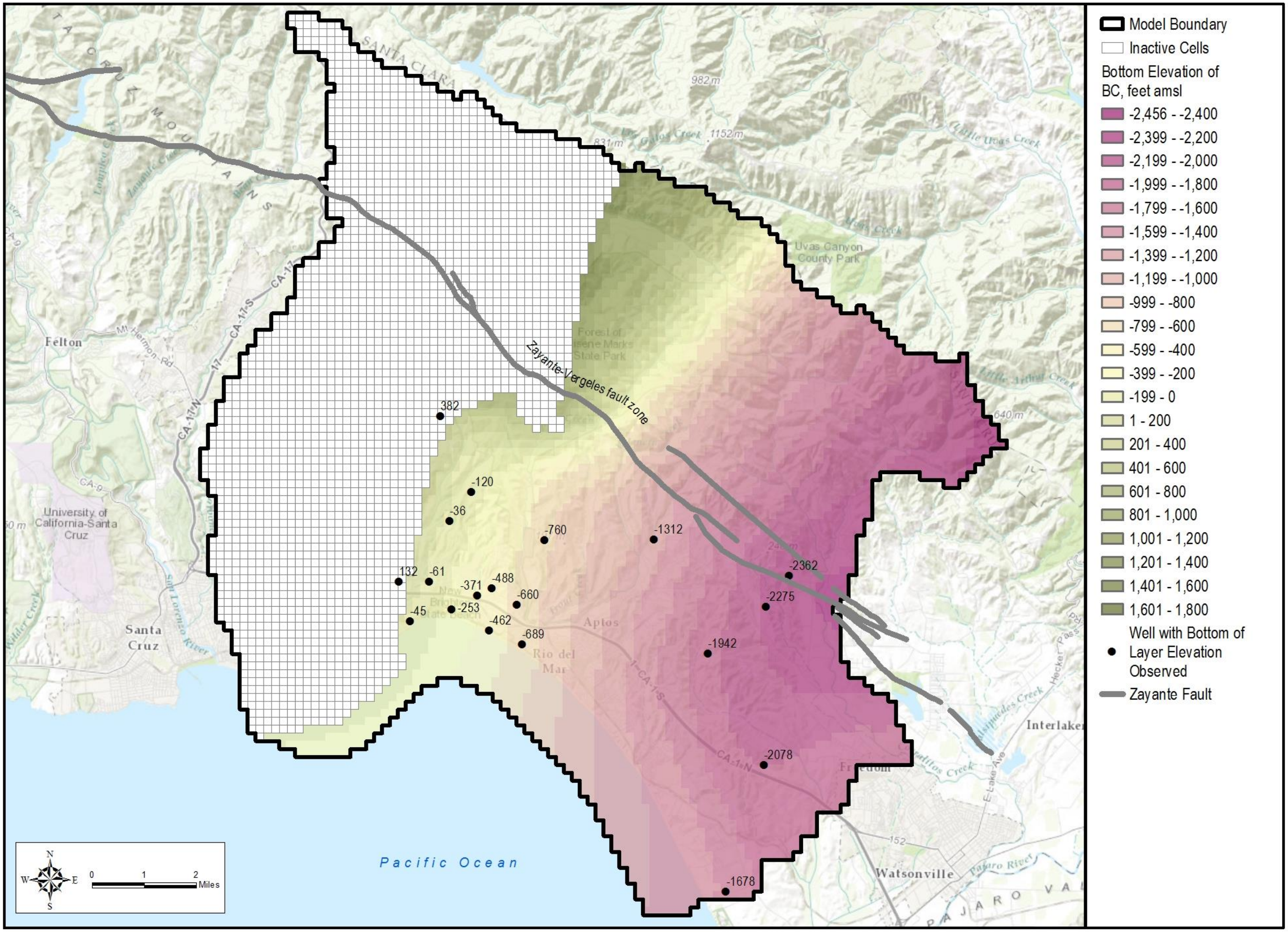

Figure 11: Base of TpBC Unit Elevations in Model

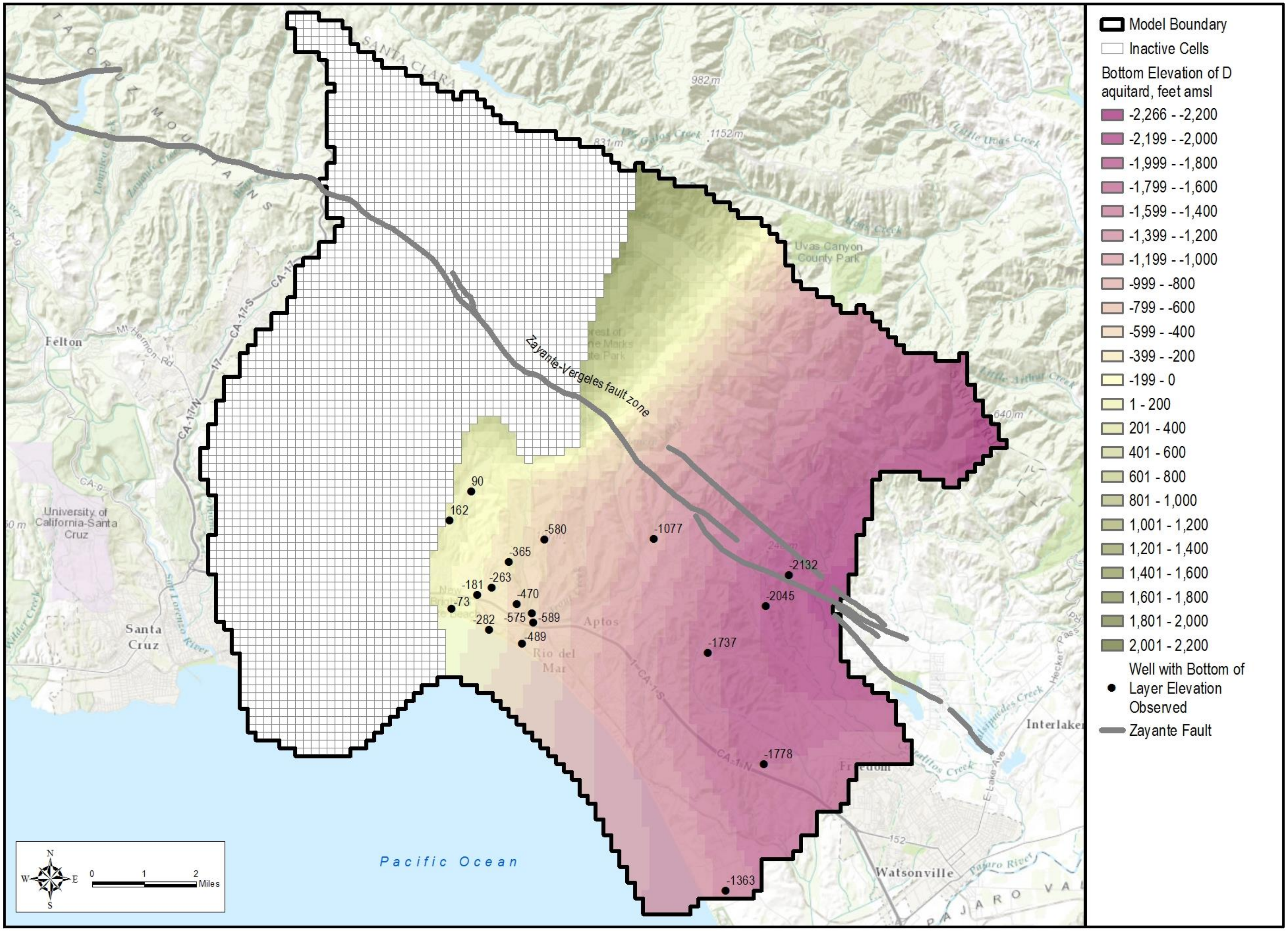

Figure 12: Base of TpD Aquitard Elevations in Model

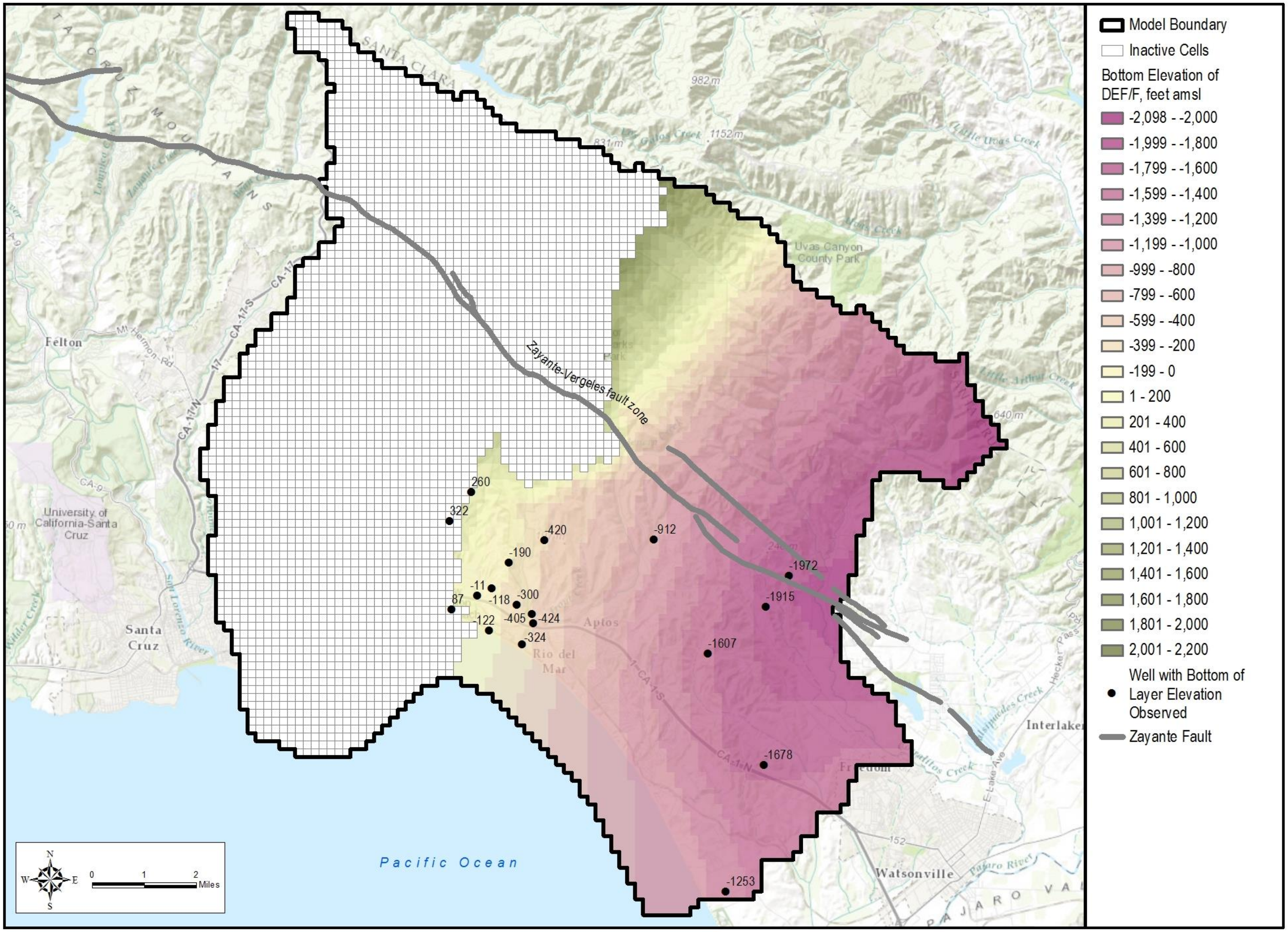

Figure 13: Base of TpDEF/F Unit Elevations in Model

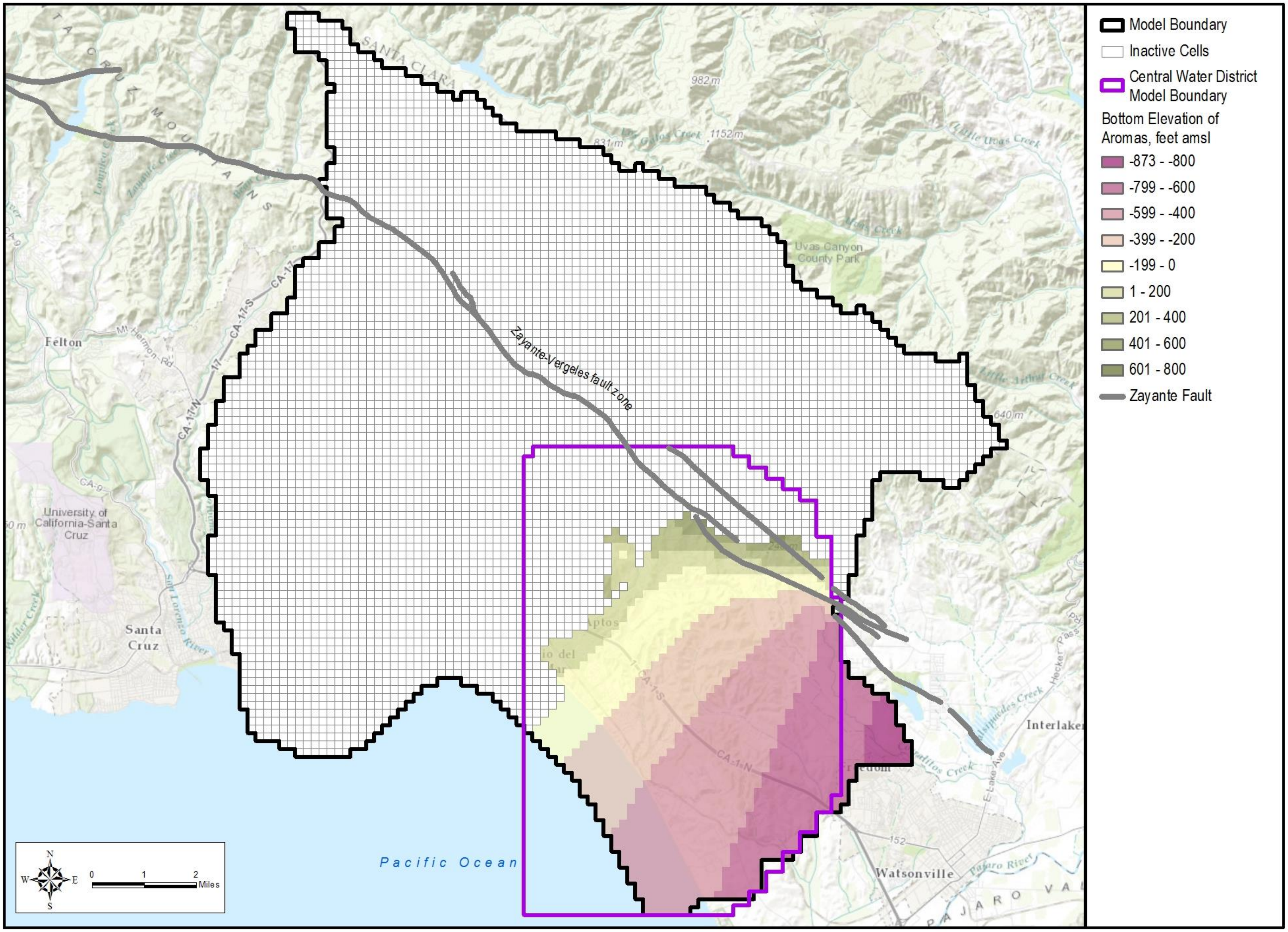

Figure 14: Base of Aromas Red Sands Elevations in Model

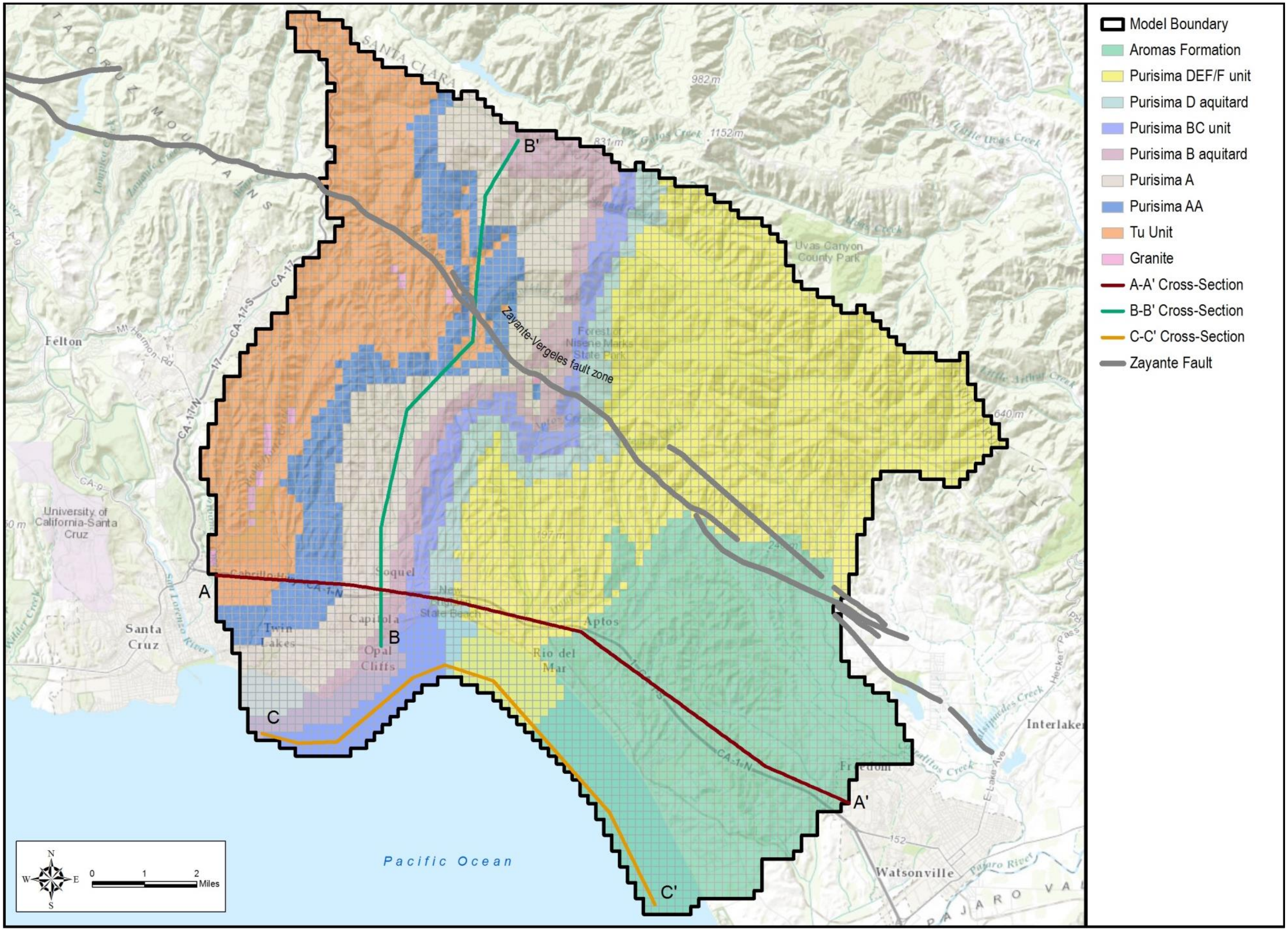

Figure 15: Simulated Aromas and Purisima Outcrop Extents

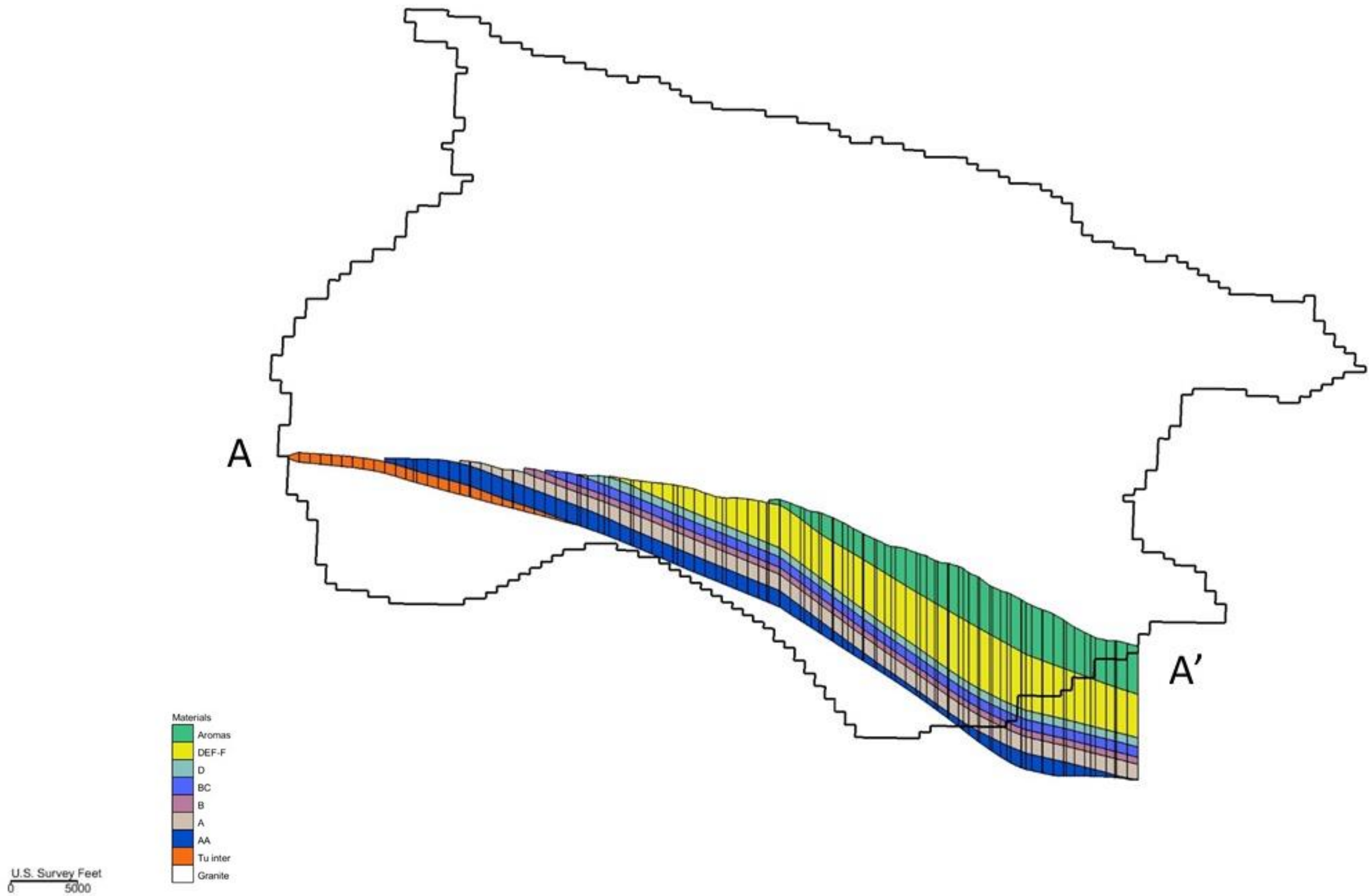

Figure 16: Simulated Cross-Section A-A'

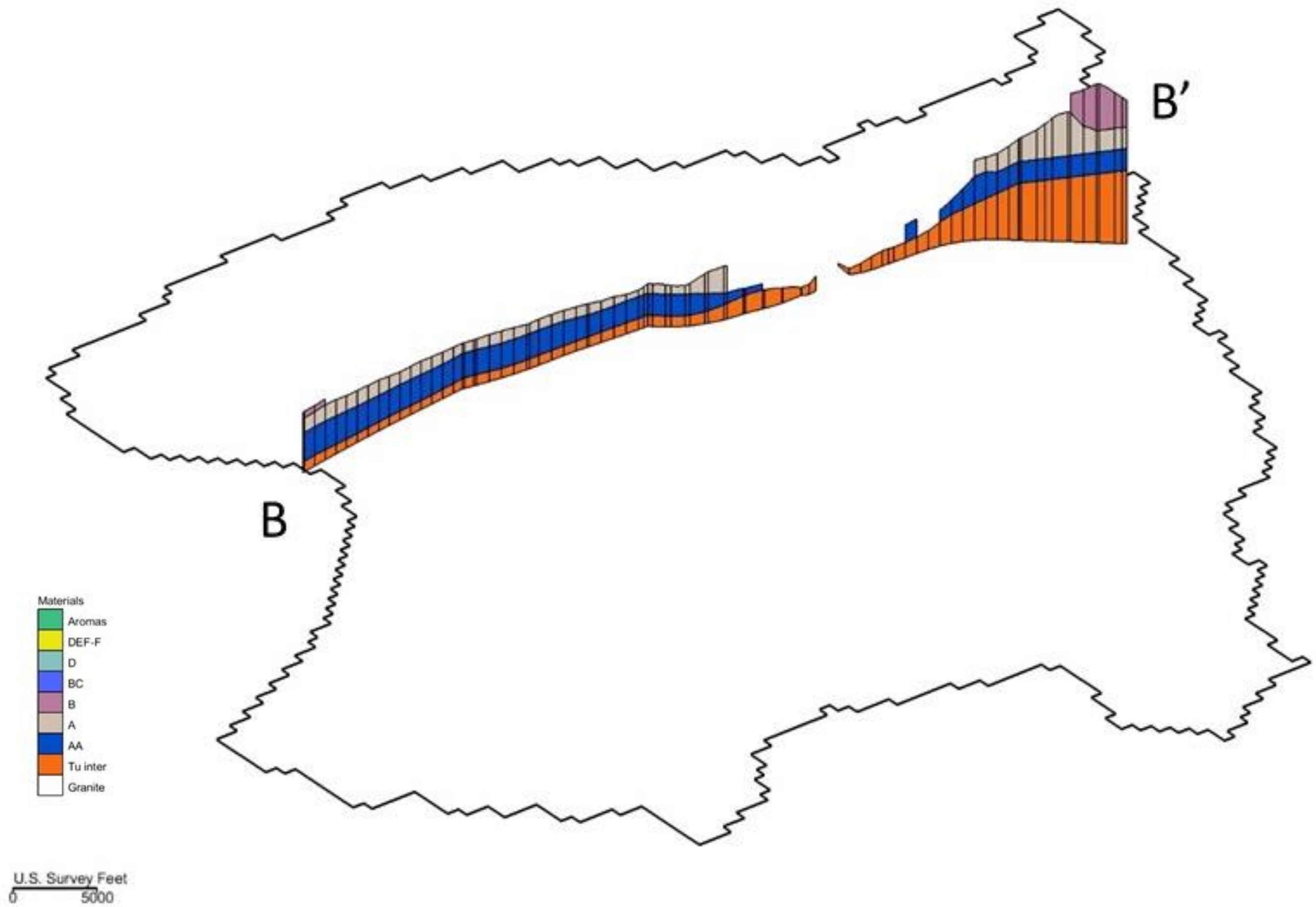

Figure 17: Simulated Cross-Section B-B′

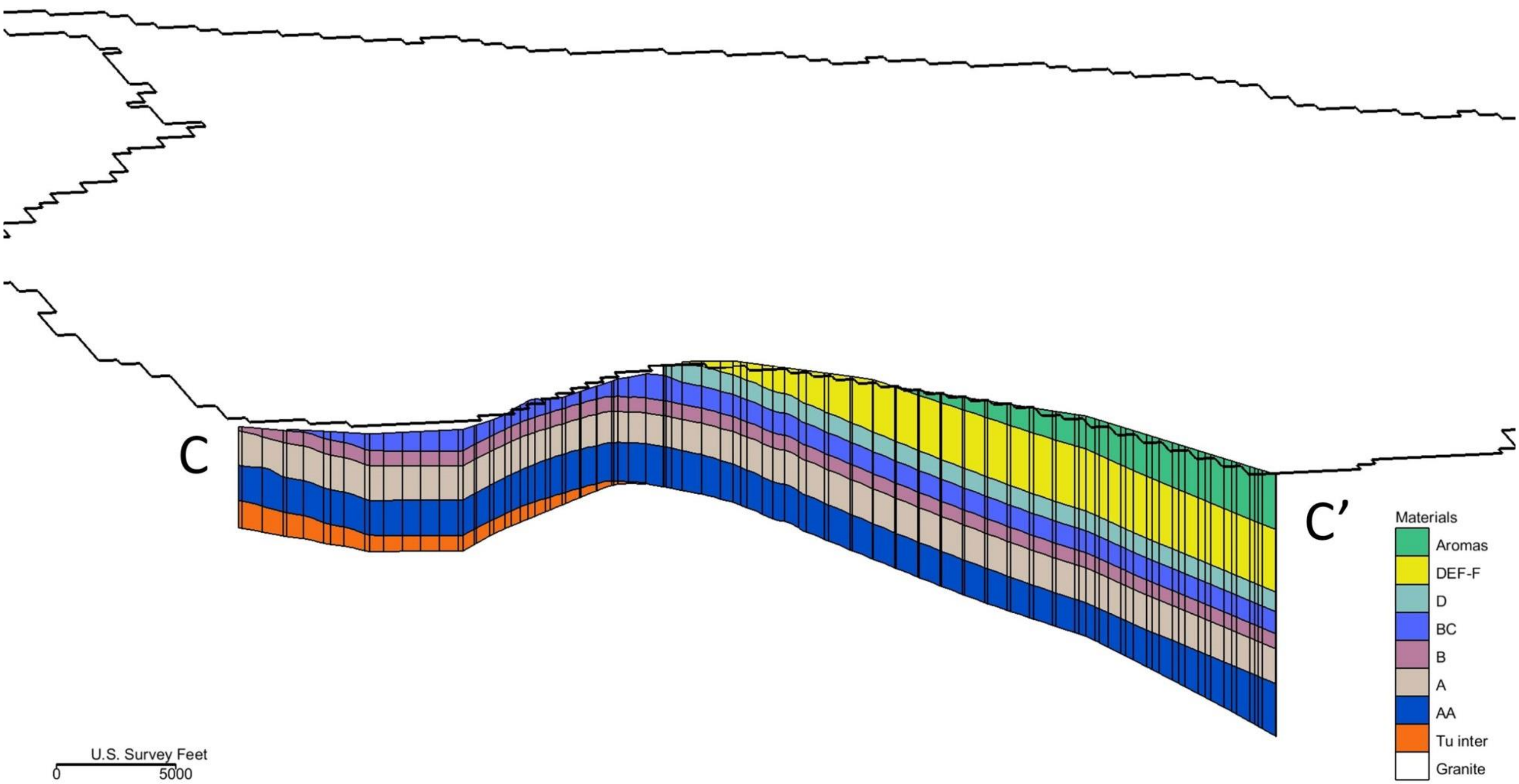

Figure 18: Simulated Cross-Section C-C′

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.

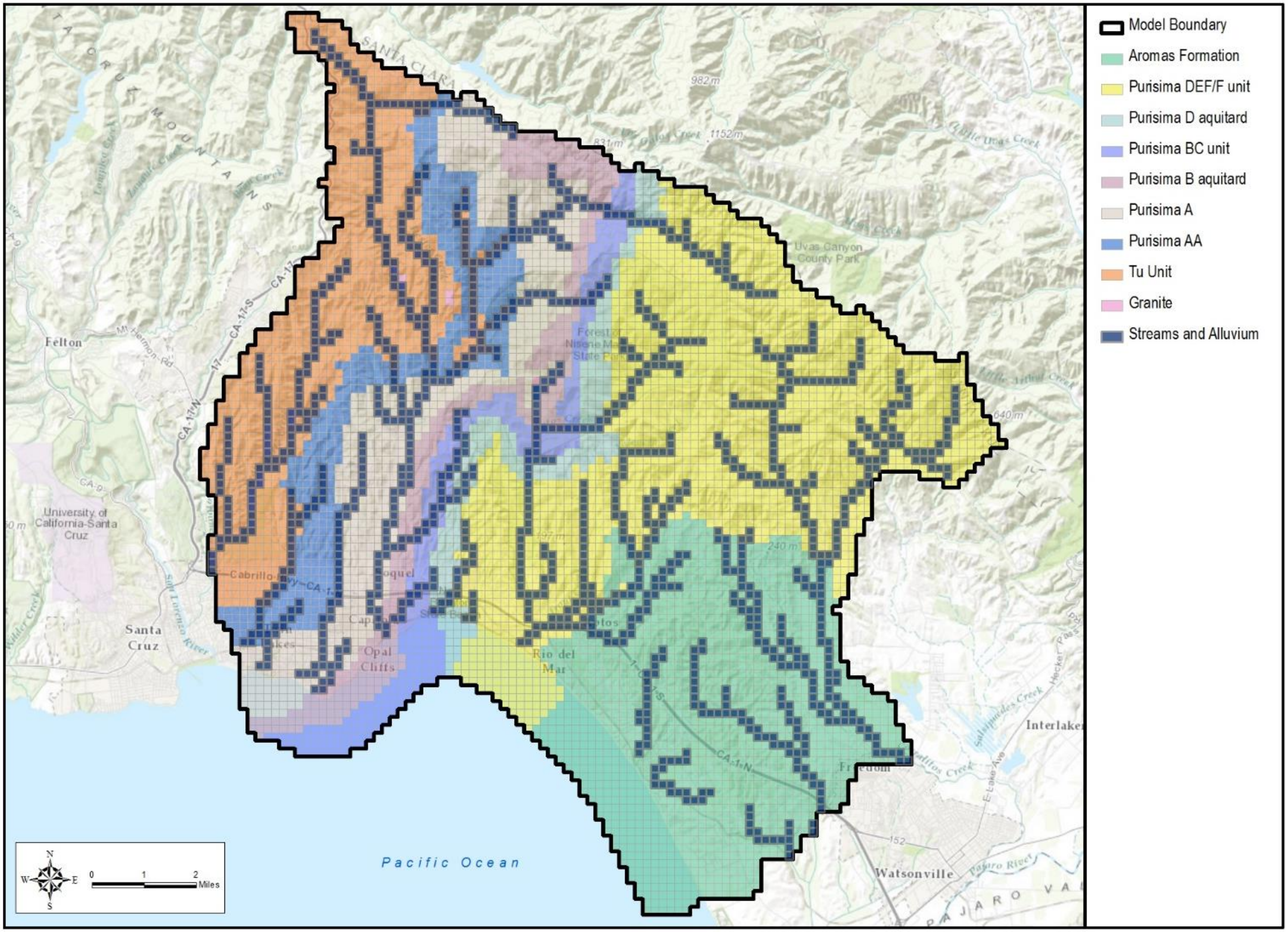

Figure 19: Simulated Extent of Streambed Alluvium

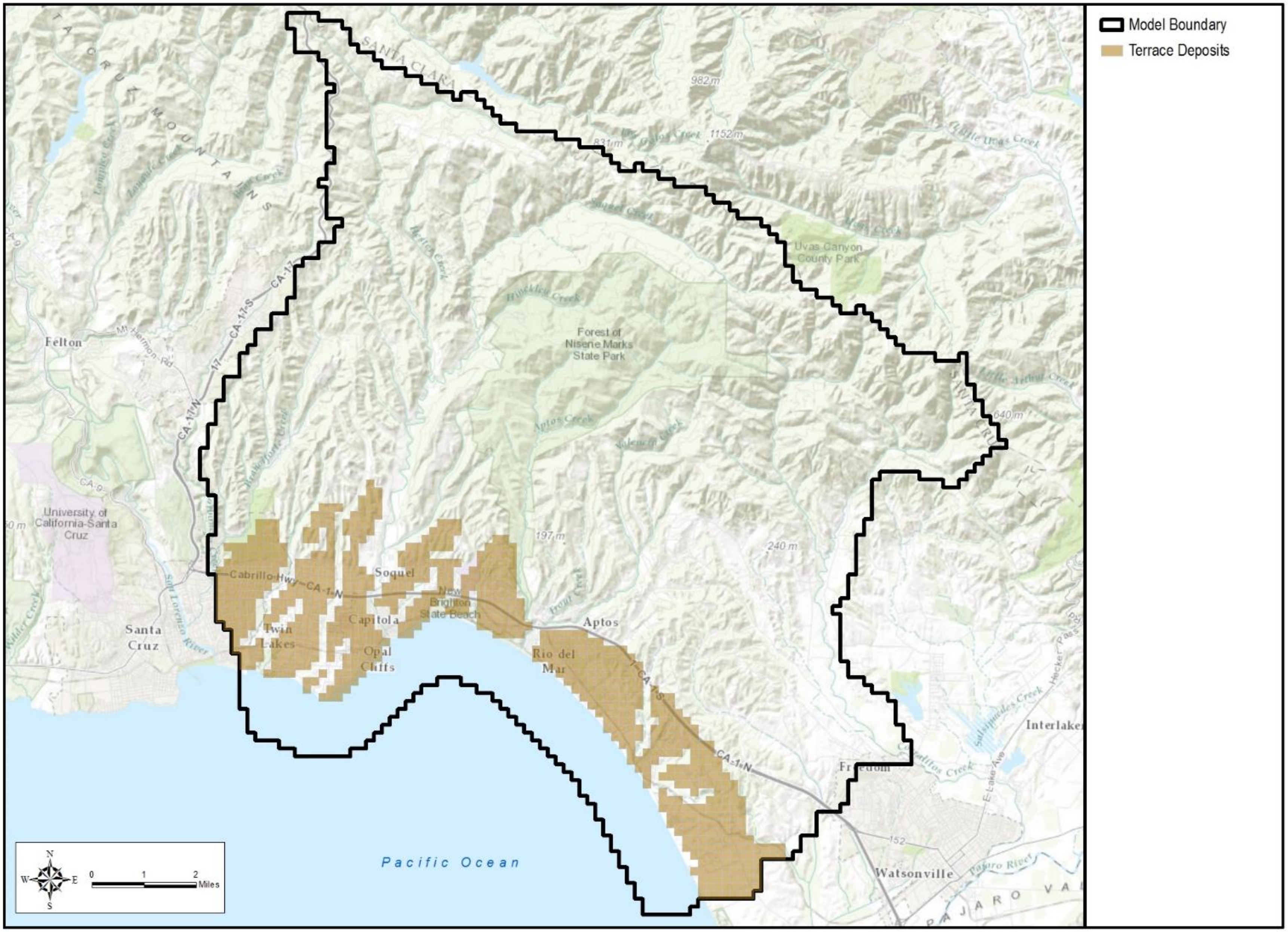

Figure 20: Simulated Extent of Terrace Deposits

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.

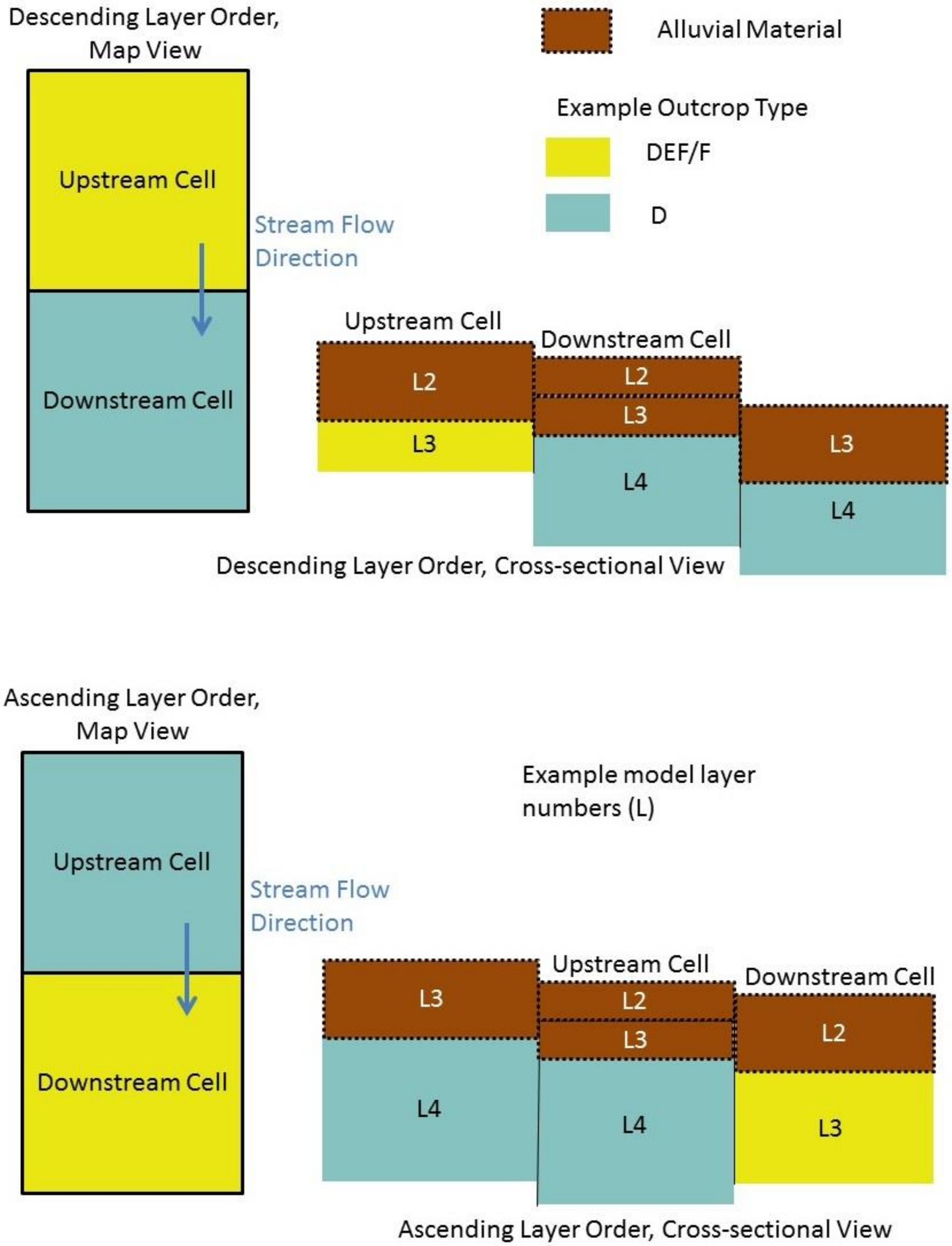

Figure 21: Example Stream Alluvium Layer Assignment

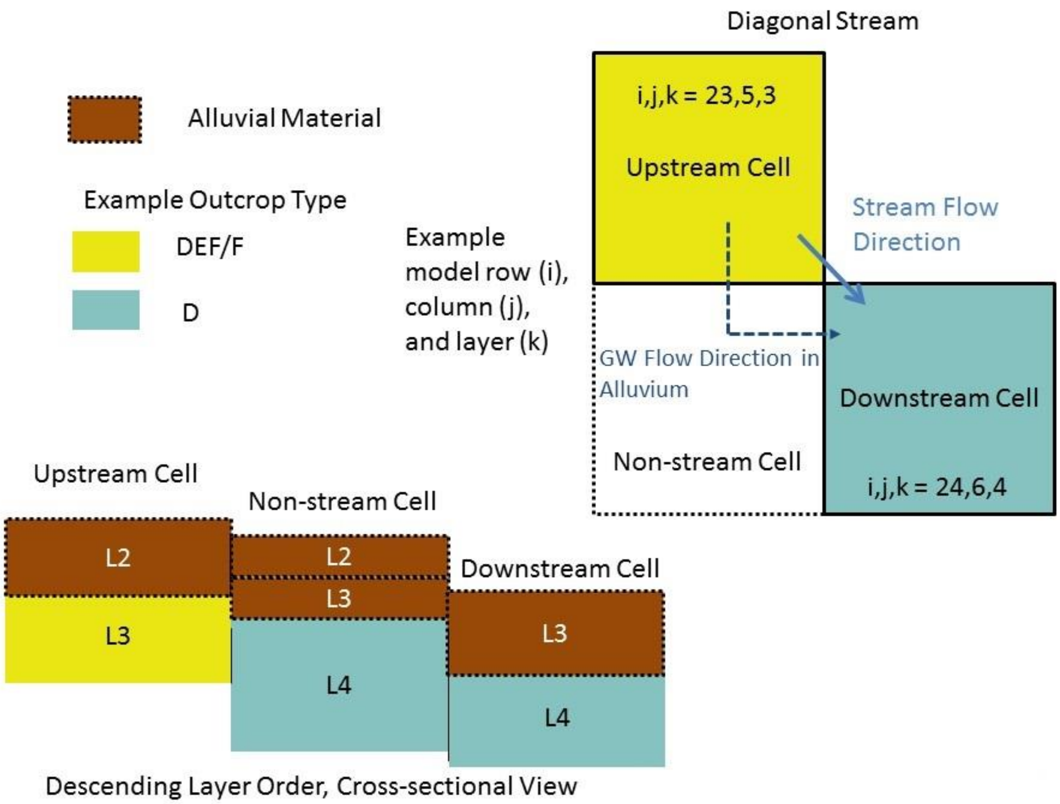

Figure 22: Example Stream Alluvium Layer Assignment for Diagonally-aligned Streams

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.

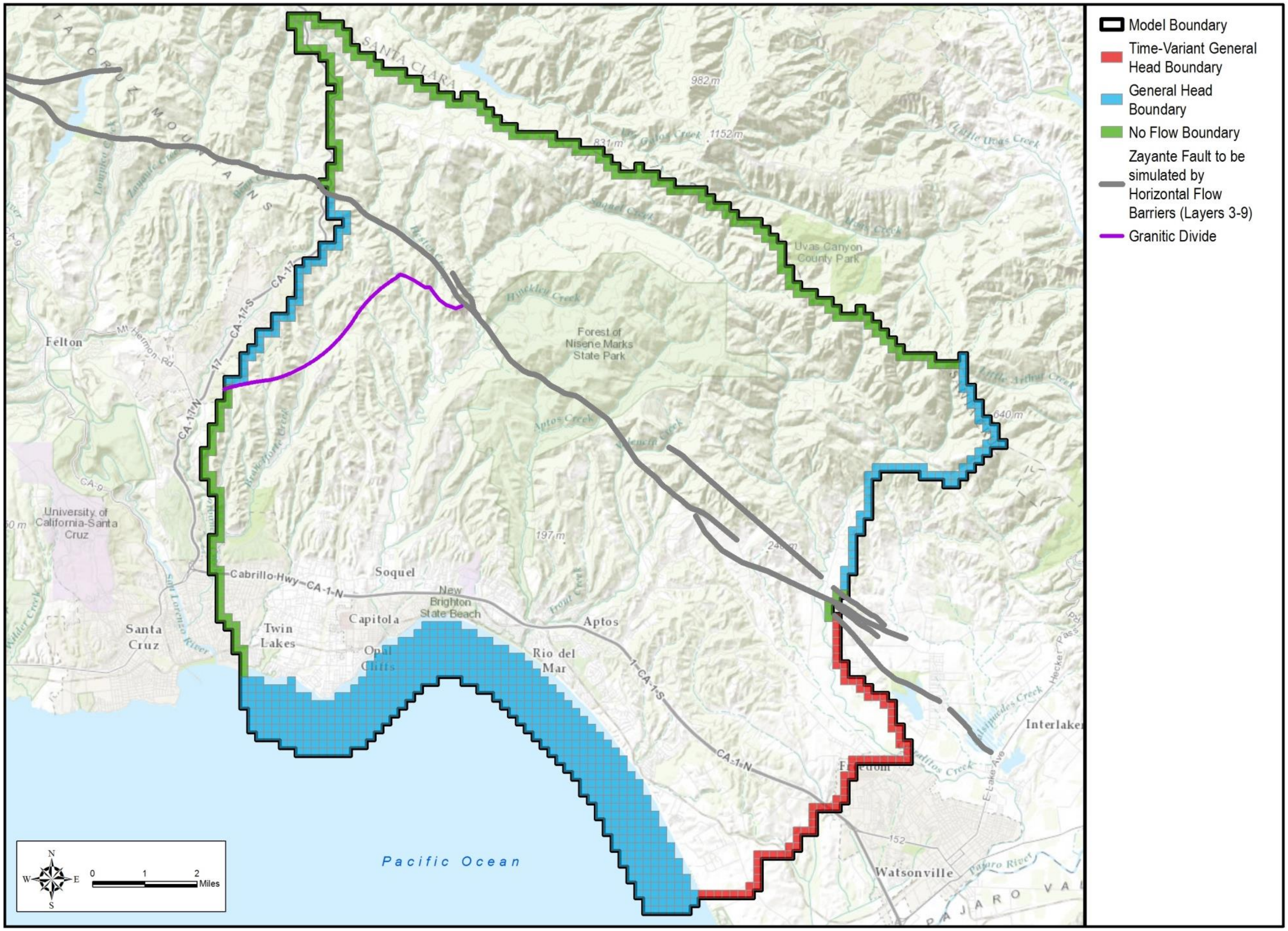

Figure 23: Generalized groundwater model boundary conditions.

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.

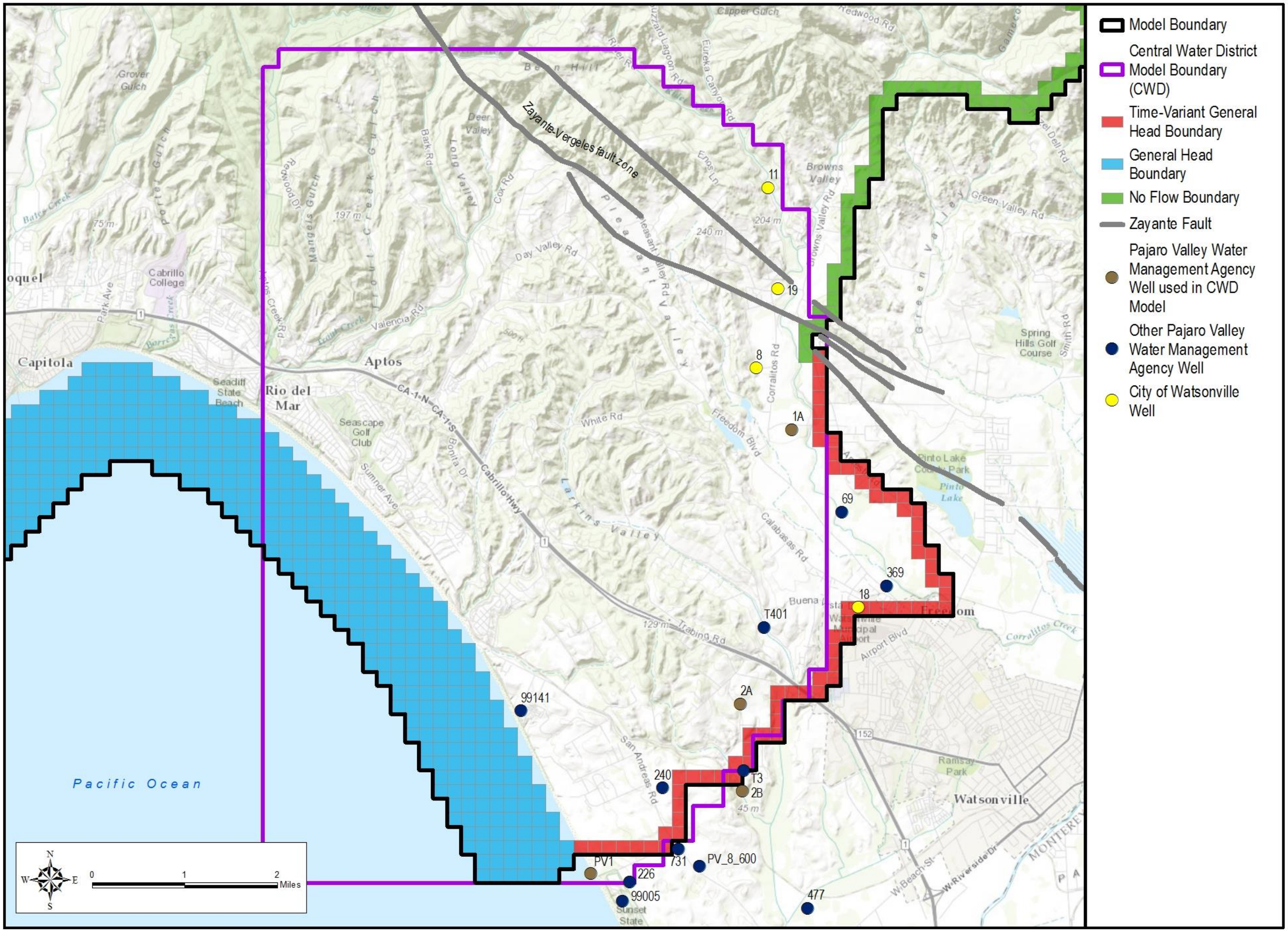

Figure 24: Southeastern Model Boundary

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)

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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.

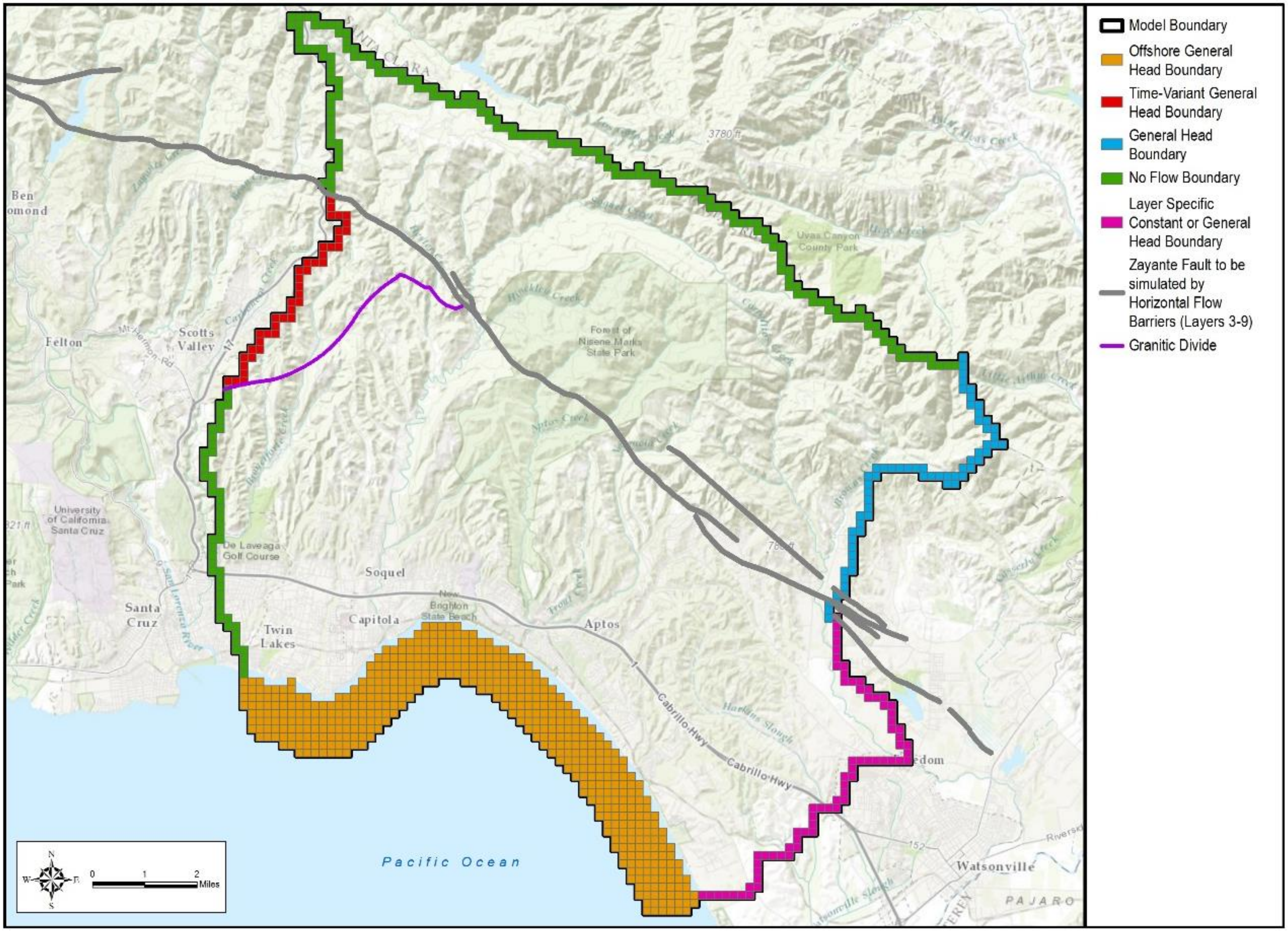

Figure 1: Summary of Model Domain Area and Boundaries (HydroMetrics WRI, 2015)

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.

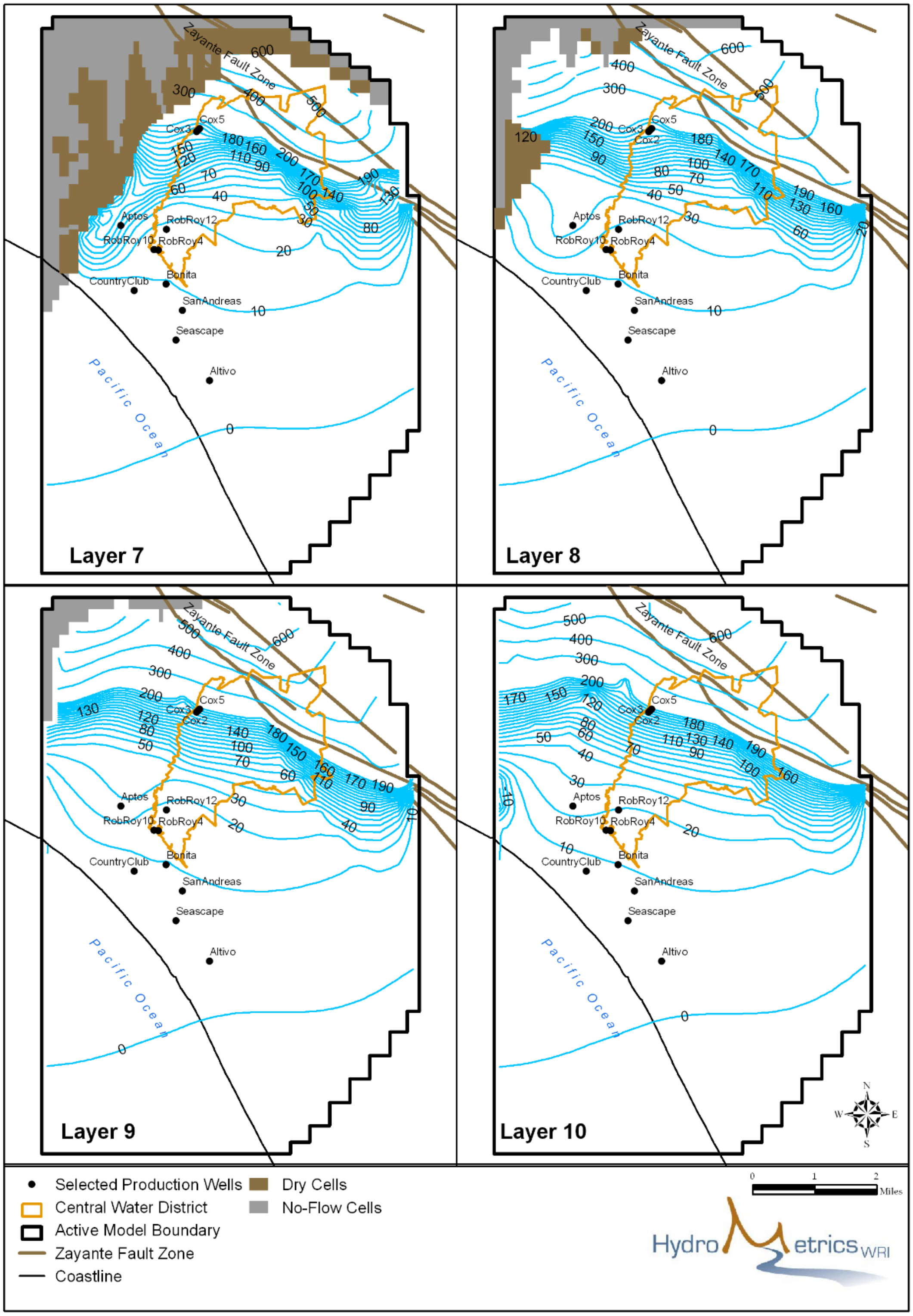

Figure 2: Simulated Groundwater Elevations (feet MSL) in Purisima Formation (HydroMetrics WRI, 2014)

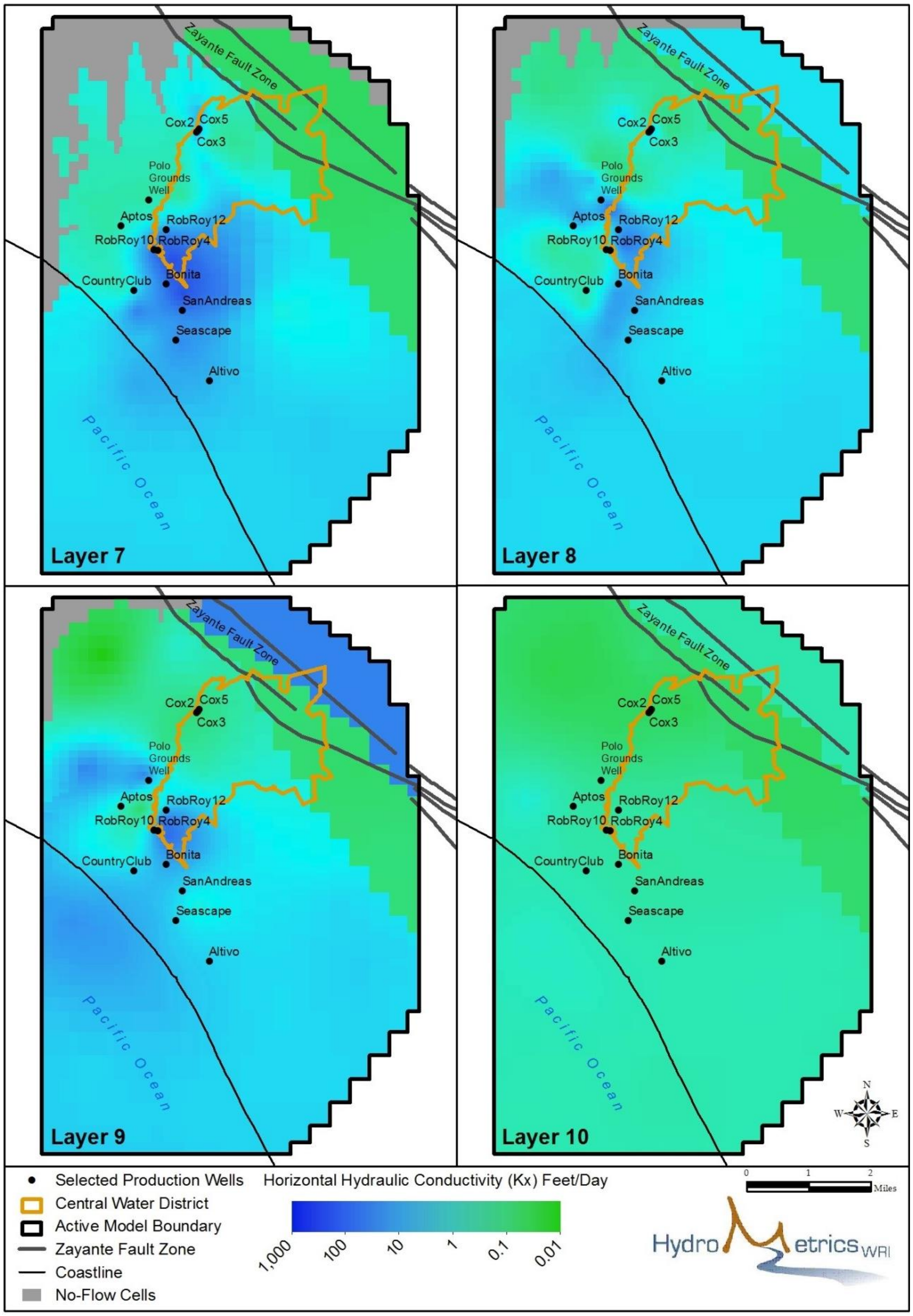

Figure 3: Horizontal Hydraulic Conductivity for Purisima Formation (HydroMetrics WRI, 2014)

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.

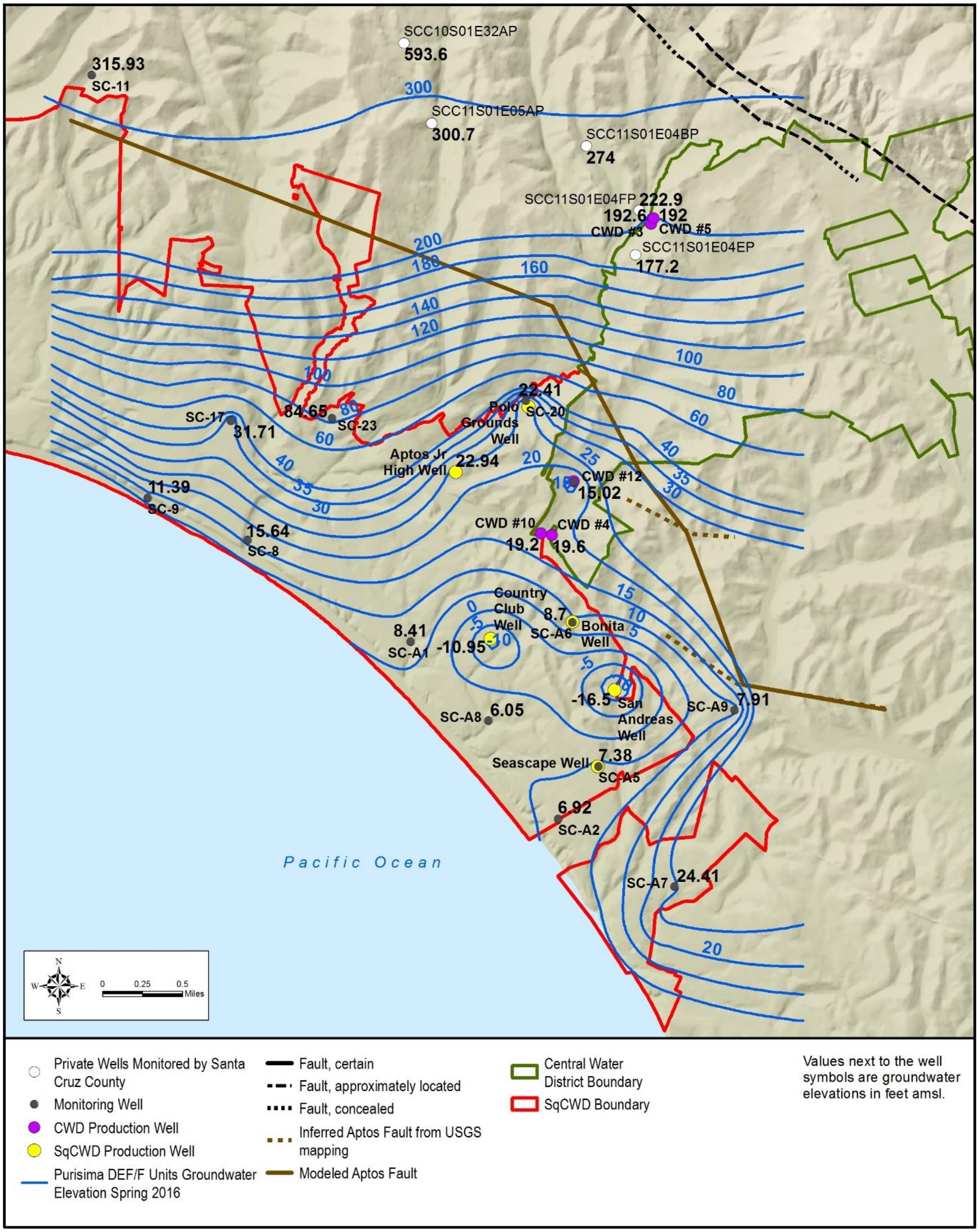

Figure 4: Faulting and Groundwater Elevations in the Aptos Area of the Santa Cruz Mid-County Basin

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.

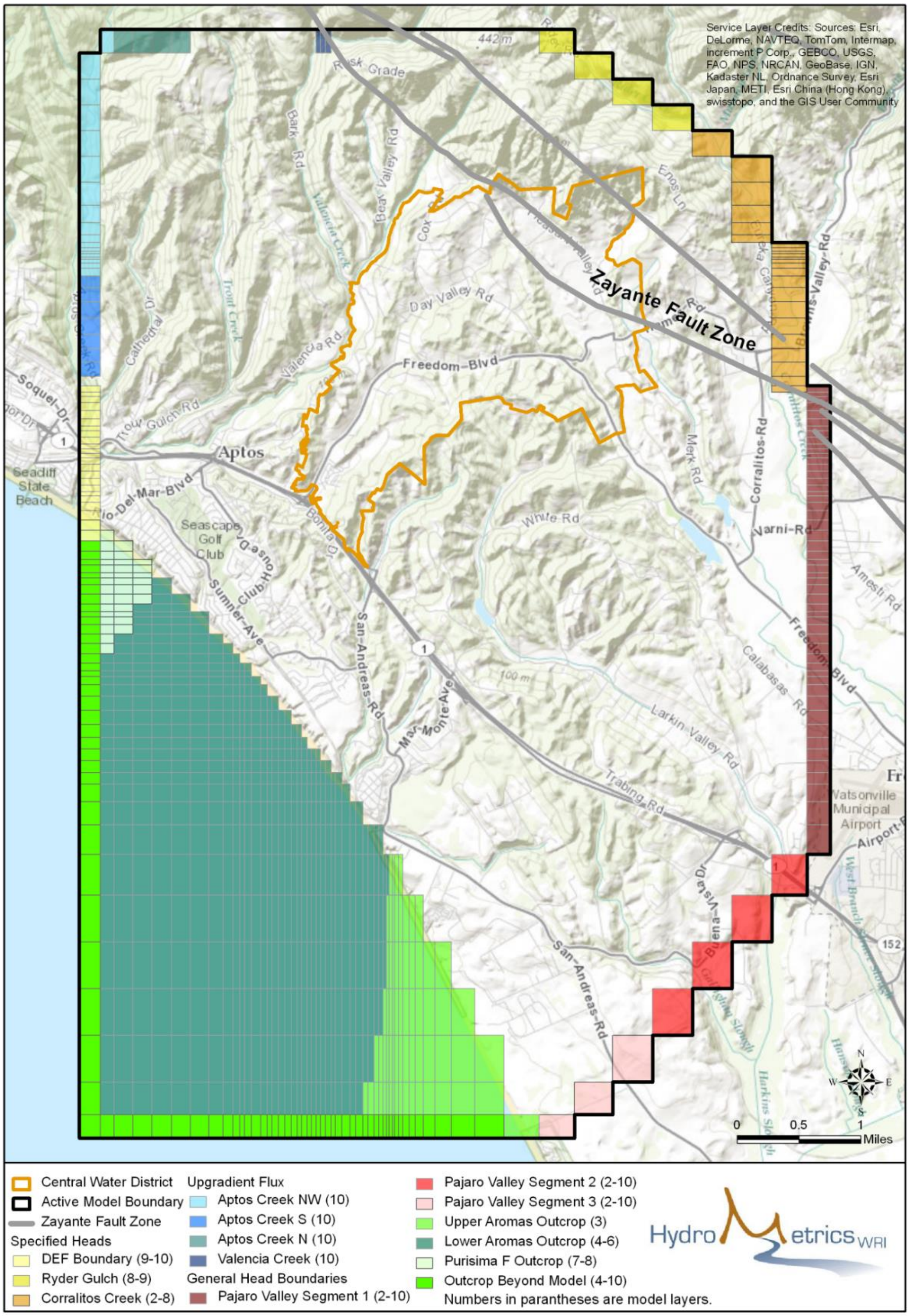

Figure 5: CWD Model Boundary Conditions (HydroMetrics WRI, 2014)

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.

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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

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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).

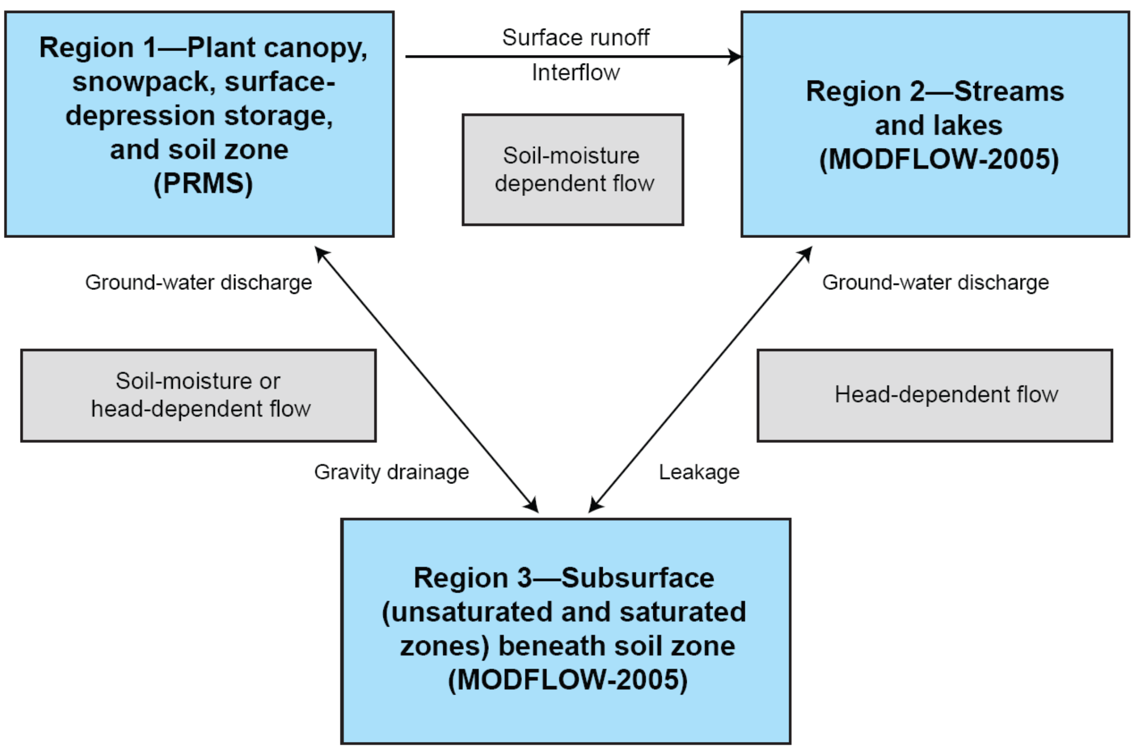

Figure 1. Diagram of Flow Exchange within GSFLOW Calculations Processes (Markstrom et. al., 2008)

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.

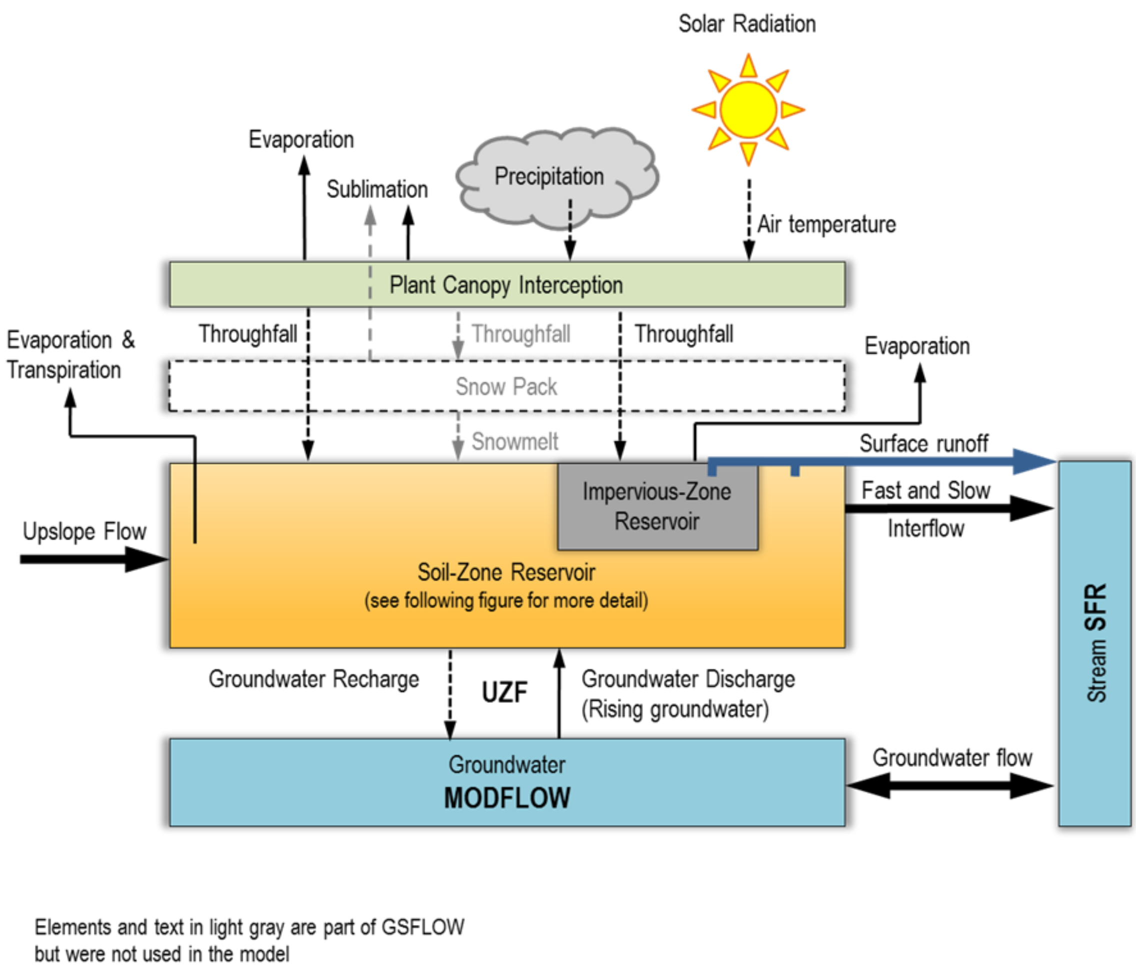

Figure 2. Summary of Watershed and Climate Inputs for GSFLOW

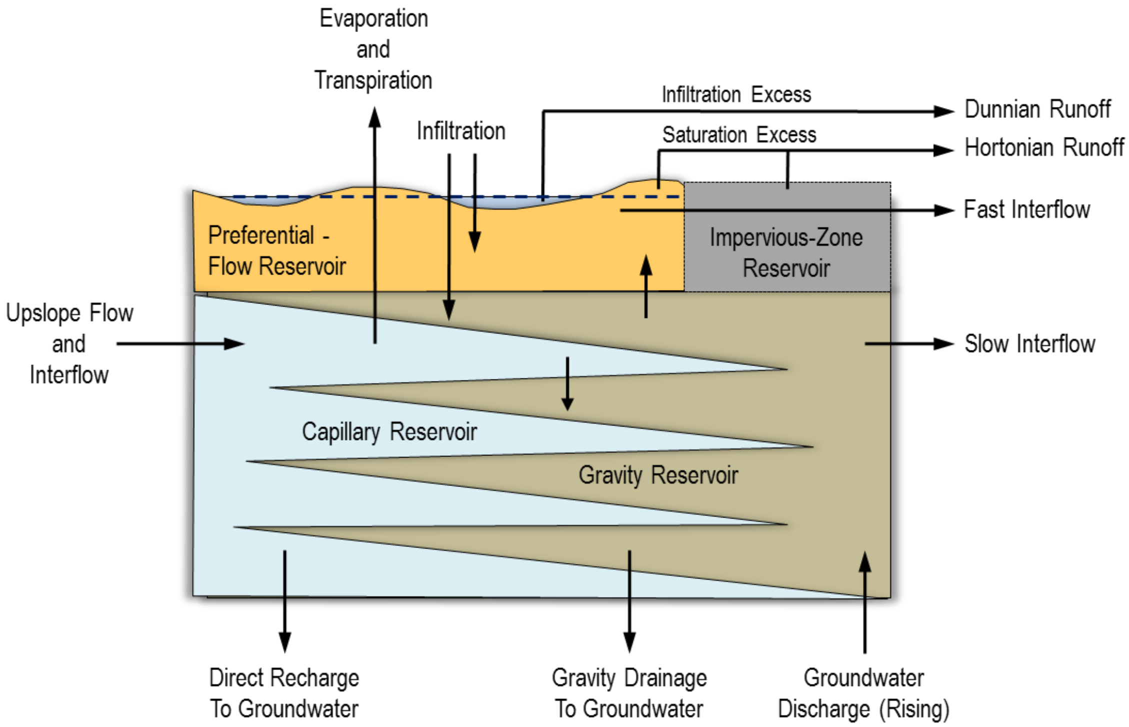

Figure 3. Soil-Zone Reservoirs Inflows and Outflows

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)

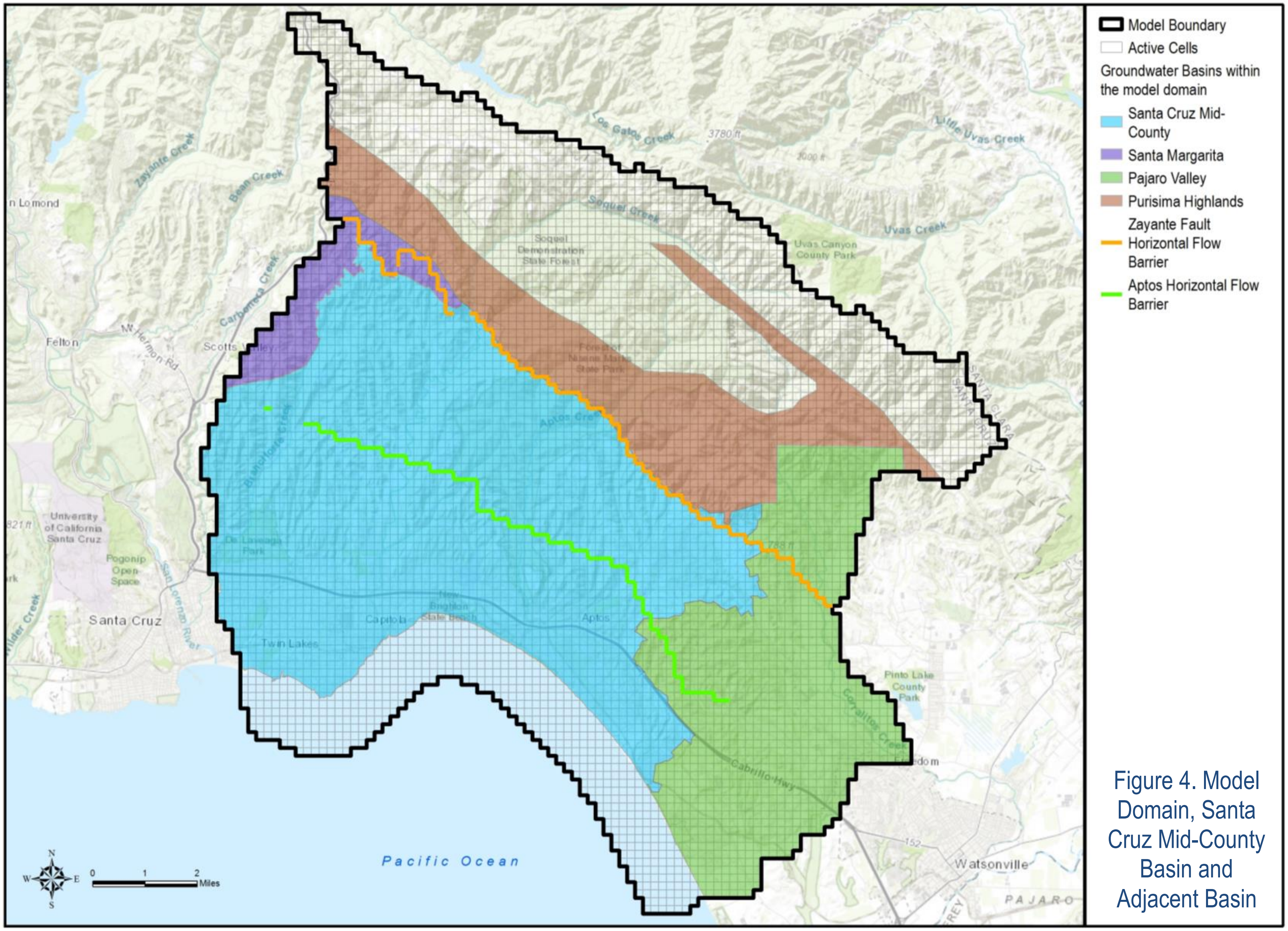

Figure 4. Model Domain, Santa Cruz Mid-County Basin and Adjacent Basin

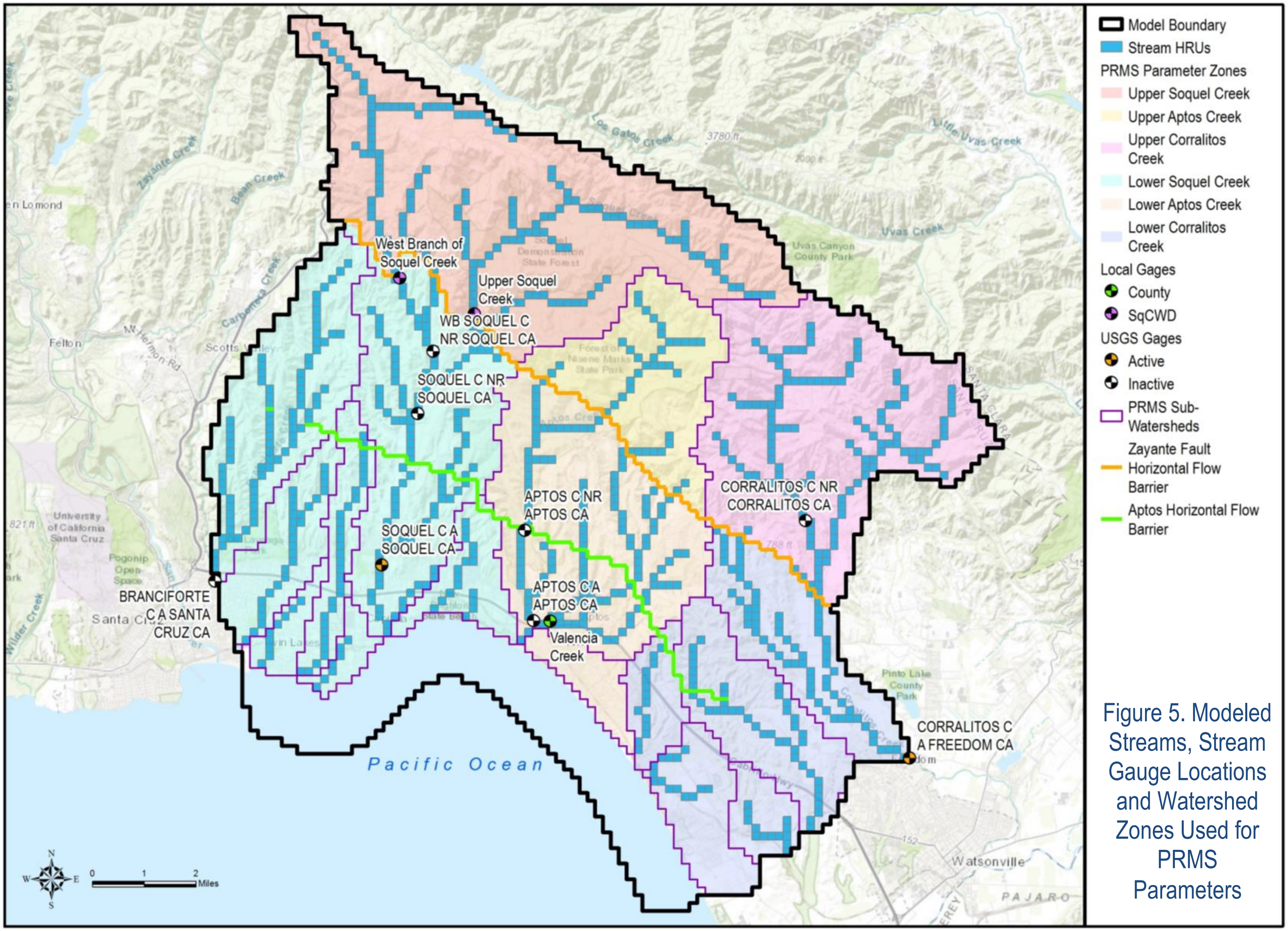

Figure 5. Modeled Streams, Stream Gauge Locations and Watershed Zones Used for PRMS Parameters

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

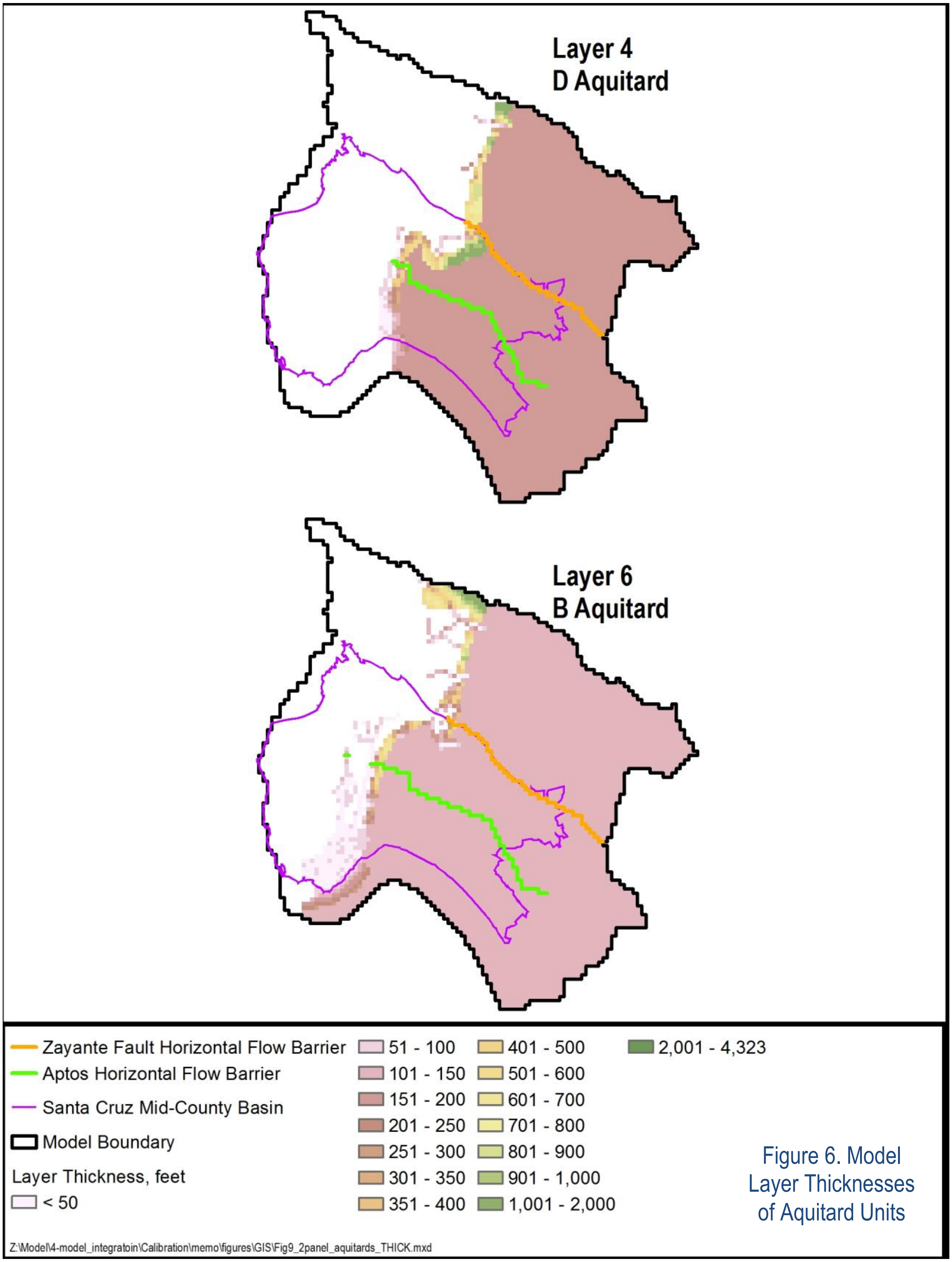

Figure 6. Model Layer Thicknesses of Aquitard Units

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.

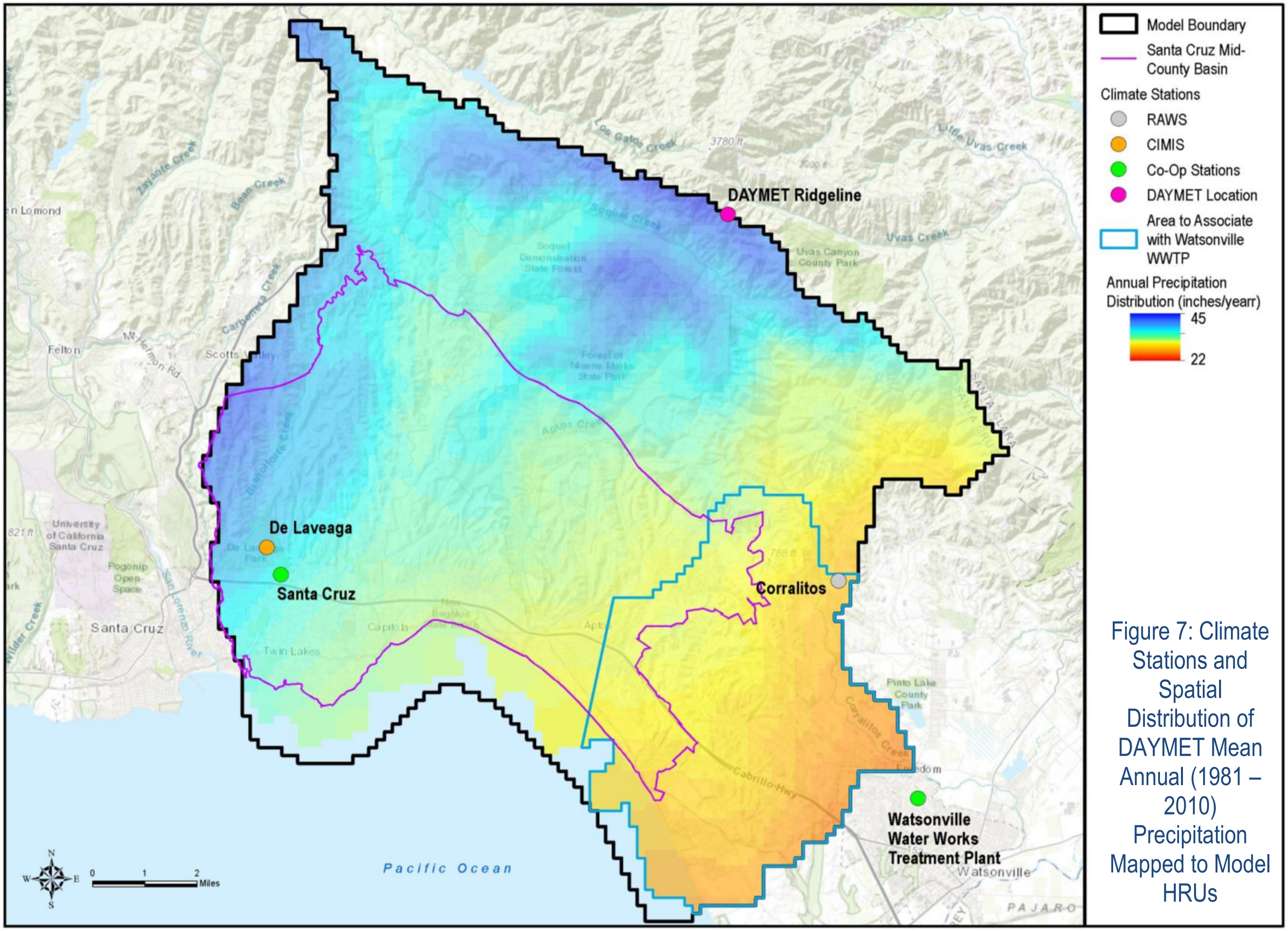

Figure 7: Climate Stations and Spatial Distribution of DAYMET Mean Annual (1981 – 2010) Precipitation Mapped to Model HRUs

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).

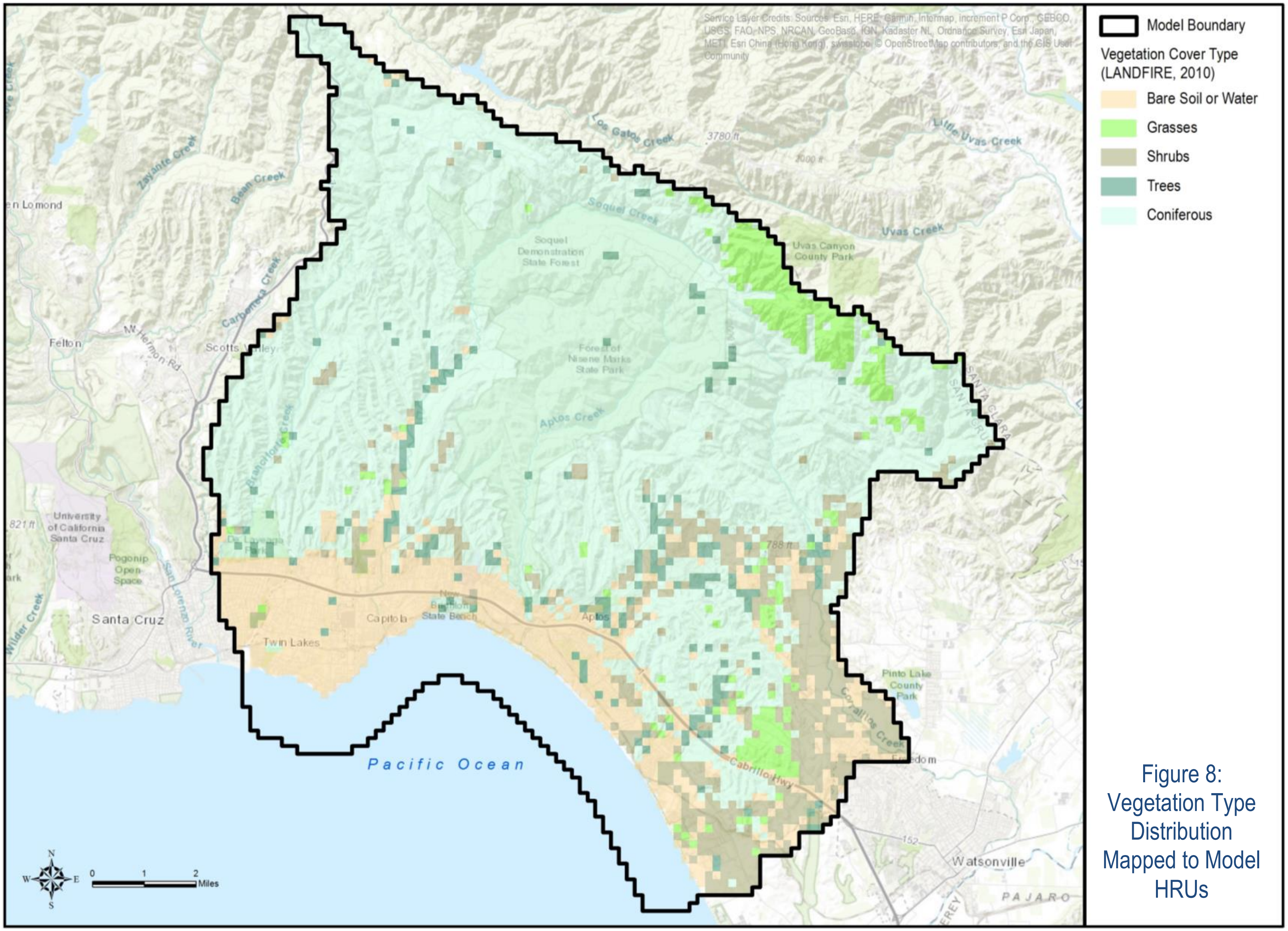

Figure 8: Vegetation Type Distribution Mapped to Model HRUs

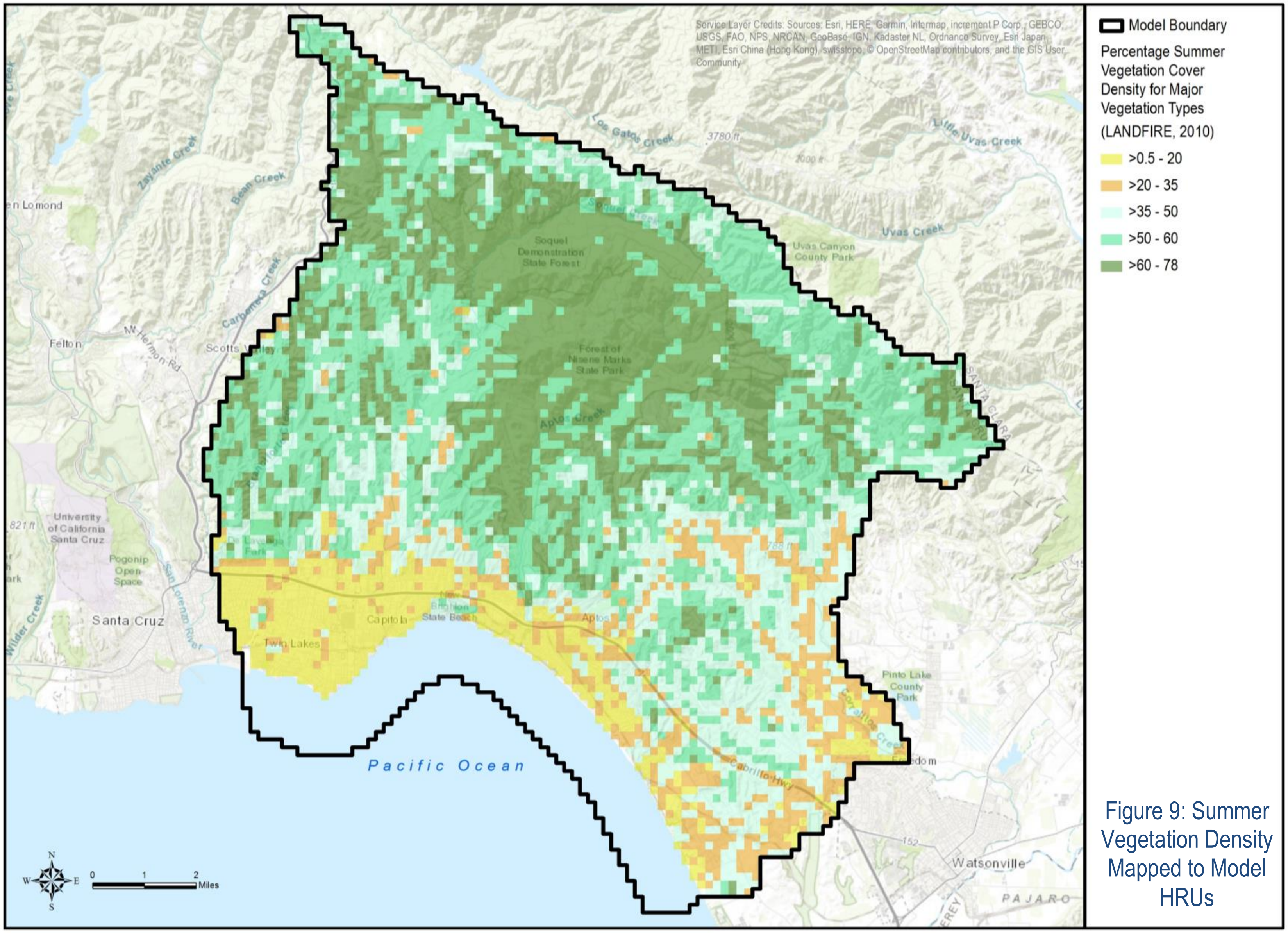

Figure 9: Summer Vegetation Density Mapped to Model HRUs