RECLAMATION

Managing Water in the West

Desalination and Water Purification Research and Development Program Report No. 150

Scattergood Seawater Desalination Pilot Plant

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

October 2008

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14. ABSTRACT
The Los Angeles Department of Water and Power (LADWP) is actively pursuing alternative water supply sources. Seawater desalination is one of the sources being considered. From previous studies, LADWP had identified the Scattergood Generating Station as the most viable site for a seawater desalination facility. To further investigate the viability of a seawater desalination facility at this site, LADWP initiated the Scattergood Seawater Desalination Pilot Project. This study and others performed by LADWP provide significant data that can assist Los Angeles in moving forward with its evaluation of seawater desalination.

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Scattergood Seawater Desalination Pilot Project

Prepared for the Bureau of Reclamation Under Agreement No. 5-FC-81-1158

by

Los Angeles Department of Water and Power

Los Angeles, California

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

October 2008

MISSION STATEMENTS

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Disclaimer

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ACRONYMS AND ABBREVIATIONS

gfd	gallons per square foot (of membrane surface) per day
gpm/sf	gallons per minute per square foot (of membrane surface)
LADWP	Los Angeles Department of Water and Power
MCL	maximum contaminant level
mg/L	milligrams per liter
mJ/cm^2	millijoules per square centimeter
MF/UF	microfiltration/ultrafiltration
NA	not available
RO	reverse osmosis
UV	ultraviolet (light)

METRIC CONVERSIONS

The metric equivalents for non-metric units used in the text are as follows:

Unit	Metric equivalent
1 gallon per minute per square foot of membrane area	40.74 liters per minute per square meter
1 gallon per square foot of membrane area per day	40.74 liters per square meter per day

1 EXECUTIVE SUMMARY

The Los Angeles Department of Water and Power (LADWP) is actively pursuing alternative water supply sources including conservation, water recycling, ground water storage, and water transfers. Seawater desalination is one of the long-term water supply sources being considered by LADWP.

From previous studies, LADWP had identified the Scattergood Generating Station as the most viable site for an LADWP seawater desalination facility. To further investigate the viability of a seawater desalination facility at this site, LADWP initiated the Scattergood Seawater Desalination Pilot Project (Project). The project is co-funded by the U.S. Bureau of Reclamation and by the California State Department of Water Resources.

By December of 2007, the project team completed the first task of the Preliminary Evaluation Study. In March 2008, the results of that study were reported in the *Preliminary Evaluation Report*. (See Attachment.)

In May 2008, the Mayor of Los Angeles City and LADWP management announced that water conservation and water recycling will be the two primary strategies in creating sustainable sources of water for the future of Los Angeles. Therefore, installation of the Scattergood Seawater Desalination Pilot Plant has been postponed indefinitely.

The Preliminary Evaluation Report, as well as other studies performed by LADWP, has provided significant data that can assist Los Angeles in moving forward with its evaluation of seawater desalination. The Bureau of Reclamation has been an important partner in those evaluations. Although LADWP has to put its research on hold, we hope to continue our research partnership with the Bureau in the future.

2 THE PROJECT

2.1 Major Tasks of Scattergood Seawater Desalination Pilot Project

The Project consisted of the following major tasks:

- Project partner kickoff meeting
- Finalizing the project work plan
- Preliminary Evaluation:
  - Preliminary Evaluation Study
  - Stakeholder Workshop 1

  - Preliminary Evaluation Report
  - Stakeholder Workshop 2
- Completion of the plant design
- Equipment procurement
- Pilot Plant Construction
- Completion of pilot testing in three phases
- Project progress communication
- Project management and coordination
- Completing the draft and final reports

2.2 Project Timeline

The project's timeline is presented graphically in Figure 1.

2.3 Major Tasks Accomplished

In August 2007, Camp Dresser & McKee was retained to provide support to LADWP in the Project. Since then, the following major tasks have been accomplished:

- Project Partner Kickoff Meeting – Meeting was held between the LADWP team and the Camp Dresser & McKee team on September 5, 2007. The key discussion points included pilot plant design and operation, procurement procedures, waste-stream discharge, and public outreach.

- Finalizing the Project Work Plan – The Project Work Plan was completed in September 2007. It documents project assumptions and formalizes project objectives. It defines project management protocols in communication, decision making, reporting, cost control, and quality management. The overall project schedule was developed along with the detailed schedule, milestones, and deliverables for Phase I pilot planning.

- Preliminary Evaluation:

  - Stakeholder Workshop 1 – On October 17, 2007, LADWP held a workshop with internal and external stakeholders including co-funding and regulatory agencies and environmental organizations. The objective of the workshop was to introduce the stakeholders to the project and invite comments and questions from the interested parties. The following summarizes the public's concerns:

    - Suggested that the project team look at desalination technologies on the effluent stream from the Hyperion Wastewater Treatment Plant and compare the energy required in treating Hyperion effluent and seawater.

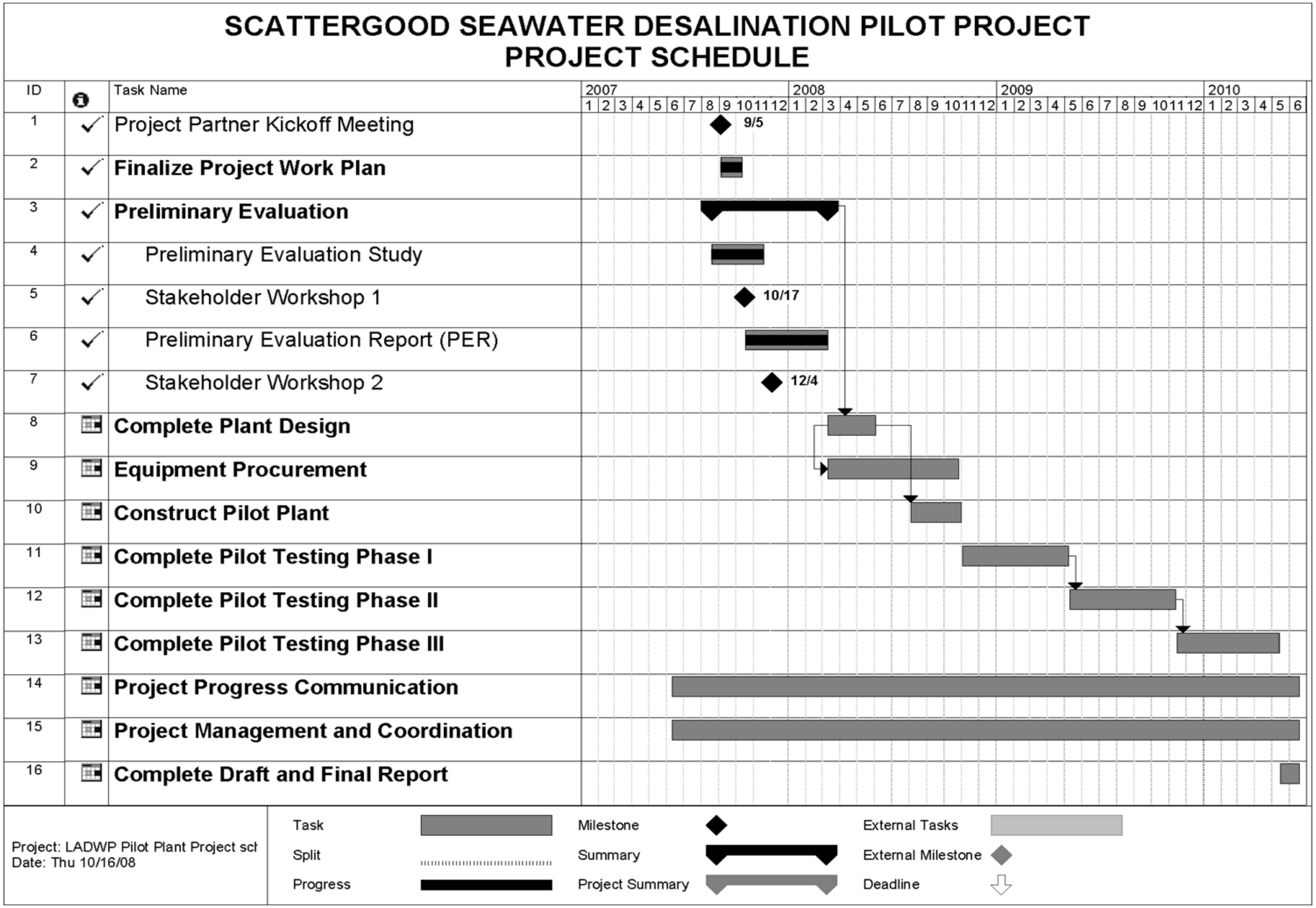


Figure 1. Pilot project schedule.

- Expressed concerns about the powerplant and the future seawater desalination plant intake and stated that intake issues and pending regulations should be considered.
- Commented that seawater desalination is not a technology but a possible water resource needed for future water supply, that desalination is premature, and that more conservation/reclamation should be achieved before proceeding with desalination.
- Asked the project team to look at all alternatives and consider how different research and development projects can work together, including data sharing, unique power plant operations/site specific, and future Scattergood operation.

o Stakeholder Workshop 2 – Stakeholder Workshop 2 was held on December 4, 2007, with internal and external stakeholders including co-funding and regulatory agencies, environmental organizations, and community representatives. The objective of the workshop was to provide the stakeholders with an update on the project and present the results of the screening evaluation performed for selection of the seawater desalination process trains for pilot testing.

  LADWP was working on completing the Preliminary Evaluation Report by the end of the year in compliance with the grant funding agreement. Upon completion of this report, the LADWP research team would pause to present the findings of the report to LADWP management and determine if the Scattergood project approach should be modified. The following is a summary of the public's comments:

  - Suggested that LADWP should prioritize water resources, with a focus on conservation and re-use, prior to further consideration of desalination.
  - Suggested that LADWP partner with stakeholders for public outreach to educate the public on available alternatives, with a focus on recycled water.
  - Commented that less energy would be required to treat the Hyperion wastewater effluent flow than to desalinate seawater and recommended that LADWP revisit previous recycled water projects.
  - Suggested LADWP do more with conservation, including community outreach and low flow toilets.
  - Advocated expanding recycled water systems for residential use.
  - Suggested retrofitting neighborhoods to catch rain water.
  - Suggested that the Santa Cruz project be considered as a model for stakeholder involvement with respect to desalination projects.

o Preliminary Evaluation Study and Preliminary Evaluation Report – The Preliminary Evaluation Study was completed in December 2007 and the

Preliminary Evaluation Report was later published in March 2008. (See Attachment.)

3 PRELIMINARY EVALUATION STUDY

The Preliminary Evaluation Study completed the following tasks:

3.1 Redefine Project Objectives

The overall pilot project objective was to examine the technical feasibility and practicality of developing a full-scale desalination plant that uses existing infrastructure to reduce potential environmental impacts. It was further refined into four primary objectives and two secondary objectives.

3.1.1 Primary Objectives

- Develop an environmentally sensitive treatment process that is adaptable to alternative source-water intakes.
- Confirm the ability to meet and exceed water quality standards and goals in a cost-effective manner.
- Optimize a pretreatment process that is robust, reliable, and sustainable.
- Evaluate the technical impacts of using either warm water or cold water as the source of supply.

The primary objectives were developed to assess the technical impacts on the desalination process and the quality of desalted water that would result from using either post-condenser warm water or cold seawater as a supply source. To achieve this, two pilot plant trains were proposed to run in parallel. One would be designated for warm water and the other for cold water, with flexibility for exchanging sources of supply during pilot testing.

3.1.2 Secondary Objectives

- Optimize desalination operating conditions for the lowest life-cycle cost.
- Develop data for additional studies.

The secondary objectives were developed to provide data for engineering, scientific, and regulatory works that may need to be done upon completion of the Scattergood Seawater Desalination Pilot Project, such as reverse osmosis (RO) concentrate disposal studies, environmental impact studies, and the California Department of Public Health permitting application.

3.2 Lessons Learned — Other Pilot Studies and Full Scale Facilities

Three pilot testing studies and three operational full-scale seawater desalination facilities were identified and studied.

3.2.1 Pilot Testing Studies

The team reviewed three pilot testing studies. Two of these studies are currently being conducted at the nanofiltration pilot facility of the West Basin Municipal Water District and the Long Beach Water Department. The third pilot study was recently completed by the Marin Municipal Water District, Marin, CA.

Lessons Learned and Applicable to the Scattergood Project

- Coarse solids removal to the size of 100 µm is required as a pretreatment for microfiltration/ultrafiltration (MF/UF).
- MF/UF proved to be an excellent pretreatment for RO desalination.
- Single-pass RO is capable of meeting regulatory requirements for drinking water.
- Second-pass RO may be required to meet project-specific boron and chloride goals.
- Increased MF/UF membrane cleaning and RO membrane biofouling was observed at the West Basin Municipal Water District pilot when warm water was used as the influent source and during the red tide events.

The selection of appropriate equipment materials, a robust design, focused project objectives, and the full attention of the pilot plant operators are critical to the success of a pilot plant project.

3.2.2 Full-Scale Plants

The project team identified the Diablo Canyon Power Plant in Avila Beach, CA; the Tampa Bay Seawater RO Facility in Tampa Bay, FL; and the Perth Seawater RO Plant, Kwinana, Australia, as relevant study cases.

Lessons Learned and Applicable to the Scattergood Project

- All three facilities employed some form of conventional media or diatomaceous earth filtration for the RO pretreatment, which may be explained by the fact that MF/UF is a relatively new technology that has only recently been applied to seawater treatment.

- The long-term success of the Diablo Canyon facility provides validation that the RO membrane technology is viable for full-scale operations on an open seawater intake in California..
- There is no conclusive support for the assertion that disinfection with ultraviolet (UV) light is the single most important factor in the successful long-term operations of the Diablo Canyon facility.
- Seasonal water quality changes can have a major impact on pretreatment performance.

3.3 Existing LADWP Facilities Related to the Scattergood Project

The existing Scattergood Generating Station and the LADWP water supply and water distribution system were studied to assess their anticipated impacts on the design and operation of the Scattergood seawater desalination project.

3.3.1 Scattergood Generation Station

A parking lot in front of the Scattergood Generating Station's main building provides sufficient space needed to accommodate the pilot plant and associated equipment. (See Figure 2.) The inlet of the screen and chamber facility of the station's cooling water intake was selected for the seawater connection. The outlet of the Unit 1 and 2 cooling loop at the screen and chamber facility was selected for the post-condensed warm-water intake.

Figure 2. Proposed location for pilot plant.

3.3.2 LADWP Water Supply and Distribution System

The existing water supply and water distribution systems have been examined to understand the conditions under which desalted seawater could be introduced into the LADWP distribution system and delivered to its customers. Pressure zones 325 and 477 were identified as the most likely candidates to receive desalted seawater from the Scattergood desalination facility. A detailed hydraulic model would be needed to define hydraulic conditions for introducing the new desalted water into the existing distribution system.

Also, current supply-water quality was studied for compatibility with the quality of the desalted seawater, which may trigger requirements for additional post-treatment of the desalted seawater.

3.4 Screening Seawater Desalination Processes and Recommended Pilot Testing Trains

Various technologies (process units) were screened, and the following process units are recommended for the Scattergood Seawater Desalination Pilot Project:

- Rotating disk filters and coarse media filtration for coarse solids removal
- Polymeric MF/UF membrane for pretreatment
- UV irradiation and no pre-disinfection for oxidation/disinfection
- RO membranes for desalination

3.4.1 Proposed Pilot Plant Design and Layout

The selected process units are combined to form two process trains that will be pilot-tested. (See Figure 3.) The proposed Train 1 consists of two in-series disk filters, polymeric MF membranes, a UV reactor, and a single-pass RO membrane system. The proposed Train 2 consists of coarse media filtration, polymeric MF membranes, a UV reactor, and a single-pass RO membrane system. The piping connections allow for intermittent change of the source-water connection.

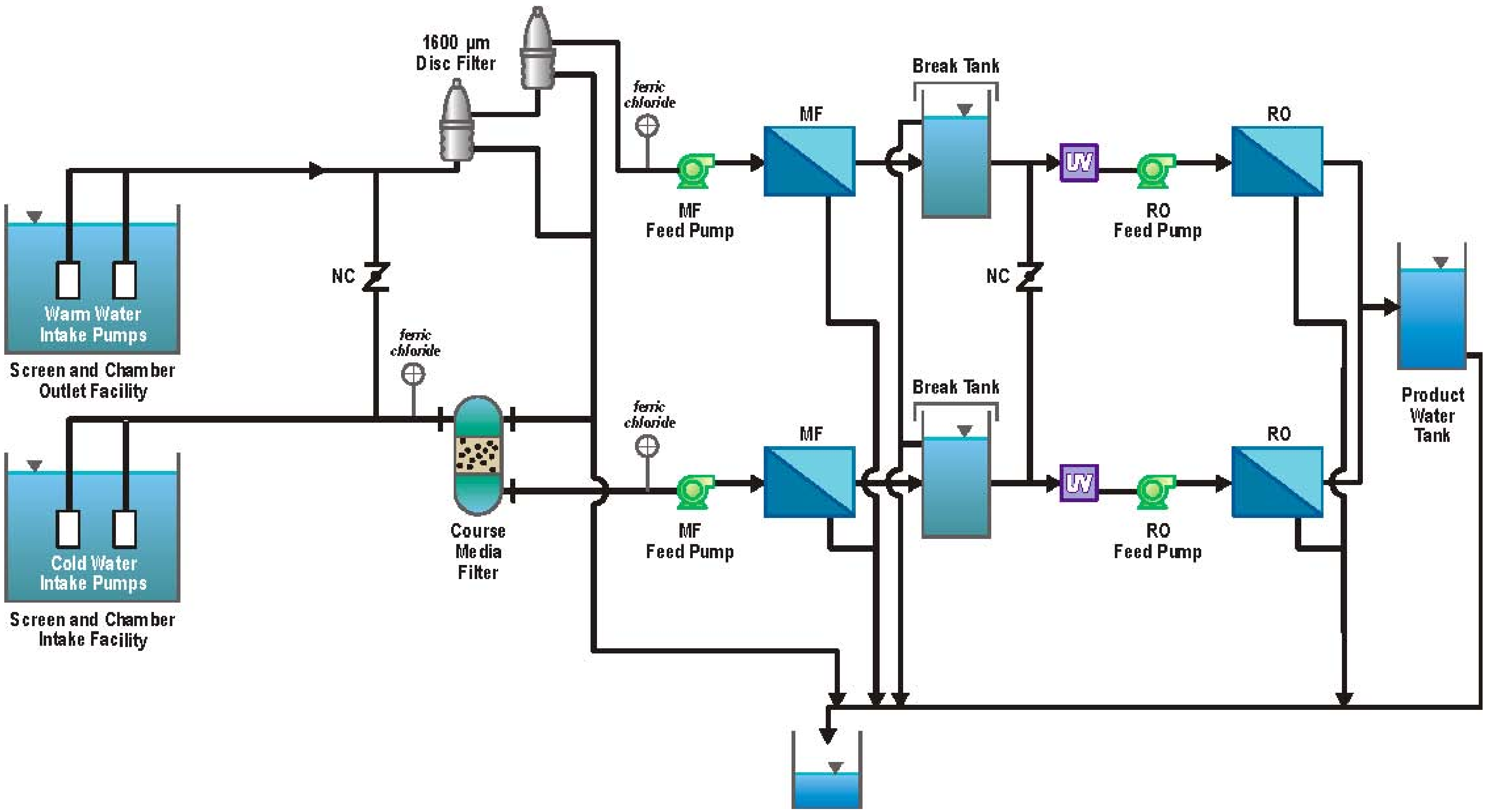


Figure 3. Proposed pilot plant process flow diagram.

3.5 Water Quality Goals

Source seawater quality, projected water quality along the treatment process train, and the finished water quality requirements have been evaluated. The relatively high concentration of bromide and boron in seawater is noted. Bromide can have adverse impacts on the formation of disinfection byproducts and the stability of disinfectant residuals. Boron concentrations in the desalted seawaters are substantially higher than in municipal water supplies. The water quality objectives for various points along the proposed process train were established. The proposed finished water quality goals, along with the regulated limits and the pilot goal, are presented in Table 1.

Table 1. Scattergood Desalination Study Proposed Water Quality Goals

Parameter	Regulated Limit	Pilot Goal	Finished Water Goal
Chloride	250 mg/L	200 mg/L	100 mg/L
Total dissolved solids	500 mg/L	400 mg/L	400 mg/L
Boron	1 mg/L	1 mg/L	0.5 mg/L
Title 22	MCL	0.8 x MCL	0.8 x MCL
Alkalinity	NA	NA	75-80 mg/L
pH	6.5-8.5	NA	8-8.5
Langelier Saturation Index	NA	NA	> 0.1-0.2
Temperature	NA	NA	80 ºF

MCL, maximum contaminant level; NA, not available.

3.6 Post-Desalination Treatment Requirements

Considering the difference between the qualities of RO desalted water and finished water goals, additional treatment will be needed at a full-scale facility.

3.6.1 Pilot Plant Operating Conditions

Beyond the water quality goals, there are a number of operational variables that must be optimized during the pilot process to determine the most appropriate, efficient, and cost-effective operating conditions for the Project. This document identified 12 variables, summarized in Table 2, that are the most critical for developing reliable design criteria for the Scattergood seawater desalination treatment process.

Table 2. Recommended Pilot Testing Variables

Process	Variable	Range	Evaluation Period
Coarse Solids Removal	Equipment type	Arkal (Train 1) and granular media filtration (Train 2)	3 months
	Coagulant dose	0–5 mg/L Ferric	Response to red tides
	Loading rate for granular media filtration	15–20 gpm/sf	3 months (concurrent with Arkal comparison)
Membrane Filtration	Flux	20–30 gfd	3 months
	Chemically enhanced backwash dose	5–100 mg/L Cl_2	As required for flux
	Chemically enhanced backwash frequency	Every backwash to weekly	As required for flux
	Coagulant dose	0–5 mg/L ferric	Response to red tide
Disinfection	UV dose	0–30 mJ/cm^2	6 months
Reverse Osmosis	Flux	8–12 gfd	As required for membrane type and temperature
	Recovery	50%	Not varied
	Membrane type	Low energy (Train 1) and high boron and chloride rejection (Train 2)	3 months (concurrent with MF flux evaluation)
	Temperature	Cold feed water (Train 1) and warm feed water (Train 2)	6 months

3.7 Future Studies

Additional tests and studies are recommended to define the source of seawater supply for the Scattergood Seawater Desalination Facility, and also to identify post-treatment that will be capable of meeting the final product water quality goals in compliance with LADWP criteria and will facilitate integration of the desalted water into LADWP water distribution system. Therefore, the following studies are recommended to be conducted concurrently with, or subsequent to, the Scattergood Seawater Desalination Pilot Project:

- Subsurface intake feasibility study for the Scattergood site.
- Product water stabilization study, looking both at blending impacts through computerized modeling and benchtop or pilot-scale corrosivity tests.
- Pilot testing of second-pass RO, if it is found to be needed for complying with the water quality goals established in this report.

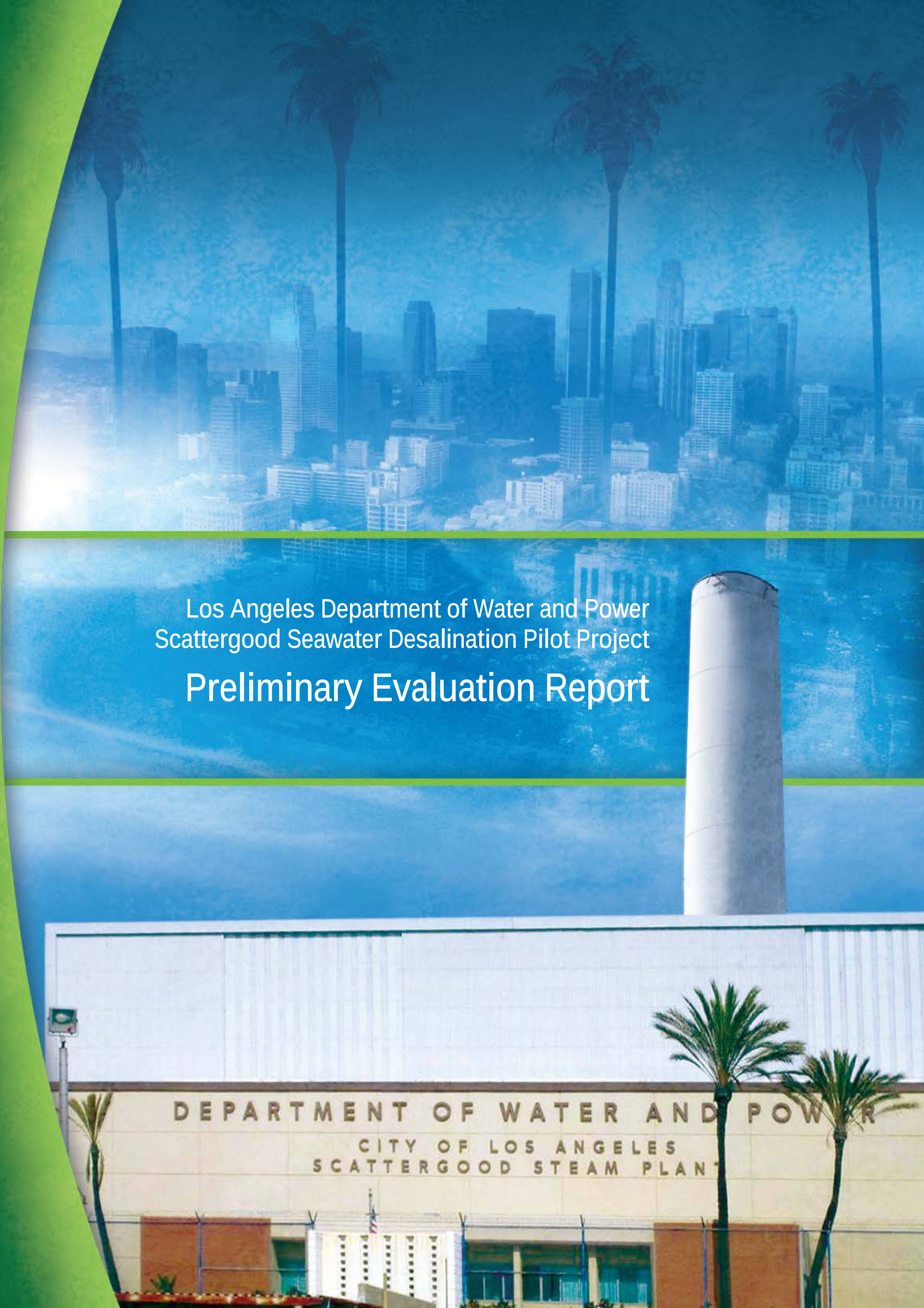
- Pilot testing of pre-treatment and post-treatment cooling towers, if it is determined that warm water is an acceptable alternative for the ultimate desalination plant source water.
- Benchtop chloramines stability testing.
- Comprehensive brine discharge evaluation.

ATTACHMENT

SCATTERGOOD GENERATION STATION
SEAWATER DESALINATION PILOT PROJECT
PRELIMINARY EVALUATION REPORT

Los Angeles Department of Water and Power
Scattergood Seawater Desalination Pilot Project

Preliminary Evaluation Report



Scattergood Generation Station Seawater Desalination Pilot Project

Preliminary Evaluation Report

March 10, 2008

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Scattergood Generation Station Seawater Desalination Pilot Project

Preliminary Evaluation Report

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Appendices

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List of Acronyms

BAT – best available technology

BW - backwash

C - Celsius

CA – cellulose acetate

$CaCO_3$ – calcium carbonate

CCR – California Code of Regulations

CDPH – (California) Department of Public Health

CEB – chemically enhanced backwash

CFU – colliform units

CIP – clean-in-place

ClO_2 – chlorine dioxide

ClO_4 – perchlorate

Cl_2 – chlorine

CRA – Colorado River Aqueduct

DADMAC - diallyldimethyl ammonium chloride

DAF – dissolved air flotation

DBOOT – design-build-own-operate-transfer

DBPs – disinfection by-products

DE – diatomaceous earth

DM – decision memorandum

DWR – California Department of Water Resources

ED – electro dialysis

EDR – electro dialysis reversal

EFM – enhanced flux maintenance

EPA - Environmental Protection Agency

FO – forward osmosis

FRP – fiberglass reinforced plastic

Gal – gallon

gfd – gallons per square foot per day

GMF – granular media filtration

gpm – gallon per minute

HAA – haloacetic acids

HPC – heterotrophic plate count

HRL – health reference level

IESWTR – Interim Enhanced Surface Water Treatment Rule

IRP - Integrated Resources Plan

kWh – kilowatt hour

LAA – Los Angeles Aqueduct

LAAFP – Los Angeles Aqueduct Filtration Plant

LABOS – Los Angeles Bureau of Sanitation

LADWP – Los Angeles Department of Water and Power

LBWD – Long Beach Water Department

LSI – Langelier Saturation Index

LT2 – Long Term 2 Enhanced Surface Water Treatment Rule

MCLs – maximum contamination levels

MD – membrane distillation

MED – multi-effect distillation

MF – microfiltration

MWD - Metropolitan Water District of Southern California

μg/L - micrograms per liter

μm – micron

mg/L - milligrams per liter

mgd – million gallons per day

MPN – most probable number

MSF – multistage flash distillation

MWD – Metropolitan Water District of Southern California

NaOCl – sodium hypochlorite

NF – Nanofiltration

NL – notification level

nm – nanometer

NO_3 – nitrate

NPDES – National Pollutant Discharge Elimination System

NTU - Nephelometric Turbidity Units

O&M – Operation and Maintenance

OEM - original equipment manufacturer

QA/QC – quality assurance/quality control

PA - polyamide

PCE – perchloroethylene

PER - Preliminary Evaluation Report

PES - polyethersulfone

PP - polypropylene

PQM – Project Quality Management

PS - polysulfone

psi – pounds per square inch

PVDF – polyvinyl fluoride

RFI – request for information

RFP – request of proposal

RO – reverse osmosis

Scattergood Pilot Project - Scattergood Seawater Desalination Pilot Project

SDI – Silt Density Index

sf – square foot/feet

SGS – Scattergood Generating Station

SPI - Seperation Processes Inc.

SWFWMD – South West Florida Water Management District

SWP – State Water Project

SWRO – Seawater Reverse Osmosis

SWTR – Surface Water Treatment Rule

TBW – Tampa Bay Water

TCE - trichloroethylene

TDS – total dissolved solids

TECO – Tampa Electric Company

TFC – thin-film composite

THMs - trihalomethanes

TOC – total organic carbon

TSS – total suspended solids

UF – ultrafiltration

ULARA – upper Los Angeles River area

US EPA – U.S. Environmental Protection Agency

UV – Ultraviolet

VBNC – viable but nonculturable

WBMWD – West Basis Municipal Water District

Executive Summary

To ensure reliable water supply and to reduce dependence on imported waters, the Los Angeles Department of Water and Power (LADWP) is actively pursuing alternative water supply sources including conservation, water recycling, ground water storage, and water transfers. In addition, LADWP is exploring other long-term water supply sources such as seawater desalination, which will further diversify its water supply portfolio and provide a local source of new water for the City's potable water and environmental needs.

As a result of an aggressive conservation program, that started in the early 1990's water use in Los Angeles today has remained the same as it was in the 1970s, even though the population base served by LADWP has increased by over one million people (see Figure ES 1).

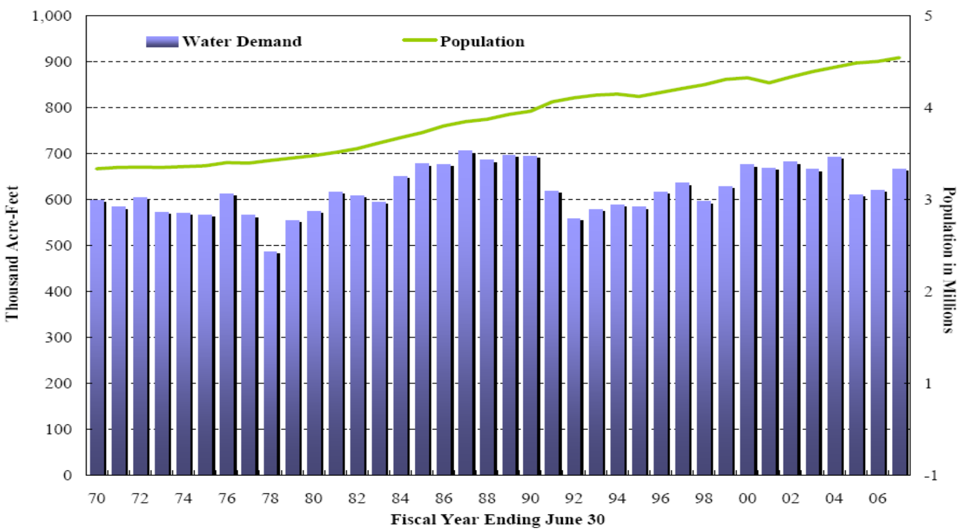

Figure ES – 1 Conservation Effects

Water conservation remains a top priority. LADWP is projecting that extended water conservation will produce an additional savings of water use equivalent to seven percent of the total water demand in 2030. At the same time, water recycling will cover four percent of the projected future water demand, a four-fold increase of the current recycled water supply. Other planned supplies, such as storm water runoff and ground water storage, are projected to provide for an additional seven percent of the water use in 2030.

In its 2003 Integrated Resources Plan (IRP), the Metropolitan Water District of Southern California (MWD) identified seawater desalination as a potential future water supply source for its service area. Similarly, the U.S. Bureau of Reclamation, California Department of Water Resources (DWR), and other federal and state agencies are providing technical and financial incentives for the water supply industry to evaluate seawater desalination as a reliable water supply source for coastal cities and communities. General public curiosity about seawater desalination and the necessity to assess a project configuration that will be environmentally acceptable is another driver for LADWP to advance its studies of this potential water supply source.

The LADWP wants its long-term water supply portfolio to be more diversified by expanding conservation, water recycling, ground water storage and water transfers, and by adding new water supply sources. As a result, the potable water supply in Los Angeles by 2030 and beyond will be more reliable and less dependent on imported water, yet providing more water for the City's environmental needs.

Previous Studies

As a responsive MWD member agency and to explore its feasibility, LADWP engaged in the study of seawater desalination alternatives. In 2002, LADWP prepared the document ***Seawater Desalination Plant Site Selection - Fatal Flaw Analysis***. This document concluded that, compared to the Harbor and the Haynes Generation Station sites, the Scattergood Generating Station (SGS) location is the most environmentally friendly and the overall best site for a seawater desalination facility.

The 2004 ***Seawater Desalinization Facility Optimization Study*** concluded that the size of the Scattergood Seawater Desalination Facility, at 25 million gallons per day (mgd), will be the most economical for the SGS site. This document also analyzed the environmental benefits of using post-condenser warm water, which reduces the energy requirement associated with desalination. However, using post-condenser warm water lowers the ultimate water quality and increases the potential for reverse osmosis (RO) membrane fouling. Finally, the study identified the existing five-mile long Hyperion Outfall as the most environmentally advantageous for the RO brine disposal.

The 2005 follow-up document, ***Brine Dilution Study,*** applied a hydrodynamic model to evaluate dispersion and dilution of the brine discharges from the proposed seawater desalination facility at the SGS site. Three options, including use of the SGS Outfall, use of the one-mile Hyperion Outfall, and use of the five-mile Hyperion Outfall, were studied. The existing five-mile Hyperion Outfall was identified as the most environmentally advantageous for the Santa Monica Bay marine life because of the possible increase in effluent salinity from the Hyperion Wastewater Treatment Plant.

In addition to these studies, LADWP is participating in a joint venture with the Long Beach Water Department to conduct studies at a seawater pilot and demonstration project located at the LADWP's Haynes Power Generation Plant.

Scattergood Seawater Desalination Pilot Project

With an overarching objective to further investigate the viability of seawater desalination as a possible water supply source for Los Angeles, LADWP initiated another study entitled Scattergood Seawater Desalination Pilot Project. The project is co-funded by the DWR through Proposition 50 and by the U.S. Bureau of

Reclamation. Camp Dresser & McKee (CDM), a nationally recognized seawater desalination consulting firm, has been retained to provide support to LADWP in the project execution.

The Scattergood Seawater Desalination Pilot Project consists of tasks that include the preparation of the study plan (Preliminary Evaluation Study), pilot plant design, installation of the pilot plant equipment, 18 months of pilot plant operations and testing, and compilation and reporting of the pilot testing results. The ***Preliminary Evaluation Report*** (PER) was prepared as a result of the first task - the Preliminary Evaluation Study.

Preliminary Evaluation Study

LADWP and CDM project teams jointly executed the Preliminary Evaluation Study and prepared the PER. The CDM Technical Advisory Team, consisting of senior project experts from CDM and its sub-consultants that included Seperation Processes Inc. (SPI) and Trussell Technologies Inc., together with CDM's project manger and task leaders, met three times internally to discuss the project issues, frame technical concepts, and provide technical guidance for execution of the work associated with Decision Memoranda (DM) 1 and 2 and the PER.

Initial draft project deliverables, including DM1, DM2 and the PER, were prepared by multiple project team members. Before submission to LADWP for review, an internal CDM quality assurance/quality control (QA/QC) team consisting of the most experienced senior seawater desalination experts reviewed the initial draft documents. The submitted documents were reviewed by the LADWP's project manager, internal experts and external consultants. LADWP and CDM's project teams discussed LADWP's review comments on DM1 and DM2 during the two submittal review meetings, and the mutually agreed upon review comments were incorporated into this draft PER.

With an objective to make this project fully transparent and to obtain benefits of multiple opinions in the shaping of the project, LADWP engaged external stakeholders in the project decision-making process and held two workshops with external stakeholders that included co-funding agencies (U.S. Bureau of Reclamation and DWR), the CDPH, and multiple environmentally concerned and community groups. These meetings were held on October 17, 2007, and December 4, 2007.

Preliminary Evaluation Study Objectives and Results

The Preliminary Evaluation Study presents multiple objectives as shown in Table ES-1. Along with the listed objectives, Table ES-1 summarizes how the study-specific objectives were met.

Project Objectives

The original overall pilot project objective was to examine the technical feasibility and practicality of developing a full-scale desalination plant that uses existing infrastructure to reduce potential environmental impacts typically associated with seawater desalination. This overarching project objective was evaluated and further refined, resulting in four primary objectives and two secondary objectives.

Table ES-1
Preliminary Evaluation Study Objectives

Preliminary Evaluation Study Objectives	How the Objectives Were Met
Redefine the Scattergood Seawater Desalination Project objectives.	The original project objectives were evaluated and redefined, resulting in four primary objectives and two secondary project objectives.
Study existing related pilot studies and full-scale facilities and draw upon lessons learned for the Scattergood pilot project.	Three currently active or recently completed pilot studies and three currently operational full-scale seawater desalination facilities were studied.
Study and understand the existing LADWP facilities related to the Scattergood project.	Existing SGS and LADWP water supply and water distribution systems were studied.
Screen seawater desalination processes and recommend pilot testing trains.	Multiple technologies for four seawater desalination unit processes were screened and the selected units were combined in two proposed pilot plant process trains.
Identify issues and define water quality goals.	Quality of feed seawater, projected desalted water quality, and finished product water quality requirements were assessed.
Evaluate post-desalination treatment requirements.	Post-treatment strategies to address finished water disinfection, stabilization, temperature, and boron and chloride concentrations were identified and evaluated.
Assess and recommend pilot plant operating conditions.	Operating conditions for RO membranes, oxidation/disinfection, microfiltration (MF)/ ultrafiltration (UF) membranes, and coarse solids removal systems have been evaluated and recommended for pilot plant testing.
Provide inputs for the proposed pilot plant design and layout.	Pilot plant key design criteria, process flow diagrams, and layout for the pilot facility were developed.
Identify future studies.	Seven additional studies have been identified to address issues associated with seawater intake, post treatment and project integration in the LADWP water supply system

Primary Objectives

The following four primary objectives were developed for the Scattergood Seawater Desalination Pilot Project:

- Develop an environmentally sensitive treatment process that is adaptable to alternative source water intakes.

CDM

This objective was developed to address the key project environmental issues, including feed water intake, disposal of the project-generated waste streams and RO concentrate, carbon footprint, as well as project aesthetics and air quality impacts. The treatment process must also be adaptable to the application of multiple source water alternatives, including post-condenser warm water, cold seawater, or subsurface intake seawater.

- Confirm the ability to meet and exceed water quality standards and goals in a cost-effective manner.

This objective was developed to address the finished product water quality issues, including microbial contamination, trace organics, temperature, corrosion stability, and concentrations of the seawater desalination-specific ions, such as boron and chloride. The water quality objective requires that the finished product water quality must be compatible with water quality currently delivered to the LADWP customers and acceptable to CDPH.

- Optimize a pretreatment process that is robust, reliable and sustainable.

Experience from other seawater desalination facilities, pilot and full-scale equally, indicates that a key component for successful operation of a seawater desalination facility is a pretreatment process which is responsible for removing all but salt impurities from the seawater. This objective sets up basic requirements that the pretreatment for the Scattergood Seawater Desalination Project must be robust, reliable and capable of receiving feed water from alternative water intakes.

- Evaluate the technical impacts of using either warm water or cold water as the source of supply.

This objective was developed to assess the technical impacts on the desalination process and desalted water quality due to using either post-condenser warm water or cold seawater as a supply source. To achieve this, two pilot plant trains will be run in parallel. One will be designated for warm water and the other for cold water, with flexibility for exchanging sources of supply during pilot testing.

The above presented primary objectives will be the central focus of the project and are considered to be critical to the success of the seawater desalination project.

Secondary Objectives

The following two secondary objectives were developed for the Scattergood Seawater Desalination Pilot Project:

- Optimize desalination operating conditions for the lowest life-cycle cost.

This secondary objective was established to develop design and operational criteria for the Scattergood Seawater Desalination Project that will result in balanced project construction, operation and maintenance costs.

- Develop data for additional studies.

This secondary objective was established to provide data for engineering, scientific and regulatory works that may need to be done upon completion of the Scattergood Seawater Desalination Pilot Project, such as RO concentrate disposal studies, environmental impact studies, CDPH permitting application, and others.

Secondary objectives have also been established to confirm that the project will provide valuable information and data relevant to this and future stages of the project's development.

Lessons Learned - Other Pilot Studies and Full Scale Facilities

Three currently active or recently completed pilot testing studies and three currently operational full-scale seawater desalination facilities were identified and studied for the Scattergood project.

Pilot Testing Studies

The team reviewed three pilot testing studies, two of which are currently being conducted by West Basin Municipal Water District at the El Segundo Power Plant Site and the Long Beach Water Department Nano-filtration (NF) Pilot Facility, and one pilot study that was recently completed by the Marin Municipal Water District, Marin, CA.

The West Basin Municipal Water District (WBMWD) has been operating a desalination pilot facility at the El Segundo Power facility since June 2002. The source water has alternated between the ambient temperature intake and warmer outfall from the power plant cooling loop. Historical data from the power plant indicates an average temperature difference between intake and outfall of 14ºF.

The WBMWD pilot facility consists of a two-stage inline strainer, MF/UF membrane filtration, and a single-pass/single-stage RO system. During its long-term operations, the WBMWD' s seawater pilot experienced a prolonged red tide event in 2005, which caused rapid fouling of the UF/MF membranes and the necessity for RO cleaning with proprietary cleaning chemicals.

Long Beach Water Department (LBWD), in partnership with LADWP, has been executing a three-phase research and demonstration program on seawater desalination since October 2001. This pilot testing has been geared toward the evaluation of a two-pass NF desalination process and studying its advantages and disadvantages over single-pass RO.

LBWD is currently in the second phase, or demonstration scale, of its testing which started in October 2006. The source water is taken from the inlet of the cooling loop at the Haynes Steam Turbine Power Plant in Long Beach. The process consists of a 100 µm in-line strainer, and Pall MF membrane filtration followed by two desalination trains in parallel. The first desalination train consists of two-pass NF membranes and the second desalination train consists of single-pass RO membranes.

The Marin Municipal Water District completed a one-year pilot study in 2006. The source water (North San Francisco Bay) contained substantially less total dissolved solids (TDS), boron and chloride than open Pacific Ocean seawater, and was subject to wide variations in water quality due to seasonal runoffs into the bay.

The pilot facility consisted of two parallel trains, with Train 1 consisting of in-series intake wedge wire screen and 100 µm disk filter followed by MF/UF membrane filtration, and single-pass RO. Train 2 consisted of in-series intake wedge wire screen and 100 µm disk filters, a coagulation-flocculation–sedimentation-granular media filtration system, and single-pass RO. A portion of the first-pass RO permeate was treated with a second-pass RO system.

Lessons Learned and Applicability to the Scattergood Project
The following lessons learned are common for all three studied facilities:

- Coarse solids removal to the size of 100 µm is required as a pretreatment for the MF/UF membrane filtration.
- MF/UF membrane filtration proved an excellent pretreatment for RO desalination.
- Single-pass RO is capable of meeting regulatory requirements for drinking water.
- Second-pass RO may be required to meet project-specific boron and chloride goals.
- Increased MF/UF membrane cleaning and RO membrane bio-fouling was observed at the WBMWD pilot when warm water was used as the influent source and during the red tide events.
- The LBWD did not yet publish information and data to support the assumed energy savings with dual NF desalination.
- Selection of equipment materials, robust design, focused project objectives, and full attention of the pilot plant operators are critical to the success of a pilot plant project.

All of the above listed lessons learned are applicable to the Scattergood Seawater Desalination Pilot Project.

Full-Scale Plants

Although several seawater desalination pilot plants have been tested in California, only a limited number of full-scale seawater desalination plants are currently in operation in the state. The project team identified the Diablo Canyon Power Plant in

Avila Beach, CA; the Tampa Bay Seawater RO Facility in Tampa Bay, FL; and the Perth Seawater RO Plant, Kwinana, Australia, as study cases relevant for the Scattergood Seawater Desalination Project.

The Diablo Canyon Power Plant at Avila Beach, CA, has been in successful operation for 14 years. The feed seawater source is from the intake to the power plant cooling loop. The temperature range is 10-18ºC. The process consists of bar screens and an in-line strainer, in-line filtration with in-series dual media and multimedia filters, Ultraviolet (UV) disinfection, and an RO membrane system with the associated chemical pretreatment system. The most noteworthy aspect of this project is that the RO membrane needed virtually no chemical cleaning or replacement in the first 10 years of operation.

Tampa Bay Seawater RO Facility receives seawater from Tampa Bay, and is located next to Tampa Electric Company's (TECO) Big Bend Power Station. The facility has an intercept structure to allow withdrawal of warm, once-through cooling seawater from two of the four circulating water systems employed by TECO. The facility also has a cool water pump that allows seawater not used for cooling to be blended with the warmer seawater, which is necessary to maintain a feed water temperature of less than 40ºC.

The project pretreatment system received substantial modifications recently. As of now, the main process consists of a chemical feed system, prescreening, conventional coagulation, a flocculation and clarification system, diatomaceous earth (DE) filtration, security filtration and a two-stage RO membrane system. In the past, the facility experienced substantial problems maintaining capacity, in large part due to inadequate performance of the pretreatment and resulting RO membrane fouling.

The Perth Seawater Desalination Project began operation in November 2006. It is located on the west coast of Australia, producing 38 mgd of potable water for the Perth Integrated Water Supply System. The feed water source is from an open intake in a coastal sound with salinity of 35-37 g/L and a temperature range of 16-24ºC. The treatment process includes coarse screening, single-stage dual-media filtration, cartridge filtration and a two-pass RO membrane system.

Lessons Learned and Applicability for the Scattergood Project

The following major lessons learned from studying the three full-scale seawater desalination facilities are applicable to the Scattergood Seawater Desalination Project:

- All three studied facilities employed some form of conventional media or DE filtration for the RO pretreatment, which may be explained by the fact that MF/UF filtration is a relatively new technology that has only recently been applied to sea water treatment.

- The long-term success of the Diablo Canyon facility provides validation that the RO membrane technology is viable for full-scale operations on an open seawater intake in California.

- There is no conclusive support that UV disinfection is the single most important factor in the successful long-term operations of the Diablo Canyon facility.
- Seasonal water quality changes can have a major impact on pretreatment performance.

Existing LADWP Facilities Related to the Scattergood Project

The existing SGS, and LADWP water supply and water distribution systems were studied to assess their anticipated impacts on the design and operation of the Scattergood seawater desalination project.

Scattergood Generation Station

The SGS facilities were studied to assess space availability for the pilot plant layout and to identify the pilot plant feed water connection. A parking lot in front of the SGS main building provides sufficient space needed to accommodate the pilot plant and associated equipment (see Figure ES–2).

The inlet of the Screen and chamber Facility of the SGS cooling water intake was selected for the seawater connection. Two locations were identified for the post-condensed warm water connection including water box drains at condensers inside of the main plant building and the outlet box of the Units 1 and 2 cooling loop at the screen and chamber facility.

Figure ES–2 Proposed Location for Pilot Plant

From a water quality perspective, the connection at the water box drains is a better option for the post-condenser warm water connection. However, due to the concerns about the feasibility of connecting inside of the main power plant building, the warm water intake has been selected to be from the outlet of the Unit 1 and 2 cooling loop at the Screen and Chamber Facility.

LADWP Water Supply and Distribution System

The existing water supply and water distributions have been examined, with the objective to understand the conditions under which desalted seawater from the Scattergood facility would be introduced into the LADWP distribution system and delivered to its customers. Pressure zones 325 and 477 were identified as the most likely candidates to receive desalted seawater from the Scattergood desalination facility. However, due to the complexity of the LADWP water distribution system, a detailed hydraulic model will be necessary to define hydraulic conditions for introducing the new desalted water into the existing distribution system.

Also, current supply water quality was studied for compatibility with the quality of the desalted seawater. The water quality of the current supplies may be substantially different from the desalted seawater with respect to water temperature, Langelier Index, and boron and chloride ion concentrations, which trigger requirements for additional post-treatment of the desalted seawater.

Screening Seawater Desalination Processes and Recommended Pilot Testing Trains

A generic treatment process train consisting of four treatment blocks (unit processes), including coarse solids removal, pretreatment, oxidation/disinfection and desalination (see Figure ES-3), is proposed for the Scattergood Seawater Desalination Pilot Project.

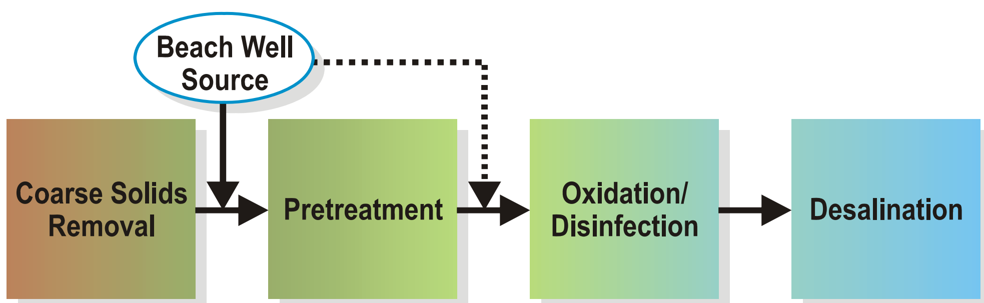

Figure ES-3 Scattergood Seawater Treatment – Process Block Diagram

The coarse solids removal unit process removes coarse particles from the seawater and protects downstream processes from sand, silts, shells and floatable materials. The pretreatment unit process is the first pathogen barrier and protects downstream RO membranes from fouling due to suspended and colloidal materials, algae and bio-growth. The oxidation/disinfection unit process is the second pathogen barrier and provides additional protection to the downstream RO membranes from fouling due to bio-growth. Finally, the desalination unit process is the third pathogen barrier that removes salts and trace organics from the seawater.

As shown in the Figure ES-3, the proposed process schematic assumes that the coarse solids removal process will be designed to produce effluent quality similar to the anticipated quality of subsurface water intake, such as beach wells. This approach was developed to simulate seawater desalination without using the once through cooling loop as a source of pilot plant supply

For each treatment block, a number of different technologies have been identified and evaluated for the Scattergood Seawater Desalination Pilot Project. The identified technologies (process units) are listed in the following Table ES-2.

Table ES–2
Alternative Treatment Process Units

Coarse Solids Removal	Pretreatment	Oxidation/ Disinfection	Desalination
Rotating Disk Filters Inline Strainer Coarse Media Filters Dissolved Air Flotation	Conventional Filtration Polymeric MF Ceramic MF Cartridge Filters	UV Irradiation Chlorine Dioxide Chloramines Nothing	Flash Distillation Multi-Effect Distillation RO NF-NF ED/EDR Membrane Distillation Forward Osmosis

Screening of the above-listed technologies has been conducted based on experience and lessons learned from this project and other seawater desalination facilities studied. As a result of this qualitative analysis, the following process units are recommended for the Scattergood Seawater Desalination Pilot Project:

- Rotating disk filters and coarse media filtration for coarse solids removal
- Polymeric MF/UF membrane for pretreatment
- UV irradiation and no pre-disinfection for oxidation/disinfection
- RO membranes for desalination

Proposed Pilot Plant Design and Layout

The selected process units are combined to form two process trains that will be pilot-tested (see Figure ES-4). The proposed Train 1 consists of two in-series disk filters, polymeric MF membranes, UV reactor, and a single-pass RO membrane system. The proposed Train 2 consists of coarse media filtration, polymeric MF membranes, UV reactor, and a single-pass RO membrane system.

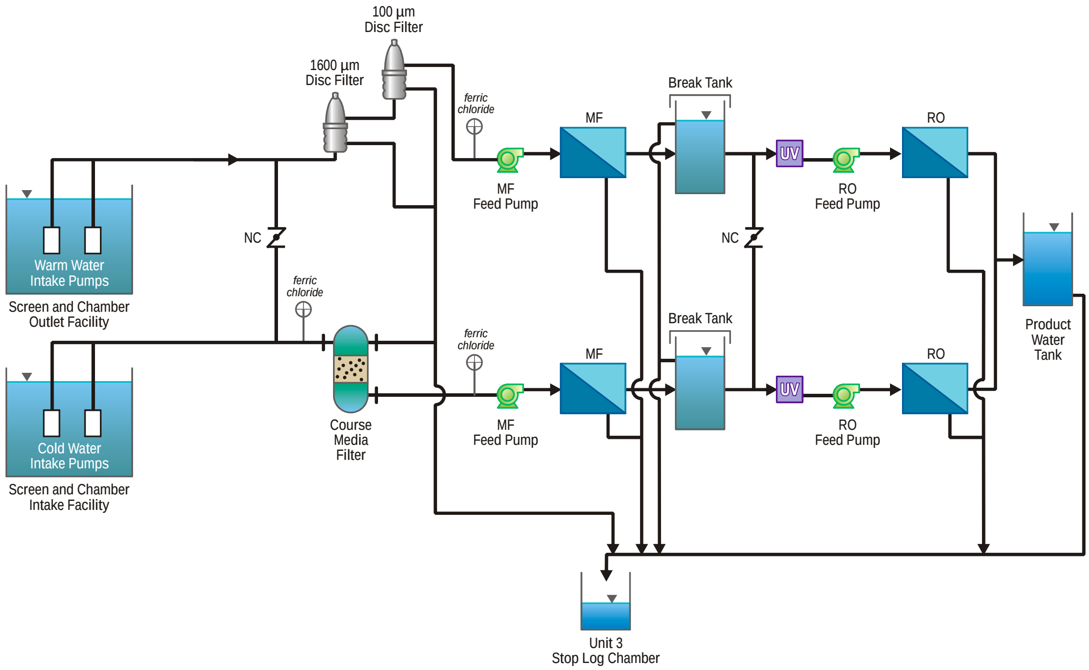

Figure ES-4 Proposed Pilot Plant Process Flow Diagram

Although the proposed Train 1 is dedicated to the post-condenser warm water and Train 2 to seawater, the piping connections will allow for intermittent change of the source water connection so that Train 1 could be supplied with cold seawater and Train 2 with post-condenser warm water. Each process train is furnished with an inline UV reactor that may be turned on or off, providing each process train with the option to be run with or without the oxidation/disinfection process.

The proposed location for the Scattergood pilot plant is at the most south parking lot in the front of the SGS main building (See Figure ES-2). The pilot plant foot print has a rectangular shape with a 100 foot by 16 foot size. In addition, a 20 foot trailer will be required to provide on office for the pilot plant operator, storage and to house control system equipment.

Water Quality Goals

Source seawater quality, projected water quality along the treatment process train, and the finished water quality requirements have been evaluated.

Source Seawater Quality

TDS of seawater in the Scattergood/El Segundo area varies from 27,000 milligrams per liter (mg/L) to 38,000 mg/L, with an average of 34,000 mg/L and predominant presence (up to 86 percent) of sodium and chloride. Also important are the relatively high concentrations of bromide and boron in seawater. Bromide can have adverse impacts on the formation of disinfection byproducts and the stability of disinfectant residuals. Boron concentrations in the desalted seawaters are substantially higher than commonly seen in municipal water supplies.

Water Quality along Proposed Treatment Process Train

Starting with general water quality of the source seawater, water quality has been evaluated for each of the unit processes along the proposed process train. Figure ES-5 provides a summary of the proposed water quality objectives along the proposed process train.

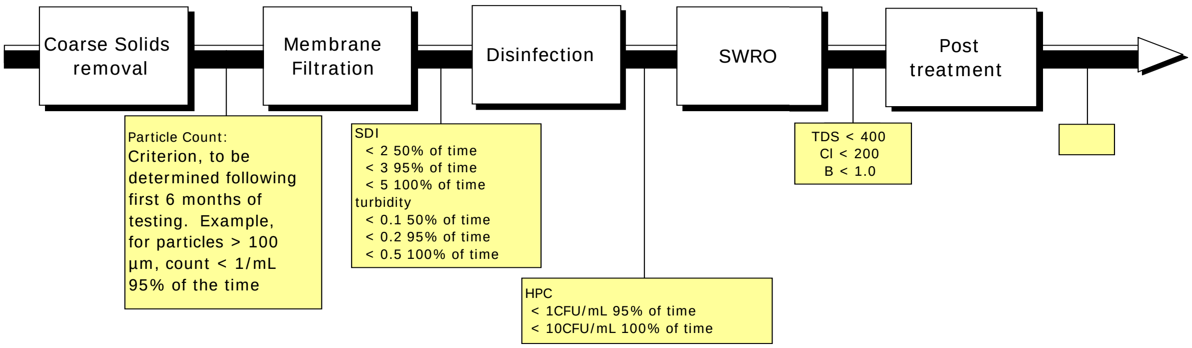

Figure ES-5 Process Flowsheet Showing Entire Seawater RO Pilot

Finished Water Quality Goals

The proposed finished water quality goals for the Scattergood Seawater Desalination Project, along with the Regulated Limits and Pilot Goal, is presented in Table ES–3. The boron and chloride goals are primarily driven by impacts on horticulture, some industrial users and compatibility with quality of the current supply sources. In addition to these goals, temperature goals and regulatory disinfection goals must be met.

Table ES-3
Scattergood Desalination Study Proposed Water Quality Goals

Parameter	Regulated Limit	*Pilot Goal*	Finished Water Goal
Chloride	250 mg/L	*200 mg/L*	100 mg/L
TDS	500 mg/L	*400 mg/L*	400 mg/L
Boron	1 mg/L	*1 mg/L*	0.5 mg/L
Title 22	MCL	*0.8 x MCL*	0.8 x MCL
Alkalinity	NA	*NA*	75-80 mg/L
pH	6.5-8.5	*NA*	8-8.5
LSI	NA	*NA*	> 0.1-0.2
Temperature	NA	*NA*	80 ºF

Post-Desalination Treatment Requirements

Considering the difference between the qualities of RO desalted water and finished water goals, additional treatment will be needed at a full-scale facility to confirm that the finished water integrates into the existing distribution system without creating undesirable side effects.

Depending on the LADWP decision with respect to the proposed finished water goals, the treatment may include any combination of the additional boron and chloride removal, temperature reduction, product water stabilization, and post-treatment disinfection

While the testing of these post-treatment alternatives has not been a primary focus of this study, it is recommended that additional studies be conducted in conjunction with this pilot to identify and optimize the most appropriate post-treatment approaches for the Scattergood site.

Pilot Plant Operating Conditions

Beyond the water quality goals, there are a number of operational variables that must be optimized during the pilot process to determine the most appropriate, efficient, and cost-effective operating conditions for the Scattergood Seawater Desalination Project. This document identified 12 variables summarized in the Table ES-4, which are the most critical for developing reliable design criteria for the Scattergood seawater desalination treatment process.

Table ES-4
Recommended Pilot Testing Variables

Process	Variable	Range	Evaluation Period
Coarse Solids Removal	Equipment type	Arkal (Train 1) and GMF (Train 2)	3 months
	Coagulant dose	0-5 mg/L Ferric	Response to red tides
	GMF loading rate	15-20 gpm/sf	3 months (concurrent with Arkal comparison)
Membrane Filtration	Flux	20-30 gfd	3 months
	CEB dose	5-100 mg/L Cl2	As required for flux
	CEB frequency	Every BW to weekly	As required for flux
	Coagulant dose	0-5 mg/L Ferric	Response to red tide
Disinfection	UV dose	0-30 mJ/cm2	6 months
Reverse Osmosis	Flux	8-12 gfd	As required for membrane type and temperature
	Recovery	50%	Not varied
	Membrane type	Low energy (Train 1) and high boron and chloride rejection (Train 2)	3 months (concurrent with MF flux evaluation)
	Temperature	Cold feed water (Train 1) and warm feed water (Train 2)	6 months

Future Studies

Additional tests and studies are recommended to define the source of seawater supply for the Scattergood Seawater Desalination Facility, post-treatment that will be capable of meeting the final product water quality goals in compliance with LADWP criteria and integration of the desalted water into LADWP water distribution system. Therefore, the following studies are recommended to be conducted concurrently with, or subsequent to, the Scattergood Seawater Desalination Pilot Project:

- Subsurface Intake Feasibility Study for the Scattergood site
- Product Water Stabilization Study, looking both at blending impacts through computerized modeling and bench top or pilot scale corrosivity tests
- Pilot testing of second pass RO, if it is found to be needed for complying with the water quality goals established in this Report
- Pilot testing of pre-treatment and post-treatment cooling towers, if it is determined that warm water is an acceptable alternative for the ultimate desalination plant source water
- Bench top chloramines stability testing
- Comprehensive Brine Discharge Evaluation

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Section 1
Project Background and Objectives

1.1 Introduction

The purpose of this Preliminary Evaluation Report is to define the overall objectives for the Scattergood Seawater Desalination Pilot Plant, providing the framework for execution of the project. The first section of this Report includes a summary of the project approach, a review of existing seawater desalination pilot and full scale plants, a description of the SGS, and a recommendation of the project objectives.

The second section includes a presentation of treatment technology alternatives available for the pilot project, an evaluation of the appropriateness of each alternative for meeting the overall project goals, and a recommendation of a treatment process for use in the pilot. The third section provides additional information on the recommended treatment process, including a discussion of water quality goals, recommended operating conditions, a preliminary site layout, process flow diagram, and a general schedule for the pilot testing evaluations. Finally, recommendations are made for future or concurrent studies, which are recommended to coordinate with this pilot work.

The overall pilot project objective, as stated in the grant application to the DWR was to examine the technical feasibility and practicability of developing a full-scale desalination plant that uses existing infrastructure to reduce the potential environmental impacts typically associated with seawater desalination. More specific project objectives will be recommended and described at the end of this section (Section 1.4), after a thorough evaluation of project history (remainder of Section 1.1), existing facilities (Section 1.2), and related studies and operating data (Section 1.3).

1.1.1 Project History

The LADWP has embarked on several studies over the past several years to review the feasibility of seawater desalination as a new water supply source for the City of Los Angeles. Recently, LADWP applied for and received grant funding from the DWR through Proposition 50 that provides a portion of the funding for a pilot study. The purpose of the pilot study is to examine the technical feasibility and practicability of developing a full-scale desalination plant that uses existing infrastructure to reduce the potential environmental impacts typically associated with seawater desalination. Specifically, the pilot study was initially focused on the technical requirements for the use of water discharged from the power plant condenser because use of this source water would minimize the potential impacts on marine life from the intake of seawater. Since the availability of post-condenser water is uncertain in the future, LADWP has since revised the scope of evaluations to also consider treatment processes associated with the use of ambient temperature seawater (cold water) and supplies that mimic beach wells. The two feed water options (warm and cold) will be pilot tested to allow direct comparison of pre-treatment, disinfection capability, and power requirements, as well as environmental and economic impacts between these water sources.

The Scattergood Seawater Desalination Pilot Project will build on the previous studies completed for LADWP, contributing to the ultimate objective of determining if seawater desalination is a viable water source for the LADWP service area.

The following summarizes the basis and key conclusions documented in LADWP's previous desalination studies.

LADWP Proposed Seawater Desalination Plant Site Selection Fatal Flaw Analysis (Psomas, 2002)

This analysis presented three potential seawater desalination plant sites, Scattergood Generating Station, Harbor Generating Station, and Haynes Generating Station. The report concluded that the SGS location offers the most siting and environmental advantages to LADWP for a desalination facility, compared to the Harbor Generating Station and the Haynes Generation Station sites.

Seawater Desalinization Facility Feasibility Study (Optimization Study), DMJMH+N (Metcalf and Eddy, 2004):

The Seawater Desalination Feasibility Study evaluated the economies of scale for an ocean desalination plant. The study concluded that a 25 MGD project was slightly more cost effective than a smaller facility, because the up-front costs of development would be recovered from a larger project yield. The report noted that the actual cost of construction and design did not change on a per unit of yield basis within the size range considered.

The report also discussed utilization of the warm-side condenser water, noting that various assumptions were made including the fact that the likely disadvantages of using warmer water, including higher boron pass and possible biofouling, might be insignificant if warm water were only encountered for the brief periods shown in the historical record. In addition, the warm feed water will be less expensive to desalinate due to decreased pumping requirements.

Considering the environmental issues and public relations, advantages offered by the five-mile long Hyperion outfall and the limited cost advantage of using the SGS outfall resulted in the report's recommendation that the Hyperion outfall be used for brine disposal.

In order to optimize the pretreatment and desalination processes, the report sets the stage for this project by recommending comprehensive piloting for the Scattergood desalination facility.

Brine Dilution Study for the Los Angeles Department of Water and Power Desalination Project at Scattergood Generating Station (Dr. Scott A. Jenkins, 2005)

This study used a hydrodynamic model to evaluate the brine dilution and dispersion for possible discharge options for a seawater desalination plant co-located with the SGS. Three options were studied including use of the SGS outfall, use of the one-mile Hyperion Outfall, and use of the five-mile Hyperion outfall.

The study provided five primary conclusions one of which determined that the Hyperion five-mile outfall offers the lowest risk for marine environmental impacts while allowing the largest desalination production capacity at the SGS because of the dilution that would occur in the mixing with the effluent from Hyperion. Use of the five-mile Hyperion outfall could in fact benefit the marine environment, however further study of these potential benefits was suggested. The study also suggested that the SGS outfall could be used with minimal impact to the marine environment for a production range of up to 25 mgd. The study concluded that use of the one-mile Hyperion outfall would likely cause a significant impact since this dilution would not occur prior to the discharge to the ocean.

In addition to these studies, LADWP is currently participating in a joint venture with the Long Beach Water Department to conduct studies at a seawater pilot and demonstration project located at the City of Los Angeles' Haynes Power Plant. Findings and lessons learned from this pilot plant will be considered throughout the implementation of the Scattergood desalination pilot plant.

1.1.2 Project Approach

The Scattergood Generating Station Seawater Desalination Pilot Project (Scattergood Pilot Project) is a collaborative effort of the LADWP and CDM team to investigate the viable treatment processes for seawater desalination at this site.

LADWP will be locating the Scattergood desalination pilot plant adjacent to the SGS and the Hyperion Treatment Facility. This location provides an opportunity to utilize the SGS seawater cooling loop as a source of water for the Scattergood desalination pilot plant, and either the SGS outfall or the Hyperion outfall for spent test water disposal. Viability of seawater desalination at this site must be demonstrated through the successful operation of a pilot plant prior to the City making any decision in regard to a full-scale plant.

The first task of this initial phase of the project is the development of a detailed Preliminary Evaluation Report (herein) that will set the stage for the pilot plant design, operation and testing.

The task includes development of two DM1 and DM2 that present the project goals, outline how data and lessons learned from other pilot and full-scale seawater desalination facilities will benefit the Scattergood Pilot Plant, process screening of potential pilot plant technologies and selection of recommended pilot plant trains.

The Decision Memoranda have been updated addressing LADWP's comments and are included as sections 1 and 2 of this Preliminary Evaluation Report. The Preliminary Evaluation Report also includes a preliminary pilot plant layout, equipment list, and experimental plan schedule.

These preliminary data will be the basis for the CDM and LADWP design teams to develop the design and procurement documents to support LADWP's Request for Proposal (RFP) process for a single original equipment manufacturer (OEM) to be responsible for supplying and installing all of the pilot plant and ancillary equipment specified.

The experimental plan outline presented in the Preliminary Evaluation Report will be expanded into a comprehensive pilot plant test protocol that supports data needed to achieve the specific project goals. The sampling locations, frequency, and methods will be prescribed in the test protocol.

The CDM team will continue to support LADWP through construction and operation of the pilot plant. The information obtained through the pilot testing, including lessons learned and test results will be compiled and presented in the Scattergood Seawater Desalination Pilot Project Report: Final Report. This report will include conclusions and technical recommendations on how LADWP could proceed with seawater desalination should they choose to do so.

The Scattergood seawater desalination pilot project will be executed in four phases, including the first phase that was described above:

- Phase I – Pilot Planning and Design
- Phase II - Pilot Installation
- Phase III – Implementation
- Phase IV – Final Report

The specific tasks defined in the project scope of work have been designated into these four project phases.

1.1.2.1 Phase I – Pilot Planning and Design

The following discussion of Phase I links the activities described above with the specific tasks defined in the project scope of work.

Preliminary Evaluation Report (Task 1)

Task 1, the Preliminary Evaluation Report consolidates project objectives defined in DM1 and identifies feasible technology/system process options that may be available for use by LADWP as presented in DM2. The DM2 also included an engineering screening that was conducted to select the process options applicable at the Scattergood Seawater Desalination Facility. Two seawater desalination process trains that included coarse solids removal, pretreatment, disinfection and desalination were selected for pilot testing. The selected pilot plant trains are presented in Section 2 of this Report.

Design of Pilot Plant and Equipment Procurement (Task 2)
LADWP and the CDM team will work together to design the pilot plant. CDM will integrate the LADWP design elements into an automated pilot plant consisting of treatment unit processes, chemical storage and feed system, interconnecting piping and storage tanks, electrical, control and instrumentation.

CDM will also prepare detailed procurement specifications, drawings, and other supporting documentation to assist LADWP in the equipment procurement.

Test Protocol (Task 4)
Water quality samples will be taken at pre-determined locations along pilot plant process trains to determine the performance of various processes and to support brine disposal evaluations. The required samples will be detailed in the pilot testing protocols. The first phase of the pilot testing protocols will be developed under Task 4. The Test Protocol will describe the pilot plant daily operation, procedures and frequency for water quality sampling and field testing and measurements, data management, inspection, and maintenance of the pilot unit processes. The water quality testing protocols will include sampling methods and standard methods for laboratory analyses. The Protocol will address water quality sampling that is to be performed in advance of pilot plant operation to characterize source water and enable QA/QC within the laboratories prior to initiation of pilot testing and sampling. The Protocol will also cover cleaning and periodic maintenance procedures and describe responsibilities of personnel involved in pilot plant operations including vendor representatives, CDM field representative, and LADWP plant operator. They will include procedures for regulatory compliance and communications between CDM, manufacturer representatives, and LADWP during routine and non-routine operation. Updates to the testing protocol will be performed under Task 8.

1.1.2.2 Phase II – Pilot Installation

Installation and Start-Up (Task 3)
In Task 3, CDM will provide engineering support during construction by replying to Request for Information (RFI) and submittal reviews. CDM will also provide technical support for permitting and prepare permit applications for (1) hazardous materials associated with the pilot plant operation and (2) for air quality compliance (i.e. Air Quality Management District).

CDM will provide LADWP with assistance during construction of the pilot plant and installation of the pilot test equipment. CDM will oversee commissioning and start-up of the test equipment and will prepare a commissioning and start-up plan, oversight of manufacturer representatives and coordination with LADWP during start-up.

1.1.2.3 Phase III– Implementation

Operation and Maintenance (Task 5)

CDM will support LADWP in daily operating and maintenance of the pilot plant including inspection, maintenance of chemical supplies, water quality sampling and data collection. CDM will train LADWP personnel and will assist in trouble shooting, repair and modification of pilot equipment. CDM will coordinate with manufacturer representatives to accomplish membrane installation and replacements, repair of equipment and institution of new operating procedures.

Compilation and Reporting Test Results (Task 7)

CDM will receive and log all daily field collected data and laboratory testing results in a predefined data log sheet. CDM will develop procedures for LADWP to populate the database with laboratory testing results and will maintain the database. On a monthly basis, CDM will be responsible for the compilation of monthly testing reports, which will include analysis and reporting of test results including analyses of plant performance, fouling characteristics, effectiveness of cleaning procedures, disinfection performance and other parameters significant to the analysis of pilot plant performance and test results.

Revision to Test Protocols (Task 8)

CDM will update and revise the test protocols developed under Task 4. These protocols will be updated for each phase of the testing and upon modification of procedures within any phase of testing.

Support for Concentrate Disposal Evaluation (Task 10)

CDM will provide support for LADWP in their coordination with the City of Los Angeles Bureau of Sanitation (LABOS) on detailed technical evaluations of waste residual disposal through the Hyperion Wastewater Treatment Plant Outfall. LADWP will be evaluating the potential for blending, minimization of the wastewater footprint, and potential biological impacts to sensitive species. The pilot plant will produce information on waste residuals useful for these evaluations. CDM will provide as needed support for these evaluations by providing information regarding chemical composition and volume of concentrate that will be disposed by sampling and analyzing the RO concentrate (brine), MF/UF backwash waste and other waste streams. The volume of concentrate and chemical composition of the waste streams will be provided to LADWP as a designated section of the monthly pilot plant test results report. CDM will also participate in the evaluation by reviewing the concentrate disposal reports and attending meetings with LABOS.

1.1.2.4 Phase IV – Scattergood Seawater Desalination Pilot Project: Final Report

The project Report is defined as Task 11 in the Agreement. This project Report will summarize the lessons learned and present analyses of all test results. The Final Report will include conclusions and recommendations on how LADWP should proceed with seawater desalination.

1.1.2.5 Project Coordination Tasks

The following tasks will be performed throughout the course of the project.

Coordination with California Department of Public Health (CDPH) (Task 6)
Agency acceptance of future desalination activities is critical to implementing a full scale plant at the Scattergood site. CDPH will be involved in the early stages of the project through the final report stage, and is therefore given its own overall project coordination task. CDM will assist LADWP in coordinating the pilot testing with CDPH and will endeavor to address issues raised by CDPH in the pilot testing and water sampling protocols to be developed as part of the Pilot Plant Test Protocols (Task 4).

Project Progress Communication (Task 9)
CDM will assist LADWP in informing the public regarding activities and progress associated with the pilot plant project. CDM will develop and maintain a web-based information sharing site that includes relevant Project Information, including data, reports, and upcoming events.

Project Management (Task 12)
Project management activities will be performed to facilitate successful execution of the project. A Project Work Plan will be prepared and used throughout the course of the project defining project team, work breakdown structure, cost loaded schedule, communication protocol and document control.

Progress reports will be prepared monthly that will include project status, budget and schedule status, and other project management issues.

QA/QC (Task 13)
QA/QC activities will be performed through all phases of the Scattergood Seawater Desalination Project through execution of CDM's quality control procedures, Project Quality Management (PQM) meetings and technical review sessions.

1.2 Related Studies and Operating Data

As part of the study phase of the Scattergood Pilot Project, the project team was tasked with identifying pilot studies and operating full scale plants relevant to the Scattergood site.

Data from these pilot plants and full scale facilities is being reviewed and used to develop a conceptual design of the pilot work for this study. The testing at other facilities has produced important data which may reduce the need for pilot work at SGS and also may avoid many of the pitfalls from prior work to improve the efficacy of the pilot approach. Review of other pilot studies and existing full scale operations is also important to ensure that the SGS studies generate new data which compliments prior research and to ensure that the studies address site-specific issues which are important at SGS.

The project team identified three seawater desalination pilot plant studies and three full scale operating desalination plants. The following discussions provide overviews of these seawater pilot testing programs and full-scale systems that are relevant to the planning of the LADWP Scattergood Seawater Desalination Pilot Project.

1.2.1 Pilot Plant Studies

In recent years, several California water agencies have embarked on seawater desalination pilot studies. In selecting the pilot studies to present in this report, the project team had to consider availability of data and applicability to the Scattergood site. Based on these criteria, the following pilot plant studies were selected and are summarized herein:

- West Basin Municipal Water District El Segundo Power Plant Site
- Marin Municipal Water District, Marin, CA
- Long Beach Water District Nanofiltration Pilot Facility

1.2.1.1 West Basin Municipal Water District

The WBMWD has been operating desalination pilot test equipment at the El Segundo Power facility since June 2002. The source water has alternated between the ambient temperature intake and warmer outfall from the power plant cooling loop. Historical data from the power plant indicates an average temperature difference between intake and outfall temperature of 14°F.

Process Description

For the majority of the testing at WBMWD, the process flow has consisted of two-stage straining, microfiltration or ultrafiltration (MF/UF), and single-pass, single-stage reverse osmosis. Figure 1-1 illustrates this process flow. Early operation, as described in subsequent discussion, did not include the Arkal strainer and included an unsuccessful attempt to control biological activity through the formation of chloramines.

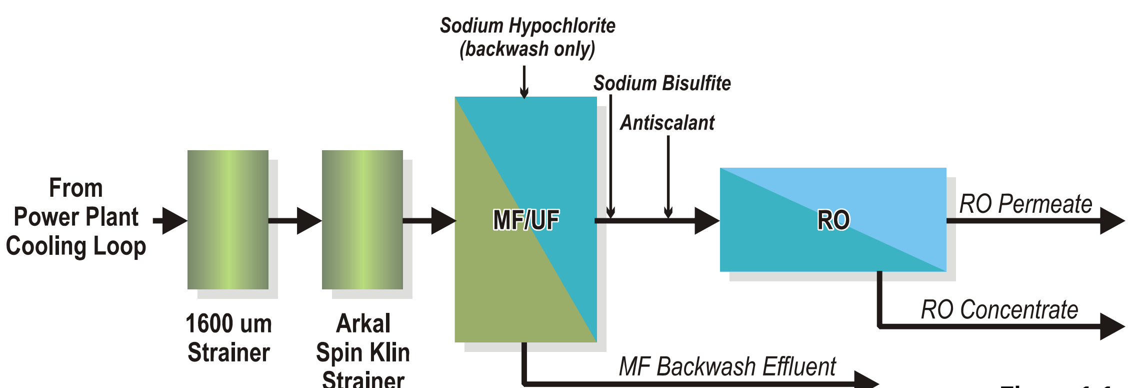

Figure 1-1
WBMWD Seawater Desalination Pilot Plant Process Flow

Highlights from the WBMWD pilot testing are summarized below, including chlorination, pretreatment, RO and water quality, and the impacts of red tide events.

Chlorination

The original process flow consisted of the addition of free chlorine upstream of the MF/UF followed by the addition of ammonia hydroxide upstream of the RO. The objective of the free chlorine addition was to provide a free chlorine residual for the MF and control bio-growth within the RO system with chloramines. This process was very effective at maintaining high flux rates on the MF system, and subsequent runs without chlorine demonstrated how beneficial the oxidant was to the MF/UF process performance. However, the bromide content indigenous to seawater interfered with the chloramine reaction and the resulting bromamines rapidly oxidized the RO membranes. The continuous chlorination/ammonia approach was abandoned and replaced with periodic chlorination of the UF/MF in the backwash and/or maintenance cleans followed by sodium bisulfite addition upstream of the RO to reduce any trace oxidant (Figure 1-1). The pilot system did not experience biological growth problems when operating on the ambient temperature intake. However, biological activity has occurred during operation on the warm water outfall source.

Pretreatment

The power plant periodically performs a heat-treat operation (roughly every 60 days) to kill shellfish which attach to the cooling loop. This results in the introduction of shell fragments and other debris into the MF feed water. Early on, this caused numerous fiber breakages or integrity loss failures for the hollow fiber MF/UF systems. West Basin has optimized their intake screening to include 1600 um strainers to protect the intake pumps followed by 100um Arkal Spin Klin disc filter to protect the MF/UF.

The Arkal Spin Klin disc filter has worked well at protecting the membrane fibers from damage, but has required considerable maintenance. The scalability of this technology for a full-scale installation presents some concern, with regard to number of components, cost and footprint. WBMWD is planning to test a pilot-scale high-rate granular media filter in parallel with the Arkal system, to assess its capability as an alternative to the Arkal.

Three different MF/UF systems have been tested to date, the US Filter CMF-S, the Zenon ZW1000, and the Pall Microza.

- US Filter accumulated over three years worth of data. However, their PVDF membrane went through a series of redesigns to improve integrity and performance.

- The Zenon ZW1000 system has operated for over one year. The integrity of the system has been outstanding, but the flux rates are somewhat lower than those of the US Filter system.

- The Pall Microza system was recently added to the site and the performance has been very promising thus far.

Reverse Osmosis and Water Quality
West Basin's product water quality goals for potential full-scale implementation of seawater desalination are still under development, but tentatively include production of water with less than 100 mg/L chloride and less than 0.5 mg/L boron. With these water quality goals in mind, a partial second-pass RO is being considered.

Numerous different RO membranes were tested. The following were considered most effective at minimizing energy consumption and maximizing boron and chloride rejection:

- Filmtec SW30HRLE
- Toray TM820
- Hydranautics SWC4+

Fouling of the RO has been minimal on the intake source, with the exception of severe red tide events. Biological fouling has occurred intermittently during operation on the warmer outfall source.

Red Tide
A severe red tide occurred in 2005 which affected the process as follows:

- Rapid fouling of the UF/MF occurred when the systems attempted to maintain previously stable operating conditions (flux, backwash frequency, etc.). During the most severe period of the event, a 25-33 percent decrease in membrane flux was required to maintain acceptable run times between chemical cleanings.
- Fouling of the RO was observed and required proprietary cleaning chemicals (more costly than generic procedures) to remove. The rate of fouling and frequency of cleaning was manageable, but greater than non red tide events.

Lessons Learned

- An attempt to directly form chloramines in seawater resulted in formation of bromamine, which damaged the RO membrane.
- A 100-micron strainer has been necessary to protect the pretreatment membranes from shell shards.
- Single pass RO is capable of meeting all regulatory requirements for potable water production. However, project specific goals for chloride and boron concentration may drive the need for a partial second-pass RO.

- Intermittent biofouling has occurred during operation on the warmwater outfall source and refinement of biogrowth control techniques will be appropriate for warmwater operation.

- Seasonal Red Tide events have impacted the ability of the treatment process to maintain capacity, but never compromised water quality.

Applicability to LADWP Project

The results of this pilot test are directly applicable to the LADWP project, as the source waters tested are very similar to that proposed for LADWP (power-plant cooling loop using an open ocean intake within one mile of Scattergood Generating Station). Each of the "Lessons Learned" itemized above should be considered in the development of the LADWP pilot test objectives and testing protocol.

1.2.1.2 Marin Municipal Water District

The Marin Municipal Water District completed a one year pilot study in anticipation of the construction of a 5-mgd plant treating northern San Francisco Bay water. This water contains substantially less total dissolved solids, boron and chloride than Pacific Ocean seawater and is subject to wide variations in water quality due to seasonal runoffs into the bay.

Process Description

The pilot study commenced in the early summer of 2005 and was completed in the summer of 2006. The process flow consisted of two parallel trains, including:

- Train 1 consisting of intake wedge wire screen followed by Arkal 100 um strainer followed by MF/UF and first pass RO

- Train 2 consisting of intake wedge wire screen followed by Boll 100 um strainer followed by conventional filtration system and first pass RO. The conventional filtration system consisted of rapid mixing with coagulant, followed by flocculation, sedimentation and granular media filtration.

A portion of the first-pass RO permeate was treated with a second-pass RO system

Highlights from the Marin Municipal Water District pilot testing are summarized below, including wedge wire intake screen, pretreatment, and RO testing results.

<u>Intake Screen and Strainers</u>

Marin operated a wedge wire screen on the pilot intake pipe in an effort to simulate a full-scale wedge wire intake screening system. This method of preventing impingement and entrainment may be considered an environmentally sensitive option and therefore data collected on the wedge wire screen is important to seawater desalination research. The wedge wire screen in conjunction with an air burst backwashing system proved to be viable.

The Boll stainless steel wedge wire strainer was compared to the Arkal Spin Klin disc filtration system. The Arkal system was found to be more effective than the wedge wire screener and was recommended for the project as it demonstrated higher particle removal efficiency and is made from non-metallic materials of construction.

Pretreatment
UF/MF was considered superior to conventional treatment and was recommended for the project. UF/MF provided better filtrate water quality for the downstream RO and was determined to have lower capital and operating costs.

Both the Zenon ZW1000 UF and the Siemens CMF-S units were piloted successfully. Each provided excellent filtrate water quality and experienced no integrity issues. However, the Siemens pilot MF system experienced significant mechanical failure of the permeate pump, which kept the unit from operating for more than two months.

Predosing of ferric salts improved the total organic carbon (TOC) removal of the UF/MF processes from 10 percent to 50 percent. Thus, a ferric dosing system was recommended for the project to be used in the event of algae blooms or red tides.

The MF/UF filtrate tank experienced biogrowth, which required painting of the tank and initiation of periodic shock chlorination.

Reverse Osmosis
The following four RO membranes were tested as part of the Marin Municipal Water District pilot study:

- Filmtec SW30HRLE
- Toray TM820
- Hydranautics SWC4+
- Koch 2822 SS

Salt rejection performance of the Dow and Toray membranes were poor compared to manufacturer's projections and was attributed to hand manufacturing of these specially ordered elements (a method not standard in 4-inch elements). A flux range of 8 to 9 gfd and recovery of 40 to 50 percent were recommended for the project.

Although the pilot test lasted one year, the Marin pilot equipment was never exposed to a severe red tide or algae growth event, which is considered possible at this intake location. An examination of the wedge wire screen performance and the comparison of the prefiltration systems under red tide conditions would have been beneficial.

The piloted desalination treatment process was determined to have achieved State, Federal and Marin Municipal Water District's more stringent water quality objective.

Lessons Learned

- A wedgewire screen on the pilot open-intake operated successfully with an air-burst backwash but did not experience a severe red tide condition.

- The Arkal strainer was recommended as the preferred strainer compared to the Boll device, based on removal efficiency and materials of construction.

- Zenon and Siemens membrane filtration pretreatment was determined to provide better filtrate quality than conventional pretreatment and offer cost advantages, as well.

- An RO flux of 8-9 gfd was established as optimum. Special order RO elements did not perform as expected.

Applicability to LADWP Project

While the feed source of the Marin Municipal Water District pilot was different from the LADWP-SGS site in substantial ways (e.g. TDS), the test results and conclusions do provide valuable information to support process and equipment selection decisions for the LADWP project. Notably the effective performance of the Arkal strainer, as well as the membrane MF/UF filtration systems, should be considered for the LADWP project.

1.2.1.3 Long Beach Water Department (LBWD)

Since October 2001, the Long Beach Water Department, in partnership with LADWP, has been executing a three phase research and demonstration program on seawater desalination. Phase A of the testing is complete and consisted of a closed loop pilot plant system fed by water collected at Pier 22 in Long Beach. This pilot testing was geared toward the evaluation of a two-pass NF desalination process and its advantages/disadvantages over single pass reverse osmosis. Pall Microza MF was utilized as pretreatment to the desalination membranes. The Phase A pilot testing equipment produced approximately 9,000 gpd.

LBWD is currently in Phase B, demonstration scale, of their testing which started in October of 2006.

Process Description

The Phase B demonstration plant equipment consists of full-scale eight-inch reverse osmosis and NF membranes and is capable of producing 300,000 gpd. The source water is taken from the inlet of the cooling loop at the Haynes Steam Turbine Power Plant in Long Beach. The process flow consists of microfiltration pretreatment feeding two desalination trains in parallel. The first desalination train consists of two-pass nanofiltration and the second desalination train consists of single-pass reverse osmosis. Process flow for this demonstration plant is shown in Figure 1-2.

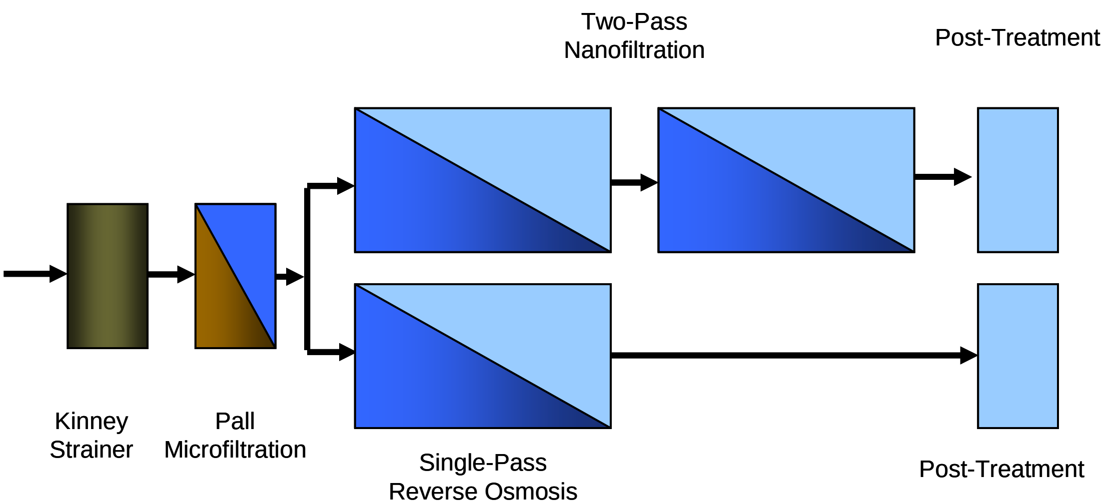

Figure 1-2
Long Beach Seawater Desalination Demonstration Plant Process Flow

The Pall Microza system is reported to have operated very well and the design flux for the full scale is 35 gfd. The Pall system, including the membrane, was previously used at another site and out-of-service for several months. A few fiber breakage events have been reported following startup at Long Beach, but these were attributed to faulty membrane storage.

LBWD is currently utilizing the following membranes:

- Seawater RO: Hydranautics SWC3+
- 1st pass NF: Dow Filmtec NF90
- 2nd pass NF: Saehan NE90S

Detailed operational data has not been published, but the energy consumption of the two-pass NF process was indicated during a site visit to be comparable to that of single pass RO.

The two-pass NF process produces water that is comparable to that of single-pass RO. A technical paper presented at the 2005 AWWA Membrane Technology Conference described the two-pass NF process producing permeate with the following attributes when operating on Pacific Ocean seawater:

- Boron, 0.5 to 1.0 mg/L
- Chloride ion, ~120 mg/L
- Total dissolved solids, ~220 mg/L

Since October 2006, the Phase B test is reported to have had only 50 percent on-line time. During a tour, the staff indicated the plant has had problems with mechanical equipment. This includes operation of the ERI energy recovery device within relatively unusual hydraulic conditions of the two-pass NF process.

Lessons Learned

The testing of the Two-Pass NF and Single-Pass RO at Long Beach is demonstrating and comparing the performance of these processes on microfiltered seawater. Early data is indicating the Two-Pass NF process is capable of efficiently producing potable quality water. However, publication of a conclusive comparison to the single-pass RO is still pending.

Applicability to LADWP Project

The Two-Pass NF process is a unique approach to desalination which is still being evaluated and has yet to clearly show an overall advantage over reverse osmosis. The LBWD personnel have indicated that a primary benefit of the Two-Pass NF operation is system flexibility, whereby specific water quality objectives can be met by adjustment of operating conditions. Additionally, they will be trialing different NF membranes in each pass in order to optimize water quality and energy consumption. Our review confirms that system flexibility is a benefit of the Two-Pass NF process. However, this comes at the expense of additional treatment equipment. LADWP's continued participation in this project should be an effective way to evaluate the Two-Pass NF process. The Two-Pass NF process does not yet warrant consideration for piloting at the SGS site. Of more direct applicability to the LADWP project is the selection of microfiltration pretreatment and the overall satisfactory performance of this pretreatment at Long Beach.

1.2.2 Full Scale Plants

Although several seawater desalination pilot plants have been operated in California, only a limited number of full-scale seawater desalination plants are currently in operation in the state. The project team identified the following full-scale seawater desalination plants to review as part of this planning phase:

- Diablo Canyon Power Plant, Avila Beach, CA
- Tampa Bay Seawater Reverse Osmosis Facility, Tampa Bay, FL
- Perth Seawater Reverse Osmosis Plant, Kwinana, Australia

1.2.2.1 Diablo Canyon Power Plant

The Diablo Canyon Power Plant at Avila Beach, CA uses seawater desalination for production of cooling water, make-up water for steam generation and potable water. This specific seawater desalination facility has been in operation for fourteen years (another system operated prior to that time). It produces 450 gpm of product water which, after subsequent treatment, is used for the drinking and industrial uses.

The seawater feed source is from the intake to the power plant cooling loop. This intake draws from a small lagoon. Temperature range is 10-18 deg C.

Process Description

Pretreatment consists of the following steps:

- Bar screens
- Custom-Built Coarse strainer (1/8 inch diameter pattern)
- In-line coagulation ($FeSO_4$ & polymer)
- Dual Media filters (4 gpm/ft2)
- Multi Media Filters (4.5 gpm/ft2)
- UV disinfection
- Cartridge filtration
- Antiscalant addition
- Chemical dosing, backwash practices, etc. have been documented

The desalination system consists of a 45 percent recovery single pass (two-stage) RO. The most noteworthy aspect of the operation is that the RO membrane needed virtually no chemical cleaning or replacement in the first ten years of operation. Operating staff credits this to regular (daily) measurement of filter effluent Silt Density Index (SDI). This SDI is maintained typically near 1. In response to deviations in the filtrate SDI, the upstream SDI (dual media filter effluent) is measured, coagulant addition is adjusted and when extremely poor feedwater conditions occur, the flow is reduced. The operating staff downplays the benefit of feedwater turbidity measurement and does not regularly monitor it, focusing their attention on the aforementioned SDI results.

Although the RO has not experienced biological fouling, the UV process has not been conclusively proven to provide a benefit and is considered by the operating staff to be a labor intensive process (cleaning and lamp replacement). However, while acknowledging these limitations, the two-stage granular-media filtration and UV process has been a very successful pretreatment process for this seawater source.

The RO high-pressure stainless steel piping is 316L, which has experienced a high rate of corrosion, requiring regular spool replacements.

Lessons Learned

- The Diablo Canyon Power Plant has achieved remarkable RO performance (fouling rate and cleaning frequency) operating on a California open-intake source for over a decade. It is notable that this source is relatively cool and the treatment process does not draw from the power plant cooling loop discharge.

- The pretreatment, consisting of two-stage granular media filtration and UV, requires diligent operator attention and skill to optimize the coagulant dose in response to changes in feedwater quality.

- Output of the treatment plant is decreased in response to poor feedwater quality to maintain pretreatment performance.

- The benefit of the UV process has not been conclusively demonstrated.

Applicability to LADWP Project

- The long-term success of this facility provides validation that the technology is viable for a full-scale facility operating on an open intake source in California.

- Diablo Canyon performance confirms the concern seen in pilot testing that output may be impacted during periods of poor feedwater quality.

- The results at Diablo provide anecdotal support to investigation of UV to control biogrowth in the treatment process.

1.2.2.2 Tampa Bay Water

Tampa Bay Water (TBW) is a regional water supplier in the Tampa Bay area. In 1998, after TBW entered a Partnership Agreement with South West Florida Water Management District (SWFWMD) to reduce groundwater pumping in the region, TBW decided to pursue a design-build-own-operate-transfer (DBOOT) seawater desalination facility to reduce groundwater pumping and provide a drought-proof alternative to their water supply portfolio.

The seawater reverse osmosis (SWRO) facility withdraws seawater from Tampa Bay, and is located next to TECO Big Bend Power Station. The facility has an intercept structure to allow withdrawal of warm, once-through cooling seawater from two of the four circulating water systems employed by TECO. The facility also has a cool water pump which allows seawater which has not been used for cooling to be blended with the warmer seawater, to maintain a feedwater temperature of less than 40ºC. The facility is designed to produce 25 million gallons (Gal) per day of finished water (expandable to 35 million gallons).

The facility experiences wide variations in feed TDS concentration, suspended solids and biological activity. Table 1-1 presents some of water quality parameters used in the design.

Table 1-1
Tampa Bay Seawater RO Facility Water Quality Data

Parameter	Design Avg	Design Min	Design Max
Intake Flow, mgd	44.5	37.8	51.9
Salinity (TDS), mg/L	26,000	16,500	31,000
Temp, C	33.3	24	44 (<40 to SWRO)
Turbidity, NTU	6-12	1	25
TSS, mg/L	16	2	47

Process Description

The Process Flow Diagram for the SWRO facility (and that which was piloted – with the exception of the cool water supply option) is shown in Figure 1-3.

The facility experienced substantial problems maintaining capacity, in large part due to inadequate performance of the pretreatment and resulting RO membrane fouling.

A major modification of the treatment process was implemented, including addition of coagulation/flocculation prior to filtration and the addition of DE polishing filters. A process flow diagram of the remedy is shown in Figure 1-4.

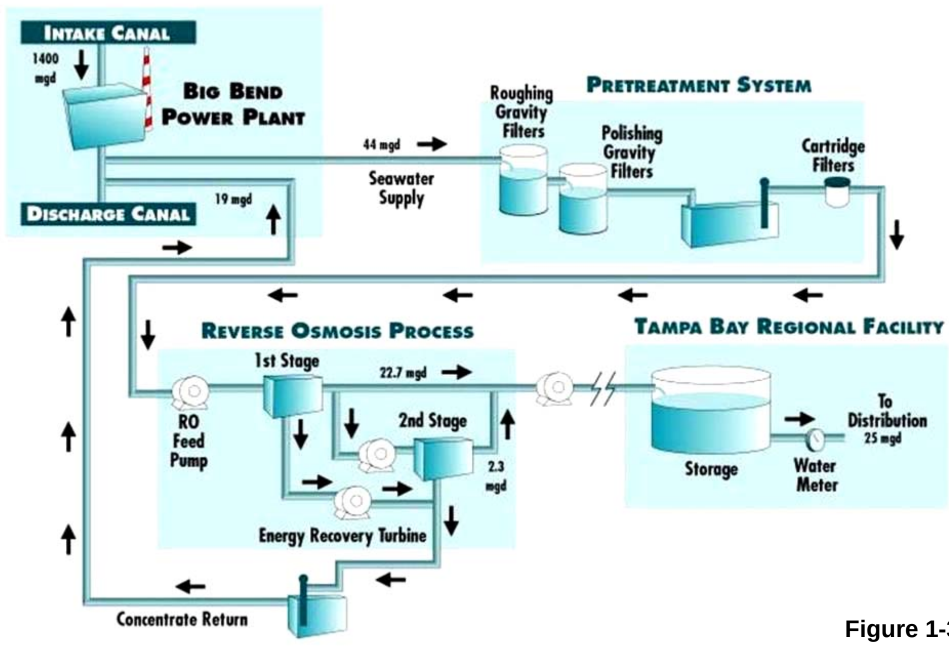

Figure 1-3
Original Tampa SWRO Process Flow Diagram

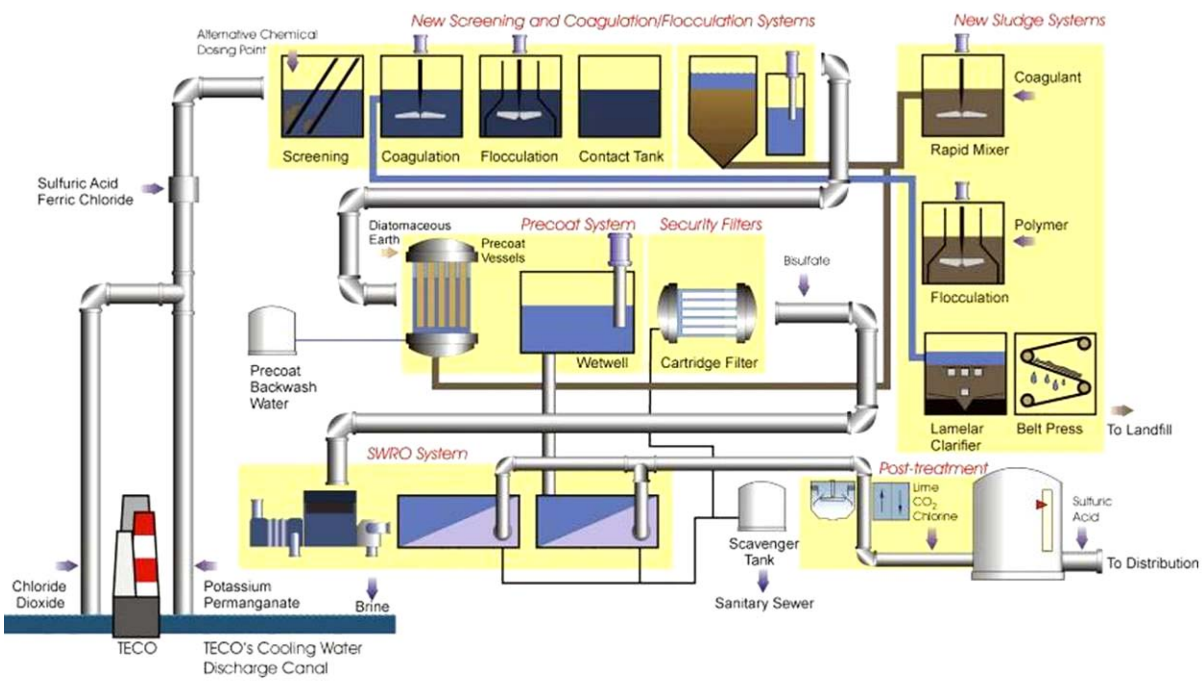

Figure 1-4
Tampa SWRO Remedy Process Flow Diagram

Lesson Learned

- Feed water quality changed, and should have been monitored more closely. Introduction of bivalves was significant and the original system Achilles' heel was how easily the air lift plugged with small shell fragments.

- Seasonal effects of a surface water and seawater blend can have a profound impact on the sustainable operation of the pretreatment process. Pretreatment inadequacies over the range of feedwater quality and conditions that ultimately exist at the site prevented the plant from successful operation.

- Too many people were involved in the pilot, and had only a glimpse or snapshot of its performance before directing the piloting process. Few understood or were involved with interpretation of the feedwater quality changes over the years, and the impact those changes were having on the piloted systems (if any). One gatekeeper, reporting to the owner of the project, should have been assigned the task of compiling all piloted information and data in one place.

- Scale up was a factor for proprietary DynaSand filters. The DynaSand pilot vessels were circular and the full-scale system utilized square filter bays.

- With the new system, potential DE break-through is possible, and operators must be diligent in monitoring the cartridge filter differential pressure. If unchecked, cartridge filters could deflect and allow direct bypass to the SWRO elements.

Applicability to LADWP Project

Many of the "lessons learned" of the Tampa project are directly applicable to the LADWP project.

- Acknowledging the substantial impacts that seasonal water quality changes can have on pretreatment performance, during development of the pilot testing protocols.

- Operation on the pilot on the actual full-scale feed source will ensure that unexpected/unknown factors are addressed (e.g. shellfish).

- Ensure scalability of pilot equipment to full-scale.

- Pilot testing is needed to confirm that the pretreatment will function properly over range of operating conditions that may be experienced at the site, to demonstrate that the project goals and objectives can be achieved, and to provide input for final design and for optimization of the process

- There are inherent risks involved in using technology that does not have a proven record in seawater reverse osmosis applications.

- Pilot testing of the post-treatment system is recommended prior to design of the full scale facility.

1.2.2.3 Perth Facility

The Perth Seawater Desalination Project began operation in November 2006. It is located on the west coast of Australia, producing 38 mgd (143,700 cubic meters per day) of potable water for the Perth Integrated Water Supply System. The feed source is from an open intake in a coastal sound with salinity of 35-37 g/L TDS and temperature range of 16-24ºC.

Publications about the project highlight its use of renewable energy (wind) and energy efficient equipment.

Process Description

The treatment process includes coarse screening, single-stage dual-media filtration, cartridge filtration and two-pass reverse osmosis.

The dual-media filters use anthracite and sand and employ sulfuric acid, ferric sulfate and coagulant aid (poly DADMAC) addition.

The RO system is a full two-pass design, where all first pass permeate is treated in the second pass. The critical water quality criteria is 200 mg/L TDS and 0.1 mg/L bromide. Interestingly, the boron target is 2.0 mg/L, which is two to four times greater than the target for desalinated water.

Pilot testing for the project consisted of four month operation of pretreatment filters, including comparison of single versus two-stage media filters. The filter performance was assessed based on analytical filtrate quality values. No pilot reverse osmosis was operated. Also, no indication of consideration of membrane pretreatment MF/UF has been noted.

Based on the pilot performance, single-stage dual-media filtration was selected.

Regarding performance of the full-scale facility, it is interesting to note that four technical papers where presented on the project at the International Desalination Association conference in October 2007, one year after startup. None provide an indication of the effectiveness of the pretreatment to achieve a low RO membrane fouling rate. Statements are made that "during commissioning" the filters are performing in accordance with the pilot results, which were characterized by filtrate analyses, not RO performance. Also, it is stated the RO design "gives expected values in terms of permeate quality." Again no reference to RO fouling rate.

Lessons Learned and Applicability to LADWP Project

Technical papers on the Perth project do not provide a complete presentation of the performance of the full-scale plant following commissioning. The absence of this information creates some suspicion regarding the performance of the single-stage dual-media filtration pretreatment, especially considering the pilot testing did not demonstrate RO performance. While this project is a showcase for energy efficiency and use of sustainable energy sources, LADWP should be cautious of following the lead of this facility regarding pretreatment selection, until such time as comprehensive RO operating data is available.

1.3 Existing Facilities and Conditions

1.3.1 Scattergood Generating Station

This section describes the existing facilities and conditions that are anticipated to affect the design and operation of the desalination pilot plant, as well as the future design and operation of a possible full scale desalination plant. Specifically, this section discusses the characteristics and operations of the Scattergood Generating Station and the surrounding water distribution system which could ultimately receive desalinated water from a potential full scale plant.

1.3.1.1 Cooling Water System Description

The function of the cooling water system is to supply a continuous source of seawater to the condensers for condensing the turbine exhaust steam. The system consists of submarine inlet and outlet pipelines into Santa Monica Bay; a screen and chamber facility; chlorine and sawdust injection facilities; condensers and internal piping; and two stop log chambers. Partial piping schematics and flow diagrams of the cooling water system are included in Appendix A.

There are three separate systems that circulate cooling water to the three condenser units. Although functionally similar, there are slight operational differences in the systems that will be important to the operation of the pilot plant, including the time the systems are activated and waste discharges into the cooling loops. These differences will be discussed in the following sections.

Intake and Discharge Pipelines

Seawater enters and exits the cooling water system through two 12 foot diameter pipelines extending west into Santa Monica Bay. The north pipeline is normally used as the intake, although butterfly valves on the pipelines allow for the flow to be reversed.

The intake into the north pipeline is approximately 2,146 ft offshore. The ocean bottom at this location is at an elevation of approximately -29.0 ft, with the top of the intake riser located at an elevation of approximately -11.0 ft. A circular velocity cap was installed on the intake riser in 1974. This velocity cap redirects the intake flow from the vertical to the horizontal direction, and helps to reduce impingement of marine organisms. The cooling water intake is subject to federal regulations under section 316(b) of the Clean Water Act.

The cooling loop discharge pipeline extends approximately 1,761 ft offshore parallel to the intake pipe. The cooling loop effluent leaves the system through a 7.5 foot diameter riser pipe. The intake and discharge are separated by a distance of approximately 400 feet.

Screen and Chamber Facility

Seawater flows from the 12 foot diameter intake pipeline into the screen and chamber facility where it is pumped into the plant and back out to the ocean. The screen and chamber facility is located just west of the main SGS facility between the beach and Vista Del Mar Avenue. An isometric drawing of the screen and chamber facility is included in Appendix B.

Upon entering the screen and chamber facility, the seawater collects in an arc shaped chamber open to the atmosphere. This chamber serves as a common suction location for the three separate circulating water pumping systems. To the north and south of the intake chamber are the discharge chambers where the water collects after being circulated though the power plant. The valving arrangement allows for the discharge water to be directed from the outlet chamber back into the inlet chamber. This configuration is used during heat treatments when no additional seawater is added to the system.

From the intake chamber, the seawater is directed through an array of eight coarse trash racks. Each trash rack bay is six ft wide with 3/8 inch x 4 inch steel bars installed at 5" on center. After the trash racks, the intake water passes through one of eight traveling screens. The traveling screens have a rectangular mesh with 3/8 inch x 3/4 inch openings. The traveling screens are driven by dual speed motors that rotate the screens at 10 or 20 feet per minute. The screens are fitted with two sets of high pressure nozzles. The normal set of nozzles forces debris through the rear side of the screens into wash troughs and debris basis adjacent to the screens. The auxiliary nozzles face the seaward side and are automatically activated during periods of high differential pressure across the screens. The combination of the trash racks and traveling screens removes most of the coarse debris from the intake water.

After passing through the screening facilities, the water is drawn into the circulating water pumps. As mentioned previously, there are three separate cooling water loops that travel to and from each of the condensers. The Unit 1 and 2 loops each include 2 pumps located on the northeast side of the facility. Unit 3 is supplied by 4 pumps that discharge into two separate cooling water pipelines before rejoining in the south stop log chamber downstream of the condenser. The unit 3 pumps are located at the southeast side of the facility.

All of the circulating pumps are vertical lineshaft mixed-flow single stage pumps optimized for pumping large volumes of water at low head. The four pumps that supply cooling water for units 1 and 2 have a design capacity of 39,000 gpm at 26 ft of total dynamic head. The four pumps that supply cooling water to unit 3 have a design capacity of 47,000 gpm at 38 ft of head.

Key characteristics of the pumps are summarized below in Table 1-2.

Table 1-2
Circulating Water Pump Data

	Units 1 and 2	Unit 3
Number of Pumps	4 (2x1+2x1)	4 (3+1)
Type of Pump	Vertical Lineshaft Mixed Flow	Vertical Lineshaft Mixed Flow
Make/Model	Peerless 42MF-1	Peerless 48MF-1
Design Capacity per Pump	39,000 gpm	47,000 gpm
Total Dynamic Head	26 ft	38 ft
Motor Size	300 HP	600 HP
Column Material	316SS	ASTM B169, Alloy 613
Bowl Material	SAE-63 Bronze	n/a
Impeller Material	Utiloy #20	Nickel Aluminum Bronze

Chlorine Injectors

Chlorine injectors are located directly downstream of each pump. Sodium hypochlorite (NaOCl) is used in the cooling water system to help limit biological growth and fouling. Typical operating characteristics of the chlorine system are described below.

Sawdust Injectors

Sawdust injectors are located downstream of each chlorine injector. The sawdust injectors allow an operator to manually add fine sawdust into the cooling water loop. This procedure is typically used to help plug tube leaks in the condenser units. SGS plant staff indicate that this procedure is typically needed a few times per year, and that no more than four 2 cubic foot bags are usually needed to stop the leaks.

The amount of sawdust added is extremely small compared to the cooling system flow, however, provisions must be included in the pilot plant pretreatment system to remove such coarse solids, preventing the risk of damage to the desalination system.

Steam Condensers

Water discharged from the circulating water pumps travels into the main power plant basement where it is circulated around the condenser units. Four electrically actuated isolation valves are located on either side of each condenser unit. Operation of these valves allows for reversal of flow through the condenser unit, which is necessary during backwash operations.

Each condenser also includes two drain valves on the condenser water box. One of these valves is located on the condenser inlet side, while the other is located on the condenser outlet side. During normal flow operation, the inlet water will be "cool" while the outlet water will be "warm". However, during backwashing, the temperature of the water will be reversed.

Stop Log Chambers and Wastewater Inputs

The stop log chambers are located downstream of the condensers. Discharge water from the unit 1 and 2 condensers mixes in the north stop log chamber before continuing to the ocean discharge, while discharge water from the two unit 3 condenser pipelines mixes in the south stop log chamber before discharging to the ocean.

Wastewater streams from various plant processes also mix with the effluent cooling water either in or directly downstream of the two stop log chambers. Waste inputs to each stop log chamber are summarized in Tables 1-3 and 1-4 below.

Table 1-3
North Stop Log Chamber (Unit 1 and 2) Waste Streams

Waste Stream Description	Treatment Technique	Permitted Flow
Cooling Tower Blowdown	None	60,000 gal/day
Storm Runoff	None	31,000 gal/day

Source: SGS National Pollutant Discharge Elimination System (NPDES) Discharge Permit Renewal Application, 2004

Table 1-4
South Stop Log Chamber (Unit 3) Waste Streams

Waste Stream Description	Treatment Technique	Permitted Flow
Floor Drains	Oil/Water Separator and Settling Basin	10,000 gal/day
Lab Drains	Settling Basin	7,000 gal/day
Condensate Polisher Regeneration	Settling Basin	19,000 gal day
Miscellaneous Low Volume Wastewater	Settling Basin	10,000 gal/day
Boiler Blowdown	Settling Basin	4,000 gal/day
Boiler Acid Cleaning Rinses	Chemical Precipitation and Settling Basin	140,000 gal/day
Boiler & Air Preheater Wash Water	Settling Basin	168,000 gal/day

Source: SGS NPDES Discharge Permit Renewal Application, 2004

The flows listed in Tables 1-3 and 1-4 are the permitted flows from the SGS NPDES discharge permit renewal application. Actual flows are generally much lower than those listed, with many flows being zero during most of the year. For example, plant staff indicated that cooling tower blowdown is no longer a common plant operation. It should be noted that there are no flow meters or flow monitoring devices currently installed to record exact wastewater flows. However, even assuming that the waste discharges are at their maximum permissible levels, they only combine for 449,000 gallons per day, which is 0.1 percent of the total volumetric flow of 495 mgd through the cooling water system.

The waste streams entering the south stop log chamber (unit 3) receive partial treatment from a settling basin, which should remove most of the heavier constituents.

Downstream of the stop log chambers and wastewater inputs, the cooling water travels back to the screen and chamber facility. Water from the unit 1 and 2 condensers enters the outlet chamber on the north side, while water from the unit 3 condenser enters on the south side. Water from all three condenser units then mixes in a common chamber, which is open to the atmosphere on the north and south sides, before entering the 12 foot diameter discharge pipeline back into Santa Monica Bay.

Cooling Water Quantity

The flow quantity in the cooling water system will be important to the successful design and operation of the desalination pilot plant. Based on flow data between February 1, 2002 and July 31, 2007, the maximum discharge from the cooling water loop was 495 mgd, with significant variability throughout the period. Table 1-5 below summarizes the average, maximum and minimum flow values for the separate cooling systems over the record period.

Table 1-5
Scattergood Cooling Water System Flows

	Minimum Flow (mgd)	Maximum Flow (mgd)	Average Flow (mgd)
Unit 1 and 2	19	225	170
Unit 3	0	270	135
Total	19	495	305

The cooling loop for the unit 3 condenser had a total of 313 days with zero flow (unit 3 was offline) during the five-and-a-half year record period, whereas unit 1 and 2 had continuous flows throughout. This is due to the fact that generating units 1 and 2 must operate continuously to burn biogas generated at the Hyperion wastewater treatment plant located adjacent to SGS. Therefore, a more reliable water supply for the pilot plant will be available from the unit 1 and 2 cooling water loops. Figure 1-5 presents the daily flows in the unit 1 /2 and unit 3 cooling loops over the past several years.

Flow quantity will also be a critical consideration for a full scale facility. For example, if a 12.5 mgd facility is constructed with 50 percent recovery, a continuous cooling water flow of 25 mgd will be required. Based on the flow data over the past five-and-a-half years, the flow dropped below 25 mgd for only one day on the unit 1 and 2 cooling loop, whereas unit 3 had flows below 25 mgd 21 percent of the time (322 days). Obviously this makes the unit 1 and 2 system more attractive as a possible supply. However, it should be noted that power plant operations are subject to change due to power requirements, regulations, and operational strategies. Therefore, a detailed flow reliability analysis considering future plant operations and cooling loop hydraulics would be required before recommending a connection location for a full scale plant if warm water is proven to be a viable alternative for full scale facilities.

Cooling Water Quality

As would be expected, water quality in the cooling water loop is very similar to that of the incoming seawater. The primary exceptions are added chlorine and increased temperature, both of which are discussed separately later in this report. A review of water quality monitoring data contained in the SGS NPDES 2004 permit renewal application indicates most other constituents with monitoring requirements were essentially unchanged between the intake and discharge. Notable exceptions include:

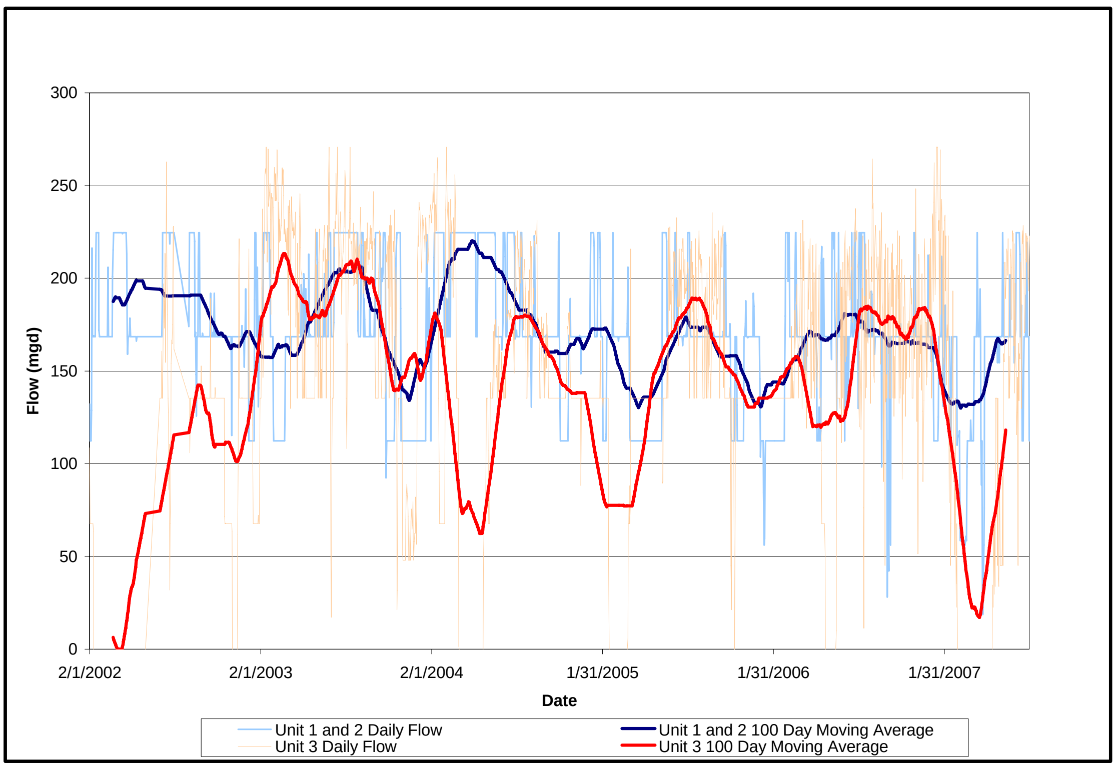

Figure 1-5
Unit 1 /2 and Unit 3 Cooling Water System Daily Flow
Feb 2002 – July 2007

- Boron measured slightly higher on the outfall than the intake (4.0 mg/L vs. 3.6 mg/L)
- Bromide measured slightly higher on the outfall than the intake (51.6 mg/L vs. 49.0 mg/L)
- Total suspended solids (TSS) measured higher in the outfall than in the intake (7.8 mg/L vs. 6.4 mg/L)
- COD measured higher in the outfall than in the intake (430 mg/L vs. 340 mg/L)
- Copper, Nickel, and Zinc concentrations were slightly elevated in the outfall compared to the intake. These elevated levels are likely caused by the cooling water passing through the condenser tubes, which have high compositions of copper and nickel.

It should be noted that the parameters described above are based on 2 samples each as noted in the NPDES renewal permit.

Another parameter of interest is pH. According to data recorded between February 1, 2002 and July 31, 2007, the pH of the cooling loop discharge ranged from 7.69 to 8.55, with an average of 8.03.

Due to the importance of source water quality on design and operation of desalination facilities, the pilot study will focus on collection and analysis of additional water quality data at various points in the system.

1.3.1.2 Facility Operations with Potential to Affect Pilot Plant

This section describes routine operations at the SGS that have the potential to affect the operation of the proposed desalination pilot plant. Because the pilot plant will be taking water from the cooling water system, it is important that operations of the cooling water system be understood to the greatest extent possible. Likewise, it will be necessary to ensure that pilot plant operations in no way interfere with normal power generating operations at SGS.

Heat Treatments and Water Temperature

Water temperature is an important consideration in the design and operation of a desalination facility due to its effect on treatment processes. Changing temperature affects the permeability of the membranes used in pretreatment as well as the rejection characteristics of the reverse osmosis membranes. Water temperature is also a critical consideration when evaluating the suitability of the desalinated water for delivery into the existing distribution system.

Cooling water discharge data between February 1, 2002 and July 31, 2007 show a temperature range from 55 to 128 degrees, with an average of 77 degrees. Figure 1-6 below presents a cumulative relative frequency plot of the temperature over this period. It can be seen that the discharge temperature was below 94 degrees 95 percent of the time. It should be noted that the discharge temperatures described above are averages of the discharge temperature from each separate outfall. Scattergood plant staff indicated that temperatures for each separate discharge are also available, and should therefore be evaluated prior to design of the pilot plant.

In order to help control marine growth within the cooling water loop, periodic heat treatments are performed on the cooling water system. During a heat treatment, the ocean intake and discharge lines are closed, and the cooling water discharge re-circulates back into the cooling water intake until the temperature is increased to the desired value. Heat treatment operations are typically performed once very six weeks, with a duration of approximately 8 hours. During a heat treatment, the temperature can reach 115 degrees F downstream of the condenser, and up to 110 degrees F in the intake chamber. Heat treatments can also cause the release of significant marine growth that is attached to surfaces throughout the system. This release can continue for several days following the completion of the heat treatment procedure.

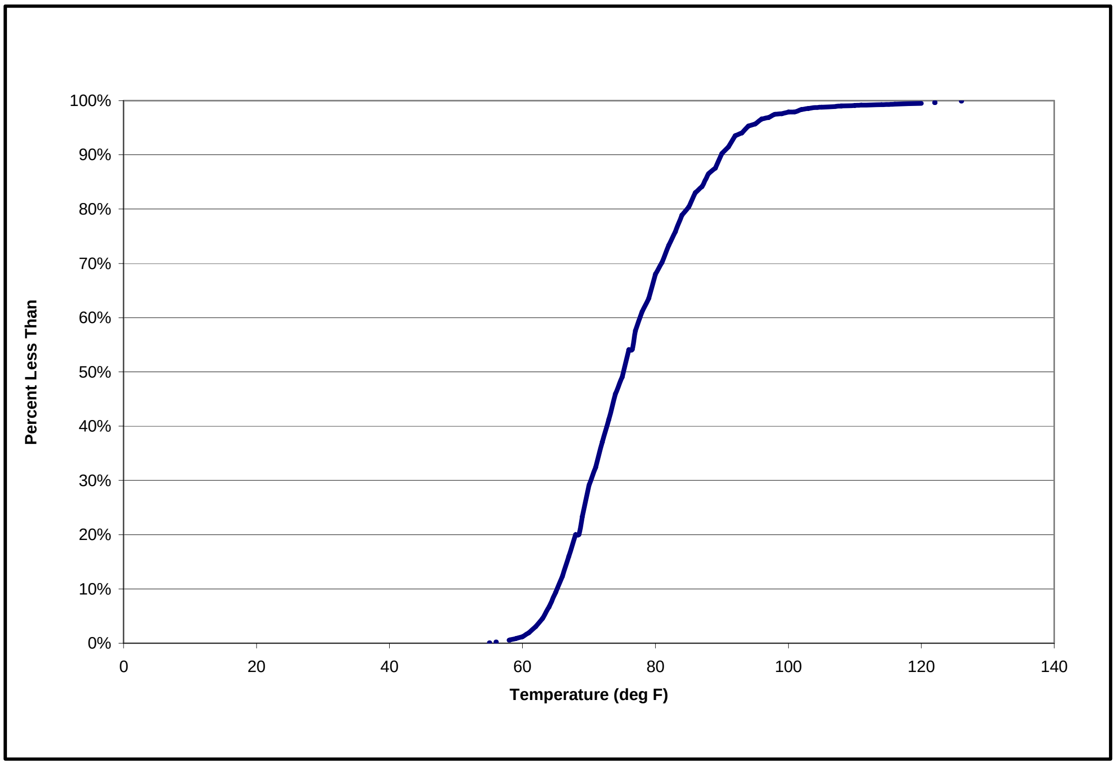

Figure 1-6
SGS Cooling Water Loop Discharge Temperature
Feb 02 – July 07
Cumulative Frequency Distribution

Chlorination

Liquid 10 to 12 percent strength NaOCl is regularly added to the cooling water traveling to all three condenser units. NaOCl injection is controlled by a timer, with 30 minute injection periods occurring every eight hours. The total feed volume is approximately 300 gallons per day.

According to data recorded between February 1, 2002 and July 31, 2007, average total residual and free chlorine in the cooling water discharge was 0.15 mg/L and 0.10 mg/L respectively. The maximum total residual chlorine recorded was 0.70 mg/L, however, the data indicates that residual chlorine was below 0.35 mg/L 95 percent of the time. Figure 1-7 presents cumulative relative frequency curves for both total residual and free chlorine in the cooling water discharge. Since chlorine is injected immediately downstream of the circulating water pumps, chlorine levels will be higher closer to the pump discharge.

The presence of free chlorine can damage reverse osmosis membranes. Therefore, it will be necessary to dechlorinate the feedwater to the pilot plant using bisulfite or sodium thiosulfate. It should also be noted that LADWP expects that chlorine discharge from the cooling water loop will eventually be completely restricted due to tighter discharge regulations.

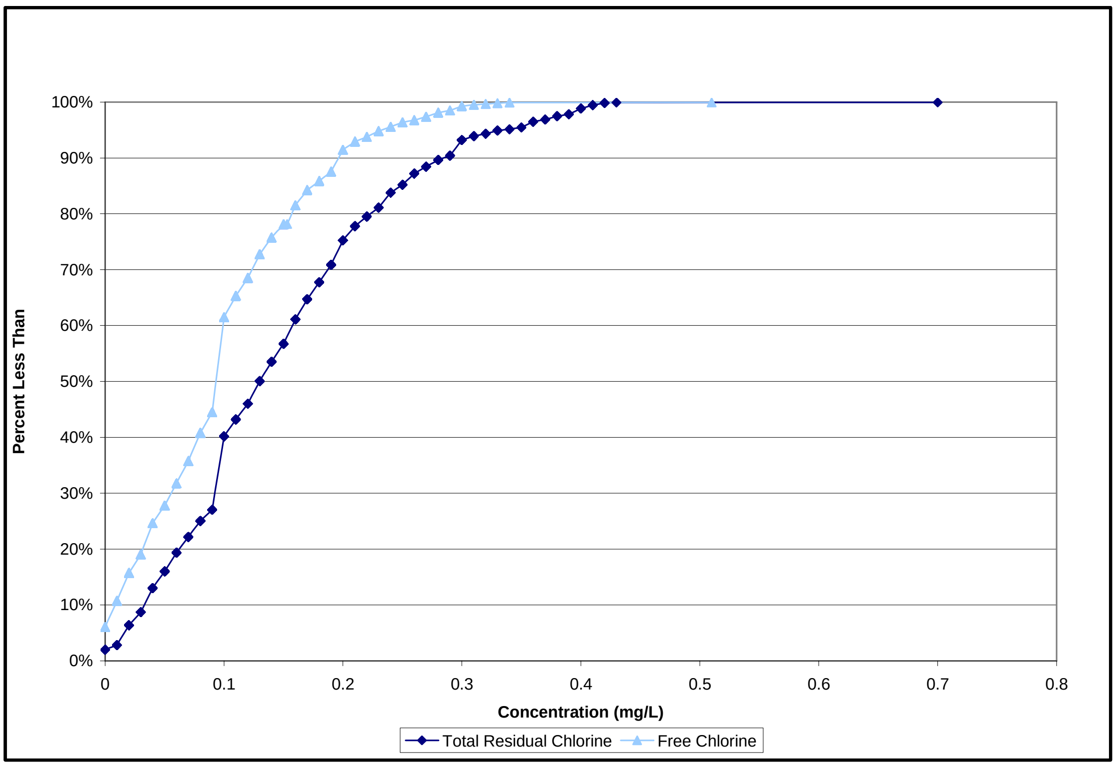

Figure 1-7
SGS Cooling Water Loop Discharge Chlorine Concentration
Feb 02 – July 07

Backwashing

Cooling system backwashing operations involve modifying valve positions to reverse the flow of water around the condenser unit. The flow is only reversed in the immediate vicinity of the condenser (i.e. water is still flowing into the ocean intake pipe, through the circulating water pumps, to the condenser unit, and out the ocean discharge). Backwashing events are typically short in duration, approximately 60 minutes, but can occur weekly or even daily. A noticeable amount of debris may be dislodged from the condenser tubes during backwashing, and the hot and cold side of the condenser cooling water flow is reversed. The reversal of the flow temperature would become important if it were decided to connect the pilot plant intake lines to the condenser water box drains.

Chemical Cleaning

Occasional chemical cleaning operations are performed on components of the cooling water loop, such as the condenser tubes. These cleanings are infrequent, typically done only once every four to five years. However, when a cleaning is performed, chemical concentrations will reach levels that could damage the reverse osmosis membranes. Consequently, during cleaning operations the pilot plant should be shut down or appropriately isolated.

1.3.1.3 Pilot Plant Connection to Existing System

The pilot plant will extract and discharge test water from the cooling water loop described in the previous sections. One intake connection will be needed upstream of the condensers to provide a "cool" water supply, while another intake connection will be needed downstream of the condensers for a "warm" water supply. In addition, a minimum of one discharge connection will be needed at some point to discharge the test water back into the cooling water system. It should be noted that the discharge connection(s) will discharge the combined permeate and concentrate, which is essentially the exact same seawater that was taken into the plant. Any chemically modified wastes generated during the pilot study will be disposed of in an alternate manner.

Based on discussions with SGS operations staff, the following two locations were identified as possible connection points:

- Screen and chamber facility; or
- Condenser water box drains

These locations are identified in Figure 1-8. The following sections describe the advantages and disadvantages of each possible connection location.

Connection at Screen and Chamber Facility

The screen and chamber facility provides the easiest access to the cooling water system. A photo of this location is shown in Figure 1-9. Both intake and discharge chambers are open to the atmosphere where submersible or self-priming pumps could be installed for intake of cool and/or warm water. Pilot plant discharge water could also be emptied into the discharge chamber. Piping and power connections could be routed around the fence at the perimeter of the facility and then east through the piping tunnel to the pilot plant.

Figure 1-8

SGS Aerial View

CDM

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Figure 1-9
Screen and Chamber Facility at Scattergood Generating Station

Cool water could be taken directly from the intake chamber. This chamber will be filled with water regardless of which units are operating. In addition, it is upstream of the chlorine injection facility. The only time when water from this chamber may see chlorine residual is during a heat treatment when discharge water is directed into the intake.

One drawback from taking cool water from the intake chamber is that the seawater is unscreened at this point. However, this problem can be mitigated by installing two intake pumps (i.e. one duty and one standby) both fitted with coarse screens and regularly maintained. A regular maintenance schedule would be necessary to ensure that one of the pumps is always available for operation and that screens do not become choked with seaweed, barnacles, or other debris.

The main drawback of making warm water connections at the screen and chamber facility is the possibility that waste discharges upstream of the connection point could affect the water quality feeding the pilot plant. This possibility should be somewhat minimized by the fact that waste flows are small and that the bulk of the wastewater flows are directed to the Unit 3 discharge rather than the Unit 1 and 2 discharge. However, the Unit 1 and 2 discharge receives waste flows from storm water run-off and boiler blow-down, and a number of waste flows typically directed to the Unit 3 discharge are also hard piped to the Unit 1 and 2 discharge, creating some risk that the warm water source for the pilot could be impacted.

In a full scale facility it would clearly be preferential, and possibly be required, to have the intake located upstream of any waste discharges. Regardless of the fact that the system would be designed to remove all contaminants of concern, it is always best practice to provide as many protective barriers to contamination as feasible, including avoiding waste discharge lines into potable water intakes. There are considerable unknowns in the variability and impacts of the wastewater flows, and it would therefore present a far more controlled system for the pilot if the waste flows could be avoided.

Connection at Condenser Water Box Drain

The second possible connection location is inside of the main power plant basement at the condenser water box drain lines. A photo of this location is shown in Figure 1-10. There are two 3-inch drain lines on each condenser, one on the cool side and one on the warm side. The advantage of using this location relates exclusively to the warm water flows, as it would be upstream of the stop log chambers, where the SGS waste streams are discharged. Even though the waste stream volumes are relatively small compared to the total cooling water flow, the waste streams provide an additional source of contaminants that should be avoided.

Figure 1-10
Condenser Water Box Drain

There are drawbacks to using the water box drains as the connection location, which apply to both the cold and warm water sources. Routing of the conveyance pipelines out of the power plant basement would be challenging, as the connection point is approximately 60 feet below grade level in the lowest basement of the facility.

Both warm and cold water inputs would have higher chlorine residuals at this location, and during backwash operations the temperature of the pilot plant feed water would be reversed for approximately 60 minutes. Finally, the temperature directly downstream of the condensers may be slightly higher than the temperature in the outlet chamber, however, it is not clear how much of an impact his short travel time actually has, or whether it would present any issues for the pilot plant.

Recommended Connections

From a water quality perspective, it would be recommended that connections to the existing cooling water loop be made at the screen and chamber facility for the cold water and at the water box drains for the warm water. This would minimize the impact the power plant operations can have on the pilot, providing a cool water source upstream of chlorine addition and the sawdust injectors, and providing warm water upstream of all wastewater inputs.

However, due to concerns about the feasibility of connecting inside of the main power plant building, the project team recommends that the warm water intake also be placed at the screen and chamber facility near the outlet of the unit 1 and 2 cooling loop. The pilot plant design and operations teams will need to work closely with Scattergood staff to identify engineering controls and operational procedures to minimize the possibility of wastewater inputs impacting the pilot plant operations.

Two self-priming pumps with appropriate screening should be placed at the intake chamber for cool water supply, with piping routed through the access tunnel and to the pilot plant. Likewise, two self-priming pumps should be installed to draw warm water from the outlet chamber. A single discharge for all pilot plant test water should be installed within the stop-log chamber to route the water back into the discharge flow.

CDM believes this configuration will minimize impacts to the existing power plant and operations while maximizing the value of data obtained from the pilot study.

1.3.2 LADWP Water Supply

As described in LADWP's 2005 Urban Water Management Plan, a full scale water desalination facility, if constructed at a future date, could be a small but important component of the City's overall water supply portfolio. The purpose of this section is to briefly describe LADWP's existing water supply, both in terms of its sources and quality, in order to better define the product water conditions that would be required for blending into LADWP's existing distribution system.

1.3.2.1 Existing Water Supplies

In order to provide a safe and reliable water supply to the City of Los Angeles, LADWP has developed an extensive portfolio of water supplies, including imported surface water from the Los Angeles Aqueduct (LAA) and the Metropolitan Water District of Southern California (MWD), local groundwater, and recycled water. In addition, LADWP and the citizens of Los Angeles have undertaken significant water conservation efforts to reduce the demand for potable water. LADWP's current potable water demand is approximately 660,000 acre-feet per year, with a projected increase to 776,000 acre-feet per year by the year 2030 (LADWP, 2005, 2006).

Figure 1-11 shows the sources of LADWP's water supply during 2006. It should be noted that the percentage of water provided by each main supply source (LAA, MWD, and groundwater) varies significantly from year to year due to a variety of factors, including snowfall and environmental considerations. Figure 1-12 shows the contribution of each water source to the City's overall supply between 1970 and 2004. Brief descriptions of each of these water supplies are included in the following sections.

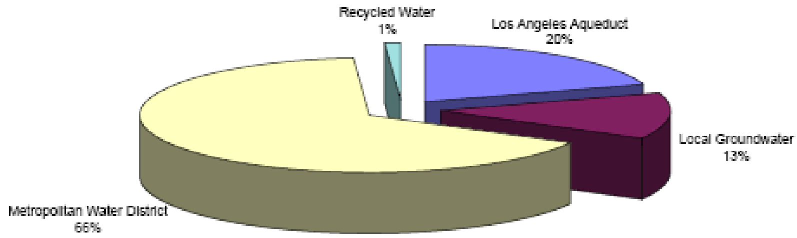


Figure 1-11
LADWP Water Supply Sources, 2007
(Source: LADWP Water Quality Report, 2007)

Los Angeles Aqueduct

The first phase of the Los Angeles Aqueduct was completed in 1913 by LADWP, and an extension was completed in 1970. The LAA collects water in the Owens Valley and Mono Basin on the eastern slope of the Sierra Nevada and conveys it by gravity southwest to the City of Los Angeles.

The LAA has the capacity to convey up to 560,000 acre feet per year of water. However, over the past several decades environmental concerns have surfaced that have resulted in significant limitations on the quantity of water available from the aqueduct. LADWP estimates that average deliveries from the LAA through 2030 will be approximately 276,000 acre-feet per year, or approximately 35 - 40 percent of total supply (LADWP, 2005).

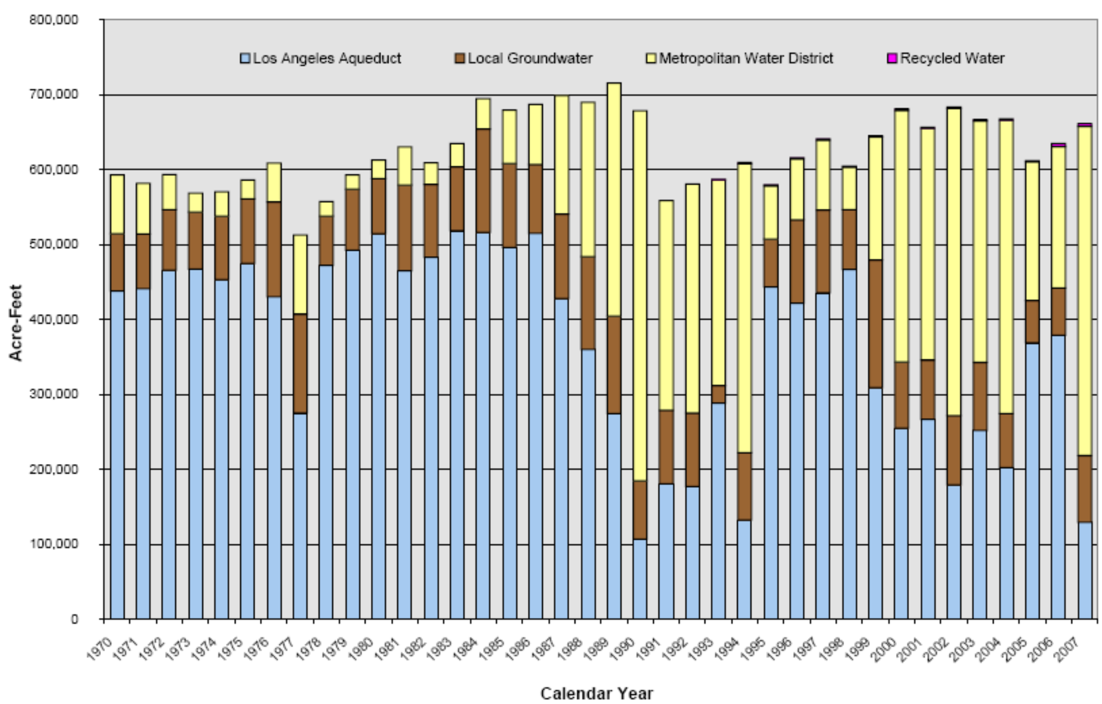


Figure 1-12
LADWP Historical Water Supply
(Source: LADWP 2005 Urban Water Management Plan)

Metropolitan Water District

LADWP also purchases imported surface water from MWD. MWD is a domestic and municipal water wholesaler with 26 member agencies in Southern California. MWD owns and operates the Colorado River Aqueduct and is a contractor for water from the State Water Project, which is owned and operated by the California Department of Water Resources.

<u>Colorado River Aqueduct</u>
The Colorado River Aqueduct (CRA), completed in the early 1940's, draws water from the Colorado River at Lake Havasu and conveys it west to Southern California urban areas. Although the CRA has the capacity to deliver approximately 1.2 million acre-feet per year, complex and evolving legal agreements and variable hydrologic conditions can result in significantly lower deliveries. MWD's basic allotment to Colorado River water is 550,000 acre-feet per year; however, MWD has worked with other regional Colorado River stakeholders to maintain deliveries closer to 700,000 acre feet during most years (MWD, 2003).

<u>State Water Project</u>
MWD's other major source of water is the State Water Project (SWP). The State Water Project is a massive water conveyance system comprising pump stations, pipelines, canals, storage reservoirs, and power plants. Water in the SWP originates in the San Francisco-San Joaquin Bay-Delta (Bay-Delta) in central California and is transferred via an extensive aqueduct system to users throughout the State, including MWD member agencies in Southern California.

The SWP was originally conceived to deliver 4.23 million acre-feet per year, with MWD entitled to 2.01 million acre-feet. MWD's current water resource planning projections estimate that average deliveries from the SWP through 2020 will average 1.5 million acre-feet per year, with a minimum dry year supply of 650,000 acre-feet per year (MWD, 2003). However, ongoing environmental concerns in the Bay-Delta and hydrologic variability can result in significantly lower deliveries.

Local Groundwater

Local groundwater provides approximately 15 percent of the City's total water supply in normal years, and up to 30 percent during dry years. LADWP has annual groundwater entitlements of approximately 107,000 acre-feet per year in the Upper Los Angeles River Area (ULARA), Central, and West Coast groundwater basins. Typically, approximately 86 percent of the City's groundwater supply is extracted from the ULARA basin, with the remaining 14 percent coming from the Central Basin. LADWP does not currently use its groundwater entitlement in the West Coast Basin (1,503 acre-feet per year) due to water quality concerns.

Recycled Water

LADWP continues to be aggressive in increasing recycled water usage within the City. Recycled water use is expected to increase significantly over the next few years from existing levels as new customers are brought online. It is expected that by fiscal year 2007/08, LADWP's water recycling sales will double to around 8,350 acre-feet per year. LADWP's objective is to maximize the use of recycled water as a local water resource.

1.3.2.2 Water Quality

LADWP consistently provides customers with high quality water that meets or exceeds drinking water standards set by the U.S. Environmental Protection Agency (EPA) and CDPH. High quality water is ensured by enacting source water protection measures and providing state-of-the-art water treatment. This section briefly describes existing water quality and treatment processes in LADWP's system, and discusses the potential impacts of introducing water from a desalinated water source.

Existing Water Quality and Treatment Processes

Water delivered from the LAA is generally very high in quality due to its origin high in the eastern Sierra Nevada. Water from the LAA receives treatment at the Los Angeles Aqueduct Filtration Plant (LAAFP) prior to being distributed to customers. Treatment at LAAFP includes ozonation, flocculation, and filtration followed by chlorine injection for disinfection. Although chlorine is an effective disinfectant, LADWP is currently in the process of changing to disinfection with chloramines to reduce the formation of disinfection by-products.

Untreated water purchased from MWD is treated at the LAAFP. Treated water purchased from MWD is treated by water treatment plants owned and operated by MWD. MWD plants that treat water eventually purchased by LADWP include the Jensen, Weymouth, and Diemer Plants.

The Jensen Treatment Plant treats SWP water from the Bay-Delta. Water is treated with flocculation, sedimentation, and filtration followed by chloramination for disinfection. The Weymouth and Diemer Treatment Plants primarily treat Colorado River Water and some SWP water. The Weymouth and Diemer Plants also treat water by flocculation, sedimentation, filtration, and chloramination.

Local groundwater sources are generally high quality and only require disinfection prior to distribution. However, some supply aquifers in the San Fernando Valley have been degraded due to improper chemical disposal practices. Specific constituents of concern include trichloroethylene (TCE), perchloroethylene (PCE), nitrate (NO_3), perchlorate (ClO_4), and hexavalent chromium. LADWP carefully monitors wells located in these areas to ensure that water quality always complies with state and federal regulations. Moreover, LADWP is working with other local stakeholders to identify and implement remediation and wellhead treatment alternatives to improve water quality and ensure the continued viability of this supply.

In accordance with state and federal regulations, LADWP maintains a comprehensive water quality monitoring, testing, and reporting program. The latest water quality report, which describes water quality testing results in LADWP's various service areas, is included in Appendix C.

1.3.3 LADWP Water Distribution System

A full scale seawater desalination facility would ultimately discharge into LADWP's existing water distribution system to augment existing supplies. This section briefly describes the most likely areas that could be served with product water from a full scale plant. Due to the complexity of LADWP's water distribution system, it will be necessary to conduct detailed hydraulic and water quality modeling prior to the introduction of a new water source to fully understand how the new source will interact with the existing system.

LADWP's water distribution system covers over 450 square miles with 2,400 feet of elevation change. It contains over 7,000 miles of pipelines, 70 pump station, more than 100 pressure zones, and over 100 reservoirs and tanks. Water enters the system from the LAAFP, interconnections to MWD transmission pipelines, and well fields. The system also contains interconnections to water systems owned and operated by other municipalities and agencies. Since a full scale desalination facility would likely be constructed near the SGS, the most likely locations to receive the desalinated water would be those areas in close proximity to the plant, which are pressure zones 325 and 477.

1.3.3.1 Pressure Zone 325

The nearest zone to SGS is pressure zone 325, which is located just north of SGS and is generally bounded by Santa Monica Bay on the west, Imperial Highway on the south, the 405 Freeway on the east, and Jefferson Boulevard on the North. The zone contains primarily mortar lined steel and ductile iron pipes. Water pumped into this zone could be transferred via gravity through pressure reducing valves into pressure zone 205, which includes Marina Del Rey and Venice. Connecting to pressure zone 325 would require high service pumping facilities at the treatment plant, which could discharge—at least partially—into the existing 16 inch ductile iron transmission line under Vista Del Mar Avenue.

1.3.3.2 Pressure Zone 477

The 477 pressure zone is located to the east of SGS in an area generally bounded by Crenshaw Boulevard, Century Boulevard, Western Avenue, and Florence Avenue. As with the 325, the 477 contains primarily mortor lined steel and ductile iron pipes. Although the service area for pressure zone 477 is further from SGS than zone 325, there is an existing 24 inch ductile iron pipeline that operates in the 477 zone that terminates near Pershing Drive and Imperial Highway, just south of Los Angeles International Airport. This 24 inch pipeline connects to 36 inch welded steel pipelines under Sepulveda and Century Boulevards which ultimately have gravity access to several additional pressure zones through multiple pressure reducing stations. In short, by boosting water to the 477 zone, a much larger portion of LADWP's service area could potentially receive water from the desalination facility with possibly minimal expansion of existing infrastructure.

1.3.4 Integration of New Desalination Supply

The treatment processes in a seawater desalination facility can be optimized to provide water of extremely high quality that can be conditioned to blend with existing supplies and infrastructure. One of the primary objectives of the pilot study is to identify the optimal treatment scheme that will achieve these objectives. At a minimum, the desalination product water will need to meet all state and federal drinking water regulations, as well as goals for the removal of unregulated and emerging contaminants.

Because of the lack of minerals in desalinated water, it can be extremely aggressive and corrosive within a distribution system. This issue can be further complicated with the use of warm water and with residual levels of chlorides. Post treatment, and possibly in-plant blending, would be required for a full scale treatment process to effectively blend the product water into the existing distribution system.

Ultimately, several factors will need to be considered when determining which areas of the City should receive water from the desalination system. These factors include the capacity of the facility, anticipated product water quality, pipeline material compatibility to desalinated water, and various operational considerations. Depending on the final system configuration, some areas could receive desalinated water only, while others could receive desalinated water blended with other water supplies, such as those from MWD and the LAA.

It should be emphasized once again that the discussion above provides only general information on how the water supply from a new full scale desalination facility could be integrated into LADWP's existing water distribution system. Specific recommendations about connection locations and new and expanded conveyance facilities cannot be accurately made without detailed hydraulic and water quality modeling. LADWP staff has performed preliminary hydraulic capacity evaluations. Additional detailed hydraulic and water quality analysis need to be performed should LADWP decide to proceed with a full scale desalination facility.

1.4 Project Objectives

The overall pilot project objective, as stated in the grant application to the DWR was to examine the technical feasibility and practicability of developing a full-scale desalination plant that uses existing infrastructure to reduce the potential environmental impacts typically associated with seawater desalination. Based on this overall objective, LADWP and the CDM team have developed four primary and two secondary objectives for the pilot project. The primary objectives will be the central focus of the project and are considered critical to the success of the seawater desalination pilot. Secondary objectives have also been established to insure that the project will provide valuable information and data relevant to this and future stages of the overall project.

The goals presented in this section were developed collaboratively between the CDM team, LADWP, and the technical advisory team in order to insure that all critical aspects of the project would be addressed. A DM1 Coordination Meeting was held at LADWP offices on September 26, 2007 and a DM1 review meeting on October 23, 2006, involving key members of the project team to discuss and refine these goals prior to completion of this Report. The following section defines these objectives and discusses how they will be utilized to develop a treatment process capable of achieving all of the project goals.

1.4.1 Primary Objectives

The following primary objectives have been developed for the Scattergood Seawater Desalination Pilot Project:

- Develop an environmentally sensitive treatment process that is adaptable to alternative source water intakes.
- Confirm the ability to meet and exceed water quality standards and goals in a cost effective manner.
- Optimize a pretreatment process that is robust, reliable and sustainable.
- Evaluate the technical impacts of using either warm water or cold water as the source of supply.

1.4.1.1 Environmentally Sensitive Treatment Process

The first objective is to develop an environmentally sensitive treatment process that is adaptable to alternative source water intakes. LADWP understands that any treatment process which is not seen as environmentally sensitive will not be usable for a future treatment facility. As such, the selection of the process and the optimization of operating conditions must focus on environmental concerns as a primary objective. From a technical perspective, the chief environmental concerns relevant to the treatment process will include feed water requirements, waste concentrate impacts, carbon footprint, aesthetics, and air quality impacts. The treatment process must also be adaptable to multiple source water intake alternatives, as the ultimate supply option has not yet been determined.

Feed Water Requirements

The volume of water required for the treatment facility will be dictated by the efficiency, or hydraulic recovery rate, of each component in the treatment process. Processes with low hydraulic recovery rates will require larger feed water volumes, compounding any concerns that may be raised relevant to withdrawal of the source water. While the ultimate intake approach will need to be selected as part of a separate evaluation, the treatment process selection for the pilot testing must include consideration of the source water volume impacts of the various treatment alternatives.

Waste Concentrate Impacts

Selection of an environmentally sensitive treatment process must consider both the quantity and quality of waste produced from each component in the treatment process. Processes which rely on chemical conditioning or regular chemical cleaning will require disposal of the wastes produced by the process. Such wastes could have environmental impacts which would need to be mitigated through further treatment or neutralization of the waste products. Processes which involve only physical separation, such as reverse osmosis or membrane filtration, will produce wastes which are concentrated versions of the source water. Such wastes would be expected to have lower environmental impacts, provided the concentrations and volumes do not present toxic conditions at the discharge location. Similar to the intake alternatives, the ultimate concentrate disposal approach will need to be selected as part of a separate evaluation, however, the pilot project must address the need to minimize waste volumes and waste quality impacts through the selection of the treatment process and optimization of operating conditions.

Carbon Footprint

Desalination processes can be energy intensive. Historically, and internationally, desalination plants have had to be located adjacent to power plants, primarily because sizable quantities of the power or waste energy from the power plants were used for operation of the desalination facilities. Today the available desalination technologies allow for much lower energy usage and considerably smaller carbon footprints than traditional desalination facilities. The selection of the treatment process and the optimization of operating conditions must consider the impacts of energy consumption in order to minimize environmental impacts from greenhouse gas emissions.

Aesthetics and Air Quality

While the previously described environmental issues are commonly considered the most significant relevant to desalination facilities, process selection must consider the impacts of the evaluated alternatives on overall aesthetics and air quality. Processes which have large footprints or high vertical profiles are considered less desirable at a coastal location, particularly given the close proximity of the Scattergood site to public beach recreation areas. Similarly, processes which involve increased risk of air quality impacts, such as saline mists or unintended release of hazardous chemicals should be avoided.

Alternative Source Water Intakes

Two alternate feed water supplies are available at the SGS for this pilot study. These include cold water drawn from the existing SGS intake and warm water drawn from the discharge side of the condenser cooling loop. In addition to these source water alternatives, LADWP is considering the use of beach well, or sub-surface intakes for a future supply alternative. It will be critical that the information gained in this study be applicable for process selection and optimization, regardless of the ultimate source water approach selected. While it will not be practical to install and develop a beach well that is representative of full-scale operation during this pilot testing period, the water quality produced by a beach well will be simulated, to the extent possible, using coarse solids separation and pretreatment of the cold water supply.

1.4.1.2 Water Quality

The second primary objective is to confirm the ability to meet and exceed water quality standards and goals in a cost effective manner. A successful pilot project must confirm that the treatment process selected can achieve a consistent product water quality which not only meets or exceeds existing and anticipated drinking water regulations, but is also acceptable to LADWP and the public for meeting aesthetic and other water quality goals. Specific water quality goals for this project will be presented within section 3 of this Report, however, the primary parameters of concern when evaluating the treatment processes will include:

- Microbial pollutants, including algae, *Cryptosporidium*, *Giardia Lamblia*, as well as bacterial and viral contaminants
- Trace organic compounds, including algal biotoxins, fuel additives, disinfection byproducts, and other compounds found in prevalence in the vicinity of the Scattergood intake
- Boron, which is only partially removed by common desalination technologies, but can cause problems for lawn irrigation and other water use alternatives
- Chloride, which can be corrosive to the distribution system and has aesthetic concerns for the public

The treatment processes need to achieve the water quality goals to address public health objectives, CDPH requirements, and other LADWP goals in a cost effective manner. Treatment processes which are not affordable are not viable for future implementation. Lifecycle cost considerations will therefore be used in selection of the most appropriate treatment alternatives

1.4.1.3 Pretreatment Process

The third primary objective is to optimize a pretreatment process that is robust, reliable, and sustainable. As discussed previously, relevant to existing desalination plants and previous pilot studies, the success of a desalination facility will be dictated primarily by the effectiveness and reliability of the pretreatment process. It will therefore be critical that the pilot project identify, develop, and implement a pretreatment process capable of consistently providing acceptable quality water to the desalination process regardless of the numerous and sometimes drastic changes which occur in the source water quality.

Robust Operation

Any pretreatment process that is incapable of handling changing water quality conditions will not be practical for a seawater supply. Source water may change drastically as a result of red tide events, heavy rains, or urban run-off and may be impacted by routine or intermittent operating practices at the power plant. The selected treatment process must be robust enough to continue efficient operation during these changing water quality conditions. This may require the ability to adjust operating conditions as the source water changes, decreasing filtration rates, increasing backwashing frequency, or adding coagulant or chemical cleanings in reaction to an extreme source water event.

Reliable Process

The pretreatment process will likely be relied on as the primary step for microbial pathogen removal. Microfiltration and ultrafiltration systems, for instance, have been found to provide more than 5-log units of removal for bacteria, *Giardia*, and *Cryptosporidium*. This is a significantly higher level of removal than can be consistently verified for most desalination processes or for typical disinfection practices. Reliable water quality from the pretreatment process will therefore be critical, both for providing a safe water supply and for protecting downstream desalination processes. The pretreatment process must be capable of addressing shell fragment loading, microbial loading, and rapid changes in water quality without allowing adverse impacts to carry through into the desalination process.

Sustainable Approach

Sustainability is an important consideration in the development of any water treatment approach. A sustainable process must be capable of producing water that meets both current and future water quality and quantity needs and does not rely exclusively on a water supply, energy source, or waste disposal alternative that is at risk of being unavailable in the future. This requirement relates to both the first and second of the primary project goals, described previously, and underlies the need for a flexible approach, which can be adapted to the numerous uncertainties of the future.

1.4.1.4 Impacts of Warm or Cold Water

The last of the primary objectives is to evaluate the technical impacts of using either warm or cold water as a source of supply. This evaluation will provide flexibility to consider SGS post-condenser water (warm) or cold water from the existing intake structure. In either case the concentrate and permeate flows from the treatment processes during pilot testing will be recombined and sent back to their source to avoid having an impact on the SGS plant operation.

Post-condenser water will differ from intake water primarily in temperature, however, it may also include slightly elevated metals concentrations and suspended solids from other treatment processes within the SGS cooling loop. It will be critical that the treatment processes be designed and operated in a way that provides optimal and reliable treatment for both sources of supply. To achieve this, two pilot plant trains will be run in parallel. One will be designated for warm water feed and the other for cold water feed. The following will be evaluated:

- Impact of post condenser water on biological fouling

- Impact of temperature on flux rate and salt passage (chloride and boron)
- Impact of power plant operating practices (heat treat, reverse flow, sawdust injectors) on process reliability

It is also important to consider the temperature of the water that may one day be fed to the distribution system. Significant variation from the current temperature of the water in the distributions system will not be acceptable. The project team will therefore consider processes associated with warm and cold water feed with respect to minimizing impacts to the end user.

1.4.2 Secondary Objectives

While it is the primary objectives which are seen as the most critical to the success of this project, secondary objectives have also been established, which identify valuable information that will be obtained during the pilot testing operation. These include the need to:

- Optimize desalination operating conditions for the lowest life cycle cost, and
- Develop data for additional studies

1.4.2.1 Desalination Operating Conditions

The first of the secondary goals is the need to optimize desalination operating conditions for the lowest lifecycle cost. While cost considerations for the entire process are a primary consideration of the pilot objectives, we have established a secondary objective specific to the desalination process. Design and operating conditions for the desalination process will impact plant footprint, energy usage, and waste flow volumes, with trade-offs in optimizing each of these parameters. Our evaluation will consider a life cycle cost approach in determining recommended design and operating conditions for flux, recovery, and projected energy use.

1.4.2.2 Data for Additional Studies

Beyond the primary objectives of the pilot project, it is important for the project to provide critical information for future and concurrent studies being conducted by LADWP. This data must include, at a minimum:

- Waste flow characterization for a related Brine Discharge Study
- Product water quality data and recommendations for post-treatment, which may be used for future design of a post-treatment process
- Performance and design data needed for progressing to the next phase of the Scattergood Seawater Desalination Pilot Project
- Realistic and confirmed projection of power requirements for the full treatment process

- California Department of Public Health support of the treatment process

1.4.3 Specific Treatment Goals

The pilot plant process train will have four process components: Coarse Solids Removal, Pretreatment, Oxidation/Disinfection and Desalination. These are presented graphically in Figure 1-13. Technologies will be evaluated for each of these process components, based on the goals established here-in and on specific evaluation criteria developed from these goals. The evaluation approach and recommended treatment processes are detailed in Section 2 and 3 of this Report. Collaborative workshops were held between the CDM team, LADWP, and other external stakeholders on October 17 and December 4, 2007 to present these project objectives and identify the recommended treatment approach for meeting these goals.

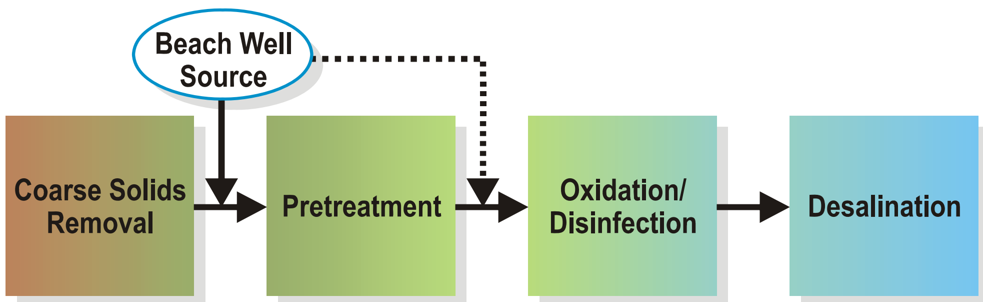


Figure 1-13
Treatment Process Train

Section 2
Process Screening Evaluation

This section of the Preliminary Evaluation report presents the process screening evaluation that was performed to identify the appropriate treatment process for the Scattergood Seawater Desalination Pilot Project. The process screening was developed as DM2, which has been updated to reflect LADWP's input and is included herein as Section 2 of this report.

2.1 Process Screening Objective

The objectives of Process Screening Evaluation were (1) to identify the technology/process options appropriate for the pilot plant, (2) to provide an evaluation of the different process alternatives, and (3) to recommend process train(s) that meet the Project's objectives. These objectives are to be achieved while minimizing unnecessary costs and maximizing the potential for a project that is environmentally sustainable.

One of the most important environmental issues for the full-scale project is the manner in which the seawater, which serves as the source water for the project, will be obtained. Three types of sources have been considered for this site. These include: a) Warm water taken from the power plant's existing condenser discharge, b) Cold water, taken from some type of future or existing open ocean intake, or c) Cold water taken from future beach wells or subsurface intakes. Source waters currently available for the pilot plant are more limited and include only warm and cold water from the Scattergood cooling loop. However, because of the broader number of intake alternatives being considered for the full-scale plant it will be critical that data developed during this study be applicable regardless of the source water alternative selected during future studies.

This section will focus on the available seawater desalination technologies and the upstream processes that will be considered to optimize the operation of the desalination process. As previously mentioned this process will include the following components: Desalination; Pretreatment; Disinfection; and Coarse Solids Removal.

For each of these process components, available technologies will be reviewed and evaluated in terms of environmental sustainability, product water quality, operations and maintenance (O&M) requirements and life cycle costs. Consideration will also be given to uncertainties and whether a technology has been fully developed.

This Section will address the following topics:

- Which method of desalination is most appropriate?
- Which methods of pretreatment are most appropriate upstream of the desalination process?

- Which methods of oxidation and/or disinfection should be utilized upstream of the desalination?
- Which methods should be employed to control the coarse solids that may adversely affect pretreatment?
- Recommended pilot treatment trains.

2.2 Desalination

There are a considerable number of methods currently utilized for the desalination of water. The selection of the most appropriate desalination technology should be made based on environmental and cost considerations for each alternative process. However, it must also be considered that the choice of desalination technology will influence both the quality of the treated product water (*e.g.* hardness, total dissolved solids, chloride, sodium, bromide, boron, etc.) and the selection of processes upstream (pre-treatment) and downstream (post-treatment) of desalination. As such, the process evaluation will begin with selection of the desalination technology, and will then continue through each upstream process to develop the most appropriate treatment train for the Scattergood Seawater Desalination pilot.

Two basic approaches are commonly considered for seawater desalination. The first approach is based on physical separation using semipermeable membranes. The second approach is based on distillation, utilizing thermal energy to effect phase change of seawater (liquid or vapor), separating pure water from the salt solution. A detailed assessment of each of these approaches follows.

2.2.1 Membrane Processes

Some membranes can selectively permit or prohibit the passage of certain ions, and desalination technologies have been designed around these capabilities. Three fundamental driving forces are used in these desalination membrane systems: pressure, concentration, and electric potential. Reverse Osmosis and nanofiltration membranes are pressure driven processes and forward osmosis is a concentration driven process. Figure 2-1 illustrates the basic concept of osmosis.

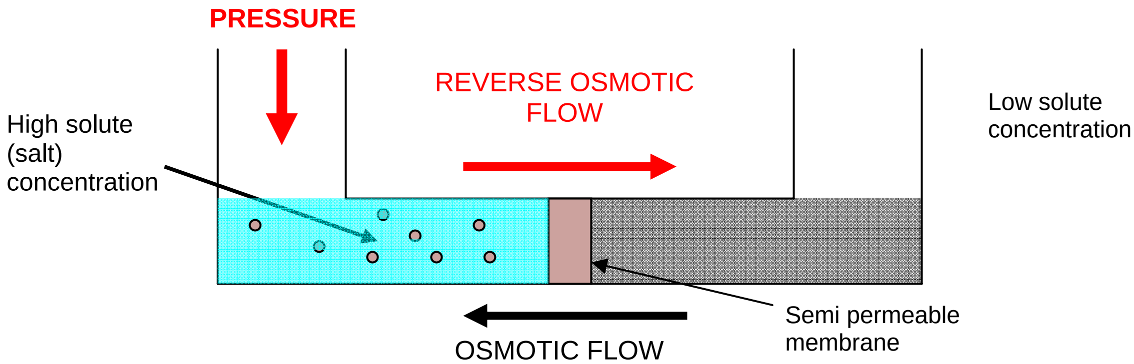


Figure 2-1
Basic Concept of Osmosis

Unlike reverse osmosis, electrodialysis is an electric potential driven process. Of these, both reverse osmosis and electrodialysis are mature technologies in wide use but electrodialysis is not cost competitive for desalting waters at seawater salinities (Amjad, 1993). Nanofiltration is usually employed for water softening and is not ordinarily considered for seawater desalting applications, but innovative research being conducted by the City of Long Beach has shown promise. Forward osmosis has not yet been developed on a commercial scale. A brief discussion of each follows below.

2.2.1.1 Reverse Osmosis (RO)

RO currently represents the state-of-the-art of desalination technology. This is because its ability to reject a variety of contaminants ensures that all the treatment objectives are met in a single process, with lower energy consumption, lower feed water flows, and no thermal impacts in the brine discharge, as are common for thermal desalination processes. Improvements in SWRO membranes and energy recovery devices have made SWRO membranes even more cost effective than previously. Moreover, RO is an established technology that is commercially offered by several vendors. Some of the largest new desalination plants that use SWRO membranes include the 84 MGD plant in Ashkelon, Israel; 45 MGD plant in Fujairah, UAE; 38 MGD plant in Perth, Australia; 36 MGD Tuas plant in Singapore; 33 MGD Point Lisas, Trinidad and Tobago plant; 32 MGD plant in Carboneras, Spain; 20 MGD plant in Yuhuan, China; and 13 MGD plant in Fukuoaka, Japan.

The general characteristics of RO membranes, including the physical structure of the membranes, treatment efficiencies, recovery rates, energy requirements and membrane fouling are discussed below. Comparison with other available technologies is provided in Section 2.3.

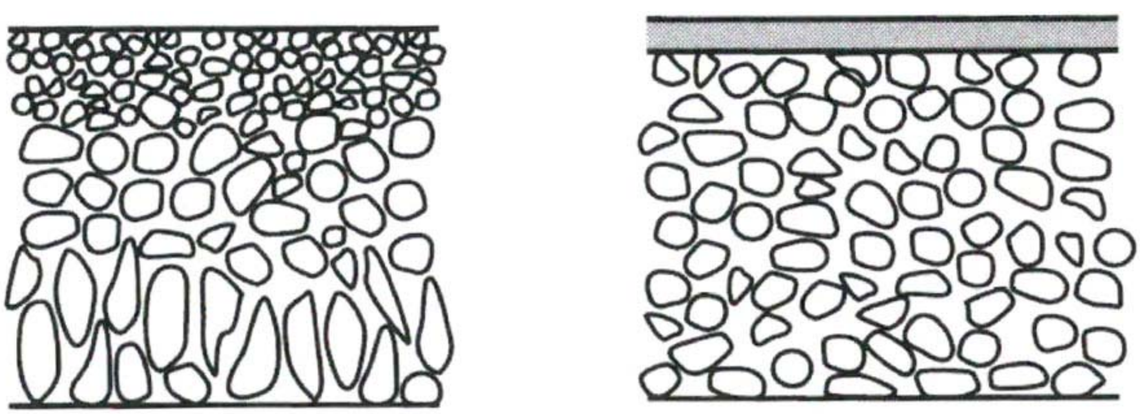
Structure of RO Membranes
Reverse osmosis is a pressure driven membrane operation in which the feedwater is pressurized to exceed its own osmotic pressure. The water then passes through a

dense membrane, which is engineered to retain salts and low-molecular weight solutes.

The first RO plant was constructed in Coalinga, California and began operating in 1965 using commercial RO membranes like those developed at UCLA (Loeb and Johnson 1967). The original asymmetric cellulose acetate (CA) membranes, developed in 1960s, were less permeable than modern thin-film composite (TFC) membranes and required higher driving pressure (in excess of 1200 pounds per square inch [psi] for seawater). Additionally, the ability of the original CA membranes to reject salts was significantly less.

Figure 2-2 illustrates the assymetric structure of the cellulose ascetate membrane on the left versus the thin film composite TFC membrane on the right. With the asymmetric structure, the membrane is of the same material with a dense layer at the top and porous layer beneath. In contrast, with the TFC membrane, the dense layer and porous support are separately engineered such that the dense layer is much thinner.

(a) (b)



(a) The original cellulose acetate membranes developed at UCLA and

(b) The more modern thin film composite membranes that came to dominate the market during the 1990s.

Figure 2-2
Illustration of the Difference Between the Structure of RO Membranes

Today, there are a variety of modified and improved blends of CA membranes available to the desalting industry, but these membranes are rarely used in large-scale desalination applications. These CA membranes can tolerate continuous exposure to low concentrations of chlorine (0.1 to 0.5 mg/L at 25 ºC), which is an advantage for biofouling control in seawater applications. They are, however, susceptible to hydrolysis, which compromises the membrane's salt rejection performance. Hydrolysis of CA membranes is accelerated if the operating pH is less than 4 or greater than 6.5 and beyond 30ºC (Mallevialle et al. 1996). Therefore, acidification of the seawater is a must for desalination with CA membranes.

The development of TFC membranes provided greater salt rejection and higher water production. The TFC membranes are made by forming a thin, dense, solute rejecting surface film on top of a porous structure. The material of construction for the top surface film layer is mostly aromatic polyamide (PA) and the bottom support layer is polysulfone (see Figure 2-2). The thin non-porous top layer contributes to contaminant rejection and the porous bottom layer provides the mechanical strength. Because of the "thin" top layer, pressure required to drive water through the membrane material is significantly reduced. For example, Water Factory 21, which was designed with the CA membranes, had a design pressure of 500 psi. Today, facilities at the same location, using modern TFC membranes, have a design pressure that is half this value. To ensure adequate productivity, SWRO membranes are typically exposed to 800-1000 psi, which overcomes the resistance from osmotic pressure of the salt and the "skin" layer of the dense membrane.

The TFC membranes are stable over a broad pH range (2-11) and can withstand temperatures as high as 45 ºC. However,, unlike the CA membranes, they are susceptible to degradation by free chlorine. Although the rate at which membranes succumb to attack by free chlorine is a function of pH, their performance gradually (and sometimes catastrophically) deteriorates upon exposure.

Treatment Efficiency

The United States Environmental Protection Agency (USEPA) has designated RO as a best available technology (BAT) for removal of numerous inorganic contaminants, including antimony, arsenic, barium, chloride, fluoride, nitrate, nitrite, boron, selenium, radionuclides, TDS and emerging contaminants, including endocrine disrupting compounds (synthetic and natural hormones) and several pharmaceutical compounds.

Current SWRO membranes typically remove 99.5 to 99.8 percent of the TDS from the seawater. A few analytes, such as boron, are not rejected as well. Consideration for additional treatment such as a double pass RO (where permeate water produced in first pass is treated again in a second pass) is frequently made to achieve product water quality goals for boron. New membranes continue to be developed by SWRO manufacturers, with membranes targeted for high boron rejection currently being offered to avoid the need for a double pass system under certain operating conditions. Tailoring of the most appropriate SWRO design will depend on the feedwater temperature, system operating conditions, and desired finished water quality established for the system.

Recovery Rate

The amount of water that can be recovered using current SWRO membranes ranges from 35 to 60 percent, depending on the initial water quality, water temperature, the quality of product water desired, and the specific membranes involved.

Energy Requirements

Because membrane processes are based on physical separation, they do not require thermal energy to vaporize the water. As a result, the energy consumption for an SWRO plant is 12 to 14 kilowatt hour (kWh)/1000 gal and considered relatively low when compared to other available technologies.

Membrane Fouling

The bane of all membrane processes is fouling. An SWRO plant requires comprehensive pretreatment and chemical conditioning of the feedwater for successful operation.

All of the above will be considered in the process evaluation presented below in Section 2.2.3.

2.2.1.2 Electrodialysis (ED) / Electro-Dialysys Reversal (EDR)

The ED process applies an electric potential that moves dissolved salt ions through an electrodialysis stack consisting of alternate layers of cationic and anionic ion exchange flat sheet membranes, creating alternate channels of desalted product water and concentrated reject water. A modification of the ED process, termed EDR, periodically reverses the polarity of the applied electrical potential on the stack to minimize the effects of inorganic scaling and fouling by converting product channels into concentrate channels. So, while the pressure driven system (such as RO and NF membranes) selectively passes water and retains dissolved salts, the electrically driven system extracts the dissolved salts and retains the water.

All cations attempt to migrate to the cathode and all anions attempt to migrate to the anode. Cation-exchange membranes allow only cations to pass and anion-exchange membranes allow only anions to pass. The net effect is to remove the salt from every other cell. In EDR, the polarities are regularly reversed, dislodging deposits on the membrane surface. An example of an EDR system used for wastewater desalination is presented in Figure 2-3.

Figure 2-3 Electrodialysis Reversal Desalination Equipment in Gran Canaria, Spain

ED/EDR processes are used for non-seawater desalination applications throughout the world; however, they are not currently used for seawater desalination. Unlike RO/NF membranes, where energy cost is based on the volume of water treated; for ED/EDR processes, it is also directly proportional to the salts removed. Therefore, these processes are only suitable for brackish waters with a salinity of less than 12,000 mg/L TDS. With higher salinities the ED/EDR process becomes more costly than other membrane based desalination technologies. Bacteria, non-ionic substances and residual turbidity are not affected by this process and can therefore remain in the product water and require further treatment before drinking water standards are met. Moreover, GE/Ionics is the only established ED/EDR manufacturer in the USA. As a result, the purchase of an EDR system is a sole source contract and there is limited competition.

Since ED/EDR are not used for seawater desalination, these processes will not be further evaluated.

2.2.1.3 Nanofiltration Membranes

NF membranes were primarily developed as a membrane softening process to offer alternatives to chemical softening and the membrane is used to soften water while controlling disinfection by-products (DBP) precursors and removing color. The commercially available TFC NF membranes are characterized by a porous (around 2 nanometers (nm) pore diameter, hence their name) and negatively charged skin layer. Because of the negative charge on the membrane material, divalent hardness ions are removed to a greater extent than are monovalent ions (e.g. 95 percent calcium removal and 70 percent sodium removal). The higher concentration of single charged ions on the permeate side also helps reduce the osmotic backpressure. This, combined with a loose membrane skin layer, reduces the hydraulic pressure requirements to 500-600 psi in seawater applications. Recognizing these advantages, Long Beach Water Department has developed and recently patented an innovative two pass nanofiltration method for the desalination of seawater.

The "Long Beach Method" uses nanofiltration membranes in a two-pass configuration, where product water from the first pass is treated again in the second pass. The LBWD has performed extensive testing of this technology at a 9,000 GPD pilot unit and, with support from the United States Bureau of Reclamation and LADWP, is in the process of evaluating this technology at a 150,000 GPD prototype demonstration scale. According to recent reports (Le Guoellec et al., 2006), the first NF pass operates at 525 psi and removes >90 percent TDS while the second NF pass operates at 250 psi removes 93 percent TDS, resulting in a total salt reduction of about 99 percent at an estimated energy savings of 20-30 percent. The overall recovery of this process is about 40-45 percent for seawater desalination, so both the overall TDS reduction and recovery are comparable to SWRO. Rejection of specific ions, such as boron, however, may be lower for the two pass nanofiltration process. Additional discussion and process schematic for the Long Beach demonstration project were included in Section 1.2.1 – Pilot Plant Studies.

Since LADWP is currently involved in the Long Beach project and is tracking its progress, the process will not be further evaluated for the Scattergood pilot plant.

2.2.1.4 Forward Osmosis

In contrast to the RO process, forward osmosis (FO) uses osmotic pressure gradient to drive the desalination process. Essentially, it uses the natural tendency of water to flow from a lower osmotic pressure solution (e.g. seawater) to a higher osmotic pressure solution using a "draw solution". The fresh water is then separated from the draw solution using an additional separation process. FO can only be competitive with RO if this secondary separation step is made significantly easier and more cost effective than RO operations (Miller and Mayer 2005).

Although, several options for draw solute are under study today, the approach developed by Prof. Elimelech of Yale University has brought FO much closer to being a feasible solution. The draw solution being employed at Yale consists of highly concentrated ammonium carbonate, prepared by mixing ammonia and carbon dioxide gases. Upon moderate heating (~58 ºC), ammonium carbonate decomposes back into ammonia and carbon dioxide gases, leaving behind the desalinated water. For drinking water production this separation will have to be very complete, more so than what is currently being achieved. Figure 2-4 presents a photo of a pilot scale model of an FO unit developed at Yale University.

Figure 2-4
Yale University Prototype of Forward Osmosis System

The thermal recovery of ammonia and carbon dioxide (from the draw solution) is one of the major consumers of energy for this particular FO process. At this stage, energy use (kWh/1000 gal) of this process is not known; however, the relatively low temperature recovery of draw solution makes the process attractive if a cheap source of low-grade heat is available. Details regarding the collection and recovery of the ammonia and carbon dioxide are also not available. Unlike RO process, this technology is still in the development stage and there are no full-scale installations.

For the FO process to be successful, new membranes with different properties must be developed. Commercially available thin-film composite polyamide membranes, common to RO applications, have not been entirely successful in FO applications because of poor mass transfer, owing to their "asymmetric" nature – but, of course, it is exactly their asymmetric nature that is responsible for high salt rejection. At the present time few membrane manufacturers are developing membranes suitable for FO.

Due to the limited development of this technology, forward osmosis will not be further evaluated for the Scattergood pilot plant.

2.2.2 Thermal Technologies

The second approach commonly considered for seawater desalination is based on distillation and the use of thermal energy. Thermal technologies all work on the principle of evaporating the saline water and then recondensing the vapor to make distilled water.

Thermal technologies dominated the desalination field prior to the 1990's. Even today, approximately 40 percent of the world's desalted water is produced by thermal processes to distill seawater or brackish water into freshwater. All large-scale thermal processes involve heating water to the boiling point to produce the maximum amount of water vapor. Water boils at 100 ^{o}C under atmospheric pressure, however, by decreasing the pressure, the temperature needed to boil water, "the boiling point," can be reduced. To take advantage of this principle, commercially available distillation technologies are designed to allow "multiple boiling" in a series of vessels that operate at successively lower temperatures and pressures.

Thermal processes can produce water with very low salt concentrations (TDS 10 mg/L or less), from salt concentrations as high as 60,000-70,000 mg/L.; however there are multiple limitations associated with distillation processes for seawater desalination.

One of the most important limitations of thermal technologies is their high energy requirement. Because distillation involves a vaporization step, thermal energy required to vaporize seawater is high, typically around 28 to 101 kWh/1000 gal of fresh water produced (Wade 2001). It should be noted that this thermal energy is in addition to electrical energy required for the thermal processes. The thermal energy alone is two to six times higher than the total energy required for a membrane process. Often, large distillation plants are coupled with steam or gas turbine power plants for better utilization of the fuel energy and to maximize the synergies of the two processes. As a result, thermal technologies are more commonly used in the Middle East region, where fuel is abundant and cheap, and where the large land requirements are not cost prohibitive or considered as ecologically detrimental. In addition to thermal energy, these processes also require electrical energy to run the process equipments and pumps, etc.

There has long been a continuing interest in solar energy as a source of heat for accomplishing the evaporation but technologies are not yet available that are suitable for a large-scale project in metropolitan Los Angeles. As a result virtually all thermal technologies available for projects of the kind contemplated by LADWP utilize fossil fuels as an energy source, although most can be adapted to the use of steam from nuclear power plants as well. Thus, most thermal desalination plants have a large carbon footprint.

The scaling of sparingly soluble salts at elevated temperatures on the insides walls of pipes and equipment is another operational issue that reduces the heat transfer efficiency of the heat exchangers, increasing the overall energy required for distillation.

Other principal issues with the application of the distillation processes for seawater desalination include the high capital cost and large space requirements. Because seawater is highly corrosive in nature, special alloys, such as cupronickel alloys, aluminum, and titanium, are used most commonly in desalination with distillation processes. These special alloys add significantly to the capital cost of a distillation plant, particularly with the large surface area required for efficient distillation.

Moreover, disposal of brine from thermal distillation could raise considerable permitting concerns. This is because (1) brine coming out from a thermal distillation process is at a greater temperature compared to ambient feedwater temperature, and (2) heavy metals and other contaminants are picked up in the brine through erosion and corrosion of material from the pumps, heat exchangers, and pipes.

The CDPH has also expressed concern regarding the lack of available data on the effectiveness of thermal processes at removing microbial contaminants.

Commercially available thermal technologies included in the following discussion are: Multistage Flash Distillation, Multi Effect Distillation, and Membrane Distillation.

2.2.2.1 Multistage Flash Distillation (MSF)

MSF accounts for the greatest installed thermal distillation capacity worldwide. In the MSF process, water is heated in a series of stages, each with successively lower pressures and temperatures. Vapor generation or boiling caused by reduction in pressure is known as *flashing* (illustrated in Figure 2-5). As the water enters each stage through a pressure-reducing nozzle, a portion of the water is flashed to form vapor. In turn, the flashed water condenses on the outside of the condenser tubes and is collected in trays. As the vapor condenses, the latent heat is used to pre-heat the seawater that is being returned to the main heater, where it will receive additional heat before being introduced to the first flashing stage. The condensate collected in each stage forms the product, and the whole process is driven by the sub-atmospheric pressure gradient through the stages. The advantages of the MSF include: (1) proven technology, (2) ability to handle large capacities, (3) can operate using waste thermal energy.

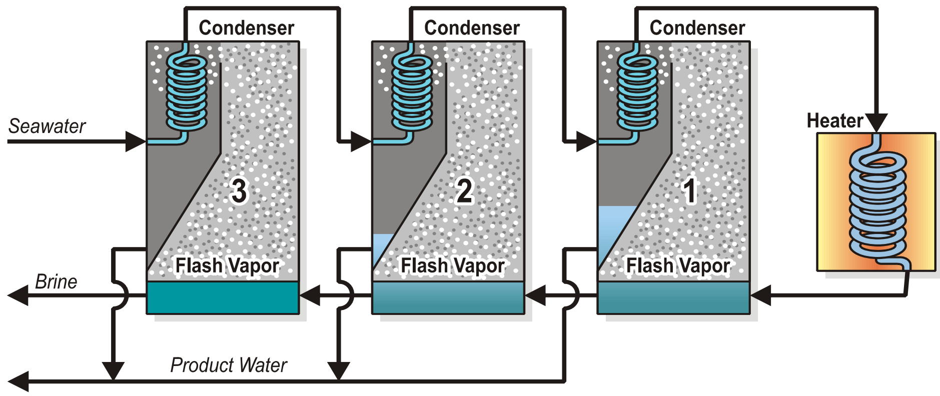


Figure 2-5
Multiple Stage Flash Distillation

2.2.2.2 Multi Effect Distillation (MED)

In MED several boilers or "effects" are arranged in series, each operating at a lower pressure and temperature than the preceding one. Typically, there are 8 to 16 effects in a typical large plant. Vapor produced by evaporation can be condensed in a way that uses the heat of vaporization to heat salt water at a lower temperature and pressure in each succeeding effect, allowing water to undergo "multiple boiling" without supplying any additional heat after the first effect. To accomplish this, seawater in the first effect is heated to the boiling point. To promote rapid boiling and evaporation, seawater is sprayed onto heated evaporator tubes or may flow over vertical surfaces in a thin film (see illustration in Figure 2-6). This not only reduces the energy for distillation but also reduces the electrical power consumption. As a result, energy costs for operating an MED plant are lower than that of an MSF plant.

2.2.2.3 Membrane Distillation (MD)

Membrane distillation is an emerging technology for separations that combines the use of both thermal distillation and membranes. MD involves the transport of water vapor from a saline solution through the pores of a hydrophobic membrane. The large contact angle of water with the hydrophobic membrane prevents liquid water from penetrating the pores, and water vapor is transported across the membrane in response to a change in partial pressure across the membrane due to a thermal gradient.

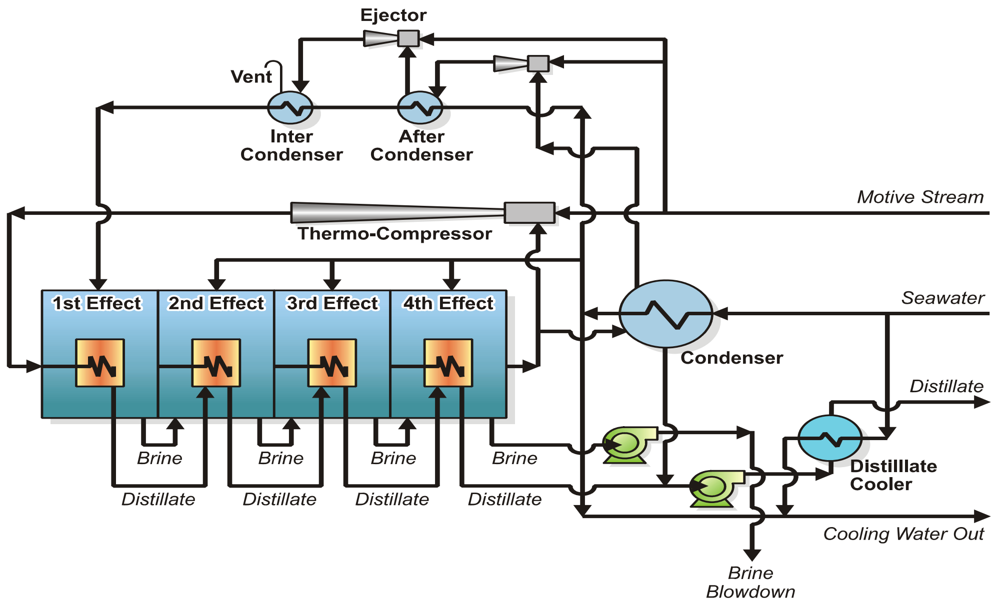


Figure 2-6
Multiple Effect Distillation

The efficiency of an MD process largely depends on membrane, module design, and heat recovery from the permeate stream. Although energy required for vaporization is quite high, the process is typically run at relatively low temperature (~70 ºC) and thus can make use of waste heat or low grade heat sources. Potential advantages of MD are (1) the ability to use low grade, inexpensive heat sources, (2) smaller footprint, and (3) lower capital costs than conventional distillation processes (Miller and Mayer 2005). Membrane fouling could be a problem, but is expected to be less severe than conventional membrane processes. Membrane degradation (loss of hydrophobicity) is another operational challenge with this process. This process, like forward osmosis is in an early stage of development.

2.2.3 Analysis

Although several desalination processes are covered in the preceding discussion the only alternatives that can be implemented in the near-term for a project of this scale in a location like Scattergood are RO, MSF, and MED. Table 2-1 summarizes the advantages and disadvantages of the RO membrane process and MSF and MED thermal processes. These are discussed more fully in relationship to the project goals and evaluation criteria in the subsequent sections, with a recommended process identified in Section 2.2.4.

CDM

Table 2-1
Comparison of Desalination Processes

Desalination Process	Advantages	Disadvantages
Membrane Process (RO)	Proven technology Life cycle cost less than half thermal process CDPH accepted BAT for removal of many inorganic contaminants	Requires reliable pretreatment process Less effective is removing boron (< 1.0 mg/L), chloride (<150 mg/L) and bromide (<0.3 mg/L) Post treatment required to achieve anticipated boron, chloride and bromide goals
Thermal Process MSF MED	Proven technologies Ability to handle large capacities Can operate using thermal waste Achieves low boron (< 0.1 mg/L), chloride (< 10 mg/L) and bromide concentrations (0.05 mg/L) Less pretreatment requirements Simpler cleaning and maintenance	High energy requirements resulting in large carbon footprint Warm brine may pose additional obstacles for environmental acceptable High capital cost Large space requirements Lack of data on effectiveness of thermal processes at removing microbial containments Uncertainty whether the process could be permitted

Each of these processes are further evaluated using more specific criteria including: 1) Environmental sustainability, 2) Suitability as a high quality domestic supply, 3) Operations and maintenance, and 4) Uncertainty.

2.2.3.1 Environmental Sustainability

Environmental sustainability has many components. Four of the most prominent among them are space requirement, energy requirement, impact of the water intake on marine life, and impact of the brine discharge on marine life.

LADWP has secured the necessary space for a desalination facility that can be developed in a manner that is consistent with the applicable zoning, and potentially improve the existing aesthetics in the proposed site. Although space requirements for RO are considerably less than for thermal processes, any of the three desalination processes being evaluated could be located at the Scattergood site.

Feedwater flows for a thermal process would likely be 2 to 3 times higher than SWRO, running the risk of larger impacts on marine life. In addition to the feedwater impacts, energy requirements and impact of the brine discharge will also be primary environmental differentiators between RO and the thermal processes.

Energy Requirement

As displayed in Table 2-2, the minimum energy required to desalt seawater is approximately 3.8 kWh/1000 gal. This requirement is based on fundamental thermodynamics and represents an absolute minimum below which energy requirements will never fall no matter how much technological development takes place. Also presented is the current industry performance where energy requirements are concerned for the three processes listed above. MSF and MED both use two forms of energy, electrical energy and thermal energy (usually in the form of live steam). For purposes of comparison the energy in the steam has been converted to the equivalent amount of electrical energy that steam might have generated. Energy requirements range from as high as 100 kWh/1000 gal for some thermal process to as low as 14 kWh/1000 gal for the most efficient seawater RO facilities. Clearly RO has significant advantages where energy is concerned. On the other hand, studying the make-up of this energy requirement, it becomes clear why thermal processes are attractive when waste steam is available. Also shown are the future projections for energy requirements for seawater RO based on current research work. These projections suggest a further reduction of 30 percent or so is a reasonable expectation in the future as RO and energy recovery technologies continue to develop. If these changes are accomplished seawater RO will approach approximately 280 percent of the theoretical minimum energy requirement.

Table 2-2
Comparison of Industrially-Proven, Large-Scale Desalination Processes

Desalination Process	**Energy Consumption kWh/1000 gal**		
	Electrical	**Thermal [1]**	**Total**
Minimum For Seawater [2]			3.8
Current Industry Performance [3]			
MSF	13 to 19	38 to 82	51 to 101
MED	8 to 10	28 to 82	36 to 92
RO	14 to 17	NA	14 to 17
Future Projections [4]			
RO	10.5-11	NA	10.5-11

1. Thermal energy (steam) is expressed as kWh, assuming an 18 percent conversion of thermal to electrical energy.
2. Minimum energy required to desalt seawater based on thermodynamic principles, adapted from Stoughton and Lietze (1965).
3. Adapted from Blank et al. (2007), Wade (2001) and informal survey of RO desalters conducted by Trussell Technologies, Inc. (2006), expressed as kWh/1000 gal, assuming 18 percent conversion of thermal energy into electrical energy.
4. Adapted from ADC Phase II test report (2006), 2 KWh/1000 gal added to account for energy in pretreatment.

Brine Disposal
LADWP has studied the potential impacts of brine discharge from a seawater RO plant that determined that the nearby 5-mile Hyperion outfall could be used for SWRO brine discharge with potential benefits to the marine environment. The study also concluded that the SGS outfall could be used with minimal impact to the marine environment for a production range of up to 25 mgd.

On the contrary, the disposal of brine from thermal distillation could raise additional environmental concerns. This is because (1) brine coming out from thermal distillation is at a greater temperature compared to ambient feedwater temperature, and (2) heavy metals and other contaminants are picked up in the brine through erosion and corrosion of material from the pumps, heat exchangers, and pipes. Regulatory agencies may have concerns regarding the potential impacts of the thermal discharge and elevated metal concentrations on marine organism in the vicinity of the discharge point.

SWRO therefore, offers advantages with respect to brine disposal compared to thermal processes for seawater desalination.

Table 2-3 provides an overall summary of these three candidate technologies from the standpoint of these environmental issues. All have in common the problem of finding ways to prevent impingement and entrainment and to manage the impact of brine discharge. The principal differentiator between these processes is energy consumption. As shown in Table 2-3, the thermal desalination plants have a large carbon footprint and potential for additional environmental issues associated with hot brine. Therefore, the RO is the more environmentally sensitive desalination process.

Table 2-3
Suitability for Environmental Sustainability

<table>
<tr><th rowspan="2">Process</th><th rowspan="2">Energy
kWh/1000 gal</th><th rowspan="2">Entrainment & Impingement</th><th colspan="3">Brine Discharge</th></tr>
<tr><th colspan="2">Salinity</th><th>Flow</th></tr>
<tr><td>MSF</td><td>51 – 101</td><td>2-3 x more feedwater required than RO</td><td>1.2-1.3 x seawater</td><td rowspan="2">Brine is also hot</td><td>3-6 times fresh water produced</td></tr>
<tr><td>MED</td><td>28 – 92</td><td>2-3 x more feedwater required than RO</td><td>1.2-1.3 x seawater</td><td>3-6 times fresh water produced</td></tr>
<tr><td>RO</td><td>14 – 17</td><td>Requires intake with twice the flow of product water</td><td>2 x seawater</td><td></td><td>Equal to fresh water produced</td></tr>
</table>

2.2.3.2 High Quality Domestic Supply

In principle, all these processes have equal capability to deliver a high quality domestic supply, and all three processes produce a water that is highly corrosive due to the lack of mineral content. Although most surface waters also require pH adjustment following coagulation, the pH adjustment for desalted water is more significant. Boron, chloride and bromide are mineral quality issues of particular significance. Table 2-4 presents a comparison of LADWP water sources and product water from applicable desalination technologies with respect to these specific water quality issues.

Table 2-4
Comparison of Water Quality Parameters Important to Domestic Use – LADWP Water Supplies and Desalinated Seawater

Water Source	TDS	Corrosion	Boron	Chloride	Bromide
Owens River	195 mg/L	Requires pH adjustment	0.4 mg/L	25 mg/L	< 0.02 mg/L
Colorado River	450 mg/L	Requires pH adjustment	0.13 mg/L	66 mg/L	-
State Project Water	275 mg/L	Requires pH adjustment	0.19 mg/L	50 mg/L	< 0.3 mg/L
Typical Domestic Water	< 400 mg/L	Not corrosive	< 0.3 mg/L	< 100 mg/L	< 0.05 mg/L
MSF Product	10 mg/L	Corrosive	< 0.1 mg/L	< 10 mg/L	< 0.05 mg/L
MED Product	10 mg/L	Corrosive	< 0.1 mg/L	< 10 mg/L	< 0.05 mg/L
SWRO Product	< 350 mg/L	Corrosive	< 1.0 mg/L	< 150 mg/L	< 0.3 mg/L

Although desalination by SWRO membranes results in high quality water that meets and exceeds the drinking water regulations, there are specific ions that are present in much higher concentrations in desalinated water than in typical domestic drinking water, and pose a significant concern if not properly addressed. The ions of concern are boron, chloride, sodium, and bromide.

Boron

Although water desalinated by RO may meet the current CDPH notification level (NL) of 1 mg/L for boron, it will likely be higher than the levels in the LADWP's current water supplies. The boron in the desalinated water may also be high enough to be toxic to some plants important to horticulture. The research performed to date on boron toxicity indicates that the accumulation of boron in some agriculture plants leads to chlorosis (e.g. chlorophyll death) and in extreme cases necrosis (e.g. cell death).

A boron concentration greater than 2 mg/L is unhealthy for most plants, while a boron concentration greater than 1 mg/L is still unhealthy for many plants. If the boron concentration is maintained below 0.5 mg/L, boron toxicity should not result in significant issues regarding plant appearance and death. Many common plants are affected by boron levels between 0.5 and 1 mg/L. These include: Camelias, Crape Myrtles, Gardenias, Giant Bird of Paradise, Heavenly Bamboo, Hydrangea, Lily of the Nile, Oranges, Lemons, Philodendrons, Photinias, Pink Trumpet Vine, Roses, Southern Magnolias, Violet trumpet vine, Wheeler's dwarf pittosporum, and xylosma (Hortscience, 2005). Photos for some of these plants are included in Appendix D of this Report.

Recently developed high boron rejection membranes may be capable of producing boron levels as low as 0.5 mg/L when treating cold water at typical seawater pH, however, if a boron treatment goal is established significantly below the CDPH notification level, additional post-treatment may be required for a SWRO process. This could include second pass RO, ion exchange, or post-treatment blending with a low boron water.

Chloride and Sodium
Chloride and sodium toxicity to plants have been more commonly observed than boron toxicity to date because of the increased use of reclaimed water for irrigation purposes. Some of the better-known cases of chloride toxicity occurred where Redwood and Avocado trees were converted from irrigation with local water supplies to recycled water, resulting in significant impacts on the health of these species. Chloride and sodium toxicity have very similar impacts on plant life. Based on experience at other SWRO plants and on vendor performance models, a single-pass RO is expected to produce product water with approximately 150 mg/L chloride and 100 mg/L sodium when treating cold water. Higher levels may be seen when treating warm water, with some degree of variability seen between membrane manufacturer and membrane type. These sodium and chloride concentrations are 3 to 4 times higher than levels observed in existing LADWP water supplies. The increased levels of sodium and chloride ions present in the desalinated water may result in noticeable impacts on plants following the conversion to desalinated water if the water is not adequately blended or post-treatment is not employed.

Bromide
Because of the elevated levels of bromide ion in the seawater (typically around 65 mg/L), a single pass RO membrane rated at 99.5 percent removal capacity, produces product water that has 300 to 400 µg/L bromide ion, which is about five to six times higher than what is normally observed in existing water supplies. Studies have shown that the presence of bromide ion in the desalinated water exerts chlorine/chloramine demand that could accelerate decay of secondary disinfectants in the distribution system (Tseng et al., 2005; Chao, 2006). This would pose a significant challenge to maintaining a stable residual in the distribution system. Achieving a lower bromide level could require a post-treatment system, such as second pass RO or post-treatment blending.

2.2.3.3 Operations and Maintenance

In general, SWRO membranes have higher O&M requirements than MSF and MED because thermal desalination processes require significantly less pre-treatment.

While similar foulants are common to both RO and thermal processes, performing cleaning and maintenance on MSF and MED tends to be simpler. For example, biological growth in a thermal plant can be controlled using chlorine or any other disinfectant, whereas exposure to chlorine oxidizes SWRO membranes. In addition, the heat-exchangers used in the thermal processes use tubes which are 0.5 to 1.0 inch diameter. These can be readily cleaned with online tube cleaning systems for periodic sand and silt removal.

SWRO systems are more susceptible to fouling by particulate matter and suspended solids, requiring a reliable pre-treatment for successful operation. However, even with MF/UF membrane pretreatment and chemical additions, the capital and O&M costs of an SWRO plant are expected to be well under half the cost of any thermal process due to the high energy requirements of thermal processes.

While there are many SWRO desalination plants operating successfully around the world, Tampa Bay Desalination plant and those which have been operating in the Persian Gulf for some time are reminders of down-time, loss of production, and expense associated with ineffective pretreatment ahead of SWRO systems.

2.2.3.4 Uncertainty

For the purposes of this document, the technologies that are not yet fully developed are rated as "uncertain" and technologies that have been around for decades are rated as "certain". Both MSF and MED processes have been widely employed for desalination in the Middle East region since the 1960s. Even today, approximately 40 percent of the world's desalted water is produced by thermal processes to distill seawater or brackish water into freshwater. However, such a process has never been permitted for use at a large scale facility in the United States, and there is a fair amount of uncertainty over whether such a process could be permitted under the current regulatory conditions.

SWRO membranes have seen a significant amount of successful use in recent years, following a period of much less certain conditions, with the technology in a considerable state of transition. CA membranes were never successful in large scale seawater applications. The older SWRO plants in the Persian Gulf were all built using a polyamide hollow fiber technology marketed by Dupont until recently. All of the newer reference plants, however, are using the newer TFC technology, which has proven reliable for continuous operation and removal of the target contaminants. We have therefore rated SWRO as a low uncertainty.

Some of the largest new desalination plants that use SWRO membranes include the 84 MGD plant in Ashkelon, Israel; 45 MGD plant in Fujairah, UAE; 38 MGD plant in Perth, Australia; 36 MGD Tuas plant in Singapore; 33 MGD Point Lisas, Trinidad and

Tobago plant; 32 MGD plant in Carboneras, Spain; 20 MGD plant in Yuhuan, China; and 13 MGD plant in Fukuoaka, Japan.

2.2.4 Recommendation

Table 2-5 presents a qualitative comparison of the three principal processes discussed above with respect to several issues of interest. MSF and MED both get an excellent rating from the standpoint of the quality of the water they produce, requirements for operations and maintenance are low (apart from the energy usage) and their design can be accomplished with only moderate technical risk, most of which relates to permitting of the process. On the other hand they both require extremely large amounts of energy and physical square footage for the treatment facility, resulting in both a high capital and high O&M cost. Both thermal processes rate low from the standpoint of environmental sustainability because their brine is much hotter than the ambient ocean, their feed water requirements are significantly higher, their energy usage is more, and their physical footprint is much larger.

Table 2-5
Overall Comparison of Desalination Alternatives

Desalination Process	Energy KWh/1000 gal	Environmental Sustainability	Water Quality			Lifecycle Cost
MSF	51 to 101	Poor	Excellent	Low	Medium	High
MED	36 to 92	Poor	Excellent	Low	Medium	High
SWRO	12-15	Good	Good	Medium	Low	Medium

Distillation technologies are not as suitable to the Southern California environment as are membrane driven processes. More importantly, distillation technologies are less environmentally sustainable, requiring the generation of large amounts of heat which requires the consumption of large quantities of fossil fuels.

Reverse osmosis is the most attractive process for desalination at the Scattergood site, due to environmental considerations, significantly lower costs, and the uncertainty of the regulatory environment for thermal desalination processes in the United States. Adequate pretreatment will be a major consideration for protecting the SWRO process and additional post-treatment may also be required due to the higher levels of boron, chloride, and bromide found in SWRO product, when compared with thermal processes.

2.3 Pretreatment

One of the major concerns in the wider application of RO membranes for seawater desalination is the loss of membrane productivity due to foulants present in seawater. RO membrane fouling can be caused by inorganic deposits (scaling), adsorption of organic molecules (organic fouling), particulate deposition (colloidal fouling) and microbial adhesion and growth (biofilm formation), all of which may happen simultaneously. Thus, providing adequate pretreatment is essential to maximize the longevity and efficiency of desalination membranes. This section provides a detailed discussion of various pretreatment processes designed to prevent particulate, microbial, and organic foulant deposition on the RO membrane surface. The processes that are considered in this section include the following:

- Granular Media Filtration
  - Conventional Filtration
  - In-line or Direct Filtration
- Membrane Filtration
  - Polymeric Membrane Filtration
  - Ceramic Membrane Filtration

Table 2-6 summarizes a list of pretreatment technologies employed at full-scale seawater RO plants around the world. Of the nine plants listed in Table 2-6, the majority of them use some form of conventional treatment/granular media filtration (GMF), with only three of them using membrane filtration. The heavy leaning toward GMF is due primarily to the relatively recent advances and well proven advantages of the membrane filtration.

A detailed assessment of each of these technologies including commercial availability, performance, design criteria, and operation and maintenance requirements will be discussed.

2.3.1 Granular Media Filtration (GMF)

For the six plants that use some form of conventional treatment, the water reaching the GMF has been primarily pretreated using two different approaches. The more common approach is in-line filtration or direct filtration where a coagulant is added ahead of the GMF, and another approach is conventional filtration where GMF is preceded by coagulation, flocculation, and sedimentation

Table 2-6
A List of Pretreatment Technologies Employed at Full-Scale RO Plants

Plant location		**Ashkelon, Israel**	**Point Lisas, Trinidad**	**Tampa**		**Carbonera, Spain**	**Dhekelia, Cyprus**	**Tuas, Singapore**	**Diablo Canyon, California**	**Fukuoka, Japan***	**Yuhuan China**
				Old	**New**						
Pretreatment		Coagulation	Coagulation/ flocculation/ sedimentation	Coagulation	Coagulation	Degrit, coagulation	Degrit/ coagulation/flocculation	Coagulation/ flocculation/ dissolved air flotation	in-line coagulation	UF-membrane	UF-membrane
Filtration	**Type**	Single-stage dual-media gravity	Deep-bed dual-media	Two-stage Dyna sand	I- Stage: Dyna-sand, II- Stage: Diatomaceous earth	Single-stage dual media pressure	Single-stage dual-media gravity	Single-stage mono-media gravity	I- Stage: deep-bed dual-media, II- Stage: deep-bed multi-media	8" Spiral wound, PVDF material	8" Spiral wound, PVDF material
	Top media	80cm/1.4mm Anthracite	150cm/1.0mm Anthracite	I- stage 0.6mm sand; II- stage 0.9mm sand	Cellite AW Hyflo Supercel NF	Anthracite	Anthracite	Sand	I-Stage: 107 cm/1.0 mm anthracite over 53 cm/0.5 mm sand; II-Stage: 91 cm/1.0 mm anthracite over 45 cm/0.65 mm sand and 23 cm/0.35 mm garnet	Not Applicable	Not Applicable
	Bottom media	80cm/0.65mm sand	80 cm/0.65 mm sand			Sand	Sand			Not Applicable	Not Applicable
	Filter rate	2.9 gpm/sf	6 gpm/sf	6 gpm/sf	3 gpm/sf	2.9 gpm/sf	NA	NA	I-Stage: 4 gpm/sf; II-Stage = 4.5 gpm/sf	NA	NA

NA = Not Available
***This is the only facility that utilizes subsurface intake system (all others have open intake system).**

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2.3.1.1 Conventional Filtration

As shown in Figure 2-7, the conventional treatment consists of coagulation, rapid mix, flocculation, and sedimentation prior to granular media filtration. Conventional filtration has historically been the most popular choice for surface water treatment plants because it can treat a wider variety of water quality and responds better to rapid changes in source water, when compared with direct or inline filtration. There are several successful seawater desalination plants employing conventional filtration at capacities greater than 10 MGD.

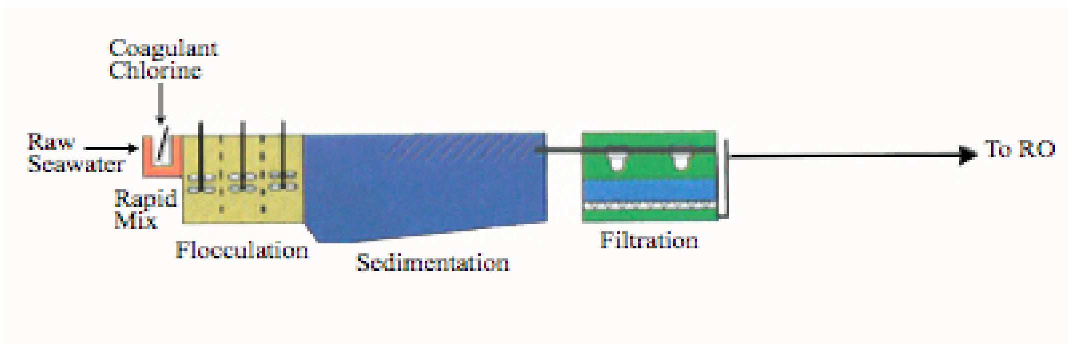


Figure 2-7
Schematic of Conventional Treatment Followed by Single Stage Deep-bed Media Filtration

The Trinidad Point Lisas desalter is an example of a large ocean water RO desalination facility (33 MGD capacity) operating with conventional deep-bed dual GMF filtration as the pretreatment to RO membranes. The full-scale plant consists of 10 deep bed-dual media filters (62 inch/1.0 mm anthracite coal over 31 inch/0.65 mm crushed sand); all single stage, each operating at a filtration rate of 6 gpm/sf [Trussell and Jacangelo, 2004]. Pretreatment to GMF includes ferric chloride as the coagulant (10 to 15 mg/L dose) with sufficient chlorine to maintain a residual of 0.1 to 0.5 mg/L in the effluent of the sedimentation basins. Since the start-up in April 2002, these conventional deep bed filters have generally achieved the target water quality of low SDI (2-3) and low turbidity (<0.02 nephelometric turbidity units [NTU]), even though there were frequent spikes of high turbidity and algae matter in the raw water quality during this period. The water quality produced by this conventional filtration process has generally resulted in a stable operation of SWRO membranes that require chemical cleaning at a 4 to 6 months interval [Thompson et al., 2005]. It should be noted, however, that the Point Lisas facility is currently considering installation of membrane filtration upstream of the RO to allow for plant expansion and improve the reliability of the water quality feeding the RO.

Several disadvantages of conventional filtration exist. These include: (1) higher capital and O&M costs, (2) higher coagulant dosages generally required to form settleable floc (as well as higher chemical costs and greater sludge production), and (3) larger footprint. Another granular media filtration alternative that mitigates some of these deficiencies is direct/in-line filtration, which is discussed next.

2.3.1.2 Direct or In-line Filtration

The direct filtration process includes coagulation, rapid mixing, flocculation, and filtration. In some cases, the flocculation can be omitted, with flocculation occurring in the deep-bed itself. The latter treatment train is also referred to as in-line filtration and has been employed in drinking water plants to shield expensive NF/RO membranes from colloidal, microbial, and organic foulants (see Figure 2-8).

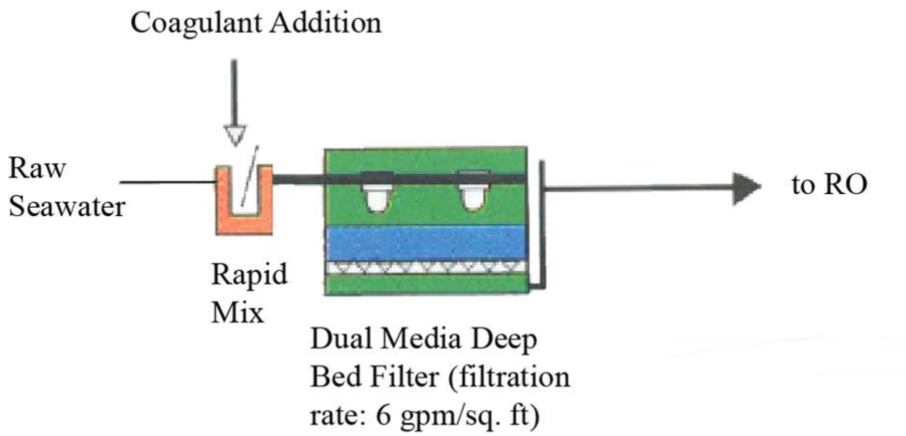


Figure 2-8
Schematic of In-line Filtration

In-line filters are suitable for waters that do not have high turbidity (< 10 NTU). The Pacific Ocean water near Los Angeles is expected to vary only in the range of 1 to 2 NTU, with occasional red-tide events approaching or exceeding 10 NTU. The typically low and stable turbidity of the Pacific Ocean water makes the in-line filtration an attractive option for pretreatment. However, it should be considered that red tide events may last weeks or months requiring a seawater plant to either adjust to the added turbidity and biomass loads or shut down for the duration of the event. Because flocculation and sedimentation tanks are not required in this alternative, an in-line filtration train has a lower capital cost than a conventional treatment process of the same capacity. Additionally, lower coagulant dosages are required because the goal is charge neutralization to form a filterable pinpoint –sized floc, rather than sweep-floc coagulation used in conventional filtration which forms large settleable floc. Therefore, employing in-line filtration results in lower chemical costs as well as reduced sludge handling and treatment. However, there are some important process concerns with regards to the operation of an in-line filtration plant that need to be highlighted.

Contrary to the common belief, GMFs do not remove particles by physical straining alone. Instead particles are removed when they adhere to the filter grains or on previously deposited particles. Engineering surface chemistry of particles using coagulant is the most important step in the successful operation of an in-line filter.

Because sedimentation and flocculation are omitted, less response time is available to the operators to react to changes in source water quality. The insufficient tuning of coagulant dosage in response to a sudden increase in turbidity, SDI, and algal concentration during a red-tide events or other seasonal events, can lead to inconsistent filtered water quality that may not always meet the requirements set by the RO membrane manufacturers. Therefore, most successful plants using in-line filtration operate on water sources of consistent quality.

The principal concern about the use of GMF as the sole pretreatment for reverse osmosis in seawater is the fact that the process does not reduce colloidal foulants to sufficiently low levels. While the process has a long and successful record as a pretreatment for disinfection in freshwater applications, its record in preparing surface waters (from the ocean) for reverse osmosis is not as consistent. While there are examples of successful pretreatment with GMF, even these installations show there is room for improvement.

2.3.2 Membrane Filtration

MF and UF are the two processes that are most often associated with the term "membrane filtration". These membranes provide a physical barrier, resulting in more complete rejection of particles greater than a specified size (on the order of 0.1 µm for MF and on the order of 0.01 µm for UF). Membranes of this kind remove particles down to such small sizes that they both remove pathogens and also particles that adversely affect the aesthetic appearance of the water. As a result, these membranes are now widely used for treatment of drinking water without the use of coagulants. The treatment plants that result are less costly, require less space and produce less sludge than conventional granular media facilities. Membrane filtration has also been successfully employed for several years in the treatment of secondary effluent to make it suitable for reverse osmosis.

Granular media filters require the use of coagulants to alter the surface of the particles suspended in the water so that they agglomerate to form larger particles (conventional treatment and direct filtration) and adhere to the filter media as the water passes through (conventional treatment, direct filtration and in-line filtration). One advantage of GMF processes is that the agglomeration of small particles to form larger ones can result in the removal of some extremely small particles, including many not removed by microfiltration and some not removed by ultrafiltration. The disadvantage is that the rejection of particles of a given size is not as complete as it is in membrane processes. Put another way, there is no well-defined particle size cut-off above which complete removal is assured. Membrane filtration overcomes this important shortcoming.

In recent years, competition among manufactures and increasing number of successful installations has dramatically decreased both initial and long-term costs of membrane filtration. As a result, membrane filtration has been widely accepted for surface water treatment by regulatory and municipal water agencies.

The progress of membrane filtration in seawater applications, however has been slower, though some progress has been made (see Table 2-6). A 13 MGD seawater plant in Fukuoka, Japan utilizing UF technology as a pretreatment has been in operation since June 2005. Recently, another 20 MGD seawater RO desalination facility with UF membrane pretreatment began operating at the Yuhuan Power Plant in Yuhuan, China. Also, MF/UF pretreatment for seawater applications have been extensively pilot tested in California by various water purveyors including Carlsbad, Long Beach Water Department, West Basin MWD, and Marin MWD. Based on successful piloting, these utilities are now considering MF/UF membrane pretreatment for their future full-scale seawater desalination plants.

Membrane-based pretreatment still faces two significant operational challenges in seawater applications. These include:

- Accelerated fouling during red tide events, and
- Shell fragment or debris induced membrane fiber damage

The accelerated fouling during red tide events can probably be addressed using in-line coagulation with an appropriate coagulant at the right dosage or alternatively by lowering the operating flux. The issue with membrane fiber damage is a complex issue because it is often site specific and is highly dependent on the raw water source, but it also relates to the way these membranes are being manufactured. All commercially available MF/UF membranes for seawater desalination application are polymeric in nature. One alternative would be to remove the fragments before membrane filtration. Another would be to make thicker-walled polymeric membrane fibers, so that their longevity against sharp shell fragments and debris is increased. A third alternative would be to use ceramic membranes that are more durable than polymeric membranes. A detailed assessment of polymeric and ceramic membranes is presented next.

2.3.2.1 Polymeric Membrane Filtration

Polymeric membranes are formed using either CA or synthetic polymers, such as polypropylene (PP), polyvinyl difluoride (PVDF), polysulfone (PS), or polyethersulfone (PES). The various membrane materials have different properties, including pH and oxidant sensitivity, and hydrophobicity (see Table 2-7). Most synthetic polymeric membranes are naturally hydrophobic and only upon surface modifications do they become hydrophilic. Therefore, these membranes have a special storage requirement -- they must be stored wet or filled with a wetting agent. If allowed to dry, they may experience a change in structure resulting in a loss of membrane permeability.

Table 2-7
Characteristics of Selected Membrane Materials

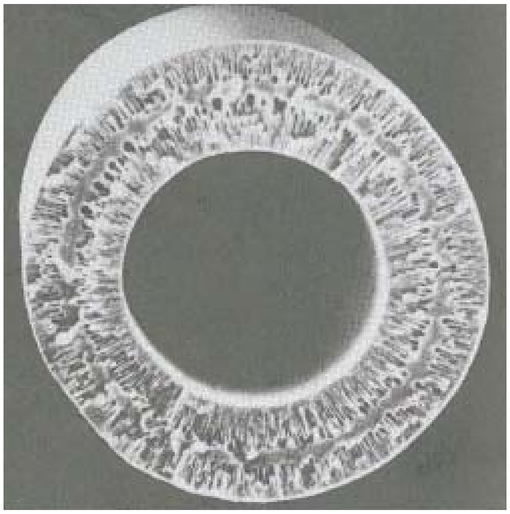
Membrane Material	Membrane Classification	Hydrophobicity	Oxidant Tolerance	pH Range	Fouling Resistance/ Cleanability
Polyvinyl difluoride (PVDF)	MF/UF	Modified hydrophilic	Very High	2-11	Excellent
Polypropylene (PP)	MF	Slight hydrophobic	Low	2-13	Acceptable
Polyethersulfone (PES)	UF	Very hydrophilic	High	2-13	Very good
Polysulfone (PS)	UF	Modified hydrophilic	Moderate	2-13	Good
Cellulose acetate (CA)	UF	Naturally hydrophilic	Moderate	5-8	Good

(Adapted from Microfiltration and Ultrafiltration Membranes for Drinking Water, Manual of Water Supply Practices, M53)

Although polymeric MF/UF membranes are found in many configurations (hollow fiber, spiral wound, flat sheet, plate and frame), hollow fiber is the most popular option available where water treatment is concerned. These fibers have an inside diameter ranging from 0.4 to 1.0 mm and a wall thickness ranging from 0.07 to 0.6 mm (see Figure 2-9). The physical strength of the fibers allows them to be backwashed.

Hollow-fiber membranes are operated in either an inside-out or outside-in mode. During inside-out operation, the feed enters the fiber lumen and passes through the fiber wall to generate filtrate (Figure 2-9b). During outside-in operation, the filtrate is collected in the fiber lumen after the feed is passed through the membrane. Typically, MF/UF with outside-in operations do not require any pre-treatment beyond coarse-straining, whereas, a clarification unit or higher quality feedwater (e.g. lower TSS) is sometimes required prior to inside-out configurations.

The pressure that is used to drive water through the membrane material is termed as transmembrane pressure. Depending upon the way membrane modules are pressurized, they are available in two basic configurations: pressure-vessel systems (Figure 2-10) and submerged systems (Figure 2-11). Pressure systems are operated under positive pressure (between 3 to 35 psi) and submerged system are under negative pressure (between -1 to -10 psi). Submerged systems tend to accommodate larger modules than pressure vessel systems and eliminate the need for pressure



A

C

B

Figure 2-9
Hollow Fiber Membranes:
(A) Scanning electron microscope image of end view with cacrovoids for water passage,
(B) Example of a hollow fiber module
(C) Water permeating through hollow fibers

vessels to house the membranes. Additionally, submerged systems generally require fewer valves and piping connections. As a result, submerged membranes have conventionally been preferred over pressurized membranes for large size installations (greater than 20 MGD), however, the most appropriate selection depends on the specifics of the feedwater to be treated and on the particular bidding environment at the time of selection.

Figure 2-10

Pressure Vessel Configuration Membrane Filtration (Pall Corporation System)

Figure 2-11

Submerged configuration membrane filtration (Siemens Water Technologies)

Table 2-8 provides a list of key low-pressure membrane manufacturers in the USA. Note that only X-flow (Norit), Hydranautics, Pall Corporation, Zenon and US-Filter have seawater experience at pilot- or full-scale. Because many of these polymeric membranes have experienced significant fouling and fiber breakage in seawater applications, interest in ceramic membranes, which are mechanically and chemically more durable, is growing. A brief description of ceramic membranes and a side-by-side comparison of polymeric to ceramic membranes are presented in the following section.

Table 2-8
List of Key Low-Pressure Membrane Manufacturers in the USA

Manufacturer	Representative product name	Product specification
Aquasource	Ultrafiltration modules (SM, A, L B)	Hollow fiber, pressurized system, inside-out flow, MWCO = 35,000 – 100,000 Da
Hydranautics*	Ultrafiltration modules (HYDRAcap and HYDRAcapLD)	Hollow fiber, pressurized system, inside-out flow, Nominal MWCO = 150,000 Da
Koch Membrane Systems	Microfiltration modules (ROMICON® MF 5 and ROMICON® MF 6)	Hollow fiber, pressurized system, inside-out flow, 0.2-0.3 micron pore size
	Ultrafiltration modules PMPW™-8 and PMPW™-10	Hollow fiber, pressurized system, inside-out flow, Nominal MWCO = 100,000 Da
Pall Corporation*	Microfiltration module (Microza hollow fiber USV modules)	Hollow fiber, pressurized system, outside-in flow, 0.1 micron pore size
Siemens*	Memcor® XP and Memcor CMF	Hollow fiber, pressurized system, outside-in flow, 0.04 micron nominal pore size and 0.1 micron absolute pore size
	Memcor® XS and Memcor CMF-S	Hollow fiber, submerged system, outside-in flow, 0.04 micron nominal pore size and 0.1 micron absolute pore size
X-Flow (Norit)*	Ultrafiltration modules (XIGA™, Seaguard)	Hollow fiber, pressurized system, outside-in flow, 0.025 micron pore size
Zenon (GE Water & Process Technologies)*	Ultrafiltration modules (ZeeWeed® 500 and ZeeWeed® 1000)	Hollow fiber, submerged system, outside-in flow, 0.02-0.1 micron pore size

* Manufacturers with seawater experience.

2.3.2.2 Ceramic Membrane Filtration

Ceramic membranes are made by sintering inorganic materials into a clay-like ceramic form. Construction materials can be aluminum oxide, titanium oxide, zirconium oxide, or a carbon composite. These membranes are thicker than polymeric membranes and are usually formed into a monolith of tubular membranes (see Figure 2-12). These tubular membranes have relatively large inner diameters, ranging from 1 to 2.5 cm. The tubular membranes are usually placed inside stainless steel or fiber glass-reinforced plastic tubes that are sealed using a gasket and outer ring clamps. The feedwater, which is under pressure, flows through the inner lumens of the tube, and the permeate is collected in the outer shell of the module. During the filtration process, particles are retained on the lumen side if their size exceeds the diameter of the membrane pores. Because of the large channel diameter, it is easier to clean the retained particles on the lumen side. Table 2-9 compares advantages and disadvantages of tubular ceramic membranes with hollow fiber polymeric membranes. Because of the limited full scale facilities and lack of any operating data on seawater, ceramic membranes are not recommended for further evaluation at this time.

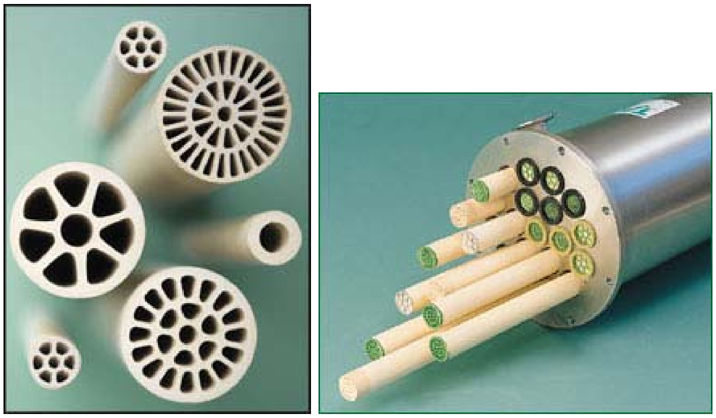


Figure 2-12
Tubular Ceramic Membranes
(Pictures from www.tami-industries.com)

Table 2-9
Comparison of Hollow Fiber Polymeric Membranes with Tubular Ceramic Membranes

Hollow Fiber Polymeric membranes
Advantages
Use of a widely-employed, common technology
■ Well-documented performance and high reliability at large scale
■ High surface area to volume or packing density of membrane
■ Fibers can be backwashed
■ Low transmembrane pressure, usually 0.2 to 1.0 bar
■ Light weight
■ Low capital cost
Disadvantages
■ Small tube diameter membranes are susceptible to plugging unless prescreening is employed
■ Wet storage
■ Susceptible to integrity loss due to shell fragments or sharp objects
■ High packing density of the fibers can sometimes present difficulties in detection of membrane integrity breach

Tubular Ceramic Membranes
Advantages ■ Higher resistance to very large range of pH, generally from 0 to 14 ■ They are able to sustain high temperatures (sometimes greater than 100) and high pressures. ■ They are able to maintain high product water fluxes during operation, if proper cleaning and backwash procedures are followed. ■ Unlike polymeric membranes, ceramic membranes are mechanically more stable and are expected to have significantly fewer integrity breaches. ■ Bacteria resistance ■ High abrasion resistance ■ Dry storage after cleaning ■ Longer membrane life (> 10 years) ■ Overall, they are often easier to maintain and clean than polymeric membranes, which can translate into a lower operating cost. Disadvantages ■ Higher capital cost ■ No full-scale installations on water treatment plants ■ Proprietary technology ■ Only one viable manufacturer in the USA, Kruger NGK ■ Heavy weight of the modules necessitates special handling procedures. ■ Lower surface area to volume ratio or “packing density” of membrane; which can result in increased foot print

2.3.3 Analysis

The following discussion reviews the two principal pretreatment alternatives using the following five criteria: 1) Environmental sustainability, 2) Suitability as a high quality RO feedwater, and 3) Operations and maintenance, 4) Uncertainty, and 5) Lifecycle Cost. Table 2-10 shows a qualitative overview of the in-line filtration and polymeric MF/UF pretreatment alternatives from the standpoint of these evaluation criteria.

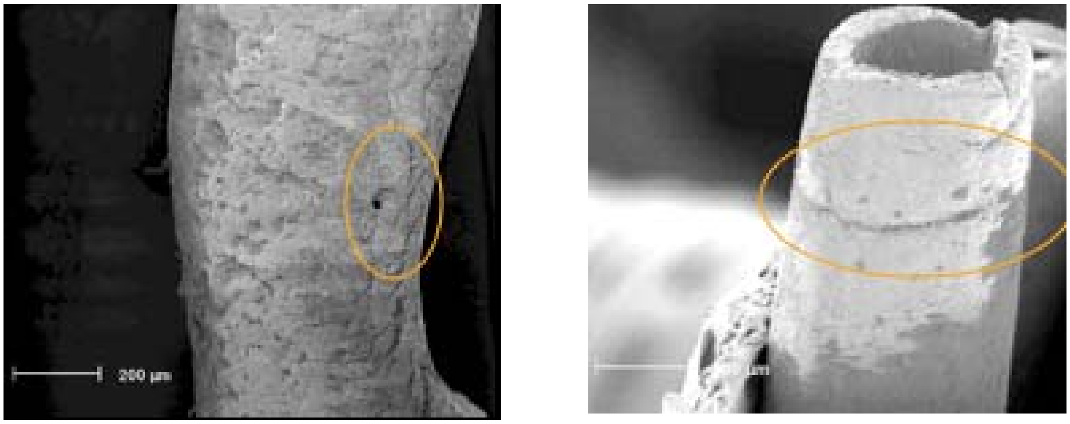
Table 2-10
Overview of the Pretreatment Alternatives

Pretreatment process	Environmental sustainability	Water quality	O&M	Technical uncertainty	Cost
In-line filtration	Medium	Good	Low	Low	Medium
Polymeric MF/UF	Excellent	Excellent	Low	Medium	Medium
Ceramic MF/UF	Excellent	Excellent	Low	High	High

MF/UF are rated excellent from the standpoint of environmental sustainability because (1) their footprint requirement is smaller given the high density of membrane surface area to building footprint, (2) their chemical and sludge handling costs are lower, as coagulant is added only during the feedwater quality upset events (in-line filters require continuous dosing of coagulant).

From the standpoint of providing a high quality feedwater to SWRO membranes, membrane based pretreatment is best because (1) they provide filtered water quality that always meets the traditional influent water quality goal (SDI < 3.0), independent of the raw seawater particulate concentration, (2) they achieve higher removals of bacteria and other viable microorganism, which significantly reduces the biofouling potential of the RO feedwater. In addition, low-pressure membranes receive additional log-removal credits for Cryptosporidum, Giradia cyst, and viruses, which would help reduce the disinfection requirements following the RO treatment.

All three alternatives look similar from the standpoint of O&M. From the standpoint of technical uncertainty, polymeric membrane based pretreatment received a medium rating because in several seawater pilots, these membranes have experienced frequent fiber damage due to sharp shell fragment and debris (see Figure 2-13). Ceramic membrane based pretreatment, however, received a high uncertainty rating, given the lack of any operating data, even at a pilot level, for ceramic membranes treating seawater. Lifecycle costs for in-line filtration and polymeric membranes are similar, while the cost of ceramic membranes is currently much higher.



(a) **(b)**

Figure 2-13 Membrane Fiber
With (a) Penetrating Hole (b) Mechanical Damage Including Laceration
(Adopted from Huehmer et al. (2005)

2.3.4 Recommendation

Based on the above discussion and analysis, polymeric MF/UF membranes are recommended for pretreatment to RO membranes for the Scattergood desalination pilot test. Because membrane filtration has experienced operational difficulties at other pilot facilities during red tide events, we also recommend that the LADWP include a chemical dosing system to allow coagulant addition upstream of MF/UF system. Red tide events may also require reduction of the MF/UF flux rate during the event by 25 to 33 percent to maintain reasonable cleaning intervals, as has been noted in other pilot facilities. These issues will be discussed further in the protocol development phase and evaluated during the pilot testing. Where granular media filtration is employed for coarse solids removal, coagulants should be added ahead of that process rather than into the MF/UF feed.

2.4 Disinfection

The oxidation/disinfection step in the SWRO process is provided to reduce biofouling of the RO membranes. Experience has shown that even with MF/UF pretreatment, biofouling is still a significant concern when applying SWRO. By disinfecting the microorganisms that pass through the pretreatment stage, the mass loading of viable microorganisms onto the surface of RO desalination membranes can be minimized. Moreover, disinfection done prior to RO may also be counted toward the overall microbiological reduction requirements established by the CDPH and the USEPA Long Term 2 Enhanced Surface Water Treatment Rule (LT2). The popularity of polyamide TFC membranes has made biological control a key issue due to their inability to tolerate exposure to oxidants like chlorine. To increase the longevity of RO membranes, these oxidants are often eliminated upstream of RO membranes using sulfur based reducing agents, which are known to cause their own unique biofilm problems.

Additional post treatment disinfection would also be required for a full scale plant to comply with CDPH regulations and to provide a disinfection residual. This post treatment disinfection is further discussed in Section 3.

The four disinfection alternatives that are considered here include:

- UV Irradiation
- Chlorine Dioxide
- Chloramination
- No pre-disinfection

A detailed assessment of each of these alternatives follows.

2.4.1 Ultraviolet Irradiation

UV light provides a physical process for the biofilm control without the disadvantages associated with chemical disinfection. UV light is the portion of the electromagnetic spectrum with wavelengths between 100 and 499 nm. Germicidal wavelengths are located in the spectral region of 200 nm to 300 nm. Microorganisms are inactivated by UV light as a result of photochemical damage to nucleic acids. The amount of cell damage depends on the dose of UV energy absorbed by the microorganisms and their resistance to UV. Most bacteria and protozoa require relatively low UV doses for inactivation. A UV dose is a product of UV intensity and the exposure time, expressed as Joules/m^2 (mJ/cm^2). UV intensity is a function of feedwater quality combined with UV equipment design optimization. Exposure time is directly related to flow rate and retention time which are controlled by optimizing reactor design and lamp spacing to minimize short-circuiting.

UV technology is gaining popularity in drinking water and wastewater settings for disinfection because it does not leave any residual following application (e.g. no issues with THM formation) and because it is cost competitive with chorination using sodium hypochlorite. A 0.4 MGD seawater RO plant in Diablo Canyon, California utilizing UV technology (following a media filter) for RO biofouling control has been in operation since 1992 (Prato et al. 2001). This plant has 3 UV units, each operated at 254 nm wavelength. Dosage is 30 mJ/cm^2. Near constant pressure differential seen in eight years of available operating data suggests that UV irradiation is able to effectively prevent biofilm growth in the RO elements. This plant is performing so well that seawater RO membranes did not require any significant chemical cleanings since the start-up. Another utility in Southern California, LBWD, will also be testing UV irradiation technology to prevent biofilm growth on desalination membranes.

2.4.2 Chlorine Dioxide

Chlorine dioxide (ClO_2) is a neutral compound of chlorine in the +IV state oxidation state. It is a greenish-yellow gas, which is highly soluble in water. Chlorine dioxide cannot be compressed or stored commercially as a gas because it is explosive under pressure. Therefore, it is never shipped. It is generated on-site using sodium chlorite as the feedstock. As shown below, a number of different approaches are used to convert sodium chlorite to chlorine gas:

$$5NaClO_2 + 4HCl \rightarrow 4ClO_2(g) + 5NaCl + 2H_2O \quad (1)$$
$$2NaClO_2 + HOCl \rightarrow 2ClO_2(g) + NaCl + NaOH \quad (2)$$
$$2NaClO_2 + Cl_2(g) \rightarrow 2ClO_2(g) + 2NaCl \quad (3)$$

Reactions 1, 2, and 3 explain how generators can differ even though the same feedstock sodium chlorite is used and why pH is important for some generators while it is not for others. In most commercial generators, there may be more than one reaction taking place. Therefore, one key issue is the purity of the chlorine dioxide generated, which is defined as:

$$Purity = \frac{[ClO_2]}{[ClO_2] + [Cl_2] + [ClO_2^-] + [ClO_3^-]} \times 100 \quad (4)$$

There is considerable variability in the attainable yield for the different types of generators. The maximum attainable yield with acid-chlorite generator (Eq. 1) is 80 percent. For the aqueous chlorine-chlorite system (Eq. 2), the maximum yield is 80-92 percent. A variation of the aqueous chlorine-chlorite system is a recycled aqueous chlorine-chlorite system, which results in a higher yield, 92-98 percent, with 10 percent excess chlorine (Cl_2). For the gaseous chlorine-chlorite systems (Eq. 3), yield varies between 95-99 percent with less than 2 percent excess Cl_2 leaving the system.

There is data available from DOW/FilmTec that indicates RO membranes are tolerant of up to 500 mg/L pure chlorine dioxide exposure for one week. However, their tolerance to oxidation by free chlorine is poor. Even though the development of newer generators is helping to reduce excess chlorine generation, the small amounts of excess free chlorine in the generated chlorine dioxide solutions is one of the main obstacles in using this technology for biofouling control for RO membranes. Some manufacturers now claim to have achieved 99.5 percent yield without any trace of excess chlorine; though, such claims have not been verified on seawater applications. There are no known full-scale installations on seawater that use chlorine dioxide for biofouling control of RO membranes.

In all these different types of generators, the ratio of sodium chlorite to chlorine is important. Insufficient chlorine feed will result in a large amount of unreacted chlorite and excess chlorine feed may result in the formation of chlorate ion. One of the most serious difficulties with chlorine dioxide is the lack of reliable and practical techniques for the routine evaluation and differentiation of chlorine dioxide, chlorites, and chlorates in both the generator discharge and the treated water. Because chlorine dioxide uses chlorine (or sodium hypochlorite), all complicated handling and safety procedures applicable to chlorine are automatically applicable to chlorine dioxide. As mentioned earlier, chlorine dioxide prepared by many common processes may contain significant amounts of free chlorine, which could defeat the objectives of using chlorine dioxide to avoid oxidation of membrane material. Finally the chemistry between chlorine dioxide and bromine is also not well established. An additional concern is the chlorine dioxide by-products, chlorite and chlorate, which are regulated by the CDPH.

Thus questions must be answered about the purity of the chlorine dioxide produced, about the resistance of common seawater membranes to chlorine dioxide and regarding the interaction of chlorine dioxide with the bromide ion present in seawater and careful consideration must be given to the resulting by-products.

LADWP is already supporting work at LBWD’s NF-NF demonstration site where a high purity chlorine dioxide generator will be tested in an attempt to answer these questions.

2.4.3 Chloramines

From rigorous testing at Aqua 2000 in San Diego (City of San Diego and Montgomery Watson 1995), and later at the Water Factory 21 (Orange County Sanitation District), full-scale application at West Basin and several other wastewater reclamation plants, it is known that RO membranes are reasonably tolerant to chloramines. This is primarily because chloramines are much weaker oxidant than free chlorine. This strategy of using chloramines ahead of seawater RO membranes was explored in pilot studies by West Basin (Shoenberger 2005). In these studies, the same dosing approach used to form chloramines in wastewater and drinking water applications was applied to seawater, namely sequential addition of chlorine and ammonia to process flow. Unfortunately, the residual produced when applied to seawater oxidized RO membranes. A close examination of chemistry has revealed that the traditional approach of forming chloramines results in the formation of bromamines and chlorobromamines in seawater, both of which are more potent oxidants than chloramines and behave much like free chlorine.

One alternative to avoid formation of bromamines would be to add “pre-formed” chloramines to seawater. The pre-formed chloramines is expected to react much more slowly with bromide ion to form bromamines. At this stage, however, this strategy has not been demonstrated. Experiments involving pre-formed chloramines to control bromamines for seawater desalination are being conducted at West Basin and more information will be available in the near future.

2.4.4 No Pre-Disinfection

The approach in this alternative is to rely on the pretreatment process alone to prevent bacteria from reaching the RO membrane and forming a biofilm. RO systems that do not have a biocide, or disinfection process, for the feedwater are likely to suffer from biological activity. The removal of microorganisms by MF/UF membranes is not always complete, particularly when the membrane integrity has been compromised, and it can therefore be extremely difficult to maintain a sterile environment on the RO elements.

Partial removal by MF/UF membranes. Because of wide pore size distributions, smaller size bacteria can sometimes pass through both MF and possibly UF membranes. West Basin's desal pilot project had a noticeable biofouling issues when operating on warmer feed water. The analysis of the heterotrophic plate count data collected during their study showed that around 30 percent of the time MF filtrate had a significant number of HPC present, indicating that bacteria were getting through the MF process. While membrane integrity issues were also a concern during this pilot, it did not appear that all of the HPC hits could be directly linked to a membrane integrity failure.

Membrane integrity losses may accelerate biofouling of RO membranes. Incidental membrane fiber breakage is common to all types of polymeric membrane filtration plants. In such cases, disinfection following pretreatment provides an additional line of defense against bacteria reaching to the RO elements.

Small, viable but nonculturable organisms (VBNC) may also pose a problem: There is some evidence in the literature that suggests that in the nutrient deficient environment of seawater, many of the marine microorganisms enter into a viable but nonculturable state as a defense to starvation conditions (Oliver 1999). These organisms are not detected by traditional, culture based analytical method, like the HPC method. The size of these organisms can be as small as 0.2 micron, which means that they may be difficult to remove by membrane filtration. When environmental conditions are conducive, these organisms can resuscitate on the surface of the RO membranes and form a biofilm (Winters 2006).

2.4.5 Analysis

The following discussion reviews these pre-oxidation/disinfection alternatives using the following five criteria: 1) Environmental sustainability, 2) Suitability as a high quality domestic supply, 3) Operations and maintenance, 4) Uncertainty, and 5) Cost. Table 2-11 shows a qualitative overview of the four principal pre-oxidation/disinfection alternatives from the standpoint of these evaluation criteria.

Table 2-11
Overview of Pre-Oxidation/Disinfection Alternatives

Alternative	Environmental Sustainability	Water Quality	O&M	Life Cycle Cost	Uncertainty
UV Irradiation	Good – although largest facility, highest energy requirements	Excellent – no byproducts	Excellent	Low	Medium
Chlorine Dioxide	Good – requires use of multiple hazardous chemicals	Fair – may cause DBPs if excess chlorine, chlorate, or chlorite	Fair – on site generations adds complexity to O & M	Medium	High
Chloramines	Good – requires use of multiple hazardous chemicals	Good – lower potential for DBP formation	Good – although risk of bromamine formation may cause RO damage	Low	High
No Pre-disinfection	Excellent	Good	Good – although bacteria may pass MF/UF membranes and result in biofouling	None	High

All the alternatives look relatively similar with regard to environmental sustainability. Alternative A, ultraviolet irradiation, was rated slightly lower because it requires the largest facility and has the highest energy requirements though it should be noted that the low UV dose required reduces the energy and footprint requirements compared to those necessary for a larger UV dose. This alternative does not require the use of hazardous chemicals, reducing the risk of chemical spills or other related environmental impacts.

Alternative A, UV irradiation, looks best in terms of water quality because it minimizes the potential for organic and inorganic byproduct formation while at the same time eliminating biofouling of the RO membranes. While alternative D, the no pre-oxidation/disinfection alternative, rates good in terms of water quality, it must be stated that it is not certain that the application of MF/UF membranes in the absence of a pre-oxidation/disinfection step will avoid biofouling problems on the RO membranes. Alternative C, chloramines, was also rated "Good" because of the potential for DBP formation. Alternative B, chlorine dioxide, was rated lowest of the four alternatives ("Fair") in terms of water quality because of the potential for DPB formation if excess free chlorine is fed and because of the potential for inorganic byproducts chlorite and chlorate.

Regarding O&M, Alternative A, UV irradiation, is rated the highest ("Excellent") because it is the easiest of the four alternatives to operate to avoid biofouling problems. Alternative B, chlorine dioxide, is rated lowest ("Fair") because of the potential problems that may arise if excess or insufficient free chlorine are fed. Alternative C, chloramines, and Alternative D, no pre-oxidation/disinfection, are slightly down-rated in terms of O&M ("Good") because of the potential for the applications to result in oxidation of the RO membranes (due to formation of bromamines when chloramines are applied) or to fail to prevent biofouling of the RO membranes (due to inability of MF/UF membranes to inactivate bacteria when no pre-oxidant/disinfectant is applied).

With regard to cost, Alternative A, UV irradiation, is competitive with Alternative B, chlorine dioxide, and Alternative C, chloramines, but Alternative C is rated slightly better ("Low") than Alternatives A and B ("Medium"). Alternative D, the no-pre-oxidation/disinfection alternative, has no cost but may not result in prevention of biofouling of the RO membranes. With respect to technical uncertainty, Alternative A, UV irradiation, has been tested and is in use at several operational desalination facilities. The process was therefore rated as "medium" in terms of technical uncertainty, which is a better rating than the other three alternatives, all of which are rated "high" in terms of technical uncertainty given that they have not yet been successfully applied in practice or have significant concerns on their effectiveness.

2.4.6 Recommendation

As indicated above, biofouling of RO membranes remains one of the most intractable problems encountered in seawater desalination, particularly with warm water. At this time, UV irradiation technology appears to be the most viable biofouling control alternative for the LADWP's future piloting effort, due to the uncertainties and O&M requirements for the other disinfection alternatives. We recommend that pilot testing be conducted side by side with and without UV irradiation technology (1) to determine the extent of biofouling in the absence of any disinfection, and (2) to confirm the effectiveness of UV irradiation for biofouling control in a seawater setting

2.5 Coarse Solids Removal

The main objective of this section is to present a technology overview of processes capable of preventing coarse solids (sediment, shell fragments, debris, suspended solids, and aquatic life) from reaching the seawater desalination pre-treatment processes. The primary mechanism of coarse solids removal is through physical screening (or straining), which can be accomplished by processes listed below or a combination of these processes depending on the intake feed water quality and the type of the pre-treatment downstream.

- Rotating Disc Filters
- Inline Strainers
- Coarse Media Filtration

- Dissolved Air Flotation

A detailed assessment of each of these technologies including commercial availability, performance history, design criteria, and operation and maintenance requirements is provided below.

2.5.1 Rotating Disc Filters

Arkal Water Filtration Systems, one of the leading manufacturers of the rotating disc filter technology, is based in Israel and has representation in the United States. At the heart of their Spin Klin Disc Filtration technology are specially designed discs that are diagonally grooved on both sides to a specific micron size. A series of these discs are stacked on a specially designed spine (shown in Figure 2-14), which creates multiple filtration channels with a significant number of valleys and traps for solids. During the filtration process, the discs are tightly compressed together by the force of spring. Water is then passed through the stack of discs using an applied differential pressure (e.g. maximum 29 psi for 100 micron) and filtration occurs as water travels through the grooves or filtration channels at the designed specific micron size, from the outer edge of the discs to the center element. The stack of specially grooved discs with multiple intersections increases the probability of retaining the particles of a specified size, providing efficient particle removal and longer filtration cycles.

The Arkal discs are color coded and come in different grades ranging from 20 to 400 micron (most commonly employed is around 100 microns). This proprietary disk filter has seen wide application in pilot-scale seawater desalination process trains in the United States (e.g. Port Hueneme, San Patricio, WBMWD, Carlsbad, Marin). Table 2-12 qualitatively describes the types of particulate retained and passed during a seawater desalination pilot study at the Naval Facilities Engineering Service Center located in Port Huenema, California.

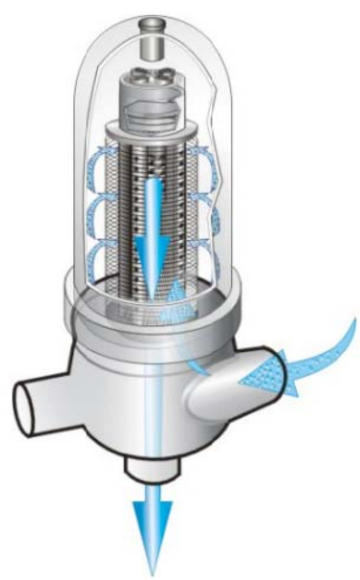


Figure 2-14
Spin Klin Arkal Filter in Normal Filtration Mode

Table 2-12
Description of Particulate Constituents on Filters and in Filtrate
(Adapted from (Huehmer et al. 2005))

	Red discs	**Black discs**	**Green discs**	**Gray discs**
	130 μm	**110 μm**	**65 μm**	**25 μm**
Retained on Filters	Particulates larger than 150μm and flocks of organic residuals and silt	Zooplankton and larvae; Algae >90μm; flocks of organic residuals; and sand & silt>200μm	Larvae and eggs; diatoms, golden algae and dino-flagellates	Zooplankton, larvae and eggs; flocks of organic residuals; silt algae >25-30μm including dino-flagellates
Present in Filtrate	Some zooplankton, mostly larvae <150μ	Diatoms and dino-flagellate. Smaller algae.<90 μm	Algae smaller than 40 - 50μm. Silt & sand particles <50 μm.	Algae <25-30μm. Very fine silt/sand particles <20 μm.

These disc filters are available in various sizes, ranging from inch to 1 inch (dia), and more filtration "spines", or stacks of filter discs, are added to meet increased flows. The filtration rate per spine varies from 10 gpm to 70 gpm, depending upon the raw water quality, grade and diameter of discs. The solids retained during filtration are collected at the surface of the disc stacks and these solids are removed during a backwash. During a backwash, the spring compression on the discs is released and a jet of water, along with compressed air, is passed over the discs, which removes all the solids from the entire surface of the discs. The backwashing cycle can be initiated either by timer or pressure differential. When the influent solids content is high the frequency of backwash increases, but the filtered water quality does not degrade.

The advantages of rotating disc filters include the following:

- Automated operation
- Corrosion resistance material (filters are made up of polypropylene material and are housed in a polymeric chamber)
- Lightweight makes them amenable to easy cleaning
- Modular design offers a wide range of options for system layouts and operational flexibility (see Figure 2-15)

The disadvantages of rotating disc filters include the following:

1. No full-scale application on seawater desalination
2. Limited solids loading capacity
3. Proprietary technology
4. Large footprint requirement.

5. Site specific filter cut-off required with some barnacle larvae as small as 50 microns

Figure 2-15
Spin Klin modularity allows for a wide range of system layouts

2.5.2 In-Line Strainers

S. P. Kinney Engineers, Inc., located in Carnegie, Pennsylvania, is one of the leading manufactures of in-line strainers, however, similar systems are manufactured by Hayward, Fluid Engineering, and Amiad, among others. Kinney has over 50 installations in the United States on seawater sources, including one at the seawater desalination demonstration plant in Long Beach. An automatic self cleaning strainer consists of a rotating drum with threaded holes containing one of many types of metallic strainers (shown in Figure 2-16). The construction material for the rotating drum is Ni-resist or aluminum bronze and for the metallic strainers it is either stainless steel, super duplex stainless, or monel. The straining media is available in different mesh sizes, ranging from 20 to 400 micron. For seawater applications, sacrificial zinc anodes are often installed inside the drum to prevent corrosion of metallic parts when corrosion resistant materials are not used.

Figure 2-16
Kinney Automatic Self Cleaning Strainer: Outside body and different types of straining media.

Feed water enters the inlet connection, located in the lower portion of the body, under positive pressure (e.g. around 20 psi) and water flows around the outer surface of the drum. The coarse solids particles are strained out by the screen and filtered water leaves the system through an outlet opening located diametrically opposite the inlet. As each row of straining media is rotated past the backwash slot, a reversal of flow occurs, flushing the suspended particles from the screening device. This reversal of flow can be actuated by a timer or a pressure differential switch (or both). If the flow reversal frequency needs to be increased then the rotational velocity must be increased. The rejected solids will accumulate in the strainer and a waste stream, or "backwash" stream is provided. Using a clear panel in the side of the strainer body, the solids content at a given condition can be qualitatively assessed and the backwashing frequency or wasted volume adjusted as needed. The straining media can also be inspected or changed through this opening which allows operations to visually inspect the process while the strainer is in operation.

2.5.3 Coarse Media Filtration

Another alternative is deep bed GMF, operating at a high filtration rate, as a pre-screen to low-pressure membranes for a pretreatment process train for seawater desalination. The high rate GMF is the same technology that has been implemented for drinking water and seawater desalination around the world.

High rate deep bed GMF has been pilot tested at rates as high as 40 gpm/ft^2 on surface waters, but has not been pushed to these limits on seawater. One of the highest rate deep bed GMF design filtration rates is 13.5 gpm/ft^2 at the Los Angeles Aqueduct plant. In drinking water facilities, the design rate of these GMFs is controlled by regulatory considerations (i.e. CDPH places upper limits on the filter rates that can be used if credit for removal of Giardia, Cryptosporidium or viruses is to be obtained by the filtration step). In this application, the GMF will serve as a protective barrier to low-pressure membrane pretreatment for seawater desalination and will not be impacted by these CDPH limits. The depth of media and recommended loading rate will depend on the feed water quality, product water quality requirements, and other specific conditions for the application, and must be determined at a later date if this process is selected.

The proposed high rate deep-bed GMF should be conceived as a roughing filter that will pre-screen solids to prevent potentially damaging debris and solids from reaching the MF/UF membranes. In addition to its primary purpose which is to protect the MF/UF membranes from sharp objects, the deep-bed filters will serve to reduce the solids loading to the MF/UF membranes and provide the potential for increased flux rates.

It is important to note that no coagulant addition may be required under normal operating conditions. However, during red-tide events or other seasonal high turbidity or organics events, coagulant addition could assist in improving the filterability of the flocs thus sustaining the filtration rates of both granular media and membrane filtration units without compromising the filtrate water quality. Thus, by protecting MF/UF membranes with a complementary pretreatment, such as high rate deep bed GMF, the treatment train will produce a more consistent, high quality RO feed water, even under the worst ocean water quality conditions. Because significant portions of the raw ocean water solids will be removed by the GMF, MF/UF fluxes may be potentially increased or backwashing frequencies potentially decrease. Other significant advantages of the high rate GMF include the following:

1. Use of a widely-employed and practiced technology
2. Well-documented performance and high reliability at large scale
3. Fewer parts and greater simplicity
4. Non-proprietary technology made of readily available materials and with readily available replacement parts
5. Greater energy efficiency (lower energy requirement).

2.5.4 Dissolved Air Flotation

Dissolved air flotation (DAF) is a unit operation for the separation of solid and semisolid (floc) particles from a liquid phase that has been used for clarification of potable water for over 40 years (Crittenden et al. 2005). Air bubbles are introduced near the bottom of the basin containing the water to be treated. As the bubbles move upward through the water, they become attached to the particles and the buoyant force of the combined particle and air bubble will cause the particles to rise to the surface. Thus, particles that have a higher density than a liquid can be made to float. Once on the surface, the particles are collected by a skimming operation.

As a general rule, DAF is most effective in solid-liquid separations involving:

1. The separation of low-density particulate matter such as algae and oily wastes,
2. Supplies with high dissolved organic matter (natural color),
3. Low-to-moderate turbidity waters, and
4. Low temperature waters.

In 2005, a full-scale "in-filter DAF process" was implemented at the Tuas Seawater Treatment Plant in Singapore to protect sand media gravity filters. The primary reason for selecting DAF was the high oil content (~ 10 mg/L) of the raw seawater. Conventional DAF is also approved as a best available technology for *Cryptosporidium* removal by the USEPA. As DAF is not a proprietary process, there are multiple vendors of DAF equipment.

Because heavy particles are difficult to float, generally, DAF is not effective against shells, some larvae, sand, or silty material present in seawater. As a result, there are significant concerns that this material would either accumulate in the DAF or pass directly through the DAF. Without an additional coarse-screening process, this material, which has been identified in previous studies as the primary constituents to be addressed by any coarse screen technology (NWRI, 2005), is still a concern for potential downstream pretreatment processes like MF/UF membranes.

2.5.5 Analysis

The following discussion reviews these coarse solids removal alternatives using the following five criteria:

1. Environmental sustainability,
2. Suitability as a high quality domestic supply,
3. Operations and maintenance,
4. Uncertainty, and
5. Cost.

Table 2-13 shows a qualitative overview of the four principal coarse solids removal alternatives with regard to these evaluation criteria.

Table 2-13
Overview of Coarse Solids Removal Alternatives

Alternative	Environmental Sustainability	Water Quality	O&M	Uncertainty	Cost
Rotating Disc Filters	Good	Excellent	Good	Medium	Medium
Inline Strainers	Good	Good	Good	Medium	Low
Coarse Media Filters	Excellent	Excellent	Excellent	Low	Medium
Dissolved Air Flotation	Good	Poor	Good	High	Medium

All the alternatives look similar with regard to environmental sustainability, however, Alternative C, coarse media filters, was rated higher ("Excellent") because it opens the possibility to return entrained organisms to the ocean, during periods when coagulant is not employed. With respect to water quality, Alternative A, rotating disc filters, and Alternative C, coarse media filters, rated highest ("Excellent"); whereas, Alternative B, in-line strainers, was rated slightly lower ("Good"), because of some performance issues that have been reported at other seawater pilots testing both rotating disc filters and inline strainers (Marin, California is one example). This poor performance may be related more to the mesh size used than the strainer configuration, however, some uncertainty remains on the reliability of the currently available inline strainers. Alternative D, DAF, was rated "Poor" because the technology does not remove effectively heavy particles that are difficult to float (e.g., shells, some larvae, sand, and silty material). This poor performance of in-line DAF with respect to water quality is enough to remove it from further consideration on the project.

With respect to O&M, Alternative C, coarse media filters, ranks highest ("Excellent") because GMF is a straightforward application of a technology commonly used in full-scale seawater desalination; whereas, Alternatives A and B, were ranked slightly lower ("Good"). For the rotating disc filter, the lower ranking was due to the numerous parts that require a higher degree of maintenance to assure proper functioning. For the inline strainers the number of parts is considerably less, however, there is additional concern of clogging, blinding, or damage to the screening mechanism which could create a higher level of maintenance. Regarding cost, Alternative A, rotating disc filters, and Alternative C, coarse media filters, are comparable, both given a ranking of "medium," while the inline strainers were ranked better, at a "low" cost. With regard to technical uncertainty, Alternative C, high-rate GMF, is ranked the best (low technical uncertainty) because it is a proven technology regularly employed in seawater desalination; whereas, Alternatives A and B are ranked somewhat lower (medium technical uncertainty) because of either uncertainty in the reliability of the produce water (inline strainers) or a lack of history for use in full scale seawater applications (rotating disc filters).

2.5.6 Recommendation

Based on the above assessment, the two coarse solids removal technologies that show the most promise for the pilot study include: (1) rotating disc filters, and (2) coarse media filters. While inline strainers are the most common method used in water treatment for coarse solids removal upstream of MF and UF membranes, their use has not been fully implemented at full scale seawater facilities for these purposes. In contrast, the rotating disc filters have proven to be an effective coarse solids removal step in other recent pilots conducted here in California (Marin, West Basin, Carlsbad). Inline strainers do appear to be functioning relatively well, however, at the Long Beach demonstration plant, and could prove to be an equally effective alternative to the rotating disc filter. The project team recommends that rotating disc filters and coarse media filters both be incorporated into the pilot plant, operated on parallel process trains to better characterize the performance characteristics in a side-by-side evaluation.

2.6 Recommended Treatment Trains for Pilot Study

This Section provided a review of the treatment technologies and processes available to the City of LADWP for a seawater desalination pilot plant study. Our analysis included an assessment of: 1) seven alternatives for desalination (reverse osmosis, forward osmosis, nanofiltration, electrodialysis/electrodialysis reversal, multi-stage flash distillation, multiple effect distillation, and membrane distillation), 2) three pretreatment processes (conventional/inline granular media filtration, polymeric membrane filtration, and ceramic membrane filtration), 3) four oxidation/disinfection alternatives (UV irradiation, chlorine dioxide, chloramines, and no pre-disinfection), and 4) four coarse solids removal technologies (rotating disc filters, inline strainers, high rate deep-bed GMF, and dissolved air flotation).

The evaluation criteria used to assess the suitability of a process for the LADWP's pilot plant study were: (1) environmental sustainability, (2) ability to provide a high quality domestic water supply, (3) requirements for operations and maintenance, (3) technical uncertainty and (4) lifecycle cost. Discussion of these recommendations were presented previously and are summarized below in Table 2-14

Table 2-14
Summary of Recommendations for Pilot Testing Process

Desalination		Pretreatment		Oxidation/Disinfection		Coarse Solids Removal	
Process	**Recommendation**	**Process**	**Recommendation**	**Process**	**Recommendation**	**Process**	**Recommendation**
MSF	Do not pursue	Conventional Treatment	Do not pursue	UV	Include in pilot	Rotating disc filter	Include in pilot
MED	Do not pursue	Direct Filtration	Do not pursue	Chlorine dioxide	Do not pursue	Inline strainers	Continue involvement with Long Beach Project
SWRO	Include in pilot	Polymeric MF/UF	Include in pilot	Chloramines	Do not pursue	Coarse media filtration	Include in pilot
Membrane Distillation	Do not pursue	Ceramic MF/UF	Do not pursue	No pre-disinfection	Include in pilot	DAF	Do not pursue
Forward Osmosis	Do not pursue						
EDR	Do not pursue						
NF-NF	Continue involvement with Long Beach Project						

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2.6.1 Discussion of Testing

The above recommendations include two parallel treatment trains treating the same source water or being split between warm and cold source water. These are presented below in Figure 2-17. The principal difference between the trains is the manner in which they handle coarse solids. Train A employs a granular media filter and Train B a rotating disc filter, however, additional differences may also be recommended for the two process trains, such as dedicating one to warm and one to cold water, employing high boron rejection RO elements in one of the two trains, bypassing the UV in one of the two trains, or operating the pretreatment or RO systems at different filtration rates or recoveries. Specifics of the operating conditions are identified in Section 3 of this Report, and were developed through discussions between the technical advisory team and the LADWP project team.

Provision should be made for coagulant addition upstream of MF/UF membranes, on both trains. This may prevent accelerated MF/UF fouling during seasonal upsets and red-tide events. A by-pass line for UV irradiation technology would allow testing with and without disinfection. Importantly, the two parallel trains provide the needed flexibility to test a variety of technology combinations within the timeframe reserved for this piloting effort.

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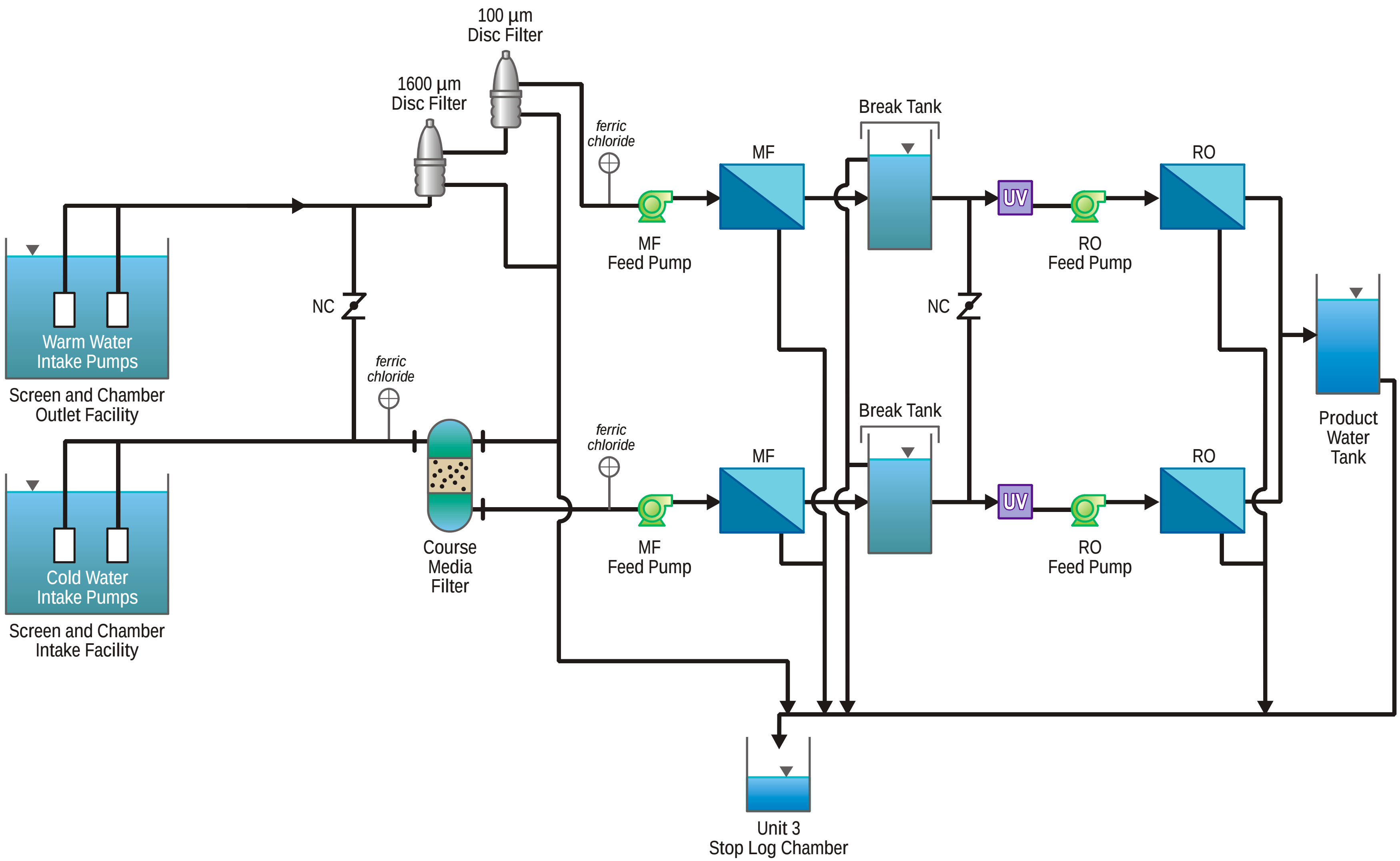

Figure 2-17
Recommended Treatment Trains for the LADWP's Seawater Pilot Plant.

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Section 3
Process Recommendations

This section includes processes recommendations for the Scattergood Seawater Desalination Pilot, including water quality goals (Section 3.1), recommended operating conditions (Section 3.2), pilot description (Section 3.3), schedule of principal investigations (Section 3.4), post-treatment considerations (Section 3.5), and recommendations for future studies (Section 3.6).

3.1 Water Quality

The purpose of this discussion is to develop and explain the water quality criteria that will be used to evaluate the performance of the desalination process at various points in the treatment train. The discussion will begin with some general comments about the water quality of the source water, seawater, followed by discussion of the water quality goals that have been set for the unit process and for the domestic water supply (finish water quality). It is the difference between these water qualities that drives the design of the desalination process itself. For purposes of this discussion, the overall process train will be divided into the five general steps shown in Figure 3-1 and water quality criteria useful for monitoring process operation and control will be specified for the output from each of these treatment steps (yellow boxes). It should be noted that these are the same unit processes presented previously in sections 1 and 2 of this report, with the addition of post treatment which will be required to produce acceptable water which blends effectively with existing water in the distribution system.

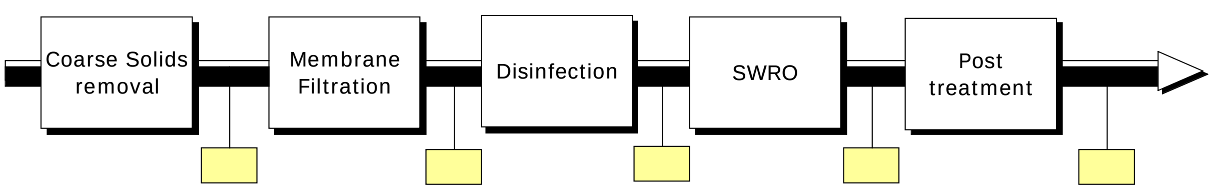


Figure 3-1 Overall Process Train Showing Points where Water Quality Operational Parameters Will Be Specified (Yellow)

3.1.1 Seawater Quality

Although it does vary slightly from one place to another, the relative concentrations of the minerals in seawater are remarkably consistent. This observation was made in 1884 by Dittmar, who after sailing around the world and studying seawater, published the first complete exposition on its mineral quality (Dittmar, 1884). Table 3-1 summarizes an update on the mineral character of average seawater as determined by Dittmar and compares it to the local water supply in Los Angeles and to national statistics. Work done at El Segundo in connection with the West Basin Project shows that the TDS of seawater in the Scattergood/El Segundo area varies from 27,000 mg/L to 38,000 mg/L, but averages, 34,000 mg/L a composition virtually indistinguishable from that identified by Dittmar. In Table 3-1, the minerals in each water are ranked by their relative abundance in seawater. Together, sodium and chloride make up 86 percent of seawater's mineral content. More importantly, RO is more efficient at rejecting divalent ions like calcium, magnesium, and sulfate. As a result, seawater that has been desalinated by RO is dominated by chloride and sodium to an even greater degree than is the seawater itself. Also important are the relatively high concentrations of bromide and boron in seawater. Bromide is present in seawater at much lower levels than are chloride and sodium (Table 3-1), but even at trace levels it can have adverse impacts on the formation of disinfection byproducts and the stability of disinfectant residuals. Boron is important because seawater RO does a relatively poor job of removing boron, resulting in concentrations in the desalted water that are rarely seen in municipal water supplies. As will be seen, all these minerals, sodium, chloride, bromide and boron are important to understanding the suitability of a desalted supply that is to be put to domestic use.

Table 3-1
Comparing the mineral quality of Seawater with the LA Domestic Supply and with Other Surface Waters in the U.S.

Constituent	Seawater[1]	LAAFP[2]	U.S. Waters[3]	
			Median	Upper Quartile
Chloride (mg/L)	18,506	25	10	20
Sodium (mg/L)	10,293	34	30	80
Sulfate (mg/L)	2,583	30	30	75
Magnesium (mg/L)	1,240	5.8	10	20
Calcium (mg/L)	390	26	40	60
Potassium (mg/L)	371	3.7	2	4
Alkalinity (mg/L)	137	100	190	250
Bromide (mg/L)	63	< 0.02	0.02	0.06
Boron (mg/L)	4.4	0.42	0.08	0.2
Fluoride (mg/L)	1.0	0.57	0.2	0.4
TDS (mg/L)	33,533	195	330	480

1. Typical composition found by Dittmar in 1884
2. The treated water from the Los Angeles Aqueduct Filtration Plant
3. JMM, 1985, Water Treatment: Principles & Design

3.1.2 Process Water Quality Criteria

Knowing the general water quality of seawater and the limitations and potential weaknesses of the technologies employed, water quality criteria can be established for each of the unit processes. Criteria for the upstream processes will be primarily based on the water quality needed to protect the operation of the downstream processes, while the criteria for the final desalination step will be based on compliance with regulatory requirements. The following discussion presents these criteria for each of the unit processes included in the desalination pilot. Following this discussion, additional water quality goals will be discussed, some of which will require subsequent post-treatment processes to achieve.

3.1.2.1 Coarse Solid Removal

Pilot testing of membrane filtration as a pretreatment for SWRO at Southern California Power Plants, as discussed in section 1.2, suggests that the process should be preceded by a unit operation designed to remove shards, shell fragments and other materials that may adversely impact membrane integrity. An appropriate water quality goal for determining whether the coarse solids removal process is producing a water quality suitable for feeding a low-pressure membrane is a particle size distribution. Particle counting to characterize the effluent from the coarse solids removal process is the most meaningful measurement to assess the product water quality. However, in the absence of data, the particle counting goals established in this memorandum are an approximation of what can be anticipated and may require revision.

A concentration of particles greater than 100 µm must count less than 1/mL 95 percent of the time. This is based on the fact that the recommended disk filter will incorporate a 100 µm cut-off for particle size. After particle counting data has been collected, it is recommended that the particle size requirements be revised, as needed. These goals are presented graphically in Figure 3-2.

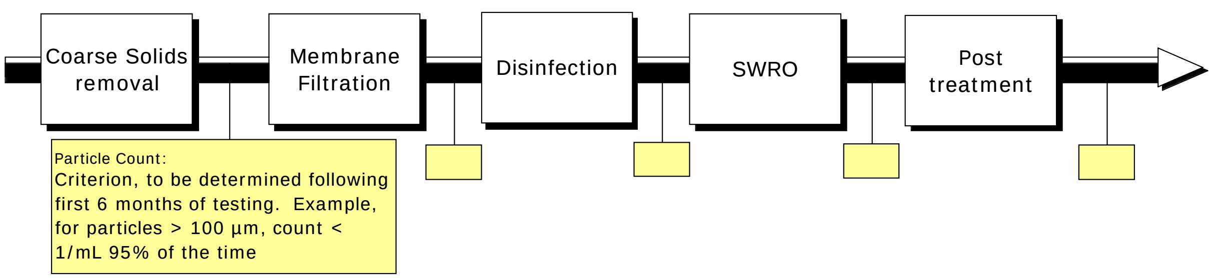


Figure 3-2 Process Flowsheet Showing water Quality Criteria Following Coarse Solids Removal

3.1.2.2 Membrane Filtration

The implementation of low-pressure membrane filtration as the selected pretreatment process ensures that a consistent, high quality feedwater is provided to the SWRO process. To measure the effectiveness of this SWRO pretreatment process, 15-minute SDI and turbidity will be monitored. SDI is the industry standard for spiral wound desalination membranes, such as SWRO. Although it is not always clear what an SDI measurement means in terms of a water's fouling potential, RO manufacturers recommend an average feedwater SDI between 2 to 3 and a never to exceed value of 5 should be met. It has been decided that the Scattergood desalination pilot will employ membrane filtration as the principal pretreatment process. To ensure compliance with regulatory requirements for filtration of surface water, the permeate turbidity cannot exceed 0.15 NTU for 2 consecutive readings with turbidity measurements being reported every 15 minutes. A median turbidity of < 0.1 NTU must also be met to ensure a high quality SWRO feedwater. These goals are presented graphically in Figure 3-3.

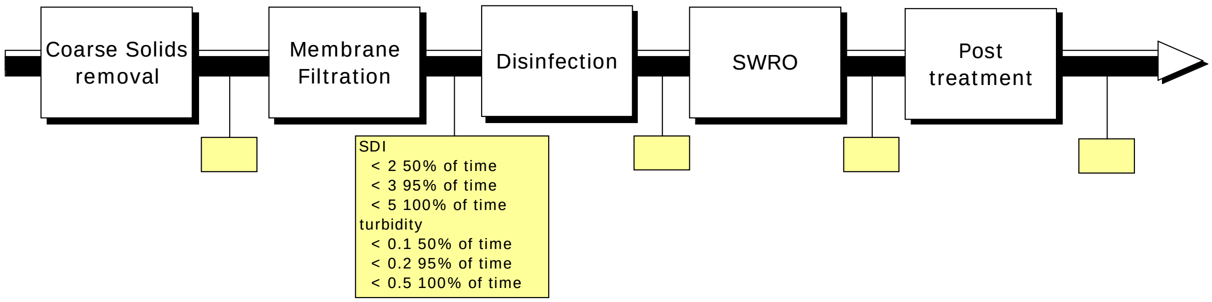


Figure 3-3 Process Flowsheet Showing Water Quality Criteria Following Membrane Filtration

3.1.2.3 Pre-Desalination Disinfection

Biofouling is one of the classic problems encountered when desalinating ocean water with reverse osmosis membranes and this problem has not been completely resolved. Biofouling has occurred even downstream of the most advanced pretreatment technologies, such as low-pressure membrane filtration, and is particularly persistent when treating warm seawater. To address the potential of controlling biofouling, the project team will investigate a disinfection process on the low-pressure membrane filtrate before being fed into the SWRO. Using the data generated by the WBMWD seawater pilot testing, the heterotrophic plate count (HPC) was below detection in 70 percent of samples. This means that 30 percent of the time, positive HPC results were being attained for the low-pressure membrane filtrate.

On a similar note, WBMWD has been actively monitoring the viable but VBNC levels through the treatment train. VBNC is an attempt to quantify those bacteria that cannot be cultured using typical analytical methods. There is some debate as to the significance of a VBNC measurement because it is impossible to establish the "viability" of the microorganisms being measured using nucleic acid quantification methods. Regardless, WBWMD's data collected by U.C. Irvine using an epifluorescence method shows that although the VBNC counts were reduced from $10^{6.5}$ down to between $10^{4.3}$ and $10^{4.6}$ through the low-pressure membrane (MF and UF) filtration, there was still significant removal through the RO process as the RO permeate contained only $10^{3.7}$. This means that we are depending on the RO process to provide approximately 1-log of additional VBNC removal. All these organisms which are retained on the RO membrane could potentially cause biofouling. For this pilot project, water quality goals to assess the disinfection process to control SWRO biofouling have been identified based on the more widely applied HPC to achieve less than 1 CFU/mL 95 percent of the time and never to exceed less than 10 CFU/mL (see Figure 3-4).

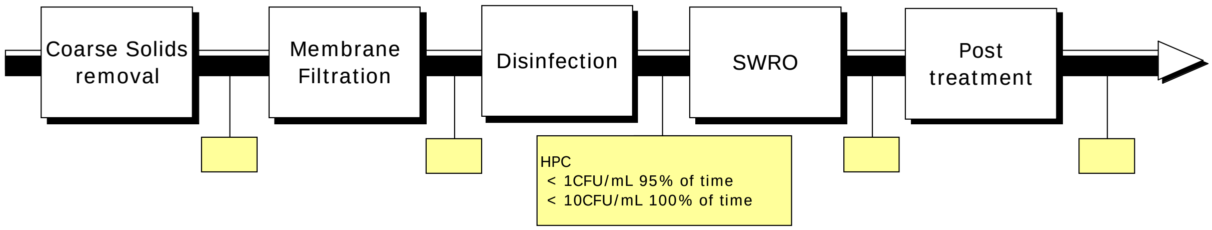


Figure 3-4 Process Flowsheet Showing Water Quality Criteria Following Disinfection

3.1.2.4 Desalination

SWRO is the central process in the overall treatment train that we are depending upon to transform highly mineralized seawater to a potable water quality. SWRO removes dissolved salts along with other constituents of concern from the feedwater, producing a water quality that far exceeds established drinking water regulations for most parameters. There are more than four established membrane manufacturers of SWRO elements active in the U.S. market, and many companies have various products available for SWRO applications.

The CDPH requires that seawater desalination plants supplying water to domestic systems meet conventional drinking water regulations, specifically achieving the maximum contaminant levels (MCLs) established under California Code of Regulations (CCR) Title 22. In addition, CDPH requirements specify that treatment facilities be designed to target no higher than 80 percent of the regulated limit for the treated constituents. Water quality goals for the SWRO system have therefore been established to comply with this 80 percent target for all parameters regulated as MCLs.

While there are a myriad of parameters regulated by CDPH, the parameters of concern for SWRO are typically TDS, chloride, and boron, as the product water quality for all other parameters should be expected to fall far below the regulated MCLs. Based upon seawater pilot testing performed at WBMWD for various membrane fluxes (10 and 12 gfd) and feedwater temperatures (15 to 30^{o}C), the typical SWRO permeate contained TDS ranging from 100 to 180 mg/L, chloride concentrations ranging from 59 to 100 mg/L, and boron concentrations ranging from 0.3 to 1.0 mg/L using FilmTec's SW30HRLE4040 and Toray's TM810 SWRO membranes.

This can be compared with a TDS secondary MCL of 500 mg/L and a chloride secondary MCL of 250 mg/L, and the 80 percent treatment goals of 400 mg/L TDS and 200 mg/L chloride. For boron, there is no MCL, but rather a non-regulated notification limit with CDPH. As a result, the target boron concentration was set at the notification level of 1 mg/L. Table 3-2 presents the regulated limits and treatment goals for the SWRO pilot. The most critical of these goals (TDS, chloride, and boron) are presented graphically in Figure 3-5 for the SWRO system.

Table 3-2
Scattergood Seawater Desalination Pilot Water Quality Goals

Parameter	Regulated Limit	SWRO Pilot Goal
Chloride	250 mg/L	200 mg/L
TDS	500 mg/L	400 mg/L
Boron	1 mg/L	1 mg/L
Title 22 Parameters	MCL	0.8 x MCL

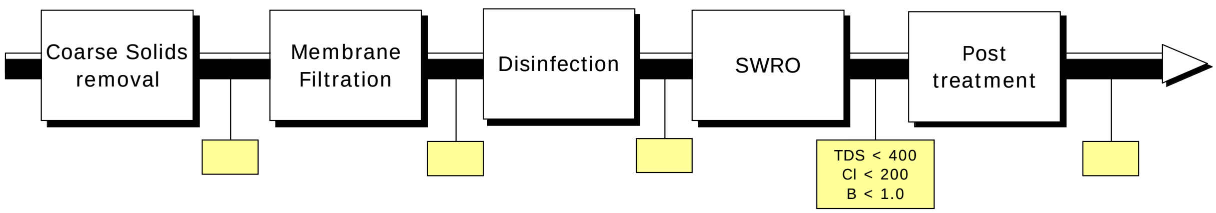


Figure 3-5 Process Flowsheet Showing Water Quality Criteria Following SWRO

3.1.2.5 Process Water Quality Summary

Figure 3-6 provides a summary of the water quality objectives defined in this discussion. These water quality objectives have been established to assess the various treatment processes in the overall seawater desalination treatment train. Each treatment process has a unique water quality objective that has been clearly defined based upon regulations or water quality concerns. It is recommended that the water quality objectives for the coarse solids removal process be re-evaluated after some data collection has occurred.

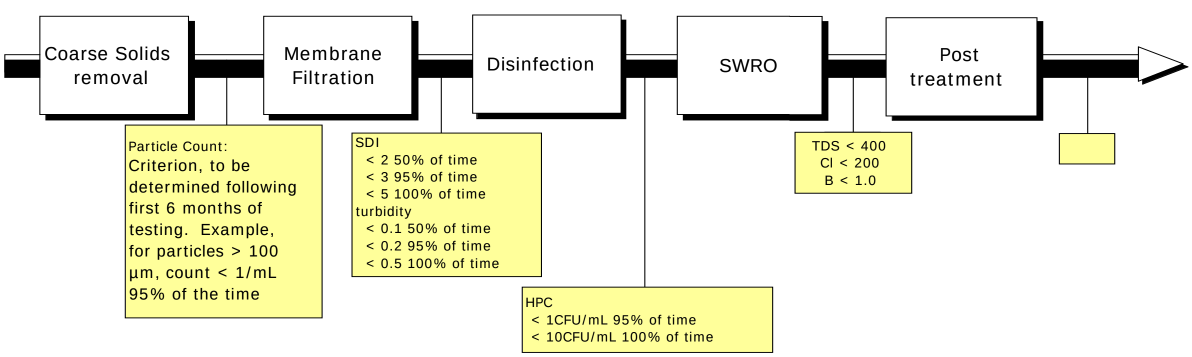


Figure 3-6 Process Flowsheet Showing Entire Seawater RO Pilot

3.1.3 Finished Product Water Quality Goals

While the unit process water quality goals defined above will ensure that the treatment process removes all regulated contaminants below their allowable limits, post treatment processes will be required to produce a water compatible with the existing domestic supply and in compliance with CDPH disinfection requirements. Finished product water quality goals will therefore be discussed below, with recommendations for how to achieve these goals discussed further in Section 3.5 – Post Treatment Considerations. This discussion will focus on the disinfection requirements, the mineral goals that derive from the unique mineral quality of desalted seawater, and the temperature, which will only be a concern when treating warm water. As a result, the discussion will address the targets that must be set for sodium, chloride, bromide and boron, as well as the targets that should be set for calcium, alkalinity and pH.

3.1.3.1 Regulated Disinfection Requirements

Disinfection requirements for drinking water supplies have been established by CDPH based upon guidelines established in the USEPA Long Term 2 Enhanced Surface Water Treatment Rule LT2 and the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBP). The LT2 includes compliance requirements for viruses, *Giardia* cysts, *Cryptosporidium*, and turbidity. Stage 2 DBP requires monitoring the concentrations of trihalomethanes ([THMs]- chloroform, bromoform, bromodichloromethane, and dibromochloromethane) and five haloacetic acids (HAA_5 – monochlor-, dichlor-, trichlor-, monobrom-, dibrom-acetic acid) at various points in the distribution system and determining an annual running average for each sampling location, referred to as a "local running average." The total THM (TTHM) concentration cannot exceed 80 µg/L and the HAA_5 concentration cannot exceed 60 µg/L.

Disinfection of SWRO permeate is unlikely to result in significant DBP formation, even if free chlorine is used, because of the extremely low organic precursor concentration (<0.5 mg/L). However, careful considerations need to be made when blending the desalinated product water with an existing water supply, due to the higher than typical levels of bromide in desalinated seawater.

The requirements to meet the LT2 vary depending upon the source water quality and the selected treatment process train. The required total log removal of viruses and *Giardia* cysts dictated by the rule are constant and have not changed since they were established by the original USEPA Surface Water Treatment Rule (SWTR). However, CDPH has indicated that higher removal requirements for *Giardia* and viruses (up to two additional log credits) may be required for source waters with unusually high coliform bacteria (greater than 10,000 most probable number [MPN]/100 mL).

Cryptosporidium removal requirements have been in a state of change over the last several years. They were initially adopted as part of the temporary Interim Enhanced Surface Water Treatment Rule (IESWTR), currently in force by CDPH, but were superseded by stricter requirements in the recently enacted LT2, which has not yet been incorporated by CDPH. Regulated removal requirements for each of these rules are listed in Table 3-3.

Table 3-3
Pathogen Removal/Inactivation Requirements

Pathogen	Log Removal				
	SWTR	IESWTR	LT2 ESWTR		Current CDPH
			Minimum	Maximum	Maximum
Giardia	3	3	3	3	5
Virus	4	4	4	4	6
Cryptosporidium	--	2	3	5.5	2

The log removal requirements established by the LT2 for *Cryptosporidium* vary depending on the level of *Cryptosporidium* found in the source water during two years of initial monitoring. For source waters falling in the lowest bin classification (Bin 1), having less than 0.075 oocysts/L, the minimum log removal of 3 will be required. For source waters falling in the highest bin classification (Bin 4), having greater than or equal to 3 oocysts/L, the maximum log removal of 5.5 will be required.

In order to ensure that multiple barriers are applied, CDPH does not allow all the *Giardia* and virus requirements to be met through physical removal alone. Specifically CDPH requires that any process train include sufficient disinfection to accomplish a minimum 0.5 log *Giardia* inactivation and 2 log virus inactivation, regardless of the level of removal achieved through physical processes. Such requirements were not established for *Cryptosporidium*, which is not readily inactivated through chlorination.

The possible combinations to achieve the maximum removal requirements for *Giardia*, virus, and *Cryptosporidium* are shown in Table 3-4 for process trains involving membrane filtration, SWRO, and disinfection. The log removals shown in Tables 3-4 represent the highest log removals that can be credited to microfiltration and reverse osmosis under the current CDPH regulations and guidances. Use of an approved ultrafiltration system in lieu of microfiltration could result in additional virus removal credits, however, a minimum of two inactivation credits would be required through free chlorination, regardless of any additional credits given to the membrane filtration system. It should be noted that actual credit for membrane filtration systems is determined based on challenge testing for the individual manufacturer and model, and may be less than the credits shown in Table 3-4 for some manufacturers. It should also be noted that the 2-log removal designation for reverse osmosis is based on stated policy and letters issued by CDPH rather than on actual challenge testing for the RO membranes. Continuous monitoring of conductivity to confirm a minimum 2-log removal of TDS will be required by CDPH to receive the 2-log *Giardia*, *Cryptosporidium*, and virus removal credits for RO.

Table 3-4
Possible Process Trains to Meet Maximum Pathogen Removal/Inactivation Requirements

Pathogen	Log Removal						
	Objective	Removal Credit			Disinfection Credit		
		MF	RO	Total	Minimum	UV	Free Cl_2
					UV Option		
Giardia	3	4	2	6	0.5	4	0
Cryptosporidium	4	4	2	6	--	4	0
Virus	5.5	0.5	2	2.5	2	0	2
					No UV Option		
Giardia	3	4	2	6	0.5	0	0.5
Cryptosporidium	4	4	2	6	--	0	0
Virus	5.5	0.5	2	2.5	2	0	2

Table 3-5 presents the required CT dose (disinfectant concentration multiplied by reaction time) to meet the minimum primary disinfection limits established by CDPH using either UV or free chlorine.

Table 3-5
Minimum Inactivation Requirements for Either UV or Free Chlorine

Inactivation	Required CT Dose[1]	
	UV (mJ/cm^2)	Free Chlorine (mg/L-min)
2-log Virus	100	1.0
0.5-log *Giardia*	1.5	14

1. Assumes temperature 20ºC, pH 8, and chlorine residual < 1.4 mg/L

3.1.3.2 Boron, Chloride and Sodium

As mentioned earlier, SWRO can have concentrations of sodium, chloride and boron that are unusually high when compared to ordinary domestic supplies. Very high levels of sodium intake have been demonstrated to have adverse effects on hypertension. As a result, from the middle 1970s until the late 1990's there was an active dialogue within the regulatory community, with the idea that this effect might lead to the regulation of sodium in drinking water. Ultimately The USEPA made the decision not to regulate sodium because, even at the highest levels normally observed in drinking water, the sodium intake from drinking water is not a significant part of the overall sodium intake.

Similarly, for boron, animal tests have shown adverse effects on the reproductive systems of rats and male dogs, however the USEPA recently decided not to regulate boron (USEPA, 2007). This decision was made because, in the USEPA's judgment, boron is not likely to occur at levels of concern in U.S. drinking water systems. In making this judgment the USEPA used animal testing data to develop a health reference level (HRL) of 1.4 mg/L for boron. The USEPA's HRL is an estimate of the concentration that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure. The USEPA found that only 3.1 percent of U.S. groundwater systems surveyed exceeded the HRL and no U.S. surface water system was above half of the HRL.

Chloride has not been raised as a health issue where drinking water is concerned. Thus, none of these three minerals are known to have important health effects at the concentrations that might appear in desalted water.

Nevertheless, they have all been established to have adverse effects on horticulture (art of cultivating fruits, vegetables, flowers, or ornamental plants), which is important to the average homeowner and to many businesses. These impacts on horticulture are also discussed in Section 2.3.2.2. Appendix D provides photos of some of the more common plants that were identified in the discussion in Section 2.3.2.2 as being affected by boron levels of 0.5 to 1 and chloride levels of 100 to 150 mg/L.

3.1.3.3 Bromide

In contrast to sodium and chloride, which are unusually high in seawater, bromide is quite low. Moreover the removal of bromide achieved by SWRO is comparable to the removal of chloride. Nonetheless, the level of bromide that results (0.4 to 0.6 mg/L) is high when compared to most drinking water supplies (see Table 3-1). The Colorado River ranges from 0.06 to 0.12 mg/L and averages around 0.1 mg/L, but State Project Water can be quite a bit higher. In fact, the bromide levels in desalinated seawater are comparable to the highest levels observed in State Project Water and, where that supply is concerned, high bromide levels have been associated with the formation of unusually high levels of brominated DBPs.

State Project Water is also known to have a rather high level of natural organic matter and this natural organic matter also serves, along with bromide, as a necessary precursor for the formation of brominated DBPs. Fortunately SWRO is extremely efficient in removing TOC and as a result, natural organic matter is virtually absent in the permeate and DBP formation is minimal. Thus brominated DBPs are not a serious issue for the desalted seawater itself. However, these DBPs can be expected to form in zones where desalted water blends with other supplies and free chlorine is used for DBP residual maintenance. Fortunately, even this problem diminishes if combined chlorine is used and LADWP will have completed its chloramines conversion by the time desalination is implemented.

Work done with desalinated waters in Southern California, (particularly at the West Basin Municipal Water District), has also shown that high levels of bromide in SWRO permeate can have adverse impacts on the stability of the chloramine residual used in the distribution systems.

3.1.3.4 Corrosion Control

In contrast to sodium, chloride, and boron, the concentrations of calcium, sulfate, and alkalinity can be unusually low in seawater desalted by reverse osmosis. Calcium and alkalinity are particularly important because the desalted product water is traditionally "conditioned" so that it is at or slightly above calcium carbonate saturation as a way of managing corrosion of the distribution system and consumer plumbing. This "conditioning" is commonly accomplished by adding lime and carbon dioxide to the desalinated water during post treatment. Each component is added in roughly the same proportion to produce a water whose calcium hardness is equal to its alkalinity (when both are expressed as mg/L CaCO3). Figure 3-7 illustrates the principle, showing the saturation pH that must be maintained as a function of the lime added. Ironically, the more lime that is added, the lower the pH required to maintain calcium carbonate saturation. Because a pH of slightly above eight is usually sought, the process results in a significant increase in hardness.

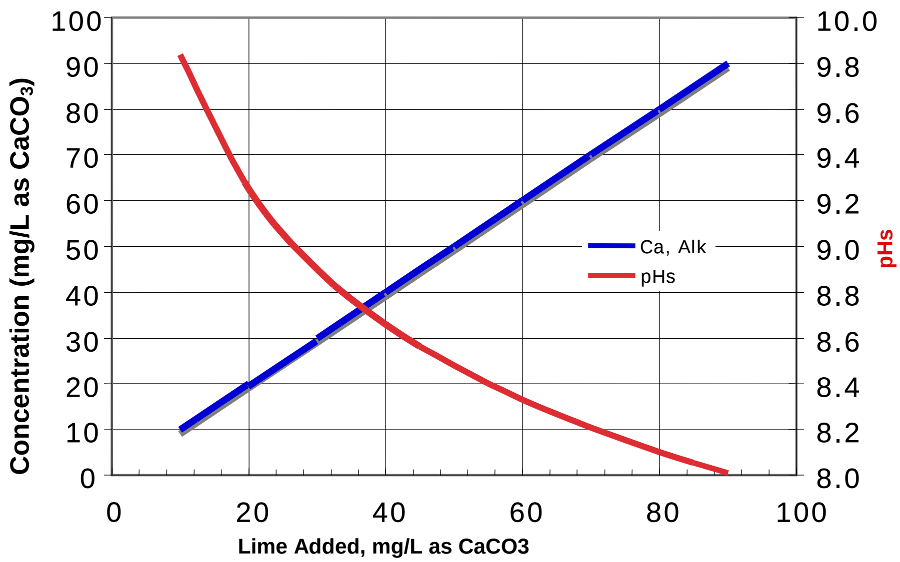


Figure 3-7 Saturation pH (pHs), calcium hardness and alkalinity as a function of lime added to desalinated seawater

Calcium Carbonate Saturation

The idea that the formation of calcium carbonate films might protect pipe from corrosion probably originates from the late 19th or the earliest part of the 20th century. The concept advanced was that certain hard groundwaters have a chemistry that is suitable for forming a protective calcium carbonate film, sometimes referred to as an "eggshell lining" (scaline water), while others do not (aggressive water). In a paper published almost 70 years ago, Professor Langelier proposed a simple index of calcium carbonate saturation based on chemical equilibria (Langelier, 1936). Langelier's idea was that his index would serve as a more reliable tool for determining if a water's chemistry was scaline or aggressive. The Langelier Saturation Index (LSI) was based on a simple scheme:

1. If LSI > 0, then the water is scaline and could form a protective calcium carbonate coating.

2. If LSI = 0, the water is at equilibrium with calcium carbonate, and would neither form a protective coating or dissolve one.

3. If LSI < 0, the water is aggressive and would dissolve any protective calcium carbonate coating, should one be present.

Table 3-6 summarizes the water quality of several southern California water treatment plants where calcium hardness, alkalinity and the saturation of calcium carbonate is concerned. It should be noted that MWD plants all adjust their pH to maintain saturation with calcium carbonate, but LADWP does not.

Table 3-6
Corrosion Related Water Quality for Several Major WTPs in Southern California

	LAAFP	Diemer WTP	Jensen WTP	Weymouth WTP
Calcium, mg/L	65	92.5	67.5	80
Alkalinity, mg/L as $CaCO_3$	100	77	85	71
pH	7.7	8.2	8.2	8.3
LSI	-0.3	0.2	0.1	0.2

Langelier never published any studies examining the degree to which calcium carbonate scale forms on water pipe, nor the degree to which such films, once formed, would protect the pipe from corrosion. Nevertheless, in part because the idea of a protective calcium carbonate scale was already widely accepted, in part because Langelier's development of the index is based on fundamental chemistry, in part because the LSI is easily implemented, and, in part because the index is closely tied to the pH, which we now understand to be a master index governing the solubility of most metal scales (Sillen, 1959), the LSI caught on right away. It didn't hurt that the California section of AWWA published a report two years later concluding that the LSI seemed to be a useful index of corrosion; red water complaints being less for waters where the natural LSI was greater than -0.5 (DeMartini, 1938).

In the late 1950's Professor Stumm at Harvard University published two studies that seriously examined the role of calcium carbonate in Corrosion (Stumm, 1956, 1960). Stumm confirmed that calcium carbonate does deposit on the surface of corroding iron, but he also showed that the role of calcium carbonate in mitigating corrosion of iron is a complex one involving modification of the nature of the surface scale on the pipe and the reduction of anodic surfaces, not the formation of a simple protective coating or "eggshell" lining. Local conditions created on the corroding iron surface, are often more important to calcium carbonate precipitation than is the bulk saturation as assessed by the LSI.

pH Target

The pH is the master variable controlling the solubility of virtually all oxides, hydroxides and carbonates, which form on the surface of corroding metals and protect them. These same substances also control the stability of cementaceous surfaces (Trussell and Morgan, 2006). Raising the pH not only reduces the solubility of these surfaces, it also acts to directly reduce the rate of reactions at the corrosion reaction's cathodic surface.

Table 3-7 summarizes water quality information gathered from several utilities using soft water. With the exception of Boston, none of these water supplies maintains positive calcium carbonate saturation.

Table 3-7
Corrosion Related Water Quality Maintained by Several Large Municipal Supplies Using Soft Water

Constituent	Boston	Portland	Seattle	East Bay MUD	San Francisco
TDS, mg/L	60	50	37	30	40
Alkalinity, mg/L as $CaCO_3$	27	17	15	20	27
pH	9.3	8.0	8.5	8.8	8.8
Calcium, mg/L	16	15	23	22	22
LSI	0.3	-1.3	-0.4 to -1.0	-0.2	-0.1

Influence of Chloride

Most of the water supplies listed in Table 3-3 have extremely low levels of chloride (typically less than 10 mg/L). Chloride, known as the "aggressive ion" is thought to play an important role in the acceleration of corrosion and pitting, presumably because of its high mobility and small size. It is known to be very effective at penetrating surface scales, and is associated with spotting, etching, and corrosion of polished or plated surfaces. Chloride is often found at extremely high concentrations at the center of corrosion pits. The aggressive behavior of chloride can, in part, be overcome by passivation brought about by bicarbonate or phosphate ions. As a result, a strategy of maintaining calcium carbonate saturation or using orthophosphate may be prudent choices where desalinated water is concerned.

The finish product water goals for corrosion protection have been defined to achieve levels similar to the existing water quality, as presented in Table 3-1, namely calcium 20 to 35 mg/L and alkalinity of 50 to 90 mg/L as $CaCO_3$. However, product water goals and recommended corrosion control approaches are best developed based on water quality modeling and bench top testing using desalinated product water.

3.1.3.5 Temperature

Using the warmer condenser discharge water raises aesthetic issues for consumers of the desalinated product water. If the desalinated water is not brought to the same temperature as the Department's current supply, consumers are likely to notice changes in temperature and complain. As a result cooling of the water is a requirement if the desalination plant is to be operated on the Scattergood condenser discharge water. A product water quality goal of 26.5ºC (80ºF) is therefore recommended to maintain a finished water temperature comparable with the existing water in the distribution system.

3.1.3.6 Finished Water Quality Goals Summary

Figure 3-8 summarizes the criteria for mineral quality, which derive from the proceeding discussion. The TDS value selected is a bit derivative from other values. If the highest levels of calcium and alkalinity are selected this goal may be slightly exceeded. The boron goal is primarily driven by impacts on horticulture and a combination of horticultural requirements as well as those of industrial users drive the chloride goal. In addition to these goals, temperature goals and regulatory disinfection goals must be met for the finished water, as discussed above. A summary of the regulated limits, pilot testing goals (following SWRO), and recommended finished water goals is presented in Table 3-8. A discussion of the post treatment considerations for achieving the finished water goals is included in Section 3.5.

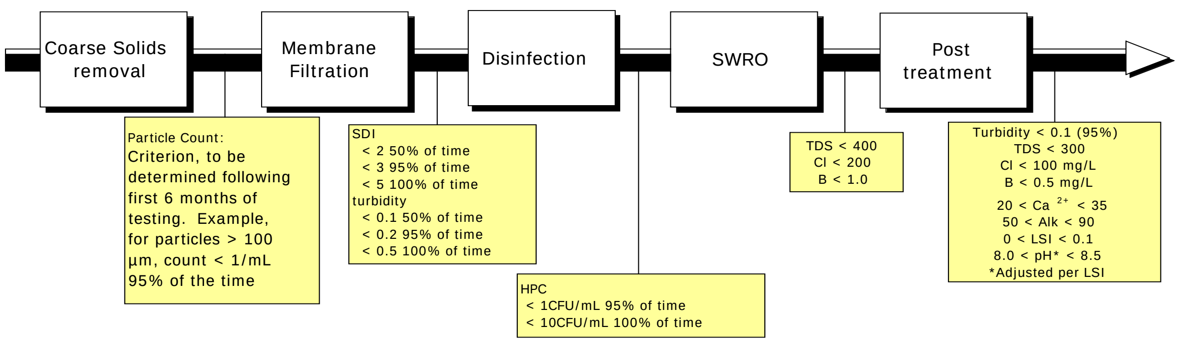


Figure 3-8 Process Flow Diagram Showing Mineral Quality Criteria Following Post Treatment

Table 3-8
Scattergood Desalination Study Water Quality Goals

Parameter	Regulated Limit	*Pilot Goal*	Finished Water Goal
Chloride	250 mg/L	*200 mg/L*	100 mg/L
TDS	500 mg/L	*400 mg/L*	400 mg/L
Boron	1 mg/L	*1 mg/L*	0.5 mg/L
Title 22	MCL	*0.8 x MCL*	0.8 x MCL
Alkalinity	NA	*NA*	75-80 mg/L
pH	6.5-8.5	*NA*	8-8.5
LSI	NA	*NA*	> 0.1-0.2
Temperature	NA	*NA*	80 ºF

3.2 Recommended Operating Conditions

Beyond the water quality goals, there are a number of operational variables which must be optimized during the pilot process in order to determine the most appropriate, efficient, and cost effective operating conditions for the Scattergood site. While there are numerous operating conditions which can be varied, this discussion will focus primarily on the variables we believe are the most critical for developing reliable design criteria for the treatment process. Each of these variables are discussed below, as they relate to the unit process they are a part of. The discussion will begin with reverse osmosis and conclude with the coarse solids removal variables.

3.2.1 Reverse Osmosis

The reverse osmosis system should be designed to simulate a full scale facility to the extent possible. Membranes for seawater desalination are available from a number of different vendors, accomplishing varying levels of salt rejection, and supplied in sizes up to 18-inch diameter. General information on the seawater RO system configuration was discussed previously in Section 2 of this report. Based on accepted practices in the industry and on the conclusions drawn in Section 2, the following assumptions can be made for a seawater RO system used at the Scattergood site:

- Spiral wound, TFC membranes will be used
- Salt rejection rating for the membranes will be between 99.5 to 99.8 percent
- A single-stage process will be used, rather than the two-stage process commonly used with brackish water reverse osmosis

- Multiple membrane elements, each 40 inches long, will be housed in-series within a fiberglass reinforced plastic (FRP) pressure vessel, with the vessel accommodating between 6 and 8 membrane elements, 7 elements being the most common for larger systems.

- A product water or permeate stream will consist of desalinated water making up between 40 and 60 percent of the total flow.

- The remaining flow will consist of a concentrated waste stream or reject, containing the majority of the dissolved solids

The following presents a brief discussion of specific recommended operating conditions for membrane size, flux, recovery, acid and antiscalant feed, membrane type, and feedwater temperature.

3.2.1.1 Membrane Size

While seawater RO membranes are available in sizes ranging from 2.5-inch diameter to 18-inch diameter, the most commonly used is the 8-inch element, representing the vast majority of the full scale desalination facilities world-wide. Larger elements are a relatively recent development, which has not yet gained widespread use, but provides a cost-competitive alternative for large desalination facilities producing more than 10 mgd in product water flow. The smallest size elements, 2.5-inch diameter, are commonly used in household desalination units and can be purchased readily at home improvement stores for personal household uses. 4-inch diameter elements tend to be used most commonly in pilot testing and in small packaged water treatment plants, producing less than 100,000 gallons per day. These elements are often produced on demand, and do not have a widespread market comparable to the markets for either household 2.5-inch or municipal 8-inch diameter elements.

It is a common practice to pilot test using 4-inch elements for full scale facilities which will employ the more common 8-inch elements. While this practice allows for smaller pilot units and lower cost equipment, several membrane vendors have expressed concern with this approach, based on the following rationale:

- 8-inch commercial products are reportedly more uniform in their construction than comparable 4-inch elements

- 4-inch elements will typically have slightly poorer rejection than their 8-inch counterparts, which can lead to overly conservative design considerations in a full scale plant

- 4-inch elements do not often incorporate the latest element design improvements that are available in 8-inch

- 8-inch elements have better hydraulic performance than 4-inch elements, which will lead to more uniform fluxes along the length of the pressure vessel

- Scalability of 8-inch elements from the pilot into a large system, especially a SWRO system, is easier and minimizes unknowns
- Manufacturer's performance models are more accurate for 8-inch elements
- Membrane variability is minimized in 8-inch models

Concerns about the higher variability in 4-inch element performance and the inconsistencies seen between 4-inch and 8-inch product water quality, suggest that the use of 8-inch elements in the pilot will provide a better characterization of the performance to be expected in a full scale facility. As such, it is our recommendation that a minimum of seven 8-inch diameter, 40-inch long elements be employed in each train for the Scattergood Desalination Pilot.

3.2.1.2 Flux

Membrane flux represents the filtration rate across the membrane surface, expressed as gallons per day per square foot of membrane area, or gallons per square foot per day (gfd). Flux is an important consideration with reverse osmosis, as it will have a major impact on both the capital and operating costs of the facility. A lower flux will require more membrane area, higher capital cost, and larger plant footprint. However, a higher flux will increase the required feed pressure, resulting in higher power requirements and higher operating costs. The Affordable Desalination Coalition is investigating operations in the range of 6 to 9 gfd, which they believe will result in a lower overall lifecycle cost for desalination, however, most existing seawater reverse osmosis facilities operate closer to 10 gfd.

An additional consideration with the operating flux is that salt rejection increases with increasing flux. This phenomenon is counter-intuitive for many people observing desalination performance, since it is the opposite of what has traditionally been seen at conventional filtration facilities. In desalination, this can best be described as a higher ratio of product water diluting a more constant passage of salt across the membranes. Increasing the flux will increase this dilution factor, improving the quality of the product water. Ultimately, determination of the most appropriate flux for a seawater desalination facility will involve a trade-off between capital cost, operating costs, and desired product water quality. Typical operating fluxes for seawater desalination facilities range from 8 to 12 gfd. We recommend testing over this entire range to determine the optimal operating conditions for the Scattergood plant.

3.2.1.3 Recovery

Product water recovery is the ratio of product water flow to feed water flow, representing the overall production efficiency of the desalination system. Higher recoveries produce lower waste flow, but also produce a more concentrated waste stream. A 50 percent recovery system will concentrate dissolved solids by 100 percent, while a 75 percent recovery system will increase them four fold. The concentrated solids result in a higher scaling potential for sparingly soluble salts, such as calcium carbonate, as well as an increased osmotic pressure, which must be overcome to produce water through the membranes.

Brackish water and reclaimed water desalination facilities, which are low in TDS, typically operate at recoveries between 70 and 80 percent, which is generally limited by scaling potential of the sparingly soluble salts. For seawater systems, however, the TDS is much higher, and it is the osmotic pressure which limits the recovery. Recoveries in the range of 45 to 55 percent are typically seen as the most economical due to a trade-off between feed pressure, which increases with higher recovery, and waste volume, which decreases with higher recovery. Figure 3-9 presents a projection of power consumption verses recovery for three different feed water temperatures (adapted from Wilf and Klinko, 2001). While power consumption will vary with membrane type, flux, and energy recovery measures employed, the general trends shown in Figure 3-9 will hold.

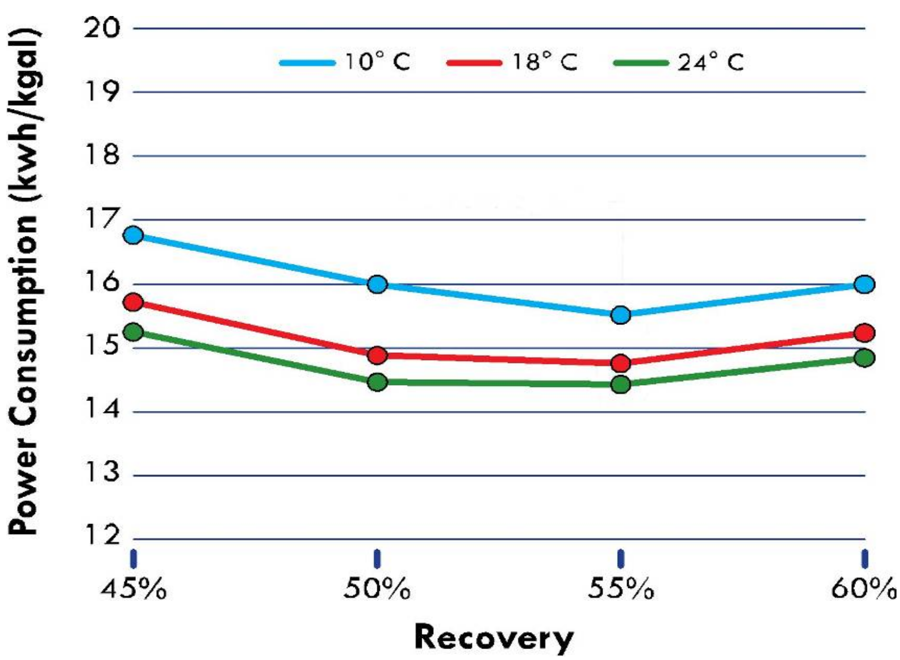


Figure 3-9 Projected Impact of Recovery on Power Consumption for SWRO (Adapted from Wilf and Klinko, 2001)

In addition to the impact on energy use, a higher recovery will increase the salt concentrations in the permeate, resulting in a poorer product water quality. Operational seawater desalination facilities typically maintain between 40 and 50 percent recovery, although some facilities are in operation at recoveries as low as 30 percent. For the purpose of this pilot study, we are recommending that the recovery be maintained at a constant rate of 50 percent in order to limit the number of variables tested during the piloting period. This recovery provides the highest water quality without increasing the power consumption outside the optimal range.

3.2.1.4 Use of Acid or Antiscalant

Acid addition and scale inhibitor (antiscalant) are commonly used to prevent scaling in reverse osmosis. Acid addition increases the solubility of calcium carbonate and magnesium hydroxide, while antiscalant forms organic complexes preventing scaling from a number of different compounds. Because of the low recoveries used in seawater desalination facilities, the use of acids and antiscalants are less important than in brackish water desalination, where much higher recoveries are achieved.

Vendor projections based on current Scattergood intake water quality for a SWRO system maintained at 10 gfd flux, 50 percent recovery, and 15 ºC, with typical low energy SWRO membranes (Hydranautics SWC5+) result in a concentrate water quality that is 64 percent saturated in calcium sulfate, less than 1 percent saturated in silicon dioxide, and containing a LSI of 1.7. Previous pilots on California seawater have operated without the use of antiscalant, and have demonstrated that organic fouling from biological activity is a far higher risk than inorganic scaling. It is our recommendation that capabilities be included to allow for feeding of up to 3 mg/L antiscalant, however, no antiscalant or acid addition are recommended for normal operation of the Scattergood pilot.

3.2.1.5 Membrane Type

While there are a considerable number of TFC SWRO membranes available on the market, representing a broad range of salt rejections and specific fluxes, the membranes of interest for this pilot can generally be divided into two categories: (1) low energy SWRO elements, and (2) high boron rejection/high chloride rejection elements. The low energy elements include models such as Hydranautics SWC5, Toray 820L, and Filmtec SW30XLE. These elements are rated as having 99.8 percent salt rejection at the manufacturer’s factory test conditions, however, chloride rejection in a system configured with a seven element vessel will be closer to 99.5 percent at 15 ºC (10 gfd, 50 percent recovery), with boron rejection around 85 percent.

High boron/high chloride rejection elements include models such as Hydranautics SWC4+, Filmtec SW30HRLE, and Toray 820C. These elements are also rated as having 99.8 percent salt rejection, however, chloride rejection for the conditions listed previously are projected to be slightly higher at 99.6 to 99.7 percent, with boron rejection greater than 90 percent. This improved rejection of chloride and boron may be necessary to meet water quality goals, particularly when treating warm water, however, there is a trade-off in using these elements, in that they will require a higher feed pressure to operate at similar flux and recovery. Vendor projections indicate that this could be approximately 100 psi or roughly 10 percent additional feed pressure when using high boron/high chloride rejection membranes.

We recommend that both low energy and high boron/chloride rejection membranes be tested side-by-side on the same source water to compare the operation of each in terms of product water quality and operating parameters. Data provided from this testing will be invaluable in comparing vendor model results with actual pilot results, providing a more accurate picture of the achievable operating conditions at the Scattergood site.

3.2.1.6 Temperature

Temperature has a dramatic impact on RO performance. Increases in temperature will result in considerably lower feed pressure requirements, and therefore energy use, when flux and recovery are maintained at a constant operating point. This relationship is presented in Figure 3-10, showing manufacturer projections of feed pressure and temperature for two different fluxes and two different SWRO element types (Projections are based on Hydranautics SWC5 and SWC4+ elements, 50 percent recovery, and seawater quality listed in Table 3-1). As this figure indicates, an increase from 10 to 30 °C can decrease the projected feed water requirements by as much as 200 psi.

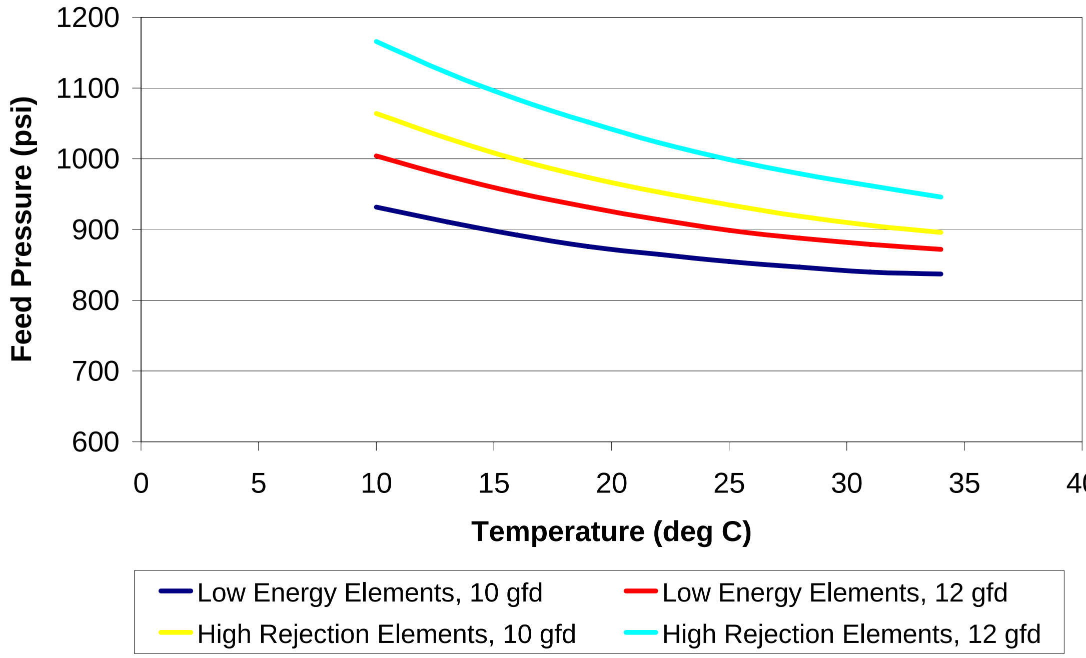


Figure 3-10 Projected Impact of Temperature on Feed Pressure for SWRO

While these temperature impacts may be considered advantageous, they bring with them a negative side as well, which may be considered more significant than the positive impacts an increased temperature may produce. With the increased flux, higher temperatures also increase the salt passage, resulting in a poorer water quality. With boron and chloride the most constraining parameters in product water quality, this increased salt passage can result in a water quality which does not meet the treatment goals, depending on the flux, recovery, and membrane type used.

The relationship between feed water temperature and product water boron is presented in Figure 3-11, based again on manufacturer projections for two membrane types and two fluxes (Hydranautics SWC5 and SWC4+ elements, 50 percent recovery, and seawater quality listed in Table 3-1). This figure indicates that a boron goal of 1.0 mg/L, based on the currently regulated notification level, can be met at temperatures below 22ºC for either membrane type at fluxes greater than 10 gfd. Using the high boron rejection membranes, this goal can be met at temperatures as high as 34 ºC, representing the 98th percentile condition for the current Scattergood outfall temperature.

A tighter boron goal of 0.5 mg/L can also be met using the high boron rejection membranes, but only at temperatures up to 15ºC for 10 gfd operation and up to 20ºC for 12 gfd operation. It should therefore be assumed that using the low energy elements would require additional treatment of the SWRO product to reduce boron levels to the finished water goal of 0.5 mg/L, particularly when treating warm water.

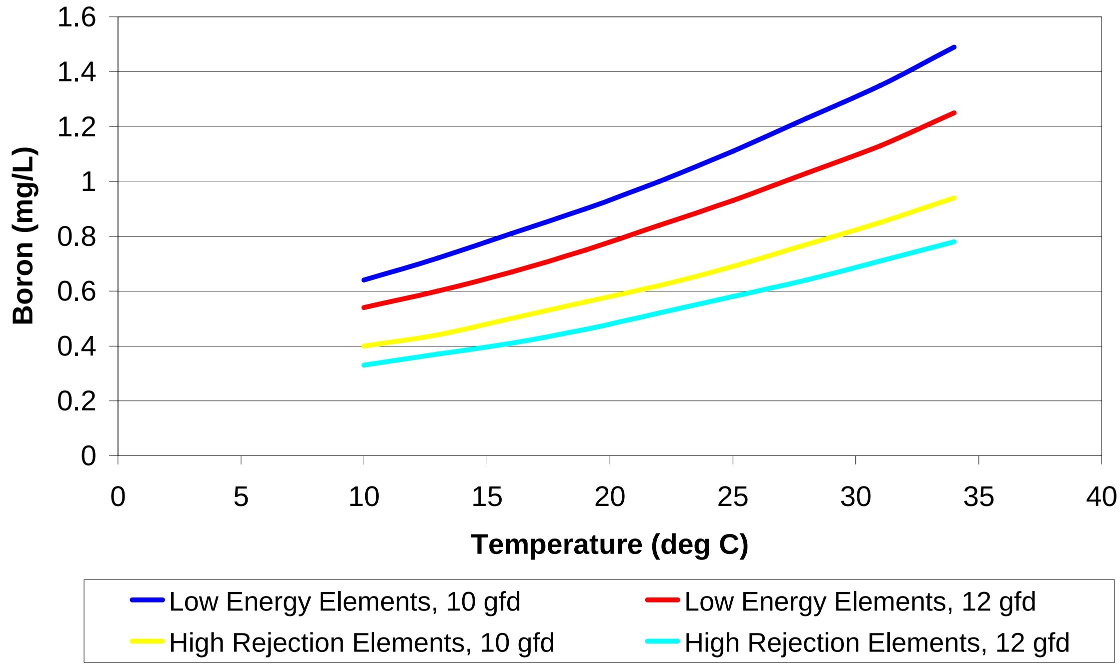


Figure 3-11 Projected Impact of Temperature on SWRO Permeate Boron

Beyond these temperature impacts, which are well documented in vendor projections and previous studies, it should be considered that higher temperatures may increase biological fouling on the RO membranes, as has been observed at other pilots referenced previously. It is therefore recommended that the pilot be operated using both warm and cold water from the Scattergood Power Generation Facility, operated side-by-side at similar operating conditions, to confirm the impact temperature has on membrane performance and finished water quality.

3.2.2 Membrane Filtration

The purpose of the membrane filtration system is to protect the reverse osmosis system from particulates and biological fouling, while providing disinfection credits required by CDPH. Membrane filtration systems are available from a number of different manufacturers, using membrane made from a number of different materials. Only a handful of these systems have experience treating seawater, and only three of the systems tested on seawater are also certified by CDPH for surface water treatment. These include the following three systems:

- Pall Microza Pressurized Microfiltration System
- GE/Zenon Zeeweed 1000 Submerged Ultrafiltration System
- Siemens Memcor CMF-L Pressurized Microfiltration System

Although previous pilot studies have shown differences in performance between these three systems, all have demonstrated similar product water qualities. It is therefore not seen as critical to compare the performance of these systems side-by-side at the Scattergood site, but rather to optimize the performance of a single system based on the conditions experienced during the pilot testing. It should be assumed that data can be used from other pilots conducting side-by-side comparisons to determine the relative performance of the various membrane systems. For the purpose of sizing of equipment and preliminary site layout development, a Zenon Zeeweed 1000 submerged ultrafiltration system has been assumed.

3.2.2.1 Flux

The most critical parameter for optimizing the operation the membrane filtration system is the flux. Similar to the RO system, the membrane filtration flux is a measure of the overall filtration rate for the membranes, expressed as gallons per square foot of membrane per day (gfd). Higher membrane fluxes will require less membranes and lower capital costs, however, they may also experience more rapid membrane fouling, requiring frequent chemical cleanings and higher operating costs. The most appropriate membrane flux will depend on the membrane system selected, based upon review of operating data at other seawater pilots and on the recommendation of the membrane system supplier. For the submerged Zenon system, we are recommending a design flux between 20 to 30 gfd, based upon performance of a similar system at the West Basin pilot.

It is recommended that the membrane filtration flux be optimized during the pilot testing by operating side-by-side units at different fluxes, using identical source water. Chemical cleanings can then be conducted, as needed, based upon manufacturer recommendations, in order to maintain performance at the selected flux. From the data developed during this comparison, a lifecycle cost evaluation can be conducted to select the most appropriate operating flux for subsequent testing.

3.2.2.2 Chemical Cleaning

Chemical cleanings are periodically conducted on membrane filtration systems to maintain the desired operating flux and recover operation after membrane fouling has occurred. Chemical cleanings can be relatively infrequent clean-in-place events or more frequent chemically enhanced backwashes. Each is described briefly below:

Chemical Clean-in-Place (CIP)
CIP's are typically conducted between once every two weeks to once every two to three months. Thirty day cleaning frequencies are the most common, however, cleaning frequencies vary considerably from plant to plant and will likely change over the life of a single treatment plant. CIP's for the membrane filtration systems listed above typically utilize high doses of chlorine solution (up to 1000 mg/L) followed by citric acid solution (typically pH 2) to remove organic, biological, and inorganic foulants from the membrane surface and pores. Cleaning durations last from two to eight hours, often involve heating of the cleaning solution, and may require use of proprietary surfactant cleaning agents. Because of the high chemical requirements and long down time involved in a CIP, it is recommended that these be minimized, with other operating conditions maintained to prevent CIPs more frequently than once every 30 days.

Waste generated from the CIPs will require neutralization and disposal to the Hyperion wastewater treatment plant. CIP waste should not be disposed of with the Scattergood outfall.

Chemically Enhanced Backwash (CEB)
These miniature cleanings have been referred to as CEBs, maintenance cleans, mini-cleans, or enhanced flux maintenance (EFMs), depending on the manufacturer or the audience. CEBs are conducted between once every backwash to once per week. Less frequent CEBs typically involve higher chemical doses, with weekly CEBs often approaching CIPs in the dose of chemicals used. Other seawater pilots referenced previously have found that frequent CEBs using low doses of sodium hypochlorite (up to 50 mg/L) can significantly reduce biological fouling on the membrane filtration system, allowing operation at higher fluxes without the high downtime associated with regular CIPs.

For the Scattergood pilot it is recommended that a CEB frequency, dose, and methodology be developed based on manufacturer inputs, to maintain flux at the desired rate. We are not recommending a separate study period for CEB optimization, but rather that the operation be flexible to allow changes in the CEB methodology to react to changing source water conditions.

3.2.2.3 Coagulant Dose

Although coagulant is not required for removal of pathogens or biological constituents with membrane filtration, the use of low doses of coagulant has been shown to improve hydraulic performance of membrane filtration systems, while enhancing the removal of dissolved organic compounds. Ferric chloride is a commonly used coagulant, which has been used successfully on seawater to aid in the pretreatment process. Surface water treatment plants frequently employ ferric chloride doses in excess of 20 mg/L, however, seawater studies have shown that far lower doses, in the range of 3 to 5 mg/L, are effective for coagulation of seawater.

While these low doses will have very low cost impacts in a lifecycle analysis for the entire plant, the reliance on coagulant for every day operation is not warranted, and could result in permitting difficulties for the membrane backwash water. It is therefore recommended that coagulant addition in the membrane filtration feed be employed only during a red tide event requiring enhanced removal of organic and biological constituents.

3.2.3 Disinfection

Disinfection is included in this pilot as a means of preventing biological fouling on the reverse osmosis membranes rather than as a primary treatment step. It is assumed that disinfection for regulatory compliance can be achieved through a combination of membrane filtration removal credits, reverse osmosis removal credits, and post filtration disinfection credits, as discussed in Section 3.1.2.5. The UV disinfection system should therefore be designed for bacterial inactivation as the primary focus. As discussed in Section 2 of this report, it may be determined that disinfection is not required upstream of the reverse osmosis system to prevent biological fouling, however, it will be critical to document the effectiveness of the pretreatment process with and without the use of UV using both warm and cold water as a source.

We recommend that piloting be conducted on parallel process trains, one using UV disinfection and one without, with both trains treating identical source water. This evaluation is recommended for a duration of six months, looking at both source water alternatives. A UV dose of 30 mJ/cm^2 is recommended based on discussions with UV vendors and information on microfiltration permeate UV transmittance data developed during the West Basin desalination pilot (greater than 95 percent transmittance was seen during this testing).

3.2.4 Coarse Solids Removal

Coarse solids removal is included primarily as a means of removing debris, such as shell fragments and barnacles, which can damage or compromise the integrity of the membrane filtration fibers. As an additional benefit, it may be possible to utilize the coarse solids removal step for reduction of suspended solids and biological loading on the membrane filters during red tide events. Such a benefit would be less likely with rotating disc filters, but could be realized when utilizing GMFs. The most critical variables to be optimized for the coarse solids removal stage will therefore be the type of technology utilized (whether rotating disc filters or GMFs), the filtration rate for GMF units, and the coagulant dose utilized when GMF units are employed. Each of these issues is described briefly below:

3.2.4.1 Equipment Type

An evaluation of the benefits and drawbacks of the two coarse solids removal alternatives was included in Section 2.5 of this Report. Specific advantages are seen in the GMF alternative in their ability to be combined with coagulation to address increased organic, biological, and suspended solids loading from red tide events. At present, however, there are no seawater plants or pilots utilizing granular media filters as pretreatment to membrane filtration. It will therefore be critical in this pilot to conduct a baseline comparison of the two alternatives side-by-side, treating identical source water, to ensure that both are capable of producing acceptable quality water for the membrane filtration feed.

It is therefore recommended that the two coarse solids removal alternatives be compared side-by-side using identical source water for a period of three months to confirm their effectiveness at removing debris and suspended solids damaging to the membrane filtration fibers. Should both processes be deemed effective at producing acceptable quality water, testing should be continued using GMF units rather than rotating disc filters, due to the added benefit anticipated for the GMFs during red tide events.

3.2.4.2 GMF Filtration Rate

The filtration rate is similar to the flux rate for membranes, and is a measure of the flow rate of water over a unit area of filtering surface. For granular media filters, this is typically reported as gallons per minute per square foot of media (gpm/sf). A high filtration rate has been recommended, on the order of 15 to 20 gpm/sf, as discussed previously in Section 2.5.3, based on the use of these filters for roughening or coarse solids removal rather than conventional filtration. Filtration rate will impact both the quality of water produced by the filters and the rate at which they become plugged, resulting in either breakthrough of suspended solids or elevated headloss over the filters. Optimizing the filtration rate will require testing at different rates over the proposed range to confirm both the product water quality and the achievable filter run lengths between backwashing. It is assumed that the highest filtration rate which can meet the water quality goals will be utilized for the pilot. It is therefore recommended that GMF filtration rate be varied and optimized during the period in which the technology is operated side by side with the rotating disc filters.

While filtration rates for rotating disc filters can also be varied, the product water quality from disc filters does not change with filtration rate, making it a less critical design criteria. It is therefore not recommended that disc filter filtration rate be varied during the pilot testing.

3.2.4.3 Coagulant Dose

Similar to the discussion above relative to membrane filtration, coagulation will not be required under normal operating conditions to meet the water quality objectives of the granular media filters or the rotating disc filters. Coagulant may, however, be employed in conjunction with granular media filters to react to red tide events, reducing the solids, organic, and biological loading onto the membrane filtration stage. It is therefore recommended that ferric chloride, at a dose in the range of three to five mg/L, be employed upstream of the granular media filters only during a red tide event. It is not recommended that coagulant be used upstream of rotating disc filters.

3.2.5 Recommended Operating Conditions Summary

Table 3-9 presents a summary of the recommended operating conditions for each unit process, as discussed previously.

Table 3-9
Recommended Pilot Testing Variables

Process	Variable	Range	Evaluation Period
Coarse Solids Removal	Equipment type	Arkal (Train 1) and GMF (Train 2)	3 months
	Coagulant Dose	0-5 mg/L Ferric	Response to red tides
	GMF Loading Rate	15-20 gpm/sf	3 month (concurrent with Arkal comparison)
Membrane Filtration	Flux	20-30 gfd	3 months
	CEB Dose	5-100 mg/L Cl2	As req'd for flux
	CEB Frequency	Every BW to weekly	As req'd for flux
	Coagulant Dose	0-5 mg/L Ferric	Response to red tide
Disinfection	UV dose	0-30 mJ/cm2	6 months
Reverse Osmosis	Flux	8-12 gfd	As req'd for membrane type and temperature
	Recovery	50%	Not varied
	Membrane Type	Low energy (Train 1) and High boron and chloride rejection (Train 2)	3 months (concurrent with MF flux evaluation)
	Temperature	Cold feed water (Train 1) and Warm feed water (Train 2)	6 months

3.3 Pilot Description

The proposed treatment process is presented in Figure 3-12, showing the four unit processes and anticipated flow requirements for each unit process. A proposed site layout is also presented as Figure 3-13, showing a general arrangement for a pilot plant fitting within the parking lot on the west end of the Scattergood site. A general equipment list is also presented in Table 3-10, identifying recommended sizes and general design criteria for each of the major equipment pieces.

Table 3-10
Scattergood Desalination Pilot
Preliminary Equipment List

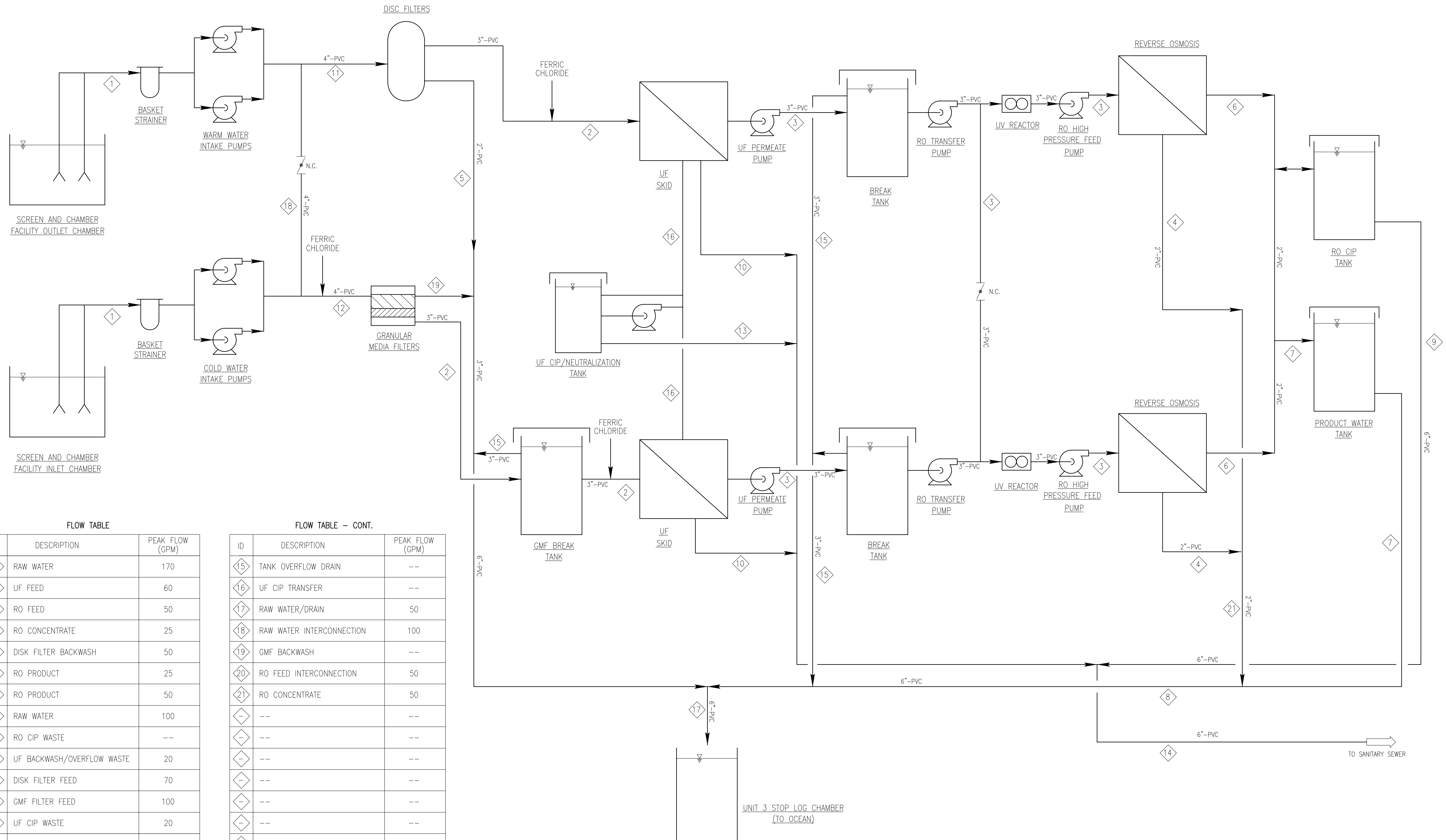
Process/Equipment	No. Units (duty + standby)	Description	Capacity	Power Requirements
Seawater intake pumps[2]	2+2	Fiberglass horizontal end suction self priming type. Fybroc Model 1600 2x3x6	170 gpm @ 75 ft TDH	480v/3ph/60hz 10 HP
Ferric Chloride Storage Tank	1	HDPE Chemical Drum	55 gallons	n/a
Ferric Chloride Metering Pump	3+0	Solenoid operated diaphragm meetering pump (Pulsatron)	0-10 gpd	115v/1ph/60hz
Basket Strainers[2]	2+2	4" Hayward duplex basket strainer w/ 1/16" plastic screen	170 gpm	n/a
Disk Filters	1+0	Arkal/PEP Opal 2" Series Spin-Klin disc filters w/ 2 pods, suction and discharge manifold, and NEMA 4X control panel	60 gpm	460v/3ph/60hz
Disk Filter Backwash Tank	1+0	HDPE tank	110 gallons	n/a
Disk Filter Backwash Pump	1+0	Centrifugal end suction booster pump	50 gpm @ 115 ft TDH	5 HP 460v/3ph/60hz
Granular Media Filters (GMF)	2+1	Fiberglass pressure vessels w/ 6-8 ft bed depth and 15-20 gpm/sf loading rate	30 gpm	n/a
GMF Break Tank	1+0	HDLPE tank	550 gallons	n/a
UF Feed Transfer Pump	1+0	Fiberglass close-coupled end suction centrifugal transfer pump. Fybroc model 1530 1.5x3x6	60 gpm @ 15 ft TDH	480v/3ph/60hz 1 HP
Ultrafiltration (UF) Membrane Skid[2]	2+0	GE Zenon Z-BOX S6 w/ (6) ZeeWeed 1000 UF membranes. Skid includes process tank, backpulse tank, PLC, valves, instruments, and permeate pump	50 gpm	480v/3ph/60hz 3 HP
UF Air Compressor Skid	1+0	Air compressor w/ 180 gallon receiver		480v/3ph/60hz 3 HP
UF CIP/Neutralization Skid	1+0	Skid mounted CIP/Neutralization tank and transfer pumps	n/a	480v/3ph/60hz 2 HP

Process/Equipment	No. Units (duty + standby)	Description	Capacity	Power Requirements
UF CIP Chemicals	5	33" diameter tanks fo the following chemicals: citric acid, sodium hypochlorite, caustic soda, sodium bisulfite, and hydrochloric acid	n/a	n/a
RO Feed Break Tank[2]	2+0	HDLPE tank w/ black coating	550 gallons	n/a
RO Feed Transfer Pump[2]	2+0	Fiberglass close-coupled end suction centrifugal transfer pump. Fybroc model 1530 1.5x3x6	50 gpm @ 25 ft TDH	480v/3ph/60hz 1 HP
UV Reactor[2]	2+0	Trojan UVSwift Model B04 UV reactor vessel w/ 304SS Ballast Panel and manual cleaning system	50 gpm 40mJ/cm^2	208-240v/1ph/60hz
High Pressure RO Feed Pump[2]	2+0	Duplex stainless steel quintaplex plunger pump	45 gpm @ 1200 psi	40 HP 480V/3P/60HZ
Reverse Osmosis System[2]	2+0	-(2) 8" Pressure vessels in series -4 elements in first vessel -3 elements in second vessel -Pressure vessels mounted on common skid w/ electrical panels, cleaning tank, and pump -CIP/Neutralization Tank	20 gpm permeate	480V/3P/60HZ
Product Water Tank	1+0	HDLPE tank w/ black coating	550 gallons	n/a

Notes:

1. All equipment sizing is preliminary and subject to change.

2. Designated equipment will be split between two independent process trains



FLOW TABLE

ID	DESCRIPTION	PEAK FLOW (GPM)
1	RAW WATER	170
2	UF FEED	60
3	RO FEED	50
4	RO CONCENTRATE	25
5	DISK FILTER BACKWASH	50
6	RO PRODUCT	25
7	RO PRODUCT	50
8	RAW WATER	100
9	RO CIP WASTE	--
10	UF BACKWASH/OVERFLOW WASTE	20
11	DISK FILTER FEED	70
12	GMF FILTER FEED	100
13	UF CIP WASTE	20
14	WASTE	--

FLOW TABLE – CONT.

ID	DESCRIPTION	PEAK FLOW (GPM)
15	TANK OVERFLOW DRAIN	--
16	UF CIP TRANSFER	--
17	RAW WATER/DRAIN	50
18	RAW WATER INTERCONNECTION	100
19	GMF BACKWASH	--
20	RO FEED INTERCONNECTION	50
21	RO CONCENTRATE	50
-	--	--
-	--	--
-	--	--
-	--	--
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-	--	--
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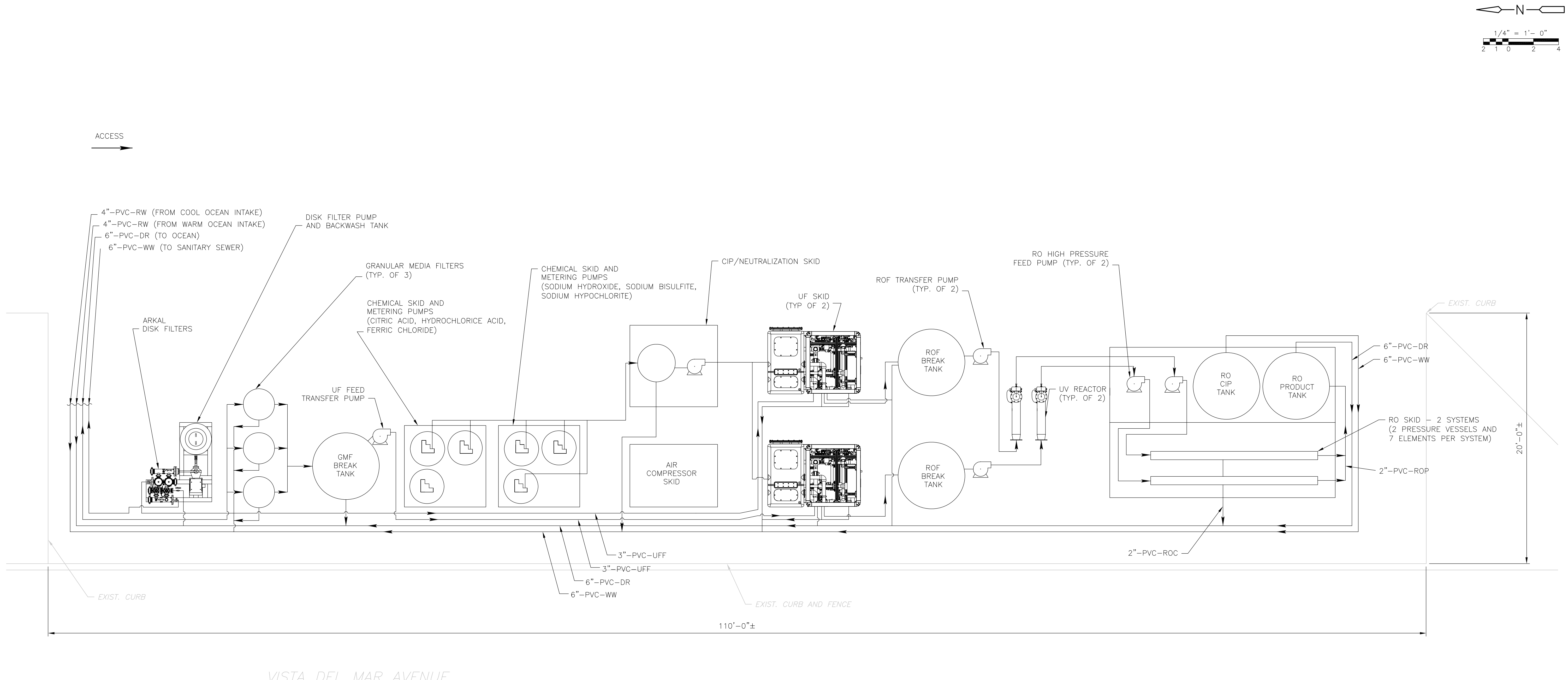
REV. NO.	DATE	DRWN	CHKD	REMARKS

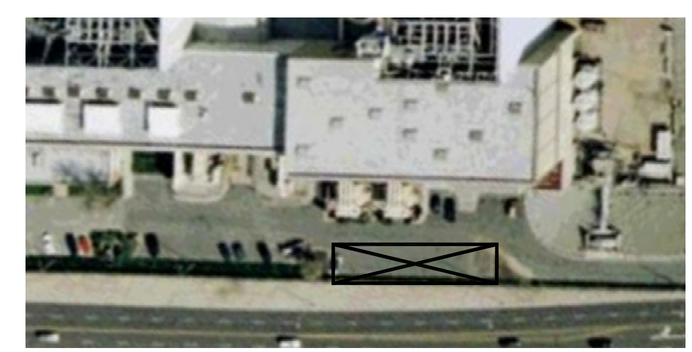
DESIGNED BY: CAO
DRAWN BY: SMP
SHEET CHK'D BY: GW
CROSS CHK'D BY:
APPROVED BY:
DATE: 11/16/07

LOS ANGELES DEPARTMENT OF WATER AND POWER
SCATTERGOOD DESALINATION PILOT PROJECT

PROCESS FLOW DIAGRAM

PROJECT NO. SCATTERGOOD
FILE NAME: P&ID–1.dwg
SHEET NO.
FIG. 3–12





KEY MAP
N.T.S.

LEGEND

RW	RAW WATER
UFF	ULTRA–FILTRATION FEED
ROF	REVERSE OSMOSIS FEED
ROP	REVERSE OSMOSIS PRODUCT
ROC	REVERSE OSMOSIS CONCENTRATE
DR	DRAIN
WW	WASTE WATER
UF	ULTRA–FILTRATION
CIP	CLEAN–IN–PLACE
GMF	GRANULAR MEDIA FILTERS
PVC	POLY VINYL CHLORIDE PIPE

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: CAO
DRAWN BY: SMP
SHEET CHK'D BY: GW
CROSS CHK'D BY:
APPROVED BY:
DATE: 11/16/07

LOS ANGELES DEPARTMENT OF WATER AND POWER
SCATTERGOOD DESALINATION PILOT PROJECT

GENERAL SITE LAYOUT

PROJECT NO. SCATTERGOOD
FILE NAME: C-1.dwg
SHEET NO.
FIG. 3–13

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3.4 Schedule of Principal Investigations

The pilot operations will include an initial 18-month testing period, focusing the evaluations on the operational variables discussed above in Section 3.2. Figure 3-14 presents a preliminary schedule for five primary investigations. Each of these is described briefly below:

- Investigation 1: Coarse Solids Removal
- Investigation 2: Membrane Filtration Flux Optimization
- Investigation 3: RO Membrane Evaluation
- Investigation 4: Impact of UV
-
- Investigation 5: Impacts of Cold vs. Warm Feed Water

A preliminary outline for the Pilot Testing Protocol is included as Appendix F of this

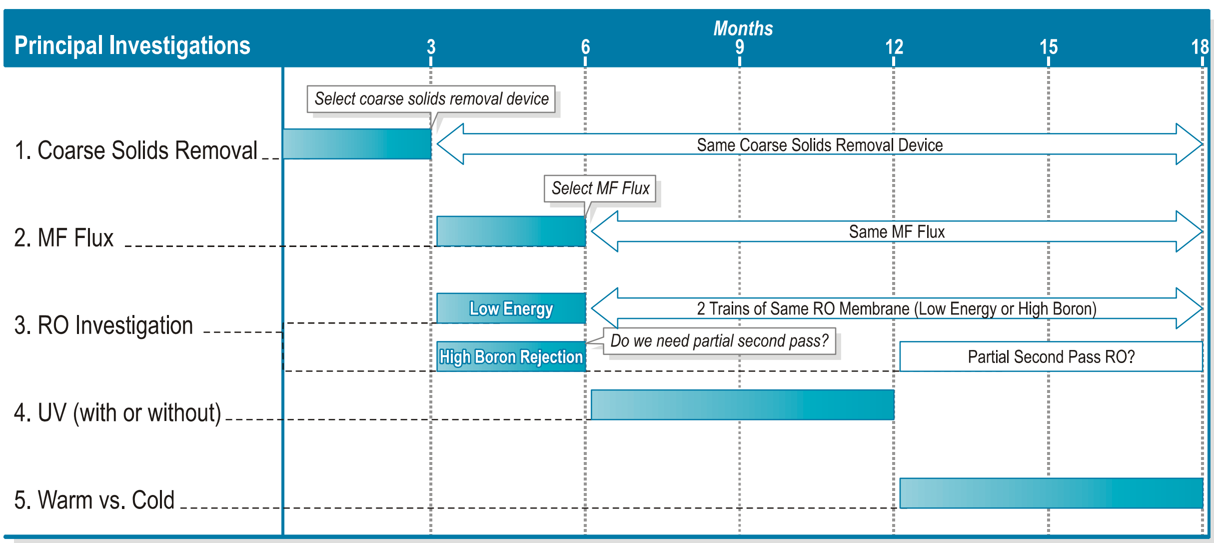

Figure 3-14 Schedule of Principal Investigations

Report.

3.4.1 Investigation 1 – Coarse Solids Removal

This investigation will include a side-by-side comparison of GMF filters and rotating disc filters for coarse solids removal, with both alternatives treating the same source water. Source water during this investigation may be warm or cold. It will be critical that the membrane filtration system be operated during this investigation, however, UV disinfection and reverse osmosis operation are not essential for Investigation 1.

The evaluation will look at optimizing filter loading rate and backwashing for the GMF and will compare fiber breakage rate and membrane filtration feed water particle counts to evaluate the relative effectiveness of the two coarse solids removal alternatives.

This investigation is expected to last for a total of three months. At the end of this investigation, the most appropriate coarse solids removal alternative will be identified and used for all subsequent testing in the pilot.

3.4.2 Investigation 2 – Membrane Filtration Flux Optimization

This investigation will compare alternate membrane filtration operating fluxes for treatment trains operated side-by-side using the same source water and coarse solids removal approach. The purpose of this investigation is to determine the fouling rate and required maintenance cleaning approach needed to maintain different operating fluxes for the membrane filtration system. This investigation should look at both warm and cold water, as water temperature is expected to have an impact on operating flux. Although it is not critical to operate the downstream processes during this investigation, it is recommended that Investigation 3 be operated concurrently using the RO equipment.

This investigation is expected to last for a total of three months. At the end of this investigation, the most appropriate membrane filtration flux will be selected for subsequent testing in the pilot.

3.4.3 Investigation 3 – RO Membrane Evaluation

This investigation is proposed to be done concurrently with Investigation 2. Investigation 3 will involve side-by-side operation of two reverse osmosis membrane alternatives, one using low energy SWRO membranes, and the second using high boron rejection membranes to identify the water quality which can be achieved for each membrane type. It will be critical to feed both RO trains from identical source water, however, testing should be conducted with both warm and cold source water at varying RO fluxes to characterize the impacts on finished water quality. UV disinfection is recommended as a conservative operating approach prior to the UV investigation.

This investigation is expected to last for a total of three months. At the end of this investigation, the most appropriate SWRO membrane will be selected for subsequent testing in the pilot. It will also be determined whether second pass or partial second pass RO is warranted or required for meeting the finished water quality goals, and whether such equipment should be procured for the final pilot investigations.

3.4.4 Investigation 4 – Impacts of UV

This investigation will compare RO operation with and without UV disinfection to determine whether the use of UV disinfection has a measurable impact on the performance of the SWRO system. Side-by-side process trains will be operated on the same source water, with all operating conditions identical, apart from the use of UV on one of the two process trains. This investigation should look at both warm and cold source water, and should include investigations at varying RO fluxes.

The investigation is recommended to last for a minimum of six months. At the end of this investigation, it will be determined whether the continued use of UV disinfection is warranted for the remainder of the pilot.

3.4.5 Investigation 5 – Impacts of Cold vs. Warm Feed Water

This investigation will compare the performance of the recommended process trains using side-by-side operation of both warm and cold feedwater. The investigation will look at product water quality, RO operating performance and fouling rates to identify and quantify the process impacts of using warm water as a feed source.

The investigation is expected to last for a total of six months, and should include multiple operating fluxes for the RO system. Second pass or partial second pass RO may also be utilized during this portion of the testing. At the end of this investigation, data will be available for determination of design criteria for the RO and pretreatment processes, as well as for developing a post-treatment recommendation.

3.5 Post Treatment Consideration

While a goal has been established to meet or exceed water quality regulations in the SWRO product, additional treatment will be needed at a full-scale facility to ensure that the finished water integrates into the existing distribution system without creating undesirable side effects. Finished product water goals have therefore been established, and were presented previously in Table 3-6, comparing regulated limits, pilot treatment goals, and additional goals needed for the finished water. Post-treatment will be required to achieve finished water quality goals from the SWRO product. This treatment may include any combination of the following:

- Additional boron removal
- Additional chloride removal
- Temperature reduction
- Product water stabilization
- Post treatment disinfection

While the testing of these post-treatment alternatives has not been a primary focus of this study, it is recommended that additional studies be conducted in conjunction with this pilot to identify and optimize the most appropriate post-treatment approaches for the Scattergood site. The recommendations are presented on Table 3-9, and described more fully in the following text.

3.5.1 Additional Boron Removal

As described in Section 3.1, the finish product water quality goal for boron has been defined as 0.5 mg/L to prevent adversely impacting plants sensitive to boron toxicity. During the pilot testing period, the RO operating conditions will be modified to determine what boron concentration can be reliably achieved with the SWRO plant, and to confirm the membrane vendor projections, presented previously in Figure 3-11. Upon determining the achievable boron concentrations, additional post-treatment will be considered, as appropriate. These post treatment alternatives are identified in Table 3-11, and include either a second pass RO system or post-treatment blending using distribution system water. It is recommended that second pass RO be tested if it is found that modified operating conditions cannot reliably and efficiently meet the finished water boron goal. Operating conditions which will be modified to make this determination include: increasing membrane flux, decreasing RO recovery, use of high boron rejection membranes, and consideration of using only ambient temperature (cold) feedwater.

Blending with distribution system water should also be considered, based upon water quality modeling, however, the relatively high levels of boron in California Aqueduct water (which approach 0.4 mg/L), may make such an approach infeasible.

Table 3-11
Summary of Post Treatment Alternatives

Constituent/ Parameter	SWRO Water Quality Goal	Finish Product Water Goal	Alternatives	Proposed Pilot Plant Variable		Additional Studies
Boron	1 mg/L	0.5 mg/L	Modified operating conditions			
			Increase RO flux rate	X		
			Decrease RO recovery	X		
			Decrease feedwater temperature	X		
			High Boron rejection membrane	X		
			2^{nd} pass RO		X	Desktop study – RO vendor models
					X	Pilot Test – as needed
			Blending in distribution system		X	Desktop study – water quality model
Chloride	250 mg/L	100 mg/L	Modified Operating Conditions			
			Increase RO flux rate	X		
			Decrease RO recovery	X		
			Decrease feedwater temperature	X		
			High Boron rejection membrane	X		
			2^{nd} pass RO		X	Desktop study – RO vendor models
					X	Pilot Test – as needed
			Blending in distribution system		X	Desktop study – water quality model
Temperature	N/A	80 deg F	Pretreatment cooling		X	Pilot Test – as needed
			Post treatment cooling		X	Pilot Test – as needed
			Blending in distribution system		X	Desktop study – water quality model
			Blending feed water (warm/cold)			Do not test
			Use cold feed water	X		
Product Water Stabilization	N/A	Non-corrosive	Calcite contactor		X	Desktop Study – water quality model Bench or pilot scale study (pipe loops or coupons)
			Lime/CO2			
			Neutralization with Sodium Compounds			
			Phosphate addition			
Post Treatment Disinfection	N/A	2-log virus removal and chlorine residual	Chlorine		X	Desktop Study – water quality model Bench study (Effects of Bromide)
			Chloramines			

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3.5.2 Additional Chloride Removal

Chloride concentrations in SWRO are also elevated compared to typical domestic water. As with boron, the SWRO will meet CDPH regulatory limits for chloride (250 mg/L), however, introducing a water supply with an increased chloride concentration could have significant impacts on plant life. The finished water chloride goal has therefore been defined as 100 mg/L. In order to reduce the chloride concentration to meet this goal, modified operating conditions will likely be required, and a second pass RO system should be considered, particularly when treating warm water.

Similar to boron, the product water goal may be accomplished by blending the SWRO product water with existing distribution system water, which currently averages 25 mg/L of chloride. As indicated in Table 3-9, the feasibility of blending can be evaluated using a water quality model.

3.5.3 Temperature Reduction

While no temperature goals are established for the pilot plant, nor are any requirements dictated by USEPA or CDPH regulations, SWRO product water temperature will be high when treating warm water, and could be expected to have negative consequences in the distribution system, including increased corrosion and possible customer complaints. A water quality goal of 26.5ºC (80ºF) has therefore been established, which may require cooling of the finished water or feed water when post-condenser cooling water is used as the raw water source. It is therefore recommended that cooling alternatives be evaluated, should a warm water source be considered, and that these alternatives include the use of one or more of the following:

- Pre-treatment cooling tower
- Post-treatment cooling tower
- Post-treatment blending with distribution system water
- Blending of warm and cold feed water
- Use of only ambient temperature feed water

An evaluation of the cooling alternatives for the pilot plant is included in Appendix E of this Report.

3.5.4 Product Water Stabilization

As discussed previously in Section 3.1, three principle approaches to corrosion management are in common practice, including: 1) adjustment of calcium carbonate saturation, 2) adjustment of pH and/or alkalinity without regard to calcium carbonate saturation, and 3) the use of orthophosphate with or without zinc. Each of these is described briefly below.

3.5.4.1 Calcium Carbonate Saturation

The mechanism behind calcium carbonate saturation is described in Section 3.1.3.2. Calcium carbonate can be added to the product water through the addition of carbon dioxide and lime, which is the most common method currently used for product water stabilization after seawater reverse osmosis.

Because of the maintenance concerns associated with lime feed systems, some seawater plants have utilized fixed bed calcite contactors, while maintaining the use of carbon dioxide as the carbonate source. While calcite contactors are more costly than lime feed systems (from a capital perspective), the simplicity of operation and comparable lifecycle costs have resulted in an increased interest in their use at seawater plants. A new seawater desalination plant in Sand City, California, for instance, will utilize calcite contactors for product water stabilization.

3.5.4.2 pH Adjustment

The pH adjustment approach takes advantage of the role of pH as the master variable controlling the solubility of virtually all oxides, hydroxides and carbonates which form on the surface of corroding metals and protect them. These same substances also control the stability of cementaceous surfaces (Trussell and Morgan, 2006). Raising the pH not only reduces the solubility of these surfaces, it also acts to directly reduce the rate of reactions at the corrosion reaction's cathodic surface.

The addition of the sodium compounds, such as sodium hydroxide (caustic soda) or soda ash, to the RO Permeate will result in sufficient alkalinity to maintain the preferred range of 40 to 60 mg/L alkalinity, but will not add the calcium cation needed for a balanced finished water. Calcium chloride can be used for this purpose, because it adds the lowest amount of anions to the water. It is also available as a highly concentration solution of up to 38 percent. It should be noted that adding a sodium compound would increase the overall TDS content of the finished produce water, while the use of calcium chloride could complicate the ability to meet finished water chloride goals.

3.5.4.3 Phosphate Addition

Phosphate addition was first proposed for corrosion control as a result of work conducted by the City of Long Beach in the late 1960s. The original formulation, a combination of zinc orthophosphate and sulfamic acid, was applied to control the corrosion of galvanized iron and cast iron surfaces. Subsequent work suggests that orthophosphate is the principle active ingredient and that adding modest amounts of orthophosphate results in the anodic inhibition of the corrosion of iron, copper and lead surfaces. Orthophosphate addition is arguably the most effective means of corrosion control available to potable water systems today.

Today utilities use orthophosphate for corrosion control. Notable examples are the American Water Works Company, which uses orthophosphate throughout most of its systems and the City of New York who uses it for controlling corrosion in its Catskills supply. Orthophosphate is often used in conjunction with another product water stabilization technique. Our understanding is that LADWP uses orthophosphate as the primary method for corrosion control in much of its water supply.

3.5.4.4 Product Water Stabilization Summary

While multiple alternatives are available for product water stabilization of the RO permeate, the most appropriate method should be selected based on water quality data developed during the pilot testing, water quality modeling for the distribution system, or through the use of a benchtop or pilot scale study using pipe loops or metal coupons. Such studies, as presented in Table 3-9, are recommended to be conducted in conjunction with this pilot project.

3.5.5 Product Water Disinfection

Table 3-9 defines that possible disinfection with chlorine or chloramines be considered to achieve the finish product water quality 2-log removal of viruses and disinfectant residual goals. Work done with desalinated waters in Southern California has shown that high levels of bromide in SWRO permeate can have adverse impacts on the stability of the chloramine residual used in distribution systems. Some approaches have been developed to manage the problem, but if high levels of bromide are likely to appear in the final product water, it is recommended that post-SWRO disinfection studies include bench-scale experiments designed to improve our understanding of this problem.

3.6 Recommendations for Future Studies

While the primary objectives of the pilot plant, as presented in Section 1, can be achieved through the testing approach described above, additional tests and studies are recommended to better define both the source of water to be utilized at the Scattergood site and the final product water to be achieved through post treatment. The following studies are therefore recommended to be conducted concurrently with or subsequent to the Scattergood Seawater Desalination Pilot:

- Subsurface Intake Feasibility Study for the Scattergood site
- Product Water Stabilization Study, looking both at blending impacts through computerized modeling and bench top or pilot scale corrosivity tests
- Pilot testing of second pass RO, if it is found to be needed for complying with the water quality goals established in this Report
- Pilot testing of pre-treatment and post-treatment cooling towers, if it is determined that warm water is an acceptable alternative for the ultimate desalination plant source water

- Bench top chloramines stability testing
- Comprehensive Brine Discharge Evaluation
- Product water integration study. Based on water quality data developed during pilot, this study should evaluate optimal distribution and blending of product water within existing pressure zones 325 and 477.

Section 4
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Metropolitan Water District of Southern California, Joseph Jensen Treatment Plant. Online at:
http://www.mwdh2o.com/mwdh2o/pages/yourwater/plants/jensen01.html

Metropolitan Water District of Southern California, Robert B. Diemer Treatment Plant. Online at:
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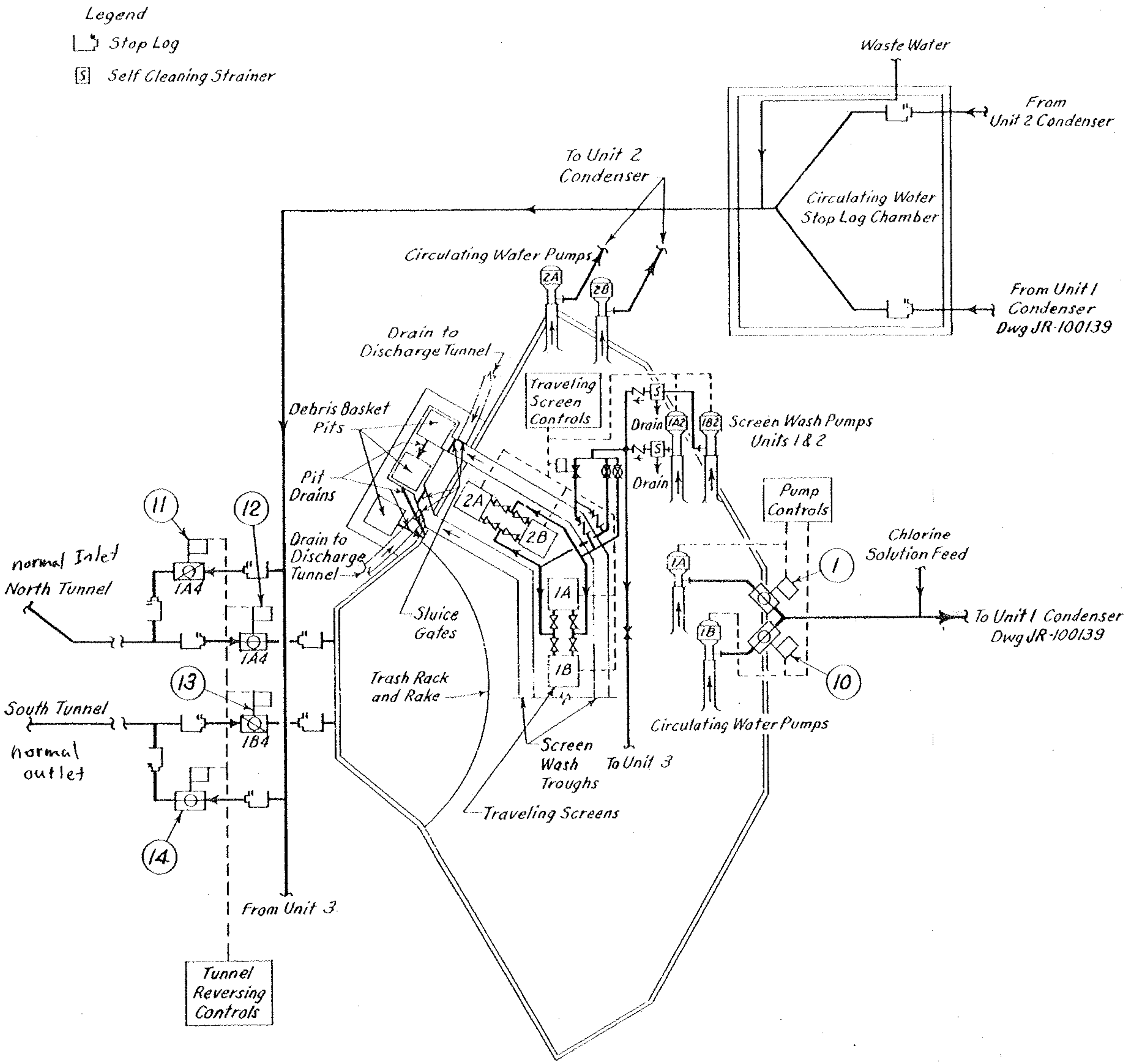
Appendix A
Scattergood Generation Station Cooling Water Schematics

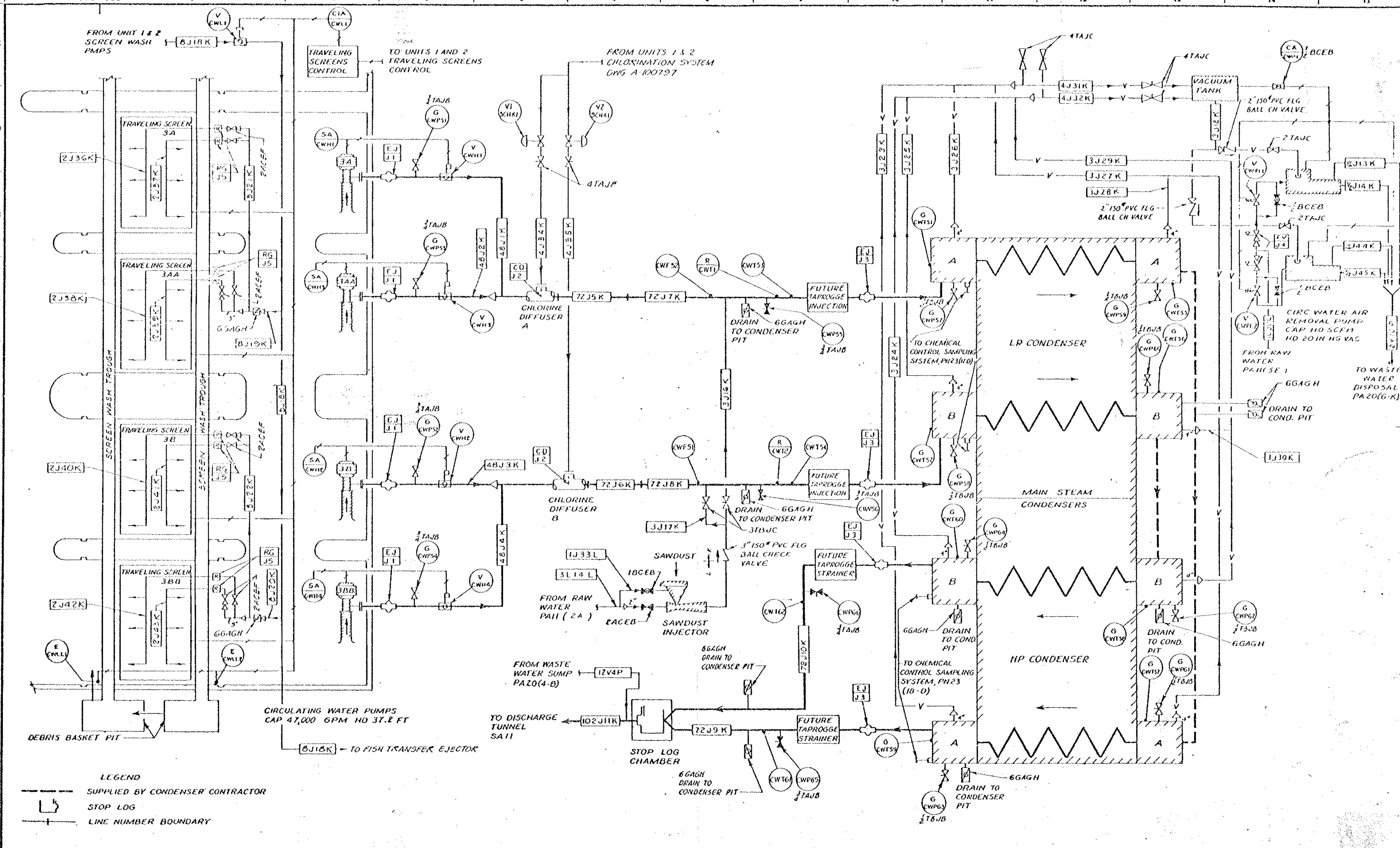


VALVE IDENTIFICATION LEGEND

1. Circulating Water Pump 1A Discharge Valve
10. Circulating Water Pump 1B Discharge Valve
11. North Tunnel - Reverse Flow Discharge Valve
12. North Tunnel - Normal Inlet Valve
13. South Tunnel - Reverse Flow Inlet Valve
14. South Tunnel - Normal Discharge Valve

SCREEN AND PUMP CHAMBER CIRCULATING WATER PIPING SCHEMATIC
SCATTERGOOD STEAM PLANT UNITS 1 AND 2

5D12 PJR100140



STANDARD SYMBOLS: DWGS J-8531A, J-8532, J-8532A, J-9371 AND S-PDR2
PIPING LINE DATA SHEETS: DWGS SD3-PDR9 AND 9A
PIPING SPECIALTY LIST: DWG SD3-PDR59
INSTRUMENT INDEX:

REVISIONS LOCATED BY GRID COORDINATES

REVISIONS

NO	DATE	INITIALS	DESCRIPTION	APPD.
1	1-7-75		REVISED TO DATE	
2	6-27-75		(15-G,H) J44 & J45 WERE J13 & J14	
3	5-31-75		[illegible]	
4	[illegible]		[illegible]	

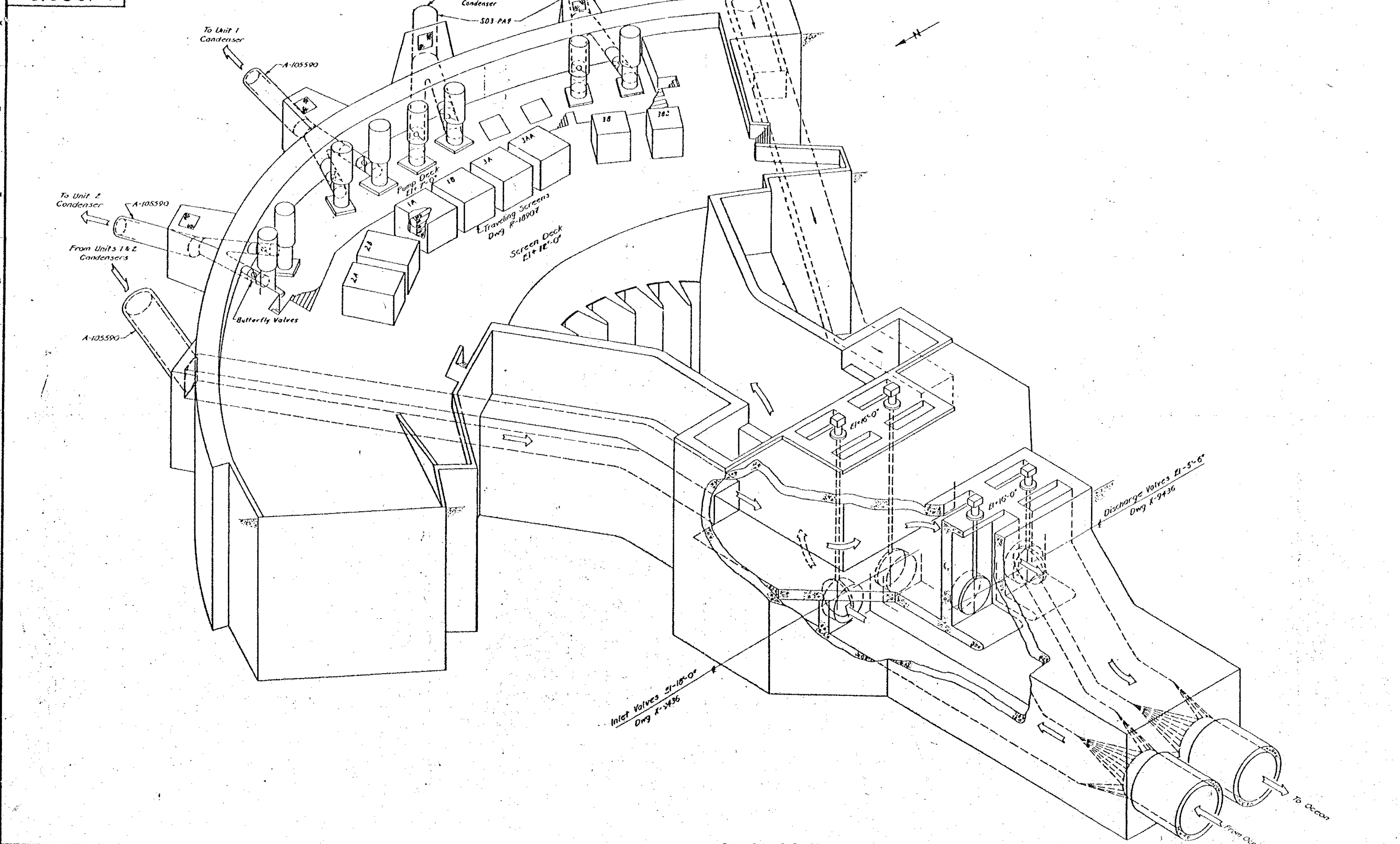
SCALE NONE
DRAWN RED DATE 12-1-69
CHECKED KRP
RECOMMENDED FOR APPROVAL
APPROVED

PIPING LINE DIAGRAM
CIRCULATING WATER SYSTEM UNIT 3
SCATTERGOOD STEAM PLANT

POWER SYSTEM
DEPARTMENT OF WATER & POWER CITY OF LOS ANGELES

SD3 PA9

Appendix B
Scattergood Generating Station Screen and Chamber Facility Isometric



Reference Drawings
A-105500 thru A-105534 } Screen and Pump Chamber Structure
A-105590 Reinforced Concrete Pipe

Revisions Located By Grid Coordinates.

No.	Date	Initials	Revisions Description	App'd
1	4/4/75	RGG	(5 B) - (14 K) Add Unit 3 CW Pipes	

Scale: None
Drawn: REB 7-15-5
Checked: ER 7-25-5
Design Engineers
Recommended for Approval
Approved

Screen and Pump Chamber Circulating Water Piping — Isometric
All Units
Scattergood Steam Plant

POWER SYSTEM
DEPARTMENT OF WATER & POWER CITY OF LOS ANGELES

Drawing Number A-100812

Job No. 3318
RG A-100812

Appendix C
Water Quality Report

LADWP

Water Quality Report 2006

Overview LADWP Water Meets or Surpasses All Water Quality Standards

I am pleased to report that LADWP consistently provided the City of Los Angeles with high quality drinking water in the year 2006. Last year, all 227 billion gallons of water supplied to the 4 million residents of Los Angeles met or surpassed all health-based drinking water standards. These standards are set by the U.S. Environmental Protection Agency (EPA) and the State of California Department of Health Services (CDHS) Drinking Water Program.

LADWP achieves this high quality water by protecting our water sources, using state-of-the-art water treatment processes, prudently maintaining and operating our facilities, and vigilantly monitoring and testing the water we serve. In 2006, LADWP conducted more than 307,300 field and laboratory tests on over 23,000 samples collected throughout the year for both regulated contaminants such as arsenic, chromium, lead, and disinfection by-products, as well as contaminants such as chromium 6 and perchlorate that are not yet regulated.

This report summarizes the results of those water quality tests and provides specific information about the quality of the water served in your neighborhood. Its purpose is to help you to make informed choices about the water you drink. In addition, this year's report spotlights some of the employees who work to ensure the high quality of your water and other information we hope you will find useful and interesting.

I would also like to take this opportunity to thank you for your water conservation efforts, and urge continued diligence during this extremely dry and potentially very warm summer.

-- H. David Nahai, President, Board of Water and Power Commissioners

Table of Contents

Our mission is to provide our customers with reliable, high quality, and competitively priced water services in a safe, publicly and environmentally responsible manner.

Drinking Water and **Your Health**

Notice from the **EPA**

All drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. Why? Because the sources of drinking water (both tap and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and in some cases, radioactive materials, and can pick up substances resulting from the presence of animal or human activity.

However, the presence of contaminants does not necessarily indicate that the water poses a health risk. In order to ensure that tap water is safe to drink, the EPA and the CDHS enforce regulations that limit the amount of certain contaminants in water provided by public water systems. CDHS regulations also establish limits for the same contaminants in bottled water to ensure the same protection for the public.

Contaminants that may be present in source waters include:

Microbial contaminants, such as viruses and bacteria that may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.

Inorganic contaminants, such as salts and metals, can be naturally occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, and mining or farming.

Radioactive contaminants that can be naturally occurring or be the result of oil and gas production and mining activities.

Organic chemical contaminants, including synthetic and volatile chemicals that are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm water runoff, agricultural application, and septic systems.

Pesticides and herbicides that may come from a variety of sources such as agriculture, urban storm water runoff, and residential uses.

Learn more about contaminants and potential health effects by calling EPA's Safe Drinking Water Hotline at (800) 426-4791 or visiting its website at *www.epa.gov.*

Your**health**

Health-Related Notices

Precautions for People with Weakened Immune Systems

Some people may be more vulnerable to contaminants in drinking water than the general population. People with weakened immune systems may have undergone chemotherapy treatment, received organ transplants, suffer from HIV/AIDS, or other immune system disorders. Some elderly and infants can be particularly at risk from infection. People with these types of health challenges should seek advice about drinking water from their health care providers. Guidelines from the EPA and Centers for Disease Control (CDC) offer ways to lessen the risk of infection by Cryptosporidium and other microbial contaminants. These are available at no cost by contacting the EPA's Safe Drinking Water Hotline at (800) 426-4791, or visiting its website at *www.epa.gov*.

Sensitivity to Chlorine and Chloramines

LADWP is gradually switching from chlorine to chloramines as its disinfectant, though customers should expect to receive both types of treatment in their water at any time. Both chlorine and chloramines are effective killers of bacteria and other microorganisms, but chloramines form less disinfection by-products and have no odor when used properly.

People who use kidney dialysis machines may want to take special precautions and consult their physician for the appropriate type of water treatment. Customers who maintain fish ponds, tanks or aquaria should also make necessary adjustments in water quality treatment, as these disinfectants are toxic to fish. For further information, please visit *www.ladwp.com/water*, click on water quality, then click on "Constituents & Hot Topics."

Customers who maintain fish ponds, tanks or aquaria should make necessary adjustments

Protecting Water Quality at the Source

Did you know that about half of all water served to LADWP customers begins as snowmelt in the Eastern Sierra? This pure, natural runoff from the Eastern Sierra slopes feeds the Los Angeles Aqueduct that delivers drinking water to Los Angeles.

Protecting this water at its source is one of the most important factors in assuring the highest possible water quality for the City of Los Angeles. LADWP works to protect the quality of our water by diligently managing the natural resources of the Eastern Sierra/Owens Valley watershed.

LADWP leases about 80 percent of its land in the Owens Valley, and ensures that at least 75 percent of that land remains undeveloped and open to the public for recreational use. To protect the watershed, policies allow camping, fishing and other recreational activities only in designated areas. LADWP also has worked closely with ranchers and farmers to develop grazing and agricultural strategies that protect the watershed by preventing soil erosion and promoting vegetation.

Here are some ways you can help protect water quality at the source when visiting the Eastern Sierra and Owens Valley.

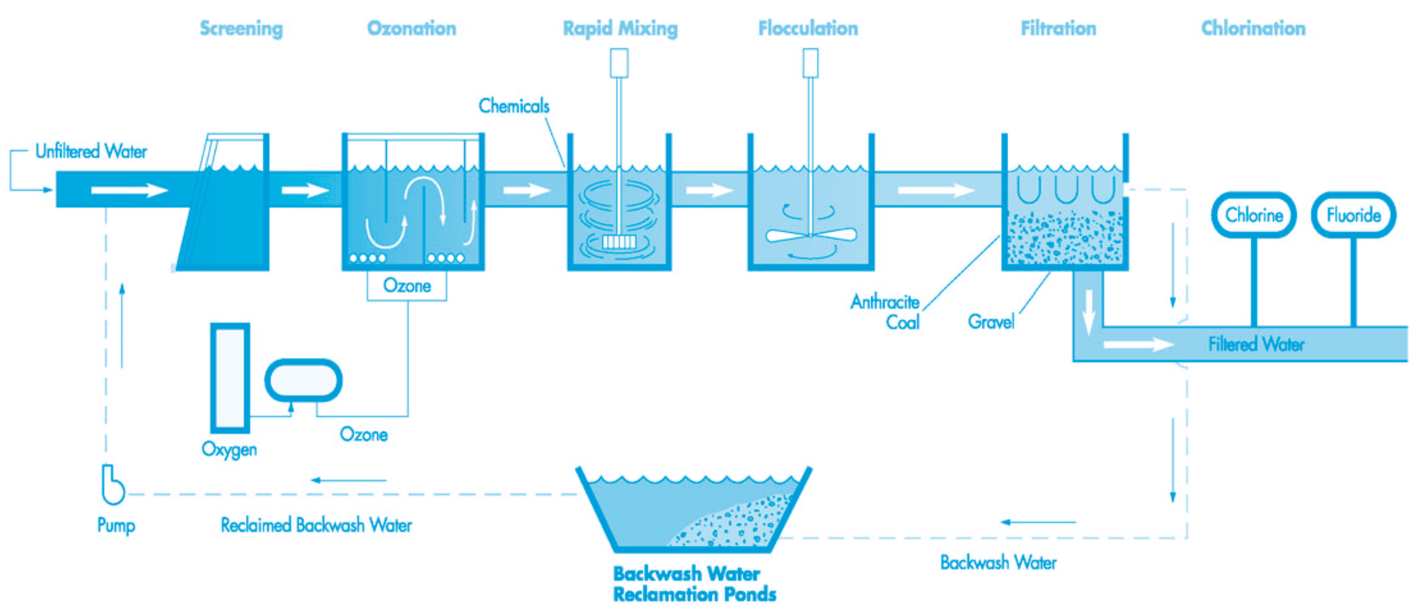
- Use designated restrooms and trash cans.
- When in the backcountry, pack out all trash and waste.
- Use established dump stations for RVs and trailers.
- Never dispose of trash, motor oil, detergents, or other chemicals by burying in the ground.
- Corral pack animals more than 200 feet from any stream or river.
- If fishing, clean your equipment to prevent the spread of harmful non-native species such as the New Zealand mudsnail.

Water**treatment**

Surface Water Treatment

All water coming from the Los Angeles Aqueduct, the California Aqueduct, and the Colorado River Aqueduct is filtered and treated to ensure a safe drinking water supply. At the Los Angeles Aqueduct Filtration Plant, water is treated as follows:

The Treatment Process



Water flows into the filtration plant by gravity and travels through a screener to remove environmental debris such as twigs and dead leaves. The process injects ozone, a super-charged oxygen molecule and a powerful disinfecting agent into the water to destroy bacteria and other impurities that affect taste, odor and color. Chemicals are quickly dispersed into the water to make fine particles called floc. A 6-foot-deep filter (crushed coal over gravel) then removes the flock and previously added chemicals. Chlorine added during the final step ensures lasting disinfection and protects the water as it travels through the City's distribution system.

Groundwater Treatment

The City's vast groundwater supply in the San Fernando Valley and Central Basin are generally clean and clear. However, LADWP also disinfects this groundwater with chlorine as a safeguard against microorganisms.

Because of a history of contaminants found in the San Fernando Valley groundwater wells, LADWP adheres to strict operating limits to keep TCE, PCE, hexavalent chromium, perchlorate and nitrates far below the maximum contaminant levels (MCLs) permitted by federal or state regulations. This provides an additional safety margin for City customers. Additionally, blending allows the use of wells that would be otherwise unavailable. In the long term, additional well field treatment will become necessary. LADWP is formulating a comprehensive groundwater treatment plan for the San Fernando Basin that will address current and future contaminants of concern.

Spotlight: **To Filter Or Not To Filter...**

One of the most frequent questions we hear from customers is: "Do water filters work and should I use one?"

You probably do not need to use a water filter. The City water delivered to your water meter by LADWP meets all State and Federal drinking water standards and is clear, taste great and is safe to drink. That said, however, LADWP is not responsible for high quality plumbing on private property. Sub-standard, illegal, old, improperly installed and/or improperly maintained plumbing may adversely affect the quality appearance or taste of water coming from the tap inside your home or business. If your plumbing is causing a water quality problem, a low-cost, point-of-use filter can improve the water quality; however, a better solution is to correct the bad plumbing causing the poor water quality in the first place.

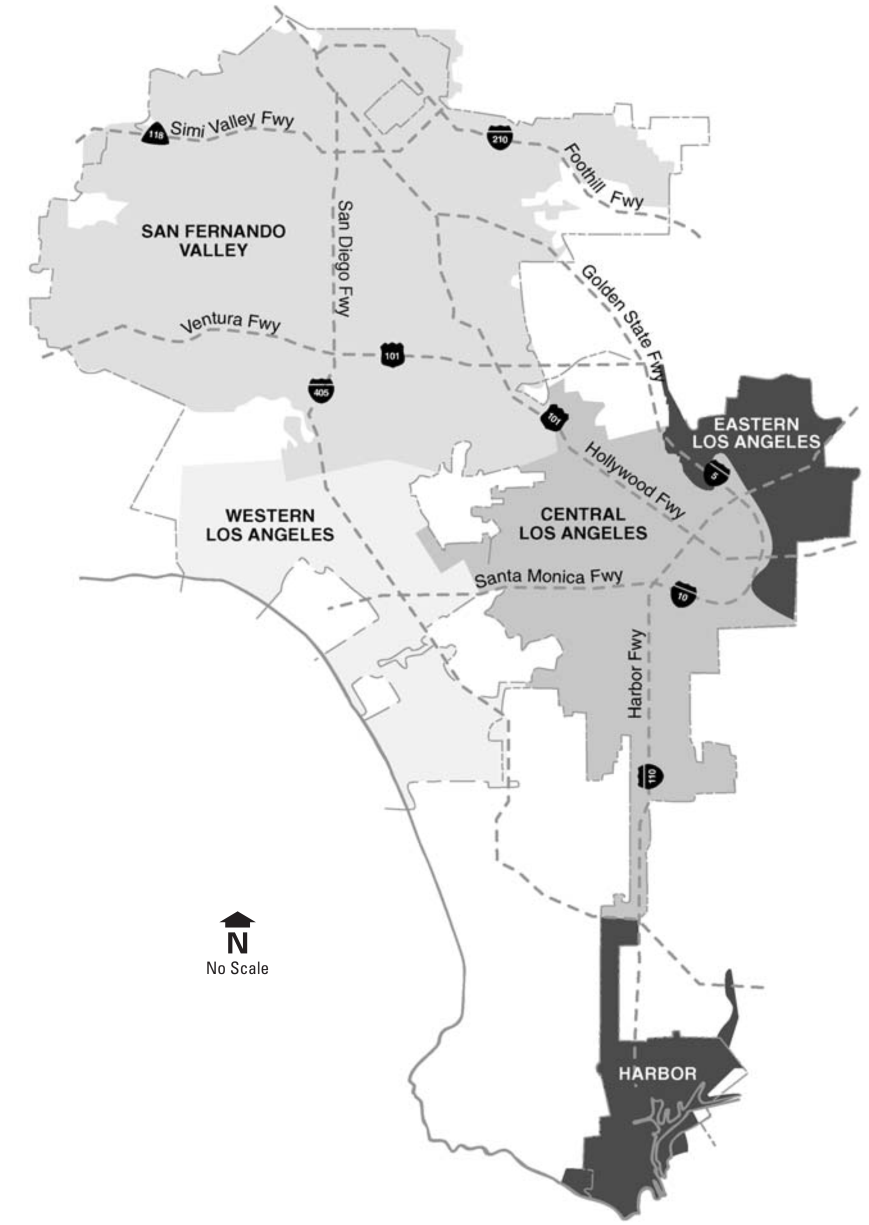
As with most products, some filters work better than others and some do not work at all. There are many types of filters available, each type works differently and will remove different substances from the water. It is helpful to know exactly why you want to filter the water before you speak to a seller of water treatment devices because that may help determine the type of filter that will best resolve the problem.

There are several resources available that can help you select a filter that works properly and meets your needs, including:

- *Consumer Reports Magazine* and Web site
- The National Sanitation Foundation (NSF), which maintains a list of approved water treatment devices, (800) 673-6275, e-mail: info@nsf.org.
- The Pacific Water Quality Association, an association of manufacturers and marketers of water treatment devices, (760) 644-7348, e-mail: info@pwqa.org.

Please note: If you do install a water filter, follow the operating and maintenance instructions very carefully. An improperly installed and/or maintained filter can adversely affect the quality of your water.

Water Quality In Your Area



Los Angeles Department of Water & Power

Communities

San Fernando Valley Communities

Arleta, Canoga Park, Chatsworth, Encino, Granada Hills, Hollywood Hills, Lake View Terrace, Mission Hills, North Hills, North Hollywood, Northridge, Olive View, Pacoima, Panorama City, Porter Ranch, Reseda, Sherman Oaks, Studio City, Sun Valley, Sunland, Sylmar, Tarzana, Toluca Lake, Tujunga, Valley Village, Van Nuys, Warner Center, West Hills, Winnetka, Woodland Hills

Central Los Angeles Communities

Baldwin Hills, Chinatown, Country Club Park, Crenshaw, Griffith Park, Hancock Park, Hollywood, Hyde Park, Koreatown, LA City Strip (parts of), Little Tokyo, Los Feliz, Mid City, Mt. Olympus, Park La Brea, Rancho Park, Silverlake, Watts, West Hollywood (parts of), Westlake

Western Los Angeles Communities

Bel Air Estates, Beverly Glen, Brentwood, Castellamare, Century City, Cheviot Hills, Culver City (parts of), Mar Vista, Pacific Palisades, Palisades Highlands, Palms, Playa del Rey, Sawtelle, Venice, West Los Angeles, Westchester, Westwood

Eastern Los Angeles Communities

Atwater Village, Boyle Heights, Cypress Park, Eagle Rock, Echo Park, El Sereno, Glassell Park, Highland Park, Lincoln Heights, Montecito Heights, Monterey Hills, Mt. Washington

Harbor Communities

East San Pedro (Terminal Island), Harbor City, Harbor Gateway (parts of), LA City Strip (parts of), San Pedro, Wilmington

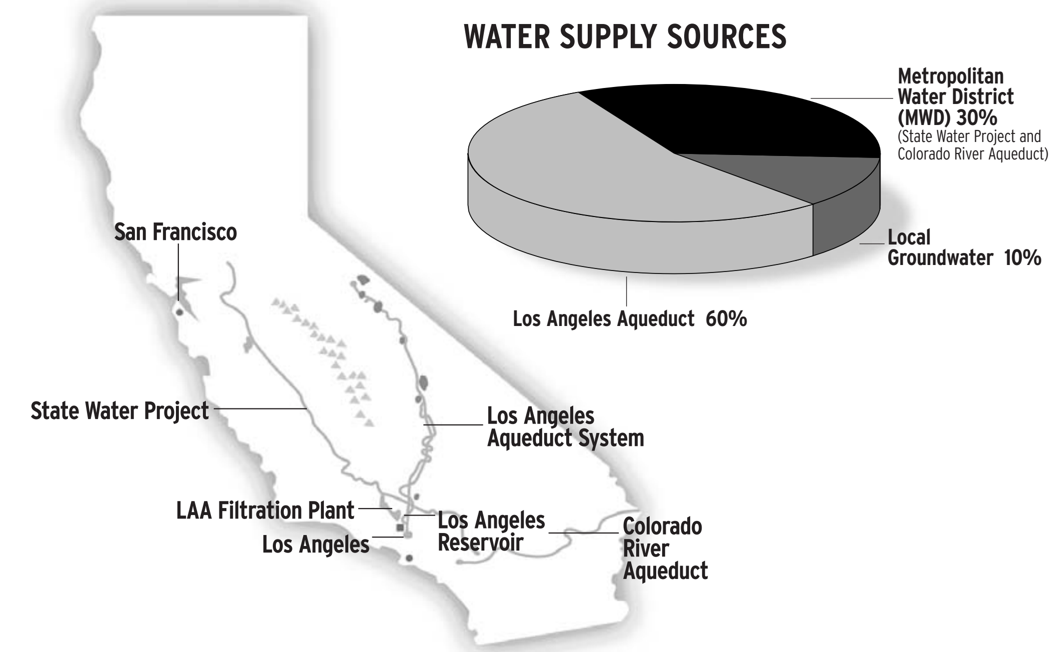
Where **L.A.'s Water** Comes From

San Fernando Valley:
Los Angeles Aqueduct, local groundwater, and MWD State Water Project.

Central Los Angeles:
Los Angeles Aqueduct, MWD State Water Project, and local groundwater.

Western Los Angeles:
Los Angeles Aqueduct and MWD State Water Project.

Harbor/Eastern Los Angeles:
MWD State Water Project and Colorado River Aqueduct.



Report for **All Water** Quality Areas

Tables I-III list the results of water tests performed by LADWP and MWD from January to December 2006. These tables include only contaminants with values that are equal to or greater than the limit of detection.

How to Read **the Tables**

The constituents/contaminants found in the water served in your area are listed as follows:

- **For San Fernando Valley Area** – water test results are under the Los Angeles Aqueduct Filtration Plant, the Northern Combined Wells, and MWD Jensen Filtration Plant columns
- **For Western Los Angeles Area** – water test results are under the Los Angeles Aqueduct Filtration Plant column
- **For Central Los Angeles Area** – water test results are under the Los Angeles Aqueduct Filtration Plant and the Southern Combined Wells columns
- **For Harbor/Eastern Los Angeles Area** – water test results are under the MWD Jensen, Weymouth, and Diemer Filtration Plants columns

Some constituents/contaminants detected are reported on a **citywide basis** as required by the California Department of Health Services. The unregulated contaminants reported on an **area-wide basis** are included for additional information on the water served in your area.

Abbreviations

< = less than (example: In Table 1, Aluminum has an average value of <50 for Los Angeles Aqueduct Filtration Plant. This means that the average value is less than 50 micrograms per liter, which is the lowest detection level (DLR) for reporting Aluminum.)

% = Total coliform is reported for compliance as percentage of positive samples, but the unit for analytical reporting of total coliform bacteria is Colony Forming Units per 100 milliliters (CFU/100 ml) of sample.

LSI units = Langelier Saturation Index (an indicator of corrosivity)

mg/L = milligrams per liter (equivalent to ppm)

NA = Not applicable

NT = Not tested

NTU = Nephelometric Turbidity Units; Turbidity is a measure of the cloudiness of the water. High turbidity can hinder the effectiveness of disinfectants.

pCi/L = picoCuries per liter

TON = Threshold Odor Number

µg/L = micrograms per liter (equivalent to ppb)

µS/cm = micro Siemens per centimeter

Calendar Year 2006 Water Quality Monitoring Results

TABLE I – HEALTH-BASED PRIMARY DRINKING WATER STANDARDS CONTAMINANTS DETECTED IN TREATED WATER

Contaminants	Units	Los Angeles Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Diemer Filtration Plant		MWD Jensen Filtration Plant		MWD Weymouth Filtration Plant		State and Federal Primary Standard (MCL or MRDL)	MEET PRIMARY STANDARD ?	State PHG or (Federal MRDLG or MCLG)	Major Sources of Contaminants In Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average				
Alpha Emitters (a)	pCi/L	<3.0 - 5.5	3.6	3.2 - 6.0	4.3	<3.0 - 6.0	4.3	<3.0 -7.2	3.6	<3.0-4.2	<3.0	<3.0	<3.0	15	YES	(0)	Erosion of natural deposits
Aluminum	µg/L	<50	<50	<50	<50	<50	<50	<50 - 58	<50	<50 - 110	81	<50 - 190	<50	1000	YES	600	Residue from surface water treatment process; erosion of natural deposits
Arsenic	µg/L	<2.0 - 7.0	2.3	<2.0 - 5.0	2.0	<2.0 - 5.0	2.0	<2.0	<2.0	<2.0	<2.0	<2.0 - 2.4	<2.0	10	YES	0.004	Erosion of natural deposits; natural hot springs
Barium	µg/L	<100	<100	<100	<100	<100 - 110	<100	<100	<100	<100	<100	<100	<100	1000	YES	2000	Erosion of natural deposits; discharge from oil drilling waste and metal refineries
Beta Emitters (a)	pCi/L	<4.0 - 8.4	4.6	<4.0 - 5.3	4.0	<4.0 - 6.4	4.0	<4.0 - 4.7	<4.0	<4.0	<4.0	<4.0	<4.0	50	YES	(0)	Decay of natural and man-made deposits
Bromate (f)	µg/L	<5.0 - 6.6	<5.0	NA	NA	NA	NA	NA	NA	<5.0 - 7.2	5.6	NA	NA	10	YES	(0)	By-product of drinking water disinfection
Nitrate (as NO3)	mg/L	<2.0	<2.0	<2.0 - 16	7.1	<2.0 - 14	7.1	<2.0 - 3.0	2.0	<2.0 - 2.4	2.1	<2.0 - 4.9	2.4	45	YES	45	Erosion of natural deposits; runoff and leaching from fertilizer use
Nitrate + Nitrite (as Nitrogen)	mg/L	<0.40	<0.40	<0.4 - 3.7	1.7	<0.40 - 3.2	1.7	<0.40 - 0.68	0.45	<0.40 - 0.54	0.47	<0.40 - 0.63	0.45	10	YES	10	Erosion of natural deposits; runoff and leaching from fertilizer use
Tetrachloroethylene [PCE]	µg/L	<0.5	<0.5	<0.5 - 1.8	<0.5	<0.5 - 1.3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	YES	0.06	Discharge from factories, dry cleaners, auto shops (metal degreaser)
Trichloroethene [TCE]	µg/L	<0.5	<0.5	<0.5 - 2.7	0.51	<0.5 - 2.5	0.51	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	YES	0.8	Discharge from metal degreasing sites and other factories
Turbidity (b)	NTU	0.38	99.98%	NA	NA	NA	NA	0.08	100%	0.05	100%	0.09	100%	TT	YES	none	Soil runoff
Uranium (a)	pCi/L	1.2 - 4.7	3.4	2.2 - 6.6	4.8	<1.0 - 6.1	5.4	<1.0	<1.0	1.1 - 1.2	1.2	<1.0	<1.0	20	YES	0.43	Erosion of natural deposits

HEALTH-BASED PRIMARY DRINKING WATER STANDARDS CONTAMINANTS DETECTED IN DISTRIBUTION SYSTEM AND REPORTED ON CITY-WIDE BASIS

Constituents / Contaminants	Units	Range	Average	State and Federal Primary Standard (MCL or MRDL)	MEET PRIMARY STANDARD ?	State PHG or (Federal MRDLG or MCLG)	Major Sources of Contaminants In Our Drinking Water
Copper (at-the-tap) (c)	µg/L	Number of Samples Exceeding AL = 1 out of 106	90th Percentile Value = 802	TT, AL=1300 (d)	YES	170	Internal corrosion of household water plumbing systems
Fluoride	mg/L	Range = 0.11 - 1.3	Average = 0.57	2	YES	1	Erosion of natural deposits; water additive that promotes strong teeth
Lead (at-the-tap) (c)	µg/L	Number of Samples Exceeding AL = 2 out of 106	90th Percentile Value = 10	TT, AL=15 (d)	YES	2	Internal corrosion of household water plumbing systems
Total Chlorine Residual	mg/L	Range = 0 - 6.0	Average = 1.7	4.0	YES	4.0	Drinking water disinfectant added for treatment
Total Coliform Bacteria	%	Range: 0 - 1.3% Coliform Positive Samples	Average = 0.3 % Coliform Positive Samples (b)	5% of monthly samples are coliform positive	YES	(0)	Naturally present in the environment
Total Haloacetic Acids	µg/L	Range = 10 - 134	City-wide Highest Running Annual Average = 45	60	YES	none	By-product of drinking water disinfection
Total Trihalomethanes [TTHM]	µg/L	Range = 25 - 111	City-wide Highest Running Annual Average = 60	80	YES	none	By-product of drinking water chlorination

TABLE II – AESTHETIC-BASED SECONDARY DRINKING WATER STANDARDS CONSTITUENTS/CONTAMINANTS DETECTED IN TREATED WATER

Constituents/Contaminants	Units	Los Angeles Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Diemer Filtration Plant		MWD Jensen Filtration Plant		MWD Weymouth Filtration Plant		State and Federal Standard MCL	MEET SECONDARY STANDARD?	Major Sources of Contaminants In Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average			
Aluminum	µg/L	<50	<50	<50	<50	<50	<50	<50 - 58	<50	<50 - 110	81	<50 - 190	<50	200	YES	Residue from some surface water treatment process; erosion of natural deposits;
Chloride	mg/L	20 - 31	25	21 - 39	32	23 - 53	32	47 - 97	66	44 - 56	50	42 - 98	61	500	YES	Runoff/leaching from natural deposits; seawater influence
Color	Units	4 - 5	4	3 - 5	4	3 - 7	4	1 - 2	2	1 - 2	1	1 - 4	2	15	YES	Naturally-occurring organic matter
Corrosivity (e)	LSI	(-0.46) - (-0.17)	-0.29	(-0.35) - 0.77	0.12	(-0.35) - 0.94	0.12	0.07 - 0.29	0.2	0.02 - 0.26	0.14	0.04 - 0.30	0.19	non-corrosive	NO/YES/YES/ YES/YES/YES	Natural or industrially influenced balance of hydrogen, carbon and oxygen in the water; affected by temperature and other factors.
Foaming Agents (MBAS)	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05 - 0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	500	YES	Municipal and industrial discharges
Manganese NL = 500	µg/L	<20	<20	<20	<20	<20 - 46	<20	<20	<20	<20	<20	<20	<20	50	YES	Leaching from natural deposits
Odor	TON	<1 - 1	<1	<1	<1	<1	<1	2	2	2	2	2	2	3	YES	Naturally occurring organic materials
Specific Conductance	µS/cm	265 - 368	338	308 - 699	616	374 - 749	616	536 - 810	652	411 - 539	480	482 - 829	595	1600	YES	Substances that form ions when in water; seawater influence
Sulfate	mg/L	20 - 39	30	25 - 151	118	33 - 151	118	106 - 159	132	55 - 86	69	78 - 162	116	500	YES	Runoff/leaching from natural deposits
Total Dissolved Solids [TDS]	mg/L	138 - 225	195	184 - 468	451	251 - 490	451	307 - 458	378	236 - 304	273	270 - 481	344	1000	YES	Runoff/leaching from natural deposits
Turbidity	NTU	0.10 - 0.2	0.12	0.10 - 0.25	0.14	0.10 - 0.80	0.14	0.04 - 0.06	0.05	0.04	0.04	0.05 - 0.07	0.06	5	YES	Soil runoff
Zinc	µg/L	<50	<50	<50	<50	<50 - 2830	<50	<50	<50	<50	<50	<50	<50	5000	YES	Corrosion control additive; runoff/leaching from natural deposits

Calendar Year 2006 Water Quality Monitoring Results

TABLE III – UNREGULATED DRINKING WATER CONSTITUENTS/CONTAMINANTS DETECTED IN TREATED WATER

Constituents/Contaminants	Units	Los Angeles Filtration Plant		Northern Combined Wells		Southern Combined Wells		MWD Diemer Filtration Plant		MWD Jensen Filtration Plant		MWD Weymouth Filtration Plant		Major Sources of Contaminants In Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	
Alkalinity	mg/L	71 - 117	100	81 - 191	145	120 - 205	145	71 - 84	77	76 - 87	82	63 - 85	71	Erosion of natural deposits
Boron NL = 1000	µg/L	340 - 590	420	140 - 530	320	130 - 530	320	<100 - 160	130	150 - 210	190	100 - 150	130	Erosion of natural deposits; residue from surface water treatment process
Bromide	µg/L	<20	<20	<20	<20	<20 - 39	<20	NT	NT	NT	NT	NT	NT	Runoff/leaching from natural deposits; seawater influence
Calcium	mg/L	19 - 29	26	26 - 72	60	28 - 80	60	31 - 43	37	24 - 29	27	24 - 42	32	Erosion of natural deposits; natural hot springs
Chromium 6	µg/L	<1.0	<1.0	<1.0 - 3.7	<1.0	<1.0 - 2.8	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	Industrial discharge; erosion of natural deposits
Magnesium	mg/L	4.1 - 7.2	5.8	5.5 - 18	14	6.0 - 22	14	13 - 20	17	11 - 13	12	11 - 20	15	Erosion of natural deposits
pH	units	7.5 - 7.8	7.7	7.4 - 7.9	7.6	7.4 - 7.9	7.6	8.1 - 8.3	8.2	8.1 - 8.3	8.2	8.3- 8.4	8.3	Naturally occurring dissolved gases and minerals
Phosphate (as Phosphorus)	µg/L	<10 - 10	<10	<10 - 54	30	12 - 961	30	NT	NT	NT	NT	NT	NT	Erosion of natural deposits, agricultural run-off
Potassium	mg/L	2.7 – 4.5	3.7	2.7 - 4.6	3.8	2.8 - 4.4	3.8	2.8 – 3.9	3.2	2.3 – 2.8	2.6	2.5 – 4.0	2.9	Erosion of natural deposits
Radon (a)	pCi/L	NA	NA	<100	<100	<100 - 530	<100	<100	<100	<100	<100	<100	<100	Decay of natural deposits
Silica	mg/L	14 - 20	18	16 - 25	21	19 - 25	21	NT	NT	NT	NT	NT	NT	Erosion of natural deposits
Sodium	mg/L	24 - 41	34	24 - 48	44	40 - 48	44	52 - 85	65	39 - 56	47	48 - 91	62	Erosion of natural deposits
Total Hardness (as $CaCO_3$)	mg/L	68 - 101	88	91 - 259	215	91 - 276	215	134 - 185	161	110 - 128	120	114 - 189	140	Erosion of natural deposits
Total Organic Carbon [TOC]	mg/L	1.4 – 1.8	1.6	0.59 – 2.1	1.0	<0.3 - 1.3	1.0	1.9 – 2.7	2.3	2.2 – 2.8	2.4	1.8 – 2.7	2.2	Erosion of natural deposits
Vanadium NL = 50	µg/L	<3.0	<3.0	<3.0 – 8.0	<3.0	<3.0	<3.0	<3.0 – 3.5	<3.0	<3.0	<3.0	<3.0 – 3.4	<3.0	Erosion of natural deposits

UNREGULATED CONTAMINANTS REPORTED ON AREA-WIDE BASIS

Contaminants	Units	Central Los Angeles		Harbor/Eastern Los Angeles		San Fernando Valley		Western Los Angeles		Major Sources of Contaminants In Our Drinking Water
		Range	Average	Range	Average	Range	Average	Range	Average	
Bromodichloromethane [BDCM]	µg/L	4.6 - 28	16	7.1 - 24	14	5.0 - 24	15	3.9 - 28	15	Disinfection by-product of chlorination
Bromoform	µg/L	<0.5 - 18	4.4	0.5 - 7.4	3.7	<0.5 – 5.9	1.6	<0.5 - 9.1	1.4	Disinfection by-product of chlorination
Chlorate NL = 800	µg/L	117 - 252	191	104 - 726	250	22 - 313	168	340 - 851	609	Disinfection by-product of chlorination
Chloroform	µg/L	2.6 - 74	30	4.0 - 33	16	6.0 - 71	29	1.1 - 87	40	Disinfection by-product of chlorination
Dibromochloromethane [DBCM]	µg/L	2.7 - 24	12	7.1 - 17	11	4.0 - 23	9.6	1.2 - 16	7.7	Disinfection by-product of chlorination

Terms Used in the Tables

Detection Limit for Reporting Purposes (DLR): The DLR is the lowest level at which all CDHS certified laboratories can accurately and reliably detect a compound. The DLR provides a standardized basis for reporting purposes. For example, if two separate laboratories report that lead is "not detected," it is understood that the amount of lead in both waters was less than the DLR for lead.

Primary Drinking Water Standard or PDWS: MCLs and MRDLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the Public Health Goals (PHGs) (or MCLGs) as is economically and technologically feasible. Secondary MCLs are set to protect odor, taste, and appearance of drinking water. For certain contaminants, compliance with the MCL is based on the average of all samples taken throughout the year.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by EPA. For known or suspected carcinogens, EPA automatically sets the level at zero.

Maximum residual disinfectant level (MRDL): The level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap.

Maximum residual disinfectant level goal (MRDLG): The level of a disinfectant added for water treatment below which there is no known or expected risk to health. MRDLs are set by the EPA.

Milligram per liter(mg/L), microgram per liter(µg/L): These are units of measure used to indicate the amount of a contaminant in a certain volume of water. One milligram per liter is equivalent to one part per million (ppm). Likewise, one microgram per liter is equivalent to one part per billion (ppb).

Public Health Goal (PHG): The level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency Office of Environmental Health Hazard Assessment.

Treatment Technique (TT): A required treatment process intended to reduce the level of a contaminant in drinking water. For example, the filtration process is a treatment technique used to reduce turbidity (the cloudiness in water) and microbial contaminants from surface water. High turbidities may be indicative of poor or inadequate filtration.

Notification Levels (NL) - State: Health-based advisory levels established by CDHS for chemicals in drinking water that lack maximum contaminant levels (MCLs). When chemicals are found at concentrations greater than their notification levels, certain requirements and recommendations apply.

Regulatory Action Level (AL) - Federal: The concentration of a contaminant established by EPA that, if exceeded, triggers treatment or other requirements that a water system must follow.

Footnotes

(a) Radiological data for LADWP samples are based on 2006 monitoring except for radon which was tested in 2005. Radiological monitoring is done every four years.

(b) The new reporting requirement for treatment plant turbidity is: report the highest single measurement and the lowest monthly percentage of measurement that is less than or equal to 0.3 NTU. The turbidity level of the water from water filtration treatment plant must be less than or equal to 0.3 NTU in 95% of the measurements taken each month and shall not exceed 1.0 NTU at any time.

Turbidity is a measure of the cloudiness of the water and is a good indicator of water quality and filtration performance.

(c) At-the-tap monitoring was conducted in 2006 according to the Federal Lead and Copper Rule guidelines. Although the City's source and treated waters have little if any detectable lead, studies were conducted and corrosion control is scheduled for implementation, as required by the Lead and Copper Rule.

(d) A system is out of compliance if the Action Level is exceeded in the 90th percentile of all samples at the customer's tap.

(e) Corrosivity values were taken from calculated Langelier Index: negative value means that the water may be corrosive, positive value means that the water is non-corrosive.

(f) Bromate is a by-product of ozonation and is tested only in water treated with ozone. Diemer and Weymouth filtration plants will eventually use ozone to treat the water.

LADWP Spotlight

Water quality inspectors respond to customer concerns and questions—and investigate in person if necessary. Pictured, from left: Calvin Loretto, Charles Lembke, Koon Lui, Michael Renwick, Nathan Aguayo (supervisor), and Luis Macias.

Customer Service

Water Quality Inspectors Make House Calls

Is your water looking slightly orange or emitting a strange odor? If you have questions or concerns about the quality of your water, the LADWP Water Quality Customer Services Group is here to help.

A team of six certified water quality inspectors is dedicated to monitoring water quality at the customer level—from the tap of your home or business. They field an average of 15 to 20 calls per day, responding to customers' concerns and questions, and make about 50 "house calls" every month.

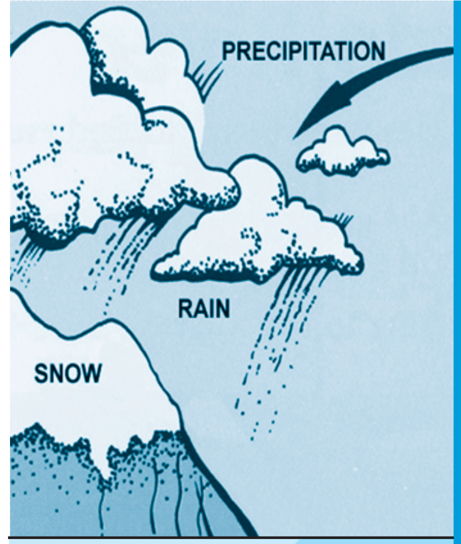
Typical inquiries involve the hardness of the water, or the levels of fluoridation, sodium, and other elements present. Complaints are mostly related to taste, odor, or discoloration. If the issue cannot be resolved over the phone, an inspector will visit your home or business to investigate the problem in person.

During a typical visit, the inspector will perform a "safety of supply" check to make sure the customer's water is safe to drink. This can involve testing and sampling the water from the customer's tap as well as from the nearest distribution line to help determine whether the problem originates in the City's or customer's plumbing.

Among the most common problems, for instance, discoloration of tap water is usually related to water standing for an extended period in corroded pipes within the customer's property. Flushing the water, or letting it run for a few minutes, usually clears up the problem. Although corrosion is not a safety issue, inspectors will still sample and test the water as an added safety measure. Occasionally the problem stems from the water supplied to the customer. For instance, algal growth in aqueducts and reservoirs that typically develop during the summer may create a musty odor. Such problems do not affect the safety of the water and are managed and resolved by LADWP within a few days.

After laboratory tests are completed, the inspector will contact the customer with the results and offer any suggestions for improving the situation. If a problem exists within the distribution system, the inspector will initiate corrective measures.

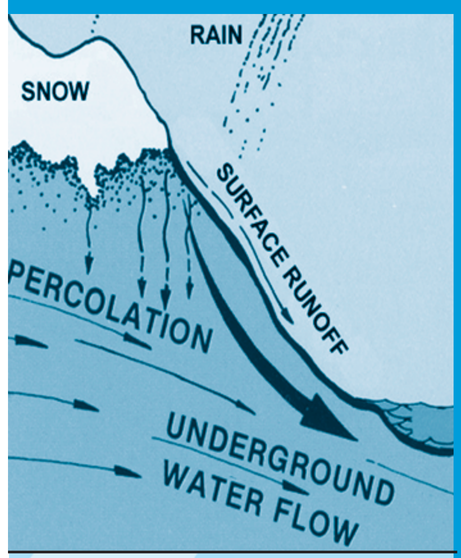
Customers can speak to a water quality inspector by calling our Water Quality Hotline at (213) 367-3182. The hotline is staffed from 7:30 a.m. to 4 p.m. Monday through Friday, except for holidays. If you call after hours, please leave a message including your name, address, telephone number, and a brief description of the problem or request and we will return your call on the next business day.



Precipitation

Water vapor from condensation in the atmosphere turns to rain or snow and falls to the ground. Precipitation can have some atmospheric pollutants in it.

Water Cycle



Infiltration and Runoff

Snow melt and rain soaking into the ground is called infiltration or percolation. Water can also flow into rivers and streams to lakes, reservoirs, and oceans. Runoff can pick up dissolved minerals and pollutants from the soil. Although infiltration can be a filtering process, it also allows the water to dissolve minerals or pollutants that may be present.

Did you **know?**

The LADWP water system includes more than 7,100 miles of mains and trunk lines. In the past eight years, LADWP has removed about 10 miles of pre-1940 trunk lines. In the next 10 years, LADWP plans to upgrade or replace about 60 miles of trunk lines.

Research on Disinfection By-Products

One of the most significant distinctions of drinking water in the United States compared to other parts of the world is that we practice continuous disinfection of our treated water supplies. This provides some of the safest water anywhere in the world, and helps prevent many water-related diseases that plague other nations.

However, some studies suggest possible long-term and short-term adverse health effects associated with disinfection by-products (DBPs), especially one group of by-products known as total trihalomethanes (TTHMs).

A few recent studies suggest possible short-term effects, including low birth weight and miscarriages. Yet other studies show no such linkages or the results were inconclusive. Long-term studies also have associated TTHMs to adverse health effects such as cancer. Scientists continue to study TTHMs to provide a clearer understanding of the risks involved.

LADWP encourages women who are pregnant or think they may become pregnant to consult their physicians regarding drinking water and pregnancy. LADWP will continue to keep customers informed about the results of any future studies. LADWP also will continue to diligently track and implement new regulations as they go into effect. Please visit us online at *www.ladwp.com/water/quality*.

LADWP currently meets all the disinfection by-product standards (see Tables I and III on pages 6-9). In addition, LADWP is in the process of switching from chlorine to chloramines to maintain water disinfectant residual, which will further reduce levels of TTHMs.

Update on Surface Water Treatment Rule

The Surface Water Treatment Rule (SWTR), administered by CDHS, is a drinking water regulation designed to help safeguard reservoir supplies from microbiological contamination that may occur when rain runoff from nearby hillsides and slopes enters the water. In Los Angeles, SWTR applies to four open water reservoirs – Lower Stone Canyon, Encino, and Upper and Lower Hollywood.

LADWP has successfully met the compliance deadlines for all four open reservoirs that were subject to SWTR requirements. Construction of support facilities will continue but water from these reservoirs will no longer be served unless it is filtered.

LADWP has complied with SWTR by removing these reservoirs from regular service. The following is a progress report for each of the reservoirs affected by SWTR.

Upper and Lower Hollywood Reservoirs – were replaced by two 30-million-gallon tanks on July 2001.

Encino Reservoir – was removed from service on December 27, 2002. The permanent air gap was completed in August 2004. Operation of a new microfiltration plant to treat the reservoir water along with related facilities began in January 2006. This plant currently produces high quality drinking water at a maximum capacity of up to ten million gallons per day.

Lower Stone Canyon Reservoir – was removed from service on December 28, 2004. The permanent air gap and associated work for the reservoir was completed on September 12, 2005. A new microfiltration plant to treat the reservoir water and other related water facilities are expected to be completed by September 2007.

Update on Enhanced SWTR and Message for Cryptosporidium

Protection of surface water sources as outlined in the SWTR regulation is very important to the quality of treated drinking water. The Long-Term 2 Enhanced Surface Water Treatment Rule (LT2) is the latest drinking water regulation related to the treatment of surface water. LT2 provides for further protection from microbial pathogens like *Cryptosporidium* and *Giardia*. Required microbial monitoring under LT2 started in July 2006. In preparation for compliance to this rule, LADWP has been monitoring its source and treated waters for *Cryptosporidium* and *Giardia* since 2005. Although both were not detected in the finished treated water, *Cryptosporidium* was detected in some raw water reservoirs and the L.A. Aqueduct at very low concentrations of 1 to 2 oocyst per 10 liter sample. Below is CDHS's statement regarding *Cryptosporidium*:

Cryptosporidium is a microbial pathogen found in surface water throughout the U.S. Although filtration removes *Cryptosporidium*, the most commonly used filtration methods cannot guarantee 100 percent removal. Our monitoring indicates the presence of these organisms in our source water and/or finished water. Current test methods do not allow us to determine if the organisms are dead or if they are capable of causing disease. Ingestion of *Cryptosporidium* may cause cryptosporidiosis, an abdominal infection. Symptoms of infection include nausea, diarrhea, and abdominal cramps. Most healthy individuals can overcome the disease within a few weeks. However, immuno-compromised people are at greater risk of developing life-threatening illness. We encourage immuno-compromised individuals to consult their doctor regarding appropriate precautions to take to avoid infection. *Cryptosporidium* must be ingested to cause disease, and it may be spread through means other than drinking water.

Message for Radon

Radon is mostly found in areas outside of California. In 2005, very low levels of radon were detected in some of our water supplies that serve the Central Los Angeles area (see Table III on pages 8-9). There is no established drinking water standard or monitoring requirement for radon. Radon, entering a home through tap water, is a small source of radon in indoor air. Although the radon levels were well below what EPA is currently considering as a standard, the EPA has asked us to share the following information with you to help you better understand radon.

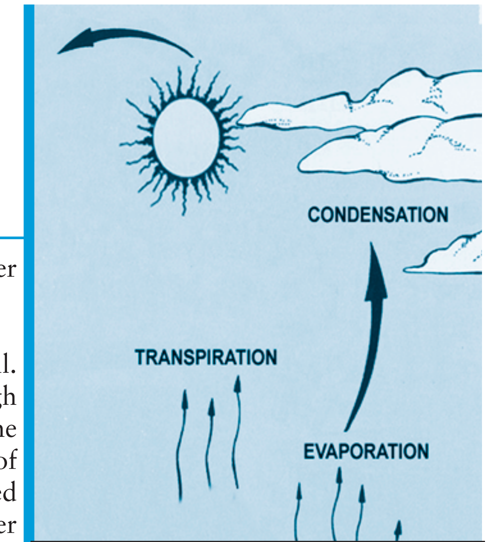
Radon is a radioactive gas that you can't see, taste, or smell. It is found throughout the U.S. Radon can move up through the ground and into a home through cracks and holes in the foundation. Radon can build up to high levels in all types of homes. Radon can also get into indoor air when released from tap water from showering, washing dishes, and other household activities. Compared to radon entering the home through soil, radon entering the home through tap water will in most cases be a small source of radon in indoor air. Radon is a known human carcinogen. Breathing air containing radon can lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. If you are concerned about radon in your home, test the air in your home. Testing is inexpensive and easy. Fix your home if the level of radon in your air is 4 picoCuries per liter of air (pCi/L) or higher. There are simple ways to fix a radon problem that aren't too costly. For additional information, call your State radon program or call EPA's Radon Hotline (800-SOS-RADON).

Drinking Water Source Assessment and Protection Program

In July 2002, LADWP completed an assessment of drinking water sources in the Owens Valley and Mono Basin watersheds that supplement the Los Angeles Aqueduct supply. These sources are most vulnerable to geothermal activities that release naturally occurring arsenic in creeks that feed into the Owens River. Other activities that may impact water quality in these watersheds are livestock grazing, wildlife, and unauthorized public use of reservoirs. The extent and significance of water quality impact from these activities are not yet fully determined. Regular monitoring for Cryptosporidium and Giardia indicates that their presence is infrequent and at very low levels.

Assessment for groundwater sources in San Fernando and Sylmar was completed in December 2002. Assessment for groundwater sources in the Central Basin was completed and submitted in March 2003. Since these wells are located in urban areas, they are most vulnerable to the following activities that are associated with contaminants found in the well water; dry cleaning, chemical processing/storage, fertilizer/pesticide storage, metal finishing, and septic system. LADWP closely manages the use of this water by blending it with water from other sources to ensure that the drinking water standards are not exceeded. A copy of the assessment can be obtained by contacting LADWP Regulatory Affairs and Consumer Protection Group at (213) 367-3335.

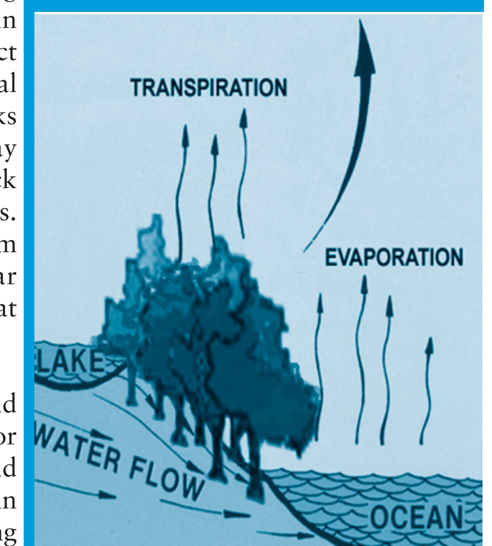
In December 2002, MWD completed its source water assessment of its Colorado River and State Water Project supplies. Colorado River supplies are considered to be most vulnerable to recreation, urban/storm water runoff, increasing urbanization in the watershed and wastewater. State Water Project supplies are considered to be most vulnerable to urban/storm water runoff, wildlife, agriculture, recreation and wastewater. A copy of the assessment can be obtained by contacting MWD at (213) 217-6850.



Condensation

Water vapor from evaporation and transpiration condense to form clouds and fog. Water droplets can be created around small particles and dust in the air.

Water Cycle



Evaporation

Water in lakes and oceans can evaporate, or turn to water vapor through heat from the sun. Water vapor can come from plants through transpiration. These processes are cleansing as contaminants and water pollutants are left behind.

About This **Report**

The 2006 Water Quality Report was prepared by the Los Angeles Department of Water and Power (LADWP). This report is required by the California Department of Health Services (CDHS) and was prepared in accordance with CDHS guidelines. It was produced and mailed to you at a cost of 25 cents. This report is printed on recycled paper.

Contact Information

ABOUT THE LOS ANGELES DEPARTMENT OF WATER AND POWER (LADWP)

LADWP, the largest municipal utility in the nation, was established more than 100 years ago to provide a reliable and safe water and electric supply to the City's 4 million residents and businesses.

LADWP is governed by a five-member Board of Water and Power Commissioners, appointed by the Mayor and confirmed by the City Council.

The Board meets regularly on the first and third Tuesdays of each month at 1:30 p.m. Meetings are held at:

Los Angeles Department of Water and Power
111 North Hope Street, Room 1555H
Los Angeles, CA 90012-2694

The meeting agenda is available to the public on the Thursday prior to the week of the meeting. You can access the Board agenda at *www.ladwp.com* or by calling (213) 367-1351.

For general information about LADWP, call 1-800-DIAL DWP (1-800-342-5397) or visit ***www.ladwp.com***.
For questions regarding water quality, call the LADWP Water Quality Customer Services Group at (213) 367-3182.
For questions regarding this report, please call Cesar Vitangcol at (213) 367-1767.

Want to know more about your drinking water and related regulations?

Los Angeles Department of Water and Power . . . . *www.ladwp.com*
California Department of Health Services (CDHS) . . . . *www.dhs.ca.gov/ps/ddwem*
U.S. Environmental Protection Agency (EPA) . . . . *www.epa.gov*

A Message to Our Customers

The Los Angeles Department of Water and Power would like to thank and congratulate our customers for conserving water.
The residents and businesses of Los Angeles used the same amount of water in 2006 as they did 25 years ago, despite a population increase of one million people. During this dry and potentially very warm summer, we urge you to continue to be vigilant in saving water. The water you save today may be the water you need tomorrow.

Messages for Non-English-Speaking Customers

This report contains important information about your drinking water. If you have any questions regarding this report, please contact us at (800) 342-5397.

Este informe contiene información importante sobre su agua potable. Si tiene alguna pregunta sobre este informe, por favor comuníquese con nosotros llamando al (800) 342-5397.

本報告包含有關您的飲用水的重要資訊，您對本報告如有任何疑問，請致電：（800）342-5397。

Báo cáo này có tin tức quan trọng về nguồn nước uống của quý vị. Nếu quý vị có thắc mắc về báo cáo này, xin liên lạc với chúng tôi tại số (800) 342-5397.

この報告書には皆さんの飲料水に関する重要な情報が含まれています。この報告書に関して何かご質問があれば(800) 342–5397 までお問い合わせください。

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Appendix D
Plants Adversely Affected by High Levels of Boron (0.5 to 1 mg/L) and Chloride (100 to 150 mg/L)

Appendix D
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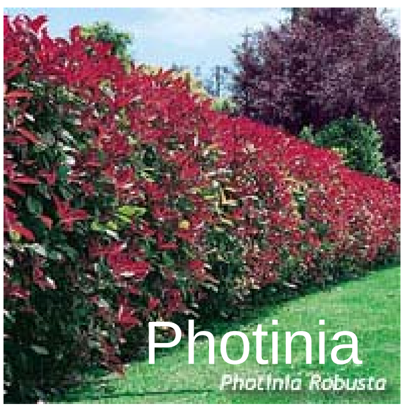


Rose


Southern
Magnolia


Violet
Trumpet
Vine


WheelerÕs
dwarf
pittosporum

Appendix E
Scattergood Cooling Evaluation Memorandum

WHAT ARE THE ALTERNATIVES FOR TEMPERATURE CONTROL WITH A WARM WATER SUPPLY?

As discussed in the introduction, one of the most important environmental issues for the full-scale LADWP seawater desalination project is the manner in which the seawater, which serves as the source water for the project, will be obtained. Currently, two types of sources are in consideration: a) Cold water, either from beach wells or from an intake engineered to prevent both impingement and entrainment, or b) Warm water taken from the power plant's condenser discharge. Using cold water from beach wells or from an engineered subsurface intake reduces environmental impact because these systems can be designed to eliminate entrainment and impingement. Using warm water from the condenser discharge reduces environmental impact because this water has already been removed from the ocean and processed through the generating station. The purpose of this memorandum is to examine action that might be taken to cool the warm water if the second option is selected.

If, to reduce environmental impact, a decision is made to use the warmer condenser discharge water, the desalinated water must be brought to approximately the same temperature as the Department's current supply, otherwise consumers are likely to notice changes in temperature and complain. As a result, cooling of the water is a requirement if the desalination plant is to be operated on Scattergood's condenser water. This section will provide an introduction to cooling towers, evaluate relative benefits of cooling the warm, untreated seawater or warm, desalinated water, and provide recommendations for the pilot testing, if needed.

E.1. Is Cooling Necessary? Temperature has an important impact on a consumer's perception of water quality. Not only is warm water unpleasant, but it increases our sensitivity to off-flavors and odors. It is for this reason that scenes with ice-cold water are used for marketing. Also important are changes in temperature. Even those consumers who are not ordinarily sensitive to warmer water are likely to notice when changes in water temperature take place. Under the conditions in most water systems, only small temperature changes take place between the treatment plant and the consumer. Moreover it is well established that both corrosion and biological activity increase rapidly with temperature. This would seem to suggest that we cannot rely on decreases in temperature which might take place between the treatment plant and the distribution system, though it remains to be seen if warmer water might exhibit greater changes. For the time being, it seems prudent to examine the difference between the temperature of the Scattergood condensor discharge (e.g. warm seawater supply) and the current water supply coming from the Los Angeles Aqueduct Filtration Plant. Figure E.1 presents a probability distribution of the difference in temperature between the Scattergood condensor discharge and the LAAFP.

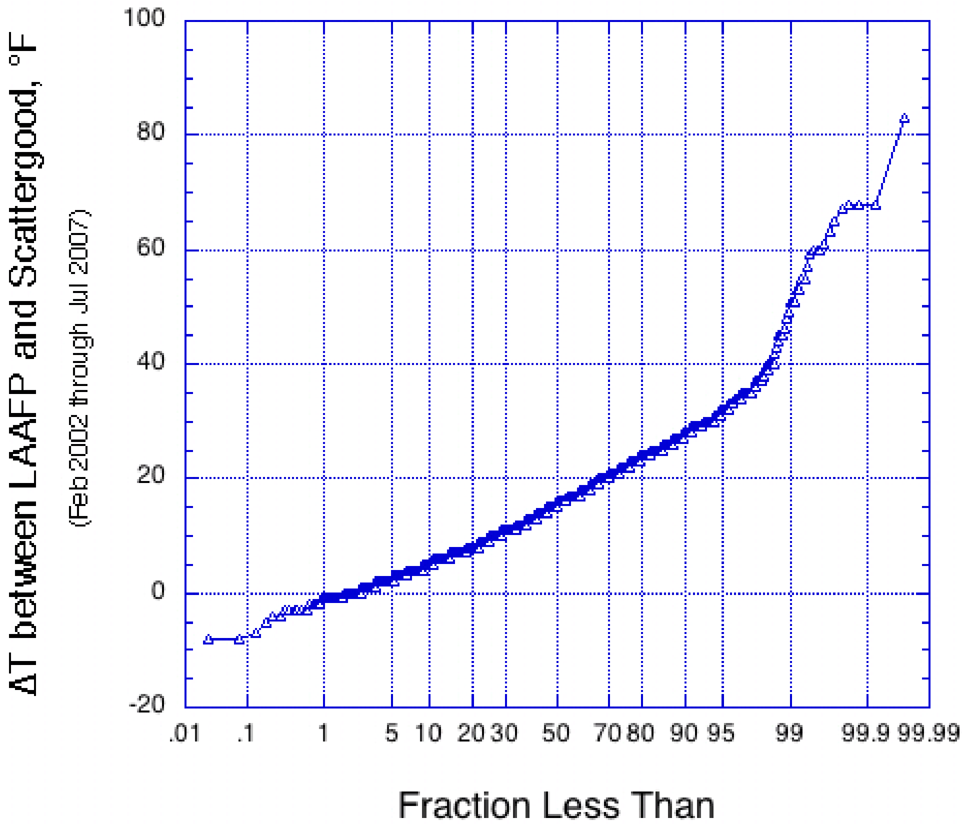

Figure E.1 Probability Plot of the Daily Differences in Temperature Between the Scattergood Condensor Discharge at the Treated Water Leaving the Los Angeles Aqueduct Water Treatment Plant For The 5 ½ Years Between February 2002 and July 2007

Ironically the figure shows that the condensor discharge is colder than tap water 1 percent of the time. The temperature difference shown in figure E.1 is approximately 15°F 50 percent of the time and over 20°F about 30 percent of the time. About 1 percent of the time the temperature difference is 104°F or above, warm enough to prevent the use of reverse osmosis membranes. Looking at the sudden change in the slope of the plot, it seems likely that the temperature differences in the top 3 percent are influenced by the heat treatment practice at the power plant. Studying Figure E-1 leaves little doubt that action must be taken to cool the water. The remainder of this discussion will focus on how this might be accomplished.

E.1 Introduction to cooling towers: Cooling towers are normally used to remove the heat created in process flows in industry. Examples of such process flows are the ammonia in large air conditioning systems, steam exiting steam turbines in inland power plants, and hot process flows in petroleum refineries, and petrochemical plants. As the name implies, evaporative cooling towers all use the evaporation of water to get red of excess heat. A useful rule of thumb is that evaporating one gallon of water will cool one hundred gallons of water about 10°F. The term BTU (British Thermal Units) is often used in rating cooling equipment of this kind. One BTU of cooling capacity is the heat which must be removed to cool one pound of water 1°F. One ton of air conditioning is 12,000 BTU/h, enough to freeze one ton of ice in 24 hours.

Because these evaporative cooling towers accomplish their cooling by taking advantage of the heat that water loses during evaporation, the lowest temperature they can achieve must be determined. In principle this temperature is the "wet bulb" temperature, the temperature of a freely evaporating water surface. The Ambient wet bulb temperature is a condition measured by a device called a psychrometer. A psychrometer (Figure E-2) places a thin film of water on the bulb of a thermometer that is twirled in the air. After twirling for some time, the thermometer will show a stable, reduced temperature. This low point when no additional twirling reduces the temperature is called the wet bulb temperature.

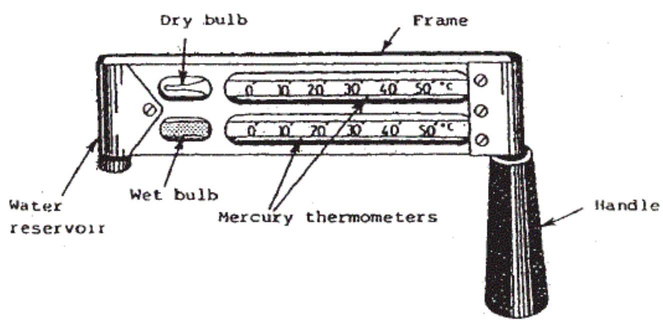

Figure E-2 Psychrometer (used to measure wet bulb temperature)

Obviously, the water in a cooling tower cannot be cooled to a temperature below the wet-bulb temperature – the temperature of saturated air at equilibrium with the humidity in the atmosphere. This temperature depends on the temperature of the air and it's relative humidity and, as a result, it varies from day to day. It is highest on hot-humid days and lowest on cold days with low humidity. Using thermodynamic information, the wet bulb temperature can be determined from the ambient air temperature and the relative humidity. Table E-1 summarizes several examples.

Table E-1 Relationship between dry bulb temperature, relative humidity and wet bulb temperature.

Dry Bulb Temperature	Relative Humidity	Wet Bulb Temperature
50°F	40%	40°F
60°F	50%	50°F
70°F	35%	55°F
85°F	55%	73°F
90°F	60%	78°F

Several years of data are required to develop a "design" wet-bulb temperature that can be used to size an evaporative cooling tower. Preliminary information has been compiled around the world and is widely available through the manufacturers of cooling towers. Specific design numbers have not been researched for this project, but a reasonable design wet-bulb temperature for the Southern California Coast is on the order of 71 ºF.

But an evaporative cooling tower that can bring water all the way to wet bulb temperature is prohibitively expensive. As a result such towers are normally designed to approach the wet bulb temperature to a certain degree. In fact the difference between the actual water temperature the tower is designed to achieve and the wet bulb temperature is called the "approach". Evaporative cooling towers are commonly designed for an approach of approximately 5°C or 9°F. On the Southern California Coast such a tower could be expected to maintain a water temperature of approximately 80°F or less, a temperature within the range of normal drinking water in the warm season.

E.1.1. Open circuit evaporative cooling towers: A schematic of an open circuit-cooling tower is shown in Figure E-3. Water is introduced into the top of the cooling tower and trickles downward through the "fill" or "packing" as air travels in the opposite direction, driven by fan.

As water moves downward some of it evaporates. This evaporation action removes the heat from the water and adds it to the air. The hot, moist air is ejected from the fan stack, and cooled water comes out from the drain lines located at the bottom of the tower. This approach to cooling is also known as direct cooling.

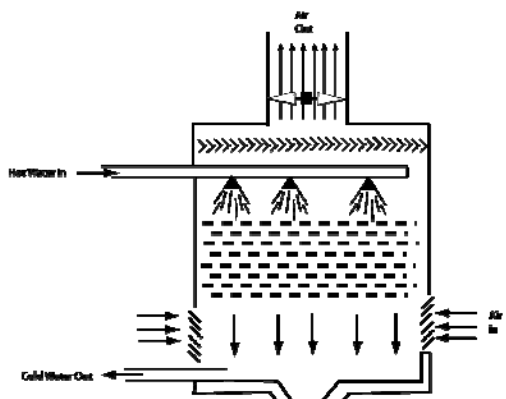

Figure E-3. An Open Circuit Evaporative Cooling Tower.

Open Circuit Cooling Towers cool the water that flows through them directly. As a result, they bring the water directly to the difference between the wet bulb temperature (T_w) and the approach (ΔT_A), as described in the following expression:

$$T_{cooled\_water} = T_W - \Delta T_A$$

The lower the wet-bulb temperature (which indicates either cool air, low humidity or a combination), the colder these towers can make the water.

In order to maximize evaporation, a cooling tower puts each gallon of water it treats in intimate contact with a tremendous amount of air. The air-to-water ratios in these towers range from several hundred to a thousand or so and the water coming out of the tower usually contains contaminants scrubbed from the air. As a result, whereas an open-circuit tower could be used without question to cool the warm seawater entering a desalination plant at Scattergood, it would be appropriate for cooling the desalinated product water itself, not if it is to be used as a potable supply. Work would have to de done to establish what sort of treatment (probably disinfection) that would be required downstream.

E.1.2 Closed circuit or recirculating evaporative cooling towers. In the process industry, where cooling towers are most often used, the objective is usually not to cool the water itself, rather the objective is to cool some other process flow. As a result, the most common arrangement for an evaporative cooling tower is to have it coupled with an external heat exchanger that removes heat from incoming warm process flow and transfers it to cold water that recirculates in the cooling tower. Figure E-4 illustrates such a design.

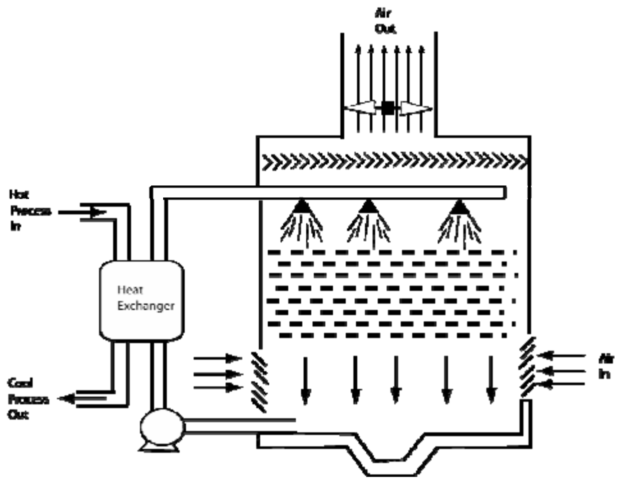

Figure E-4. Closed circuit recirculating cooling tower

In the Scattergood project, such a closed circuit cooling tower arrangement would isolate the desalinated water, which is being cooled from the recirculating cooling water that is in contact with the air. This resolves the dilemma described earlier with regard to the contamination that occurs in an open circuit tower. Such a cooling arrangement does, however, have three important disadvantages: 1) it is more expensive 2) it cannot reach temperatures as low as the open circuit design can, and 3) these towers have a waste discharge from the recirculating stream.

The first shortcoming has an obvious origin, namely the cost of the heat exchanger and the recirculating loop. The second reason is subtler. It has to do with the fact that it would take an infinitely efficient heat exchanger to bring the process water to the same temperature as the cold water in the cooling tower. As a practical matter heat exchangers are also designed to "approach" the temperature of the cold water in the tower within a specified tolerance. This tolerance, also called the "approach temperature" is also commonly 5°C. Thus, in Southern California, using a design wet bulb temperature of 71°F, the coolest such a tower could get the product water is 71 + 9 + 9 = 89°F, considerably higher than that achievable by the open circuit tower discussed previously. Perhaps the third shortcoming is the more insidious. Because recirculating cooling towers evaporate water from a recirculating loop, fresh water must be added. As a result the salinity of the water in the recirculating loop increases and antiscalants must be added to the recirulating water to prevent scaling on the heart exchanger. Corrosion inhibitors are also sometimes used. The net result is that these towers produce yet another waste stream whose discharge must be managed.

E.1.3. Wet Surface Air Cooler. A wet surface air cooler is an evaporative cooling tower designs that attempts to overcome one of the disadvantages of the traditional closed circuit tower, namely it's poor approach, while maintaining the separation between the recirculating cooling water and the process water to be cooled. In this design the packing in the cooling tower is replaced with a tubing bundle through which the warm desalinated water passes. This design is illustrated in Figure E-5.

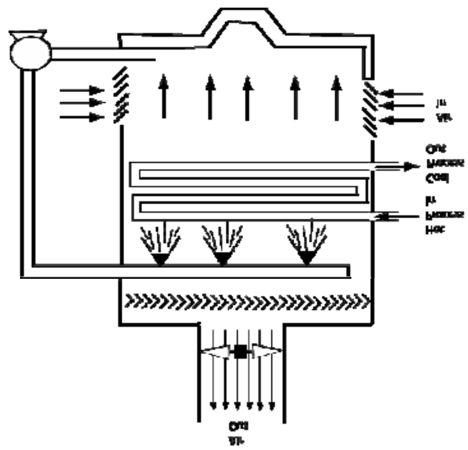

Figure E-5. Schematic of a Wet-Surface Air Cooler

In the preliminary study for Scattergood desalination facility conducted by Metcalf and Eddy, the wet-surface air cooler was the technology proposed for cooling the RO permeate. This design has the same conceptual advantages and disadvantages as the closed circuit recirculating evaporative tower with heat exchanger shown in Figure E-4, but because of its greater surface area design specifications indicate that it can achieve the nearly the same overall approach as an open circuit cooling tower, namely 10°F. The principle disadvantage of these devices is that they are much less common than the other two and, so far as we are aware only one manufacturer, namely the Niagara Blower Company in Buffalo, NY, offers them. Preliminary information indicates that this is an expensive cooling alternative.

E.2. Location of the Cooling tower in the Process flow Sheet. There are three places a cooling tower might be considered in the flow sheet of the desalination process (Figure E-6): 1) before any water treatment begins, 2) after coarse solids removal or, 3) after the water has been desalinated. The following discussion addresses the advantages and disadvantages with each:

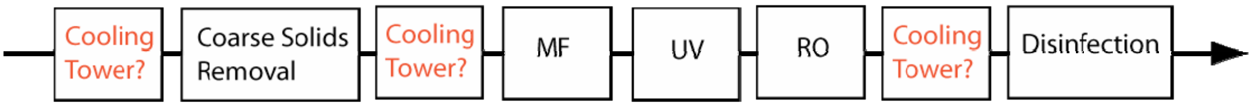

Figure E-6 Candidate Locations for a Cooling Tower in the Desalination Flowsheet.

Both of the upstream cooling alternatives share several advantages: 1) For a relatively modest additional cost, they can be designed with sufficient capacity to cool the water even when Scattergood is undergoing “Heat treatment”, allowing for uninterrupted operation, 2) The more inexpensive “open circuit” cooling tower design can be used, allowing for lower cost and cooler water and no further study would be required to satisfy public health requirements, 3) Assuming reverse osmosis is used, cooler water entering the desalination process will result in improved rejection of boron, chloride and sodium, reducing the fraction of the product water that must be put through a second pass, and 4) biofouling problems associated with warm water can be avoided. The principle disadvantage is that if the tower is put on the influent, then it must be designed to handle twice the flow. Seawater is much more corrosive but this may not be a serious problem as towers often operate with highly saline water and some designs use entirely inert materials.

Uninterrupted Operation - The temperature of the discharge from the Scattergood condenser increases significantly during the heat-treatment process. In the absence of a cooling tower on the influent side, the exposure to such high temperature water damage the polymeric membranes used in the RO (Sharma et al., 2003). As a result either the operation of the desalination plant would be interrupted or significant raw water storage would have to be provided.

Open Circuit Towers - Open circuit cooling towers (Figure E-3) are cheaper and can achieve lower temperatures than their closed circuit counter parts (Figure E-4). As mentioned earlier, Open-circuit cooling towers depend on intimate contact between the air and the water being cooled for their operation and, as a result, the product water would be considered contaminated by drinking water standards and the appropriate level of downstream treatment must be established. This problem is not an issue if these towers are employed prior to the desalination process.

Improved water quality - Another significant advantage gained by the influent cooling option is the superior quality of the desalinated water. Again work done at West Basin showed increased boron, chloride, sodium, and TDS concentrations in the permeate when warm water was used.

Reduced biofouling - Experience at other desalination facilities operating with warm water (West Basin, Tampa, and Kuwait, Bahrain, etc.) suggests increased biofouling of RO membranes. Cooling ahead of desalination will significantly reduce this problem.

As mentioned earlier, two upstream locations are possible, before or after, coarse solids removal. Based on information currently available it would seem best to put the tower upstream of granular media filtration, but downstream of the Arkal filters. This is because of the possibility of slimes sloughing off the cooling tower media. Such slimes could be effectively removed by the granular media filters, but are likely to blind the Arkal filters. Testing is probably required to confirm the best location upstream of the cooling tower upstream of the desalination.

The principle advantage of locating the cooling tower on the downstream side of the desalination process: 1) the tower would be designed for approximately one half the hydraulic capacity and 2) the desalinated water is less corrosive than the raw seawater, so will not require any special material for cooling tower construction.

The principle disadvantages are: 1) open circuit cooling towers cannot be employed unless studies are conducted on their water quality impacts, 2) there will be increased risk of biofouling of the RO membranes, 3) product water will have higher levels of boron, chloride, sodium and bromide, necessitating that a larger fraction of the flow to pass through RO a second time, 4) either storage of influent seawater will be required or the plant must shut-down during the Scattergood the heat-treatment process .

E.3 Possible Cooling Equipment. Because cooling towers are not normally used as part of drinking water treatment, a brief discussion of some of the equipment choices is in order. The following discussion, though it introduces specific manufacturers, is not sufficiently exhaustive as will be required for design, but it is intended to serve as an adequate background for pilot plant decision-making. For purposes one manufacturer will be introduced for each type of cooling tower and some perspective will be provided on the size and nature of the equipment.

E.3.1 Open and Closed circuit cooling towers. Where open circuit cooling towers are concerned the Marley 800 Class Cooling tower seems an appropriate choice. These towers are induced draft, counter current cooling towers designed for use in seawater service. Figure E-7 is a schematic illustrating such a tower. Such a tower, designed to reduce the temperature of the 50 mgd of influent flow from 125°F to 80°F would be approximately 200 Ft. long, 50 Ft. wide and 40 Ft. in height. A tower of the same hydraulic capacity but designed to cool from 95°F to 80°F would be approximately 150 ft. long, 50 ft. wide and 40 ft. in height. A similar, but smaller tower designed to take 20 mgd of product water from 95°F to 81°F would be approximately 91 Ft. long, 25 Ft. wide and 25 Ft. in height.

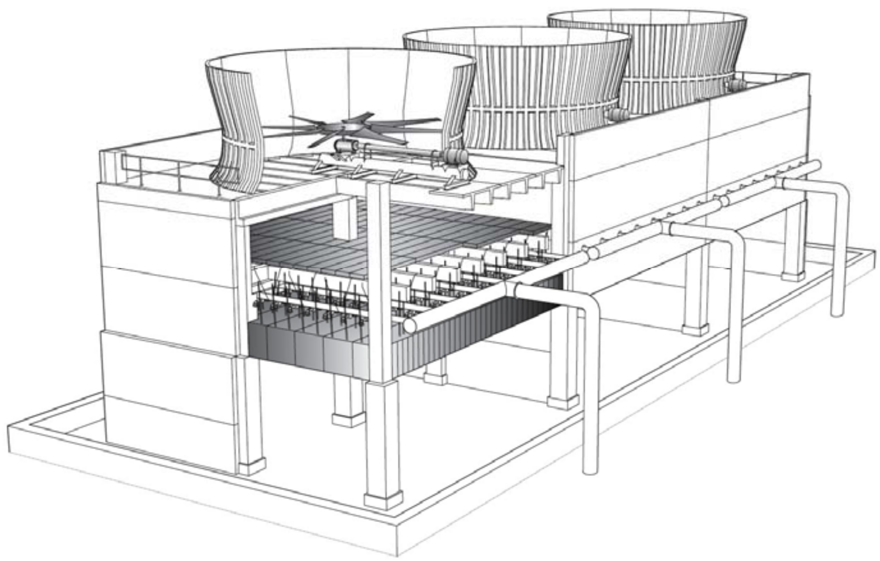

Figure E-7 Schematic of a Marley Class 800 Cooling Tower Designed for Seawater service (adapted from SPX website)

Depending on the capacity of the pilot plant, Delta cooling towers, Inc. of Rockaway, NJ manufactures a series of cooling towers constructed of PVC and polyethylene. These may be suitable for flows from 20 to 2 or 3 mgd. Recirculating towers using heat exchangers to cool product water would be similar in size.

E.3.2 Wet Surface Air Cooler. Although we have preliminary cost information we do not yet have any design information on the Niagra blower, Inc. wet surface air cooler. This is a patented new technology which is being used in industry to gain a closer "approach" to wet bulb in applications where an open circuit cooling tower is not considered suitable because of potential product release or product, product contamination or environmental impact. From the Niagara website, it is clear that pilot-scale units are available because these units are manufactured for small as well as large applications. The key to Niagara's patents appears to be in the design of the heat transfer tubing introduced into the tower.

E.4 Analysis. The following discussion reviews these cooling alternatives using the following five criteria: 1) Environmental sustainability, 2) Suitability as a high quality domestic supply, and 3) Operations and maintenance, 4) Uncertainty, and 5) Cost. Table E-3 shows a qualitative overview of the four principal cooling alternatives from the standpoint of these evaluation criteria.

Table E-3 Overview of Cooling Alternatives

Cooling Alternative	Type of Tower	Size	Environmental Sustainability	Water Quality	O&M	Cost	Technical Uncertainty	Open Questions
A. Directly Cooling Condenser Discharge	**Open circuit**	50 Ft wide, 40 Ft. tall and 150 to 200 ft. long	Good Largest facility	Excellent Š 80°F Improves quality of RO permeate	Good Should reduce biofouling on RO. Tower will require banacle control unless after GMF?	$1.1 to $1.4m	medium	1) Will tower grow slime? 2) Will weekly off-line chlorine control barnacles? 3) will tower Fog? 4) before or after coarse solids removal?
B. Cooling RO Permeate	**Open Circuit**	25 Ft wide, 25 Ft. tall and 90 ft. long	Excellent	Good Š80°F larger 2nd pass required	Excellent Should use free chlorine residual for slime control.	$0.5m	medium	Need to learn about post-treatment requirements
C. Cooling RO Permeate	**Closed circuit**	25 Ft wide, 25 Ft. tall and 90 ft. long	Excellent	Fair Š90°F larger 2nd pass required Also, can't get water below 90·F on hot, humid days	Good Strraightforward to maintain, but more equipment.	$2 m	Low	
D. Cooling RO Permeate	**WSAC**	Unknown, probably comparable to above	Excellent	Good Š80°F larger 2nd pass required	Good Strraightforward to maintain, but more equipment.	$3 m	Low	Need to learn more about WSAC

All the alternatives look pretty good from the standpoint of environmental sustainability. Cooling alternative A, direct cooling of the desalination plant influent with an open circuit tower, was down-rated a little bit because it requires the largest cooling facility. From the standpoint of water quality, Alternative A looks best because it improves the quality of the RO permeate while also providing the coolest product water. Alternative C, cooling the permeate with a closed circuit tower, was rated poorly because it will be unable to provide cold water on warm humid summer days. This fact, may make this alternative not worth exploring further. From the standpoint of O&M Alternative B, cooling the product with an open circuit tower got the best rating because it uses the smallest, simplest tower and because it is expected that testing will show downstream treatment is minimal. Alternative B is also the most attractive from the standpoint of capital cost. Alternative D is the most expensive. Alternatives A and B were both down-rated a bit from the standpoint of technical uncertainty because additional testing is required to finalize design requirements. Our understanding of the relative merits of both cooling Alternatives A and B could be strengthened if they were carried forward into pilot testing. Where Alternative A is concerned tests should address the question as to its ideal location (before or after coarse solids removal) as well as to address questions of barnacle control. Where Alternative B is concerned, testing should address water contamination and downstream treatment requirements.

Appendix F
Pilot Testing Protocol Outline

LADWP Scattergood Seawater Desalination Pilot

Pilot Testing Protocol

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