2012 INTEGRATED RESOURCES PLAN UPDATE

SOQUEL CREEK WATER DISTRICT

Accepted by the Board:	September 18, 2012
Prepared by:	District Staff
Purpose:	Update of the 2006 Integrated Resources Plan with new information on water supply conditions and demand projections, re-evaluation of potential water supply alternatives, and analysis of mandatory water restrictions in lieu of a supplemental supply.

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Glossary and Acronyms

AF	acre-ft (325,851 gallons)
afy	acre-feet per year
Aromas	Aromas Red Sands Aquifer
BAG	Basin Advisory Group
BIG	Basin Implementation Group
CDPH	California Department of Public Health
cfs	cubic feet per second
CIP	Capital Improvement Projects
City	City of Santa Cruz
County	County of Santa Cruz
District	Soquel Creek Water District
gpcd	gallons per capita day
EIR	Environmental Impact Report
EPA	Environmental Protection Agency
GWMP	Groundwater Management Plan
HCP	Habitat Conservation Plan
IRP	Integrated Resources Plan
MCL	Maximum Contaminant Level
mgd	million gallons per day
PAC	Public Advisory Committee
PHG	Public Health Goal
ppb	parts per billion
Purisima	Purisima Formation
RO	Reverse Osmosis
scwd²	**scwd²** Desalination Task Force
SLVWD	San Lorenzo Valley Water District
SGC	Seascape Golf Course
SqCWD	Soquel Creek Water District
SVWD	Scotts Valley Water District
SRP	Satellite Reclamation Plant
UWMP	Urban Water Management Plan
WQ	Water Quality

1. EXECUTIVE SUMMARY

1.1 Introduction

The State of California faces a water shortage crisis and our coastal community is no different. Planning for a long-term reliable, high quality and affordable water supply that protects groundwater resources is paramount for Soquel Creek Water District. Our endangered water supply is challenged with environmental and legal limitations, and the District is responsible for meeting the current and beneficial water needs of the community. Planning efforts must be dynamic in nature, to adapt to new information and conditions to effectively plan for today and the future.

Beginning in the mid-1990's, Soquel Creek Water District took the first step in responding to evidence of groundwater overdraft with its original roadmap known as the *1999 Draft Integrated Resources Plan*. In 2006, the Integrated Resources Plan (IRP) was revised with updated information and further evaluation of potential water supply alternatives. Based on more recent information developed on the groundwater conditions of the Soquel-Aptos basin and reduced demand projections, this 2012 IRP Update reflects the most recent information and is intended to serve as a the District's water resources planning document until 2030, based on current assumptions and the District's Urban Water Management Plan.

1.2 Purpose and Findings of 2012 IRP Update

The District's 2012 IRP Update is a long-term water plan that offers a diversified strategy emphasizing water-use efficiency through demand management (i.e. conservation and re-use), groundwater management, and supplemental supply development. The IRP Update serves as a roadmap through 2030 for maintaining water supply reliability for our customers and protecting the local environment.

Key water supply planning objectives for this update include:

- **Water supply planning objectives to recover the groundwater basin**
    - Limit groundwater pumping to 2,900 acre-feet per year (afy) (also known as the recovery pumping goal) [1];
    - Reduce groundwater pumping to the recovery pumping goal within 6-8 years; and
    - Continue to limit groundwater pumping at the recovery pumping goal to achieve basin recovery and to restore groundwater levels to prevent seawater intrusion. (Estimated to be at least 20 consecutive years.)
- **Water supply planning objectives once the groundwater basin has been restored and protective levels are achieved**
    - Limit groundwater pumping to 4,000 afy on average (also known as the post-recovery goal) [2]; and

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[1] This recovery pumping goal of 2,900 afy was developed by HydroMetrics, WRI (Appendix A)

[2] This post-recovery pumping goal of 4,000 afy was developed by HydroMetrics, WRI (Appendix A)

- Modify the post-recovery goal, as needed, based on adaptive management and observed groundwater levels.

The 2012 IRP Update components and findings that have been identified to meet the District's water supply planning objectives include the following:

- **Demand Management**
  - Continue and increase conservation efforts, focusing on conservation measures that are estimated to cost less per acre-foot of water saved than other supply options such as the operational cost of desalination; and
  - Evaluate recycled water options as feasible and can be permitted.

- **Groundwater Management**
  - Limit groundwater pumping to the recovery pumping goal of 2,900 afy and restrict pumping to this level until restoration of protective groundwater levels is achieved to prevent seawater intrusion (estimated to be at least 20 consecutive years);
  - Continue monitoring coastal groundwater levels and water quality;
  - Redistribute groundwater pumping inland;
  - Continue to encourage the Soquel-Aptos Area Groundwater Management Joint Powers Authority to establish a Groundwater Replenishment District and encourage the County of Santa Cruz to establish conservation measures for non-District pumpers;
  - Support groundwater recharge protection and enhancement projects and policies;
  - Re-evaluate the post-recovery pumping goal of 4,000 afy once the groundwater basin is restored to determine whether pumping may be increased or decreased; and
  - Use an adaptive management approach to revise the recovery pumping goal and the post-recovery pumping goal based on observed groundwater levels and quality.

- **Conjunctive Use Supplemental Supply Projects**
  - Continue to evaluate the **scwd^2** Regional Seawater Desalination Project with the City of Santa Cruz (City); and
  - Continue to support the evaluation of a potential water exchange project with the City of Santa Cruz.

- **Local Supplemental Supply Alternatives**
  - Consider further evaluation of a District-only desalination facility should the **scwd^2** Regional Seawater Desalination Project with the City of Santa Cruz no longer be pursued in the future or the feasibility of a modified Soquel Creek off-stream division project; and
  - Continue to evaluate and consider implementing mandatory water restrictions and a moratorium should the **scwd^2** Regional Seawater Desalination Project with the City of Santa Cruz no longer be pursued in the future.

2. BACKGROUND OF WATER PLANNING EFFORTS

This Integrated Resources Plan (IRP) Update for Soquel Creek Water District represents the current knowledge and understanding of water supply resources, projected future water demands, and established policies/goals to meet the objectives of providing a reliable and safe water supply for District customers while preventing degradation of local groundwater and surface water resources. All objectives and components of the 2012 IRP Update were previously considered and agreed upon by the Board of Directors in public meetings.

2.1 1999 Draft Integrated Resources Plan (Draft IRP)

In July 1997, the District launched an open, community-based, collaborative discussion and decision-making process with the formation of a Public Advisory Committee (PAC) to make recommendations regarding the current and future water demand and supply for the District. The PAC was comprised of more than 20 individuals representing a broad spectrum of stakeholders in the area, including homeowners, environmental groups, business, governmental agencies and private well owners. The PAC regularly met over an 18-month period and produced a *Draft Integrated Resource Plan* (Draft IRP) in 1999 that concluded: (1) the District's aquifers were in overdraft and that water conservation should be maximized; and (2) a supplemental water supply would also be needed to stabilize existing coastal groundwater levels and meet projected water demand to build-out based upon adopted Santa Cruz County and City of Capitola General Plans. The PAC identified a number of supplemental supply options and developed a short list of potentially viable options for further evaluation.

2.2 2006 Integrated Resources Plan

In March 2006, the Draft IRP was revised and adopted to reflect updated information that included revisions to the demand projections and conservation savings, and the results of evaluating previously identified and new supplemental supply options. The adopted *Integrated Resources Plan, 2006* (2006 IRP) is a multi-faceted plan with the following components:

- **Demand management**: Continue and increase conservation efforts and evaluate site-specific recycled water for irrigation use;
- **Groundwater management**: Limit groundwater pumping to no more than 4,800 afy and continue monitoring of coastal groundwater levels and water quality, redistribute groundwater pumping inland, support groundwater recharge protection and enhancement projects and policies;
- **Conjunctive Use Supply Project:** Develop a regional seawater desalination facility with the City of Santa Cruz; and
- **Local Supplemental Supply Alternatives:** Further evaluate the feasibility of a modified Soquel Creek diversion project or a local-only desalination facility.

2.3 Highlights and Status Updates of 2006 Components

Since acceptance of the 2006 IRP, the District has been working on all of the components mentioned in Section 2.2. Following is a brief status update of key components from the 2006 IRP:

Demand Management

- A report entitled *Water Recycling Facilities Planning Study - Final Report* (Black and Veatch, 2009) evaluating satellite reclamation facilities concluded that site-specific recycled water is technically feasible but is neither a cost-effective nor sufficient water supply alternative at this time for the District.
- The District's conservation program continues to expand and now includes a host of rebate incentives, a free home and business water survey program, and a strong educational outreach component. The District has implemented all applicable conservation/demand management measures identified by the California Urban Water Conservation Council as key urban water conservation program components.
- The District adopted the *2010 Urban Water Management Plan* which includes revised demand projections for 2010-2030 that reflect ongoing conservation reductions.
- The District evaluated two mandatory water restriction scenarios (which assumed a moratorium would be enacted to prevent new or expanded water use) to identify potential water demand reductions: (1) Mandatory Water Restrictions, Enforcement Approach and (2) Mandatory Water Restrictions, Full Toolbox Approach. Both scenarios were evaluated by the District's Conservation Department to identify the measures and associated costs that would be required to reduce demand to the District's recovery pumping goal of 2,900 afy.

Groundwater Management

- The District has been pumping at or below the 2006 IRP recommended 4,800 afy for several years; however, coastal groundwater levels remain below elevations that are required to protect the aquifers from seawater intrusion. The District's aquifers remain at risk for seawater intrusion in the Purisima Formation and remain at risk for further seawater intrusion in the Aromas Red Sands.
- The District completed an environmental review for the construction of up to four new groundwater production wells and the conversion of an existing irrigation well to a municipal production well, and certified the Well Master Plan Environmental Impact Report (EIR). All of these well sites are located inland of Highway 1 and in the Purisima Formation. These new wells will enable the District to redistribute some pumping away from the vulnerable coastal region and better manage drawdown of groundwater levels.
- Ongoing implementation of the *2007 Groundwater Management Plan* adopted by the Soquel-Aptos Area Groundwater Management Joint Powers Authority (SqCWD and Central Water District) occurs under the direction of the Basin Implementation Group (BIG) with technical input from the Basin Advisory Group (BAG). The BIG conducts an annual review and prepares an annual report which summarizes groundwater conditions in the Soquel-Aptos area, documents the status of groundwater management activities from the previous year, and recommends any amendments to the Groundwater Management Plan.
- HydroMetrics Water Resources, Inc., the District's consulting hydrogeologists, hereinafter referred to as HydroMetrics, prepared a report dated January 2009 entitled "*Groundwater Levels to Protect against Seawater Intrusion and Store Freshwater Offshore*" and a letter report dated September 15, 2009 entitled "*Modeled Outflow to Achieve Protective Water Levels*". These reports establish the groundwater elevations at coastal monitoring wells that protect the Purisima Area against seawater intrusion and the estimated outflows to the ocean necessary to maintain those protective levels. Modeled outflow was used to estimate the District's post-recovery pumping goal for the Purisima Area.

- HydroMetrics, the District's consulting hydrogeologists, prepared a letter report dated April 3, 2012 entitled "*Revised Protective Groundwater Elevations and Outflows for Aromas Area and Updated Water Balance for Soquel-Aptos Groundwater Basin*" **(Appendix A)**. The report establishes the groundwater elevations at coastal monitoring wells that protect the Aromas Area against seawater intrusion and the estimated outflows to the ocean necessary to maintain those protective levels. The estimates for protective outflow are used to establish the District's post-recovery pumping goal for the Aromas Area. The report also uses protective outflow estimates from the 2009 HydroMetrics reports mentioned above to establish the District's post-recovery pumping goal for the Purisima Area. The report was adopted by the Board on April 3, 2012 to serve as the guideline for planning future pumping with respect to policy decisions on establishing: (1) the recovery pumping goal to restore the basin; (2) the level of risk associated with protective outflow determinations; and (3) the timeframe planned for restoring the basin and then increasing pumping to the post-recovery pumping goal.

Conjunctive Use Supply Projects

- After an extensive evaluation of the recommended alternatives identified in the 2006 IRP, a collaborative seawater desalination facility with the City of Santa Cruz was identified by the District Board to be the most viable overall solution to further pursue that could provide a sufficient, reliable and flexible water supply to supplement our threatened groundwater supply.
- In 2007, the two agencies joined together and formed **scwd^2** to further evaluate a 2.5 million gallon per day desalination facility that could be used by the District to significantly reduce pumping in vulnerable areas and enable groundwater levels to recover to elevations protective against seawater intrusion. A comprehensive list of technical and environmental studies for this project is available on the **scwd^2** Desalination Program Website at www.scwd2desal.org/Page-Documents_Technical_Project_Reports.php. The draft Environmental Impact Report (EIR) for this project is scheduled to be released in late 2012.
- The District also has been working with the County of Santa Cruz (County) and the City on the feasibility study for a water exchange. The County provided the District with a letter report dated May 11, 2011 entitled, "*Status Report on the Potential for Surface Water Transfers in Northern Santa Cruz*" that included preliminary evaluation, potential benefits and challenges, and next steps. The District formally stated its support of this conceptual project. A status update by the County to the SqCWD Board of Directors is scheduled for October 2012.

2.4 2012 Integrated Resources Plan Update

This 2012 Integrated Resources Plan Update (2012 IRP Update) is based on information and developments since 2006 and includes:

(a) Updated demand information from the *2010 Urban Water Management Plan*;

(b) Updated groundwater post-recovery pumping goal and recovery pumping goal estimates based on HydroMetrics' analysis on *"Modeled Outflow to Achieve Protective Water Levels"* and "*Protective Groundwater Elevations and Outflows for Aromas Area and Updated Water Balance for Soquel-Aptos Groundwater Basin"*;

(c) Decisions and direction from the Board based on the March 6, 2012 Workshop on Water Supply Planning regarding target objectives and supply alternatives; and

(d) Findings and Conclusions from the Board based on the June 5, 2012 Workshop on Mandatory Water Restriction Scenarios to Reduce Demand to 2,900 acre-feet per year.

3. WATER SUPPLY PLANNING: GOALS AND PROBLEM STATEMENT

3.1 Groundwater Management Goals

Groundwater management in a geologically complex coastal environment involves recognizing a wide range of variables and uncertainties and must be adaptive based on actual basin response to pumping changes. The goals of Soquel Creek Water District, as outlined in the *2007 Groundwater Management Plan*, still hold true:

- Ensure water supply reliability for current and future beneficial uses *(Goal 1, Water Quantity)*;
- Maintain water quality to meet current and future beneficial uses *(Goal 2, Water Quality)*; and
- Prevent adverse environmental impacts *(Goal 3, Environmental Impacts)*.

3.2 District's Water Supply Problems

At present, the main concerns regarding the District's water supply are:

- The sole source of potable water supply is an overdrafted, shared coastal groundwater basin. The Purisima Formation is at high risk of seawater intrusion; the Aromas Red Sands Aquifer has actively occurring seawater intrusion. While seawater has not yet reached District production wells within the Aromas Red Sands Aquifer, coastal production wells within the Pajaro Valley (just south of the District's service area) have been contaminated.
- Reduced District pumping has not shown a sufficient increase in groundwater levels.
- The District is the largest single user of groundwater within the Soquel-Aptos Basin and production wells are vulnerable to seawater contamination.
- The District, as an appropriator, needs to take the lead to address groundwater overdraft within the groundwater basin because it is legally entitled to only take the amount of groundwater that is surplus to the present cumulative needs of private pumpers with overlying property rights.
- Current predictions of likely climate change impacts would reduce groundwater recharge and increase sea level.
- The District has an insufficient, unreliable water supply to sustainably meet current and future beneficial uses within its service area.

3.3 Changes to Demand Projections and Target Pumping Yields since 2006 IRP

Water supply planning is a dynamic process and requires an adaptive strategy that allows agencies to effectively plan and understand the reality of changing conditions. Just as the District initiated an update in 2006 to revise the previous 1999 Draft IRP, new data and information gave impetus to initiate a second update to the IRP. **Table 3-1** illustrates changes to the District's demand projections and target pumping yields since the 2006 IRP.

Table 3-1: Changes to Demand Projections and Target Pumping since 2006 IRP			
Changes	**2006**	**2012**	**Potential Effects on Water Supply Planning**
Updated demand projections through 2030	• In the 2006 IRP, the District's projected water demand for 2030 was 5,640 afy (with conservation).	• In the 2010 UWMP, the District's projected water demand for 2030 is 4,830 afy before factoring in additional conservation to reduce demand 4,120 afy).	• Newer projections show a reduction in water demand. • Based on projections for 2030, water demand is 800 afy less than projected in 2006 and 1,520 afy less than assuming conservation targets.
Updated groundwater analysis for sustainable and target pumping goals	• In the 2006 IRP, the District's sustainable yield was not to exceed 4,800 afy. • In the 2006 IRP, it was assumed any amount above the sustainable yield plus an additional 500 afy would be provided by a supplemental supply until basin recovery is achieved.	• Based on new 2012 evaluation, the recovery pumping goal is established at 2,900 afy to be maintained for approximately 20 years to recover the basin. • Based on new 2012 evaluation, the District's post-recovery goal should average 4,000 afy.	• The recovery pumping goal of 2,900 afy is 35% less than projected 2015 demands with anticipated conservation savings (4,448 afy) • The District's groundwater yield after basin recovery is at least 800 afy less than the 2006 IRP estimate of 4,800 afy.

4. WATER SUPPLY CONDITIONS AND SUPPLEMENTAL SUPPLY OBJECTIVES

In order to quantify the amount of supplemental supply needed, technical analyses were completed to estimate how much groundwater the District can pump during and after groundwater basin recovery to meet groundwater management objectives. Water supply planning must take into account unknown but likely factors that impact supply and demand. This section documents the assumptions used, the analysis, and the conclusions on which the District's statement of water need is based.

4.1 Establishing Post-Recovery Groundwater Pumping Goal

Hydrogeology is the study of the interrelationships of geologic materials and processes with water, especially groundwater. Highly complex in nature, hydrogeologic studies are often a combination of information that is known, estimated, and unknown.

The known factors were identified as:

- Geology of Purisima and Aromas formations (understood fairly well)
- Coastal groundwater levels
- Groundwater levels at inland monitoring wells
- District groundwater pumping (quantity and quality)
- Central Water District, City of Santa Cruz and Cabrillo College groundwater pumping (quantity)
- Rainfall values(at a regional level)
- Soquel Creek streamflows

The estimated factors (with uncertainty) were identified as:

- Amount of deep recharge in the basin
- Amount of groundwater flow:
  - Out to ocean for maintaining protective elevations
  - Out to Pajaro Valley
- Stream/aquifer interactions
- Agricultural and private pumping
- Consumptive use factors/ return flow percentages

More
↑
Level
of Certainty
↓
Less

The unknown factors were identified as:

- Location of seawater interface in the Purisima Formation
- Locations of offshore geologic outcrops and corresponding Purisima layers
- Amount of groundwater flow:
  - Between Purisima and Aromas
  - Between the aquifer layers
  - Into the District
- Speed of groundwater flow towards the coast

- How much of the District's post-recovery pumping goal can be safely sustained using existing/planned groundwater wells

Using these sets of known, estimated, and unknown factors, HydroMetrics performed groundwater modeling to establish the District's post-recovery pumping goal as shown in Table **4-1**. A post-recovery pumping goal of 4,000 afy has been identified as the estimated volume of water available to the District after the groundwater basin has been restored to protective levels which prevent seawater intrusion occurrence.

The 4,000 afy post-recovery pumping goal is based on the 70th percentile of the modeling results for protective outflow which reflects the uncertainty of hydrogeologic conditions offshore. There are insufficient offshore data to calibrate the groundwater models so each model extending offshore from each coastal monitoring well was run with 100 reasonable parameter sets of hydrogeologic values. For at least 70 of the runs of each model, the 70th percentile of protective elevations and outflows protected the aquifers from seawater intrusion. Using the District's adaptive management approach, estimates for the post-recovery pumping goal will be revised if protective elevations cannot be maintained or seawater intrusion is observed to advance while pumping is within the estimated goal after recovery.

Table 4-1: District's Post-Recovery Pumping Goal based on Protective Outflow within 70% Percentile

Post-Recovery Water Balance Component	Purisima	Aromas Red Sands
Recharge from precipitation (afy)	5,400	4,200
Modeled protective outflows to ocean-70th percentile (afy)	775	1,950
Flow to Pajaro Valley based on contour maps (afy)	0	370
Total available consumptive use (afy)	4,625	1,880
Non-District consumptive use (afy)	1,992	754
Total available District consumptive use (afy)	2,633	1,126
Return flow percentage excluding septic (afy)	6%	6%
District post-recovery pumping goal (afy)	2,800	1,200
	= 4,000 afy (total)	

4.2 Establishing Recovery Pumping Goal to Achieve Protective Groundwater Levels

In order for the groundwater basin to be protected against contamination by seawater intrusion, less water needs to be extracted to allow groundwater levels to be increased to protective levels. HydroMetrics recommended pumping below the post-recovery goal (4,000 afy) until protective groundwater levels are achieved. The recovery time or how long pumping would need to be reduced in order to achieve protective groundwater levels is dependent on the District's annual pumping as shown in **Table 4-2** below:

Table 4-2: Estimated Time Period to Recover Basin based on Annual Pumping and Level of Uncertainty

Annual District Pumping (acre-feet/year)	Duration to Eliminate Accumulated Pumping Deficit and Restore Basin (years) *	Uncertainty (years)**
2,500	14	4 - 90
2,700	17	4-140
2,900	20	4-270
3,300	30	5- never
3,700	70	7-never

* *Based on 70th percentile protective outflows for post recovery goal*
** *Based on 50th and 90th percentile protective outflows for post recovery goal*

For at least 50 of each model's 100 runs representing the uncertainty of hydrogeologic conditions offshore, the 50th percentile of protective outflows protected the aquifers from seawater intrusion. For at least 90 of each model's 100 runs, the 90th percentile of protective outflow protected the aquifers from seawater intrusion. The 70th percentile was used to establish the post-recovery pumping goal to address uncertainty without being overly conservative.

4.3 Additional Factors and Risks Considered

4.3.1 Potential Future Water Quality Standard for Chromium-6

Naturally occurring hexavalent chromium (Chromium-6) is generally present throughout the Aromas Red Sands Aquifer, which currently provides about one-third of the District's water supply and is the primary source of water for the service area from Rio Del Mar to La Selva Beach. Chromium-6 is a known human carcinogen from chronic inhalation exposure and a probable human carcinogen from chronic oral exposure. Currently, total chromium is regulated under the primary drinking water standard or Maximum Contaminant Level (MCL) of 50 parts per billion (ppb) for the State and 100 ppb for the Federal government. In 1999, the State began to evaluate whether a specific MCL was appropriate for Chromium-6, based on concerns about potential carcinogenicity when ingested.

A California State MCL has yet to be developed; however, a draft Chromium-6 Public Health Goal (PHG) of 0.02 ppb was adopted by the State in July 2011. PHGs are non-enforceable goals based solely on public-health considerations, and do not take practical risk management factors (e.g., treatment technology availability, benefits, and costs) into consideration. Drinking water with contaminant levels exceeding a PHG can still be considered acceptable for public consumption.

The California Department of Public Health (CDPH) will use the adopted PHG to develop a Chromium-6-specific State MCL. A Federal drinking water standard for Chromium-6 is also being developed by the U.S. Environmental Protection Agency (US EPA). Depending upon the standards adopted by the CDPH and US EPA, meeting future regulations for Chromium-6 may impact up to six production wells within the District's system as shown in **Table 4-3** and would require some level of treatment or abandonment.

Table 4-3: Potential District Wells Impacted by Chromium-6 Regulations

District Groundwater Production Well	Current Detected Levels of Chromium-6 (ppb)	Estimated Pumping Capacity Based on Well Master Plan (afy)
Bonita	12	650
Country Club	7	300
San Andreas	16	800
Seascape	18	620
Altivo	39	500
Sells	30	430

4.3.2 Climate Change

Climate change is another factor to consider in the context of all other stresses impinging on local water resources. Climate change research indicates the potential for more intense storms with greater runoff and less recharge into the aquifers, more frequent/intense droughts and increasing sea levels.

Notable climate change predictions related specifically to our coastal community include:

- Reduced recharge: Preliminary findings predict as much as a 30% reduction in local recharge between 2071-2100 (USGS, 2012); and
- Sea level rise: Estimate 14 inches of sea level rise by year 2050 based on 1990 sea level (Vermeer/Rahmstorf - Proceedings of National Academy of Science) and an average of 14.8 inches of sea level rise relative to year 2000 sea level (Scripps Institution of Oceanography, 2012). Both referenced climate change sources predict significant sea level rise between years 2050 and 2100.

With the potential decline in groundwater recharge rates, in conjunction with predicted rises in sea level, the District recognizes that planning for the impacts of climate change is an increasingly important component of water planning as it likely will further reduce the amount of groundwater availability. Additionally, sea level rise will increase the risk and extent of seawater intrusion as increased pressure from rising seawater pushes the freshwater/seawater transition zone inland at an increased rate.

4.4 Supply Shortfall and Need for Water

4.4.1 2006 IRP Supply and Demand Projections

Demand projections in the 2006 IRP were based primarily on the District's 1999 Draft IRP and revised to reflect a new start year of 2000 (5,463 af) rather than starting with the 1996 estimate of 5,480 af. Assumptions and trends were then applied to establish demand projections through 2030. At the time, the sustainable groundwater yield was estimated to be no more than 4,800 afy. With the inclusion of water conservation programs and efforts, the District's water shortage problem was estimated to be 10-15% s shown in **Figure 4-1**.

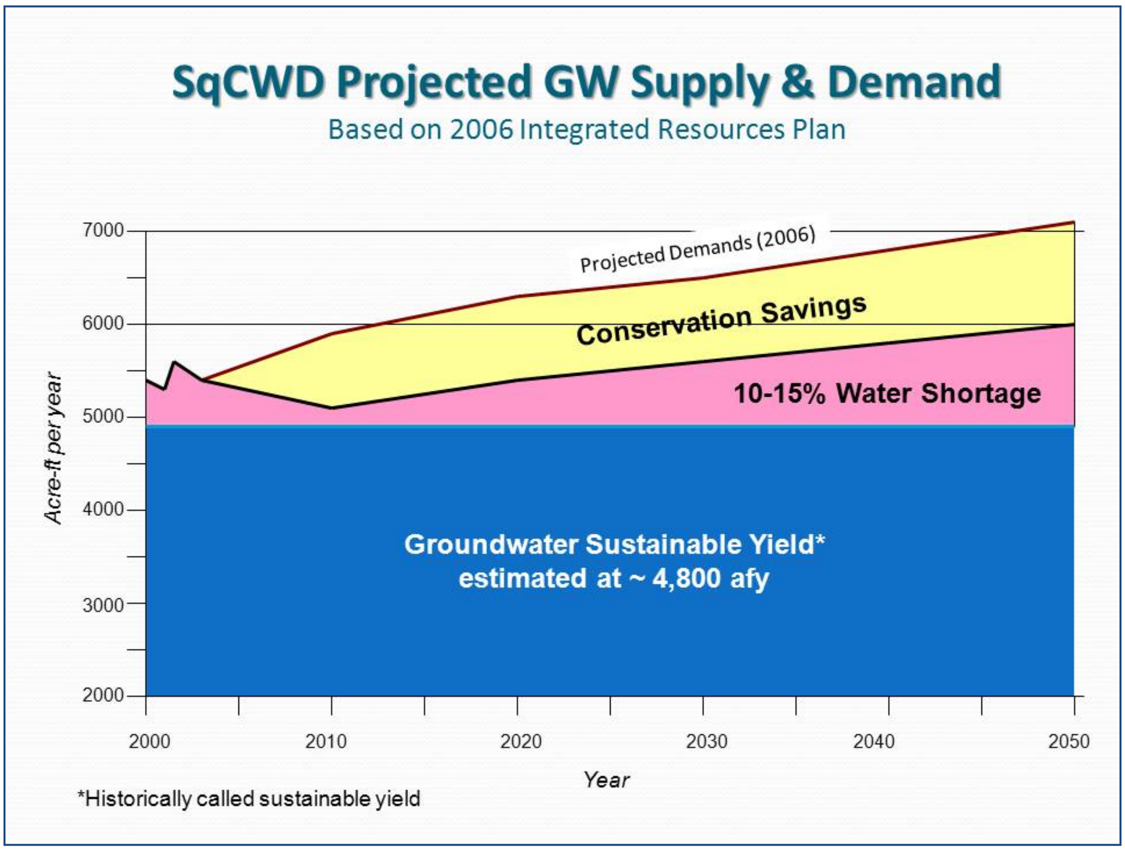


Figure 4-1: Projected Groundwater Supply and Demand based on 2006 IRP

4.4.2 Current Supply and Demand Projections

The projected water demand originally identified in the 2006 IRP was not realized and updated demand projections were conducted for the 2010 UWMP. A reduction in demand projections was based on two significant factors: (1) declines in annual water production due to conservation and other factors; and (2) decreases in baseline population estimates within the District's service area. Further explanation on the analysis conducted to revise the District's projected water demand is contained in Section 4 of the District's 2010 UWMP.

The District's most current updated demand projections and anticipated conservation savings from the 2010 UWMP, and the recovery pumping goal of 2,900 afy are used to estimate the District's supply shortfall as shown in **Table 4-4** and **Figure4-2**:

Table 4-4: District's Future Supply and Demand Projections, 2015-2030

	2015	2020	2025	2030
Projected Demand before conservation savings (afy) *	4,621	4,738	4,787	4,834
Anticipated conservation savings (afy) *	173	347	533	718
Adjusted Projected Demand (afy) *	4,448	4,392	4,254	4,116
Limited Groundwater Pumping Goal to Restore Protective GW Levels (afy)	None	2,900	2,900	2,900
Estimated Supply Shortfall (afy)		**1,492**	**1,354**	**1,216**

* Source: 2010 District UWMP.

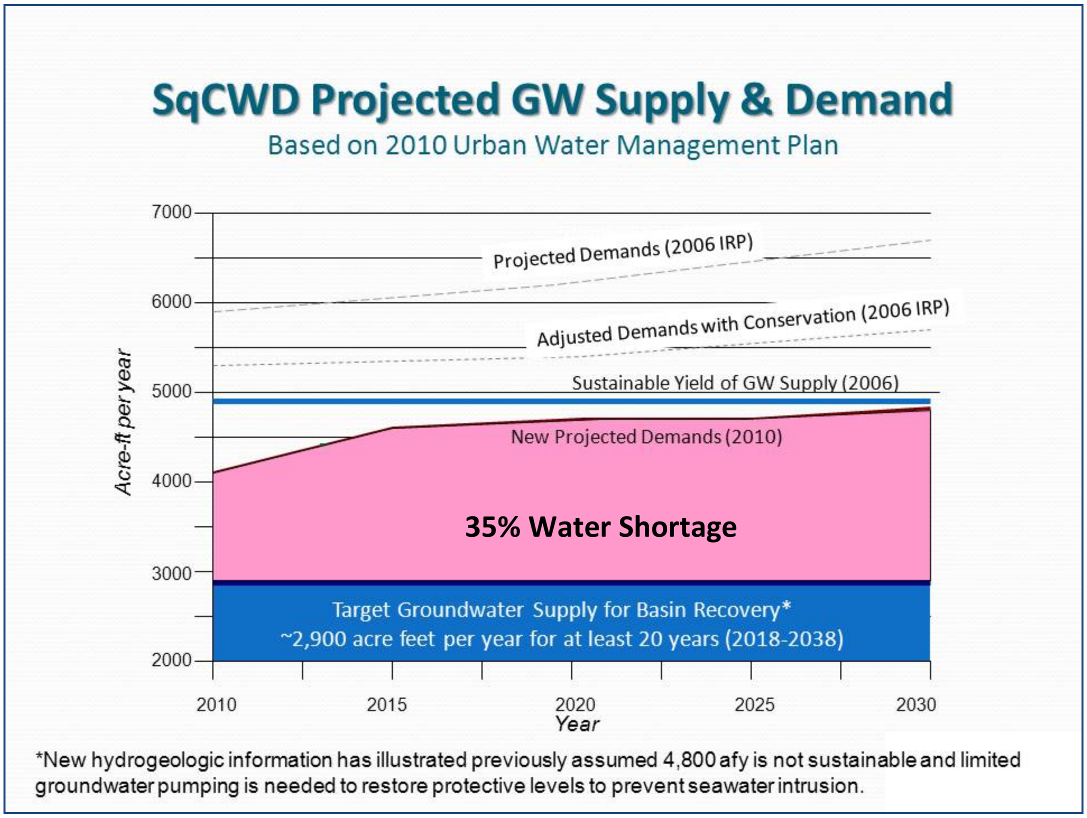


Figure 4-2: District's Projected Groundwater Supply and Demand based on 2010 UWMP

4.5 Establishing Targets for Supplemental Water Supply Quantity, Availability Date, and Duration

At the March 6, 2012 Workshop, the Board established the following water supply planning objectives:

To recover the groundwater basin:

- Limit groundwater pumping to 2,900 afy (also known as the recovery pumping goal);
- Reduce groundwater pumping to recovery pumping goal within 6-8 years which was selected by the Board as a reasonable time period given the process required to develop projects; andContinue to limit groundwater pumping at the recovery pumping goal for approximately 20 years (year-in, year-out) to achieve basin recovery and restore groundwater levels to prevent seawater intrusion.

Once the groundwater basin has been restored and protective groundwater levels are achieved:

- Limit groundwater pumping to 4,000 afy on average (also known as the post-recovery pumping goal); and
- Modify the post-recovery pumping goal, as needed, based on adaptive management and observed water levels.

5. SUPPLEMENTAL WATER SUPPLY ALTERNATIVES

In order to limit groundwater pumping to the recovery pumping goal of 2,900 afy to restore the basin and prevent seawater intrusion, a supplemental source of water is critical to meet the District's supply shortfall. Several water supply alternatives were identified in the 2006 IRP that warranted re-evaluation based on the new recovery pumping goal, as well as other information that has transpired since the 2006 IRP. In addition, the District looked at several new potential supply alternatives:

1. No Project- Continue groundwater withdrawals as-is
2. **scwd**^{2} Regional Desalination with the City of Santa Cruz (City)
3. Soquel Creek Off-Stream Diversion
4. District-Only Desalination within Soquel Creek Water District's Service Area
5. Satellite Reclamation (small-scale recycled water)
6. Glenwood Reservoir
7. Water Exchange
8. District-Only Desalination (similar to **scwd**^{2} Project)

For the alternatives 1-8 listed above, information presented within this Section 5 identified the current stage of project development and assessed the options using the same criteria: availability, reliability, implementation risk and uncertainty, operational flexibility, cost, environmental impacts, water quality, and ease of implementation.

The District Board also looked at potential water use restriction alternatives to achieve the pre-recovery pumping goal without a supplemental supply:

9. Mandatory Water Restrictions with the Enforcement Approach
10. Mandatory Water Restrictions with the Full Toolbox Approach

For the alternatives 9-10 listed above, a detailed discussion of each alternative, including but not limited to the various components, cost, and customer impacts, is included in Section 6.

5.1 No Project: Continue groundwater withdrawals as-is

Concept:

- The District would continue pumping the groundwater basin to meet the water demands of current and future customers.

Availability:

- As stated in Sections 3 and 4, the District has identified that current withdrawals from the groundwater basin are not sustainable. The Soquel-Aptos basin is in a state of overdraft and more water is extracted than is naturally recharged through rainfall.
- Per HydroMetrics, the District's hydrogeologist, the safe yield for the District to extract out of the Soquel-Aptos basin is 4,000 afy once the basin has recovered. Prior to recovery, the recommended recovery pumping goal is 2,900 afy. Both of these yields are above the current and future District's water needs.

Implementation Risk:

- If the District continues to pump the groundwater basin in excess of the pre-recovery goal of 2,900 afy, seawater intrusion may advance.
- The District's groundwater monitoring program has shown that groundwater levels are too low to protect against seawater intrusion. To naturally raise groundwater levels, less water should be extracted out of the groundwater basin.
- Seawater intrusion reduces the amount of groundwater supply. Also, private wells near the coast may be impacted with seawater contamination.

Environmental and Water Quality Impacts:

- Primary environmental impact includes continued unsustainability of the groundwater basin and advancement of seawater intrusion.
- Once seawater intrusion occurs, it contaminates the fresh groundwater available and either requires expensive treatment or cannot be remediated and is lost as a resource.
- Future climate change impacts will further reduce groundwater recharge by as much as 30% which will further impact the amount of available groundwater in the future.

Cost and Flexibility:

- The cost of this alternative is unknown.
- The continued reliance on groundwater only provides no flexibility or reliability to the District's water supply system. If seawater intrusion occurs, the only "back up" plan would be to initiate mandatory water restrictions to reduce water demands to the limited portion of the groundwater supply that has not been contaminated.

Since the mid-80's with the installation of the District's extensive groundwater monitoring program and the developments of the Integrated Resources Plans in 1999 and 2006, the District has been proactive in responding to the overdraft conditions of the basin and addressing the water supply needs of its customers and the limited availability of its sole source of groundwater.

Continued use of the groundwater basin at current or future projected levels is not practical, feasible, or environmentally responsible.

5.2 scwd² Regional Desalination with the City of Santa Cruz

Concept:

- The District would share a 2.5 million gallon per day (mgd) seawater desalination project with the City.
- The facility would be used primarily by the District during non-drought conditions to meet customer demand and reduce groundwater pumping to allow for natural recharge of the aquifer and prevent seawater intrusion.
- The project was identified by the City and the District as the preferred option to further evaluate after separate studies: the City's Integrated Water Plan (2005) and the District's Integrated Resources Plan (2006).

Potential Yield: The minimum guarantee from this alternative is 1,148 afy .

Availability:

- Ocean water from Monterey Bay would be used as the source supply and, for practical terms, considered always available.
- The City and District have devised a Priority of Use schedule whereby the City receives first call of the plant's capacity (2.5 mgd) from May-October and the District receives first call of 2.5 mgd from December-March. For April and November, the City and District share first call of half the plant's capacity (1.25 mgd) respectively.
- In months that the City does not need or want its full allocation of desalinated water, the District may opt to run the plant, not to exceed 2.5 mgd.

Reliability:

- The desalination reverse osmosis treatment process has proven to be reliable.
- During extended drought periods, the City may opt for full operation during May-October and the District would need to rely on groundwater sources for those months.

Implementation Risk and Uncertainty:

- Implementation risk of the treatment process is low as it has been proven successful around the world and at the **scwd²** pilot plant.
- There is a higher level of implementation risk with the radial collector wells that have been identified as a potential subsurface intake.
- There is minimal implementation risk for the screened open-ocean intake.
- There is minimal implementation risk for the brine discharge.
- The agencies have been working with various regulatory agencies to discuss current permitting requirements and how they would apply to the project.
- The project requires a partnership with the City which increases project complexity and requires continued cooperation.
- The decision to have voter approval of this project increases the risk and uncertainty.

Operational Flexibility:

- The treatment process includes Reverse Osmosis (RO) membranes which provide operational flexibility.

- The plant can be sized to produce 2.5 mgd for City's needs but operated at a lower amount (approx. 1.5 mgd) to meet the District's needs.
- The plant could be expanded up to 4.5 mgd to meet City's future needs; however, any expansion would require a separate EIR and permitting. The District is not included in the expansion component.

Cost:

- Preliminary capital cost estimates are around $115 million (±30% contingency) to be shared as follows: 59% City/41% District. The District's share is estimated at $47 million.
- Operational costs are estimated at $2 million per year shared according to use.

Environmental and Water Quality:

- The project is currently undergoing thorough environmental review with a draft EIR scheduled to be released in late 2012.
- Both partners have committed to a net-carbon neutral project.
- Water quality (WQ) tests conducted during the pilot plant operation met and/or exceeded all local, state, and federal water quality standards.
- If a red tide occurs, procedures will be implemented to assure WQ standards can be met.

Ease of Implementation:

- Several permits are required including Coastal Commission, State Lands, Army Corps of Engineers, and Regional Water Quality Control Board.
- The project requires a continued partnership with the City of Santa Cruz.
- There is organized public opposition to this project.

5.3 Soquel Creek Off-Stream Diversion

Concept:

- Surface water from Soquel Creek would be diverted during winter months to reduce groundwater pumping and allow for natural recharge of the aquifer.
- Creek water would be diverted to a settling pond, then to a new surface water treatment facility and into the District's conveyance system for direct use.
- If water from the diversion exceeded immediate demand and available storage capacity, excess water could potentially be used to recharge the basin via injection wells.

Potential Yield: When most recently evaluated in 2004, it was estimated that an average of about 1,500 afy could be diverted. However, changes to the District's water rights status, recent Habitat Conservation Plan (HCP) regulations, and other factors could reduce the previously estimated yield.

Availability:

- In 2004, Linsley Kraeger Associates estimated an average annual yield of 1,500 afy using a 37 cubic feet per second (cfs) bypass (which assumed removal of a downstream impediment), a diversion capacity of 14 cfs, a storage capacity of 49 af and a treatment plant capacity of 14 cfs with operation from November 1 to April 30 (6 months).
- The adjudication fully appropriates the Soquel Creek from April 1 to November 30 so the District would theoretically only be able to divert water from December 1 through March 31

(4 months). As the 2004 yield estimate of 1,500 afy accounts for two additional months of water diversion, the actual average yield is likely less than 1,500 afy.

- In 2007, the District's water rights application was canceled due to inaction and the petition for reassignment was closed. The District may have "in trust" 7,250 afy for the proposed Glenwood Reservoir and 6,800 afy for the proposed Upper Soquel Creek Reservoir that could possibly be transferred to a downstream diversion location with a new application. An application seeking to access and change the point of diversion for 7,200 afy reserved under the original adjudication could result in nothing approved or a much smaller allocation (verbal communication with water rights attorney Peter Kiel, March 6, 2012).
- Soquel Creek is recently listed on the Coho Salmon Recovery Plan and is already federally listed for steelhead.
- A feasible diversion site and sufficient land for a 49 af storage reservoir would need to be acquired.

Reliability:

- In some years, little or no diversion may be allowed. Less than 1,500 af would be available in almost half the years.
- Given that this supply would only be available during the winter months when water demand is lowest, surplus supply would need to be stored in the groundwater basin through aquifer injection. Previous analysis conducted by Derrik Williams of HydroMetrics concluded that existing Purisima Formation wells had limited injection capacity and up to 9 dedicated injection wells could be needed.

Implementation Risk and Uncertainty:

- To transfer potential water rights from the proposed Glenwood and/or Upper Soquel Creek Reservoirs, the District would have to re-apply for water rights for a diversion on Soquel Creek.
- This process could take upwards of 10 or more years.
- A Habitat Conservation Plan (HCP) may be required which would likely reduce the amount of surface water available.

Operational Flexibility:

- This alternative is dependent on obtaining water rights on Soquel Creek and if an HCP will be required.
- The available quantity of surface water depends on numerous external factors.
- The treatment plant will need to be sized to have flexibility in yield and water quality.

Cost:

- The capital cost estimate from the 1999 IRP was $19-25 million without injection wells. In 2015 dollars, this estimate increases to approximately $40 million.
- Operating and maintenance costs were estimated at $450,000 per year in 1999.

Environmental and Water Quality:

- Soquel Creek is biologically sensitive. Impacts to fisheries and other species will be major factors.
- A full environmental review would need to be conducted and a project-level EIR prepared.

Ease of Implementation:

- Applying for water rights on Soquel Creek could be a complicated and lengthy process.
- It is unknown if a HCP would limit available yield.
- Requires new storage capacity and a new surface water treatment plant.
- District staff has never operated and maintained a surface water treatment plant before. A surface water treatment plant would require a different regulatory permit process and operational methods, and a higher level of operator certification.

5.4 District-Only Desalination within Soquel Creek Water District's Service Area

Concept:

- The District would solely develop a seawater desalination project located within the District service area capable of producing approximately 1.5 mgd. The facility would be used to meet customer demands and reduce groundwater pumping to allow for natural recharge of the aquifer and prevent seawater intrusion.

Potential Yield: The yield is estimated at 1,680 afy.

Availability:

- Ocean water from Monterey Bay would be used as the source supply and, for practical terms, considered always available.
- Locations for intake, treatment plant siting and brine disposal would need to be identified. A preliminary geologic assessment for using beach wells for intake or brine disposal was not promising due to shallow sand in the area. There is no known existing wastewater outfall or other offshore structures that could be utilized for intake or brine discharge.

Reliability:

- The desalination treatment plant process using RO membranes has proven to be reliable.
- The reliability for other components (e.g., type of intake, brine handling, etc.) are unknown.
- In 2000, the District performed a reconnaissance-level assessment of the potential for subsurface intakes in the District service area with findings that vertical wells are infeasible. Other technologies (such as "Ranney" collectors) could be considered; however, feasibility and reliability are unknown.

Implementation Risk and Uncertainty:

- The District likely would have sole ownership for decisions on the facility.
- As this project has not undergone any feasibility evaluation (other than the potential for subsurface intake) there are a lot of unknowns associated with this alternative. A major issue would be permitting given the current policies of the Monterey Bay National Marine Sanctuary.

Operational Flexibility:

- The treatment process includes RO membranes which provide operational flexibility.
- The plant could be sized to produce quantities to meet the District's needs.

Cost:

- Cost estimates have not been done on this option.
- As a District-only project, there is no cost sharing opportunity unless the District decided to pursue other partners.

Environmental and Water Quality:

- WQ tests conducted during the regional desalination project pilot plant operation met and/or exceeded all local, state, and federal water quality standards.
- If a red tide occurred, procedures would be implemented to assure WQ standards can be met.
- A full environmental review and an EIR would be needed.

Ease of Implementation:

- This alternative may require conducting the same tests/studies performed with the scwd^2 project (e.g., pilot testing, entrainment, watershed sanitary survey, etc.), thus increasing the cost and project implementation time.
- The same permit process as the scwd^2 project will be required with the Coastal Commission, State Lands, Army Corps of Engineers, and Regional Water Quality Control Board, etc.
- The project would likely take at least 10 years (the scwd^2 desal project evaluation is on year 7).

5.5 Satellite Reclamation (small-scale recycled water)

Concept:

- This alternative would provide non-potable water to large irrigation users using small-scale, satellite reclamation plants (SRP) to treat wastewater. Several large-irrigation sites were evaluated, but the feasibility criteria limited application to only one site (Seascape Golf Course (SGC)).

Potential Yield: It was estimated that this alternative could reduce SGC's irrigation demand by 134 afy. This reduction could benefit the groundwater basin; however, it would not reduce the District's pumping yield as SGC uses their privately owned well to produce water.

Availability:

- Based on Black and Veatch's 2009 *Water Recycling Facilities Planning Study*, SGC was identified as the only potential site within the District's service area capable of using an SRP to produce non-potable water for irrigation purposes. The yield was estimated at 134 afy.
- SGC currently operates its own well. If SGC was to reduce non-potable water use by 134 afy, it could help overdraft conditions within the basin; however, it would not reduce the potable water needs of the District.

Reliability:

- SRPs are a proven technology for recycling wastewater for non-potable uses (e.g., landscape irrigation).
- The available yield of non-potable water is dependent on the amount of available wastewater. Sufficient volumes of wastewater must remain in the sewer system to maintain

adequate collection parameters (flushing velocity and scour potential). Therefore, the available yield is limited by factors that cannot be controlled by the District. Based on Black &Veatch's 2009 study, there will be times when insufficient wastewater supply is available to meet SGC's water demand.

Implementation Risk and Uncertainty:

- SRPs have been used by other municipalities to remove flows from nearby sewers to produce irrigation water closer to the use area. This approach reduces the need for installation of lengthy pipes/pumps from a centralized wastewater plant to a large irrigation site.
- This alternative requires operational/cost agreements with SGC.

Operational Flexibility:

- SRPs have the potential to operate continuously year-round; however, the amount of irrigation water needed varies by season. There is higher demand in summer months and much lower demand in the winter.

Cost:

- Capital costs for one SRP to serve the SGC were estimated at $10 million in 2009.
- Operational costs for one SRP to serve the SGC are estimated at $1 million per year.
- The estimated cost of recycled water produced is approximately $7,300 per af.

Environmental and Water Quality:

- Water produced from a SRP is not for potable use and would only be used for irrigation of the golf course.
- The project would need to go through the environmental review process.

Ease of Implementation:

- SGC would be the user of the recycled water to meet their irrigation needs so implementation is dependent on operational use agreements. Hatch and Parent, who represent American Golf Corp. SGC, submitted a letter in 2007 regarding their concerns and stipulations on use of recycled water, cost, and interference with course operation and liability.

5.6 Glenwood Reservoir

Concept:

- This alternative would involve building a dam and reservoir on Soquel Creek, and would allow the District to reduce groundwater pumping to allow for natural recharge of the aquifer and prevent seawater intrusion.
- The previously proposed Glenwood Reservoir Project is located on the West Fork of Soquel Creek in the Glenwood Basin.

Potential Yield: The District holds an "In trust" water right of 7,250 af per annum. The actual annual yield from this project is unknown.

Availability:

- The District owns parcels totaling approximately 200 acres in the proposed Glenwood Reservoir area.
- Calculations of fish flow requirements and net annual retention in the proposed reservoir have not been done.

Reliability:

- Assuming sufficient storage capacity, this could be a reliable source of supply.

Implementation Risk and Uncertainty:

- This alternative was previously determined infeasible because of significant environmental and regulatory issues. Those issues have only magnified since the original evaluation.
- It is the current policy of the State Water Resources Control Board to deny any new on-stream dam applications (verbal communication with water rights attorney Peter Kiel, March 6, 2012).
- Numerous on-stream reservoir projects in Central California have been mired in prolonged and contentious permitting phases. California Fish & Game and National Marine Fisheries Service adopted guidelines specify that new permits for on-stream dams should be avoided.

Operational Flexibility:

- The West Branch of Soquel Creek, in the area of the proposed reservoir, does not overlie an area that would accommodate deep recharge of the Purisima Formation; therefore, this project would be limited to surface water storage and not direct groundwater recharge.
- Operation of a reservoir and the available yield would be subject to multiple permitting requirements.

Cost:

- The cost of this alternative is unknown.

Environmental and Water Quality:

- There are likely environmental impacts to threatened and endangered species, including but not limited to steelhead and Coho salmon.
- Dams typically present complete barriers to fish migrations, leading to significant population declines. Fish ladders are not always effective at mitigating this problem.
- Downstream aquatic habitats are impacted by restricting sediment transport.
- Solar radiation elevates water temperatures in reservoirs possibly making summer and fall water releases for habitat preservation too warm to support rearing juvenile steelhead and may exceed the species' tolerance range.
- Non-native predator species such as large-mouth bass and bullfrogs often become established in reservoirs to the detriment of native species populations.

Ease of Implementation:

- This alternative is considered infeasible based on current knowledge and understanding of regulatory climate. It would require State Water Resources Control Board water rights approval and permitting and an Army Corps of Engineers permit.
- District staff has never operated and maintained a surface water treatment plant before. A surface water treatment plant would require a different regulatory permit process and operational methods, and a higher level of operator certification.

5.7 Water Exchange

Concept:

- Santa Cruz County is leading the evaluation of amending the City of Santa Cruz's (City) water rights and making infrastructure improvements to provide surplus winter San Lorenzo River water to neighboring water agencies in both the short-term and long-term to restore groundwater levels and increase available storage for fish flows and future conjunctive use (including the limited transfer of stored groundwater back to the City during drought periods).

- As proposed by the County, the District could be the sole beneficiary of a short-term/emergency water exchange, but with construction of an intertie, Scotts Valley and San Lorenzo Water Districts (SVWD and SLVWD) would have first priority.

Potential Yield: The potential yield is not yet determined. Also, there is no indication that it would be more than a small portion of the amount needed by the District.

Availability:

- First priority is assumed to go to SVWD because they share the same hydrogeologic unit with the City and there are potential environmental benefits to Bean Creek.
- Available quantity is unknown at this time and confluence modeling is required to verify when and how much water would be available during a range of conditions that could be expected to occur.
- The yield available to the District would be reduced if the District were to transfer groundwater back to City during drought periods. Prior to determining any quantity of groundwater the District may transfer back to the City prior to basin recovery, the potential impacts to Purisima A Aquifer overdraft conditions would need to be evaluated in conjunction with the City's current operational plan for their Beltz wells which are also located in the Purisima A Aquifer. As detailed in this plan, the City increases groundwater supply from approximately 450 af in wet years to 520 af in normal and dry years, and to 645 af in critically dry years all while maintaining a 25 year average of 520 acre-ft per year.

Reliability:

- Surplus water may be diverted from the San Lorenzo River from December through March, and only when a down-stream bypass flow of at least 25 cfs could be maintained.
- Diversions would not take place during periods of high turbidity.
- In some years, little or no diversion would be allowed; therefore, reliability is low.

Implementation Risk and Uncertainty:

- The City may have to modify their water rights to transfer or change the place of use for the Tait Street and possibly Felton diversions. The unconfirmed estimate of time needed by the City to amend their water rights is 10-20 years if approved at all.
- The City is currently in negotiations regarding their Habitat Conservation Plan which may further reduce the amount of surface water available for transfer.
- An emergency (temporary) change of use permit, if approved, is limited to 180 days. Currently, there is no information on the timeframe for acquiring an emergency permit and

whether it could be reasonably obtained. Multiple temporary re-applications while pursuing a long-term transfer may be subject to full environmental and hydrologic analyses. Additionally, fisheries agencies may place restrictions even on short-term emergency transfers (verbal communication with water rights attorney Peter Kiel on March 6, 2012).
- An emergency condition must be demonstrated to receive an emergency change of use permit.
- The California Department of Public Health will require permits for consecutive systems and interties.

Operational Flexibility:
- This alternative is dependent on agreements with City of Santa Cruz as the willing supplier.
- The available quantity of water would depend on external factors (see Reliability above).
- Any increase in yield would depend on the City's ability/interest in expanding water rights, making possible infrastructure improvements to their conveyance systems from Tait Street to the Graham Hill Treatment Plant, and performing treatment plant expansion/upgrades.
- The completed intertie design concept for the Regional Desal Project would be applicable to a water exchange as well.
- Delivered water quality issues associated with this alternative would be similar to the **scwd^2** Regional Desalination Project.

Cost:
- The cost of this alternative is unknown at this time.
- The current study does not include funding for CEQA.

Environmental and Water Quality:
- The San Lorenzo River is biologically sensitive. Impacts to fisheries and other species need thorough evaluation.

Ease of Implementation:
- A change in water rights is anticipated to be a complicated and lengthy process.
- It is currently unknown whether HCP negotiations will reduce the City's available winter diversion allowance.
- This alternative would require a partnership agreement with City.

5.8 District-Only Desalination (similar to scwd^2 Project)

Concept:
- The District would solely construct a seawater desalination project similar to the scwd^2 Project that could produce at least 1.25 million gallons per day, in that the same infrastructure (e.g.., intake point, treatment facility design and general siting, brine disposal methods, etc.) would be used.
- The facility would be used by the District to meet customer demands and reduce groundwater pumping to allow for natural recharge of the aquifer to prevent seawater intrusion.

- This project was identified as a potential alternative should the scwd² Regional Desalination Project not materialize.

Potential Yield: The minimum yield from this alternative would be 1,400 afy based on a plant capacity of ~1.25 mgd.

Availability:

- Ocean water from Monterey Bay would be used as the source supply and, for practical terms, considered always available.
- Without the City of Santa Cruz or other water agencies as partners in the project, the District would have sole priority to the desalinated water supply.
- The District may evaluate potential opportunities to sell and/or distribute water to other nearby water agencies.

Reliability:

- The reverse osmosis treatment process has proven to be reliable.

Implementation Risk and Uncertainty:

- This alternative primarily has the same risk and uncertainty as identified for the scwd² desalination project.
- This project assumes that the City infrastructure would be available for the District to utilize and operate (such as location and access for intake, desalination plant, brine discharge, and pipeline conveyance).
- The District likely would have sole ownership for decisions on the facility.
- The District would have to fully fund this project by itself or assemble partners.

Operational Flexibility:

- The treatment process includes RO membranes which provide operational flexibility.
- The plant could potentially operate at a higher capacity to aid in recovery of the basin. Once the groundwater basin is restored, the plant could operate at a lesser capacity.

Cost:

- Based on preliminary costs for the scwd² project, capital costs could be upwards of $100 million.
- The operational costs are approximately $2 million per year.
- The District could potentially sell water to other agencies which would offset a portion of the District's costs.

Environmental and Water Quality:

- The project would need to go through environmental review.
- WQ tests conducted during the regional desalination project pilot plant operation met and/or exceeded all local, state, and federal water quality standards.
- If a red tide occurs, procedures will be implemented to assure WQ standards can be met.

Ease of Implementation:

- Several permits are required including Coastal Commission, State Lands, Army Corps of Engineers, and Regional Water Quality Control Board.
- This alternative would require agreements and permits with the City of Santa Cruz to utilize land and infrastructure within the City limits as well as potable water conveyance.
- The District is uncertain that it would be able to pay for a project of this size/scale by itself.

6. EVALUATION OF MANDATORY WATER RESTRICTION ALTERNATIVES

In lieu of a supplemental supply project developed, two potential "No supplemental supply" alternatives were identified:

- Mandatory Water Restrictions with the Enforcement Approach
- Mandatory Water Restrictions with the Full Toolbox Approach

This section includes a description of each mandatory water restriction alternative and the analysis performed.

6.1 Mandatory Water Restrictions with Two Approaches

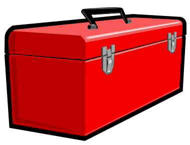
On June 5, 2012, the District Board conducted a Workshop to review the analysis of a "15% design" effort to identify and evaluate conceptual conservation-based scenarios that, in the absence of a supplemental water supply, could possibly reduce demand to the District's recovery pumping goal of 2,900 acre-feet per year (afy) and maintain the savings over a 20-year period. The analysis included evaluating (1) the methods (e.g., direct install of water-saving measures, enhanced rebates, education, behavioral outreach, etc.) that would be implemented to achieve the required water savings; (2) the total estimated costs (including staffing) to the District and the resulting impact upon rates; (3) the potential consequences to both customers and the District; and (4) the estimated level of risk and the chances of success associated with reducing demand to 2,900 afy.

The Enforcement Approach

The Enforcement Approach includes customized water budgets for all customers, monthly billing, price signals, enforcement, a moratorium on all new/expanded services, communication and behavior modification, and education. Typical residential customers would receive a monthly water budget or allocation for their household that allows for the use of about 53 gallons of water per person per day (gpcd). This is approximately a 35% reduction from the baseline residential per capita value. The District would continue to offer conservation rebates and provide guidance, but essentially, customers would be required to purchase and install water conservation devices and modify their water use as needed to comply with their water budgets. Water use in excess of the budgeted amount would be subject to a significant price penalty. Repeated water use in excess of the amount allowed by a water budget may result in having a flow restrictor placed on the service line.

The total estimated cost for this mandatory water restriction alternative is at least $117 million. The District's share of the total cost is ~$40M (to implement staffing and the components listed above for 20 years) with the remainder to paid up-front by District customers. These customer-incurred costs include purchasing/installing water-saving devices and measures to get water use within the allotted water budgets. The District recognizes this approach may cost more than the "Full Toolbox Approach" below because the work will be carried out by individual customers without the benefit of volume pricing that would be available to the District under the "Full Toolbox Approach".

The alternative would require an increase in water rates for all customers to offset the District's program costs (i.e. $40M), as well as the reduction in District revenue due to the decreased water use and sales.



The Full Tool-Box Approach

The District would provide the same programs as shown in the Enforcement Approach and customers would still have to reduce water use (the same assumed reduction of approximately 35% for typical residential customers). In addition, the District would also directly fund a host of water conservation retrofit actions (i.e. direct install programs) and measures to help customers stay within their allocated budgets. The total estimated cost for this approach is ~$117M. The District would assume 100% of the cost and no up-front cost to the customer would be needed since the District would purchase and install the conservation measures.

The Full Toolbox Approach would result in a higher rate increase than expected for the Enforcement Approach as the District would need to offset a higher program costs (i.e. $117M) as well as the reduction in District revenue due to decreased water use and sales.

Table 6-1 highlights the differences and similarities between the two scenarios in regards to a number of factors including cost, components or measures, impacts to customers, the estimated likelihood of success, and the associated degree of risk.

Table 6-2 provides a comparison of the potential **scwd²** Desalination Project alternative to mandatory water restriction approaches.

<table>
<tr><th colspan="3">Table 6-1: Comparison Chart of Conceptual Mandatory Restriction Scenarios</th></tr>
<tr><th></th><th>Enforcement Approach</th><th>Full Toolbox Approach</th></tr>
<tr><td>Required Water Use Reduction</td><td colspan="2">35%</td></tr>
<tr><td>Estimated Duration Restrictions would Need to be in Place</td><td colspan="2">20 years</td></tr>
<tr><td>Total Cost</td><td>At least $117 million</td><td>$117 million</td></tr>
<tr><td>Cost to District</td><td>$40 M (funded through rates)</td><td>$117 M (funded through rates)</td></tr>
<tr><td>Up-Front Cost to Customers</td><td>At least $77M</td><td>$0</td></tr>
<tr><td>Measures Common to Both Scenarios</td><td colspan="2">Water budgets, moratorium, monthly billing, pricing, communication and behavior modification, education, enhanced rebates, and enforcement</td></tr>
<tr><td>Additional Measures</td><td>No additional measures provided by the District.

Customer would have to purchase and install devices.</td><td>• District purchases/installs toilets, showerheads, faucet aerators and clothes washers for residential customers (est. 80% participation level).
• District purchases/installs toilets and clothes washers for commercial customers (est. 80% participation level).
• District replaces turf with low-water use landscaping, and installs graywater & rainwater catchment, pressure reducing valves and hot water recirculation systems (est. participation levels vary by measure).
• District utilizes re-circulating hydrant flushing device.</td></tr>
<tr><td rowspan="2">Impact to Customers</td><td>More Impact to Customer
• Customer directly funds conservation measures
• Greater potential for financial hardship
• Significant inconvenience</td><td>Less Impact to Customer

• District directly funds conservation measures
• Less inconvenient relative to the “Enforcement Approach”</td></tr>
<tr><td colspan="2">Common Impacts:
• Businesses may have to modify operating practices
• Reduced indoor usage
• As listed for use reductions classified as Stages 4/5 in UWMP (Table 5-9), until water budgets are developed, severely limited or restricted outdoor irrigation, filling of personal pools/hot tubs and water for aesthetic purposes & vehicle washing until water budgets would be imposed.</td></tr>
<tr><td rowspan="2">Potential Success/Risk</td><td>• Customer-Driven
• Low chance of success
• Fully depends on Customer initiative</td><td>• District-Driven
• Moderate chance of success
• Depends less on Customer initiative</td></tr>
<tr><td colspan="2">Both scenarios are conceptual, unproven and carry risk.</td></tr>
</table>

Table 6-2: Financial Analysis and Rate Impacts Comparison Chart of Conceptual Mandatory Restriction Scenarios with scwd² Desalination Project			
	District Water Supply: Groundwater, and Desalination	**District Water Supply: Groundwater Only (with Mandatory Restrictions using Enforcement Approach)**	**District Water Supply: Groundwater Only (with Mandatory Restrictions using Full Toolbox Approach)**
Selected Date for Comparison Purposes	**FY 2022/23**	**FY 2022/23**	**FY 2022/23**
WATER DEMAND (Acre-Feet)			
Total Production	4,337	2,937	2,825
Total Water Sales*	4,091	2,771	2,665
ALTERNATIVE COST to the District (Current $)	$56,065,000 (**scwd²** Project)	$39,852,000 (Enforcement Approach)	$116,436,000 (Full Toolbox Approach)
Existing Conservation Program Costs ($500K x 20 years)	$10,000,000	included above	included above
Additional Water Supply Studies/Projects ($500K x 20 years)	0	10,000,000	10,000,000
Total	$66,065,000	$49,852,000	$126,436,000
ANNUAL EXPENSES (Future $)			
Systemwide Operating & Maintenance	$15,616,000	$13,492,000	$14,036,000
Debt Service	$7,740,000	$3,700,000	$8,430,000
Pay-Go CIP/Other Non-Operating	$2,135,000	$2,593,000	$3,830,000
Total	$25,491,000	$19,785,000	$26,296,000
AVERAGE COST PER UNIT OF WATER (Future $)			
Total Annual Expenses / Total Water Sales			
Average Cost per AF	**$6,231**	**$7,141**	**$9,867**
RATE INCREASES			
Compounded Rate Increases Through 2022/23	99%	103%	182%
Average Annual Increase	6.5%	6.6%	9.9%

*The volume of water sold is less than total production due to system loss, fire protection, etc.

As shown in **Figure 6-1** and **Table 6-2,** the water restrictions that would be enforced under the Mandatory Restrictions scenarios greatly reduce the amount of water produced and sold which results in an increase in water rates and higher average cost per unit of water than with the proposed **scwd²** desalination project.

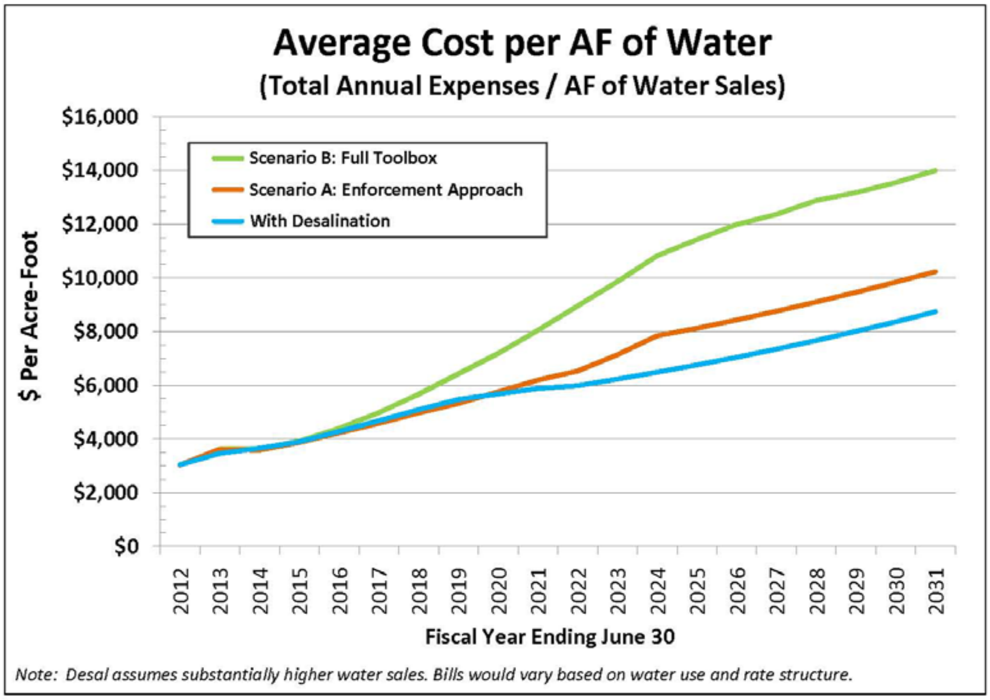


Figure 6-1: Comparison of Average Cost of Water per AF

7. CONCLUSIONS OF SUPPLY AND WATER RESTRICTION ALTERNATIVES AND THE 2012 IRP UPDATE COMPONENTS

7.1 Evaluation of Supply and Water Restriction Alternatives against District's Planning Objectives

As stated in Section 4.5, the District Board established targets for the supplemental water supply quantity needed to reduce groundwater pumping to the recovery pumping goal of 2,900 afy, the availability date of the supplemental supply, and the duration in which the supplemental supply yield would need to be maintained at their March 6, 2012 Workshop. The following questions were used to re-evaluate each alternative identified in the 2006 IRP and to evaluate new alternatives that have been identified since the 2006 IRP against the District's planning objectives:

- Objective #1: Can the project meet the target time period of coming on-line within 6-8 years to reduce groundwater pumping to 2,900 afy?
- Objective #2: Does the project yield adequate volume to meet the water supply shortage needs projected in years 2018-2020? [approximately 1,700 afy]
- Objective #3: Can the project maintain adequate volume over a sustained 20-year period?

Based on the evaluation shown in Sections 5 and 6, a summary of key issues is provided for each alternative below:

No Project- Continue groundwater withdrawals as-is

- No change in District's groundwater withdrawals which will not reduce pumping to 2,900 afy. *(Does not meet objective #1)*
- Alternative does not recognize need to reduce groundwater withdrawals so exacerbation of the groundwater basin to meet water supply needs would continue. *(Does not meet objective #2)*
- The potential for seawater intrusion and contamination of the groundwater basin will increase with the possibility of permanently fouling it as a natural resource. *(Does not meet objective #3)*
- Key Issues: Even with conservation, more groundwater is being extracted than can naturally be replenished by rainfall; continued use of the basin without a supplemental supply or mandatory restrictions is not environmentally responsible; and once the basin is contaminated with seawater intrusion it could be irreversible.

scwd² Regional Desalination with the City of Santa Cruz (City)

- Soonest known availability is within 3-6 years (2015-2018). Technical evaluation complete and environmental review underway. Still would require EIR certification, project approval, permits, and funding. *(Potential to meet objective #1)*
- Has the ability to provide adequate volume to meet supply shortage *(Potential to meet objective #2)*
- Can maintain adequate volume over a 20-year period. *(Potential to meet objective #3)*

- Key issues: Regional project; shared costs with the City of SC; District's portion estimated to be ~$40-$50M; and project scheduled for a ballot vote within the City in 2014.

Soquel Creek Off-Stream Diversion

- Soonest estimated availability is 10-20+ years for water rights. *(Does not meet objective #1)*
- Estimated yield (~1,500 afy) does not meet water shortage needs *(Does not meet objective #2)*
- Uncertain if potential yield can be maintained. With potential fisheries regulations and dependency on rainfall, the actual amounts are likely less. *(Not enough information at this time to know if it has potential to meet objective #3)*
- Key issues: District's water rights application was canceled in 2004; Soquel Creek is listed on the Coho Recovery Plan and is already listed for steelhead; preliminary cost estimate is ~$40M; and available water is dependent on rainfall, potential HCP reductions, and likely only in the wintertime.

District-Only Desalination within Soquel Creek Water District's Service Area

- Soonest estimated availability is approx. 10+ years (technical evaluation and environmental review have not been done). *(Does not meet objective #1)*
- Estimated yield could meet water shortage needs *(Potential to meet objective #2, would require additional technical studies)*
- Unknown if adequate volume could be maintained over a 20-year period *(Not enough information at this time to know if has potential to meet objective #3)*
- Key issues: There are no known structures or opportunities for intake or brine discharge and feasibility was not favorable based on preliminary geologic assessment; costs are unknown; and no cost sharing opportunities with the City of Santa Cruz.

Satellite Reclamation (small-scale recycled water)

- Even though project has the potential of coming on-line within 2-5 years, it does not contribute to the District's pumping reduction since the recycled water would reduce the potable water demands from a private well pumper such as Seascape Golf Course. *(Does not meet objective #1)*
- The estimated yield is ~134 afy and, while it would aid in the recovery of the basin, it does not provide direct benefit to the District to meet its water shortage needs. *(Does not meet objective #2)*
- The yield of this project does not contribute to the District's needs and it is unknown if volume can be maintained over a 20-year period as it is dependent on sewer supply and recycled water demands in the area. *(Does not meet objective #3)*
- Key issues: District does not have any large irrigation accounts that could utilize satellite reclamation plants (SRPs) and reduce the District's potable water use; the irrigation accounts that are applicable for SRP-uses in the District's service area currently use private wells to irrigate so beneficial use would help the basin but not the District's water shortage needs; capital cost was estimated to be $10M; and the estimated cost of recycled water produced was approximately $7,300 per af.

Glenwood Reservoir

- Soonest estimated availability is at least 10-20+ years for water rights and permitting . *(Does not meet objective #1)*
- Estimated yield is unknown. *(Not enough information at this time to know if it has potential to meet objective #2)*
- Uncertain if potential yield can be maintained. *(Not enough information at this time if it has potential to meet objective #3)*
- Key issues: This alternative was previously determined to be infeasible because of the significant environmental and regulatory issues; current policy of the State Water Resources Control Board is to deny any new on-stream dam applications; alternative will have impacts to threatened and endangered species (including but not limited to steelhead and Coho salmon); District has never operated or maintained a surface water treatment plant before; and costs are unknown.

Water Exchange

- Soonest estimated availability is at least 10-20+ years for water rights (long term) and unknown for emergency use. *(Does not meet objective #1)*
- Potential yield has not been established but is estimated to be only a small portion of the amount needed for the District. *(Does not meet objective #2)*
- City of Santa Cruz cannot guarantee that surface water will be available to the District. *(Does not meet objective #3)*
- Key issues: Emergency use application (if approved) is limited to 180 days and should not be used as an interim procedure to obtain a long-term permit; County is currently conducting Phase 2 of the Water Exchange study which will include the City's potential available water based on HCP reductions; first priority of available surface water from the City will be for Scotts Valley and San Lorenzo Water District; diversions would not take place during periods of high turbidity and, in some years, little or no water will be available; and costs are unknown at this time.

District-only Desalination (similar to scwd^2 Project)

- Soonest estimated availability is 6-10 years based on the **scwd^2** Project. Would require separate environmental review and all other tasks as outlined in the **scwd^2** Desalination Project Alternative. *(Potential to meet objective #1)*
- Conceptual design would be to size the plant to meet the District's water shortage needs. *(Potential to meet objective #2)*
- Could maintain adequate volume over a 20-year period. *(Potential to meet objective #3)*
- Key issues: Project components would be within the City of Santa Cruz and would require agreements and permits to use the City's infrastructure and associated properties; costs could be upwards of $100M and the District would be solely responsible; and there is uncertainty if the District could fund a project of this size/scale by itself.

Mandatory Water Restrictions using Enforcement Approach

- Implementation of mandatory restrictions would take about 3 years to implement and approximately 10 years to fully reach demand reductions to 2,900 afy. *(Does not meet objective #1)*
- Reduction of customers' water demands would be gradual as water budgets and behavioral change, and installation of water saving devices by customers takes time,

money and effort. It is estimated that reducing water demand to ~2,900 afy would occur in 2022/2023. *(Does not meet objective #2)*

- Mandatory restrictions would need to be in effect for at least 20 years to allow for the groundwater basin to naturally recharge to protective levels. This would be a huge burden on customers, will likely impact the local economy, and carries high environmental risk for the District if water demands increase. *(Does not meet objective #3)*
- Key Issues: Residential customers would be allotted approx. ~53 gallons per person per day; cost estimate for the District is $40M but this does not include the customers' costs to retrofit and make water saving changes at their house/business; reduced water allotments will have financial and lifestyle impacts (as shown in Table 6-1); there is not a known water agency who has restricted water use at these levels for an extended period of time; and this alternative carries high risk that customers can actually reduce their water use and sustain the restrictions for 20 years. Also, average cost of water per acre-foot and the projected average annual rate increases were higher for both mandatory restriction approaches than for the cost and rate increases projected for desalinated water.

Mandatory Water Restrictions using Full-Toolbox Approach

- Implementation of mandatory restrictions would take about 3 years to implement and approximately 10 years to fully reach demand savings to balance with the 2,900 afy supply. *(Does not meet objective #1)*
- Reduction of customers' water demands would be gradual as water budgets and behavioral change, and installation of water saving devices by the District takes time, money and effort. It is estimated that reducing water demand to ~2,900 afy would occur in 2022/2023. *(Does not meet objective #2)*
- Mandatory restrictions would need to be in effect for at least 20 years to allow for the groundwater basin to naturally recharge to protective levels. This could be a huge burden on customers and carries high environmental risk for the District if water demands increase. *(Does not meet objective #3)*
- Key Issues: Residential customers would be allotted approx. ~53 gallons per person per day; cost estimate for the District is $117M which includes the District purchasing and installing water saving devices and measures at homes and businesses; reduced water allotments will have financial and lifestyle impacts (as shown in Table 6-1); there is not a known water agency who has restricted water use at these levels for an extended period of time; and this alternative carries high risk that customers can actually reduce their water use and sustain the restrictions for 20 years. Also, average cost of water per acre-foot and the projected average annual rate increases were higher for both mandatory restriction approaches than for the cost and rate increases projected for desalinated water.

7.2 Selection of the Supply and Water Restriction Alternatives to be Considered

Based on the District's planning objectives and key issues identified above, the alternatives were grouped into three categories for further action: continue to evaluate; place in "reserve"; or, do not consider further.

Continue to Evaluate:

- **scwd²** Desalination Project with City of Santa Cruz
- Water Exchange (as an augmentation project)

"Reserve" for Potential Future Consideration (if above alternatives do not materialize):

- District-Only Desalination (same as **scwd²** but without the City of Santa Cruz as a partner)
- Mandatory Water Restrictions. Various measures identified in this alternative may be implemented based on a cost-benefit analysis.
- Soquel Creek Off-Stream Diversion

Do Not Consider Further:

- No Project- Continue Groundwater Withdrawals as-is
- District-Only Desalination (within District service area boundaries)
- Glenwood Reservoir
- Satellite Reclamation

7.3 Identification of Preferred Supplemental Supply Alternative

Of all the alternatives considered and determined to be feasible in this 2012 IRP Update, the **scwd²** Desalination Project with the City of Santa Cruz is the only project to meet the District's planning objectives of (1) coming on-line within 6-8 years to effectively reduce groundwater pumping to 2,900 afy; (2) having adequate yield capacity to fully meet projected water shortages in years 2018-2020 when groundwater pumping is reduced by 35-40% to 2,900 afy; and (3) allowing the District to meet projected demand yet sustain groundwater pumping at 2,900 afy for a 20-year period. At the March 6, 2012 Board Workshop on Water Supply Planning, the Board reaffirmed the **scwd²** Desalination Project as the preferred supplemental supply alternative to further evaluate. The Board directed staff to focus efforts on the environmental review and expressed concerns related to the growing opposition of the project within the City of Santa Cruz and the fate of the District's water supply planning efforts should the City discontinue their participation in the **scwd²** Desalination Project.

Comments noted from the Board during the March 6, 2012 Workshop specifically related to the **scwd²** Desalination Project include:

- The District should continue to evaluate the **scwd²** Desalination Project for the next three years.
- The District should continue to support the evaluation of a potential water exchange with the City of Santa Cruz; however, this project is not a replacement for the **scwd²** Desalination Project because of the timeframe required to implement the project, the inability of the project to fully meet the yield needed, and the uncertainty that the yield would be consistently available each year for 20 years.
- If the City of Santa Cruz discontinues their participation in the **scwd²** Desalination Project, the District should resume evaluating the Soquel Creek Off-Stream Diversion Project and the District-only Desalination Project (similar to **scwd²** Project).

7.4 2012 IRP Update Components

The 2012 IRP Update is a multi-faceted plan that continues to feature the components identified within the 2006 IRP and now reflects the most current data and updated information. In addition, the District conducted a re-evaluation of several alternatives identified in the previous IRP as well as new potential alternatives.

The key components and findings of the 2012 IRP Update include:

- **Demand Management**
    - Continue and increase conservation efforts, focusing on conservation measures that are estimated to cost less per acre-foot of water saved than other supply options such as the operational cost of desalination; and
    - Evaluate recycled water options as feasible and can be permitted.

- **Groundwater Management**
    - Limit groundwater pumping to the recovery pumping goal of 2,900 afy and restrict pumping to this level until restoration of protective groundwater levels is achieved to prevent seawater intrusion (estimated to be at least 20 consecutive years);
    - Continue monitoring coastal groundwater levels and water quality;
    - Redistribute groundwater pumping inland;
    - Continue to encourage the Soquel-Aptos Area Groundwater Management Joint Powers Authority to establish a Groundwater Replenishment District and encourage the County of Santa Cruz to establish conservation measures for non-District pumpers;
    - Support groundwater recharge protection and enhancement projects and policies;
    - Re-evaluate the post-recovery pumping goal of 4,000 afy once the groundwater basin is restored to determine whether pumping may be increased or decreased; and
    - Use an adaptive management approach to revise the recovery pumping goal and the post-recovery pumping goal based on observed groundwater levels and quality.

- **Conjunctive Use Supplemental Supply Projects**
  - Continue to evaluate the **scwd²** Regional Seawater Desalination Project with the City of Santa Cruz (City); and
  - Continue to support the evaluation of a potential water exchange project with the City of Santa Cruz.

- **Local Supplemental Supply Alternatives**
  - Consider further evaluation of a District-only desalination facility should the **scwd²** Regional Seawater Desalination Project with the City of Santa Cruz no longer be pursued in the future or the feasibility of a modified Soquel Creek off-stream division project; and
  - Continue to evaluate and consider implementing mandatory water restrictions and a moratorium should the **scwd²** Regional Seawater Desalination Project with the City of Santa Cruz no longer be pursued in the future.

REFERENCES

Black & Veatch. (2009, June). *Water Recycling Facilities Planning Study Final Report.* Prepared for SqCWD.

EDAW. (2005, June). *The City of Santa Cruz Program Environmental Impact Report on the Integrated Water Plan*. Prepared for City of Santa Cruz.

ESA. (2006, March 10). *Soquel Creek Water District Integrated Resources Plan*. Prepared for SqCWD.

ESA. (2011) Soquel Creek Water District (SqCWD) *Well Master Plan Environmental Impact Report.* Prepared for SqCWD.

Fiske, Gary & Associates. (2003, June). *City of Santa Cruz Integrated Water Plan*. Prepared for City of Santa Cruz.

Flint, L.E., and Flint, A.L. (2012). *Simulation of climate change in San Francisco Bay Basins, California: Case studies in the Russian River Valley and Santa Cruz Mountains: U.S. Geological Survey Scientific Investigations Report 2012–5132*. 55 p.

HydroMetrics LLC. (2009, January). *Groundwater Levels to Protect against Seawater Intrusion and Store Freshwater Offshore*. Prepared for SqCWD.

HydroMetrics LLC. (2009, September 15). *Modeled Outflow to Achieve Protective Water Levels.* Letter Report prepared for Soquel Creek Water District.

HydroMetrics WRI. (2011, May). *Soquel-Aptos Area Groundwater Management Annual Review and Report Water Year 2010.* Prepared for Soquel Creek Water District and Central Water District.

HydroMetrics WRI. (2011, August). Presentation to SqCWD Board on August 9, 2011 regarding revised estimation of sustainable yield values for aquifer system.

HydroMetrics WRI. (2012, March). *Revised Protective Groundwater Elevations and Outflows for Aromas Area and Updated Water Balance for Soquel-Aptos Groundwater Basin.* Letter Report prepared for Soquel Creek Water District.

Kiel, Peter. (2012, March 6). *Verbal communication with Laura Brown.*

Linsley Kraeger Associates. (2004, February 26). *Description and Assumptions used in the Development and Operation of the Diversion Model on Soquel Creek*. Letter Report prepared for Soquel Creek Water District.

Montgomery Watson, Moore, Iacofano, Goltsman Inc. (1999, June). *Soquel Creek Water District Draft Integrated Resources Plan*. Prepared for Soquel Creek Water District.

Ricker, John, (2011, May 11). *Status Report on the Potential for Surface Water Transfers in Northern Santa Cruz County.* Santa Cruz, CA. Santa Cruz County Environmental Health Department (SCCEH).

Scripps Institution of Oceanography. (2012, July). *Climate Change and Sea Level Rise Scenarios for California Vulnerability and Adaptation Assessment.* Prepared for the California Energy Commission.

scwd[2], Regional Seawater Desalination Program Website. Technical reports and studies available online: www.scwd2desal.org.

Soquel Creek Water District. (2007, April 17). *AB 3030 Groundwater Management Plan for the Soquel-Aptos Area*, Santa Cruz County, California.

Soquel Creek Water District (SqCWD). (2011, September). *Urban Water Management Plan Update 2010.*

Vermeer, M. and S. Rahrnstorf. (2009). *Global sea level linked to global climate change, Proceedings of the National Academy of Sciences of the United States of America, vol. 106 no. 51 21527-21532, December 22.*

8. APPENDIX

Appendix A	Letter Report entitled "*Revised Protective Groundwater Elevations and Outflows for Aromas Area and Updated Water Balance for Soquel-Aptos Groundwater Basin*" prepared by HydroMetrics, WRI (April 3, 2012)

HydroMetrics WRI

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Soquel Creek Water District
PO Box 1550
Capitola, CA 95010-1550

April 3, 2012

Subject: Revised Protective Groundwater Elevations and Outflows for Aromas Area and Updated Water Balance for Soquel-Aptos Groundwater Basin

Ms Brown:

Our January 2009 report documented cross-sectional SEAWAT-2000 models used to estimate groundwater elevations at Soquel Creek Water District's (SqCWD) coastal monitoring wells that protect the basin from seawater intrusion (HydroMetrics LLC, 2009a). A subsequent letter on September 15 included the range of modeled coastal outflows that protect the basin from seawater intrusion after groundwater levels recover to protective elevations (HydroMetrics LLC, 2009b). The outflows needed to protect the Aromas area were incorporated into a water balance developed by Johnson et al. (2004) in an attempt to develop a post-recovery pumping yield for SqCWD in the Aromas area. The letter showed that it is unlikely that the Aromas area can be completely protected to the coast.

This letter report revises the protective groundwater elevations and coastal outflows for the Aromas area, based on protecting the basin at the coastal monitoring wells. The Johnson et al. (2004) water balance calculations for both the Aromas and Purisima areas are updated using the revised coastal outflows and other recently revised estimates for recharge and flows from the Aromas area to the Pajaro Valley. The updated Johnson et al. (2004) water balance is used to calculate SqCWD's post-recovery pumping yields for the Aromas and Purisima areas based on estimates of non-SqCWD consumptive use and return flow in the SqCWD service area.

REVISED PROTECTION LOCATIONS FOR THE AROMAS AREA

The original protective elevations for the Aromas area were based on keeping the freshwater-saltwater interface at the coastline, at an elevation where the interface was historically observed in coastal monitoring wells. The interface was historically observed between the A and B screens in coastal monitoring wells, SC-A2, SC-A3, SC-A4, and SC-A8; which are located from 200 to 1,550 feet inland from the coast. Defining the protective location at the coastline results in a protective interface substantially below the well screens and the historic interface. Figure 1 shows an example of the original protective elevation; simulated by the yellow dot. This protective elevation is at the coastline, at an elevation between the SC-A2A and SC-A2B well screens. The modeled seawater-freshwater interface is slanted similar to the dashed line on Figure 1 so the interface is significantly below monitoring well SC-A2A using this protective elevation.

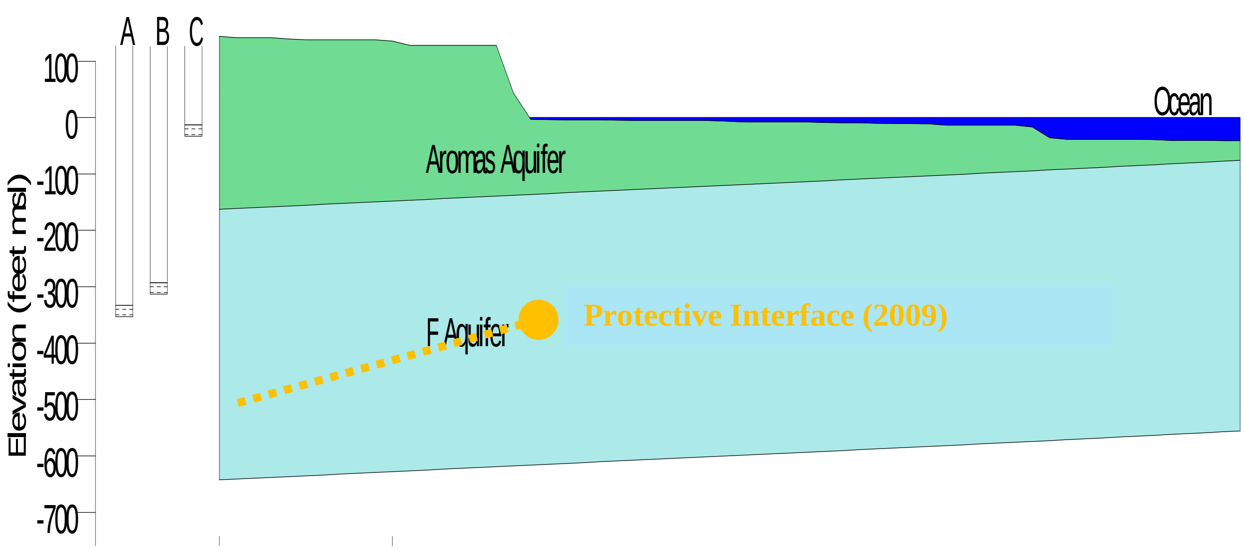


Figure 1. Example of Protective Interface Modeled in 2009 (SC-A2)

At its workshop on August 9, 2011, the Board of Directors decided to change the protective elevation location in the Aromas area to maintain the current interface location. The revised protective elevations are the heads at all but one of the SC-A coastal monitoring wells that will keep the interface within the A and B screen interval (Figure 2). The protective location for the SC-A1 well cluster is below the A screen because the interface has not been observed there. Storing water offshore from the Aromas area is no longer a goal.

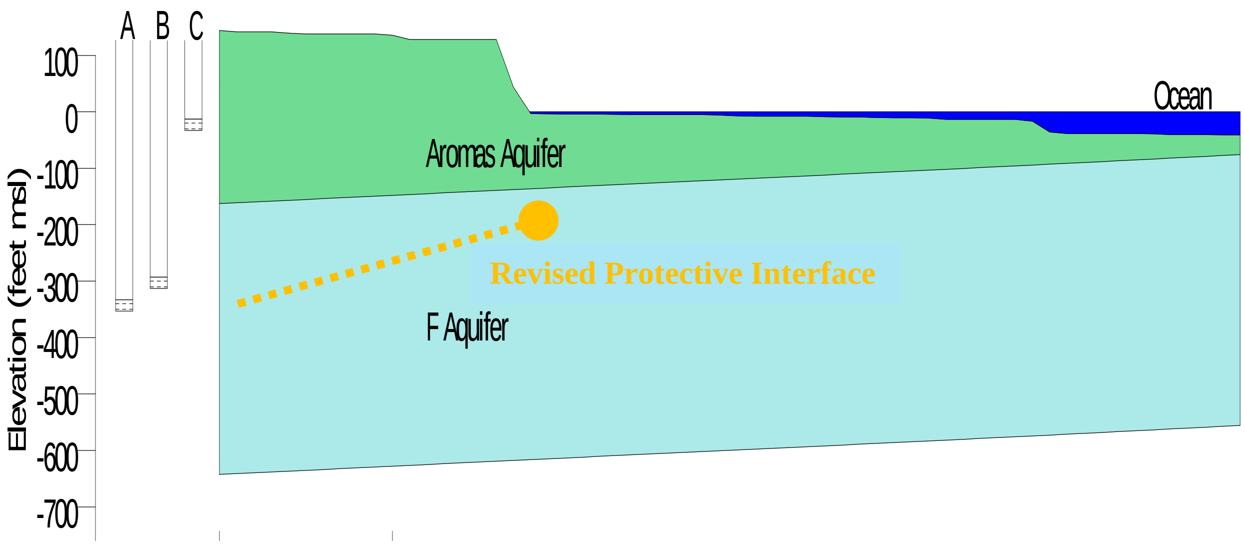


Figure 2. Example of Revised Protective Interface (SC-A2)

IDENTIFYING THE PROTECTIVE INTERFACE IN THE AROMAS AREA

The existing interface at each of the coastal monitoring well clusters is defined by chloride concentrations in the A screen and B screen (Table 1). The interface at the SC-A1 well cluster has not been detected so the protective location is established below well SC-A1A. The protective elevations are the heads at the coastal monitoring wells that maintain the existing chloride concentrations in the A and B screens.

As described in the January 2009 report, protective elevations were estimated using the USGS code SEAWAT 2000. Although the model simulates a sharp interface, there is a transition zone due to numerical dispersion that approximates the brackish concentrations observed in the A and B screens. For each simulation, the concentrations at the bottom of the A and B screens were evaluated. In some cases, the head that maintains the interface at the A screen is different than the head that maintains the interface at the B screen. In this case, the higher of the two heads is considered the protective elevation.

Table 1. Approximate Existing Chloride Concentrations for Defining Interface Location at Aromas Coastal Monitoring Wells

Well	**A screen**		**B screen**	
	Bottom Elevation (feet msl)	**Chloride Concentration (mg/L)**	**Bottom Elevation (feet msl)**	**Chloride Concentration (mg/L)**
SC-A1	-455	<250	-330	<250
SC-A8	-408	7,000	-318	<250
SC-A2	-353	13,000	-313	310
SC-A3	-207	18,000	-167	3,000
SC-A4	-354	8,000	-314	<250

REVISED PROTECTIVE ELEVATIONS IN THE AROMAS AREA

As discussed in the January 2009 report, the cross-sectional model for each coastal monitoring well was run with 100 reasonable parameter sets of aquifer and aquitard conductivities. This results in a range of 100 protective elevations. Table 2 shows the revised distribution of protective elevations for Aromas monitoring wells by percentile.

Table 2. Distribution of Protective Elevations at Aromas Monitoring Wells (feet msl)

Percentile	**SC-A1**	**SC-A8**	**SC-A2**	**SC-A3**	**SC-A4**
50	2	5	2	2	2
70	***3***	***6***	***3***	***3***	***3***
80	3	6	3	3	3
90	5	6	3	4	3
100	5	7	3	4	4

The January 2009 report suggested using the 70th percentile to establish the protective elevation. This elevation is protective for at least 70% of the cross-sectional model runs. SqCWD has adopted the 70th percentile elevations as protective elevations. For the revised protective locations, we still recommend using the 70th percentile elevation as the management objective. This recommendation can be modified in the future; if the interface continues to move inland when the groundwater elevation objective is achieved over consecutive years, the protective elevation can be revised upward.

COMPARING OBSERVED GROUNDWATER LEVELS TO PROTECTIVE ELEVATIONS IN THE AROMAS AREA

In the most recent Annual Report and Review (HydroMetrics WRI, 2011a), observed groundwater levels at the B screens of the Aromas coastal monitoring wells were compared to protective elevations. The new protective elevations are selected to maintain the interface in both the A and B screens. Therefore, observed groundwater levels in both screens should be compared to protective elevations.

Measured groundwater levels must be adjusted to account for salinity before they are compared to protective elevations. The protective groundwater elevation estimated by SEAWAT-2000 is the freshwater equivalent head (Langevin and others, 2003). The freshwater equivalent head for groundwater with a substantial amount of salinity is higher than the observed groundwater levels due to the higher density of saline water. Attachment 1 documents the saltwater adjustments for the Aromas monitoring wells, and shows hydrographs with freshwater equivalent heads.

Hydrographs in Attachment 1 compare historical observations to protective elevations. The hydrographs show that freshwater equivalent heads in the A screens of the SC-A2, SC-A3, and SC-A4 wells have been below protective elevations; and recovery at these wells is required to protect this part of the basin. The chemographs in Attachment 1 show the long-term rise in salinity at these wells. The hydrographs show freshwater equivalent heads at SC-A1 and SC-A8 have been above protective elevations. The chemographs for SC-A1 show no seawater intrusion at that location and no increase in salinity at SC-A8 since its 2007 installation.

REVISED PROTECTIVE OUTFLOWS IN THE AROMAS AREA

The freshwater outflows at the coast simulated by the cross-sectional models are evaluated using the same method as for our September 2009 letter (HydroMetrics LLC, 2009b). Cross-sectional outflows are multiplied by the width each cross-sectional model represents as defined by the midpoints between wells and the study area boundary (Figure 3). The protective outflow for each of the 100 parameter sets is the outflow that is required to maintain the protective elevation for that set. . Groundwater levels in the wells must recover to the protective elevation, however, before the identified outflow is protective. Summarizing the results of all parameter sets provides a range of 100 protective outflows. Table 3 shows the revised distribution of protective coastal outflows for Aromas monitoring wells by percentile.

Table 3. Distribution of Protective Coastal Outflows at Aromas Monitoring Wells (acre-feet per year)

Percentile	SC-A1	SC-A8	SC-A2	SC-A3	SC-A4	Aromas
50	50	475	100	350	50	1,025
70	***75***	***725***	***250***	***775***	***125***	***1,950***
80	100	800	275	875	150	2,200
90	150	900	275	1000	175	2,500
100	225	1050	300	1375	250	3,200
Cross-Sectional Width	5,010	3,818	4,011	5,257	3,232	

As with the protective elevations, we recommend that the 70th percentile of protective outflows be used for establishing post-recovery pumping yields as planning guidelines. These goals are meant to maintain protection of the Aromas and Purisima areas from seawater intrusion after groundwater levels recover to protective elevations. However, unlike groundwater elevations, it will be difficult to measure and quantify the coastal outflows in the field, especially given the uncertainties in other components of the water balance. Pumping yields should be updated based on how pumping affects groundwater levels during and after recovery to protective elevations.

NEW WATER BALANCE INFORMATION

HydroMetrics LLC's September 2009 letter used the protective outflows in water balance calculations for the Purisima and Aromas areas to estimate SqCWD's post-recovery pumping yields to protect the basin from seawater intrusion after groundwater levels recover to protective elevations. New information about components of the water balance has become available since 2009. The PRMS recharge model (HydroMetrics WRI, 2011b) provides recharge estimates for both the Purisima and Aromas areas, which are applied to the water balance.

Figure 3: Cross-Sectional Widths of Coastal Monitoring Well Models

There are several methods available to estimate flows between the Aromas area and Pajaro Valley. Estimates extracted from the Pajaro Valley Hydrologic Model (US Geological Survey, unpublished) and Central Water District DWSAP model (Johnson, 2009) were evaluated for inclusion in the water balance. Johnson et al. (2004) used the estimated gradient from a groundwater level contour map to estimate flow from the Aromas area to the Pajaro Valley. This general approach is applied to groundwater level contour maps from multiple years to provide an estimate for the water balance.

PRMS RECHARGE MODEL ESTIMATE FOR AROMAS

The PRMS recharge model estimated average annual recharge in the Aromas Red Sands outcrop portion of the Johnson et al. (2004) study area (Figure 4) to be 4,200 acre-feet per year between Water Years 1984 and 2009 (HydroMetrics WRI, 2011). This total includes 1,600 acre-feet per year from the east bank of the Valencia Creek watershed. The September 2009 report estimated annual Aromas area recharge of 2,900 acre-feet per year, based on an estimate in Johnson et al. (2004). The Johnson et al. estimate only included 10% (113 acre-feet per year) of the Valencia Creek watershed with the Aromas recharge. The updated water balance will incorporate the result from the PRMS model, which is calibrated and uses mapped outcrop areas for the Aromas.

Both the Aptos Jr. High well and the Polo Grounds well are in the east bank of the Valencia Creek Watershed. Because the east bank of the Valencia Creek watershed is included with the Aromas area recharge estimates, we include pumping from the Aptos Jr. High and the Polo Grounds production wells as part of SqCWD's pumping in the Aromas area.

PRMS RECHARGE MODEL ESTIMATE FOR PURISIMA

The PRMS recharge model estimated average annual recharge in the Purisima Formation outcrop portion of the Johnson et al. (2004) study area (Figure 4) to be 6,600 acre-feet per year between Water Years 1984 and 2009 (HydroMetrics WRI, 2011). The September 2009 report estimated annual Purisima Formation recharge of 6,100 acre-feet per year based on data in Johnson et al. (2004). The PRMS recharge study report corrected the Johnson et al. calculation to 7,000 acre-feet. The PRMS recharge model includes the west bank of the Valencia Creek watershed in the Purisima, while the Johnson et al. calculation includes 90% of the Valencia watershed in its Purisima estimate. The updated water balance will

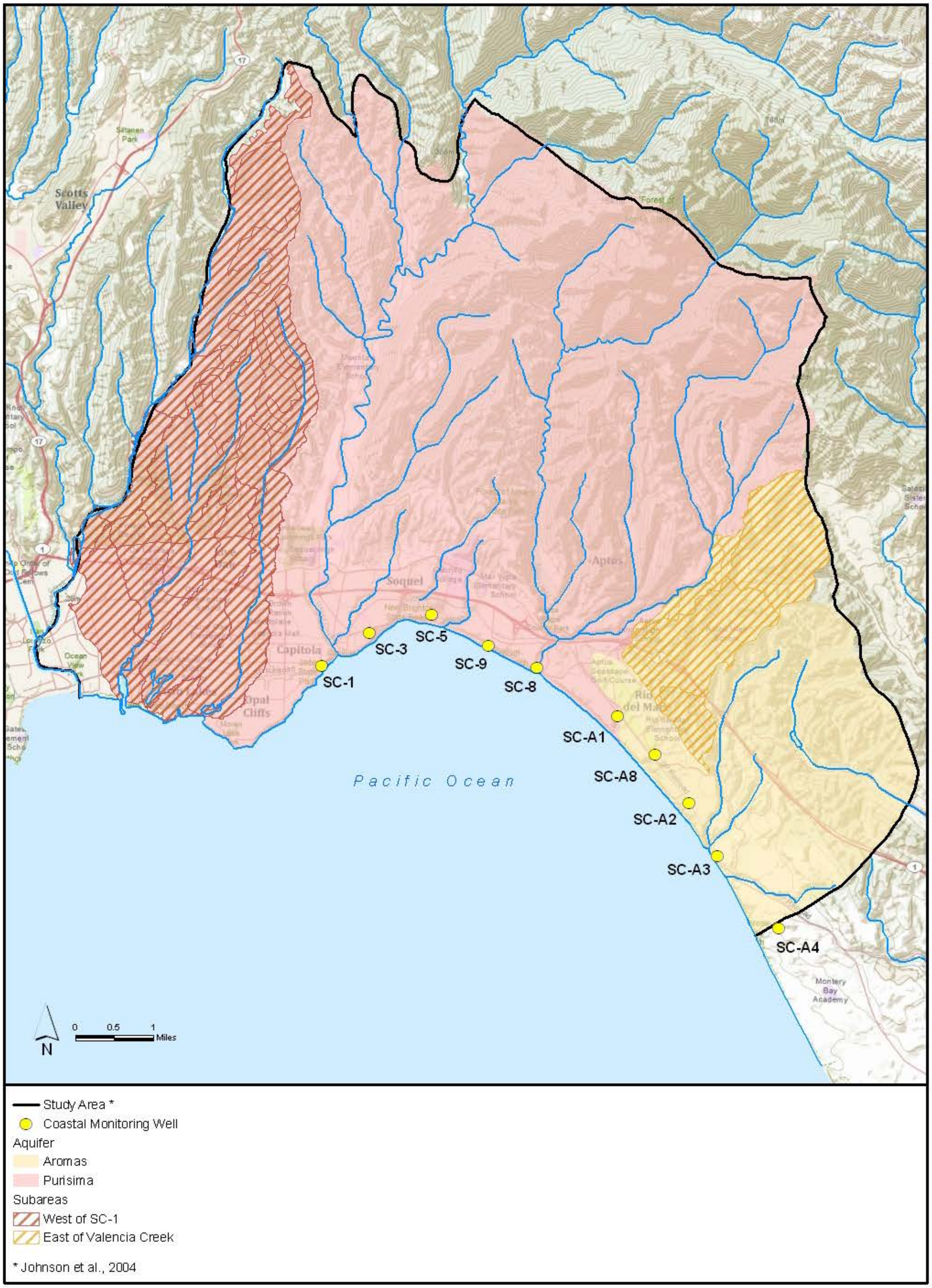


Figure 4. Aromas and Purisima Outcrop Areas in PRMS Recharge Model

incorporate the result from the PRMS model, which is calibrated and uses mapped outcrop areas for the Purisima.

As in the September 2009 report, a geographic issue arises when using Purisima recharge estimates. SqCWD does not have coastal monitoring wells west of monitoring well cluster SC-1 (Figure 4). The PRMS recharge model estimates average recharge for the area west of the SC-1 cross-sectional model boundary as 1,200 acre-feet per year. This amount is subtracted from the recharge estimate for the Purisima outcrop area; leaving an estimated recharge of 5,400 acre-feet per year for the Purisima area water balance.

PAJARO VALLEY HYDROLOGIC MODEL'S AROMAS AREA WATER BUDGET

The U.S. Geological Survey has developed a MODFLOW model for the Pajaro Valley. The final report documenting the Pajaro Valley Hydrologic Model (PVHM) has not been published. HydroMetrics WRI has obtained a draft version of the model, and has used it to evaluate the simulated water budget for the area overlapping the Johnson et al. (2004) study area in the Aromas (blue Water Budget Zone 1 in Figure 5). Table 4 shows the annual average water budget components for the PVHM simulation of Water Years 1969 through 2009. Both the water budget components for the PVHM from ground surface to the bottom of the Aromas Red Sands, and the water budget components for the entire model thickness including the Purisima Formation are shown. The water budget components excluding the Purisima are more similar to what was presented to the Board at its August 9 workshop. However, it is more appropriate to evaluate the entire model thickness because SqCWD's Aromas area production wells are screened in the Purisima Formation as well as the Aromas Red Sands, and the existing interface is located in the Purisima.

The PVHM's estimated recharge of 937 acre-feet per year is substantially less than the approximately 2,500 acre-feet per year estimated by the PRMS recharge model. However, the PVHM model estimates average total freshwater inflows to the Aromas area (Zone 1) as approximately 3,400 acre-feet per year. The total inflow into the Aromas area is much greater in the PVHM than the recharge from the PRMS model. As a result, overall outflow in the PVHM is greater, and suggests that components such as net outflow to the Pajaro Valley should not be combined with PRMS recharge estimates in an update of the Johnson et al. (2004) water balance.

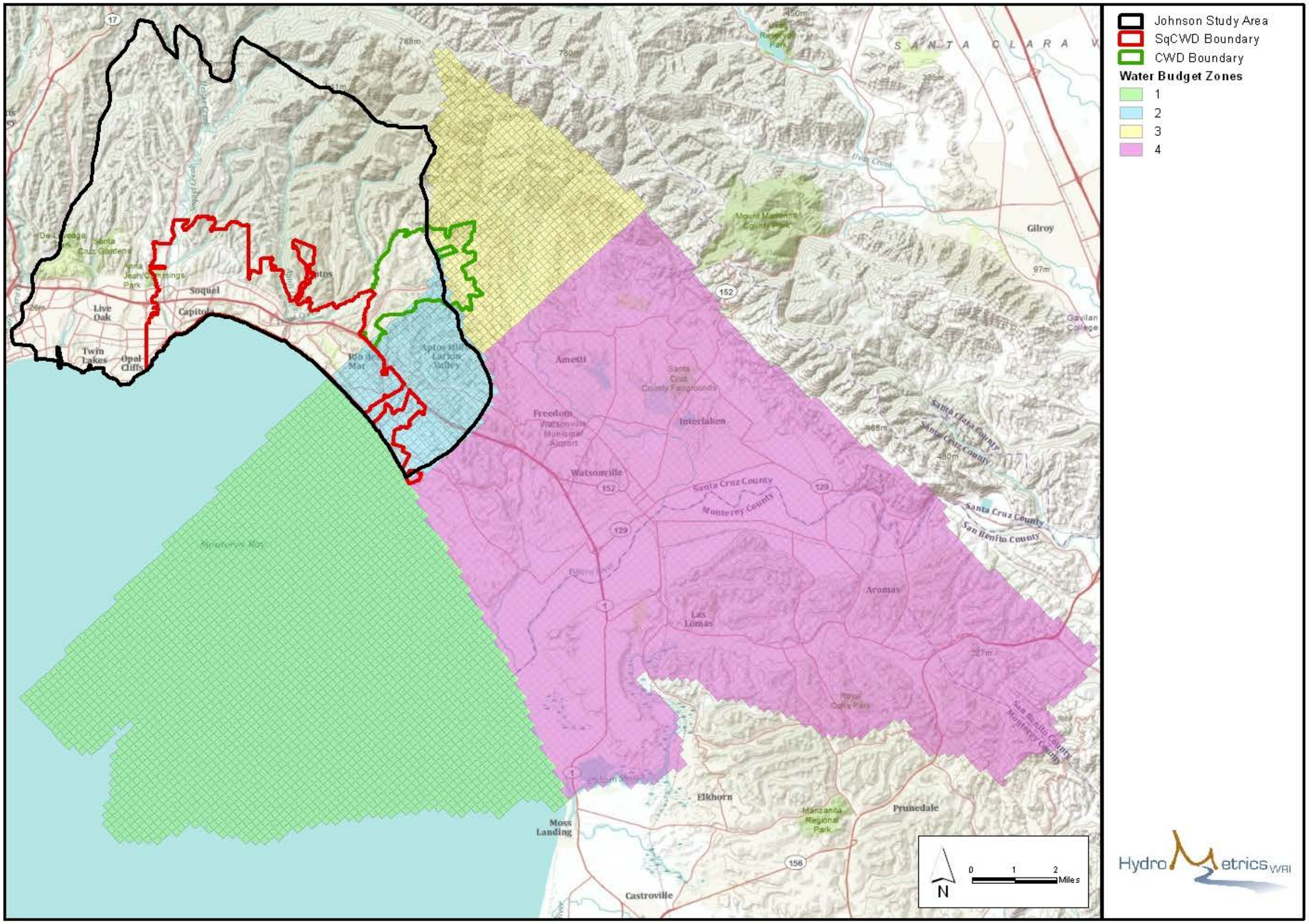


Figure 5. Pajaro Valley Hydrologic Model Water Budget Zones

Table 4. Annual Average Water Budget Components for Aromas Area Simulated by Pajaro Valley Hydrologic Model

Water Budget Component	**Annual Average Flow (acre-feet per year)**	
	Ground Surface to Bottom of Aromas	**Entire Model Thickness, Including Purisima**
Inflows		
Recharge Inflow to Zone 1	937	937
Net Western Boundary Inflow to Zone 1	1,005	2,137
Net Northern Hills Inflow from Zone 3 to Zone 1	649	329
Offshore Inflow from Zone 2 to Zone 1	363	512
Outflows		
Offshore Outflow from Zone 1 to Zone 2	204	297
Net Outflow to Pajaro Valley from Zone 1 to Zone 4	1,196	1,854

Despite the large amount of inflow estimated by the PVHM for the area, the average offshore outflow estimated by PVHM is less than the 1,950 acre-feet per year suggested as the protective outflow for the Aromas area. This is consistent with the general understanding that the area is in overdraft and offshore outflow needs to be increased to protect the area from further intrusion.

Directly using a groundwater model such as PVHM to evaluate pumping yield is also possible. However, additional calibration of the PVHM in the Aromas area would be necessary to apply the model for this purpose. Calibration of the PVHM in the Aromas area was not a priority in its development; the primary use of the model is to evaluate groundwater management activities in the Pajaro Valley.

The annual flows simulated by the PVHM do not substantially change in the years since Pajaro Valley Water Management Agency initiated the Harkins Slough Aquifer Storage and Recovery Project (started 2001). The PVHM only simulates several months of the Watsonville Area Water Recycling Project (started April 2009) so the effect of that project has not been identified in the model results.

CENTRAL WATER DISTRICT DWSAP MODEL WATER BUDGET

Johnson (2009) developed a steady-state MODFLOW model for Central Water District (CWD) to estimate capture zones, as part of the Drinking Water Source Assessments (DWSAP) for CWD's wells. One of Johnson's recommendations for further work was to analyze the simulated water budget, specifically outflows to the Pajaro Valley and the ocean. CWD provided HydroMetrics WRI with the model to perform this analysis. We approximated similar water budget zones in the CWD model (Figure 6) to those used for PVHM (Figure 5) and analyzed the budget for the Aromas area (blue zone in Figure 6). Table 5 shows the annual average water budget components for CWD DWSAP steady-state simulation.

The CWD DWSAP model's estimate for the Aromas area recharge is slightly less than the 2,500 acre-feet estimated by the PRMS recharge model, but overall inflow is substantially higher. As a result, overall outflow is greater and suggests that components such as net outflow to the Pajaro Valley should not be combined with PRMS recharge in an update of the Johnson et al. (2004) water balance.

The CWD DWSAP model estimates that all flow at the ocean is outflow. The model generally simulates heads at coastal monitoring wells that are higher than historical observations. More accurate calibration at the coast was not necessary for using the model to develop capture zones at the CWD production wells. Johnson (2009) recommends a more quantitative calibration as an area of further improvement. Such an effort would be necessary to use the CWD DWSAP model to evaluate pumping yield.

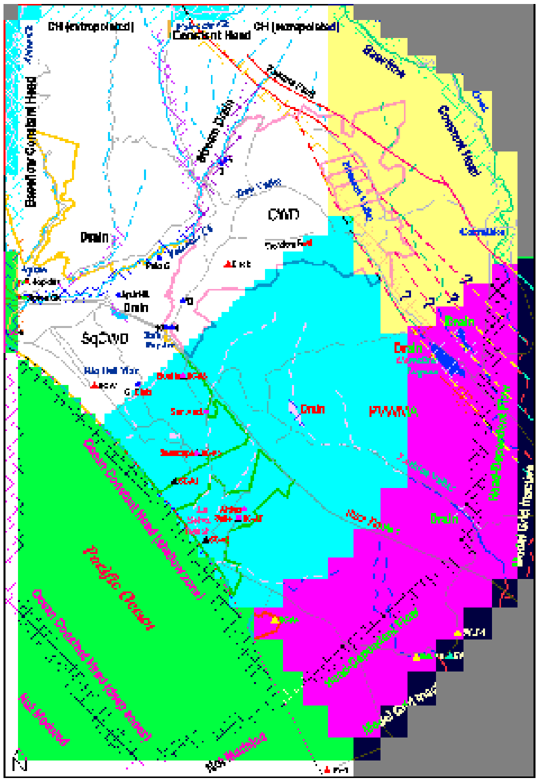


Figure 6. Central Water District DWSAP Model Water Budget Zones

Table 5. Annual Average Water Budget Components for Aromas Area Simulated by Central Water District DWSAP Model

Water Budget Component	**Annual Average Flow (acre-feet per year)**
Inflows	
Recharge Inflow to Blue Zone	1,974
Net Western Inflow from White Zone to Blue Zone	1,475
Net Northern Inflow from Yellow Zone to Blue Zone	745
Offshore Inflow from Green Zone/Ocean Constant Heads to Blue Zone	0
Outflows	
Offshore Outflow from Blue Zone to Green Zone/Ocean Constant Heads	954
Net Outflow to Pajaro Valley from Blue Zone to Violet Zone	1,669

USING GROUNDWATER LEVEL CONTOUR MAPS TO ESTIMATE FLOW TO PAJARO VALLEY

Johnson et al. (2004) estimated outflow to the Pajaro Valley based on an autumn 1991 groundwater level contour map (Luhdorff and Scalmanini, 1996). Johnson et al. concluded that the map shows a gradient (i) of approximately 3×10^{-4} feet/feet from the Aromas area to the Pajaro Valley. Using the maximum transmissivity (T) of 10,000 ft^2 per day and a flow width (W) of 20,000 feet, Johnson et al. estimated the outflow as 500 acre-feet per year using the Darcy's Law equation $Q = T \times W \times i$. Johnson et al. assumed that drought conditions similar to 1991 would occur once every five years; and therefore adopted a long-term average outflow to the Pajaro Valley of 100 acre-feet per year.

In order to refine this estimate, we used the same equation to calculate flow across the boundary between the Aromas area and Pajaro Valley based on groundwater level contour maps produced by the Pajaro Valley Water Management Agency (PVWMA) for its annual reports (PVWMA, 1993, 2007, 2009, 2010, 2011). However, the method for calculating the gradient across the boundary is different from Johnson et al. (2004). PVWMA provided Geographic Information System (GIS) shapefiles for autumn 1992, 2006, 2008, 2009, and 2010 contour maps. This allowed us to estimate the gradient from the Aromas area to the Pajaro Valley for these maps using ArcGIS Spatial Analyst software with the following steps:

1. Interpolated the contours to a 100 meter grid of groundwater elevations.
2. For each grid cell, calculated the magnitude and direction of the groundwater gradient.
3. For each grid cell intersecting the boundary, calculated the direction of the boundary at that cell.
4. For each grid cell intersected by the boundary between the Aromas area and the Pajaro Valley, used trigonometry to calculate the component of the groundwater gradient that is perpendicular to the direction of the boundary at the cell. We used the component of the gradient perpendicular to the boundary instead of the full gradient magnitude because the length of the boundary defines the aquifer width, W. Figure 7 shows the results of this calculation for the 1992 contour map (blue indicates flow to Pajaro Valley and green indicates flow to the Aromas area).

5. Averaged the components of the gradients perpendicular to the boundary for all cells along the boundary to obtain the average groundwater gradient perpendicular to the boundary.

The contour maps for 2006 and 2010 with the results of the calculation in step 4 are provided as Attachment 2. The calculation was not completed for the 2008 and 2009 contour maps, which are also included in Attachment 2. The contour map for 2008 shows a pattern of flow inconsistent with the other maps and maps for the Aromas area in the Soquel-Aptos Annual Review and Report (HydroMetrics WRI, 2011a). The contour map for 2009 shows three contours equaling zero across the boundary, which represent a flat gradient along the boundary that could not be accurately interpolated.

The calculated gradients (i) for the 1992, 2006, and 2010 contour maps are shown in Table 6. Using the range of transmissivities (T) for the Aromas Red Sands of 1,200 – 10,000 ft^2 per day (Johnson et al., 2004) and the boundary length (W) of 16,354 feet using the equation Q= T x W x i, flow from the Aromas area to the Pajaro Valley is estimated and shown in Table 6.

The estimated gradient and flow for the drought year 1992 is higher than the Johnson et al. (2004) estimates for the drought year 1991. These two years occur at the end of the 1987-1992 drought; and therefore these contour maps do not represent typical flow patterns.

The 2006 and 2010 contour maps represent more typical flow patterns and show relatively flat gradients across the basin boundary. The 2009 contour map also shows a flat gradient at the basin boundary, in a year representing the end of a relatively dry period.

The gradient across the basin boundary will increase as SqCWD raises coastal water levels to prevent seawater intrusion. This will increase the flow from the Soquel-Aptos basin into Pajaro Valley. To estimate this increased flow, we modified the typical flow patterns of 2006 and 2010 by adding a protective 3-foot groundwater elevation contour at the coastal monitoring wells SC-A2, SC-A3, and SC-A4. The resulting estimated gradients are shown in Table 6. The modified contour map for 2010 is shown in Figure 8 with the gradient calculation along the boundary between the Aromas area and Pajaro Valley (blue indicates flow to Pajaro Valley and green indicates flow to the Aromas area). Attachment 2 includes the modified contour map for 2006.

Table 6. Groundwater Level Gradient and Estimated Flow from Aromas Area to Pajaro Valley Calculated from PVWMA Contour Maps

Year	**Gradient ft/ft**	**Flow Based on Minimum Transmissivity acre feet per year**	**Flow Based on Maximum Transmissivity acre feet per year**	**Annual Rainfall Compared to Average**
1992	1.2×10^{-3}	200	1700	6th Consecutive Year Below Average
2006	-2.8×10^{-4}	-50	-380	2nd Consecutive Year Above Average
2006 with recovery	-2.3×10^{-4}	-40	-310	
2008	Pattern of flow inconsistent with other maps			2nd Consecutive Year Below Average
2009	Flat gradient along boundary could not be accurately interpolated			3rd Consecutive Year Below Average
2010	1.4×10^{-4}	20	190	1st Year Above Average After 3 Years Below Average
2010 with recovery	2.7×10^{-4}	40	370	

Based on the revised 2006 contours, groundwater continues to flow from Pajaro Valley towards the Aromas area. Based on the revised 2010 contours, however, groundwater flow increases from the Aromas area towards Pajaro Valley. For the water balance, we conservatively use the maximum flow of 370 acre-feet per year towards Pajaro Valley based on 2010 contours, as modified with protective elevations at the Aromas coastal monitoring wells.

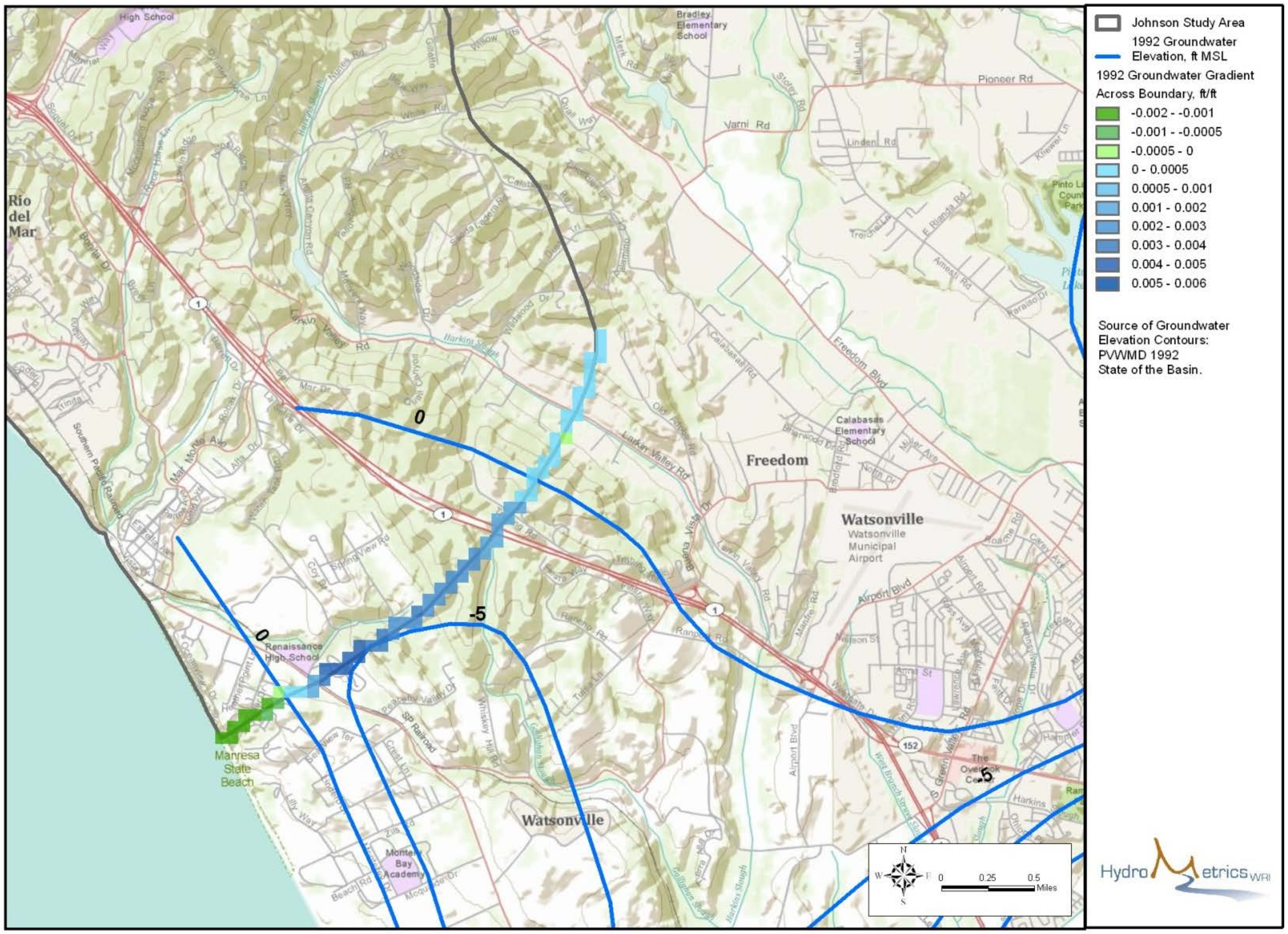


Figure 7. Components of Groundwater Level Gradient Perpendicular to Boundary between Aromas Area to Pajaro Valley Based on 1992 PVWMA Contour Map

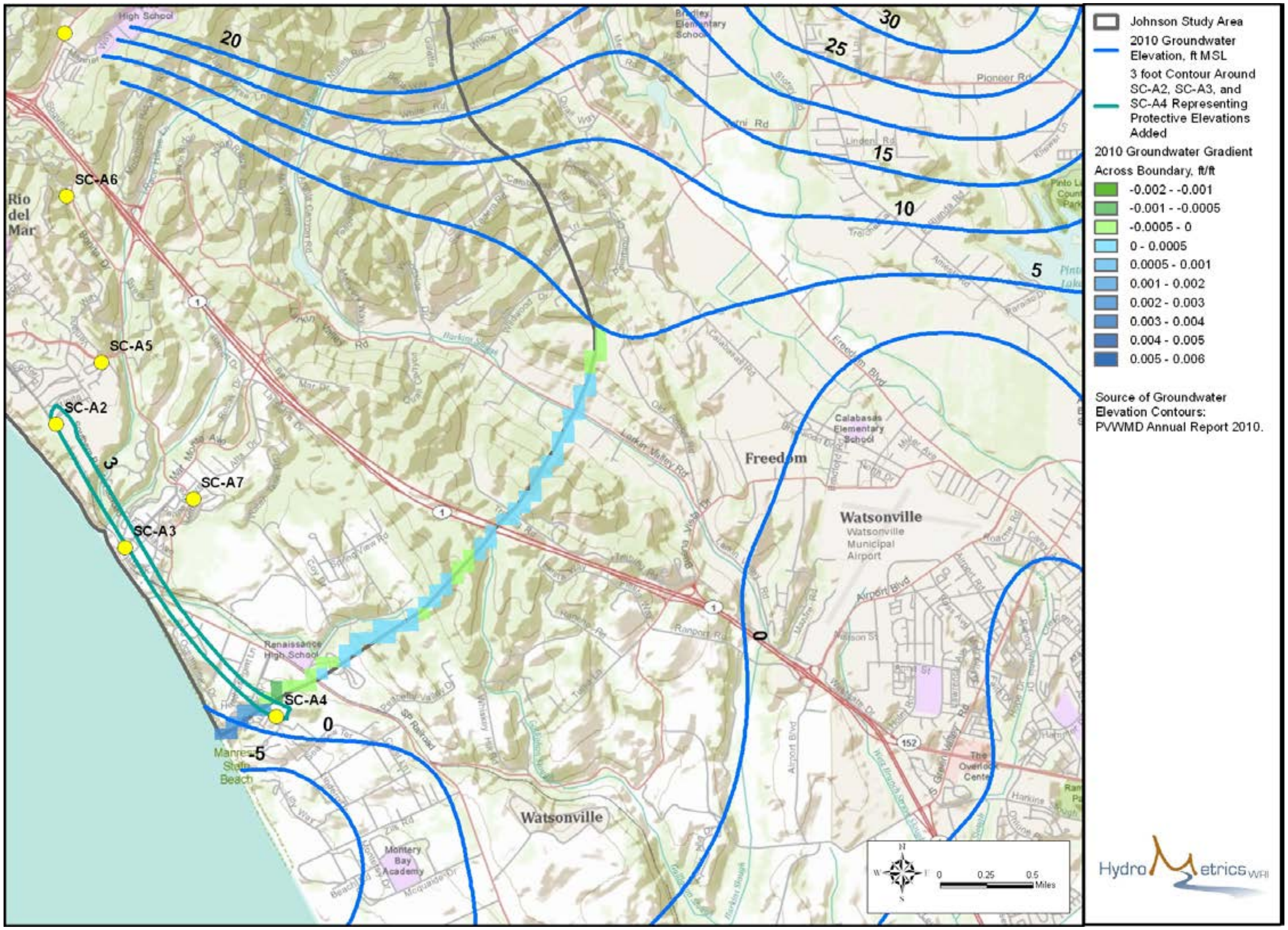


Figure 8. Components of Groundwater Level Gradient Perpendicular to Boundary between Aromas Area to Pajaro Valley Based on 2010 PVWMA Contour Map Modified with Protective Elevations at Aromas Area Coastal Monitoring Wells

UPDATE OF JOHNSON ET AL. (2004) WATER BALANCE

Johnson et al. (2004) used water balance calculations to estimate SqCWD's share of the Soquel-Aptos Basin sustainable yield. We have updated these calculations to calculate SqCWD post-recovery pumping yields in a number of ways, as shown in Table 7.

Table 7. Water Balance Calculation of SqCWD Post-Recovery Pumping Yield

Water Balance Component	Calculation
Recharge from precipitation	From PRMS Recharge Model
Protective Outflow to Ocean	From SEAWAT-2000 cross-sectional models
Flow to Pajaro Valley	From evaluation of PVWMA Annual Report contour maps
Total Water Available for Consumptive Use	Recharge MINUS Protective Outflow to Ocean MINUS Flow to Pajaro Valley
Non-SqCWD Consumptive Use	From Johnson et al. (2004) Table 5-7; with a revised estimate for Cabrillo College consumptive use based on Cabrillo College pumping in 2009 (HydroMetrics, 2011a)
Total Water Available for SqCWD Consumptive Use	Total Water Available for Consumptive Use MINUS Non-SqCWD Consumptive Use
SqCWD Return Flow Percentage	Johnson et al. (2004) Table 5-7 accounting for SqCWD parcels on septic systems
SqCWD Post-Recovery Pumping Yield	Total Water Available for SqCWD Consumptive Use DIVIDED BY (1 MINUS SqCWD Return Flow Percentage)

The non-SqCWD consumptive use is calculated differently than what is documented in HydroMetrics LLC's September 15, 2009 letter. In the previous calculations, a single consumptive use factor (1 – return flow percentage) was used to estimate both non-SqCWD and SqCWD consumptive use. In the updated water balance, non-SqCWD consumptive use is calculated separately and subtracted from total available consumptive use to calculate total water available for SqCWD consumptive use. Return flow percentages specific to SqCWD for the Aromas and Purisima areas are used to calculate SqCWD's post-recovery pumping yields. Table 8 shows the calculation of non-SqCWD consumptive use in the Aromas area and the Purisima area.

Table 8. Non-SqCWD Consumptive Use

	Aromas	Purisima
Non-SqCWD Groundwater Extraction; excluding Cabrillo College (afy)	1,403	2,668
Non-SqCWD Return Flow Percentage excluding Cabrillo College	46%	29%
Non-SqCWD Consumptive Use (afy) excluding Cabrillo College	754	1,905
Cabrillo College Groundwater Extraction in 2009 (afy)	N/A	95
Cabrillo College Return Flow Percentage from Johnson et al. (2004)	N/A	8.5%
Cabrillo College Consumptive Use (afy)	N/A	87
Non-SqCWD Consumptive Use (afy)	754	1,992

Note: Aromas area groundwater use is not adjusted for 2007 estimate of Polo Grounds Park water use because Polo Grounds well planned for conversion to SqCWD use.

Johnson et al. (2004) assumed that there is no septic system use in the SqCWD service area and the return flow of indoor use is 0%. SqCWD provided a map of parcels not connected to the sewer system and assumed to have a septic system. We calculated the percentage of parcels on septic in the SqCWD service area overlying the Purisima and Aromas (Figure 9). Based on these percentages along with the assumptions in Johnson et al. (2004) for return flow and water usage, we calculated the current return flow percentages for SqCWD in the Purisima and Aromas areas as shown in Table 9.

Table 9. SqCWD Return Flow Percentages in Purisima and Aromas Areas Based on Percentage of Parcels on Septic Systems

	Aromas	Purisima
SqCWD Parcels on Septic Systems	1,483	729
Total SqCWD Parcels	4,957	13,242
SqCWD Percentage on Septic Systems	30%	6%
Return Flow for Indoor Use on Septic (Johnson et al., 2004)	75%	75%
Return Flow for Indoor Use on Sewer (Johnson et al., 2004)	0%	0%
Average Return Flow for SqCWD Indoor Use	22%	4%
SqCWD Indoor Use Percentage (Johnson et al., 2004)	70%	70%
Return Flow for SqCWD Outdoor Use (Johnson et al., 2004)	20%	20%
Current SqCWD Return Flow Accounting for Septic Use	22%	9%

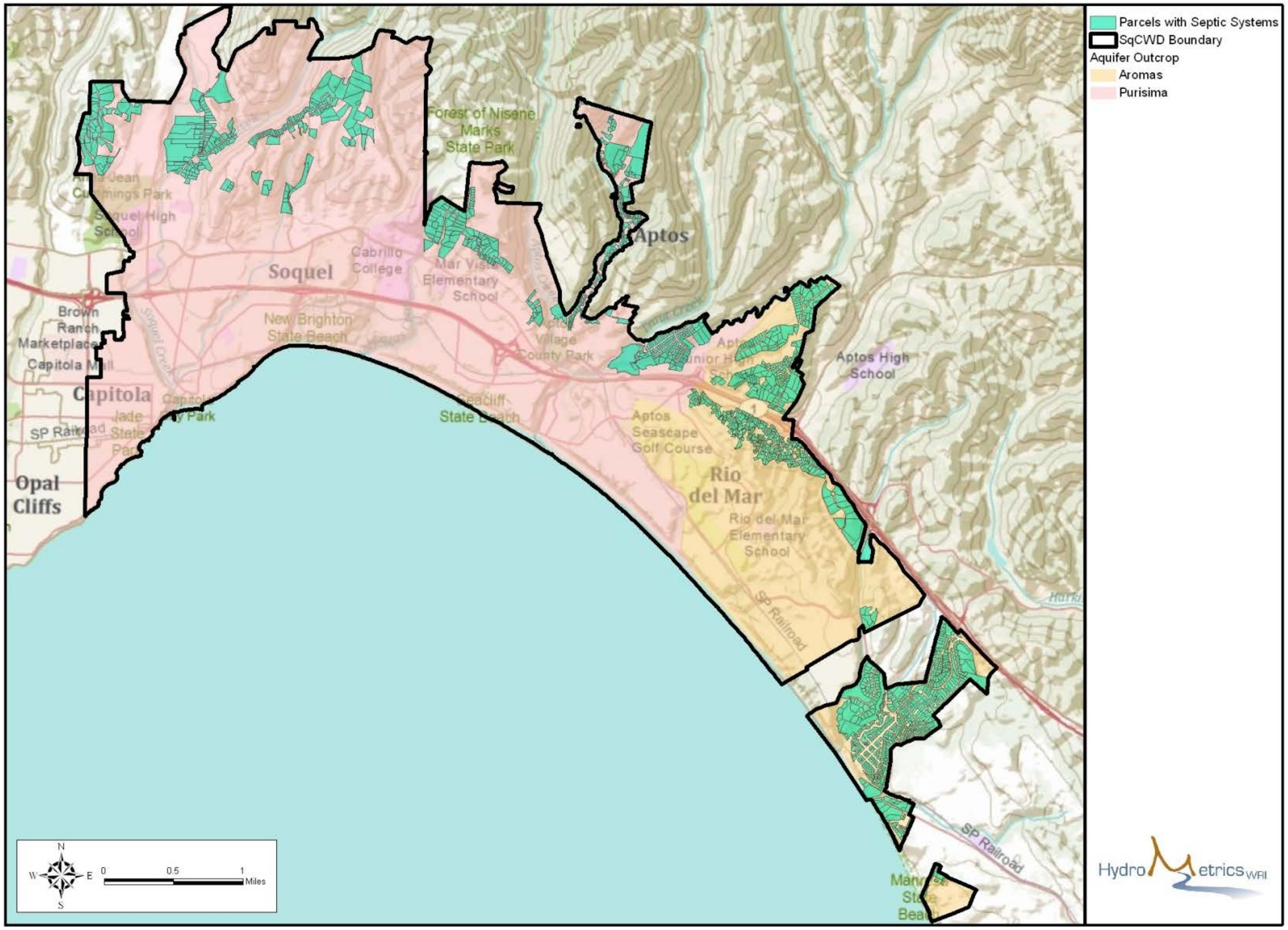


Figure 9. Parcels on Septic Systems in SqCWD Service Area

Although return flow percentages accounting for septic system use is representative of current and historical conditions, future return flow percentages may change if septic system use changes. SqCWD's Board of Directors has indicated that it intends to encourage the conversion from septic systems to sewer for water quality purposes. Therefore, the Board does not want to include return flow from septic systems in planning available water supply. We provide water balance calculations assuming no return flow from septic systems in the SqCWD area in Table 10 for the Aromas area and in Table 11 for the Purisima area, which reduces the post-recovery pumping yield for SqCWD.

Table 10 and Table 11 show updated water balance calculations for different percentiles of protective outflow for the Aromas area and for the Purisima area.

Table 10. Aromas Area Water Balance Calculation of SqCWD Post-Recovery Pumping Yield

Water Balance Component	**Protective Outflow Percentile**		
	50	**70**	**90**
Aromas area recharge from precipitation (afy)	4,200	4,200	4,200
Modeled Protective Outflows to Ocean (afy)	1,025	1,950	2,500
Flow to Pajaro Valley	370	370	370
Total Water Available for Consumptive Use (afy)	2,805	1,880	1,330
Non-SqCWD Consumptive Use (afy)	754	754	754
Total Water Available for SqCWD's Consumptive Use (afy)	2,051	1,126	576
Current SqCWD Return Flow Percentage	22%	22%	22%
SqCWD Post-Recovery Pumping Yield for the Aromas area Accounting for Septic Systems in SqCWD Area (afy)	**2,620**	**1,440**	**740**
Planned SqCWD Return Flow Percentage	6%	6%	6%
SqCWD Post-Recovery Pumping Yield for the Aromas area Assuming No Septic Systems in SqCWD Area (afy)	**2,180**	**1,200**	**610**

In addition to the range of uncertainty represented by the protective outflow percentiles, there is uncertainty to each of the other water balance components. The uncertainty of the recharge estimates related to evapotranspiration estimates has been quantified as +/- 5% or approximately +/- 500 acre-feet per year for the Basin. The above contour map gradient estimates show that uncertainty of the flow from the Aromas area to the Pajaro Valley is in the range of a few hundred acre-feet per year.

There are also a number of uncertainties that have not been quantified. Water balance estimates above with uncertainties that have not been quantified include non-SqCWD consumptive use and SqCWD return flow percentage. Another uncertainty that has not been quantified is stream-aquifer interaction. Habitat requirements for baseflow could affect available yield. Groundwater flows between the Purisima and Aromas, between aquifer layers, and into the District are also not quantified.

The water balance for the 50th percentile of protective outflows in the Aromas area results in a post-recovery pumping yield that is greater than historical pumping; and is therefore not protective. This may be a result of the 50th percentile of protective outflows not being representative of aquifer conditions, errors in the estimates for other water balance components or some combination. The Johnson et al. (2004) estimates of the upper limits for post-recovery pumping yield of 1,800 acre-feet per year in the Aromas area and 3,000 acre-feet per year in the Purisima area can still be considered upper limits, as those values are below both the 50th percentile estimates based on current return flow percentages and the average pumping since the early 1980s. For a lower limit on the post-recovery pumping yield reflecting overall uncertainty, we recommend using the estimate represented by the 90th percentile of protective outflows. The resulting range in the supply shortage from SqCWD's maximum projected demand of approximately 4,450 acre-feet per year (SqCWD, 2011) is -350 to 1,340 acre-feet per year.

Table 11. Purisima Area Water Balance Calculation of SqCWD Post-Recovery Pumping Yield

Water Balance Component	Protective Outflow Percentile		
	50	70	90
Purisima Area recharge from precipitation (afy)	5,400	5,400	5,400
Modeled Protective Outflows to Ocean (afy)	600	775	1,050
Total Water Available for Consumptive Use (afy)	4,800	4,625	4,350
Non-SqCWD Consumptive Use (afy)[1]	1,992	1,992	1,992
Total Water Available for SqCWD's Consumptive Use (afy)	2,808	2,633	2,358
Current SqCWD Return Flow Percentage	9%	9%	9%
SqCWD Post-Recovery Pumping Yield for the Purisima Area Accounting for Septic Systems in SqCWD Area(afy)	**3,080**	**2,890**	**2,590**
Planned SqCWD Return Flow Percentage	6%	6%	6%
SqCWD Post-Recovery Pumping Yield for the Purisima Area Assuming No Septic Systems in the SqCWD Area (afy)	**2,990**	**2,800**	**2,500**

These water balance calculations based on the 70th percentile of outflows provide planning-level guidelines for estimating the amount of water SqCWD can pump from the Soquel-Aptos Basin after groundwater levels recover to protective elevations. The calculations rely on estimates such as non-SqCWD consumptive use and flow to Pajaro Valley that have uncertainty, and may change over time.

After implementing pumping plans based on the post-recovery yields, SqCWD should continue to adapt its basin management based on how observed coastal groundwater levels compare with protective elevations and observed salinity concentrations. Maintaining groundwater levels at protective elevations will

[1] The calculation conservatively subtracts all of the City of Santa Cruz's assumed consumptive use of 540 acre-feet per year, even though some of the recharge for its production wells may come from the area west of the SC-1 model that has been removed from the calculation. The City is planning to pump up to 520 acre-feet per year in non-critically dry years and up to 645 acre-feet per year in critically dry years.

depend on the distribution of pumping, not just the overall pumping amount. The amount of the post-recovery yields that can be safely pumped by SqCWD's existing and planned wells is a major unknown factor that requires adaptive management.

COMPARING POST-RECOVERY PUMPING YIELDS TO HISTORICAL SQCWD PUMPING

Figure 10 compares the SqCWD's post-recovery pumping yields using the 70th percentile of protective outflows based on current return flow percentages, to measured SqCWD pumping since 1966. Pumping in the Aromas area has exceeded 1,440 acre-feet per year from 1983 to 2010, but dropped below 1,440 acre-feet in 2011. The accumulated pumping deficit for the Aromas area since 1983 totals 11,500 acre-feet. Pumping in the Purisima area exceeded 2,890 acre-feet per year from 1980 to 2008, but dropped below 2,890 acre-feet per year in the last three years (2009-2011) of historically low pumping. The accumulated pumping deficit in the Purisima area since 1979 totals 10,100 acre-feet.

Figure 10 also shows SqCWD's post-recovery pumping yields based on the 90th percentile of protective outflows based on current return flow percentages. Comparing this value to historical pumping data shows that recent pumping remains above this lower limit for SqCWD's post-recovery pumping yield. Combined Aromas and Purisima pumping has exceeded 3,300 acre-feet since 1975. Since then, the accumulated pumping deficit based on this lower limit estimate for a post-recovery pumping yield exceeds 55,000 acre-feet.

As discussed in the Annual Report and Review for Water Year 2010 (HydroMetrics WRI, 2011a), groundwater elevation recovery has been observed in Purisima area coastal monitoring wells due to the decreased pumping in 2009 and 2010 and this has continued in 2011, but the historically low pumping average of 4,170 acre-feet per year over the last three years may be at least partially due to factors that are not sustainable. These factors include a weak economy and weather conditions.

The recently observed groundwater elevation recovery in the Purisima area does not confirm that recent pumping is below post-recovery pumping yields. The protective outflows are based on maintaining protective elevations which have not yet been achieved.

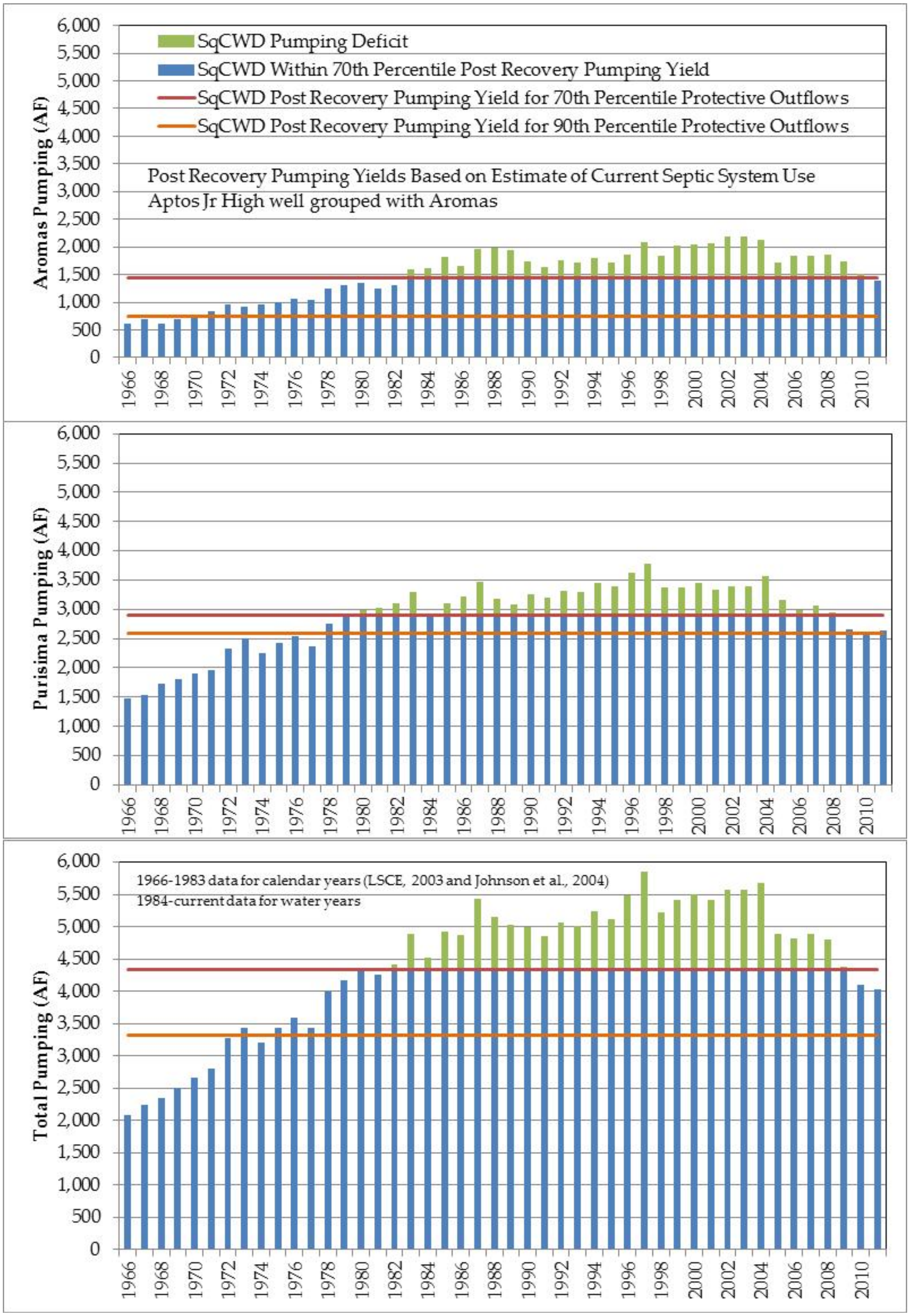


Figure 10. SqCWD Historical Pumping and SqCWD Post-Recovery Pumping Yields Based on 70th Percentile of Protective Outflows

RECOVERY OBJECTIVES

The post-recovery pumping yields are based on estimated outflows needed to maintain protective elevations. Pumping at these yields will not be protective until recovery is achieved. To recover the Soquel-Aptos Basin, pumping will need to be maintained below the post-recovery pumping yields until protective groundwater elevations are achieved. SqCWD can maximize recovery by maximizing the supplemental supply. Based on a potential non-drought supplemental supply of 2.5 million gallons per day, SqCWD could reduce its groundwater pumping to approximately 1,650 acre-feet per year from its maximum projected demand of approximately 4,450 acre-feet per year (SqCWD, 2011). Maximizing supplemental supply will minimize recovery time. Based on the potential drought scenario in which SqCWD is provided the equivalent of 2.5 million gallons per day of supplemental supply over 5 months, SqCWD could still limit its pumping to approximately 2,900 acre-feet per year by declaring a drought curtailment that achieves 15% demand reduction from May to October. Based on this scenario, pumping 2,900 acre-feet per year is the minimum recovery goal that can be achieved in all years. This goal is approximately 210 acre-feet per year below the lower limit for SqCWD's post-recovery pumping yield based on the 90th percentile of protective outflows. SqCWD can set a higher recovery goal but this will result in longer recovery times. For any goal, SqCWD will need to monitor recovery to assess whether recovery is occurring in the time frame desired.

RECOVERY TIMEFRAME

The combined accumulated pumping deficit of 21,600 acre-feet calculated above provides context for the length of time SqCWD would have to pump below the combined post-recovery pumping yield in order to recover the basin. If SqCWD pumps 2,900 acre-feet per year, the accumulated deficit would be reduced by 1,100 acre-feet per year and the deficit would be eliminated in 20 years assuming planned return flow percentages (no septic in SqCWD area). The time to eliminate the accumulated deficit can be considered an upper limit on the recovery time if SqCWD pumping of 4,000 acre-feet per year protects the Basin from seawater intrusion, assuming a redistribution of pumping that safely pumps the yield. Table 12 shows the estimated times to eliminate the accumulated deficit for different annual pumping levels.

If SqCWD's pumping is protective at an amount lower or higher than 4,000 acre-feet per year, the upper limit on the recovery time would increase or decrease, respectively. For example, based on the 90th percentile of protective outflows, pumping 2,900 acre-feet per year would reduce the accumulated deficit 210 acre-feet per year assuming planned return flow percentages. The deficit of 55,000 acre-feet based on the 90th percentile of protective outflows would be eliminated in approximately 270 years. Table 12 shows the uncertainty of estimated times to eliminate the accumulated deficit for different annual pumping levels.

Table 12. Durations to Eliminate Accumulated Pumping Deficit

Annual SqCWD Pumping (acre-feet)	Duration Based on Post-Recovery Yield for 70th Percentile Protective Outflow (years)	Uncertainty Based on Post-Recovery Yield for 50th and 90th Percentile Protective Outflows (years)
2,500	14	4 - 90
2,700	17	4 - 140
2,900	20	4 - 270
3,300	30	5 - Never
3,700	70	7 - Never

Measurable basin recovery is defined by groundwater levels rising to protective elevations; the time needed to eliminate the accumulated deficit does not predict how long it will take for water levels to observe this recovery. Additional tools and information are required to provide a more refined estimate of recovery time. These tools must accurately show the influence of pumping from SqCWD's municipal wells on coastal groundwater elevations. The cross-sectional models developed for estimating protective elevations do not include the influence of any SqCWD pumping.

Simple analysis of historical groundwater elevation data is inadequate for estimating recovery times. One difficulty is that coastal monitoring wells were installed in the mid-1980s, some years after pumping began to exceed the estimate of SqCWD's post-recovery pumping yield. In addition, groundwater levels at most of the coastal monitoring wells have been below protective elevations since installation, therefore there is no historical estimate of the conditions under which coastal groundwater elevations were protective of seawater intrusion. Other components of the water balance such as non-SqCWD consumptive use may have also changed over the time period.

We evaluated the possibility of using statistical relationships between pumping and groundwater levels from Dr. Raquel Prado's recent analysis (Prado and O'Connor, 2011) to estimate recovery time. However, the only coastal monitoring well with a constant relationship between groundwater elevation and pumping is monitoring well SC-1. Groundwater elevations in other monitoring wells have relationships with pumping that change over time and therefore are not appropriate for estimating long-term effects (Prado, 2011).

To provide a more refined estimate of recovery time, a basin-wide groundwater model is required. This modeling should be undertaken if SqCWD needs a better estimate of recovery time than the time needed to eliminate the accumulated deficit.

CONCLUSION

This evaluation provides SqCWD with guidelines to plan future overall pumping. SqCWD will need to continue its monitoring programs to assess whether management objectives are being met and adapt accordingly. It also remains important to implement other elements of the Groundwater Management Plan (SqCWD and CWD, 2007) such as the Well Master Plan (ESA, 2010), which will redistribute pumping inland.

Please let us know if you have any questions.

Sincerely,

Cameron Tana

Derrik Williams
HydroMetrics Water Resources Inc.

Attachment 1. Calculation of Equivalent Freshwater Heads, Chemographs, and Hydrographs

Attachment 2. Contour Maps for Evaluating Flow from Aromas Area to Pajaro Valley

References

ESA. 2010. *Soquel Creek Water District Well Master Plan Draft Environmental Impact Report*, State Clearinghouse No. 2006072018. Prepared for Soquel Creek Water District. September 1.

HydroMetrics LLC. 2009a. *Groundwater levels to protect against seawater intrusion and store water offshore*. Prepared for Soquel Creek Water District. January.

HydroMetrics LLC. 2009b. *Modeled outflow to achieve protective waterlLevels.* Letter to Laura Brown, Soquel Creek Water District. September 15.

HydroMetrics WRI. 2011a. *Soquel-Aptos Area Groundwater Management Annual Review and Report*. Prepared for Soquel Creek Water District and Central Water District. May.

HydroMetrics WRI. 2011b. *Estimation of deep groundwater recharge using a precipitiation-runoff watershed model Soquel-Aptos, California*. Prepared for Soquel Creek Water District, Central Water District, and the City of Santa Cruz. September. September.

Johnson, N.M. 2009. *Drinking Water Source Assessments (DWSAPs).* Prepared for Central Water District. March.

Johnson, N.M., D. Williams, E.B. Yates, and G. Thrupp., 2004. *Groundwater assessment of alternative conjunctive use scenarios- draft technical memorandum 2: hydrogeologic conceptual model*. Prepared for Soquel Creek Water District. September.

Langevin, C.D., W.B. Shoemaker, and W. Guo. 2003. *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model–Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT*). U.S. Geological Survey Open-File Report 03-426.

Luhdorff & Scalmanini Consulting Engineers. 1996. *AB 3030 Ground-Water Management Plan.* Prepared for Soquel Creek Water District and Central Water District.

Luhdorff & Scalmanini Consulting Engineers. 2003. *Ground-Water Conditions in the Soquel-Aptos Area, 2000 through mid-2003.* Prepared for Soquel Creek Water District.

Pajaro Valley Water Management Agency. 2011. *Annual Report 2010*. May.

Pajaro Valley Water Management Agency. 2010. *Annual Report 2009*.

Pajaro Valley Water Management Agency. 2009. *Annual Report 2008.*

Pajaro Valley Water Management Agency. 2007. *Annual Report 2006.*

Pajaro Valley Water Management Agency. 1993. *1992 State of the Basin.*

Prado, R. 2011. *Re: predictions based on Soquel statistical analysis.* Email to Cameron Tana. December 24.

Prado, R. and K. O'Connor. 2011. *Report on the Statistical Analysis of Ground Water Elevation Data of Monitoring and Production Wells in the Soquel Water District.* Prepared for Soquel Water District. October.

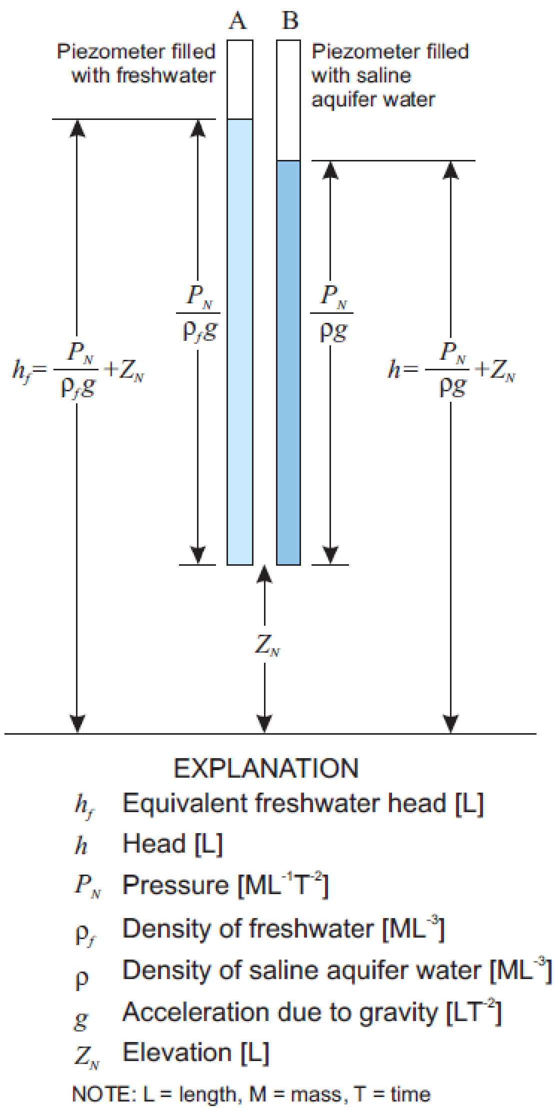
Soquel Creek Water District. 2011. *Urban Water Management Plan 2010.* Prepared for the California Department of Water Resources. September.

Soquel Creek Water District and Central Water District. 2007. *Groundwater Management Plan -2007 Soquel-Aptos Area.* April.

U.S. Geological Survey. 2011. *Pajaro Valley Hydrologic Model*. Model code and interface provided by Pajaro Valley Water Management Agency. July.

ATTACHMENT 1: CALCULATION OF FRESHWATER EQUIVALENT HEADS, HYDROGRAPHS AND CHEMOGRAPHS

Measured groundwater levels must be adjusted to account for salinity before they are compared to protective elevations. The protective groundwater elevation estimated by SEAWAT-2000 is the freshwater equivalent head (Langevin and others, 2003). The freshwater equivalent head for groundwater with a substantial amount of salinity is higher than the observed groundwater levels due to the higher density of saline water. The following figure reproduced from the SEAWAT users manual (Guo and Langevin, 2002) illustrates this. The pressures in the two piezometers are equivalent because the higher density of the saline aquifer water column makes up for the lower groundwater elevation.



In the Aromas area coastal monitoring wells, the water column above any point is a mixture of freshwater and saline water. To represent the mixture of fresh and saline water, we use the chloride concentrations measured in the A and B screens. The density for the interval of the water column in each of the screens (Δ_A and Δ_B is the interval length in equations below) is based on the chloride concentration in each screen. The density for the interval between the two screens (Δ_{AB} is the interval length in equations below) is based on the average of the A and B screen intervals. The density for the interval above the B screen is assumed to be the freshwater density.

Therefore, the calculation of pressure, P_N, at the bottom of the A screen is:

$$P_N = g(\rho_A \Delta_A + \rho_{AB} \Delta_{AB} + \rho_B \Delta_B + \rho_f \Delta_f)$$

By recognizing that the freshwater interval above the top of the B screen is:

$$\Delta_f = h - \Delta_A - \Delta_{AB} - \Delta_B - Z_N$$

, the equivalent freshwater head at the bottom of the A screen is calculated as:

$$h_f = h - \frac{\rho_A \Delta_A + \rho_{AB} \Delta_{AB} + \rho_B \Delta_B}{\rho_f} - (\Delta_A + \Delta_{AB} + \Delta_B)$$

Only water in the B screen and overlying freshwater creates pressure at the bottom of the screen so the equivalent freshwater head at the bottom of the B screen is calculated as:

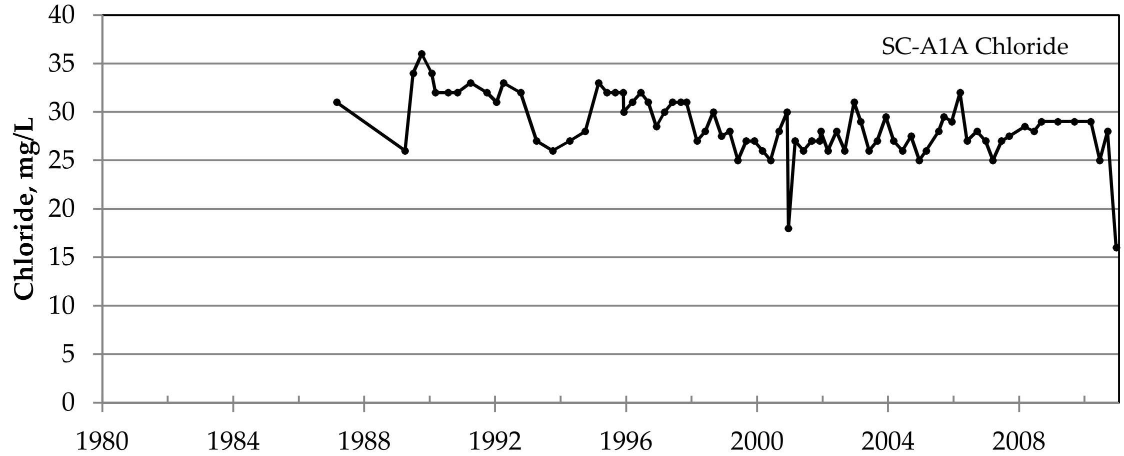
$$h_f = h - \frac{\rho_B \Delta_B}{\rho_f} - \Delta_B$$

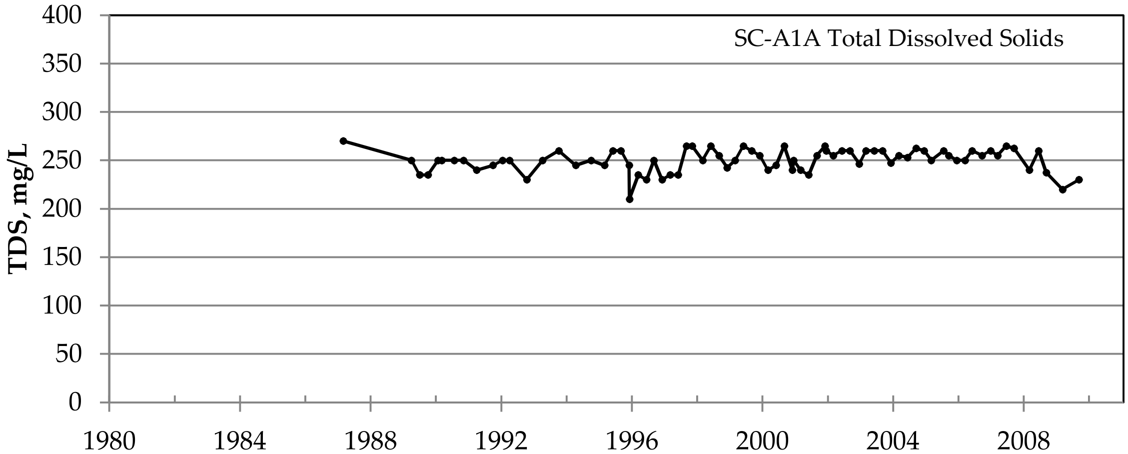
These equivalent fresh heads are plotted in grey on the following hydrographs where they can be distinguished from measured groundwater levels (all A screen wells except for SC-A1A) and can be compared to the dotted line representing the recommended protective elevations.

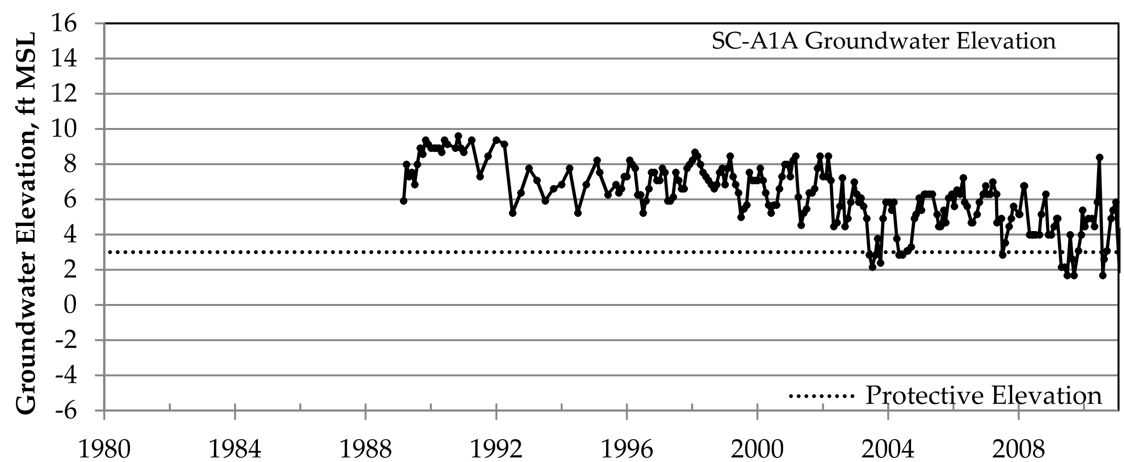
REFERENCES:

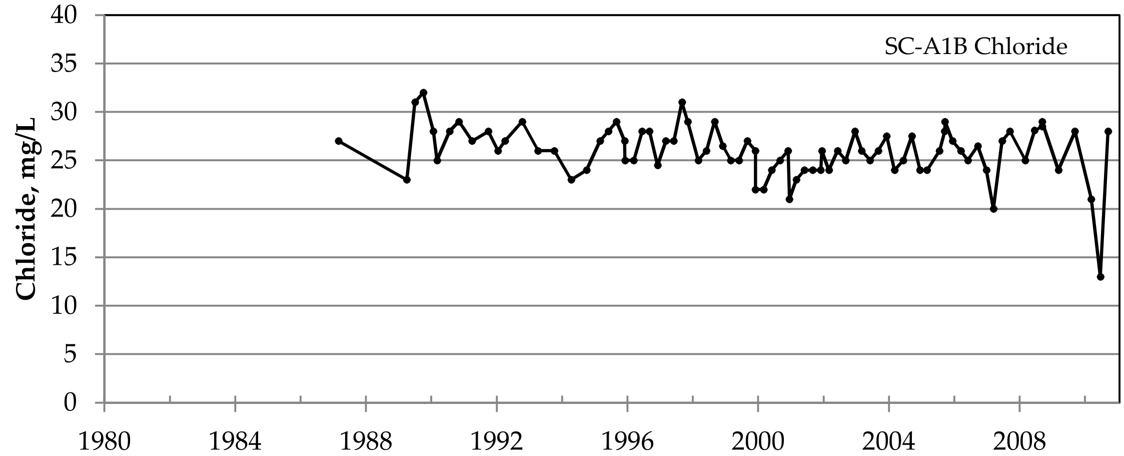
Guo, W. and C.D. Langevin. 2002. *User's Guide to SEAWAT: A Computer Program for Simulation of Three-Dimensional Variable-Density Ground-Water Flow* U.S. Geological Survey Techniques of Water-Resources Investigations 6-A7.

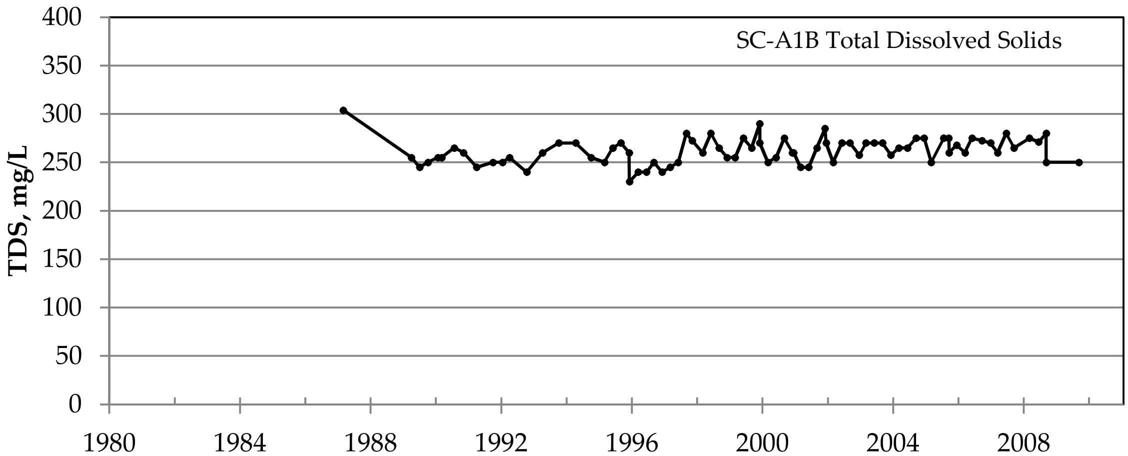
Langevin, C.D., W.B. Shoemaker, and W. Guo. 2003. *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model–Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT*). U.S. Geological Survey Open-File Report 03-426.

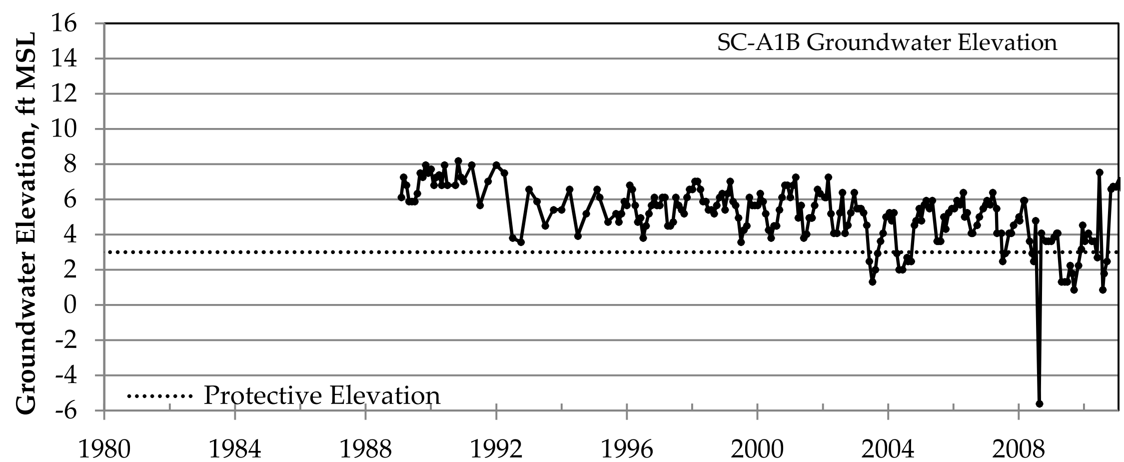

SC-A1A Chloride
Chloride, mg/L
40
35
30
25
20
15
10
5
0
1980
1984
1988
1992
1996
2000
2004
2008

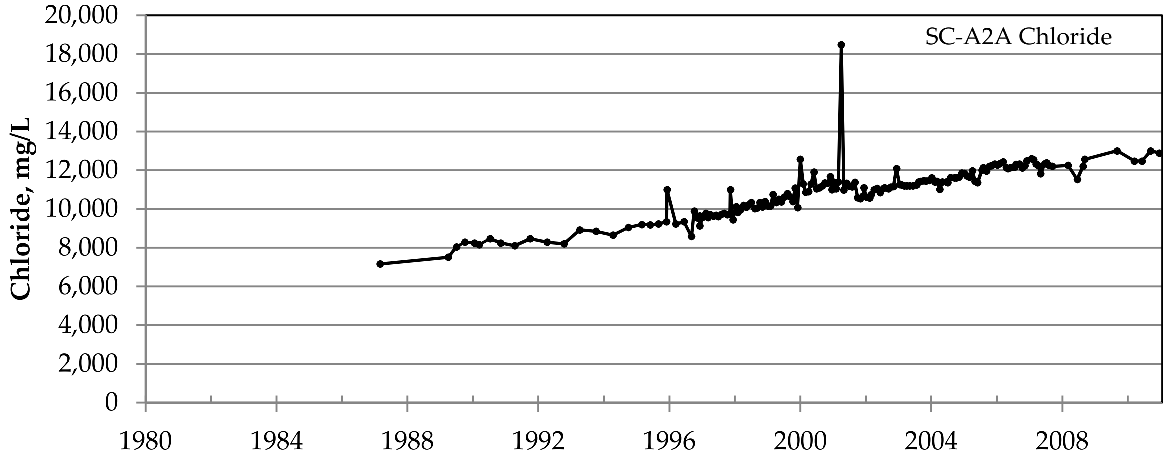

SC-A1A Total Dissolved Solids
TDS, mg/L
400
350
300
250
200
150
100
50
0
1980
1984
1988
1992
1996
2000
2004
2008

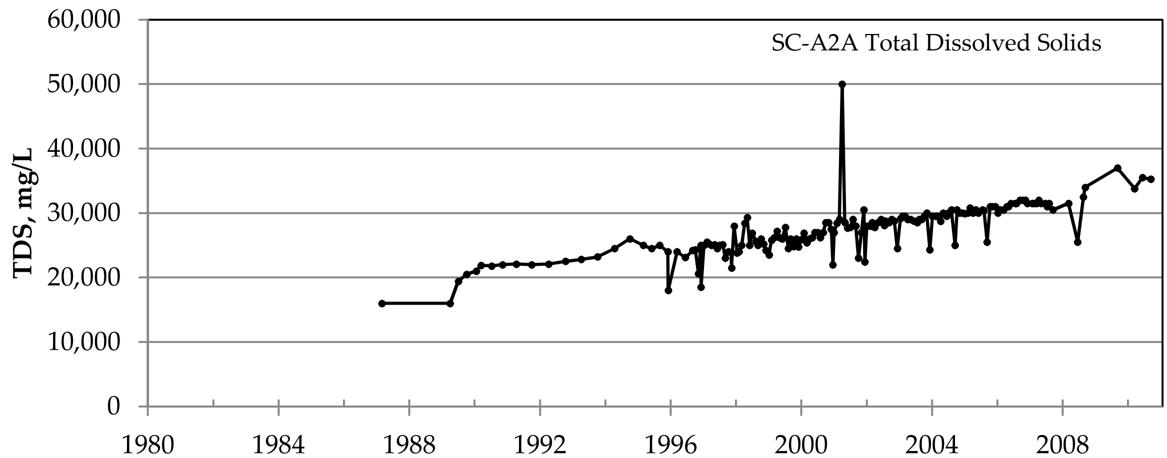

SC-A1A Groundwater Elevation
Groundwater Elevation, ft MSL
16
14
12
10
8
6
4
2
0
-2
-4
-6
Protective Elevation
1980
1984
1988
1992
1996
2000
2004
2008

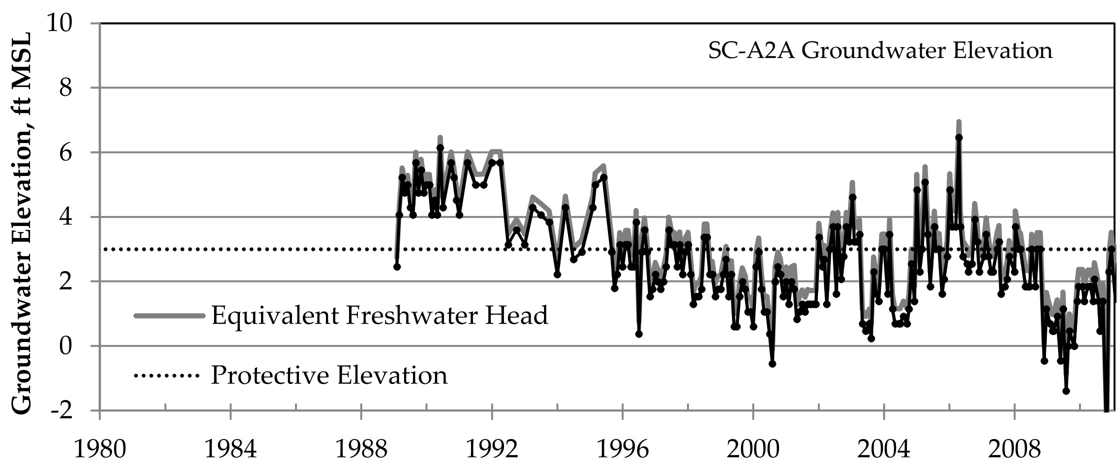

SC-A1B Chloride
Chloride, mg/L
0
5
10
15
20
25
30
35
40
1980
1984
1988
1992
1996
2000
2004
2008

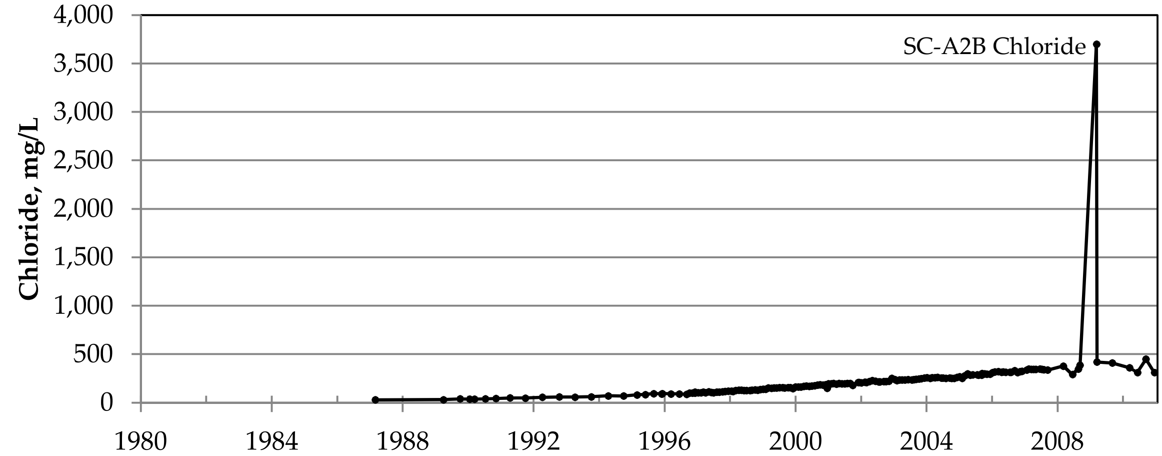

SC-A1B Total Dissolved Solids
TDS, mg/L
0
50
100
150
200
250
300
350
400
1980
1984
1988
1992
1996
2000
2004
2008

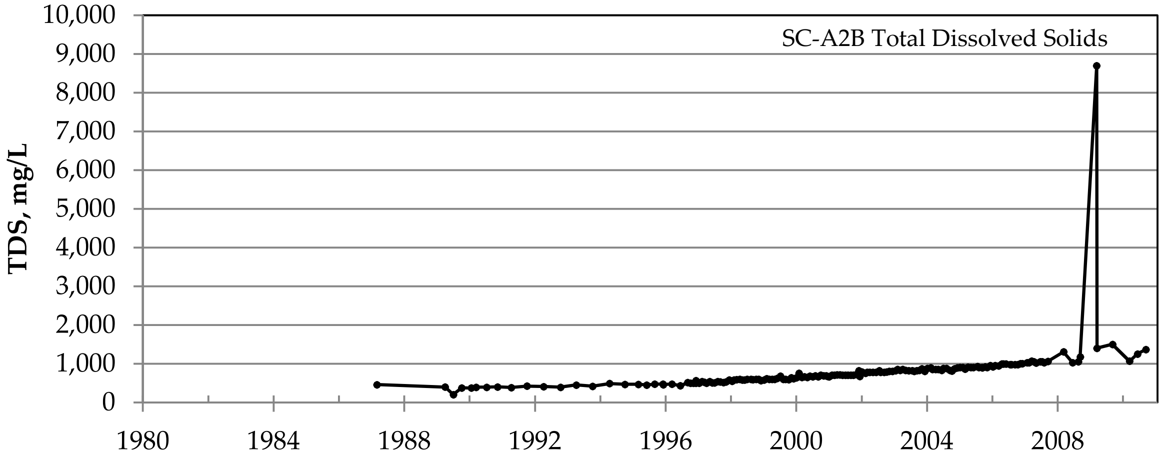

SC-A1B Groundwater Elevation
Groundwater Elevation, ft MSL
Protective Elevation
-6
-4
-2
0
2
4
6
8
10
12
14
16
1980
1984
1988
1992
1996
2000
2004
2008

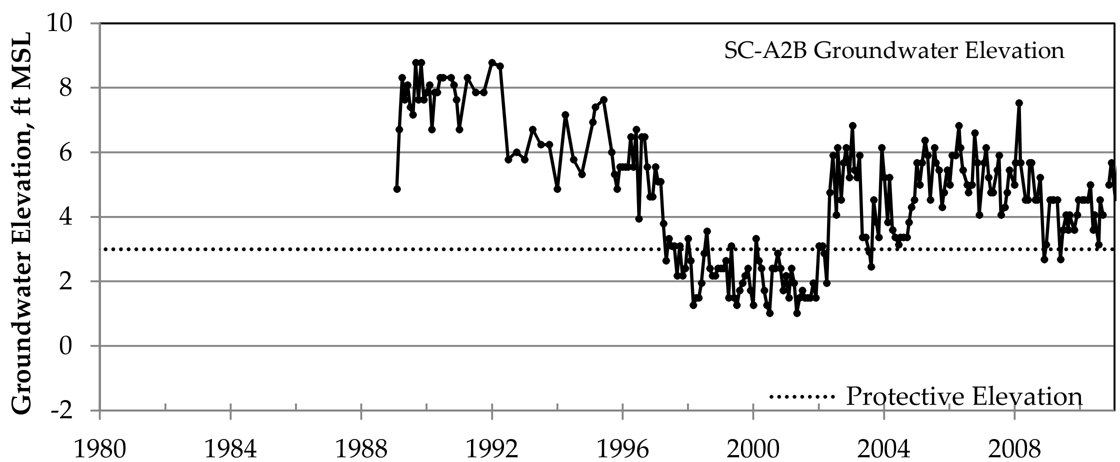

SC-A2A Chloride
Chloride, mg/L
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1980
1984
1988
1992
1996
2000
2004
2008

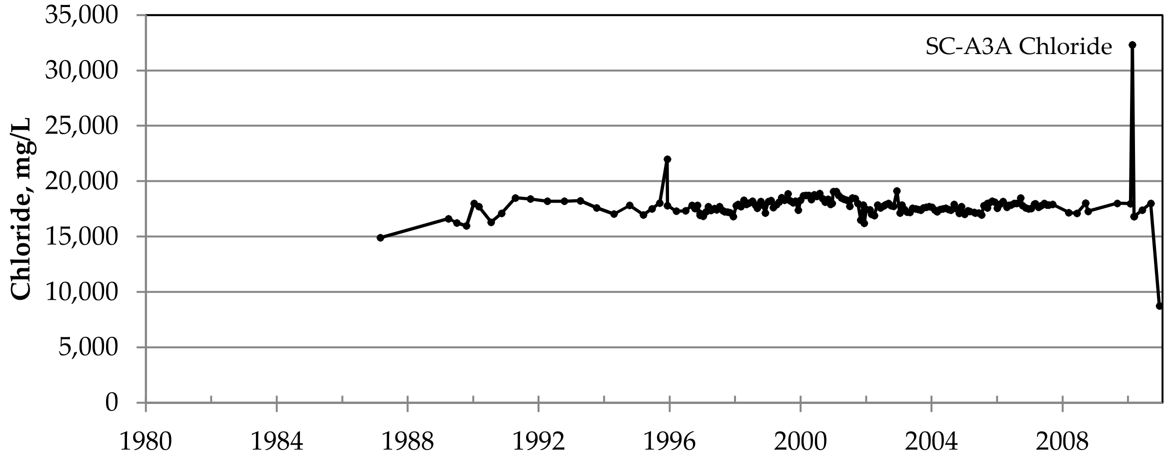

SC-A2A Total Dissolved Solids
TDS, mg/L
60,000
50,000
40,000
30,000
20,000
10,000
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A2A Groundwater Elevation
Groundwater Elevation, ft MSL
Equivalent Freshwater Head
Protective Elevation
10
8
6
4
2
0
-2
1980
1984
1988
1992
1996
2000
2004
2008

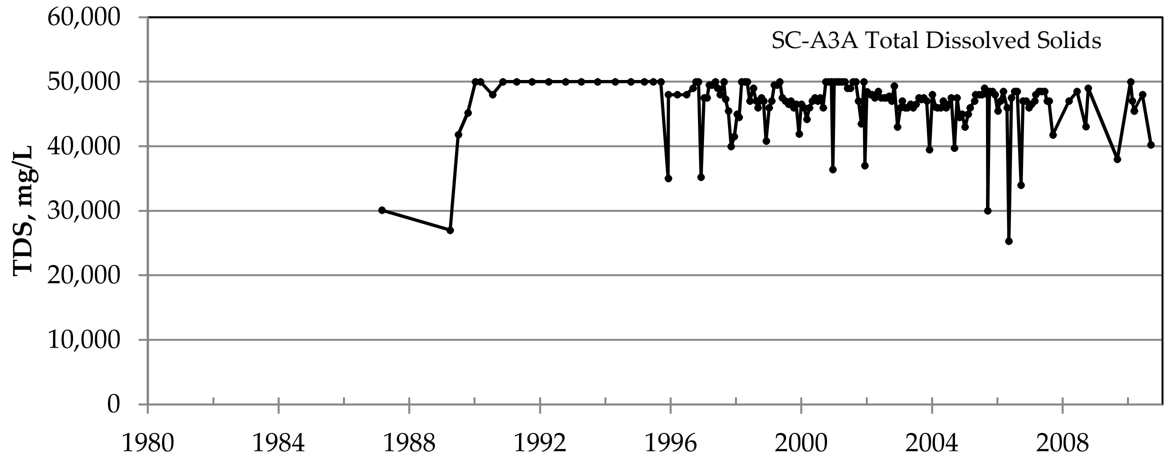

SC-A2B Chloride
Chloride, mg/L
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A2B Total Dissolved Solids
TDS, mg/L
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1984
1988
1992
1996
2000
2004
2008

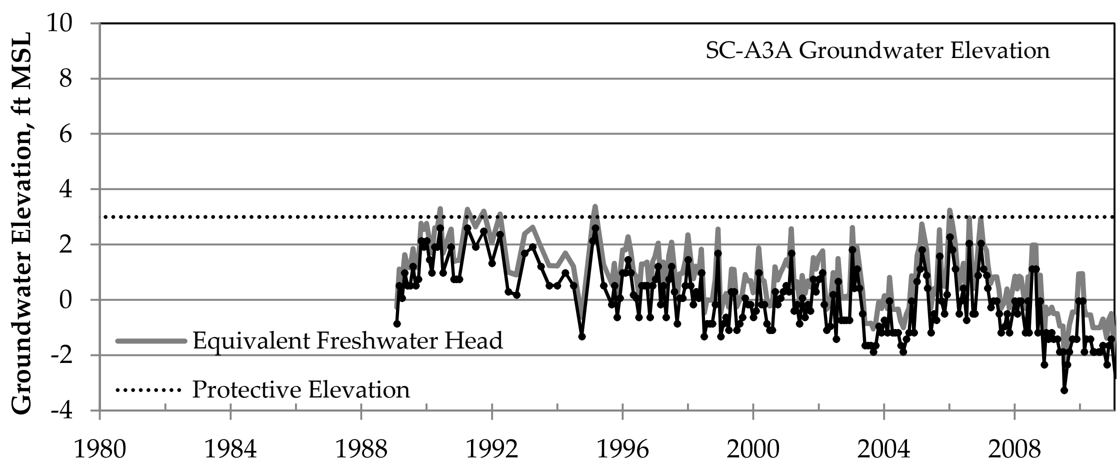

SC-A2B Groundwater Elevation
Groundwater Elevation, ft MSL
Protective Elevation
10
8
6
4
2
0
-2
1980
1984
1988
1992
1996
2000
2004
2008



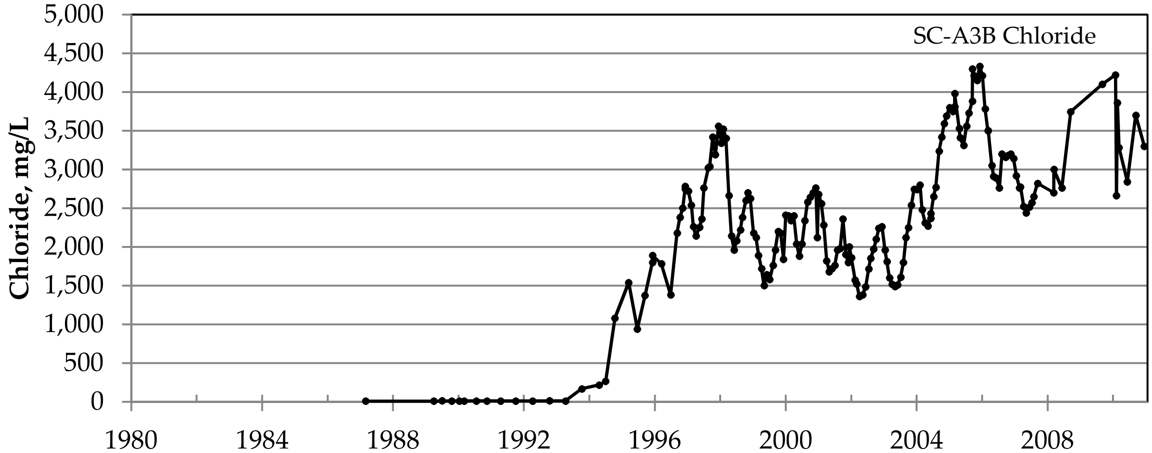
SC-A3A Chloride
Chloride, mg/L
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1980
1984
1988
1992
1996
2000
2004
2008

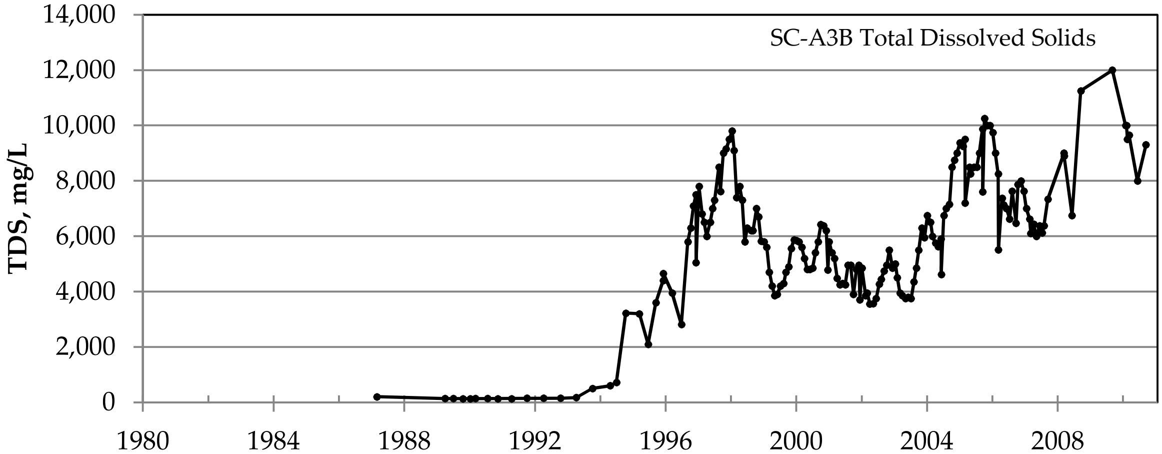


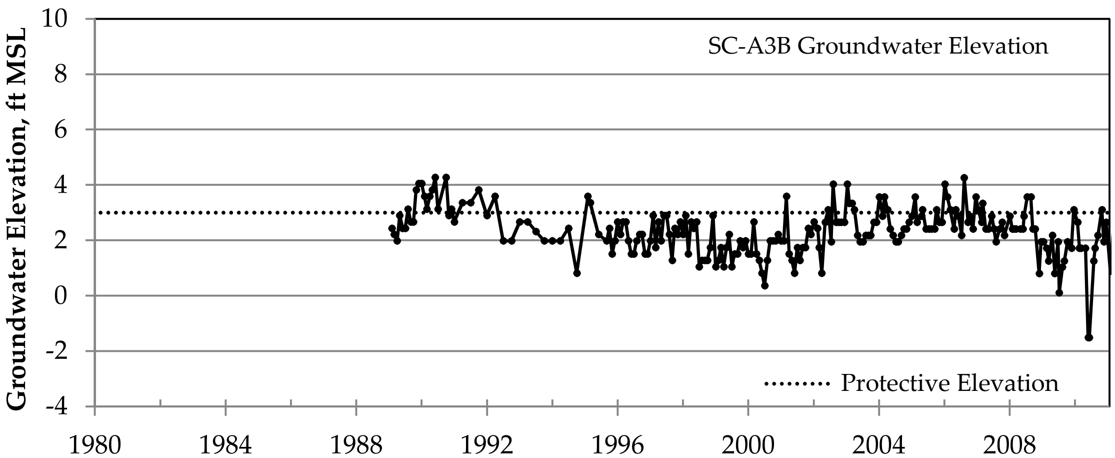
SC-A3A Total Dissolved Solids
TDS, mg/L
60,000
50,000
40,000
30,000
20,000
10,000
0
1980
1984
1988
1992
1996
2000
2004
2008

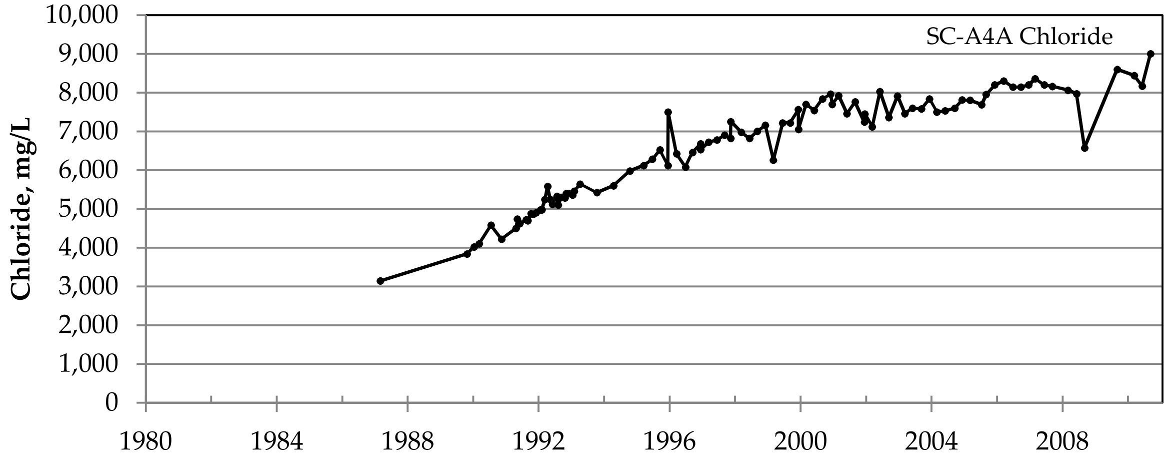


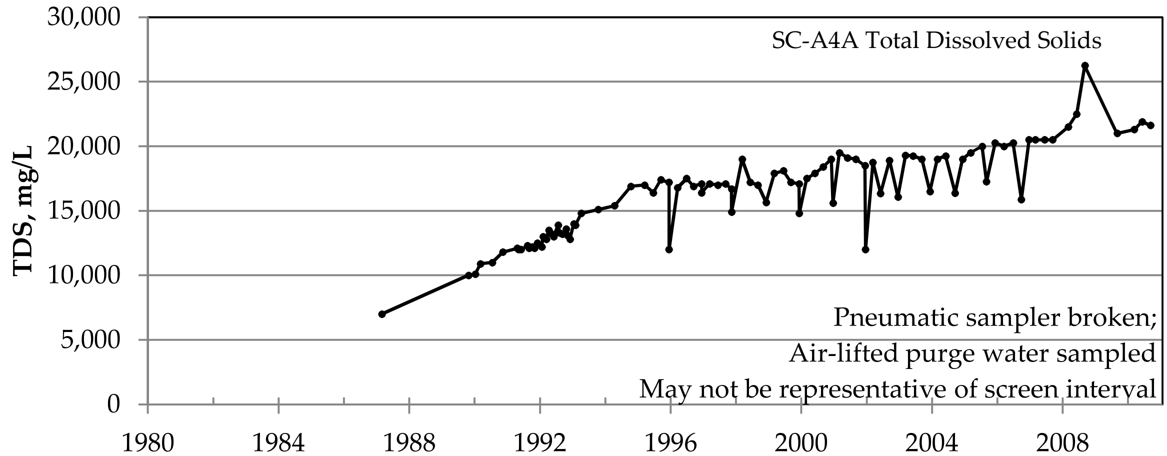
SC-A3A Groundwater Elevation
Groundwater Elevation, ft MSL
10
8
6
4
2
0
-2
-4
Equivalent Freshwater Head
Protective Elevation
1980
1984
1988
1992
1996
2000
2004
2008

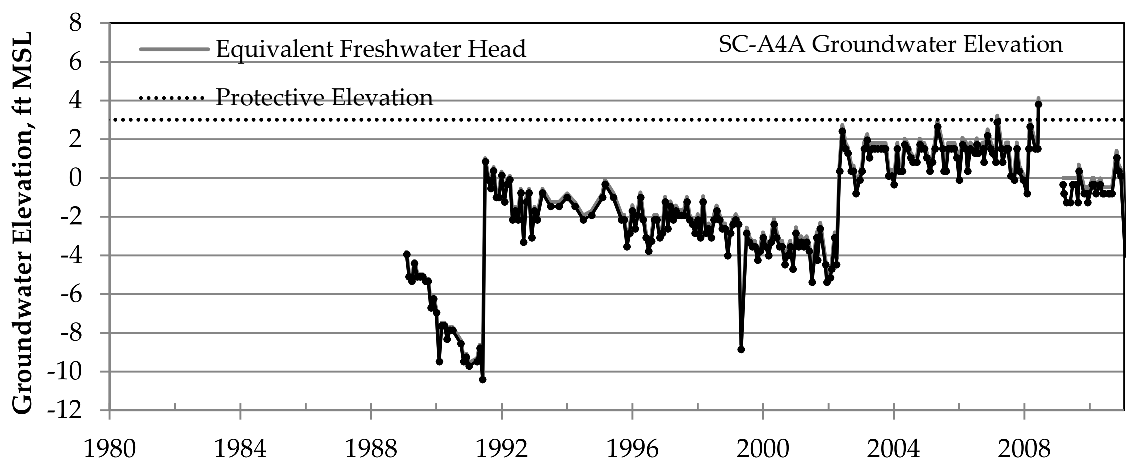

SC-A3B Chloride
Chloride, mg/L
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1980
1984
1988
1992
1996
2000
2004
2008

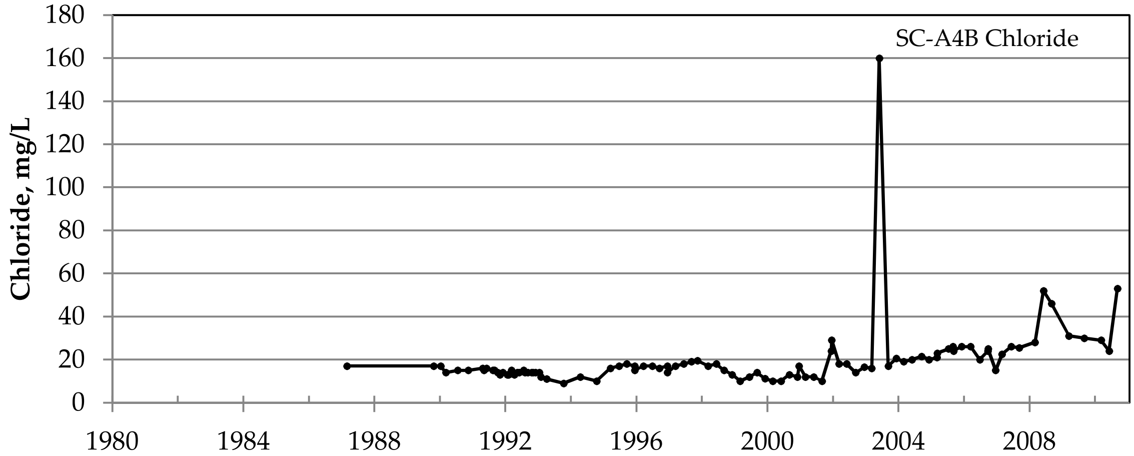

SC-A3B Total Dissolved Solids
TDS, mg/L
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A3B Groundwater Elevation
Groundwater Elevation, ft MSL
10
8
6
4
2
0
-2
-4
Protective Elevation
1980
1984
1988
1992
1996
2000
2004
2008

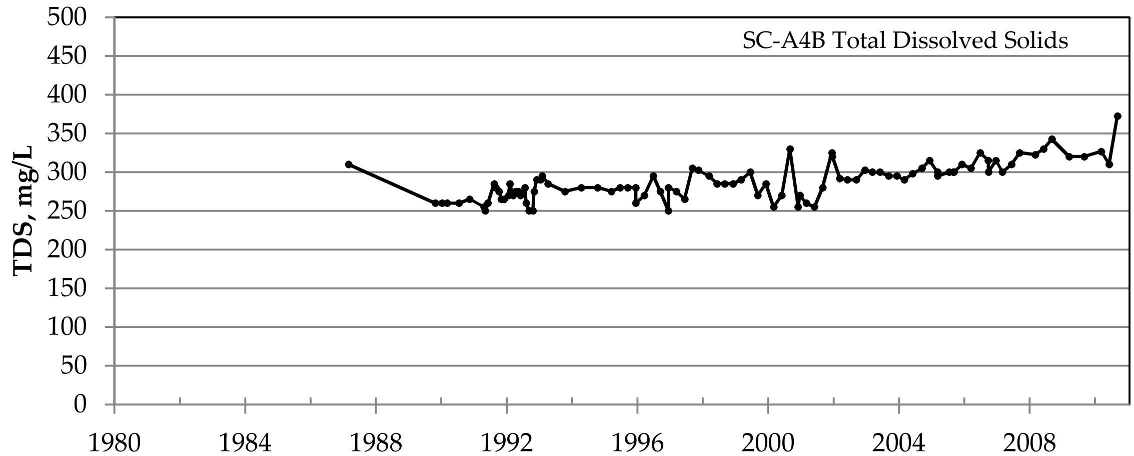

SC-A4A Chloride
Chloride, mg/L
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A4A Total Dissolved Solids
TDS, mg/L
30,000
25,000
20,000
15,000
10,000
5,000
0
Pneumatic sampler broken;
Air-lifted purge water sampled
May not be representative of screen interval
1980
1984
1988
1992
1996
2000
2004
2008

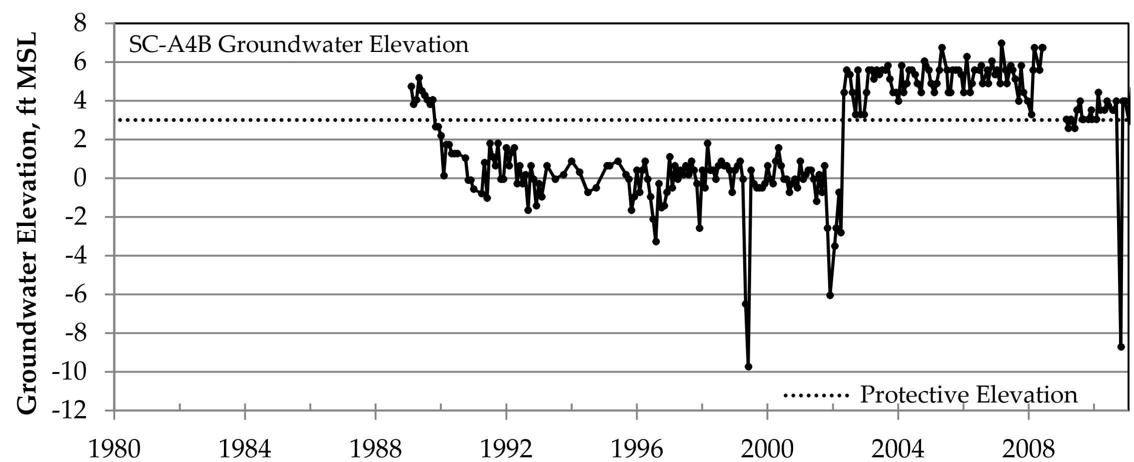

Equivalent Freshwater Head
Protective Elevation
SC-A4A Groundwater Elevation
Groundwater Elevation, ft MSL
8
6
4
2
0
-2
-4
-6
-8
-10
-12
1980
1984
1988
1992
1996
2000
2004
2008



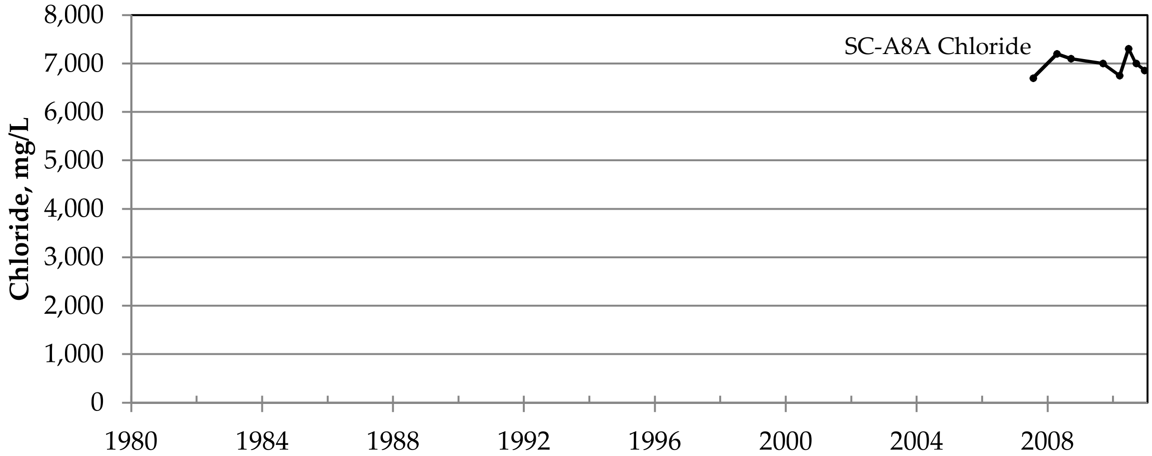
SC-A4B Chloride
Chloride, mg/L
0
20
40
60
80
100
120
140
160
180
1980
1984
1988
1992
1996
2000
2004
2008

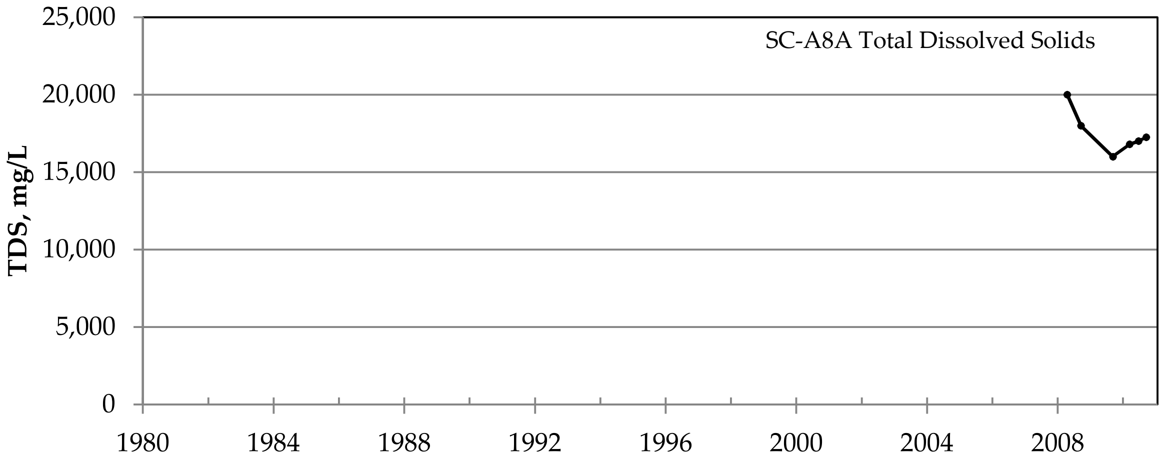


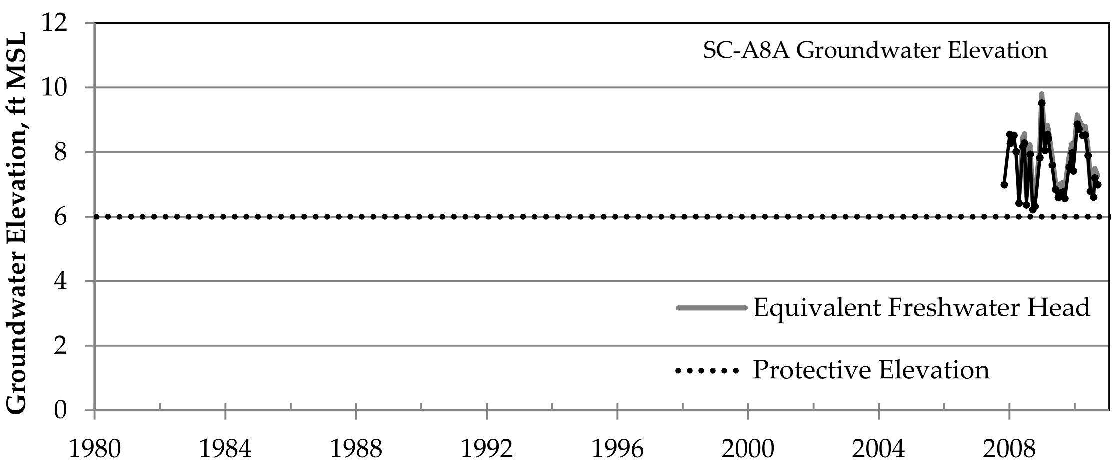
SC-A4B Total Dissolved Solids
TDS, mg/L
0
50
100
150
200
250
300
350
400
450
500
1980
1984
1988
1992
1996
2000
2004
2008

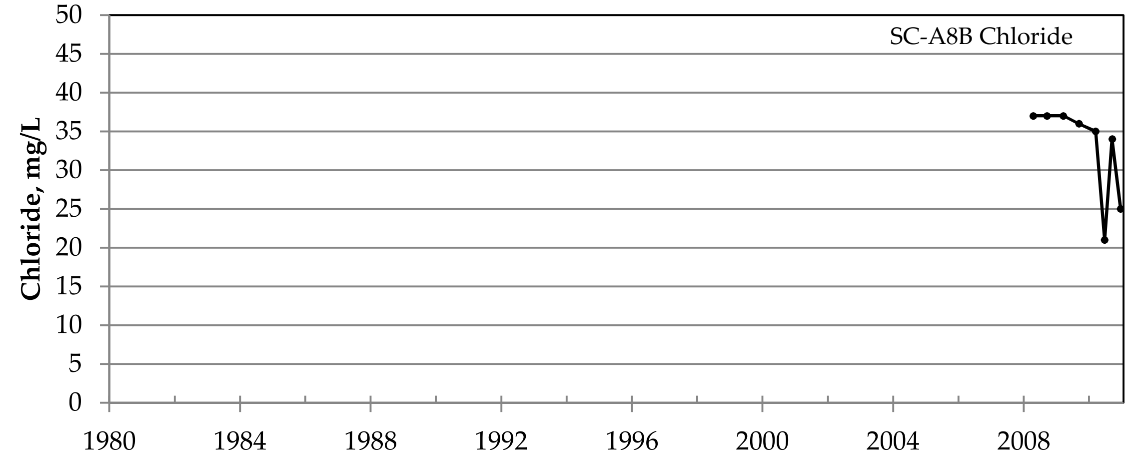


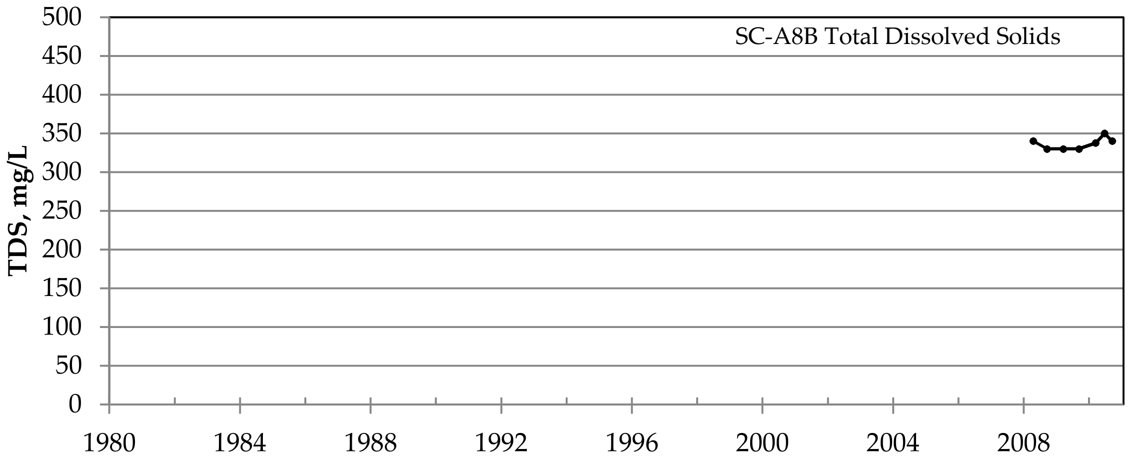
SC-A4B Groundwater Elevation
Groundwater Elevation, ft MSL
Protective Elevation
-12
-10
-8
-6
-4
-2
0
2
4
6
8
1980
1984
1988
1992
1996
2000
2004
2008

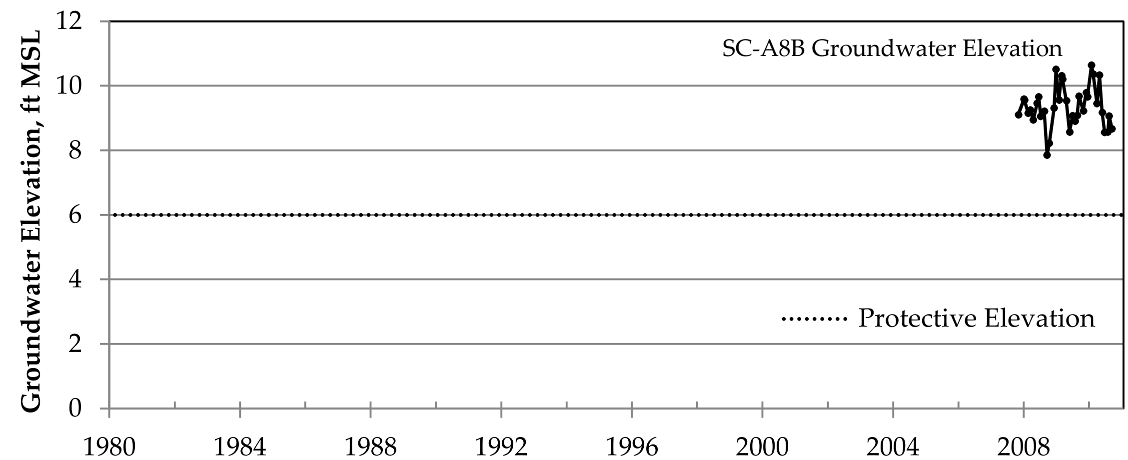

SC-A8A Chloride
Chloride, mg/L
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A8A Total Dissolved Solids
TDS, mg/L
25,000
20,000
15,000
10,000
5,000
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A8A Groundwater Elevation
Groundwater Elevation, ft MSL
12
10
8
6
4
2
0
Equivalent Freshwater Head
Protective Elevation
1980
1984
1988
1992
1996
2000
2004
2008

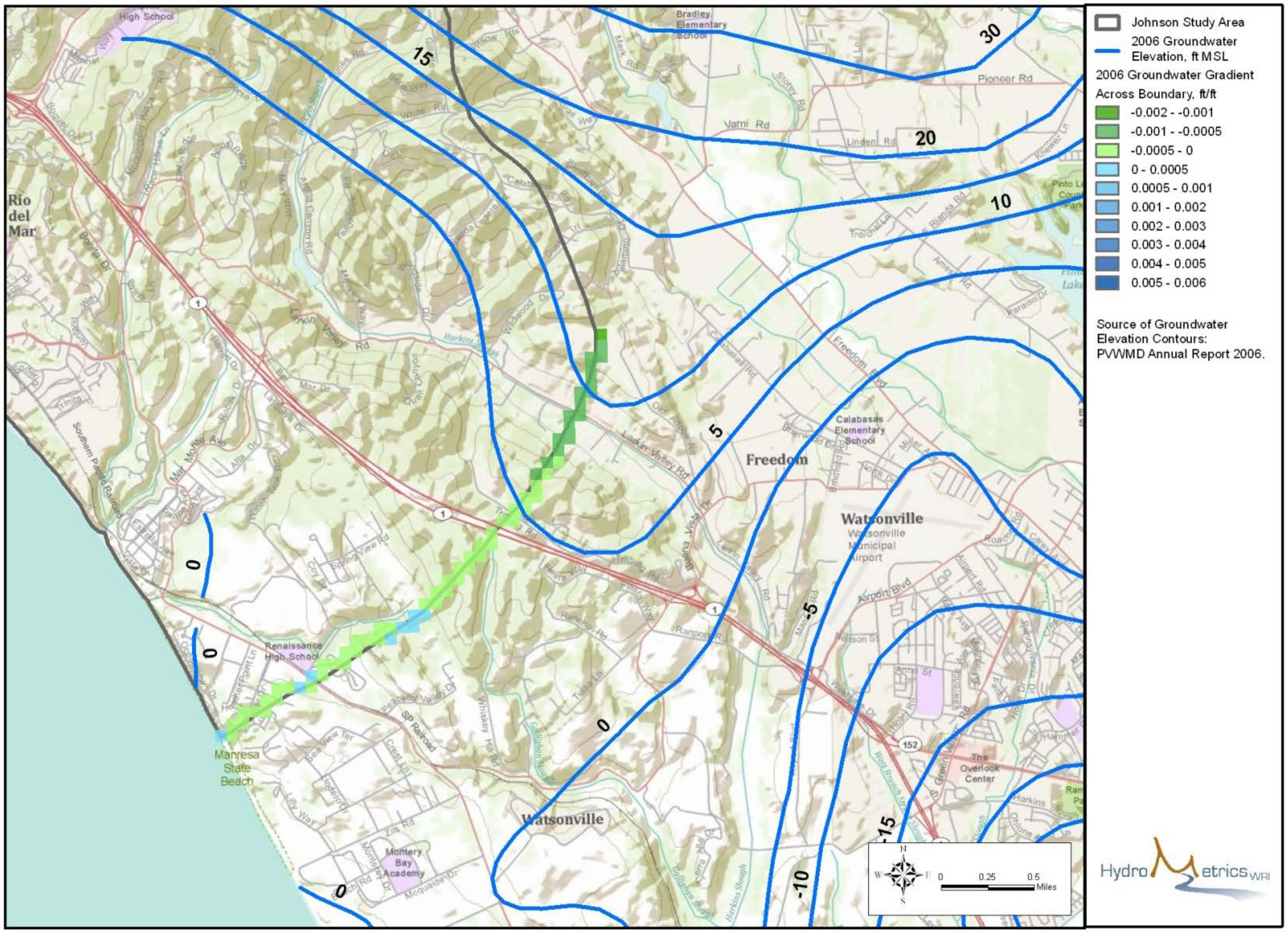

SC-A8B Chloride
Chloride, mg/L
50
45
40
35
30
25
20
15
10
5
0
1980
1984
1988
1992
1996
2000
2004
2008


SC-A8B Total Dissolved Solids
TDS, mg/L
500
450
400
350
300
250
200
150
100
50
0
1980
1984
1988
1992
1996
2000
2004
2008

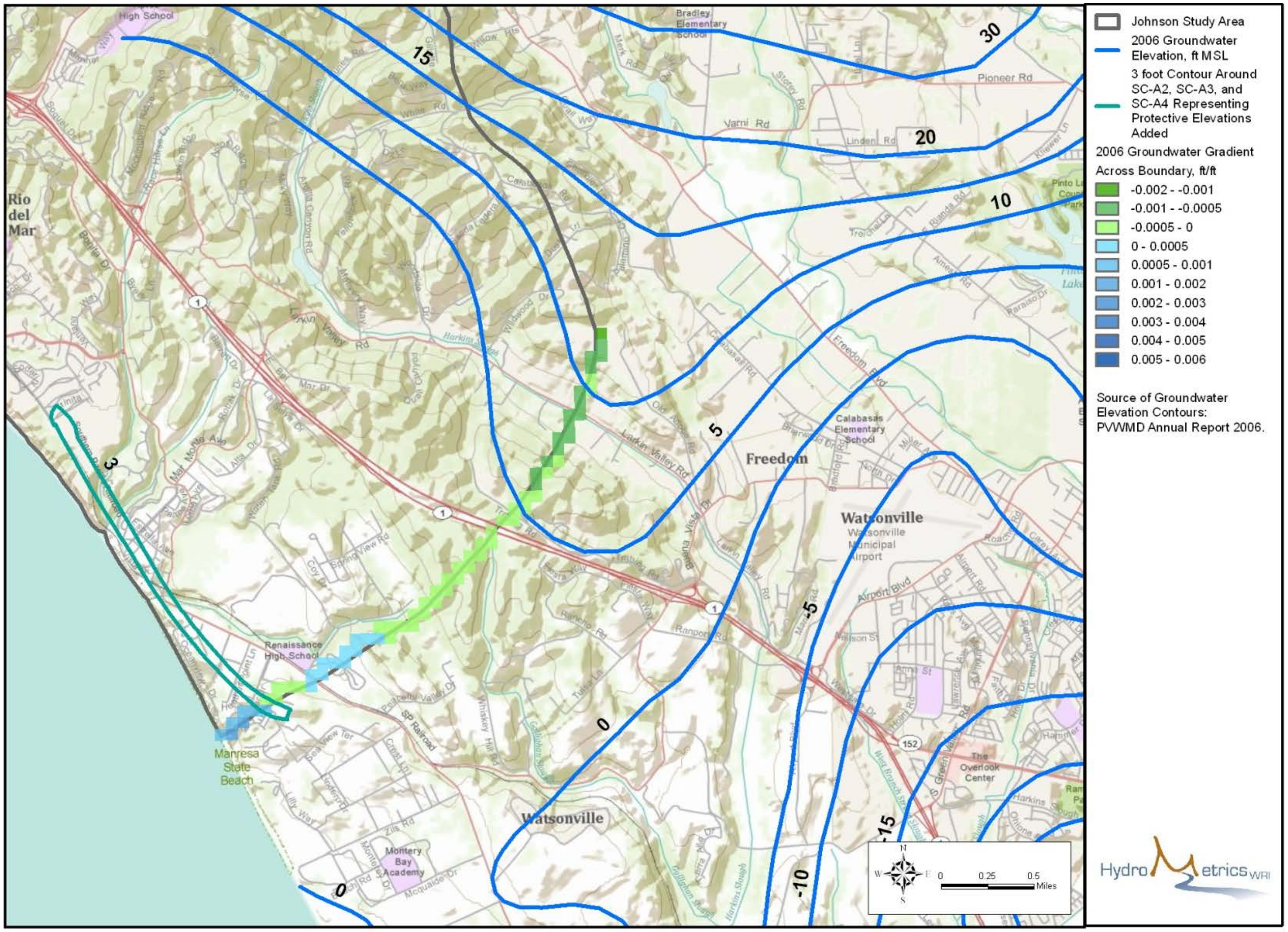

SC-A8B Groundwater Elevation
Groundwater Elevation, ft MSL
12
10
8
6
4
2
0
Protective Elevation
1980
1984
1988
1992
1996
2000
2004
2008

ATTACHMENT 2:

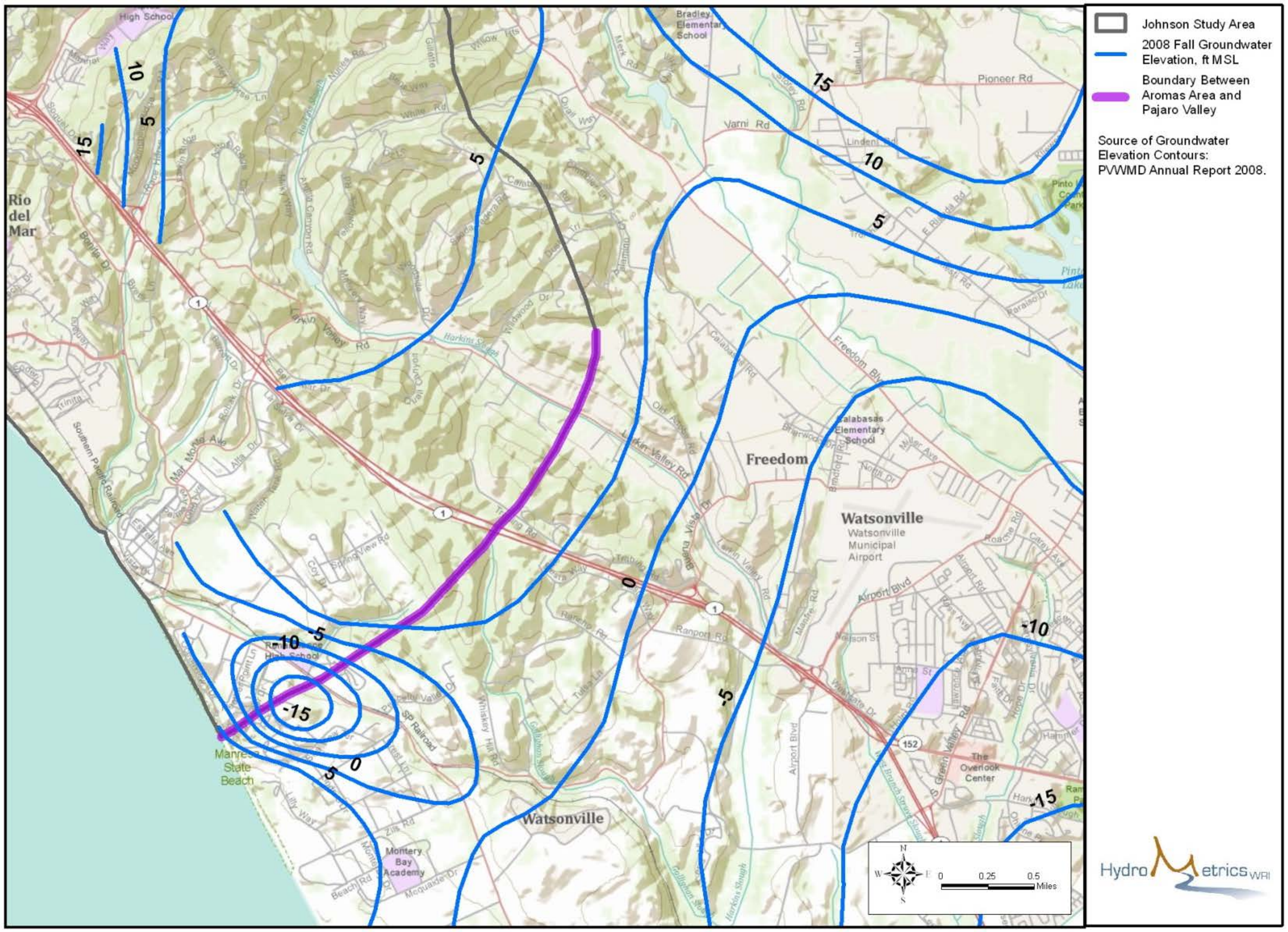
CONTOUR MAPS FOR EVALUATING FLOW FROM AROMAS AREA TO PAJARO VALLEY


Johnson Study Area
2006 Groundwater Elevation, ft MSL
2006 Groundwater Gradient Across Boundary, ft/ft
-0.002 - -0.001
-0.001 - -0.0005
-0.0005 - 0
0 - 0.0005
0.0005 - 0.001
0.001 - 0.002
0.002 - 0.003
0.003 - 0.004
0.004 - 0.005
0.005 - 0.006
Source of Groundwater Elevation Contours: PVWMD Annual Report 2006.
HydroMetrics WRI
30
20
15
10
5
0
-5
-10
-15
Rio del Mar
Freedom
Watsonville
Watsonville Municipal Airport
Manresa State Beach
Renaissance High School
Calabasas Elementary School
Bradley Elementary School
Monterey Bay Academy
The Overlook Center
Larkin Valley Rd
Airport Blvd
Freedom Blvd
Pioneer Rd
Varni Rd
0 0.25 0.5 Miles

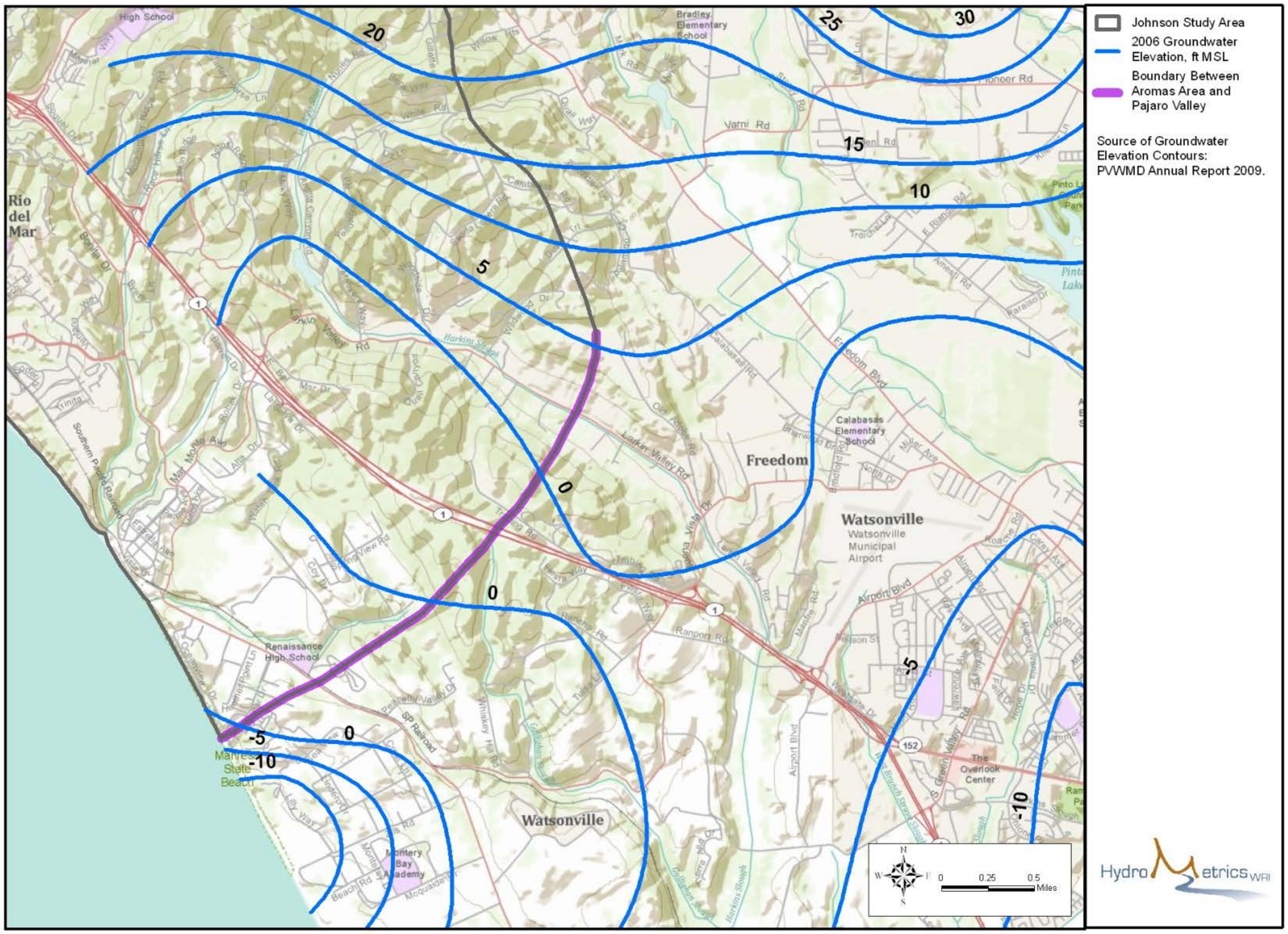
2006



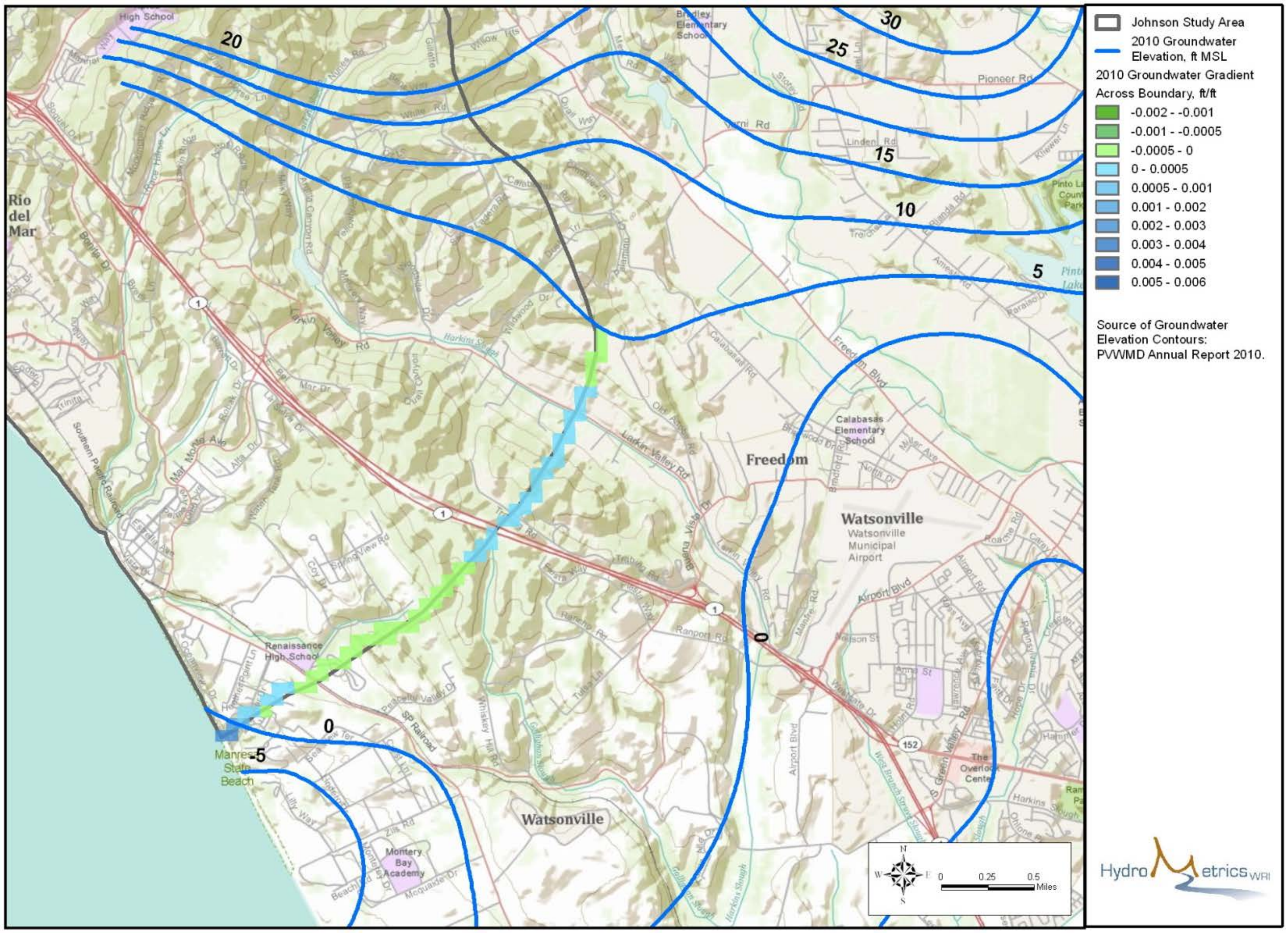
2006 - 3ft contour added


Johnson Study Area
2008 Fall Groundwater Elevation, ft MSL
Boundary Between Aromas Area and Pajaro Valley
Source of Groundwater Elevation Contours: PVWMD Annual Report 2008.
Rio del Mar
Freedom
Watsonville
Watsonville Municipal Airport
Manresa State Beach
Monterey Bay Academy
Calabasas Elementary School
Bradley Elementary School
The Overlook Center
15
10
5
0
-5
-10
-15
0
0.25
0.5
Miles
HydroMetrics WRI

2008


Johnson Study Area
2006 Groundwater Elevation, ft MSL
Boundary Between Aromas Area and Pajaro Valley
Source of Groundwater Elevation Contours: PVWMD Annual Report 2009.
HydroMetrics WRI
30
25
20
15
10
5
0
-5
-10
Rio del Mar
Freedom
Watsonville
Watsonville Municipal Airport
Manresa State Beach
0 0.25 0.5 Miles

2009


Johnson Study Area
2010 Groundwater Elevation, ft MSL
2010 Groundwater Gradient Across Boundary, ft/ft
-0.002 - -0.001
-0.001 - -0.0005
-0.0005 - 0
0 - 0.0005
0.0005 - 0.001
0.001 - 0.002
0.002 - 0.003
0.003 - 0.004
0.004 - 0.005
0.005 - 0.006
Source of Groundwater Elevation Contours: PVWMD Annual Report 2010.
30
25
20
15
10
5
0
-5
Rio del Mar
Freedom
Watsonville
Watsonville Municipal Airport
Calabasas Elementary School
Renaissance High School
Manresa State Beach
Monterey Bay Academy
0 0.25 0.5 Miles
HydroMetrics WRI

2010