

Executive Summary



The City of Santa Cruz Water Department (SCWD) and Soquel Creek Water District (SqCWD) depend upon local water supplies to meet the needs of their customers. However, the Water Department's surface waters are frequently diminished by droughts and the District's groundwater supply is threatened by declining water levels and seawater intrusion.

Each agency conducted separate integrated water planning processes and each identified seawater desalination as the best option for delivering an additional flexible and reliable water source. To take advantage of the benefits derived from a cooperative facility, the agencies joined together, forming the **scwd²** Task Force, to address their different needs and to share the investigative costs associated with the potential desalination plant. If the desalination plant is constructed, SCWD will be able to address its drought protection needs and SqCWD will be able to protect its groundwater resources from seawater intrusion. Both agencies will continue to practice conservation and curtailment to maximize efficient use of water resources.

From March 2008 through April 2009, **scwd²** conducted a comprehensive pilot plant testing program to evaluate alternative treatment systems for a seawater reverse osmosis (SWRO) desalination plant. The pilot plant was located at the University of California Santa Cruz Long Marine Laboratory and treated up to 50 gallons per minute of seawater supplied from the Lab's existing open ocean intakes. The goals of the pilot program were to:

- Demonstrate the best desalination technology. Data collected during seasonal variations, algal blooms, and storm events indicates that a robust pretreatment system is crucial to maintain reliable production while minimizing costs and energy use during desalination.
- Test any special treatment needs. Data collected during special studies indicates that the design of the desalination system will be determined by the concentrations of chloride, boron, and bromide in the seawater; achieving target water quality objectives for these parameters provides sufficient removal of other salts, minerals, regulated parameters, and selected unregulated parameters.
- Provide water quality data for regulatory approval and permitting for a potential full-scale plant. Extensive water quality monitoring and special studies indicate that the seawater off the coast of Santa Cruz is largely free of contamination, that the latest generation of RO membranes achieve regulatory and project-specific water quality goals, and that adding minerals after desalination provides a water that tastes similar to the existing supply and minimizes pipeline corrosion.

This report describes the pilot plant investigations and findings. The key conclusions and recommendations of the pilot plant testing program are:

- Seawater desalination will be a safe and reliable source of supply.
- Pretreatment should be designed to protect the downstream SWRO membranes from fouling.
- A single-stage SWRO system with a hybrid SWRO membrane combination will achieve water quality goals and require the least amount of energy.
- A robust treatment process is recommended for a SWRO desalination plant.

These are further described below followed by a summary of the **Preliminary Cost Estimate for a New Desalination Facility** and **Next Steps**.

Seawater Desalination will be a Safe and Reliable Source of Supply

The pilot program results demonstrated that seawater off the coast of Santa Cruz can be treated to provide a safe and reliable supplemental source of drinking water supply.

Extensive water quality monitoring was conducted at the pilot plant and at the site of the proposed intake for the potential SWRO plant, which is located approximately 2,000 feet off the coast at a depth of 40 feet. Figure ES-1 shows the project water quality monitoring locations. The monitoring included analysis of over 150 regulated and non-regulated water quality parameters to assess the quality of the source and treated waters. The parameters included regulated indicators of contamination such as pathogens, radionuclides, and synthetic and volatile organic compounds; along with physical parameters; and unregulated parameters including selected emerging contaminants (7 pharmaceuticals and 27 steroids), harmful marine algal toxins (domoic acid and saxitoxin), and unregulated contaminants requiring monitoring by the California Department of Public Health.

The monitoring found that Monterey Bay water is high quality and largely free of contaminants. Computer-based modeling of the Bay performed by others for the project showed that the water quality impact of the San Lorenzo River and the City's wastewater treatment plant outfall are negligible at the proposed open ocean intake location, because they are diluted by a factor of between 100,000 to one million (10^6) times depending upon tidal and weather conditions.

Comprehensive testing of the SWRO desalination treatment process found that the desalinated water meets all federal and state drinking water regulations, and that the treatment process removes potential contaminants including marine algal toxins. Taste-testing by the public, elected officials and members of the local media found that the taste of the desalinated water matches that of existing water supplies. Sixteen weeks of laboratory tests by university researchers found that the conditioned desalinated water would not be corrosive to the pipes in the SCWD and SqCWD delivery systems nor those of their customers.

Pretreatment should be Designed to Protect the Downstream SWRO Membranes from Fouling

A primary objective of the pilot test program was to determine a pretreatment approach which would protect the downstream SWRO membranes from fouling during storm events and algal blooms. Four different pretreatment systems were evaluated: granular media filters (GMF), slow sand filters (SSF), pressurized ultrafiltration (UF) membranes, and submerged UF membranes.

All four pretreatment systems produced water which met project goals for silt density index (SDI), turbidity, and total organic carbon (TOC). This was true whether treating high quality source water or treating more challenging water quality during storm events and algal blooms. The testing found that each of the four



San Lorenzo River

Santa Cruz Municipal Wharf

Weekly monitoring: chlorophyll and algae identification. HAB event monitoring: algal toxins. February 16, 2009 storm event: 24 hour and quarterly monitoring. Samples were collected at the Wharf on February 16, 2009 because ocean conditions were too dangerous to sample at the proposed intake.

City of Santa Cruz Pilot Plant Location at UCSC's Long Marine Laboratory

Continuous monitoring: salinity, pH, temperature, and turbidity. Bi-weekly monitoring: boron, TDS, and TOC. Monthly monitoring: General water quality parameters, secondary MCLs, total coliforms, chlorophyll, and algae counts/ identification. Quarterly monitoring: Title 22 inorganics, UCRM, emerging contaminants, and remaining indicators of contamination. HAB event monitoring: algal toxins.

36" Abandoned WWTP Outlet Pipe/Proposed Full-Scale SWRO Intake (Approx. 2,000 Lineal Feet)

Continuous monitoring: salinity, temperature, and turbidity. 12-day and 24 hour storm event monitoring: alkalinity, TDS, and bacterial indicators of contamination. Monthly monitoring: General water quality parameters, Secondary MCLs, Title 22 inorganics, *Cryptosporidium*, *Giardia*, bacterial indicators of contamination, and turbidity. Quarterly monitoring: VOCs, SOCs, Radionuclides, and UCRM.

72" Active Wastewater Treatment Plant Outlet Pipe (Approx. 10,850 Lineal Feet)

Outfall Diffusers (Installed Over Approximately 2,000 Lineal Feet)

pretreatment systems was successful in protecting the SWRO membrane from fouling. However, the testing also found that SDI, TOC and turbidity proved to be poor indicators of the potential for fouling. During algal blooms there was stronger correlation between membrane fouling and the amount of algal cell breakage caused by each pretreatment process. The amount of cell breakage appeared to be proportional to the pressure drop across each pretreatment process. SSF and GMF had lower pressure drops than the UF membranes.

The implications of the test results are that 1) SSF did not require chemical addition to prevent fouling, 2) removing the majority of algal cells with coagulation and clarification prior to UF or GMF filtration will likely control fouling, and 3) if granular media filters are selected for pretreatment system, gravity filters should be considered over pressurized filters.

A Single-stage SWRO System with a Hybrid SWRO Membrane Combination will Achieve Water Quality Goals and Require the Least Amount of Energy

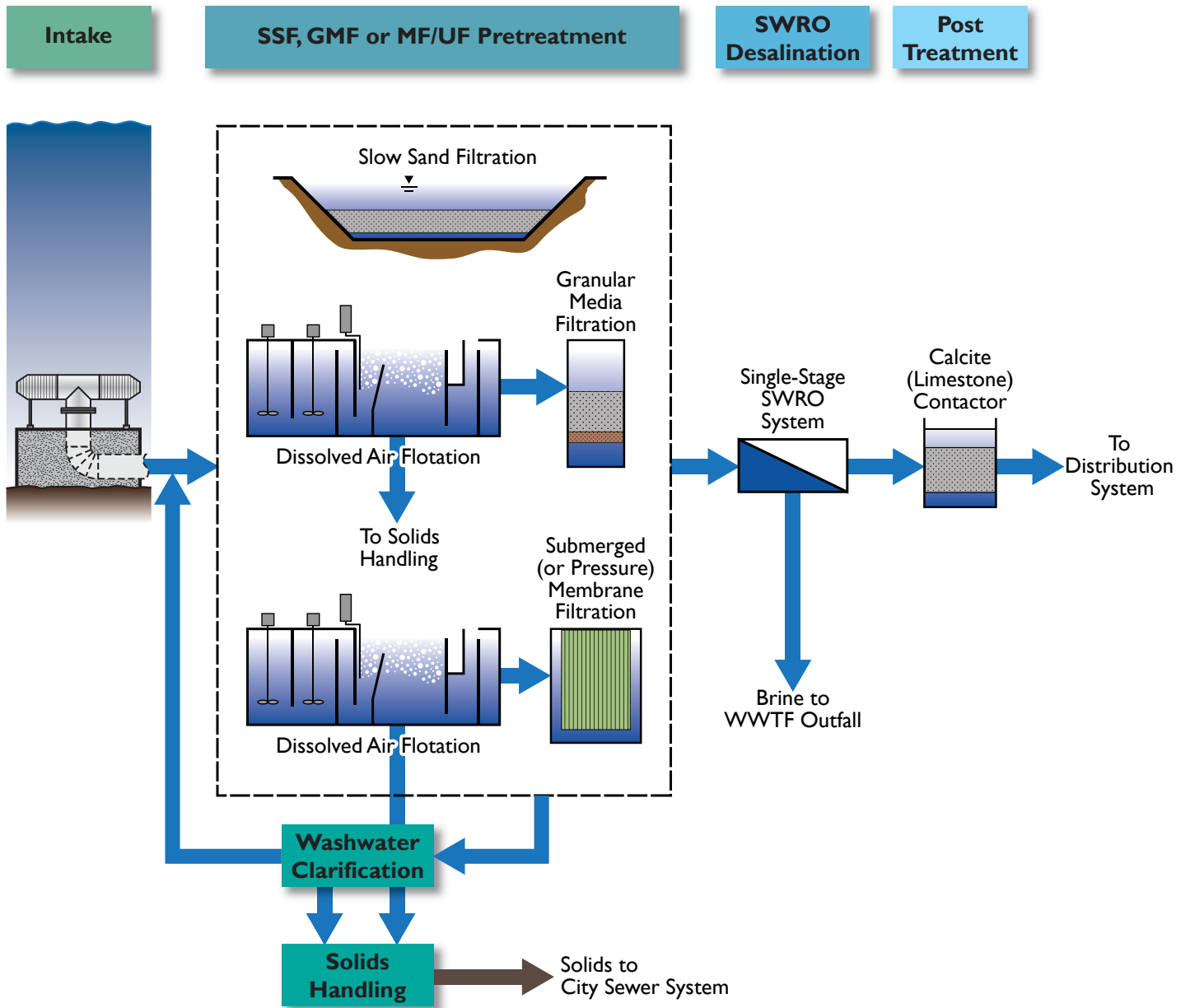
Three RO system configurations and several SWRO membranes from different manufacturers were evaluated to determine which system configuration and SWRO membrane would meet water quality goals and use the lowest amount of energy. A stringent goal was set for bromide (<0.5 mg/L) to limit the formation of disinfection by-products after the desalinated water is mixed with treated surface water in the distribution system. Equally stringent goals were set for chloride (<150 mg/L) and boron (<1.0 mg/L) so that the desalinated water would not adversely affect the growth and health of salt-sensitive plants such as roses, citrus trees, hydrangeas, crape myrtle, and others.

Water quality and energy monitoring during the pilot plant testing, coupled with desk-top analysis using industry computer models, found that a single-stage SWRO system with a hybrid combination of low-energy and high-rejection SWRO membranes achieves water quality goals with the lowest energy requirement. This RO system configuration is flexible and would be compatible with future modifications to meet more stringent water quality goals by using all high-rejection SWRO membranes or adding a second pass through low pressure reverse osmosis (LPRO) membranes.

A Robust Treatment Process is Recommended for a SWRO Desalination Plant

The treatment process for a desalination plant in Santa Cruz (assuming source water is supplied from an open ocean intake) should include pretreatment with either slow sand filters, granular media filters, or ultrafiltration membranes followed by desalination using a single-stage SWRO system with a hybrid combination of low-energy and high-rejection SWRO membranes. This treatment process will provide a high-quality water supply during the worst-case source water quality situation, which is expected to be a combination of a red tide event and warm water conditions.

Figure ES-2 presents a flow diagram of the recommended treatment process for a potential desalination plant using SSF, GMF, or UF pretreatment. The dissolved air flotation (DAF) clarification process is similar to the clarification step used during piloting; however, dissolved air is used to improve removal of buoyant material



such as algae which can contribute to fouling and clogging of SWRO membranes. The SWRO desalination process will remove salts and other dissolved constituents to produce a high purity water. The post-treatment process will add minerals and adjust pH to improve taste and stabilize the water so that it does not corrode pipes in the distribution system. The treated water will undergo a final disinfection step prior to being pumped directly into the distribution system. The brine stream, which contains the concentrated salts removed during the SWRO desalination process, will be piped to the City's wastewater treatment facility outfall and blended with treated wastewater and discharged through the wastewater facility's outfall diffuser.

Preliminary Cost Estimate for a New Desalination Facility

The cost estimates assume redundant treatment capacity to reliably produce 2.5 mgd even when some equipment is off-line for maintenance or cleaning. Estimates were prepared for the capital cost and annual operation and maintenance cost for a SWRO desalination plant which uses a robust treatment process and has a maximum production capacity of 2.5 million gallons per day (mgd; 2,800 acre feet per year) of desalinated water. Total capital cost includes the costs for construction, land, engineering design and construction services, construction management and contingencies. The capital cost does not include the intake and the conveyance of raw, treated and brine water to or from the SWRO plant. Based on a construction midpoint of June 2014, the capital cost was escalated at 3% per year to 2014 dollars.

The estimated capital cost is \$59 to \$70 million depending upon the type of pretreatment. The estimated costs are \$59 million with GMF, \$64 million with UF, and \$70 million with SSF. Section 8 includes a list of assumptions and additional information used to develop the cost estimates.

The estimated operation and maintenance (O&M) cost includes labor, power, chemicals, RO and UF membrane replacement, maintenance/repairs, and solids disposal. The O&M cost was based on an average annual production of 1.6 mgd of desalinated water, and was escalated at 3% per year to 2014 dollars. The estimated annual O&M cost is approximately \$2,300,000.

Next Steps

Several items should be completed before designing the SWRO treatment plant. These are:

- The intake study findings are needed since the intake type may impact the need for pretreatment.
- The California Department of Public Health has to review the findings of the watershed sanitary survey and determine the pathogen removal and inactivation credits for *Giardia*, *Cryptosporidium*, and viruses that the plant will be required to achieve.
- The energy study findings may impact equipment selection and integration into the treatment process.
- Although it is not expected to significantly impact the design of the treatment plant, the findings of the impingement and entrainment study should be presented prior to beginning design.
- The cost and availability of land for the treatment plant should be investigated as this may impact the treatment process.
- The ability and cost to discharge the solids to the City's wastewater plant may determine the preferred method of solids disposal.