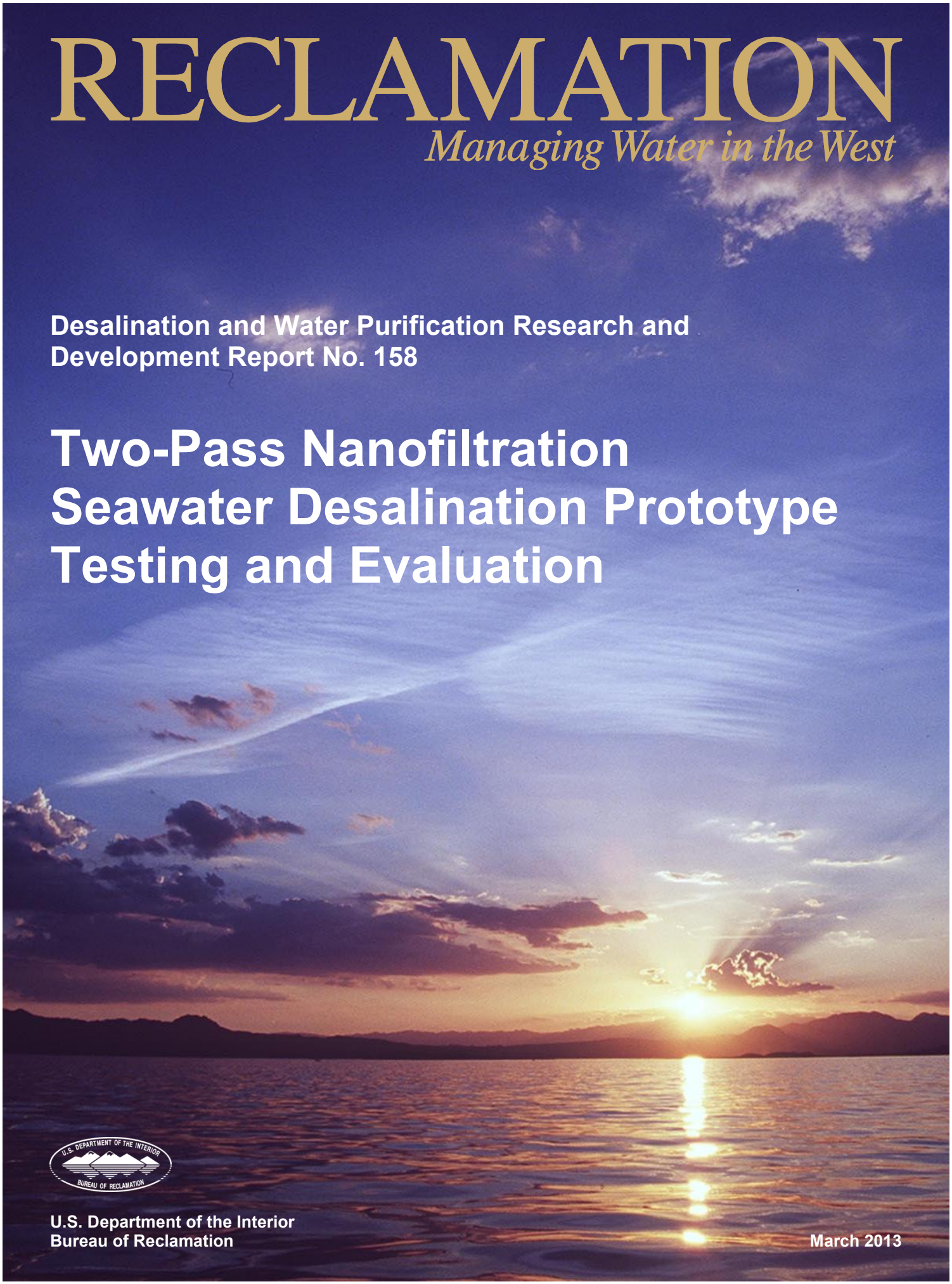

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Two-Pass Nanofiltration Seawater Desalination Prototype Testing and Evaluation

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Seawater desalination by reverse osmosis is widely practiced; however, the energy cost is high relative to that required for surface or groundwater treatment and conveyance. The Long Beach Water Department developed and patented a two-pass nanofiltration process intended to reduce the energy requirement for desalting. Compared to reverse osmosis the two-pass process provides an additional physical barrier for contaminant removal. An important feature of the process is that the second pass concentrate recycle dilutes the feed water, which allows lower feed pressures to be used. This technology had been shown to be successful in bench and pilot scale testing. To further this research, Long Beach collaborated with the Bureau of Reclamation and the Los Angeles Department of Water and Power in construction and operation of a 300,000 gallons per day seawater desalination prototype facility consisting of two parallel membrane trains designed to test the nanofiltration and reverse osmosis processes side-by-side, with the goal of minimizing desalination cost while producing permeate with water quality equal to or better than what is present in Long Beach's distribution system. This prototype was operated from October 2006 to January 2010.

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Desalination and Water Purification Research and Development Program Report No. 158

Two-Pass Nanofiltration Seawater Desalination Prototype Testing and Evaluation

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Acronyms and Abbreviations

ADC	Affordable Desalination Collaboration
AQMD	Air Quality Management District
AWWA	American Water Works Association
BLS	Bureau of Labor Statistics
CANL	California Notification Limit
CCC	California Coastal Commission
CDHS	California Department of Health Services
CF	cartridge filters
cfu	colony forming unit
CP	concentration polarization
CDPH	California Department of Public Health
ClO_2	chlorine dioxide
Corps	U.S. Army Corps of Engineers
DBPs	disinfectant byproducts
DO	dissolved oxygen
DOC	dissolved organic carbon
DOM	dissolved organic matter
DWR	California Department of Water Resource
EC	electrical conductivity
ER/ERD	energy recovery/energy recovery device
ERD	energy recovery device
ft^2	square feet
FWS	Fish and Wildlife Service
gfd	gallons per square foot per day
gpd	gallons per day
gpd/ft^2	gallons per day per square foot
gpm	gallons per minute
HMI	human machine interface
HPC	heterotrophic plate counts
IC	ion chromatography
kW	kilowatt

kWh/kgal	kilowatthour per kilogallon
LADWP	Los Angeles Department of Water and Power
LBWD	Long Beach Water Department
MCL	maximum contaminant level
MDL	method detection level
MF	microfiltration
mgd	million gallons per day
mg/L	milligrams per liter
mHPC	marine heterotrophic plate counts
mJ/cm^2	millijoules per square centimeter
NaCl	sodium chloride
NF	nanofiltration
NF^2	LBWD two-pass nanofiltration process
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
O&M	operation and maintenance
PA	polyamide
PLC	programmable logic controllers
POM	particulate organic matter
psi	pounds per square inch
PVDF	polyvinylidenedifluoride
PX	pressure exchanger
P1S1	Pass 1 stage 1
P1S2	Pass 1 stage 2
P2S1	Pass 2 stage 1
P2S2	Pass 2 stage 2
Reclamation	Bureau of Reclamation
RO	reverse osmosis
Road Map	Desalination and Water Purification Technology Road Map
RWQCB	Regional Water Quality Control Board
SCADA	supervisory control and data acquisition
SCCOOS	Southern California Coastal Ocean Observing System

SDI	silt density index
SDWA	Safe Drinking Water Act
SEC	specific energy consumption
SEM	scanning electron microscopic
SLC	State Lands Commission
SWNF	seawater NF
SW RO	seawater RO
TDS	total dissolved solids
TMP	transmembrane pressure
TOC	total organic carbon
UF	ultrafiltration
ULP	ultralow pressure membrane FilmTec XLE-400
USEPA	United States Environmental Protection Agency
UV	ultraviolet
UVT	UV transmittance
VFD	variable frequency drive
WHO	World Health Organization
XRF	x-ray fluorescence
~	approximately
°C	degrees Celsius
%	Percent
µg/L	microgram per liter

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Executive Summary

Many parts of the world, including the United States, are facing water supply challenges because traditional resources are unable to meet demands resulting from increasing population, greater per capita water usage, and the deterioration of source water quality. Seawater desalination has become an increasingly important new supply, especially to areas prone to droughts and limited water resource (e.g., California coastal region). Traditionally, seawater reverse osmosis (SWRO) has been used for seawater desalination; however, the energy cost is high relative to surface and ground water treatment. The Long Beach Water Department (LBWD) has developed and patented a two-pass nanofiltration process (NF^2), which is intended to reduce the desalting energy cost. Compared to reverse osmosis (RO, i.e., SWRO), the two-pass system in the NF^2 process can provide an additional physical barrier to contaminant removal. Additionally, an important feature of the NF^2 process is that the second pass concentrate recycle dilutes the feed water, which allows lower feed pressures to be used. This technology was proved successful in bench and pilot scale testing. To further this research, LBWD collaborated with the Bureau of Reclamation (Reclamation) and the Los Angeles Department of Water and Power (LADWP) in the construction of the 300,000-gallon-per-day (gpd) Seawater Desalination Prototype Facility (Prototype). This facility consists of two parallel membrane trains designed to test the NF^2 and RO process side by side, with the goal of minimizing desalination cost while producing permeate with water quality equal to or better than what is present in LBWD's distribution system. The Prototype was operated from October 2006 to January 2010.

Research Objectives and Approach

The primary objectives set for this research are as follows:

1. Operate an efficient pretreatment system.
2. Demonstrate that the NF^2 process is efficient and reliable.
3. Measure consistency of the long-term performance on the NF^2 process.
4. Compare the capital and direct operation and maintenance (O&M) cost of the NF^2 process against RO under the same feed water quality conditions.
5. Provide for regulatory acceptability.
    - Demonstrate that the system meets Surface Water Treatment Rule requirements (SWTR).
    - Obtain data that would allow California Department of Public Health (CDPH) approval for permitting the full-scale drinking water plant.

6. Develop design criteria (for technology transfer) relating input water quality and operating parameters to unit performance that will allow plants to be designed locally and at other locations and to permit optimization of plant operation.

7. Determine the ability of the NF^2 and RO systems to remove emerging contaminants (e.g., boron).

Specific research conducted to meet these objectives at the Prototype included:

1. Compare NF^2 and RO operational data, using the same permeate water quality end point.

2. Optimize the operation of the desalination process, particularly NF^2, including operating pressure, recovery, energy recovery devices, membrane configurations, mixed membrane use, chemical dosage, cleaning procedures, etc.

3. Demonstrate the removal of specific water quality constituents (e.g., boron, bromide).

4. Collect long-term water quality data to confirm that permeate water quality meets drinking water rules. Provide data for full-scale permitting needs.

5. Test different biofouling control methods including ultraviolet (UV) and chlorine dioxide.

6. Perform cost analysis for full-scale plant using performance data obtained from the Prototype.

Key Conclusions

Effectiveness of Microfiltration as a Pretreatment Process for NF/RO Membranes

Success of a membrane-based desalination plant depends on the effectiveness of the pretreatment. In the Prototype, the microfiltration (MF) system effectively reduced raw water turbidity to less than 0.2 nephelometric turbidity units (NTU) and produced a silt density index (SDI), a membrane fouling index, of less than 1. SDI for desalting membrane feed waters generally is required to be less than 5, as recognized by the industry. Different types of biological growth present in the raw seawater were also effectively removed. No red tide event and related performance deterioration were observed in the raw seawater; however, periodic cleaning was necessary. The transmembrane pressure (TMP) increase usually is used as an indicator of the need for cleaning. TMP was found to be dependent on the water production rate and the chlorine dosage. Higher chlorine dosage

significantly decreased MF cleaning frequency. The balance between higher chlorine cost and membrane cleaning can be optimized for a specific plant.

Efficiency and Reliability of the NF^2 Process

Different recoveries were tested on pass 1 of the NF^2 process, and approximately 40-percent recovery proved to be the optimal recovery in minimizing energy consumption. On a cumulative distribution curve of all tests performed for NF^2 process, the 50^{th} percentile overall recovery of NF^2 process was approximately 30 percent. It was verified that the overall recovery was more significantly impacted by the pass 1 recovery and that optimization of pass 1 is important to minimizing overall energy consumption. No membrane scaling was observed after 2 years of operation even without the use of antiscalant and sulfuric acid. Chemical usage was limited to chlorine (biofouling control) and sodium bisulfite (dechlorination before the desalting membranes).

The NF^2 process operated reliably throughout the test and experienced similar system downtime as the RO process. The NF^2 process produced permeate water with total dissolved solid (TDS) levels of approximately 200 milligrams per liter (mg/L), which was similar to the current drinking water TDS concentration in LBWD's system. The permeate also met the California boron goal of less than 1 mg/L (by increasing pH at pass 2). The NF^2 permeate water quality resulted in bromide levels less than 0.5 mg/L (75^{th} percentile), and other water quality parameters also met the Safe Drinking Water Act (SDWA) regulations.

Comparison of NF^2 Process with RO

The NF^2 process produced permeate water quality meeting or exceeding all drinking water regulation standards. Although a single-pass RO system process produced permeate water TDS and bromide levels similar to the NF^2 system, it was unable to meet the 1-mg/L, or lower, boron goal without the use of a second pass. Therefore, comparisons in this study were conducted on test results from the two-pass systems.

The NF^2 system resulted in lower overall recovery than a single-pass RO system; so the normalized energy consumption for the NF^2 process was slightly higher than the single-pass RO. However, two-pass SWRO is needed to achieve the same water quality endpoint for boron, which resulted in higher energy than the NF^2 process at a similar overall recovery.

Optimization of NF^2 Process

Earlier model analysis indicated that staging the membranes differently or using a mixture of tight and loose membranes increases the overall recovery while lowering energy consumption (Trussell et al., 2009). Energy optimization tests were conducted on pass 1 of the NF^2 unit by varying the number of elements in series (5 versus 7) and also by incorporating different types of membranes in the same vessel, while maintaining the same permeate water quality. The permeate

TDS for each configuration was well below the secondary maximum contaminant level (MCL) of the SDWA. The results obtained from testing of the NF 5 (five NF90 membranes in series) against NF 7 (seven NF90 membranes in series) did not yield definitive results for energy consumption savings. However, placing more ultralow pressure RO (ULP) membranes at the lead end of the vessel resulted in reduced energy consumption.

Operational Experience of Operating Desalination Facility

The operation of a seawater desalination plant requires careful material selection, quality control, and constant coordination with project partners, as in the case of collocation with a powerplant and diligent maintenance program. Exotic materials (i.e., super duplex stainless), have long lead times for replacement parts; thus, it is prudent to have many of the exotic replacement parts on hand. The corrosive operating environment quickly changes small problems into large issues, and being proactive is the key to keeping the plant operational.

Cost Analysis

This testing successfully demonstrated the comparable efficiency and reliability of the NF^2 process against RO for seawater desalination. The operation of the NF^2 process was optimized to minimize energy and chemical usage and maximize recovery, and the lessons learned can be integrated into the full-scale plant design. Water quality data collected throughout the facility (raw, permeate, concentrate, etc.) may be incorporated into the permit application process of constructing and operating desalination plants around the California coast line.

The cost data obtained may be used as a guideline in the design of a desalination plant. Based on the NF^2 cost model (Affordable Desalination Collaboration [ADC], 2009), and incorporating the Prototype operational data, the cost of product water from the NF^2 processes ranges from $4.07 to $4.24 per 1,000 gallons (/kgal) for a 50-million-gallon-per-day) (mgd) plant. For a two-pass RO process (necessary to produce equivalent water quality), the cost ranges from $4.46 to $5.02/kgal. The impact of reducing the size of the plant is significant, with an estimated produced water cost for the NF^2 process ranging from $6.69 to $7.53/kgal for a 5-mgd facility, and the cost for two-pass RO of $7.10 to $7.66/kgal. These figures were calculated based on the most current information available and should only be used as a comparative cost basis.

1. Introduction

The Long Beach Water Department (LBWD), similar to many southern California utilities, has been facing the issue of decreased potable water supplies. Because of its location, the city of Long Beach is ideally situated to take advantage of desalinated seawater as a source of drinking water. However, the primary barrier to seawater desalination as a source water has been its relatively high cost as compared to other available sources. LBWD has developed and patented a two-pass nanofiltration process (NF^2), which is intended to reduce the desalting energy cost. The process can operate at lower pressures than reverse osmosis (RO), which would allow a lower operating cost. The two-pass NF^2 process can provide an additional physical barrier to contaminant removal. Another important feature of the NF^2 process is two-pass concentrate recycle dilutes the feed water, allowing lower feed pressures to be used.

Pilot testing of the NF^2 process has demonstrated that it achieves treated water quality equivalent to or better than single-pass RO at lower operating pressures and energy cost (Le Gouellec et al., 2006). Following the pilot testing, LBWD initiated a comprehensive desalination research program with the collaboration of the Bureau of Reclamation (Reclamation), Los Angeles Department of Water and Power (LADWP) and California Department of Water Resource (DWR), which included

1. Intake and discharge-the demonstration scale underocean floor intake system (2008–2012)

2. Membrane process operations at the 300,000 gallon-per-day (gpd) Seawater Desalination Prototype Facility (Prototype) (2006–2010)

3. Mitigating water quality effects at the Prototype (2009–2010)

The intake process is a critical part of the desalination facility, and regulations such as section 316(b) of the Federal Clean Water Act mandate that intake structures minimize environmental impact (impingement and entrainment of marine life), rendering traditional open-ocean intakes or collection with existing structures more difficult to use. LBWD is researching a subsurface intake system (underocean floor seawater intake) that collects seawater filtered through engineered sand beds at slow rates. The goals of this project are to determine if the system can deliver a sustained quantity of water and of a water quality that can be used as the membrane feed water. The demonstration facility consists of an infiltration gallery (3,100 square feet [ft^2]) and discharge gallery (2,000 ft^2), connected by a 25-foot-deep wet-well. The gallery is filled with sand to a minimum depth of 6 feet (ft), and the demonstration facility has operated up to a maximum sustained filtration rate 0.15 gallons per minute per square foot (gpm/ft^2). The effluent water quality from the demonstration facility is compared to microfiltered seawater quality, which produces waters of quality acceptable as feed for desalination membranes.

The 300,000-gpd Prototype was designed and constructed to provide the maximum flexibility for testing membrane processes. The plant contained two parallel trains capable of testing the NF^2 and RO process side by side. Pressurized microfiltration (MF) membranes were used as the pretreatment process. The MF effluent was collected in a main MF filtrate tank, and divided equally into two trains, which ensured that the pretreated water quality was identical for both RO and NF^2 processes. The Prototype contained numerous monitoring points for water quality sample collection, and the plant was fully equipped with online monitoring with automatic data collection.

The goal of the mitigating water quality effects project was to adequately address system integration issues. The impact of desalinated water on distribution system pipe materials, residential plumbing, residual stability and disinfectant byproducts (DBPs) issues were investigated. Another important goal was to optimize post-treatment and blending strategies. Results supported earlier bench-scale conclusion that 50-percent water blend is safe to use in most pipe materials with the proper post-treatment strategies (Cheng et al., 2009). This report will focus on the research conducted at the Prototype.

Because no boilerplate permit application process exists for desalinated seawater, LBWD had to engage all applicable agencies and gained valuable experience in the permitting process for all applicable permits. Some agencies only required a permit exemption to be filed given that the prototype facility engaged in research only; while some agencies required full permit. In all, 13 different agencies required some form of exemption request or full-blown permit. Experienced gained, potential critical path areas unique to desalination plants, and potential approaches to streamline permitting for future desalination facilities will be discussed.

2. Process Descriptions

2.1 Objectives

The operation of the Prototype was based on the test plan developed by LBWD, Reclamation, and LADWP. Based on the test plan, the primary objectives of this program were to:

- Operate an efficient pretreatment system
- Demonstrate that the NF^2 process is efficient and reliable.
    - ***Efficiency*** is defined as:
      Maximized recovery
      Minimized energy usage
      Minimized chemical usage
      Minimized cleaning cycles
    - ***Reliability*** is defined as:
      Minimized down time
      Product water quality meets primary and secondary drinking water standards
- Measure consistency of the long-term performance on the NF^2 process.
- Compare the capital and direct operation and maintenance (O&M) cost of the NF^2 against RO under the same feed water quality conditions.
- Provide for regulatory acceptability.
    - Demonstrate that the system meets Surface Water Treatment Rule requirements.
    - Obtain data that would allow California Department of Public Health (CDPH) approval for permitting the full-scale drinking water plant.
- Develop design criteria (for technology transfer) relating input water quality and operating parameters to unit performance that will allow plants to be designed locally and at other locations and to permit optimization of plant operation.

A secondary objective of the project was to:

- Determine the ability of the NF^2 and RO systems to remove emerging contaminants (e.g., boron).

2.2 Overall System

The 300,000-gpd Prototype was designed and constructed to provide the maximum flexibility for testing membrane processes (**figure 2.1)**. The plant utilized pressurized MF membranes as the pretreatment process. The MF effluent

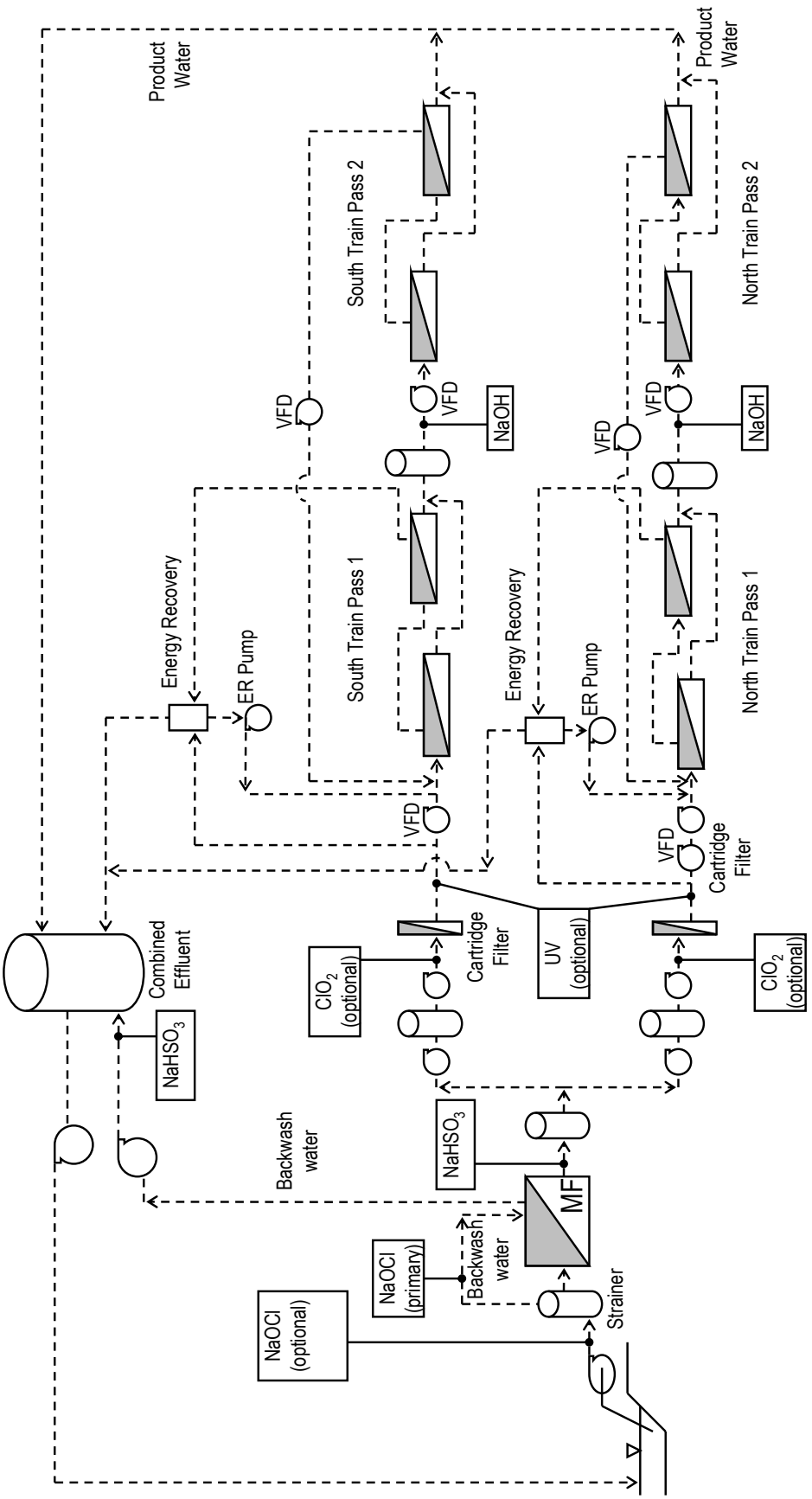


Figure 2.1. LBWD's seawater desalination Prototype process flow diagram.

utilized pressurized MF membranes as the pretreatment process. The MF effluent was collected in a main MF filtrate tank and divided equally into two trains, which ensured that the pretreated water quality was identical for both RO and NF^2 processes. The Prototype contained numerous monitoring points for water quality sample collection, and the plant was fully equipped with online monitoring with automatic data collection.

2.3 Intake and MF Pretreatment

2.3.1 Source Water

The source water for the facility was seawater diverted from LADWP Haynes Generating Station cooling water channel. Trash racks at the channel intake screen remove coarse materials. The influent raw seawater was filtered through 300-micrometer (µm) self-backwashing strainers prior to reaching the MF process (**figure 2.1**).

The facility was operated from October 2006 to January 2010. The influent seawater quality was characterized by low turbidity (**table 2.1**), ranging from 0.07–3.14 nephelometric turbidity units (NTU), with an average of 1.36 NTU. The temperature ranged from 10–27 degrees Celsius (ºC), with an average of 18 ºC. More specifics of the influent seawater quality are provided in **table 2.1**.

2.3.2 MF Pretreatment

The MF system (Microza, Pall, Port Washington, New York), shown in **figure 2.2,** was a standard Pall MF system composed of high-strength, oxidant-resistant Microza polyvinylidenedifluoride (PVDF) membranes with nominal pore size of 0.1 µm (American Water Works Association [AWWA], 2005; Pall, 2010). The membrane is 80 inches long, with an inside diameter and outside diameter of 0.027 and 0.051 inch, respectively (AWWA, 2005; Pall, 2010), operating in a dead-end filtration (outside-inside) mode (AWWA, 2005).

Two MF module racks, with 10 Microza modules in each rack, were operated in parallel. The MF system was operated up to 10-percent recycle and a minimum and maximum filtrate flow of 556 and 660 gallons per minute (gpm), respectively. The racks were backwashed at staggered intervals for 2 minutes after operating for 22 minutes. Chlorine was initially added in the backwash water but was later changed to the feed water to help reduce biological growth on the membranes. The chlorinated MF filtrate was neutralized by sodium bisulfite before entering the NF^2/RO trains.

Table 2.1. Source water quality[1, 4]

Constituent		Unit	Prototype Raw			Pacific Ocean
			Minimum	Maximum	Average	Average
General Water Quality	T	°C	14	23	19	13–20[2]
	pH	—	6.93	9.03	7.84	7.55[2]
	T-alk	mg/L	20	240	110	NA
	Turbidity	NTU	0.07	3.14	1.36	0.44–2.98[2]
	SDI	—	6.3	6.8	NA	5.7[2]
	Conductivity	µmhos/cm	39,200	51,800	48,600	45,890[2]
	TDS	mg/L	30,750	35,080	33,578	33,960[2]
Organics	TOC	mg/L	0.26	3.04	1.02	1.68[2]
	UV_{254}	abs, cm^{-1}	0.000	0.842	0.042	0.060[2]
Microbes	mHPC	cfu/100 mL	110	100,000	17,949	9,150[2]
	Coliform	/100 mL	<2	>1,600	23	109[2]
	Fecal	/100 mL	<2	80	9	113[3]
	Enterococci	/100 mL	<2	17	3	131[3]
	HPC	cfu/mL	4	1,100	150	10,417[2]
	Chlorophyll a	µg/L	<0.3	5.5	<0.3	0.05–5[3]
	Domoic acid	µg/L	<0.002			NA

[1] SDI= silt density index; mg/L = milligram per liter; µmhos/cm = µmhos per centimeter; TOC = total organic carbon; UV = ultraviolet; abs = ???; cm = centimeter; mHPC = marine heterotrophic plate counts; cfu = colony forming unit; mL = milliliter; HPC = marine heterotrophic plate counts; µg/L = microgram per liter; NA = not applicable.

[2] Data from underocean floor intake project.

[3] Data from Southern California Coastal Ocean Observing System (www.sccoos.org/data/waterquality).

[4] Refer to appendix A2 for method detection limit (MDL) of each parameter.

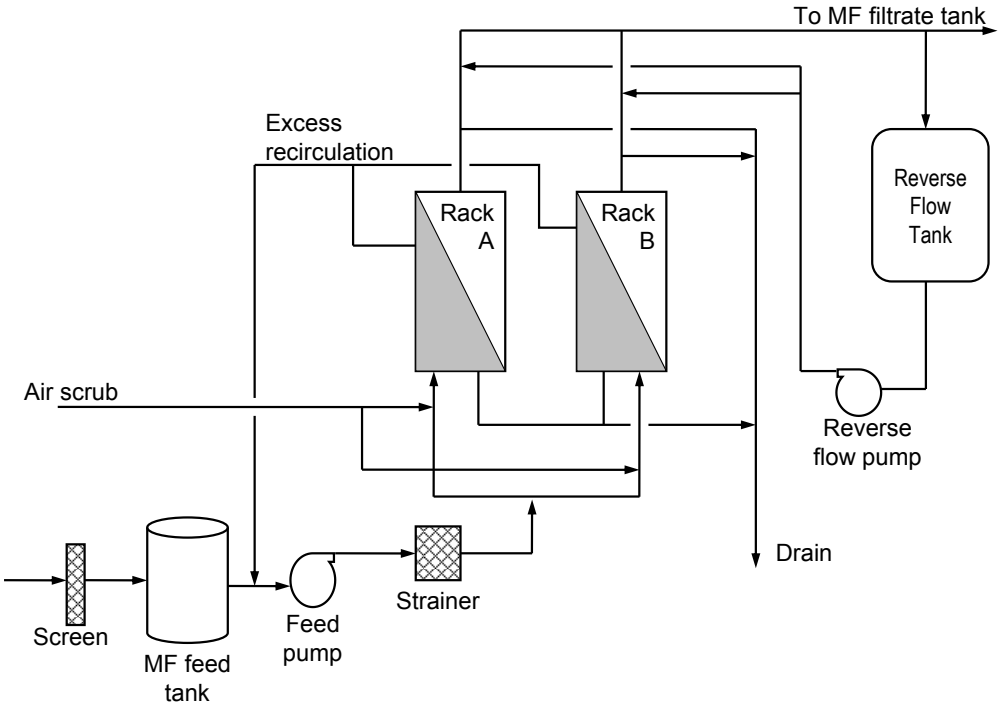


Figure 2. 2. MF process flow schematic.

Chemical cleaning with citric acid or sodium hydroxide/chlorine was performed periodically for fouling control, which was indicated by an increase of transmembrane pressure (TMP). Cleaning was performed when TMP exceeded 20 pounds per square inch (psi) (based on manufacturer's recommendation). Because the cleaning process required up to three days of MF downtime, chemically-enhanced cleaning with 500 mg/L sodium hypochlorite was occasionally used to quickly decrease the TMP when extended MF downtime was not possible.

2.4 Ultraviolet Irradiation

After MF pretreatment, one disinfection method tested at the Prototype was UV irradiation (UVSwiftSCD06, TrojanUV, Ontario, Canada). An applied dose of 40–60 millijoules per square centimeter (mJ/cm^2) was selected based on the feed water flow rate. The SwiftSCD06 dosage has been validated by the manufacturer at flow rates as low as 326 gpm, which was still higher than the average flow rate (180 gpm) at the Prototype. Therefore, the dose for the anticipated flow rate at the Prototype was estimated to be 40–146 mJ/cm^2, depending on the UV transmittance (UVT) of the feed water. A standard UV reactor constructed of 316L stainless steel was used because of the extended lead time required to design, construct, and validate a reactor constructed with a seawater corrosion resistant alloy. The UV system was provided with a water flush system (dechlorinated potable water) to minimize corrosion when the system was not in operation. The interior surfaces of the reactor were visually examined on a monthly basis (in conjunction with lamp fouling) to assess corrosion.

Because the UV dose necessary to achieve target bacterial log inactivation is dependent on temperature and UV dosage in the feed water, these parameters were monitored on a daily basis to verify the inactivation criteria. Log inactivation of marine HPCs (mHPCs) was monitored in the MF filtrate, UV effluent, and NF^2 pass 1 feed on a weekly basis to quantify log bacterial reductions.

The UV system was operated for more than 2,000 hours at several different flow conditions and was continuously monitored for signs of deceased transmittance due to changing feed water conditions. The problems associated with decreased transmittance include fouling and scaling of the quartz sleeves. The quartz sleeves were examined monthly to ensure that changing feed water and high temperatures did not promote biofouling or scaling. The UV operating conditions also were monitored with online devices that provided real-time UV dosage to ensure proper performance of the UV system.

2.5 Chlorine Dioxide Disinfection

Chlorine dioxide (ClO_2) disinfection was also tested after MF pretreatment. ClO_2 generated using the acid—chlorite method (shown below)—was injected into one of the parallel trains.

$$5NaClO_2 + 4HCl \rightarrow 4ClO_2(g) + 5NaCl + 2H_2O \quad (2.1)$$

The system selected (Prominent [Pittsburg, Pennsylvania]), generated ClO_2 by the "free-chlorine free" method. ClO_2 was added into the trains at a residual concentration of 0.5 mg/L (concentrations of up to 1.0 mg/L residual previously had been reported to be safe for polyamide [PA] membrane [Adams, 1990]). Residual ClO_2 was analyzed by modifying the amperometric titration II method (APHA et al., 1998). The modification followed the first step of the amperometric titration II method to determine the total chlorine dioxide and chlorite, and then used ion chromatography (IC) to determine chlorite concentration in the feed water (Tanuwidjaja et al., 2009).

2.6 NF^2/RO Process

Two desalting membrane treatment trains were available for testing at the Prototype, and were designated as the north train and south train based on their respective locations. Both trains were designed with the ability to operate in either one- or two-pass modes. Because each train can contain multiple passes and stages, the convention used in this report to describe the location of the treatment process will be the number of the pass (1 or 2) and the number of stage (1 or 2). For example, north train P1S1 denotes a location of pass 1 stage 1 of the north train. More details on the description of the trains are provided below.

2.6.1 Two-Pass Processes (RO-NF or NF^2)

The south train was configured and operated as a two-pass NF system throughout the test (**figure 2.3**). The NF^2 process also was tested on the north train during the latter phases of testing (2009–2010). The NF^2 process employs a two-pass system with NF membranes, and the permeate from pass 1 is used as the feed to pass 2 membranes. Pass 1 operates at around 40-percent recovery and 550 psi of pressure; and pass 2 operates at 70 to 80-percent recovery and around 200 psi of pressure. To increase recovery, pass 1 can further be divided into two stages, where the concentrate from pass 1 stage 1 (P1S1) is treated at pass 1 stage 2 (P1S2). The permeate from P1S1 and P1S2 was combined and then fed into pass 2. The two-stage configuration also was used at P2, and the final product permeate was combined from pass 2 stage 1 (P2S1) and pass 2 stage 2 (P2S2) permeate. Concentrate from P1S2 is returned to an energy recovery device (ERD) to retrieve the energy and then is discharged; while concentrate from P2S2 is recycled back to pass 1. The pass 2 concentrate recycle dilutes the feed water, which allows lower feed pressures to be used.

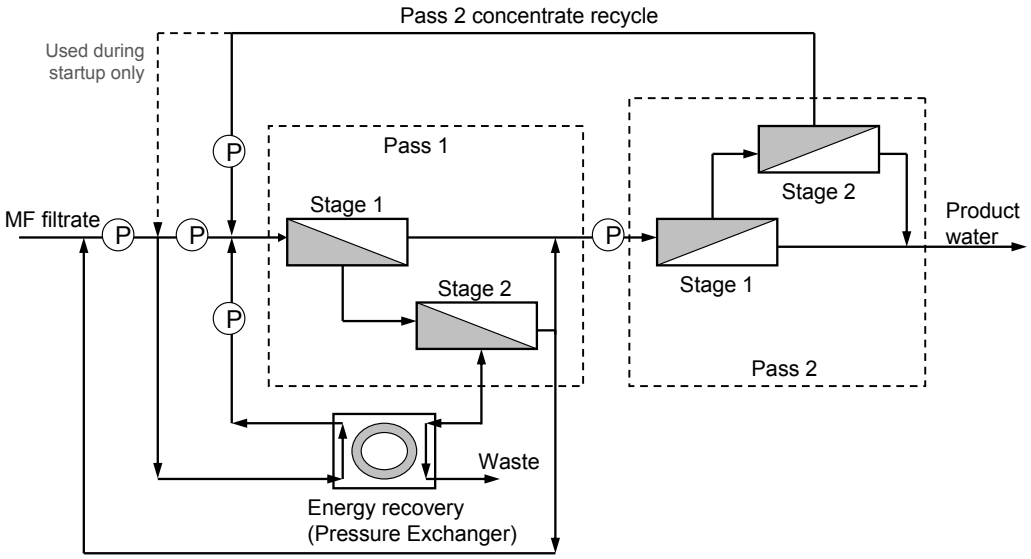


Figure 2.3. Two-pass NF^2 system schematic.

The NF^2 pass 1 permeate is used as the feed to NF^2 pass 2. Under this configuration, the TDS concentration of the MF pretreated water (approximately 34,000 mg/L) can be reduced to 340 mg/L or less when the TDS rejection in each pass is at least 90 percent.

Pass 1 of the Prototype reduces the influent seawater salinity by up to 90 percent and consists of a total of 18 vessels. Each vessel can hold a maximum of five membrane elements (**figure 2.4**). The pass 1 feed pump provides a minimum inlet pressure of 50 psi prior to the high-pressure pump. Acid and scale inhibitor chemicals pumps were included in the system to control the scaling potential of the feed water and can be injected into pass 1 feed pump discharge. After chemical addition, the pretreated water passed through a 5-micrometer (μm) cartridge filter that provided further treatment for the membranes and ensured mixing of chemicals.

Pass 1 high-pressure pump was controlled by a variable frequency drive (VFD) and provided operating pressure up to 600 psi. Additional pressure control was achieved by a pressure control valve on the discharge side of the pump.

The recovery in pass 1 was controlled by a flow control valve on the discharge of concentrate line when the pressure exchanger (PX) was not used. When PX was used, concentrate from P1S2 was discharged through the device to recover the available energy. The PX potentially can transfer up to 97 percent of pass 1 concentrate pressure to the influent, provided that the feed flow into PX is equal to the concentrate flow. An energy recovery booster pump on the discharge side of the PX provided the additional pressure to match the pressure from pass 1, the high-pressure pump. Consequently, the energy recovery booster pump controlled the recovery of pass 1 when PX was used.

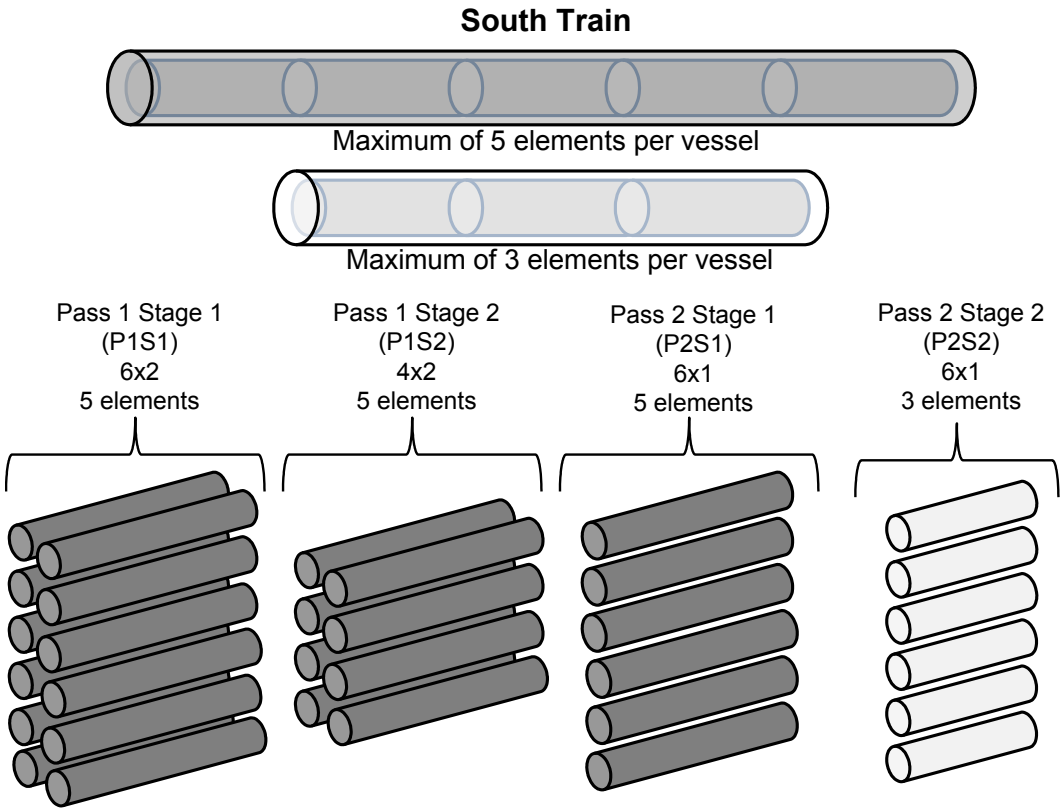


Figure 2.4. South train membrane configuration.

2.6.2 Single-Pass RO Process

The north train was initially configured as a conventional RO system consisting of two stages; then later, it was reconfigured into a two-pass system (**figure 2.5**). As shown, the vessels in pass 2 of the north train (inside red box) were left empty to represent the conventional single-pass system. Combining stage 1 and stage 2 vessels allowed the system to operate in a manner equivalent to an eight-element vessel.

The raw water feed pump provided a minimum pressure of 50 psi before the RO high-pressure pumps. Acid and scale inhibitor chemicals can be fed to control the scaling potential of the pretreated water and were injected into the RO feed pump discharge. After chemical addition, the pretreated water passed through a 5-µm cartridge filter that provided further treatment for the RO membranes and ensured mixing of chemicals.

Two high-pressure pumps staged in series pressurized the RO feed. The first RO high-pressure pump increased the feed pressure to a maximum of 600 psi, and the second pump can increase the feed pressure up to 1,000 psi. Both high-pressure pumps were controlled by a VFD and combined with a control valve on the discharge side of the second RO high-pressure pump, which allowed the testing of specific pressure and flow.

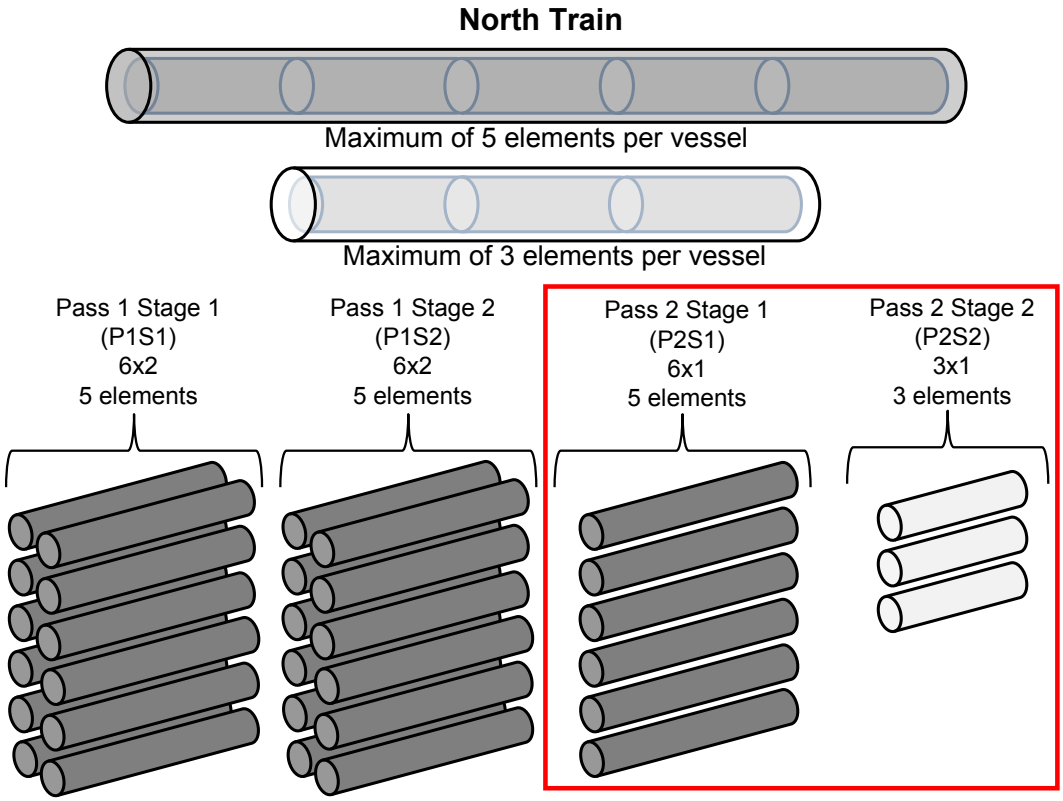


Figure 2.5. North train membrane configuration.

Conventional RO membrane systems typically operate at much higher pressures than NF membranes (up to 1,000 psi) (**figure 2.6**). RO can be a single- or two-pass process, with maximum recovery ranging from 40–50 percent. For single-pass RO, concentrate was not recycled; while the concentrate from pass 2 was recycled back to the feed water for two-pass RO, which is similar to the NF^2 process. The overall salt rejection must be greater than 99 percent for the single-pass RO process to achieve 340 mg/L TDS.

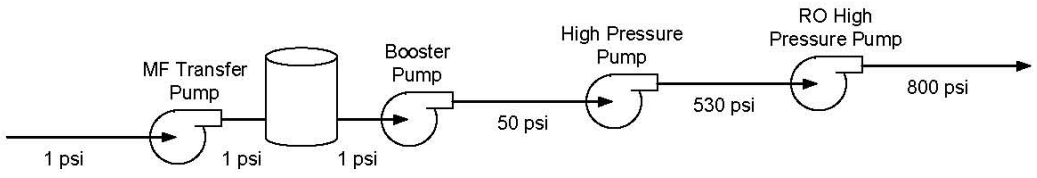


Figure 2.6. RO membrane pumping system (energy recovery portion not shown).

2.6.3 Energy Recovery Devices

The P1S2 concentrate stream consists of up to 55 percent of the feed volume of water at a pressure ranging from 500 to over 800 psi and is energy that can be recovered and returned to the process.

Historically, the most commonly used ERD is a Pelton wheel turbine. Recently developed units, isobaric ERDs, allow for significantly greater efficiency in operations, and the manufacturer performance projections for the PX indicate 20-percent greater energy recovery than the Pelton wheel turbine is possible.

The PX technology is an isobaric ERD developed by Energy Recovery, Inc. (San Leandro, California). The PX uses positive displacement to allow low-pressure pretreated seawater to be pressurized directly by the high-pressure concentrate stream from the desalination process. The device uses a cylindrical rotor with longitudinal ducts to transfer the pressure energy from the concentrate stream to the feed stream. The rotor spins inside a sleeve between two end covers with ported openings for low pressure and high pressure.

The low-pressure side of the rotor was filled with raw feed water (MF permeate), and the high-pressure side was filled with concentrate; then, the raw feed water was discharged at a higher pressure than the inlet pressure. The pressure exchanger pressurizes up to 55 percent of the P1S1 feed water to 95 percent of the pressure required, and a booster pump provided the remaining required pressure. The inefficiency in the PX was caused by the small amount of salt transfer from the concentrate to the feed (up to 2 percent) and friction loss.

2.6.4 Membranes Tested

Several commercially available membranes were selected for this study (**table 2.2**). These included NF90 (Dow Water Solutions, Midland, Michigan) and NE90 (Woongjin Chemical, Korea), which are seawater nanofiltration (SWNF) membranes; XLE (Dow Water Solutions) membrane, which is an ultralow-pressure (ULP) membrane; and SWC3+ (Hydranautics, Oceanside, California), which is a RO membrane. All membranes are made from polyamide thin film material.

2.6.5 Mobile Two-Pass NF System

A smaller mobile two-pass NF system was operated in parallel with the Prototype, with this system acting as the control. The feed water into the mobile unit was drawn from the MF pretreatment after dechlorination. No additional pretreatment was used after MF pretreatment. The spiral-wound elements were 4-inches in diameter and configured similarly to the Prototype. The system consisted of two passes, with pass 1 containing two stages of membrane system (**figure 2.7**). Pass 2 concentrate was recycled and mixed with pass 1 feed.

Table 2.2. Manufacturers' specifications for membranes tested[1]

Membrane name	SWC3+	NF90	NE90	XLE
Membrane type	RO	SWNF or NF	SWNF or NF	ULP
Description	One pass	Pass 1	Pass 2	Pass 1
Manufacturer	Hydranautics	Dow Water Solutions	Woongjin Chemical	Dow Water Solutions
Maximum operating pressure (psi)	1,200	600	600	600
Surface area (ft^2)	400	400	400	440
Flux (gfd)	18.8	18.8	17.5	28.9
Nominal rejection	99.7%	85-95%	85-95%	99.0%
Test conditions	32,000 ppm NaCl at 800 psi	2,000 ppm NaCl at 70 psi	2,000 ppm NaCl at 74 psi	500 ppm NaCl at100 psi

[1] gfd = gallons per square foot per day; % = percent; ppm = parts per million; NaCl = sodium chloride.

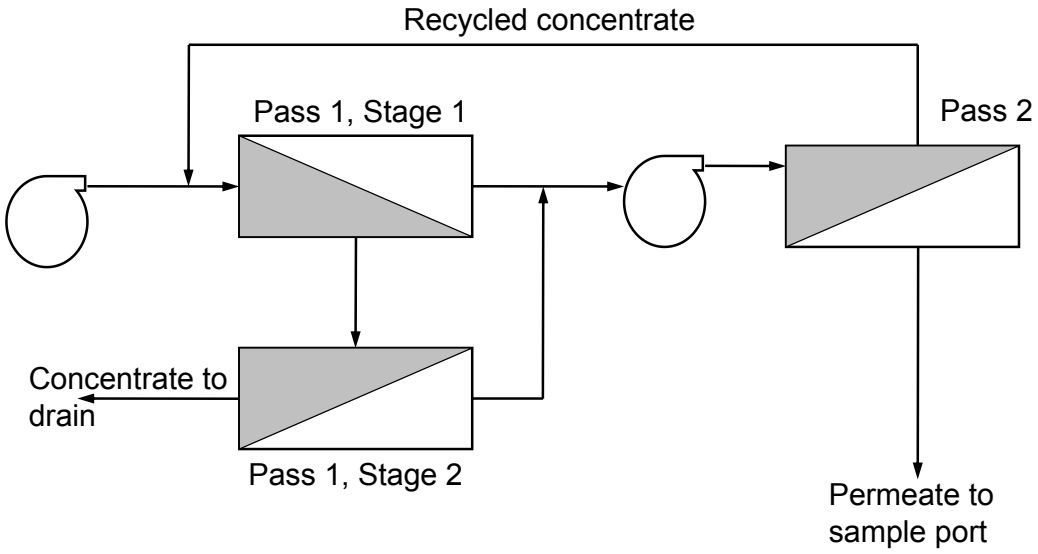


Figure 2.7. Mobile two-pass NF system schematic.

2.7 Data Collection and Analysis

Data were collected using an online monitoring system and manually as daily grab samples. The online monitoring system using the supervisory control and data acquisition (SCADA) captured the operating data from the plant.

2.7.1 SCADA System Overview

The SCADA system consisted of the following main components:

1. Programmable logic controllers (PLCs)
2. Radio telemetry equipment
3. Data highway and networking equipment
4. HMI (Human-machine interface) workstations and historian (data server)

The SCADA system was designed as a fully open and distributed control system through the utilization of multiple PLC stations and a plant-wide data network that interconnected the entire control system and subsystems to the HMI workstations. The PLCs were designated to different process areas based on location and function of each process area:

- Intake pump station
- MF and pretreatment system
- Train 1 pass 1 membrane system (south train)
- Train 1 pass 2 membrane system (south train)
- Train 1 energy recovery system
- Train 2 pass 1 membrane system (north train)
- Train 2 pass 2 membrane system (north train)
- Train 2 energy recovery system
- Effluent pump station

The following utility processes also were included:

- Clean-in-place
- Chemical treatment and UV system
- Post-treatment plant
- On-site lift station
- Backwash sump
- Power monitoring system

Table 2.3 shows the PLCs that were assigned to the above process areas and utility systems:

Table 2.3. PLC designation and process area

PLC	PLC Name	Designation	Process Area
PLC 1	Main plant PLC	MPP	Common area instrumentation, power monitoring system, transfer pump station.
PLC 2	Intake pump station	IPS	Intake pump station
PLC 3	PALL microfiltration unit	PMU	Micro filtration and pre-treatment process
PLC 4	Train 1 pass 1	T1P1	NF2 membrane process
PLC 5	Train 1 pass 2	T1P2	NF2 membrane process
PLC 6	Train 2 pass 1	T2P1	RO/NF^2 Process
PLC 7	Train 2 pass 2	T2P2	RO/NF^2 Process
PLC 8	Energy recovery system 1	ERS1	Train 1 energy recovery system
PLC 9	Energy recovery system 2	ERS2	Train 2 energy recovery system
PLC 10	Post-treatment plant	PTP	Post-treatment, combined effluent tanks, and effluent pump station, CIP.
PLC 11	Chemical feed system	CFS	Chemical feed treatment system & lift station, backwash sump pumps station.
PLC 12	Disinfection system	DIS	UV and disinfection system
PLC 14	Post-treatment system	CFS	Post-treatment analyzers and chemical feeders.

2.7.2 Human-Machine Interface Application

The Prototype's HMI was developed using InTouch 8 (Wonderware, Lake Forest, California). The InTouch HMI development software was used to create personal computer- (PC) based control and monitoring applications, and was used on computer workstations with Microsoft Windows XP operating system.

The HMI consisted of object-oriented graphics that were used to create interactive display screens that represented the process and its variables and allowed the operator to monitor and control the process. The display screens consisted of objects linked to the automation hardware (PLCs, PCs, and other data acquisition devices such as power monitoring equipment) to collect and display data. It also provided operators with the capability to change the settings and select the control mode and to start/stop the equipment by invoking the appropriate buttons and controls on the display screens. These functions were available to the user, through the Window Viewer, which was the runtime environment of InTouch.

Graphic display screens of the HMI showed the hydraulic flow diagram of the process. Real-time and historical trends were used to monitor the variations in the

process variables, and operators can trend plant performance to troubleshoot the control system. Operators also can print the snapshot of the trending charts for a selected period of time.

The historian component of the Wonderware software was used for data collection and analysis; it also was operated on a server station using Wonderware's InSQL server program in conjunction with Microsoft SQL and ActiveFactory as the front-end of the system for archiving, displaying, plotting, and analyzing data. The database allowed the sorting and downloading of subsets of the data using Microsoft Excel. **Table 2.4** shows the main components of the SCADA system.

Table 2.4. Main components of the SCADA system

Component	Model	Supplier
PLC system	Modicon Quantum and Momentum Programmable Controllers	Schneider Automation
HMI system	Intouch In SQL (Historian), ActiveFactory	Invensys Wonderware
SCADA network	Modbus TCP Network in conjunction with RS-485 Network	Schneider Automation
Telemetry	Radio modems (iNET 900) and antennas	MDS (Micro-Wave Data System)

2.7.3 Manual Data Collection Gathering and Sampling

The online monitoring data in the previous chapter was verified by manual monitoring using the instruments described in **table 2.5**.

Table 2.5. Analytical procedures

	Constituent	Instrumentation	Method
General Water Quality Parameters and Major Ions	pH	Ultrameter II (Myron L Company, Carlsbad, CA)	SM 4500 H+ B
	Temperature	Ultrameter II (Myron L Company, Carlsbad, CA)	SM 2550
	T-alkalinity	Titration method	SM 2320B
	Turbidity	Hach 2100AN (Hach, Loveland, CO)	SM 2130 B/ EPA 180.1
	Conductivity	Ultrameter II (Myron L Company, Carlsbad, CA)	SM 2510B
	TDS	Oven dry method	SM 2540C
	TSS	Oven dry method	2540 D
	Hardness (as $CaCO_3$)	Calculation based on Mg^{2+} and Ca^{2+}	SM 2340 C
	SDI	direct SDI (Applied Membranes, Vista, California)	ASTM D4189 - 07
	Na	ICS-2000 (Dionex, Sunnyvalle, California)	EPA 300.0 Modified
	Ca	ICS-2000 (Dionex, Sunnyvalle, California)	EPA 300.0 Modified
	K	ICS-2000 (Dionex, Sunnyvalle, California)	EPA 300.0 Modified
	Mg	ICS-2000 (Dionex, Sunnyvalle, California)	EPA 300.0 Modified
	F	DS-500 (Dionex, Sunnyvalle, California)	EPA300.0
	Br	DS-500 (Dionex, Sunnyvalle, California)	EPA300.0
	Cl	DS-500 (Dionex, Sunnyvalle, California)	EPA300.0
	Si	QC 2500 FIA	SM 4500-SiO_2 C
	NH_3-H	HACH DR 2500	SM 4500-NH3 D
	NO_3-N	DS-500 (Dionex, Sunnyvalle, California)	EPA300.0
	NO_2-N	QC 2500 FIA	SM 4500 NO_2^-B
	PO_4^{3-}	HACH DR 2500	SM 4500-P E
	SO_4^{2-}	DS-500 (Dionex, Sunnyvalle, California)	EPA300.0
	S^{2-}	HACH DR 2500	SM 4500 S^{2-} D

Table 2.5. Analytical procedures (continued)

Constituent			Instrumentation	Method
Metals	Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Sb, Se, Sr, Th, U, Va, Zn		Agilent 7500 CE (Agilent, Santa Clara, California)	SM 3120-B
Organics	UV_{254}		Spectronic Genesys 5 (Thermo Scientific, Waltham, Massachusetts)	SM 5910
	SUVA		Calculation based on UV 254 and dissolved organic carbon (DOC)	
	TOC		O.I. Analytical 1010 (IO Analytical, College Station, Texas)	SM 5310C
	DOC		O.I. Analytical 1010 (IO Analytical, College Station, Texas)	SM 5310C
	AOC		Standard Microbiology Lab Equipment	SM 9217
DBPs	THAA	BCAA	Varian GC-ECD	EPA 552.2.1 1995
		DBAA	Varian GC-ECD	EPA 552.2.1 1995
		DCAA	Varian GC-ECD	EPA 552.2.1 1995
		MBAA	Varian GC-ECD	EPA 552.2.1 1995
		MCAA	Varian GC-ECD	EPA 552.2.1 1995
		TCAA	Varian GC-ECD	EPA 552.2.1 1995
		HAA5	Varian GC-ECD	EPA 552.2.1 1995
	THM	BDCM	Varian 4000 Ion Trap GC-MS	EPA 524.2.4.1 1995
		$CHBr_3$	Varian 4000 Ion Trap GC-MS	EPA 524.2.4.1 1995
		$CHCl_3$	Varian 4000 Ion Trap GC-MS	EPA 524.2.4.1 1995
		DBCM	Varian 4000 Ion Trap GC-MS	EPA 524.2.4.1 1995
		TTHM	Varian 4000 Ion Trap GC-MS	EPA 524.2.4.1 1995

Table 2.5. Analytical procedures (continued)

Constituent		Instrumentation	Method
Microbes	Total Direct Counts	Standard Microbiology Lab Equipment	SM 9216
	Cryptosporidium	Standard Microbiology Lab Equipment	EPA 1622/1623
	mHPC	Marine Agar Used in Place of R2A Agar	SM 9215D
	Coliforms	Standard Microbiology Lab Equipment	AOAC 966.24
	Fecal	Standard Microbiology Lab Equipment	AOAC 966.24
	Enterococci	Standard Microbiology Lab Equipment	SMEWW 20th, 9230A-B
	HPC	R2A Agar Used	SM 9215 B
	ATP	Firefly Luciferase Test/NASA X-726-75-1	SM 9211 C
	Coliaphage	Standard Microbiology Lab Equipment	FR59#28 1602
	Male-Specific Coliphage	As specified in the USEPA UVDGM, 2006	UVDGM Appendix A
	Giardia	Standard Microbiology Lab Equipment	EPA 1622/1623
Operational	Chlorine dioxide residual	Amperometric Titration II (Severn Trent, Ft. Washington, Pennsylvania)	SM 4500-ClO_2 E
	Chlorine residual, free and total	Hach Colorimeter II (Hach, Loveland, Colordo)	HACH 8167; 8021
	ORP	Ultrameter II (Myron L Company, Carlsbad, California)	SM 2580

3. Results and Discussion

The following sections provide test result analyses from the Prototype.

3.1 MF Pretreatment

3.1.1 MF Filtrate Water Quality

The influent seawater of the Prototype experienced good water quality during the test period, as indicated by low turbidity (average of less than 1.4 NTU, **table 3.1**). The turbidity was further reduced by the MF system to less than 0.2 NTU (**figure 3.1**). SDI is another parameter generally used to evaluate whether the water is suitable for membrane process. Industry requires SDI less than 5 for membrane pretreatment to ensure proper membrane process operation (Dow, Hydranautics, etc.). The SDI of the raw water ranged from 6.25 to 6.67 (**table 3.1**), and the MF process effectively reduced the SDI to below 1 (**figure 3.2**). Although the influent seawater exhibited signs of biological activity (total coliform, fecal coliform, enterococci, mHPC, and HPC), these parameters were effectively reduced to near their detection levels after the MF pretreatment (**table 3.1**).

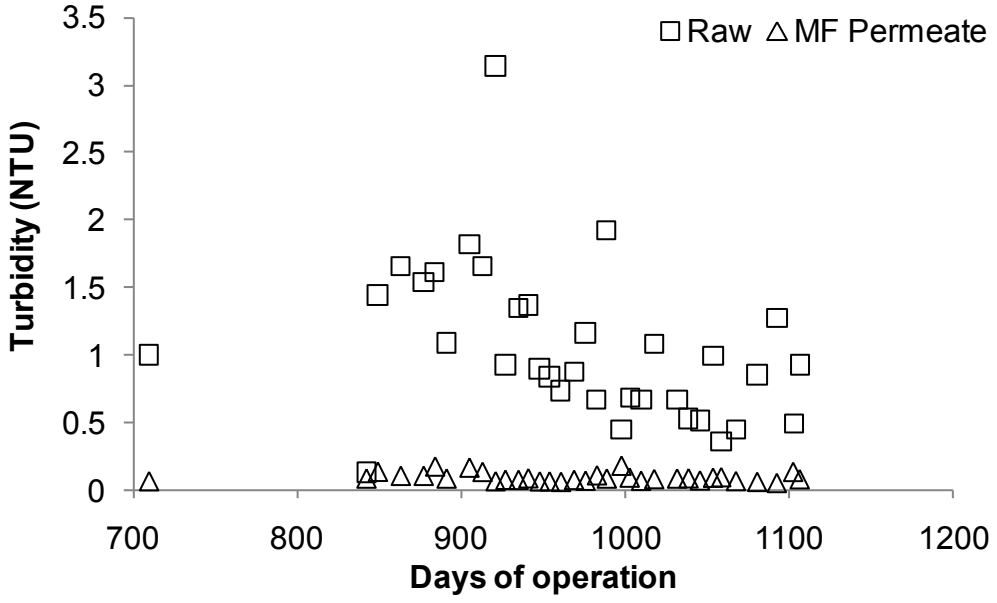


Figure 3.8. Raw and MF permeate turbidity.

Table 3.1. Source water and MF permeate water quality

Constituent		Unit	Prototype Raw			MF Permeate		
			Min	Max	Avg	Min	Max	Avg
General Water Quality	T	°C	14.1	23.2	18.9	16.1	26.3	20.2
	pH	—	6.93	9.03	7.84	6.47	8.04	7.46
	T-alk	mg/L	20	240	110	80	203	105
	Turbidity	NTU	0.07	3.14	1.36	0.00	0.20	0.09
	SDI	—	6.25	6.67	NA	0.12	0.95	0.48
	Conductivity	umhos/cm	39,200	51,800	48,600	41,400	51,900	48,900
	TDS	mg/L	30,750	35,080	33,578	26,910	33,735	31,785
Organics	TOC	mg/L	0.3	3.0	1.0*	0.3	2.4	1.4*
	UV 254	abs, cm^{-1}	0.000	0.842	0.042	0.000	0.115	0.021
Microbes	mHPC	cfu/100 mL	110	100,000	17,949	<2	4,250	1,360
	Coliform	/100mL	<2	>1,600	23	<2		
	Fecal	/100mL	<2	80	9	<2		
	Enterococci	/100mL	<2	17	3	<2		
	HPC	cfu/mL	4	1,100	150	<1	12	2
	Chlorophyll a	µg/L	<0.3	5.5	0.4	<0.3	1.3	<0.3
	Domoic acid	µg/L	<0.002			<0.002		

Notes: Refer to appendix A 2 for MDL of each parameter.

All data were collected weekly in 2008 and 2009 except for the following:
pH and temperature data measured daily from 2007 to 2010.
Chlorophyll a data collected daily from April to September, 2009.
Microbiological data collected from 10 to 20 times in 2008 and 2009.
SDI data for Prototype raw collected twice to confirm values were higher than industry guideline, and MF pretreatment was needed.

* Prototype raw collected in 2008 and 2009; MF permeate collected mainly in 2009, e.g., 65 samples collected for raw TOC and 32 samples collected for MF permeate. This is a possible explanation for the higher average TOC in MF permeate than raw.

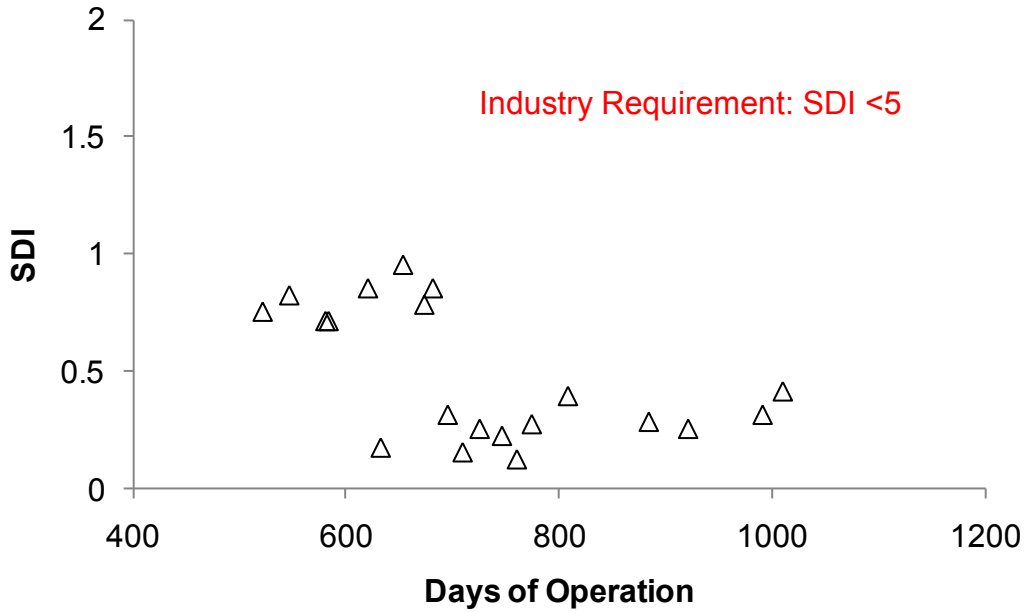


Figure 3.9. MF permeate SDI.

3.1.2 Transmembrane Pressure

An increase in the TMP indicates that fouling has occurred on the MF membranes. TMP data collected from the 3 years of MF operations are shown in **figure 3.3**. The total volume of filtrate produced over the 3 years was approximately 350 million gallons, which indicates that the MF daily production was approximately 0.32 mgd (**figure 3.4**). Although the periods between cleaning varied depending on the influent water quality, MF cleaning was performed when the TMP exceeded 20 psi (based on the manufacturer's recommendation). The TMP increase and cleaning frequency were dependent on the water production rate at the Prototype. In the later part of the testing, TMP reached 20 psi much faster and cleaning was performed more frequently (**figure 3.3**) because the MF water production was much higher than initial phases of testing. The chlorine dose applied to the MF system was increased from 1 to 2.5 mg/L around day 850, which appeared to mitigate fouling by allowing longer periods between chemical cleaning (**figure 3.5**).

3.1.3 MF Pretreatment Summary

The MF system effectively reduced raw water turbidity to less than 0.2 NTU and less than 1 for SDI. It also effectively removed different types of biological growth present in the raw seawater. The TMP increase was mainly dependent on the MF water production rate and the chlorine dosage. Increasing chlorine dose on the MF feed water from 1 mg/L to 2.5 mg/L significantly reduced the cleaning frequency, which allowed the MF system to remain in production longer.

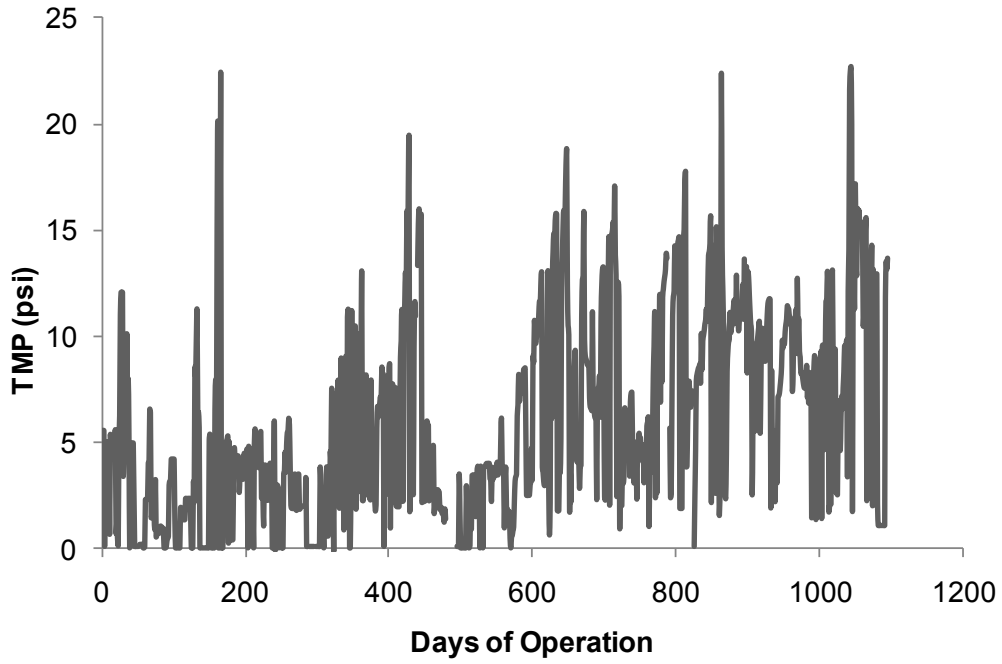


Figure 3.10. TMP change on MF over 3 years.

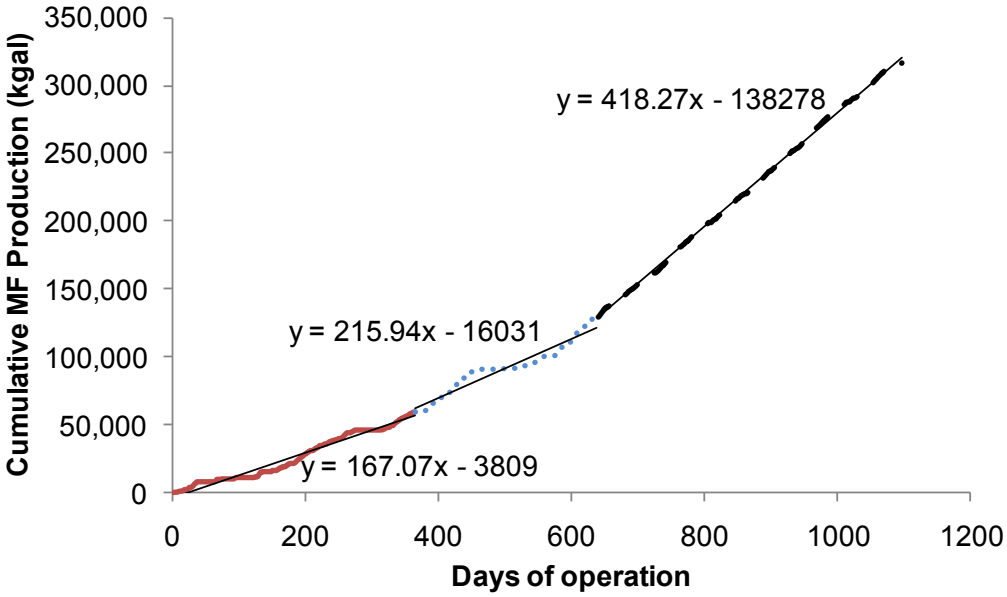


Figure 3.11. Cumulative MF production over 3 years.

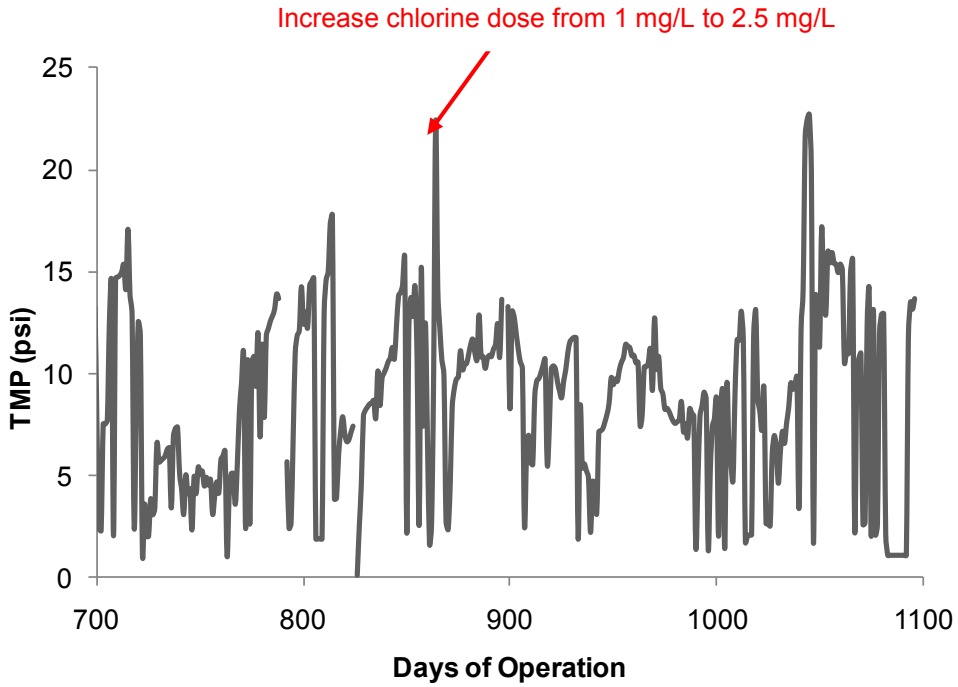


Figure 3.12. TMP change on MF over the last year testing.

3.2 NF^2 Versus RO

3.2.1 Background

RO has been the standard membrane technology used for seawater desalination. RO has a high associated cost due to the high applied pressure (800 to 1,000 psi) (Harrison et al., 2007). LBWD's patented NF^2 system desalts seawater through two passes of nanofiltration membranes. NF membranes require lower pressure (500 to 600 psi) than RO, so energy saving may be achieved. Two passes of NF membrane treatment were used to ensure that the product water meets drinking water TDS requirements because the salt rejection of NF membrane is lower than RO membrane. Recycling of pass 2 concentrate dilutes the influent seawater and reduces the feed pressure. Concentrate recycle for single-pass RO would not be beneficial because the concentrate concentration is higher than the feed water.

Specific contaminants that are unique to seawater desalination include boron, bromide, and iodide (Harrison et al., 2007). Boron is naturally present in seawater at a range of up to 5 mg/L. High level of boron can cause toxicity in plants like yellowing of leaves (Parks and Edwards, 2005). Boron has a pKa of 9.2, and boron exists as boric acid (H_3BO_3) at pH below 9.2, which easily passes through membranes. At pH above 9.2, boron hydrolyzes to borate ion ($H_2BO_3^-$), which is more easily rejected by membranes (Harrison et al., 2007). The World Health Organization (WHO) guideline for boron was set at 0.5 mg/L (WHO, 2003) and proposed to be revised to 2.4 mg/L (WHO, 2009). The California

Notification Limit (CANL) is set at 1 mg/L (Harrison et al., 2007). Although LBWD has not set a final internal water quality goal for boron, it is agreed that boron should be limited to 0.8 mg/L or less (20 percent less than the CANL).

Seawater also contains typical bromide concentration of up to 67 mg/L (Harrison et al., 2007). Bromide can react rapidly with monochloramine and accelerate its decay (Sohn et al., 2006; Trofe et al., 1980; Tseng et al., 2005). Bromide also can be incorporated into disinfectant byproducts (DBPs), and brominated DBPs have been shown to present a higher risk factor in drinking waters than chlorinated DBPs (Sohn et al., 2006; United States Environmental Protection Agency [USEPA], 1996). Iodide can be present in seawater at concentrations up to 50 µg/L, and have similar reactions as bromide (Harrison et al., 2007). Currently, there is no regulation for bromide and iodide; however, based on earlier bench-scale testing (Tseng et al., 2005), a bromide level below 0.5 mg/L presents little problems in maintaining disinfectant stability.

The test plan incorporated maximizing recovery, minimizing energy consumption, comparing the NF^2 process with RO, and demonstrating the long-term performance of the NF^2 process as the main objectives of the Prototype testing. The NF^2 process was compared with RO with respect to product water quality and overall system efficiency through a series of short-term (less than 2 weeks) and long-term testing (more than 2 weeks). The purposes of the short-term tests were to quickly obtain energy, recovery, and limited water quality information (primarily in the form of TDS) for comparative purposes. The long-term tests allowed for the collection of additional water quality analyses and operational characteristics, which substantiate the performance of the NF^2 process.

3.2.2 Permeate Water Quality

3.2.2.1 Total Dissolved Solids

TDS is the concentration of total ions in water and generally is expressed as milligrams of dissolved solids in 1 liter of water. TDS can be measured by drying and weighing the dissolved solids according to standard methods (Clesceri et al., 1998). For typical drinking waters, TDS can be calculated from electrical conductivity using a simple formula:

$$TDS = 0.5 \times EC\ (\mu S/cm)\ \text{(McNeil and Cox, 2000)} \qquad (3.1)$$

The 0.5 coefficient (McNeil and Cox, 2000) was derived from tests conducted between 22–28 °C. For simplification, temperature dependence was not considered in this report. TDS also can be calculated by summing the concentrations of all dissolved ions. In this study, for permeate water, NaCl contributed to greater than 96 percent of the TDS (appendix table A1). TDS calculated from the NaCl concentration correlated strongly with conductivity calculations (**figure 3.6**). In this report, all TDS data presented are calculated from NaCl because this parameter was analyzed consistently throughout the Prototype testing.

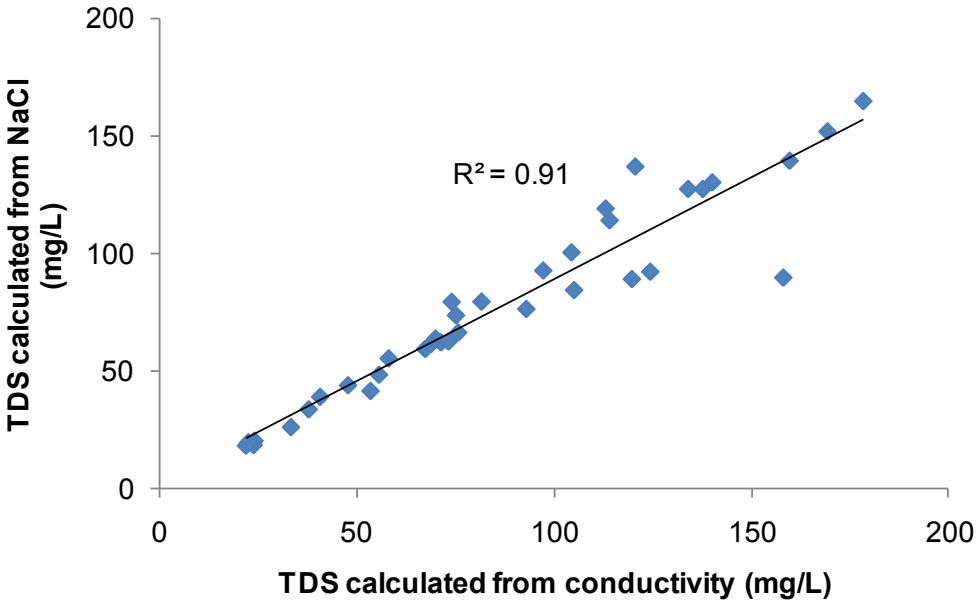


Figure 3.13. Correlations between TDS calculated from NaCl versus TDS calculated form conductivity (pass 2 permeate).

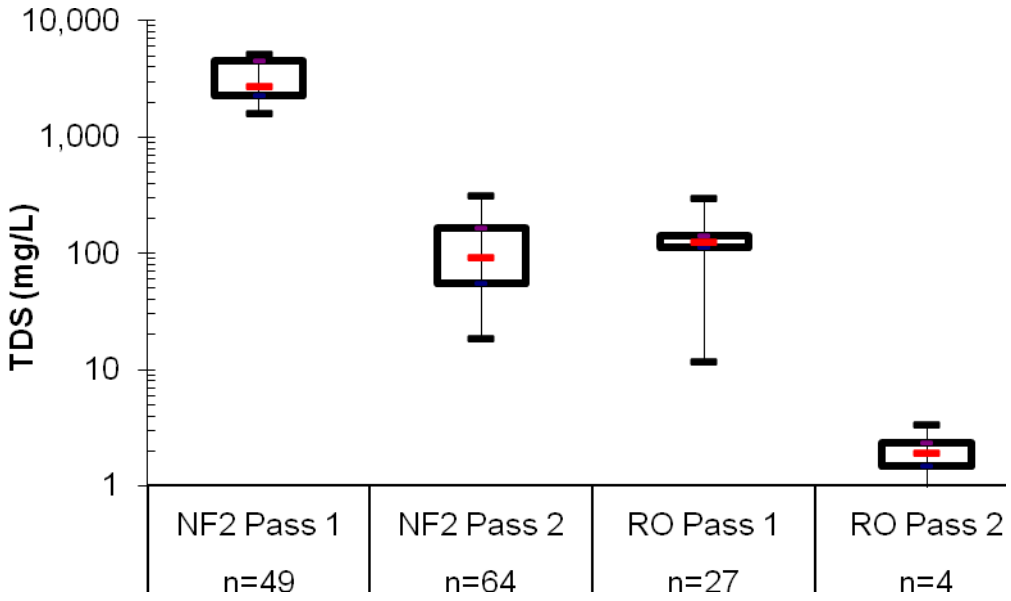
The Safe Drinking Water Act (SDWA) sets the secondary MCL for TDS at 500 mg/L (USEPA, 1996). The TDS concentration in LBWD's distribution system ranges from 230–330 mg/L (LBWD, 2006). The NF^2 process produced very similar TDS concentrations to the single-pass RO process, and the TDS from both desalination processes were similar to typical drinking water TDS concentration found in LBWD's system (**figure 3.7**). Other major water quality data for NF^2 and RO permeate are shown in **table 3.2**. Results indicate that both desalination process produced permeate of very good overall water quality. Please refer to appendix table A1 for a comprehensive list of the parameters evaluated.

3.2.2.2 Boron (B)

LBWD adopted the boron goal of less than 1.0 mg/L from the CANL guideline, and operations at the Prototype was targeted to achieve less than 0.8 mg/L whenever possible. Although RO was able to achieve similar permeate water quality as the NF^2 process, it was unable to consistently meet the goal of less than 1.0 mg/L for permeate boron (**figure 3.8**)). A second pass was needed to meet the boron goal, and the addition of NF membranes in the second pass was able to achieve the boron goal (**figure 3.8**). Lower boron goals would require a high boron rejection membrane to be used in the second pass, or pH adjustment should be performed as discussed below for the NF^2 system.

Table 3.2. Permeate water quality from NF^2 versus RO

Constituent		unit	MDL	February 14, 2008		August 14, 2008		September 12, 2008			
				NF^2 Pass 2	**RO Pass 1**	**NF^2 Pass 2**	**RO Pass 1**	**NF^2 Pass 1**	**NF^2 Pass 2**	**RO Pass 1**	**RO Pass 2**
General Water Quality	pH	NA	NA	10.8	NA	9.4	5.2	NA	10.7	NA	NA
	T	°C	NA	14.6		23.9		NA	NA	NA	NA
	Turbidity	NTU	0.05*	0.15	0.15	0.06	0.07	0.05	0.1	0.11	0.08
	Conductivity	umhos/cm	NA	NA	NA	NA	NA	6,850	461	315	7
	SDI	NA	NA	0.002	0.033	NA	NA	NA	NA	NA	NA
	TDS	mg/L	1*	52.5	149	194	166	NA	438	218	N/A
	Na	mg/L	0.32	16.80	50.50	70.00	67.00	1,826	106	82.4	3.08
	Ca	mg/L	0.38	<0.38	0.21	<0.38	<0.38	3.8	1.65	<0.38	<0.38
	Hardness (as $CaCO_3$)	mg/L	NA	0.97	0.53	NA	NA	NA	NA	NA	NA
	Cl	mg/L	0.24	18.80	79.00	98.30	100	2,874	151	111	<0.24
	SO_4	mg/L	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
	Br	mg/L	0.21	<0.21	0.39	<0.21	<0.21	17.90	<0.21	<0.21	<0.21
	B	mg/L	0.29	0.39	0.91	0.91	1.00	5.37	0.78	1.45	0.95
Metal	Al	ug/L	13	13	130	<13	130	9	5	8	13
	Cu	ug/L	0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16
	Fe	ug/L	6.8	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8
	Pb	ug/L	0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Organics	TOC	mg/L	0.1	0.1	0.1	0.26	0.17	0.1	0.16	0.18	0.28
Microbes	HPC	cfu/ml	1*	7	10	<1	140	NA			
	Cryptosporidium	P/100 mL	0.09*	<0.09	<0.09	N/A	N/A				
	Giardia	P/100 mL	0.09*	<0.09	<0.09	N/A	N/A				
	Coliaphage	P/100 mL	1*	<1	<1	<1	<1				
	Male-Specific Coliphage	P/100 mL	1*	<1	<1	<1	<1				



Note: Data for NF^2 process collected from south train (2 years) and data for RO collected from north train (1 year); n indicates number of data points.

Figure 3.14. Water quality achieved by NF^2 versus RO.

The permeate boron level was significantly affected by pH, and adjustment to greater than 9.2 for pH before the second pass allowed sufficient boron reduction to meet LBWD's drinking water boron goal (**figure 3.9**), but a pH above 10 was necessary to consistently meet the goal of less than 1 mg/L boron (**figure 3.9**). Increasing the pH did not impact the permeate TDS, which was expected because TDS rejection was not affected by pH (**figure 3.10**). It was also confirmed that increasing the pH had no effect on the pass 2 operating pressure (**figure 3.11**).

Although pH adjustment is effective for reducing boron, this should not be performed on a single-pass membrane system because high pH would accelerate the precipitation of cation ions, such as Ca^{2+} and Mg^{2+} and accelerate fouling. Therefore, a second pass is necessary to meet both boron and other water quality goals while maintaining good system performance.

3.2.2.3 Bromide (B)

Bromide is a contaminant of interest in desalinated seawater because it can cause disinfectant residual stability and DBP issues (Harrison et al., 2007). Earlier bench-scale testing at LBWD indicated that a bromide level below 0.5 mg/L generally has little negative impact on disinfectant residual stability (Tseng et al., 2005). In the Prototype, the 50^{th} percentile bromide level achieved with the NF^2 system was 0.3 mg/L after pass 2 (**figure 3.12**). For RO membranes, the 50^{th} percentile bromide level with a single pass was 0.34 mg/L, and adding a second-pass NF membrane further reduced bromide levels (**figure 3.12**).

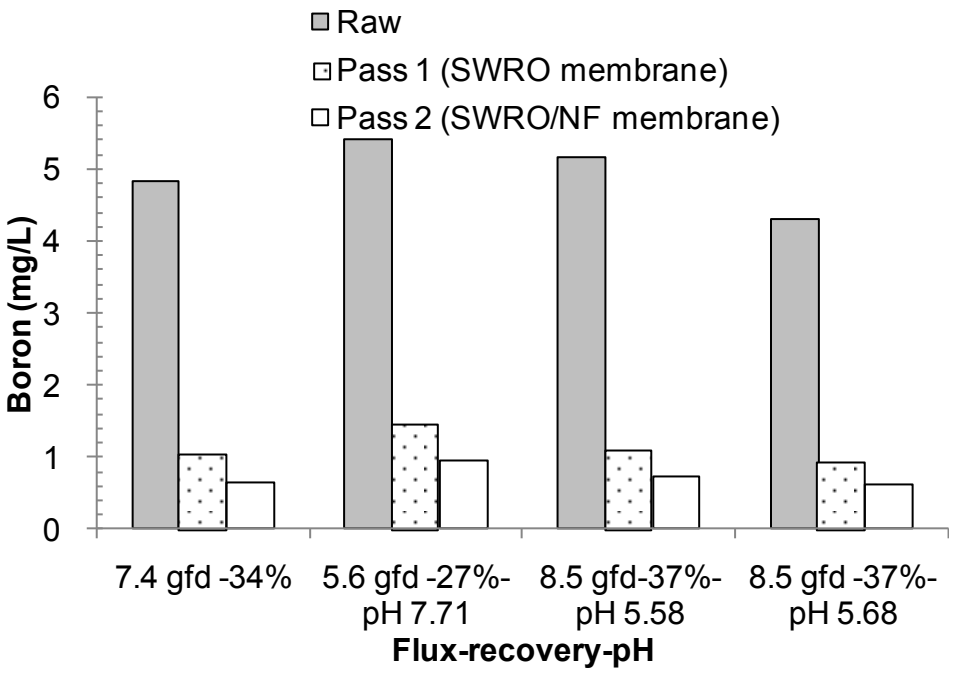


Figure 3.15. Boron removal by RO pass 1 and pass 2.

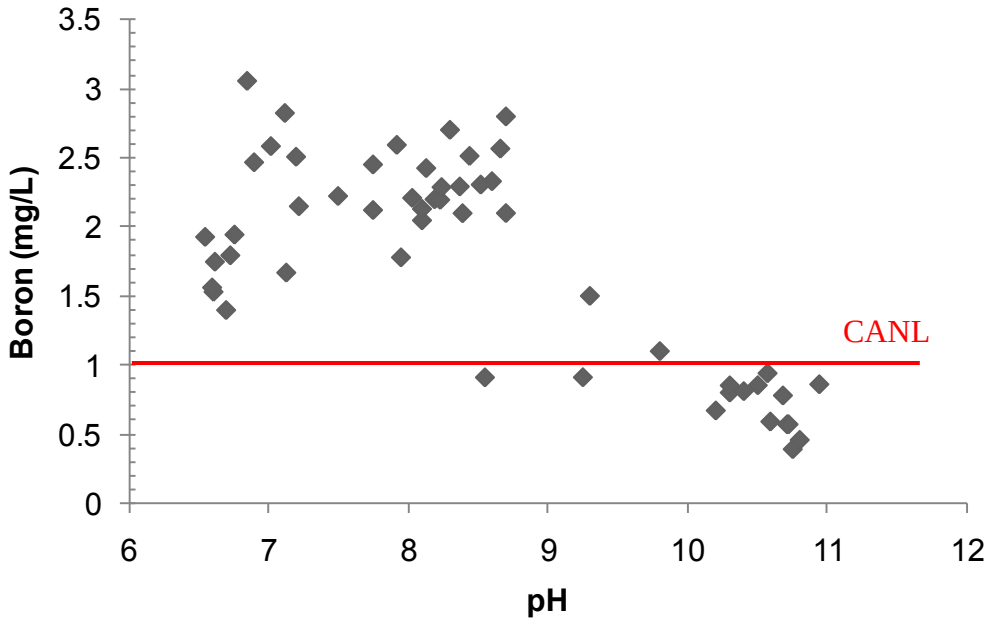


Figure 3.16. Boron versus pH at NF^2 pass 2 permeate.

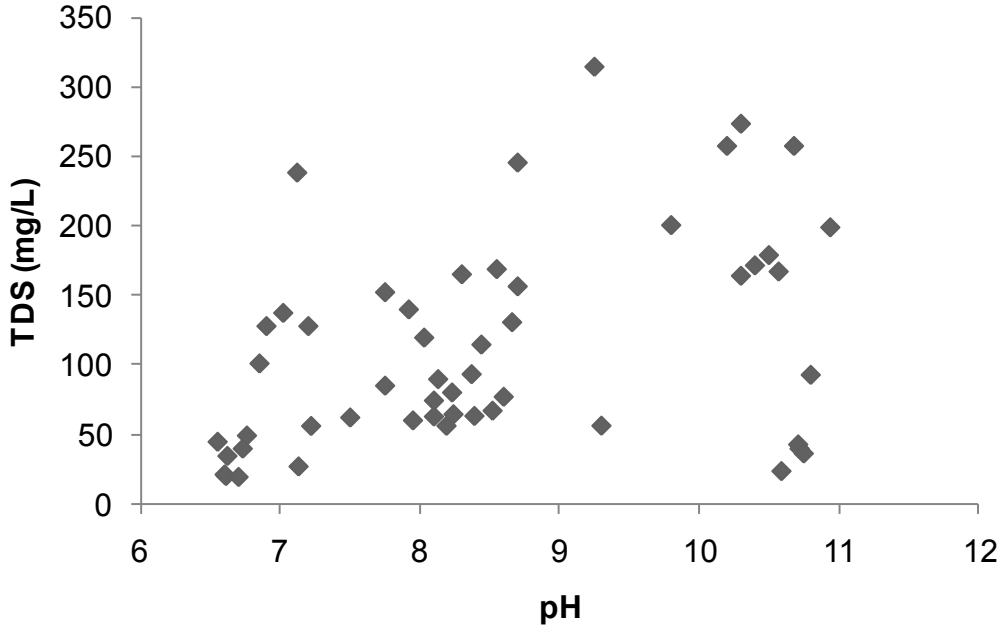


Figure 3.17. TDS versus pH at NF^2 pass 2 permeate.

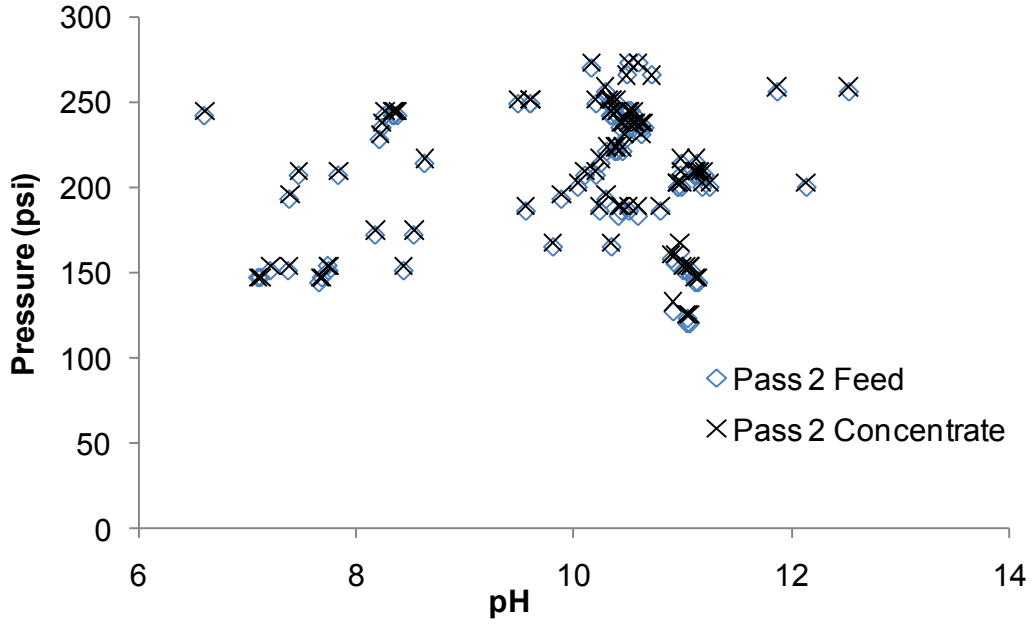
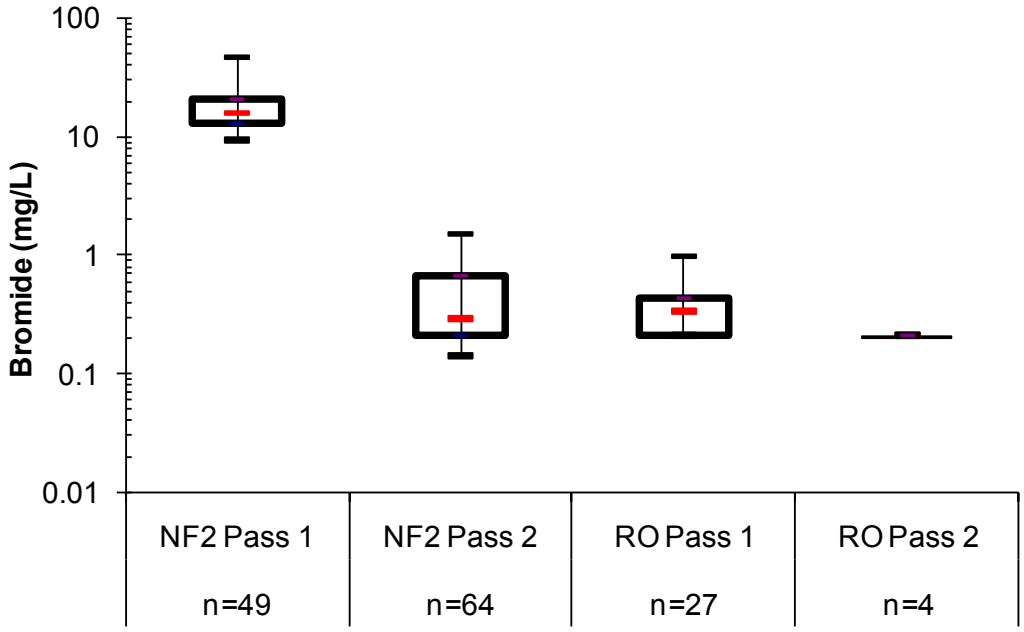


Figure 3.18. Pressure versus pH at NF^2 pass 2 permeate.



Note: Data for NF^2 process collected from south train (2 years) and RO from north train (1 year). Nondetect replaced with MDL = 0.21 mg/L; n indicates number of data points.

Figure 3.19. Bromide Levels: NF^2, RO, and RO-NF.

3.2.3 Recovery

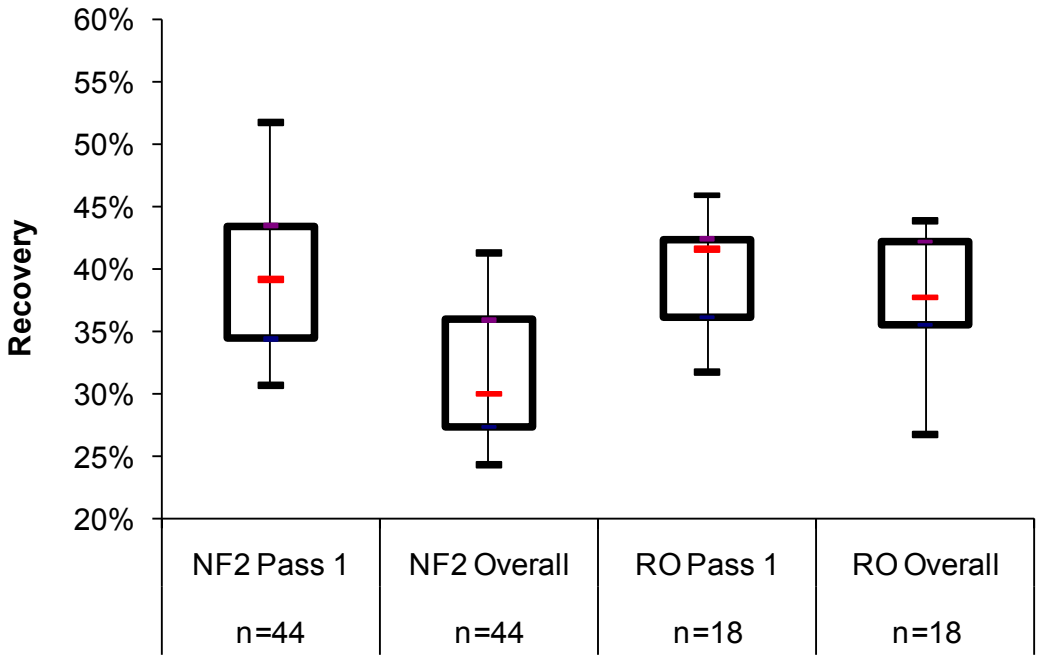
To maximize the recovery, minimize energy consumption, and compare the NF^2 and RO process, as specified by the test plan, 28 short-term tests (1 to 11 days) and 10 long-term tests (2 weeks to 6 months) were performed. The overall recovery of the two-pass system was less as compared to the single-pass RO system (**figure 3.13**). For both NF and RO systems, the recovery of pass 1 was approximately 40 percent, which was previously estimated as the optimal recovery on the energy curve (Cheng et al., 2005). The addition of the second pass lowered the overall recovery for NF^2 system to approximately 30 percent.

Many combinations are available for achieving the same overall recovery in a two-pass membrane system. For example, an overall recovery of 28 percent was achieved by several different combinations of recoveries in pass 1 and pass 2 (**figure 3.14**). This was expected based on the theoretical calculation of the overall recovery:

$$R = \frac{R1 \times R2}{1 - R1 + R1 \times R2} \tag{3.2}$$

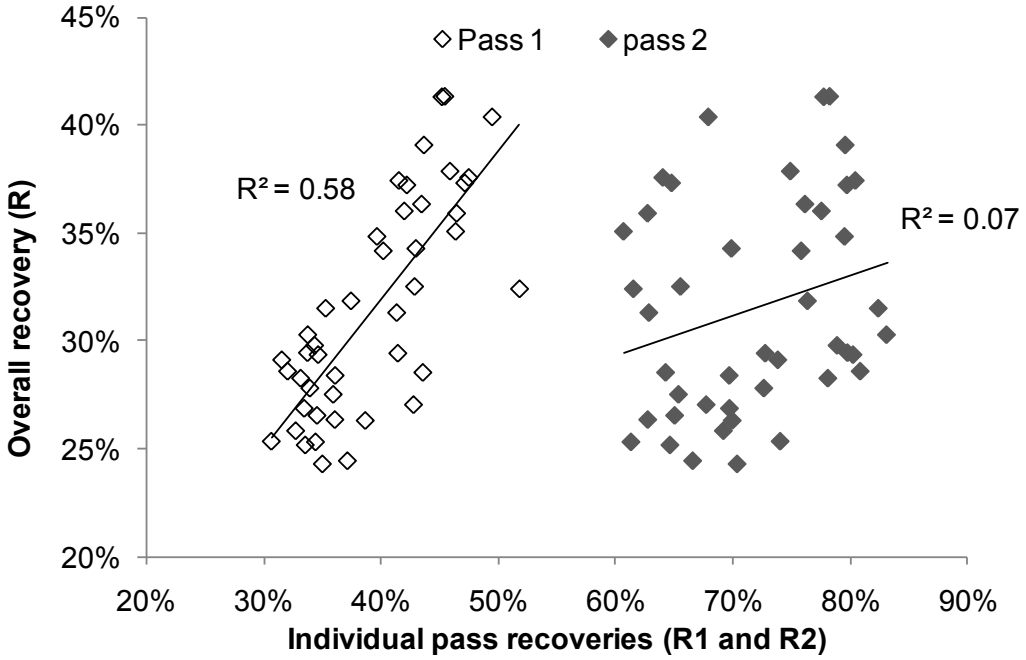
R is the overall recovery, R1 is the Pass 1 recovery and R2 is the pass 2 recovery.

Although recoveries in both passes affected the overall recovery, pass 1 was shown to correlate more directly with the overall recovery (**figure 3.14**). An R^2 close to 1 indicates a good liner correlation, and the R^2 value for pass 1 and overall recovery is 0.58; while R^2 value for pass 2 and overall recovery is 0.065. Since the pass 1 recovery more significantly impacted the overall recovery, system optimization should focus on pass 1.



Note: n indicates number of data points.

Figure 3.20. Permeate recovery by NF^2 versus RO.



Note: Recoveries are calculated based on the following equations.

$$R = \frac{P2\ permeate}{MF\ permeate\ feed\ to\ the\ train}$$

$$R1 = \frac{P1\ permeate}{Overall\ feed\ to\ the\ train\ (inclluding\ P2\ concentrate\ recycle)}$$

$$R2 = \frac{P2\ permeate}{P2\ feed\ (P1\ permeate)}$$

Figure 3.21. Overall recoveries as affected by individual pass recoveries on the NF^2 system.

3.2.4 Energy Consumption

The energy consumption per volume of water (specific energy, kilowatthour per kilogallon [kWh/kgal]) for a membrane system depends on feed water flow, feed pressure, temperature, pump efficiency and recovery. Specific energy was calculated for the feed pump, high pressure pump, ER booster pump and waste through concentrate using the following equation:

$$\text{Horsepower} = \frac{\text{Pressure} \times \text{Flow} \times 2.31}{3{,}960 \times \text{efficiency}} \qquad (3.3)$$

Where:

Pressure = pump pressure (psi)
Flow = flow rate (gpm)

Efficiency = pump and motor efficiency (%,), (Pump E = 80%, Motor E = 90%, Overall = 72%).

The horsepower for each step was summarized and the overall specific energy was calculated as follows:

$$\text{Specific energy} = \frac{\sum \text{horsepower} \times 0.746 \times 1{,}000}{\text{Permeate flow} \times 60} \quad (3.4)$$

Where:

Specific energy = energy consumed per volume of water (kWh/kgal)

∑horsepower = sum of all energy

0.746 is the conversion factor between horsepower and kilowatt (kW)

permeate flow = permeate flow rate (gpm)

The specific energy was temperature-corrected based on the following equation (Crittenden et al., 2005):

$$\text{T corrected specific energy} = \text{specific energy} \times 1.03^{(T-25)} \quad (3.5)$$

All specific energy values reported in this document were temperature-corrected and with energy recoveries device running.

The applied pressure to the NF membrane is lower than the RO membrane; in this study, the average applied pressure at pass 1 was 540 and 750 psi, respectively, for NF^2 and RO systems. Based on the pressures, the overall energy consumption was expected to be less with NF membrane. However, the NF^2 system was operated in a two-pass mode, which reduced the overall recovery (**figure 3.15**) and increased the specific energy consumption. As compared to the single-pass RO operations, the specific energy consumption for NF^2 was slightly higher than a single pass RO (**figure 3.15**).

To achieve the same water quality goals, particularly boron goals of less than 1 mg/L, a second pass was required for the RO system, which deviated from the expectation and original test plan that single-pass RO would be sufficient (**figure 3.8**). Additionally, this information was not confirmed until the latter part of the RO testing, and limited time was available for two-pass RO testing. Three tests were performed for the two-pass RO process, with duration ranging from 3–13 days (appendix A2.4-A2.6). Because one test was conducted with the energy recovery device off, the results obtained from the other two tests were used to compare against the NF^2 specific energy consumption. At similar overall recoveries, the specific energy consumption for NF^2 was lower than the two-pass RO system (**figure 3.15**).

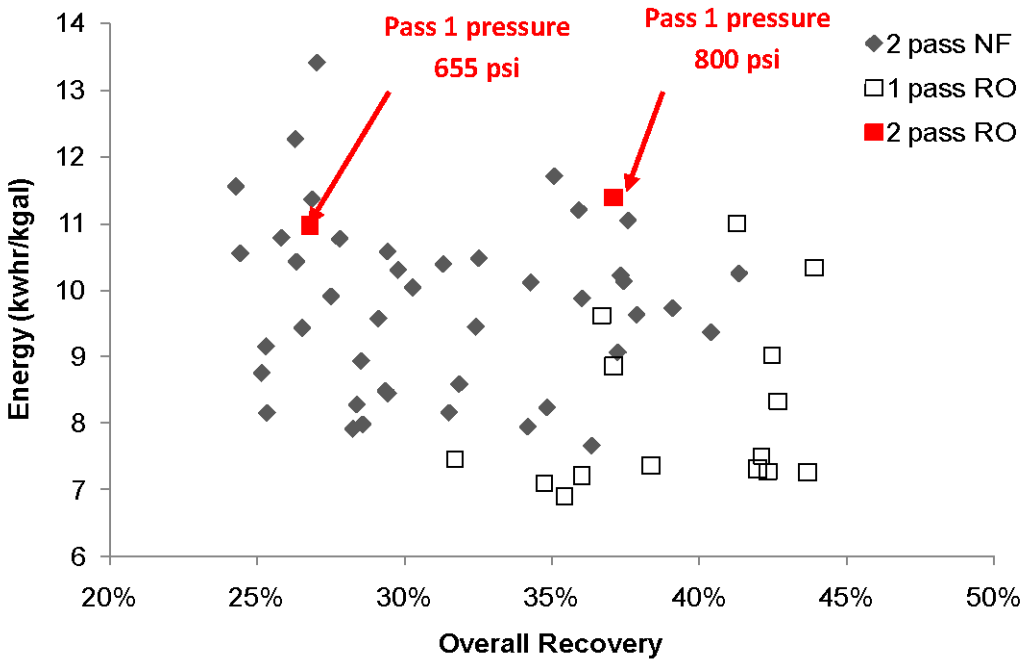


Figure 3.22. Specific energy consumption for NF^2 versus RO.

3.2.5 NF^2 Versus RO Summary

The NF^2 system produced permeate water with TDS levels of 200 mg/L, which was similar to typical LBWD distributed drinking water concentrations. The permeate also met the boron goal of less than 1 mg/L by interstage pH adjustment. The NF^2 system also reduced bromide levels to less than 0.5 mg/L (75th percentile), to ensure that disinfectant residual stability is preserved. The single-pass RO system produced permeate water TDS and bromide levels similar to the NF^2 system, but it was not able to meet the boron goal of less than 1 mg/L; a second pass was necessary to achieve this water quality target.

The NF^2 system resulted in lower overall recovery than a single-pass RO system due to the second pass, and the overall recovery was more significantly impacted by pass 1 recovery. Therefore, optimization centered on pass 1 would have a greater benefit on the overall recovery. The single-pass RO system was unable to meet the boron target of less than 1 mg/L, so the specific energy consumption comparison was made based on tests conducted with two-pass systems for both NF^2 and RO. It was found that NF^2 resulted in lower specific energy consumption as compared to a two-pass RO system at a similar overall recovery.

3.3 Energy Recovery Operations

3.3.1 Water Quality and Efficiency

Power consumption accounts for the largest cost component of producing desalinated waters (Stover, 2005). A series of short-interval RO and NF^2 performance experiments were performed to confirm the ability to meet water quality goals at different operating conditions with and without energy recovery devices-PX. These short tests averaged approximately 2 hours for the RO test and between 1–2 hours for the NF^2 tests.

Tests were performed to confirm that the use of the PX devices did not adversely affect desired permeate water quality goals (**table 3.3**). The water quality goal set for this phase of testing project was based on a TDS target of less than 500 mg/L. It is not unexpected that specific energy consumption values were higher during the short-term testing because these tests may not reflect stable conditions (**figure 3.16**). The testing was performed at the RO system without using the PX, and then with the use PX. Similar tests were conducted with the NF^2 system. The results showed that water quality was not impacted by using PX devices. However, the specific energy consumption was dramatically reduced by using the PX, with 46-percent energy reduction achieved.

Figure 3.16 shows water quality and specific energy consumption as a function of overall recovery (the data are sorted from highest to lowest overall recovery). The water quality goal of less than 500 mg/L of TDS was achieved in all tests conducted with single-pass RO and NF^2. The short-term testing also compared specific power consumption between single-pass RO and NF2 processes without using the PX. On average, the NF^2 process required about 5 percent less energy than the single-pass RO process without the use of the PX (17 kWh/kgal for NF^2 and 18 kWh/kgal for single-pass RO, average values).

Because the PX provides no physical barrier between the concentrate and the raw water, this mixing could potentially affect the final water quality. The rotor rotation is directly influenced by the velocity of the flow through the PX system. The efficiency is dependent on a balanced flow between the concentrate and feed water to minimize blending effects (**figure 3.17**). Longer-term tests were performed to ensure that the use of PX did not compromise effluent water quality.

The longer-term testing consisted of testing periods up to 2 weeks. **Figure 3.18** shows the result from this testing and proved that similar permeate TDS can be obtained through both the RO and NF^2 process with and without the PX.

Although pressure exchangers are able to reduce energy consumption, it was not clear whether efficiencies obtained match the manufacturer's projections. The efficiency of the device can be calculated by the equation below **(figure 3.19)**. Two assumptions were made: $P_1 = P_2$, and concentrate discharge pressure of 10 psi.

Table 3.3. Operating conditions for various short interval experiments[1]

Train/ PX Mode	Identifier	Feed Pressures (psi)	Feed Flows (gpm)	Flux at 25 °C (gpd/ft^2)	Overall Recovery (%)	Permeate TDS mg/L	Calculated Power with Feed Pump at 25 °C kWh/kgal
RO "OFF"	RO 1	774	225	5.27	47%	309	17.8
	RO 2	774	217	5.10	47%	319	18.1
	RO 3	774	217	5.14	47%	293	17.7
	RO 4	693	217	4.46	41%	267	18.1
	RO 5	693	217	4.50	41%	266	18.0
	RO 6	663	217	4.18	38%	269	18.5
	RO 7	540	216	2.44	23%	292	26.0
	RO 8	529	217	2.29	21%	292	27.1
RO "ON"	RO 9	746	263	4.92	37%	298	10.3
	RO 10	713	268	4.66	35%	289	10.1
	RO 11	775	261	4.91	37%	298	11.3
	RO 12	842	255	5.58	44%	311	11.0
	RO 13	663	273	4.17	30%	282	10.1
	RO 14	849	205	4.71	46%	367	11.1
	RO 15	779	211	4.04	38%	347	11.3
	RO 16	697	215	3.40	31%	332	11.1
	RO 17	666	219	3.18	29%	323	11.1
NF^2 "OFF"	NF^2 1	500	261	6.34	37%	163	17.5
	NF^2 2	524	264	6.24	40%	247	16.5
	NF^2 3	551	238	6.12	46%	300	15.6
	NF^2 4	498	261	5.70	36%	300	17.0
	NF^2 5	476	277	5.53	33%	292	17.2
	NF^2 6	458	274	5.20	32%	295	17.3
	NF^2 7	423	267	4.24	26%	331	18.6

[1] gpd/ft^2 = gallons per day per square foot.

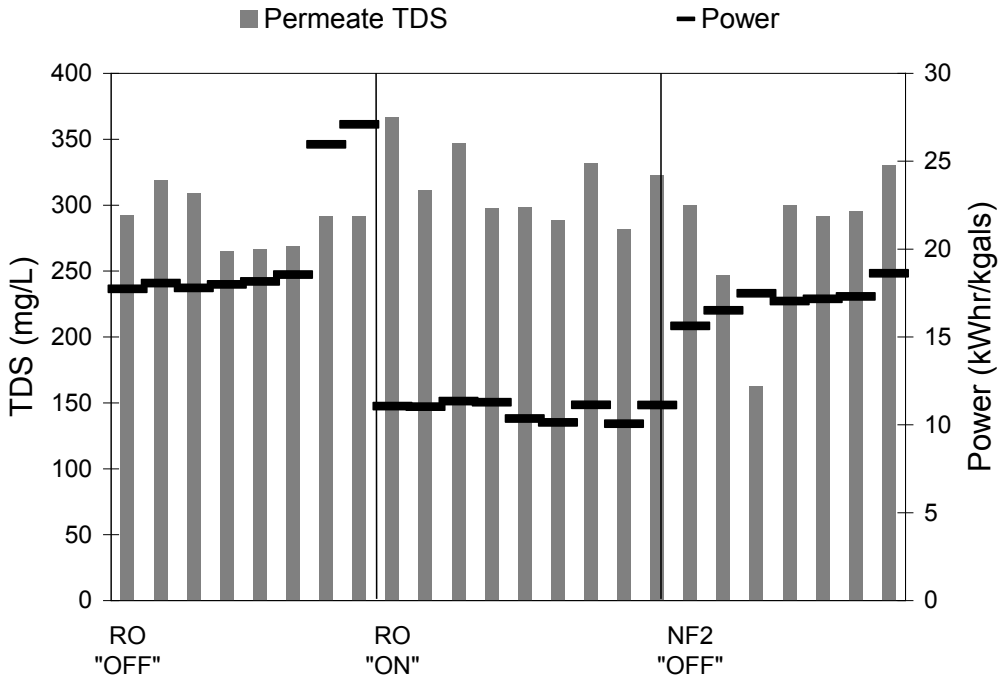


Figure 3.23. Specific energy consumption and TDS in the final permeate, with and without PX devices.

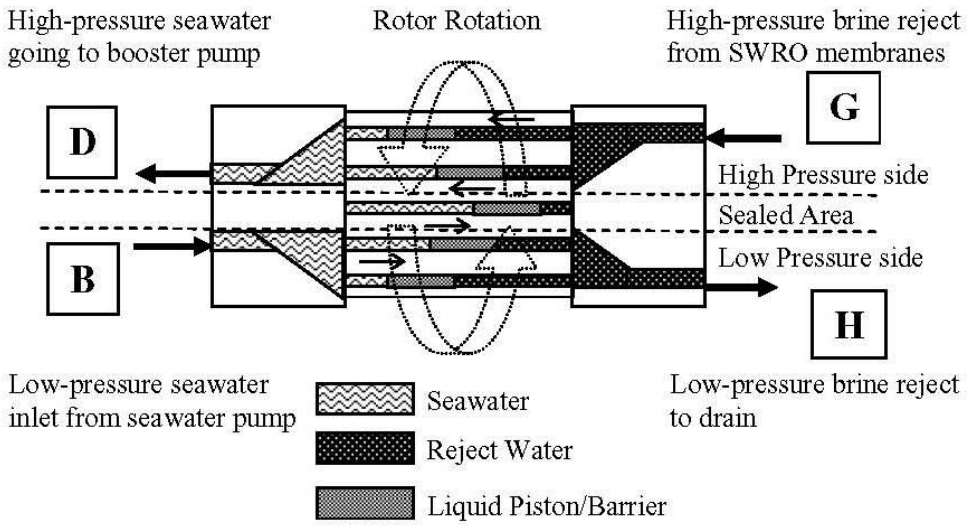
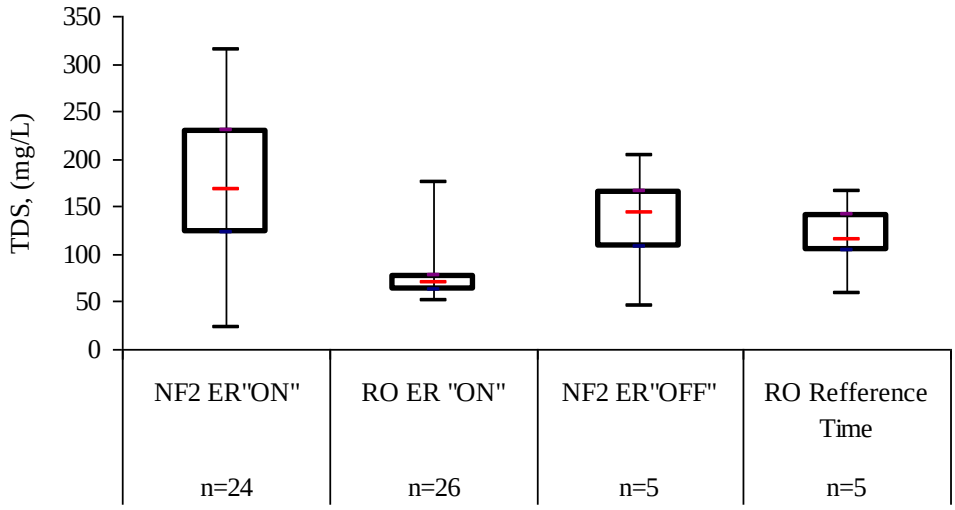
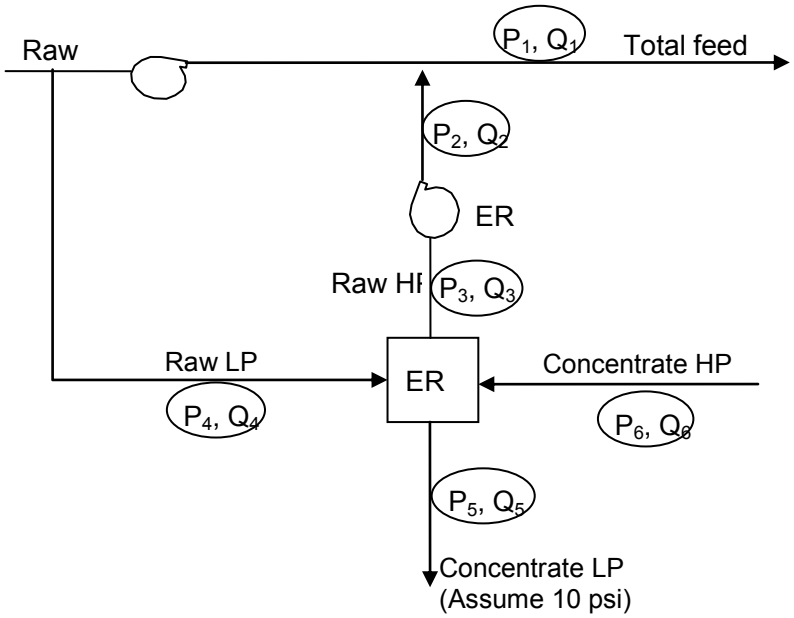


Figure 3.24. PX flow schematic.



Note: n indicates number of data points.

Figure 3.25. Permeate TDS comparison with and without PX devices.



Note: P-pressure, Q-flow, HP-high pressure, LP-low pressure.

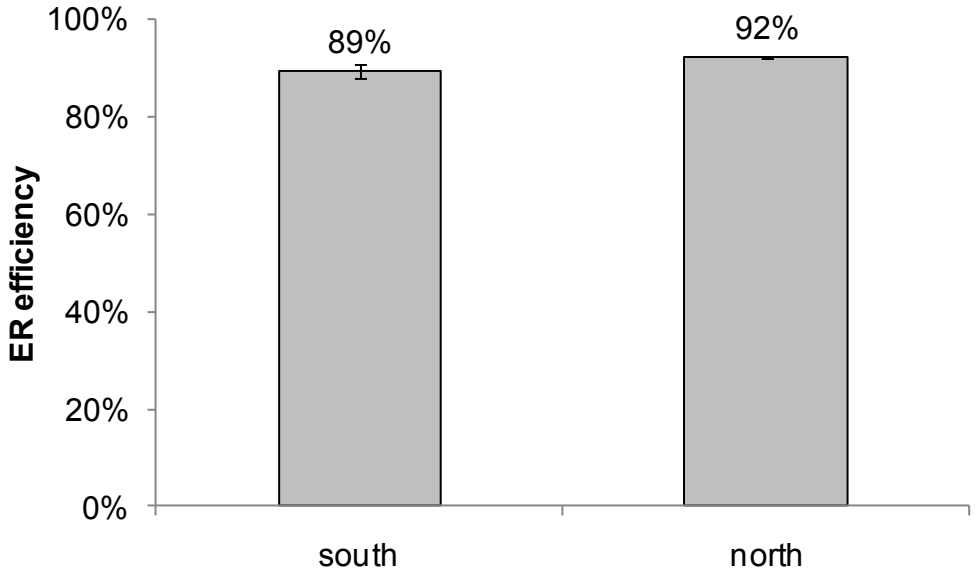
$$ER\ efficiency = \frac{P3 \times Q3 + P5 \times Q5}{P4 \times Q4 + P6 \times Q6}$$

$P_1 = P_2$

$$\frac{Power\ consumed\ by\ ER(kWhr) \times ER\ pump\ efficiency \times 1.341}{hours} + \frac{P3 \times Q3 \times 2.31}{3{,}960} = \frac{P2 \times Q2 \times 2.31}{3{,}960}$$

Figure 3.26. Energy recovery efficiency calculations.

The manufacturer's reported efficiency for the PX can be as high as 98 (average 95) percent (Anderson et al., 2009); and depending on flow conditions, the efficiency can be more than 2.5 percent lower. The actual efficiency of the south and north trains were calculated by using the above assumptions and analyzing the operating data from 2009. Test results are shown below (**figure 3.20)** and indicate that the actual efficiency for the south train was 89 percent, and the north train was 92 percent (average).



Note: Error bars indicate 95-percentile confidence interval.

Figure 3.27. ER Efficiencies for south and north trains.

3.3.2 Energy Recovery Operations Summary

Although many options currently are available for ERDs for use with desalination systems, the PX exchanger used during the Prototype tests represent some of the most efficient recovery devices currently available. Results from the short- and long-term tests with PX under multiple conditions show no adverse effects on permeate water quality. The goal of final permeate TDS below 500 mg/L was achieved under all conditions, with and without using the PX.

The efficiency of the specific PX devices used at the Prototype also was verified. The results obtained showed that the average efficiencies obtained ranged from 89–92 percent, as compared to the manufacturer's claim of over 95 percent.

3.4 Pretreatment Processes

3.4.1 Purpose and Objectives

The purpose of the UV/ClO_2 testing was to evaluate the two disinfection methods for controlling biofouling on desalination membranes and achieving pathogen inactivation (disinfection) credits required by CDPH for a full-scale seawater desalination facility.

3.4.2 Feed Water Quality

Seawater from LADWP Haynes Powerplant was treated through chlorination, MF, and dechlorination. After dechlorination, the feed water was collected into a break tank, which splits the feed water into two parallel streams (**figure 3.21**). One stream was fed into the north train, and ClO_2 was injected into this water before flowing through a cartridge filter (CF) (Claris, PALL Corporation, East Hills, New York). The south train feed flowed through the CF into a UV reactor (UVSwiftSC D06, TrojanUV, Ontario, Canada). Feed water quality has been previously presented in **section 3.1**.

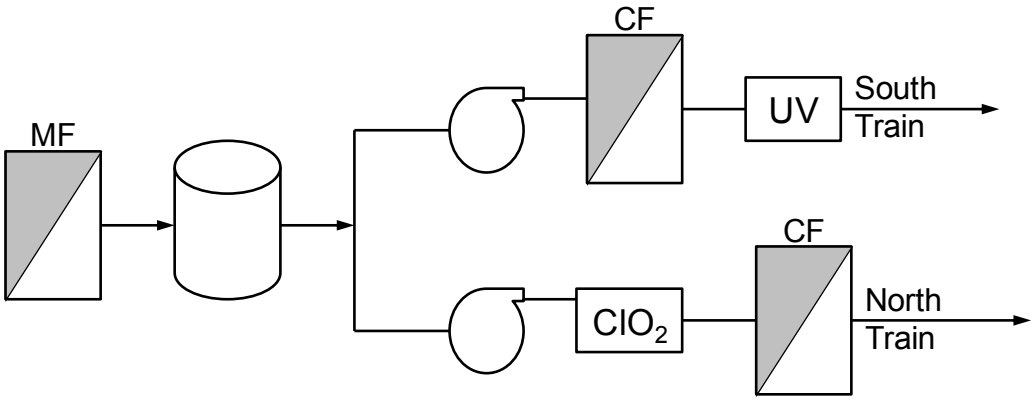


Figure 3.28. Schematic of the disinfection alternatives after MF.

3.4.3 UV Irradiation

The UV irradiation process has the potential to inactivate microbial fouling agents without damaging membranes and without leaving any disinfectant residuals. The UV reactor was operated at dosages between 40–146.4 mJ/cm^2 depending on feed water. After 6 months of operation, a pinhole leak formed on the UV reactor, and chromium and iron found on the membrane surface confirmed that corrosion occurred. Powder-coating the reactor surface resolved this issue.

A laboratory study was conducted for LBWD by University of New Hampshire (UNH) on E. coli and total coliforms subjected to UV irradiation (**appendix B**). The study showed that, under laboratory conditions, 60 mJ/cm^2 was the maximum

intensity needed to produce no measurable colonies (6 log reduction). Thus, operating the UV reactor between 40–146.4 mJ/cm^2 should be sufficient to achieve this goal. However, mHPC data shows that the UV did not effectively inactivate the microbes (**table 3.4**). One possible explanation for the ineffectiveness of UV is that the wavelength applied was not effective for inactivating the seawater marine microbes.

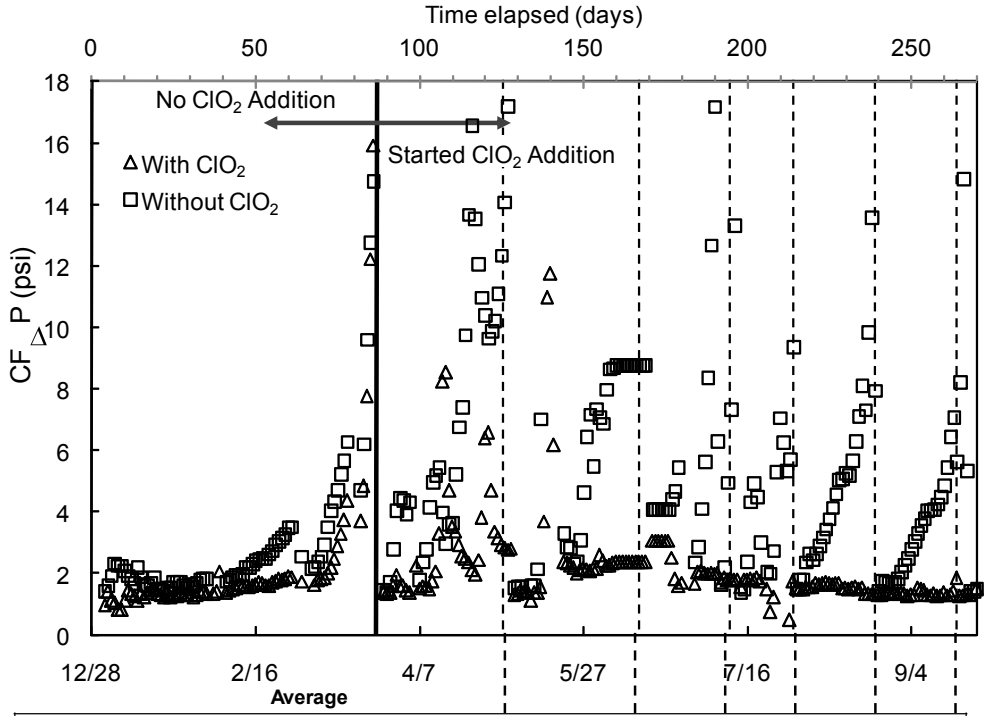
Table 3.4. mHPC data results with UV disinfection

Date	Raw	Post CF (cfu/100 mL)	Post UV (cfu/100 mL)
10/15/08	7.10E+03	5.90E+03	<20
11/5/08	1.26E+04	1.10E+04	1.48E+03
11/12/08	9.79E+04	4.45E+04	2.00E+03
11/19/08	1.50E+03	1.56E+03	1.00E+02
12/8/08	3.00E+03	9.00E+02	2.50E+01
5/13/09	1.45E+03	5.05E+02	1.58E+02
5/21/09	5.00E+03	7.25E+02	1.58E+02
5/27/09	4.28E+03	8.37E+02	3.80E+02

3.4.4 Chlorine Dioxide

Although literature suggests that ClO_2 may be effective for membrane biofouling control, the body of literature is not extensive. To determine the effectiveness of using ClO_2 for biofouling control, differential pressure (ΔP) at the cartridge filters for trains with and without ClO_2 exposure was monitored. The ΔP for the train exposed to ClO_2 remained low at around 2 psi, while the ΔP increased to approximately (~)13.5 psi after an average of 31 days in the train without ClO_2 addition (**figure 3.22**). Above a ΔP of 14 psi, the cartridge filters were replaced based on the manufacturer's recommendation. The lowered ΔP at the train with ClO_2 addition shows that ClO_2 was effective in preventing biofouling.

A short-term test was conducted to determine the effectiveness of ClO_2 application on limiting headloss buildup on the cartridge filters. The test was performed over 1 week, and the data are presented in **figure 3.23**. At day 0, ClO_2 feed was switched from the north train to the south train, which resulted in an increase in the ΔP at the north train, while the south train ΔP decreased. The ClO_2 injection was reversed for the two trains on day 4, and it was shown that the ΔP increased for the side without ClO_2 (south train) and decreased for the side with applied ClO_2 (north train).



	Average						
Differential pressure (psi)	**13.5**	17.2	17.2	9.35	9.83	14.8	12.2
Head loss (ft)	**5.67**	7.25	7.25	3.95	4.15	6.26	5.15
Time elapsed (days)	**31.2**	38	61	22	22	26	18

Note: Head loss was calculated using the following equation: ΔP (psi) = Head loss (feet) x SG x 2.311, where $SG_{seawater}$ = 1.025.

Figure 3.29. CF performance for trains with and without ClO_2.

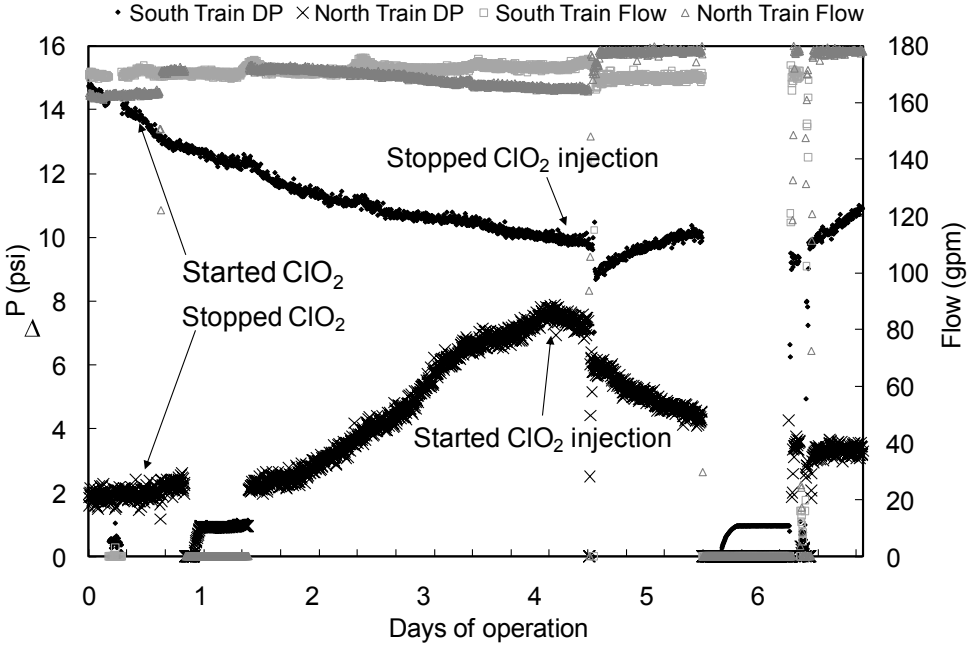


Figure 3.30. CF short test results.

The high ionic strength and high bromide concentrations in seawater interfered with ClO_2 residual measurements in seawater. Bromide reacts with chlorine to produce hypobromous acid, as shown in equation 3.6, and can cause false reading of free chlorine in the analytical tests.

$$Br^- + HOCl \rightarrow HOBr + Cl^- \quad (3.6)$$

The presence of bromide in the feed water is also significant because bromamines can be generated in the presence of chloramines as a disinfectant as shown in equation 3.7. Secondly, the reactivity of bromamines may cause significant damage to polyamide membranes.

$$Br^- + NH_2Cl \rightarrow NH_2Br + Cl^- \quad (3.7)$$

When ClO_2 was injected into seawater, approximately 80 percent of the ClO_2 was converted to chlorite, while the remaining 20 percent was converted into other compounds. These compounds were found to potentially cause membrane degradation, which resulted water quality deterioration (**figure 3.24**).

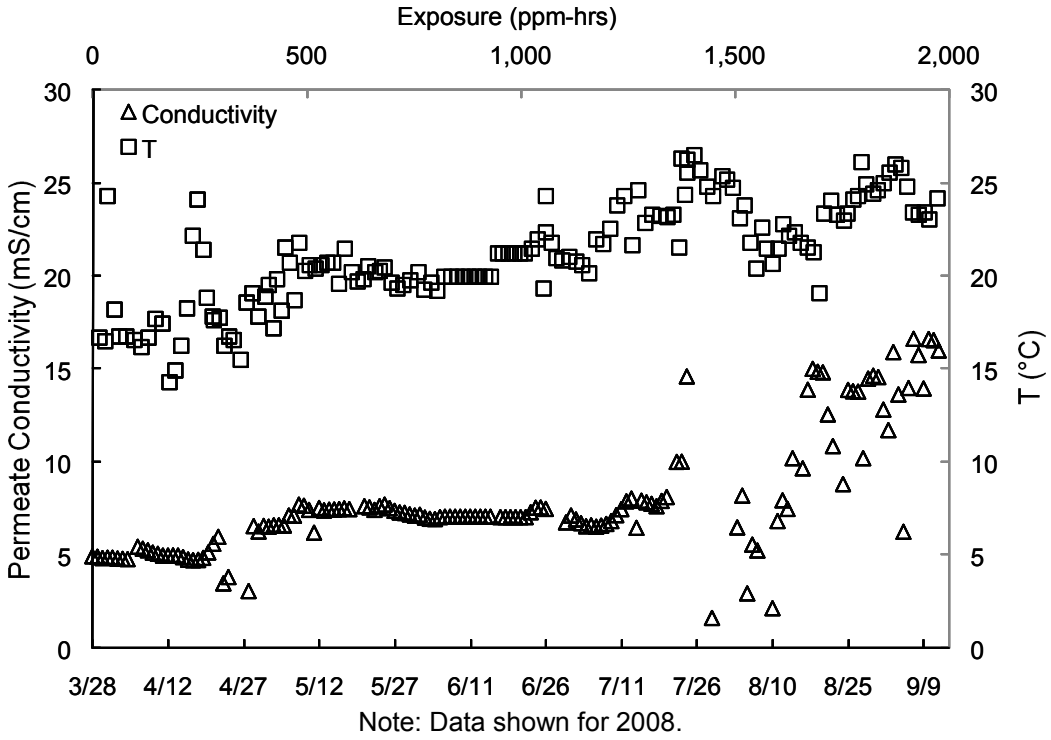


Figure 3.31. Permeate water quality for train exposed to ClO_2.

A chlorite addition test was performed on the NF90 membranes using two flat membrane test cells to verify if chlorite, instead of ClO_2, was responsible for biofouling prevention or membrane degradation. Two sheets of NF90 membranes were loaded into two parallel flat sheet testers; sodium chlorite ($NaClO_2$) was used as the chlorite source and added to the MF permeate on one side, and the

other side was fed with only MF permeate as the control (**figure 3.25**). Flux and salt rejection data are shown in **figure 3.26**, and a flux decline of up to 26 percent was witnessed for the duration of the experiment (400 hours), with a corresponding 4-percent increase in salt rejection. Based on the short-term test results, chlorite had no effect on biofouling prevention because the flux decline was observed with or without chlorite, and chlorite did not degrade PA membranes as evidenced by a constant salt rejection. Any potential membrane degradation may be caused by the other compounds generated from the reaction between ClO_2 and seawater.

3.4.5 UV Versus ClO2 Versus 4-inch Element, Two-Pass NF Mobile Unit

A 4-inch element, two-pass NF mobile unit (mobile unit) was used to compare UV to ClO_2 treatment because the Prototype test conditions were frequently changed to test various membranes and disinfection strategies. NF90 membranes were used initially for the parallel trains and the mobile unit. Pass 1 was operated under the operating pressure at 550 psi; the operating characteristics for the trains are shown in appendix A2.

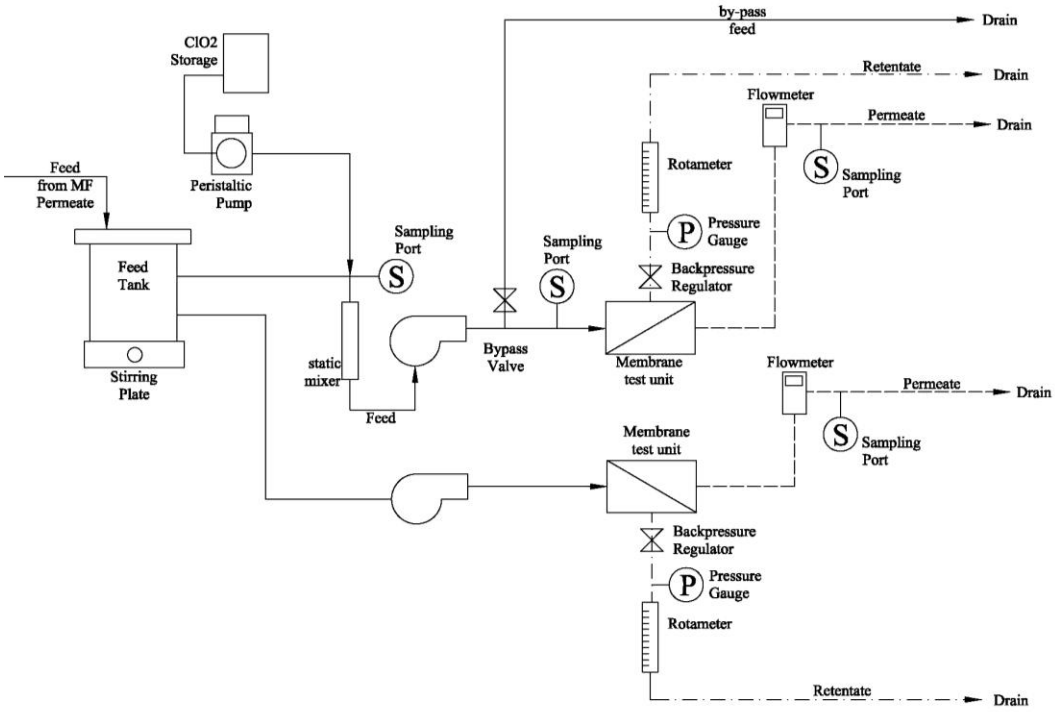
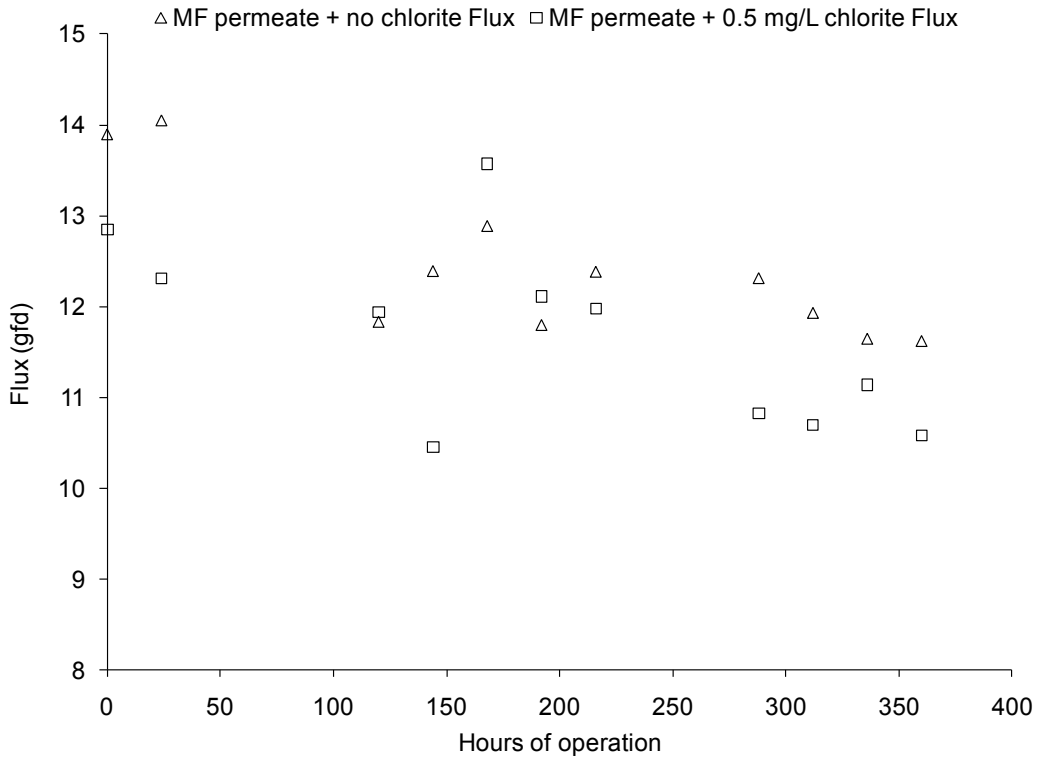
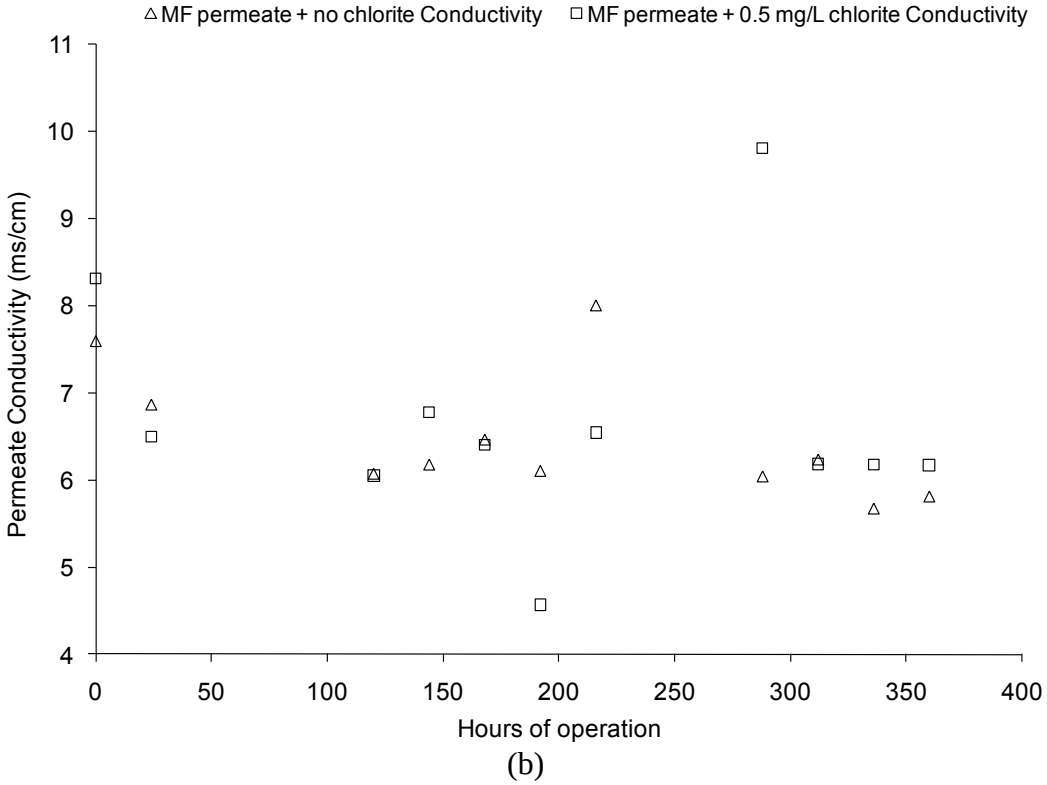


Figure 3.32. Schematic of parallel flat sheet testers.



(a)



(b)

Figure 3.33. Permeate flux and salt rejection data from chlorite test.

Based on the Prototype flux data, both north train (ClO_2) and south train (UV) achieved similar flux after stabilization, as indicated by region 1 (R1) in **figure 3.27**. Changes in membrane configuration and pretreatment methods for the trains are shown by the vertical lines on the figure. After the membrane configuration was changed (shown by the vertical lines on the figure), the flux started high and slowly stabilized again for both trains, as indicated by region 2 (R2). The flux for the two parallel trains, along with the mobile unit, stabilized and remained at around 5 gfd in this region, which suggests that there was little benefit to using UV or ClO_2 under the conditions experienced during the test.

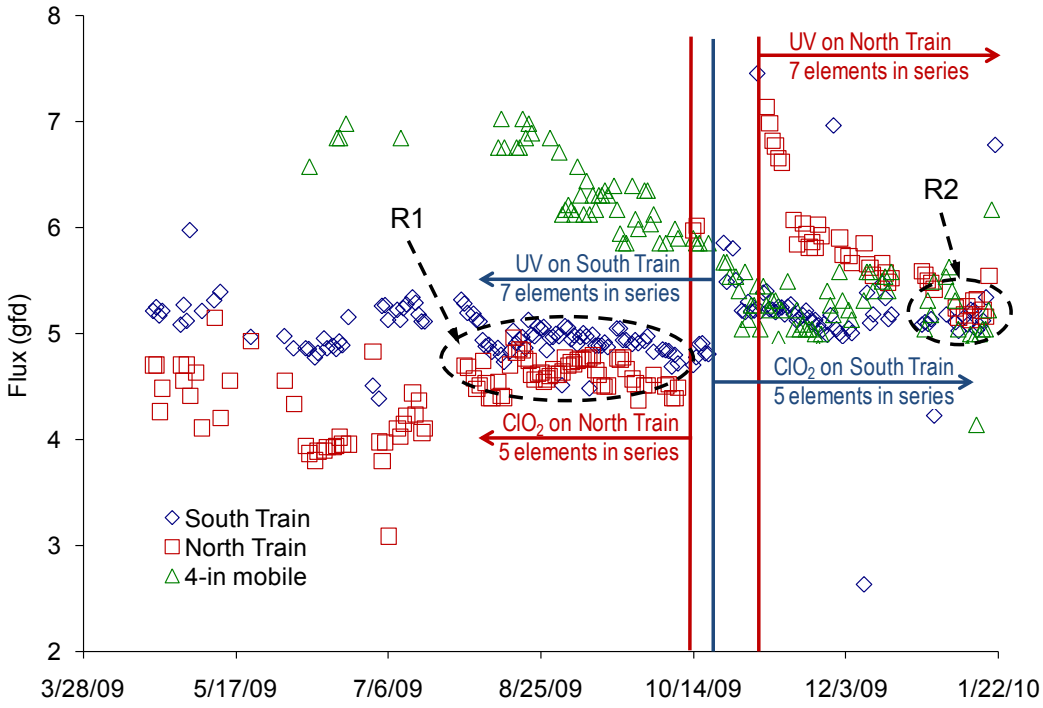


Figure 3.34. Flux performance for three parallel trains.

The train initially exposed to the ClO_2 (north train) experienced a sudden increase in salt rejection (**figure 3.28**, indicated by the light red box) during September–October 2009. This increase was due to membrane replacement where NF90 membranes were replaced with NE90 (Woongjin Chemicals). The membranes were changed back to NF90 membranes at the end of October, and the salt rejection decreased to previous levels. The salt rejection was almost parallel for the three methods except for a period when membrane degradation was experienced (August–September 2009). This indicates that the water quality experienced at this location during this time period did not require additional pretreatment beyond the MF process.

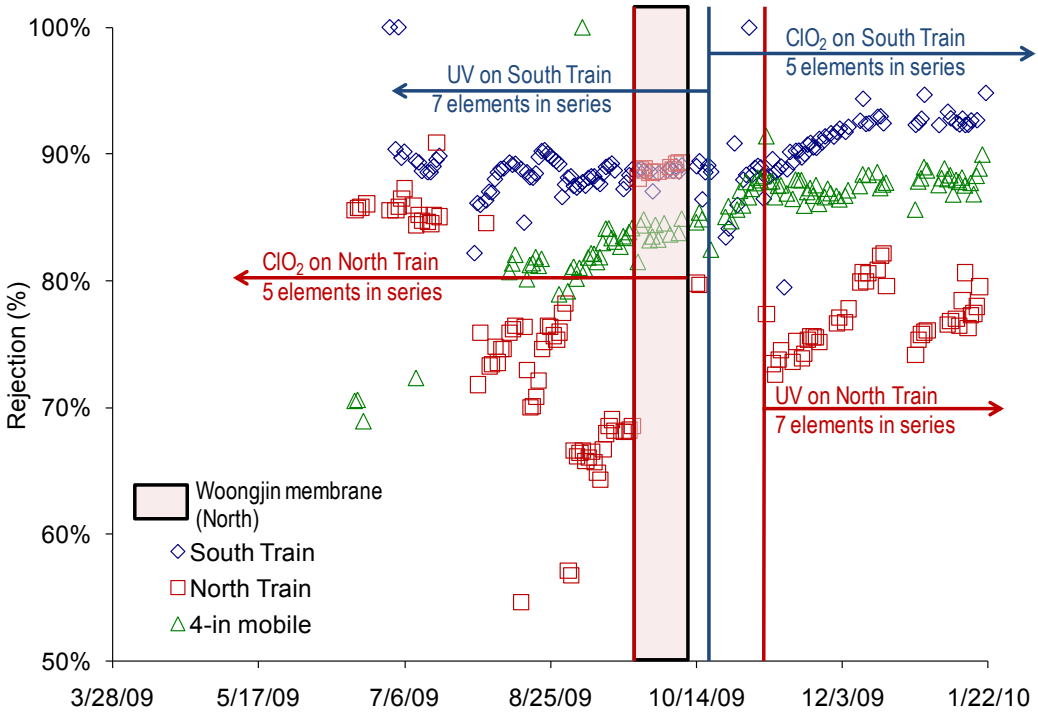


Figure 3.35. Salt rejection for three parallel trains.

Differential pressure (ΔP) data were similar for UV and ClO_2 tests until the end of test 1 in July 2009, when the ΔP increased due to change in membrane configuration (**figure 3.29**). No ΔP data are presented for the mobile unit because the instrumentation was unable to register the small changes in ΔP observed. The changes in membrane configurations are explained in **table 3.6**.

Based on the TDS rejection, flux, and ΔP data, it was concluded that there was minimal membrane fouling. Membrane autopsy and water quality analyses, however, showed signs of membrane fouling. Water quality analysis showed that some microbes were present in the membrane feed water after UV irradiation, and membrane autopsy results showed deposition on the membrane surface. This deposition can be considered part of the membrane fouling, but it was not significant enough to cause change in the operating data.

3.4.6 Pretreatment Processes Summary

Two different pretreatment methods were tested on the MF permeate at the Prototype. The first pretreatment tested was UV irradiation (UVTrojan) after MF and CF. Depending on feed water UVT, the UV reactor was operated between 40–146.4 mJ/cm^2 according to the manufacturer's calibration tests. The second pretreatment method tested was with ClO_2 into the membrane feed water at a residual of 0.5 ppm of ClO_2. The 4-inch element mobile unit was used to represent a conventional MF pretreatment and served as the control. There were no major differences observed in plant performance data between the two pretreatments strategies and the control tested.

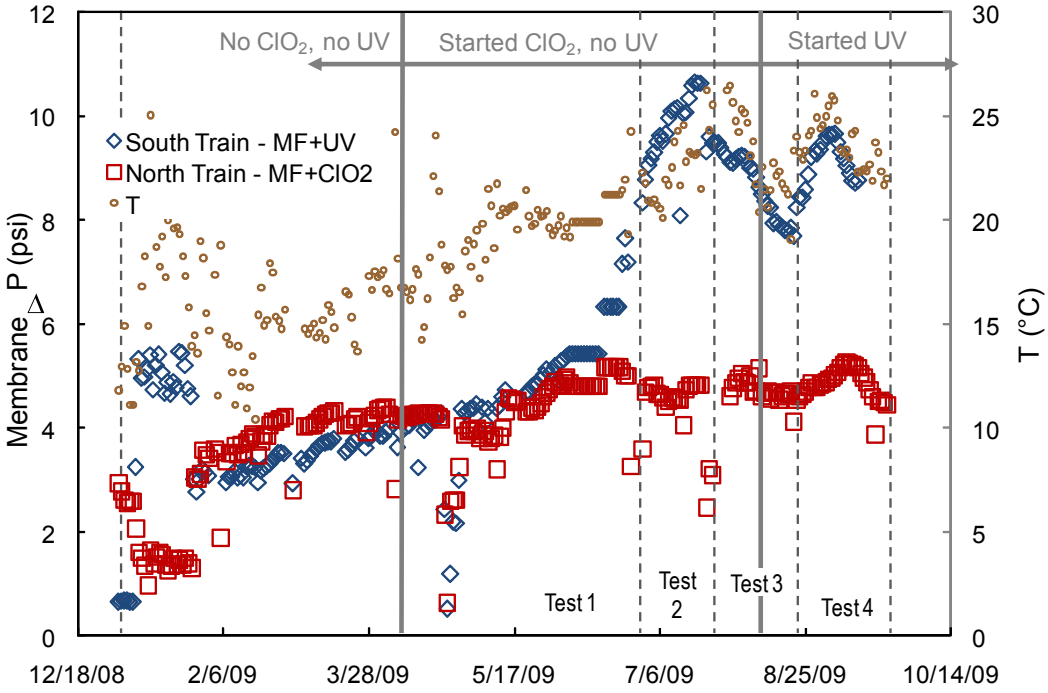


Figure 3.36. ΔP for Prototype. See table 3.5 for test description.

Table 3.5. Membrane configuration changes as shown in figure 3.29

Test Number	Start Date	End Date	Train	Configuration
Test 1	1/30/09	6/23/09	South	NF90 x 5
			North	NF90 x 7
Test 2	6/30/09	7/20/09	South	ULP(NE400) x 2 + NF90 x 5
			North	NF90 x 7
Test 3	7/22/09	8/20/09	South	ULP(NE400) x 1 + NF90 x 6
			North	NF90 x 7
Test 4	8/21/09	9/18/09	South	NF90 x 5 + ULP (NE400) x 2
			North	NF90 x 7

At a dosage between 40–146.4 mJ/cm^2, the UV process should have inactivated most of the microbes in the sample because literature suggest that 60 mJ/cm^2 is the maximum intensity needed to inactivate microbes. The mHPC data show that UV did not effectively inactivate the microbes. However, the degree of fouling experienced was not enough to cause a change in plant performance.

ClO_2 proved to be an effective biofouling prevention method. However, when added to seawater, ClO_2 can create intermediary compounds that may cause membrane degradation. It is suggested to move with caution when using chlorine dioxide in seawater desalination using polyamide membrane.

3.5 Chemical Usage

3.5.1 Offsite Cleaning – Commercial Cleaning

The membranes from the Prototype, consisting of NF90 and SWC3+ membranes, were removed after 2 years of operation and sent for cleaning using a commercial cleaning service (Siemens Water Technologies, Warrendale, Pennsylvania). The following is the cleaning procedure performed by Siemens:

- Deionized (DI) water was recirculated through the elements to eliminate large particulate matter on the membranes or in the spacers.
- Hot, softened water (43–49 ºC) with a high pH (10.5–11) (Avista P111, Avista Technologies, San Marcos, California) was circulated through the elements for 2 hours
- Hot, softened water (43–49 ºC) with a low pH (2.5–3.5) (Avista L403, Avista Technologies, San Marcos, California) was circulated through the elements for 2 hours.

A report from the commercial cleaning service is shown in **table 3.6**. This report indicated that the cleaning caused an expected slight decrease in salt rejection. The cleaning process may have removed some fouling material from the membrane surface, which contributed to better salt rejection.

Table 3.6. Precleaning and postcleaning membrane salt rejection

	Salt Rejection	
Serial number	**Precleaning**	**Postcleaning**
254	97.6%	96.0%
270	97.4%	97.0%
249	97.1%	96.5%
211	97.4%	96.8%
174	97.1%	96.1%
183	97.6%	96.8%
219	97.4%	95.9%
Average	**97.4%**	**96.4%**

3.5.2 Scale Inhibitor

Scanning electron microscopic (SEM) images were taken of the south train (NF^2) pass 1 lag elements (**figure 3.30**). The lag elements were selected because scaling condition is the worst due to the membrane exposure to the high salt concentration. Even after 2 years of operation without adding antiscalant, little

scaling was observed on the lag elements. For comparison, **figure 3.31** shows images of membrane scaling (Tzotzi et al., 2007). These results verified that antiscalant was not necessary to prevent scaling at the Prototype.

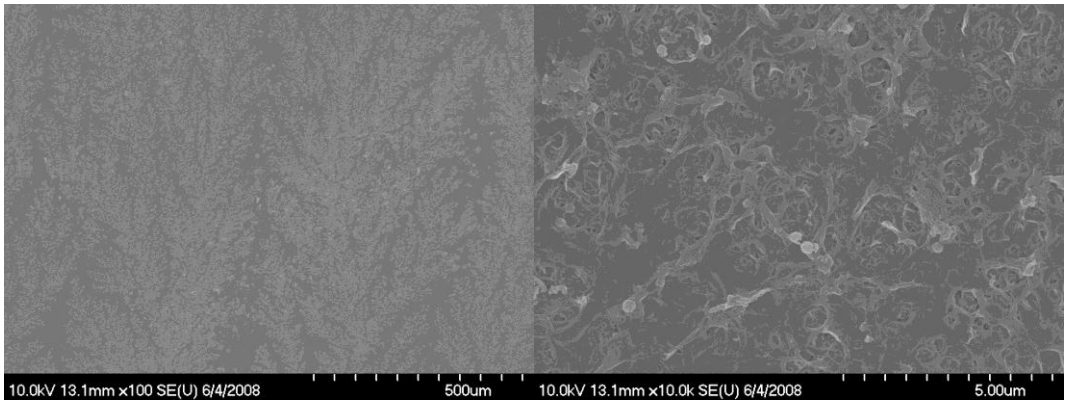


Figure 3.37. SEM images for lag element of south train pass 1, stage 2.

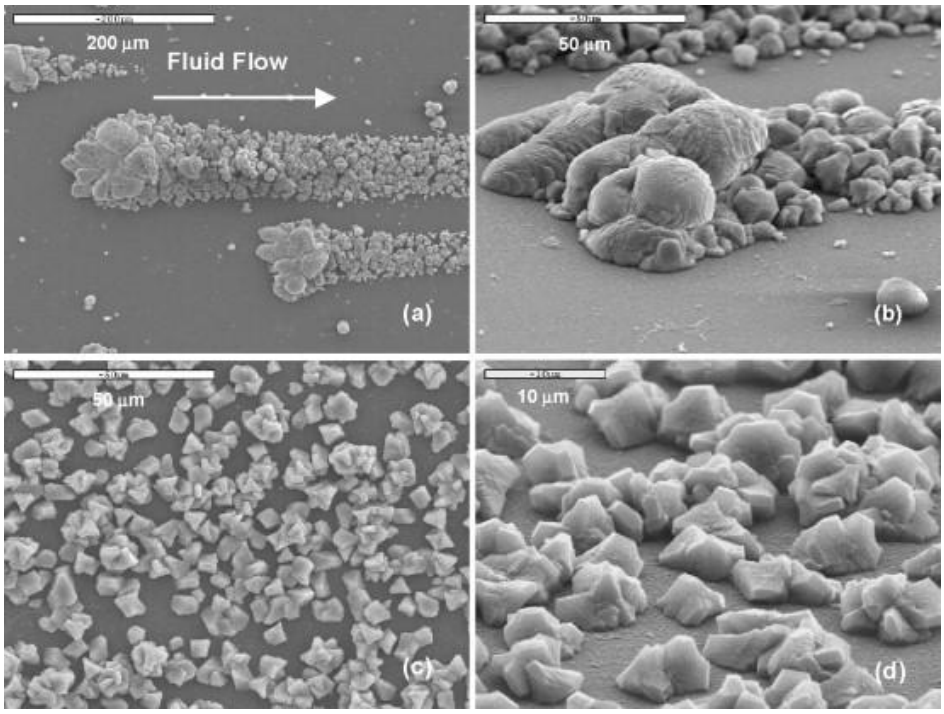


Figure 3.38. SEM micrographs of a scaled TFC-S membrane at low supersaturation level (Tzotzi et al., 2007).

3.5.3 Chemical Usage Summary

Commercial cleaning shows neither major improvement nor degradation in salt rejection. Not including scale inhibitor into the treatment process did not increase membrane surface scaling. This shows that chemical use may be reduced for future planning.

3.6 NF^2 Optimization Test

3.6.1 Background

One major objective of the Prototype research specified in the test plan is optimization of the NF^2 process. Discussions in section 3.2.3 showed that pass 1 of the two-pass system had a greater impact on the overall specific energy consumption. Therefore, optimization tests in the Prototype were focused on pass 1. Tests were performed to compare different element staging (five versus seven elements in series). The goal of this test was to quantify the effects of water quality, permeate production, and specific energy consumption between the two configurations, so that the best element configuration staging can be used in a full-scale plant

An effort was made to maintain the same membrane surface area when the configurations were changed. Tests conducted with seven elements in series used a surface area of 19,600 ft^2 (based on 400 ft^2 surface area for each element, and seven elements long by seven vessels) and tests conducted with five elements in series used a surface area of 20,000 ft^2 (5 elements long by 10 vessels). Based on earlier model analysis, concentration polarization (CP) caused the osmotic pressure at the fifth element to be higher than the applied feed pressure (Trussell et al., 2009), which would result in little or no flux after the fifth element. The modeling results suggest that arranging the vessels to operate with five or less elements in series may increase the overall recovery, which leads to lowered energy consumption.

Because the Prototype vessels can only hold a maximum of five elements in series, the last two elements of the seven-element tests were placed in a second stage, as described in the process description. With this configuration, the CP experienced in the fifth element is disrupted between the stages (**figure 3.32**), so water production may still occur after the fifth element.

Another optimization test conducted was the use of mixed membranes to minimize specific energy consumption in pass 1. The primary membranes used for the NF^2 process in the Prototype is NF90 (Dow Chemical FilmTec NF-90). Two other types of membranes tested included ultralow pressure membrane (ULP) (FilmTec XLE-400) and NE90 membrane (Woongjin Chemical). NE90 is very similar to NF 90 membrane, but the ULP membrane has more surface area, higher flux, and higher rejection (**table 2.2**). By arranging the membranes to

make the best use of their characteristics, further specific energy consumption optimization may be achieved while maintaining comparable permeate water quality.

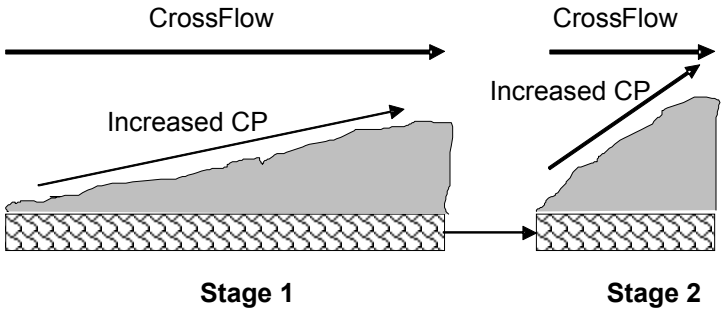


Figure 3.39. Concentration polarization effect on the membrane with five elements in stage 1 and two elements in stage 2.

Membrane configuration modeling was performed to better narrow the tests conducted at the Prototype (Trussell et al., 2009). The model, written in Microsoft Excel, modeled each membrane element separately. Inputs into this model included phenomenological coefficients, such as mass transfer and diffusion coefficients, which were obtained from manufacturers' information and pilot-scale experimental data. Using these inputs, the model calculated the permeate and brine concentrations, flows, and the associated pressures and power. The resulting water quality and power required for each scenario were summarized, compared, and subsequently ranked.

The ranking evaluation was based on striking a balance between lowered specific energy consumption and produced water quality. From this evaluation, the result showed that placing a membrane with higher rejection as the lead element (ULP), followed by a membrane with higher flux and lower rejection (NF), yields better specific energy consumption than by using all NF membranes in series. Based on the modeling results, different mixed membrane configurations were tested, including 2 ULP + 5 NF90 (two ULP followed by five NF90), 5 NF90 + 2 ULP (five NF90 followed by two ULP) (**table 3.7**). Water quality and energy consumption were compared based on each test conducted at the same condition for at least 2 weeks. Although it had little impact on the test results, it is important to note that different biofouling control methods were applied to the trains at the same time when the different membrane configurations were changed.

Table 3.7. Mixed membrane test conditions

Pretreatment Methods	Train	Pass 1 Configuration	Feed Flow, (gpm)	1st Pass Operating Pressure (psi)	Run, days	Temper-ature (°C)
40-146 mJ/cm^2 UV irradiation	South	2 ULP + 5 NF90	182	555	17.8	19.1
		1 ULP + 6 NF90	182	555	25.5	21.1
		5 NF90+ 2 ULP	180	555	34.5	21.2
	North	1 ULP + 4 NF90	152	536	23.0	16.9
		2 ULP + 3 NF90	166	551	15.0	14.5
No UV or ClO_2	South	5 NF90 (NF 5)	175	543	91.0	17.0
	North	7 NF90 (NF 7)	176	550	91.0	17.0
0.5 mg/L ClO_2	South	1 ULP + 6 NF90	179	555	63.0	15.7
	North	7 NF90	182	556	59.2	20.7
	North	7 NE90	176	550	8.8	20.5

Note: "2 ULP + 5 NF90" indicates two ULP membranes used as the lead elements and followed by five NF90 membranes. Same convention applies to the other configurations.

3.6.2 Water Quality

A TDS limit of 500 mg/L (secondary MCL as set by USEPA [USEPA, 1996]) was used as acceptable limit for the tests. All tests conducted with the five and seven elements in series and the mixed membrane tests resulted in permeate water quality that met the TDS criterion **(figure 3.33).** In most cases, the permeate TDS was similar to typical drinking water TDS levels found in LBWD's distribution system. The only significant TDS difference observed was when ClO_2 was applied. A slight increase in TDS was observed, which may be caused by ClO_2 byproducts reacting with the PA membranes.

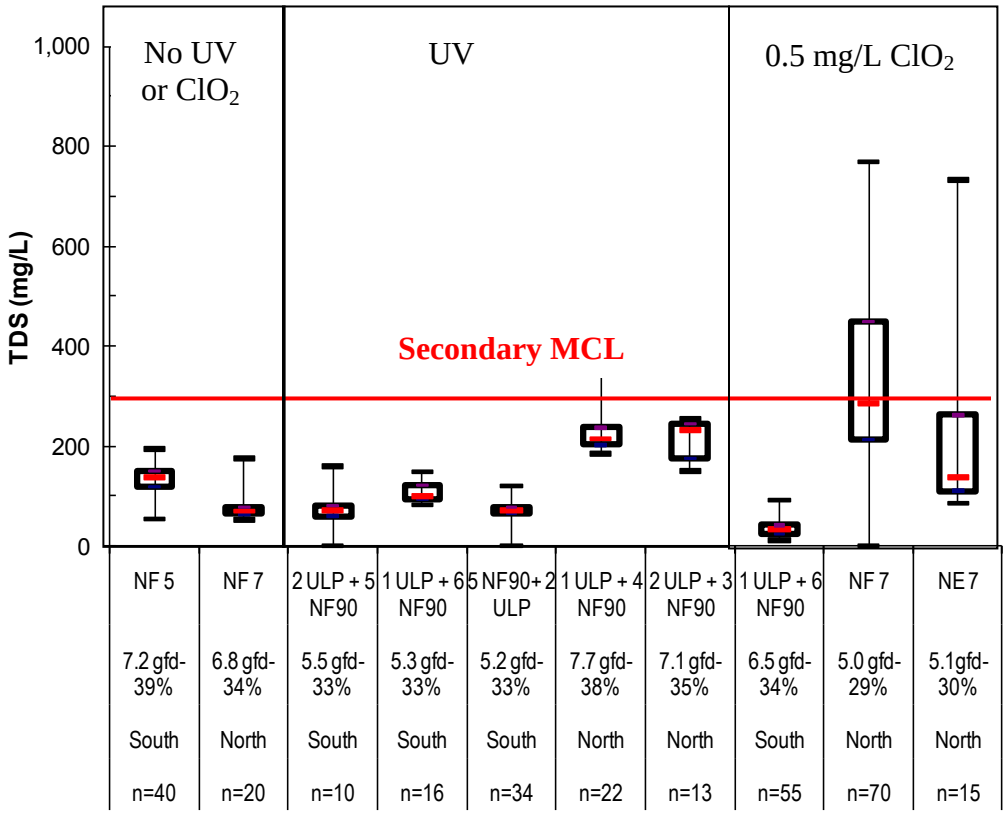
3.6.3 Energy Consumption

The specific energy consumption obtained from tests conducted comparing the five- and seven-element configurations showed that the seven-element configuration yielded slightly lower energy; however, the difference was not significant (**figure 3.34**). Contrary to the model prediction, specific energy with five elements in series did not result in lower energy than seven elements, which is possible because the two-stage arrangement of the seven elements disrupted the concentration polarization predicted by the model. Based on these results, subsequent tests were primarily conducted with seven elements in series.

The mixed membrane tests showed that placing more ULP membranes as the lead elements reduced energy consumption, as compared to placing ULP as the lag elements (**figure 3.34**). Energy consumption was the lowest when placing two ULP membranes at the lead end under all conditions tested under UV addition (**figure 3.34**). Similarly, placing one ULP membrane at the lead end reduced specific energy compared to all NF membranes when ClO_2 was applied

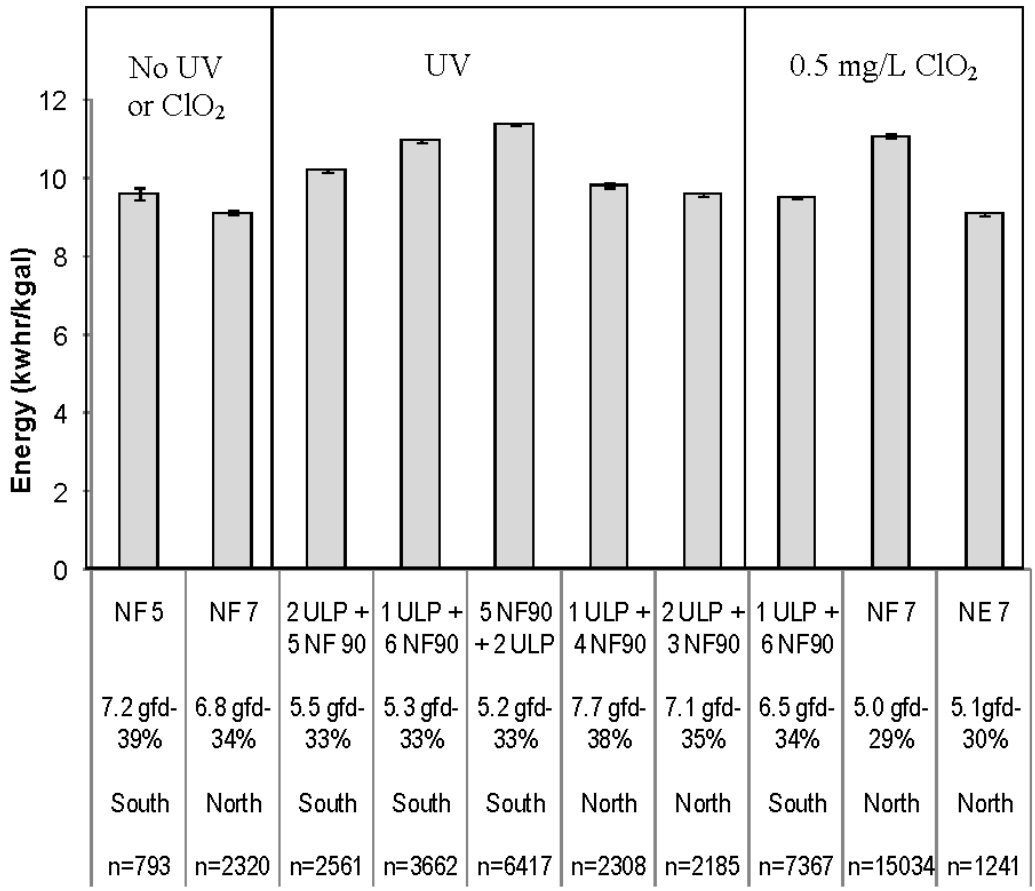
(**figure 3.34**). Although many parameters were changed in the tests, it was shown that the tests conducted with two ULP elements in the lead position yielded lower specific energy consumption than the single ULP element, which was better than the two ULP elements placed in the lag position. The results confirmed the initial modeling results (Trussell et al., 2009), which showed that more ULP in the lead position reduced energy consumption.

Although NF 7 with no UV/ClO_2 and NE 7 with ClO_2 had the lowest overall energy consumption, these results did not confirm that seven elements in series were better than five elements in series, or NE90 membranes were better than NF90. Many variables encountered by the different membrane configurations could contribute to the energy consumption difference, including different biofouling control methods and test durations.



Note: TDS was calculated with conductivity instead of chloride in this graph because limited chloride data were collected for some configurations; n indicates number of data points

Figure 3.40. Pass 2 permeate TDS with different mixed membranes.



Note: x axis indicates flux and recovery at the P1, error bars indicate 95-percentile confidence interval; n indicates number of data points

Figure 3.41. Overall energy consumption with NF 5 versus NF 7.

3.6.4 NF2 Optimization Summary

All membrane configurations tested for the NF^2 process produced comparable permeate water quality and resulted in similar TDS as compared to what was observed in LBWD's distribution system. Based on the test results, it did not appear that the specific energy consumption values were significantly different between the five-element and seven-element configurations. Tests conducted with mixing membranes showed that placing more ULP membranes on the lead end of the vessel resulted in lowered energy consumption as compared to placement on the lag end. The test results verified the modeling results, which showed that adding ULP in combination with the NF membranes resulted in lowered specific energy consumption as compared to using only NF membranes.

3.7 Operational Considerations

Although the design and operational testing program at the Prototype were developed by industry experts, many lessons were learned during the construction and operational phases of this project. This section will discuss design and operational problems encountered and provide solutions to address these problems in the future.

3.7.1 Source water and intake system

The intake pump station for the Prototype received its water from LADWP Haynes Generation Station (Haynes) cooling unit number 1 (**figure 3.35**). Although LADWP was a partner in this project, operations related to electrical generation superseded the Prototype operations. Many water supply disruptions were experienced as a result of LADWP performing various maintenance operations for electrical operations. The disruptions varied in duration and lasted from 10 minutes to over 1 month. These disruptions can be categorized as follows:

- Short term (10 minutes to 1 hour) – Short duration shutdowns are a result of LADWP performing their scheduled backflush at night. In this procedure, LADWP closes the gate valve at the discharge channel, turns off one circulating pump and forces the water to flush in a loop. As a result, the circulator discharge pressure drops; and, depending on the tide level, the loss in pressure causes the intake pump to lose suction and shut down. If suction is not recovered in a timely manner, the Prototype would shut down due to loss in feed water. One solution to prevent these occurrences is to coordinate more closely with the LADWP staff.

- Medium term (2 hours to 2 days) – Medium duration shutdowns are typically related to the LADWP staff performing maintenance on the cooling water pipeline. The most typical maintenance is "heat treatment," which aids in the detachment of shellfish that has colonized the cooling system pipeline. The Prototype intake pipeline has experienced shellfish attachment (**figure 3.36**), and the Prototype takes advantage of the scheduled heat treatment maintenance. It is noted that it may require up to 2 weeks after performing the heat treatment for the shellfish to dislodge. Careful monitoring of the intake strainer is required during this period because the shells and shell fragments may clog or pass through the strainer and interrupt operations.

- Long term (3 days to 1 month) – Long duration shutdowns are related to major repairs on the circulators and cooling system. The repairs range from repairing or replacing the circulator motors to spot welding the cooling tubes for the generator. These repairs require the circulators to be shut down and forces the Prototype operations to be halted until the powerplant resume operations.

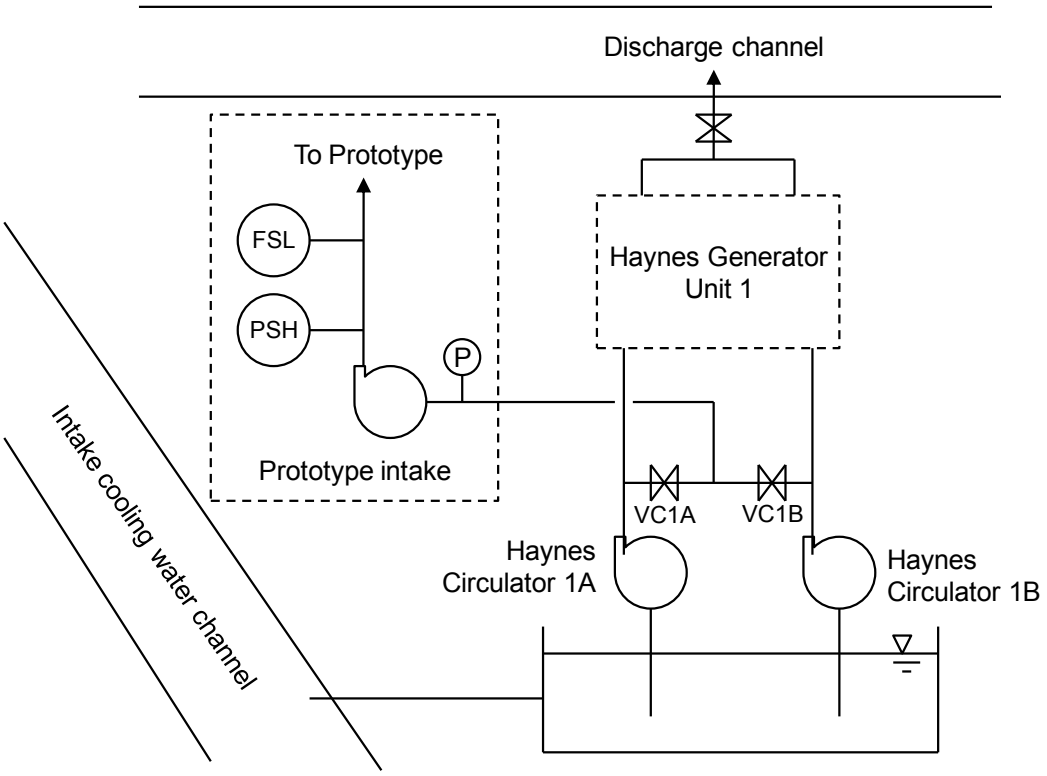


Figure 3.42. Schematic of seawater diversion for Prototype intake station.

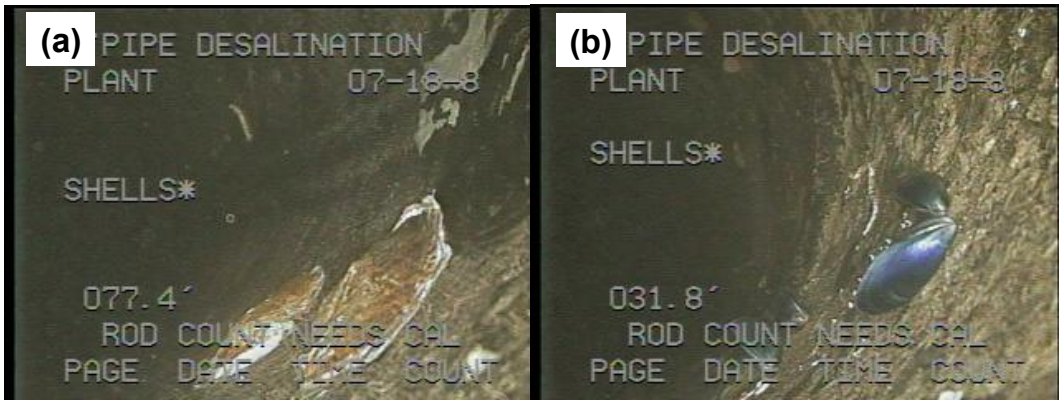


Figure 3.43. Video inspection of Prototype intake pipeline (attachment of shellfish in pipeline after 1 year of operations).

The disruptions are a function of being co-located with a powerplant and not unique to this project. Although there are some advantages to co-location, powerplant operations have priority, and shutdowns can occur without significant notification. Therefore, it is important to fully understand the details of daily powerplant operations and maintenance planning to minimize down time when these supply disruptions occur.

An intake that is not co-located with a powerplant would provide better control over seawater desalination plant operations. In a separate study, LBWD is investigating a subsurface intake system to address the issues of sustainable yield and the environmental issues of entrainment and impingement. After 1 year of operations, video inspection of the pumps and pipeline shows no signs of shellfish while maintaining design yield (**figure 3.37**). This type of intake system would be a good alternative to provide the ability to avoid supply disruptions, in addition to addressing the issues mentioned above.

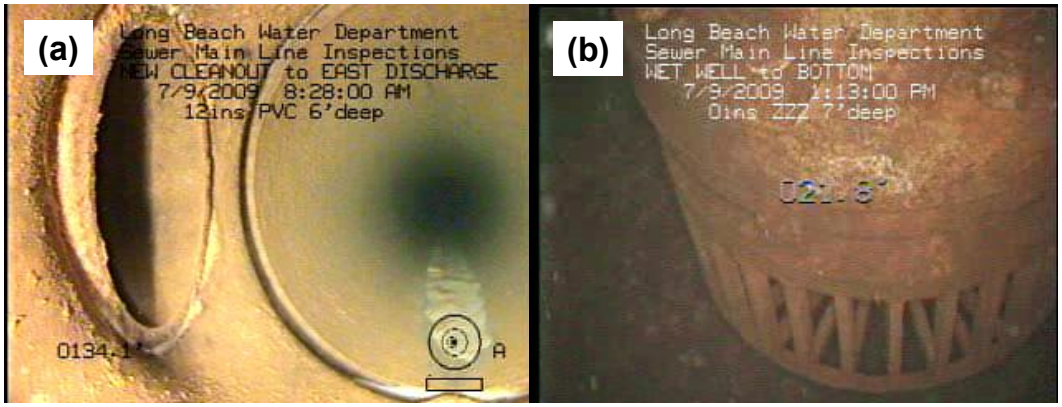


Figure 3.44. Video inspection of subsurface intake system (no attachment of shellfish in pipeline after 1 year of operations).

3.7.2 Microfiltration System

The MF system was a standard Pall MF system composed of high-strength, oxidant-resistant PVDF membranes operating in an outside to inside configuration. The MF system operates in a recirculation mode, where up to 10 percent of the flow is directed back to the suction side of the MF feed pump (**figure 2.2**). However, excess recirculation water sometimes contains residual air, possibly from the air scour cleaning process, which can cause the MF feed pump to air-bind. When this occurs, the amount of air is normally minimal, and the supply pressure is able to push the air through the pump without causing major damage to the MF feed pump. However, there were occasions when the pump was not able to discharge the air out of the system, which would cause the feed pump to fail.

To overcome this, an air-relief line was installed on the pump discharge to help get rid of minor air buildup. However, there were some instances when the air carryover from the backwash sequence was so severe that this was not sufficient. The long-term solution was to move the excess recirculation to the MF feed tank, which allowed the trapped air to vent to atmosphere in the tank. This dramatically improved the stability of the MF system, and this design configuration should be considered for improved operational stability for plants intending to use pressurized MF systems as pretreatment.

3.7.3 Coating

Due to the corrosive nature of the seawater, nonmetallic materials should be used where possible. However, it may be necessary to use metallic piping for various reasons. Although standard stainless steel material (304L or 316) will provide better corrosion resistance than steel pipe, it still can corrode quickly in this environment (**figure 3.38a**). One possible mitigation measure is to use a functional powder coating, such as Dupont Nap-Gard®, to protect the interior of the pipe (**figure 3.38b**), which is used in the oil and gas industry. The coatings were employed at the Prototype and after 3 years, the coating was still intact and corrosion on the 304L piping mitigated.

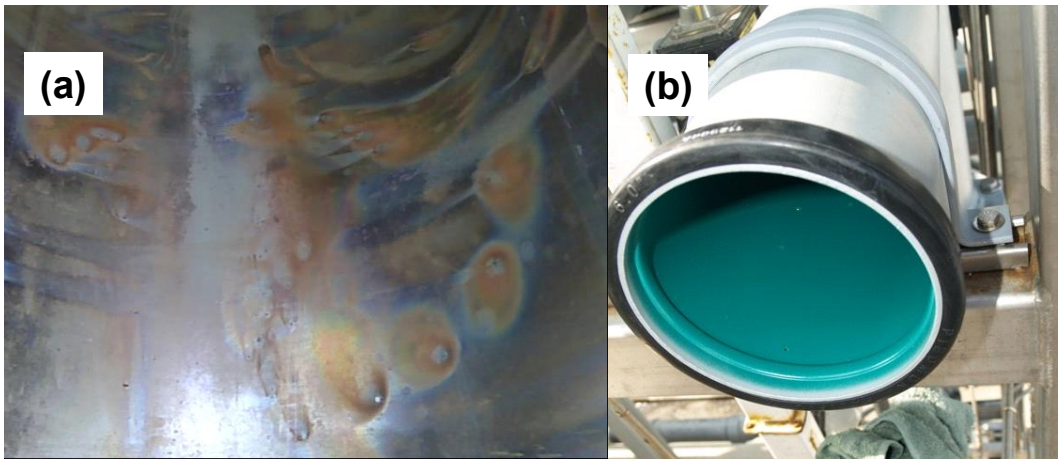


Figure 3.45. (a) Pin holes developing in 304L pipe after 6 months of operation. (b) A marine powder coating applied to 304L piping for corrosion protection.

3.7.4 Super Duplex Stainless Steel

Given the corrosive nature of seawater and the high operating pressures for the desalting membrane system, a special super duplex steel called “Zeron 100” (Zeron) was used in the high-pressure membrane system piping. Although Zeron provided great corrosion resistance, this alloy presented the following challenges:

- Super duplex stainless steel has the appearance of other stainless steels, especially after electro-polishing (**figure 3.39**). Unfortunately, some lower-grade stainless (316SS) were mixed in during the membrane system fabrication and was not detected during the Prototype construction inspection. Over time, the threads in the stainless threadolet corroded and became a safety hazard because the pipe is under high pressure and the components threaded into the threadolet may not be safely held in place. One way that this type of construction oversight can be avoided is to perform x-ray fluorescence (XRF) inspection of the pipe, welds and welded components. The XRF elemental analysis can be performed at the jobsite using a handheld analyzer during construction inspection, providing assurance against this type of mistake.

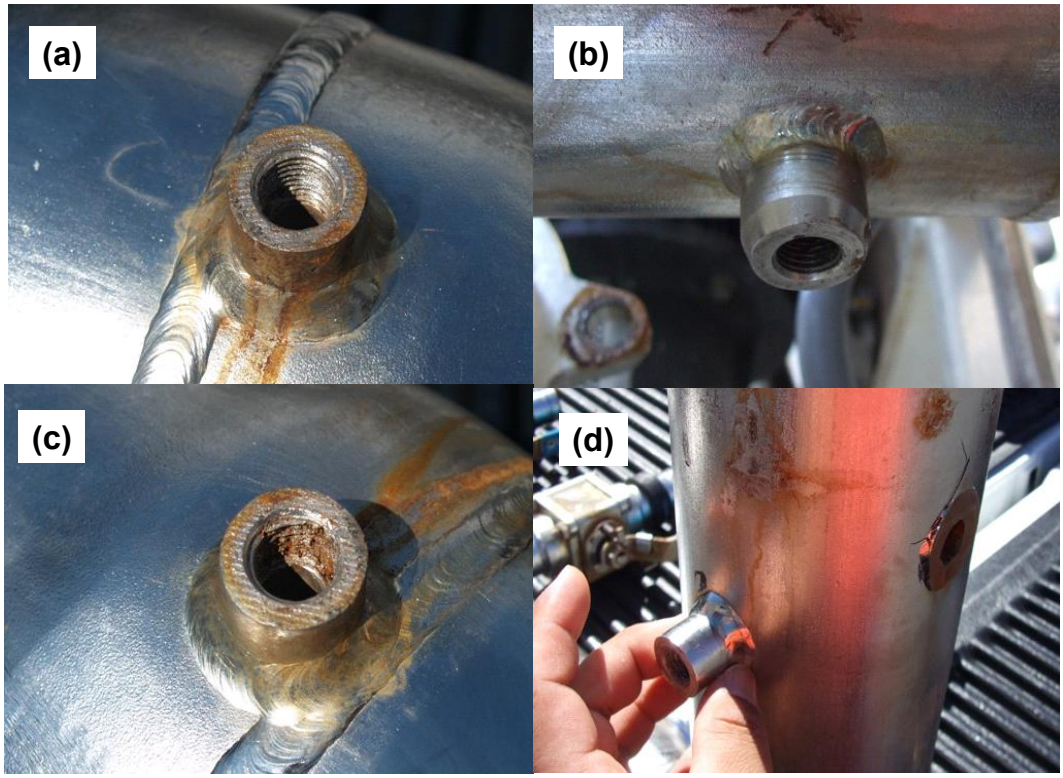


Figure 3.46. 316 stainless steel threadolet. (b) Super duplex (Zeron 100) threadolet. (c) Threads corroded away on the 316 threadolet. (d) Wire - Electrical discharge machining is used to properly remove the threadolet.

- Super duplex is classified as a "stainless steel," but it has a higher electrode potential than the more common 316 stainless steel. Although piping can be made using super duplex stainless steel, not all fittings (plugs and compression fittings) can be obtained in this exotic alloy. When a 316 fitting is inserted into a super duplex threadolet, a galvanic couple will cause the lower potential metal to corrode. The threaded parts are vulnerable to crevice corrosion and accelerate the materials degradation on the lower potential metal (**figure 3.40**).

Due to the nature of seawater desalination, it may not be possible to completely eliminate corrosion, but some steps may help decrease the effects. For example, some fittings may be fabricated from raw super duplex stock material, such as plugs. This is the best alternative because materials are at the same potential. Super duplex stainless has high chromium and molybdenum content, and using industrially available 6-percent molybdenum fitting can narrow the electrode potential and reduce the rate of galvanic corrosion. It is important to use higher potential material on the main manifold, which forces corrosion on the lower-potential fittings and may be more easily replaced. The above suggestions, coupled with a proactive routine inspection and replacement of fittings, will reduce the chance of catastrophic failure and injuries.

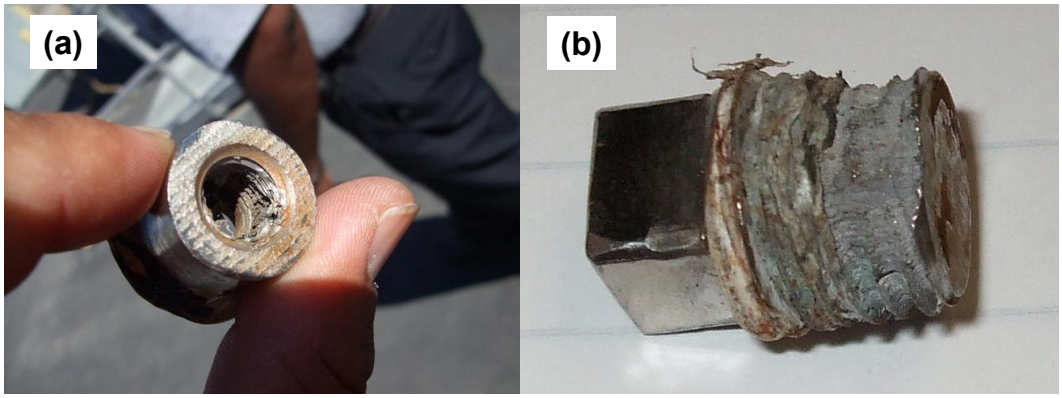


Figure 3.47. (a) 316 stainless steel threadolet where the threads have corroded. (b) Corroded 316 stainless steel plug.

3.7.5 Flow Switches

Flow switches are common mechanical devices to protect motors and pumps. A paddle or vane-style flow switch uses the force exerted on the paddle when it is inserted in a flowing fluid to actuate an electric switch. When flow impinges upon the flow switch paddle, the paddle swings and moves the magnet keeper away from the magnet on the inside of the switch body. This type of flow switch is ideal because the electrical components are encased inside the switch body and not exposed to the seawater. To maximize sensitivity, these switches use a ferritic stainless keeper (series 400 stainless steel), which can quickly corrode in the presence of seawater (**figure 3.41**). To mitigate this issue, the keeper can be manufactured from 316 stainless steel, encasing an iron plate. Therefore, it is important that the specifications explicitly require 316 stainless steel keeper rather than stainless steel flow switch during the purchasing procedure.

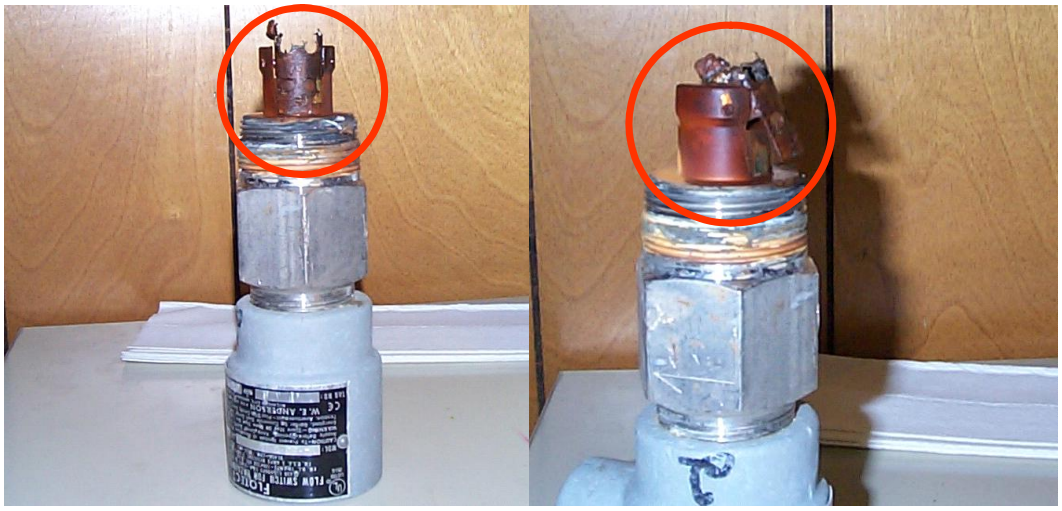


Figure 3.48. A magnetic paddle type flow switch with a corroded stainless keeper.

3.7.6 Operational Considerations Summary

The operation of a seawater desalination plant requires rigorous fabrication quality control, constant coordination with project partners (in the case of co-locating with a powerplant), and a diligent maintenance program. Exotic materials have long lead times for replacement parts; thus, it is prudent to have many of the exotic replacement parts on hand. The operating environment is corrosive, and small problems can quickly become big problems. By staying proactive and anticipating these problems, some of the problems may be mitigated, and the operations of these advanced facilities can be maintained.

3.8 Permitting

Although the construction of the Prototype started in early 2004, the permitting process for this project was initiated in 2002. The permits related to the construction and operations of the Prototype facility can be broken into four major categories:

1. Endangered Species
2. Costal Land Use
3. Waterway Use
4. Regulations

Several agencies are responsible for enforcing various aspects under each issue, and each agency required either an application for a full permit or, if adequately demonstrated, for a permit exemption. **Table 3.8** lists the agencies of concern for each of these categories and are discussed in detail below.

Table 3.8. List of permitting agencies

Issue	Permitting Agency
Endangered Species	Fish and Wildlife Service
	National Marine Fisheries Service
	California Department of Fish and Game
Costal Land Use	State Lands Commission
	California Coastal Commission
	Local Planning and Building
Waterway Use	Mineral Management Service
	U.S. Army Corp of Engineers
	Coast Guard
Regulation	U.S. Environmental Protection Agency
	Air Quality Management District
	Regional Water Control Board
	California Department of Public Health

3.8.1 Permitting Overview

This section will provide an overview of the various agencies involved in issuing construction and operating permits for the Prototype.

3.8.1.1 Endangered Species

- Fish and Wildlife Service (FWS)
    - Federal Endangered Species Act – required LBWD to consult with the FWS for list of potential species and habitats on landward portions of the project (Section 7) and submit a permit for incidental "take" of listed species and habitats (Section 10(a)). An exemption was obtained from the National Marine Fisheries Service because the Prototype used LADWP's existing intake system and was classified as temporary.
- Marine Mammal Protection Act – requires an Incidental Harassment Authorization for incidental "take" of marine mammals in Federal Waters. An exemption was granted for compliance with this act because the Prototype used LADWP's existing intake system and this facility was classified as temporary.
- California Department of Fish and Game
- California Endangered Species Act – requires a permit for incidental "take' of State listed endangered species and habitats (Section 2081) and submit a Notification, Lake or Streambed Alteration Agreement (Section 1602) for landward, coastal zone, and State waters. An exemption was granted for compliance with this act because the Prototype used LADWP's existing intake system, and this facility was classified as temporary.

3.8.1.2 Coastal Land Use

- State Lands Commission (SLC)
    - SLC grants land use leases for activities in navigable and tidal waters up to 3 nautical miles from shore ("sovereign lands"). SLC have granted certain local city government the legislative authority to grants land use leases. For land leases in the Long Beach area, the SLC granted the Long Beach City Planning and Building Department the authority to grant the lease with the option to review; and, in this case, no further review was deemed necessary by these agencies.
- California Coastal Commission (CCC)
    - California Coastal Act – the CCC governs land uses in the Coastal Zone and also has the authority to review land use consistency in Federal Waters under the Coastal Zone Management Act. The CCC can authorize local planning and building departments to issue coastal land use permits through the certified Local Costal Program. The City

of Long Beach Planning and Building Department is authorized to issue costal land use permits on behalf of CCC.

- Local Planning and Building Department
    - The local planning and building department issues construction permits and issues land use permits to cities with the certified Local Coastal Program. LBWD obtained the construction permit and a conditional coastal land use permit in the coastal zone from the City of Long Beach Planning and Building Department. The CCC did not appeal the issuance of the land use permit.

3.8.1.3 Waterway Use

- Bureau of Ocean Energy Management (formerly Minerals Management Service)
    - Outer Continental Shelf Lands Act – Bureau of Ocean Energy Management was authorized to issue lease and right-of-way grants on submerged lands within the U.S. Exclusive Economic Zone (3–200 nautical miles). LBWD obtained an exemption from the Bureau of Ocean Energy Management based on the location of the Prototype.
- Army Corps of Engineers (Corps)
    - Clean Water Act (Section 404) – the Corps is responsible for oversight of discharge of dredge or fill material into jurisdictional waters of the United States and prohibits obstructions to navigable Federal waters (Rivers and Harbors Act (Section 10)). Although the Prototype discharges into the San Gabriel River, which is deemed a navigable waterway, LBWD avoided the need for a permit by not disposing dredge or fill material into the San Gabriel River; instead, LBWD used LADWP's intake and discharge structure.
- Coast Guard
    - Marine Safety Manual – the Coast Guard is entrusted with the safety of navigation in State and Federal Waters. LBWD avoided the need for a permit by using LADWP's Intake and Discharge structure.

3.8.1.4 Regulation

- U.S. Environmental Protection Agency
    - USEPA is authorized under the National Environmental Policy Act to assess a project's environmental impact and State and Local agencies have the authority to request supplemental information under California Environmental Quality Act. LBWD submitted and was granted a categorical exclusion to the environmental impact statement through negative declaration because the Prototype was a temporary research facility. However, a full-scale facility was required to submit a complete environmental impact report.

- Air Quality Management District (AQMD)
    - AQMD was established by USEPA under the Clean Air Act to limits criteria pollutant emissions a distance of 3–25 nautical miles of the project. The Prototype was exempt because it did not create criteria pollutants.
- Regional Water Quality Control Board (RWQCB)
    - The RWQCB was established by USEPA under the Clean Water Act, issues National Pollutant Discharge Elimination System (NPDES) permits (Section 402), and can impose additional regulatory requirements (Section 403) for ocean discharge of brine from desalination process. LBWD was required to submit a full NPDES permit application. Details of the NPDES permit are discussed in the next section.
- California Department of Public Health
    - The Safe Drinking Water Act authorizes USEPA to establish minimum standards for safe drinking water, and CDPH is the primacy agency in California tasked with issuing the domestic water supply permit and enforcement. CDPH may deem the source water as an Impaired Water Source (97-005) and require more stringent standards for treatment requirements. The Prototype did not serve the desalinated waters to its customers, which allowed LBWD to be exempt from amending its water supply permit. However, the data obtained during the research operations will be shared with CDPH to assist in establishing appropriate treatment requirements in the future.

3.8.2 Special Focus on NPDES Permit

The Clean Water Act requires point source dischargers to control the types and concentrations of pollutants discharged into the water through effluent limitations and other requirements established in the NPDES permit. The effluent limits are designed to establish water quality criteria to protect beneficial use.

For the Prototype, the regulated pollutants are based on constituents that are regulated in the Los Angeles Region Basin Plan or the California Toxic Rule and were detected or expected to be present due to physical and/or chemical treatment at the facility. Because the Prototype discharges into the San Gabriel River, discharge limits are established under the "Bays and Estuaries Plan," which is much more stringent than the Ocean Plan. For example, copper discharge concentration at the Prototype was limited to 3.7 μg/L, as compared to 50 μg/L as allowed in the Ocean Plan. Based on the experience at the Prototype, several noteworthy considerations should be kept in mind for any future full-scale facility design and operations.

1. In general, effluent limits are established based on mass loading, which ensures that proper treatment is used and that dilution is not employed to

comply with final effluent concentration limits. It may be prudent to investigate potential pollutants of concern and that proper treatment is included to address these pollutants during the site selection phase. For example, copper in the raw seawater averaged 2.8 μg/L. If the desalination process operated at 50-percent recovery, then the resultant copper discharge concentration will be approximately 5.6 μg/L, which violates the maximum daily loading limit for copper discharge. Therefore, proper treatment must be included to reduce the copper discharge concentrations and must be considered in the design phase.

2. Metal analysis can be difficult due to the high salt content in the brine solution. Typical, an inductively coupled plasma with mass spectrometer detector is used for metal analysis. However, the high chloride concentration in the brine can create a chloride-chloride complex that may be analyzed as other pollutants, such as selenium. If this is not corrected, erroneously high results may be reported in the self-monitoring report. Thus, laboratory personnel assigned to analyze and report self-monitoring report results must be aware of this analytical nuance that is atypical for drinking waters.

3.8.3 Permitting Summary

The variety of permits required is very site specific. Although exemptions or waivers were obtained for many permits for the construction and operation of the Prototype, these permits will be required for a full-scale facility. Many of the permits require public comment, which will increase the lead time and require advance planning. Finally, given the number of agencies involved and the overlap of jurisdiction, it is important to systematically go through issues of concern to capture all potentially applicable permits.

4. Cost Analysis

4.1 Initial Assumptions

Cost is an important consideration in implementing a new technology, and the operational data obtained from the Prototype tests were used to perform the cost analyses. Costs associated with producing desalinated water can be calculated through two methods, either cost curves developed based on historical information or through the use of specific cost models with location-specific parameters. LBWD used both methods in making cost comparisons between the NF^2 process and RO for this project.

The advantage of using cost curves is that the estimates can be generated quickly. The limitation of this method of cost estimation is that the information provided may not be sufficiently accurate if site conditions are not similar to the conditions used for the cost curves. Examples of available curves for desalinated seawater includes the Reclamation Desalting Handbook (Watson et al. 2003) or the Cost Estimating Manual (McGivney and Kawamura, 2008). The cost capacity curves can provide estimates for the average construction cost based on specified capacity and treatment process. These curves also can be used to generate process piping, pumping, and any other items associated with building a new facility.

Cost models may be a more accurate method of providing cost estimates and, depending on the level of details incorporated into the model, may require significantly more time to generate the estimates. The LBWD used a cost model provided by the Reclamation-NF^2 cost model (Affordable Desalination Collaboration [ADC], 2009) to predict a more accurate cost associated with a full-scale desalination facility.

Generally, a cost model that uses more detailed, site-specific information should provide a more accurate estimate. Additionally, performance data collected from actual testing representative of the full-scale operations was used wherever available in the cost model. If site-specific performance information is not available, industry-established standards should be used. In this cost analysis, performance data used were based on actual data generated from the LBWD Prototype. Other information used in the model (ADC, 2009) included industry-established standards, and a short list of these assumptions is shown below (**table 4.1**). The value used for electricity is the current price per kWh paid in the Long Beach area. Based on the pilot performance data and assumptions shown, capital, operations and maintenance (nonenergy) and energy requirements can be generated from the NF^2 cost model.

Table 4.1. Selected assumptions used in the model (ADC, 2009)1

Unit Costs			
Chlorine	$	1.20	/lb
Sodium bisulfite	$	0.30	/lb
Base (lime)	$	0.05	/lb
Carbon dioxide	$	0.04	/lb
Power	$	0.12	/kWh
Cartridge Filters	$	20.00	ea
Membranes	$	550.00	ea
RO Vessels	$	8,547.00	ea
MF membrane	$	1,500.00	ea
High-pressure pump	$	372.00	/hp
	$	0.79	/kWh/day

1 /lb = per pound; ea = each

The performance data used in the NF^2 cost model were based on the optimal tests selected from numerous testing scenarios conducted over three years of operation. The three criteria used in determining the optimal test scenarios included highest overall system recovery, lowest specific energy (kWh/kgal), and highest flux (gfd). These criteria directly relate to the lowest capital cost, lowest energy cost, and the lowest overall cost, respectively. Higher recovery and flux may reduce capital cost through reducing the equipment and plant size requirements. Lower specific energy requirements translate to lower energy and product water costs. The optimal testing scenarios were selected for the single-pass RO, two-pass RONF, and NF^2 processes. **Table 4.2** shows the conditions used in classifying the optimal testing scenario for the two pass RONF and the NF^2 processes. For the two-pass RONF system, Scenario 1 yielded the lowest recovery, lowest specific energy, and highest flux, so capital and energy cost should be lowest with this scenario. For the NF^2 process, Scenario 2 resulted in the highest recovery, while Scenario 3 resulted in the highest flux. Therefore, these two scenarios should result in the lowest capital cost.

Figure 4.1 shows the cost analysis results for a 50-mgd plant with the above scenarios. Consistent with the prediction, scenario 1 in two-pass RO NF produced the lowest capital and energy cost numbers. For the two-pass NF^2 process, scenario 1, which had the lowest specific energy, also resulted in the lowest energy cost. The capital cost associated with all three scenarios was similar, with scenario 2 slightly higher even though it had the highest overall recovery.

Table 4.2. Test conditions used in cost analysis

	Two-Pass RO NF				NF					
	Scenario 1		Scenario 2		Scenario 1		Scenario 2		Scenario 3	
	Pass 1	Pass 2	Pass 1	Pass 2	Pass 1	Pass 2	Pass 1	Pass 2	Pass 1	Pass 2
Flux, gfd	6.91	15.89	5.41	11.47	6.65	19.55	6.29	15.35	7.05	15.17
Recovery (%)	42%	82%	35%	75%	46%	75%	45%	78%	44%	80%
Overall recovery (%)	34%		27%		38%		41%		39%	
Energy (kWh/kgal)	9.3	1.7	9.8	1.3	6.6	1.6	7.0	2.2	7.4	2.3
Optimization parameter	Capital, energy				Energy		Capital		Capital	

Note: The energy numbers shown above (kWh/kgal) are for the desalting process only, the energy numbers for raw pumping cost have been accounted for in a separate section of the NF^2 cost model and are site specific.

From the optimal conditions defined above, baseline capacities were assumed to be 50 and 5 mgd (**figure 4.1), respectively**. The two plant sizes were selected to provide a range of capacity that varied by an order of magnitude and represented reference points for a large system and a small system (a facility of approximately 5 mgd is being used for LBWD's projection). Baseline project life was assumed to be 30 years, the cost of power was $0.12/kWh, the interest rate for the money borrowed for the project was 5 percent, and the membrane life was 6.5 years.

4.2 Cost Analyses and Results

Capital, operations and maintenance (non-energy), and energy costs generated from the NF^2 cost model are shown in **figures 4.1 and 4.2** for 50- and 5-mgd plants, respectively. Although single-pass RO was not able to consistently meet a boron target of less than 1.0 mg/L, cost analyses are presented here for additional information only. To achieve equivalent water quality targets, a two-pass system, RO-NF or NF^2, is needed. The overall cost of the NF^2 process was consistently lower than RO-NF based on the analyses performed. The results from the NF^2 cost model confirmed that an economy-of-scale factor exists with larger facilities. Depending on the treatment selected, the average cost of product water for a 5-mgd facility was 53 to 78 percent more than a 50-mgd facility.

Among the three major cost components, capital and nonenergy O&M costs were higher for a 5-mgd plant, while energy O&M cost was the same for both sizes (**figures 4.1 and 4.2**). Several factors contributed to the higher capital and nonenergy costs for the smaller facility:

- Reduction factors, based on historical data, were used to calculate the 5-mgd costs from the 50-mgd costs. Although there is a 10-fold decrease in scaling down from 50 to 5 mgd, the reduction factors did not decrease proportionally. The reduction factors provided in the model ranged from 20–44 percent, depending on the component (e.g., yard piping, site work, etc.); this disproportional reduction in cost factors contributed to the increased product water cost for the smaller-scale plant.

- Permitting was assumed to cost $10 million in the cost model and was independent of plant size. For a 5-mgd plant, permitting cost accounted for 15 percent of the overall capital cost, but only 3 percent for a 50-mgd plant.

- The contributions for the membrane replacements, solid disposal, maintenance, labor and chemical cost, to the cost of produced water was higher for the 5-mgd facility as compared to the 50-mgd plant. This is premised on historical data. In the case of labor, a minimum number of staff is necessary to operate the facility, but this number of staff does not increase proportionally based on the flow rate.

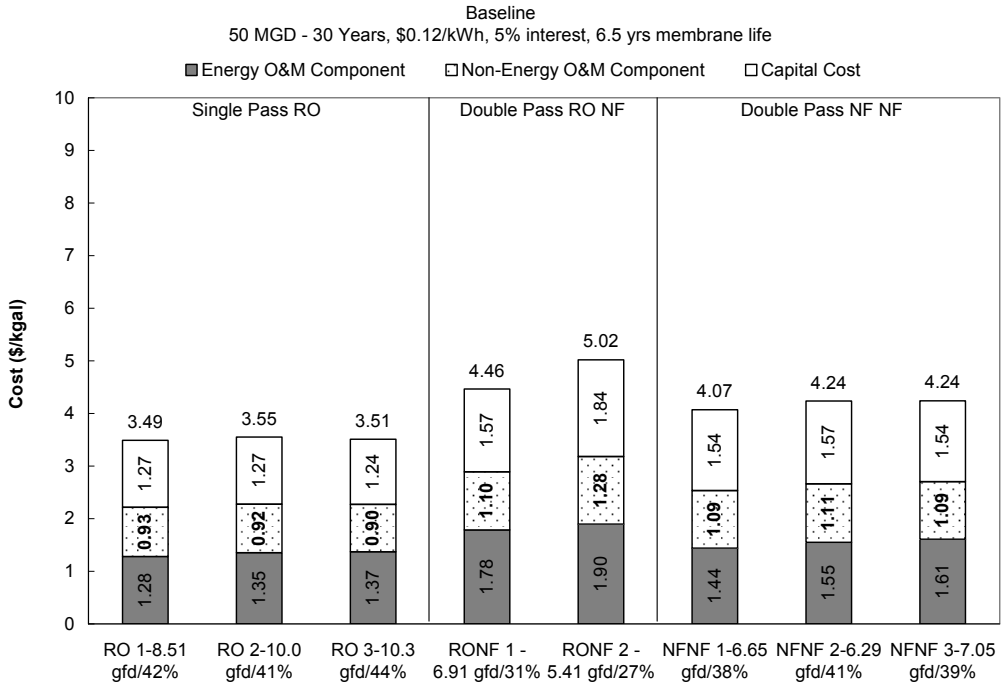


Figure 4.1. Baseline condition for 50-mgd NF^2 cost model.

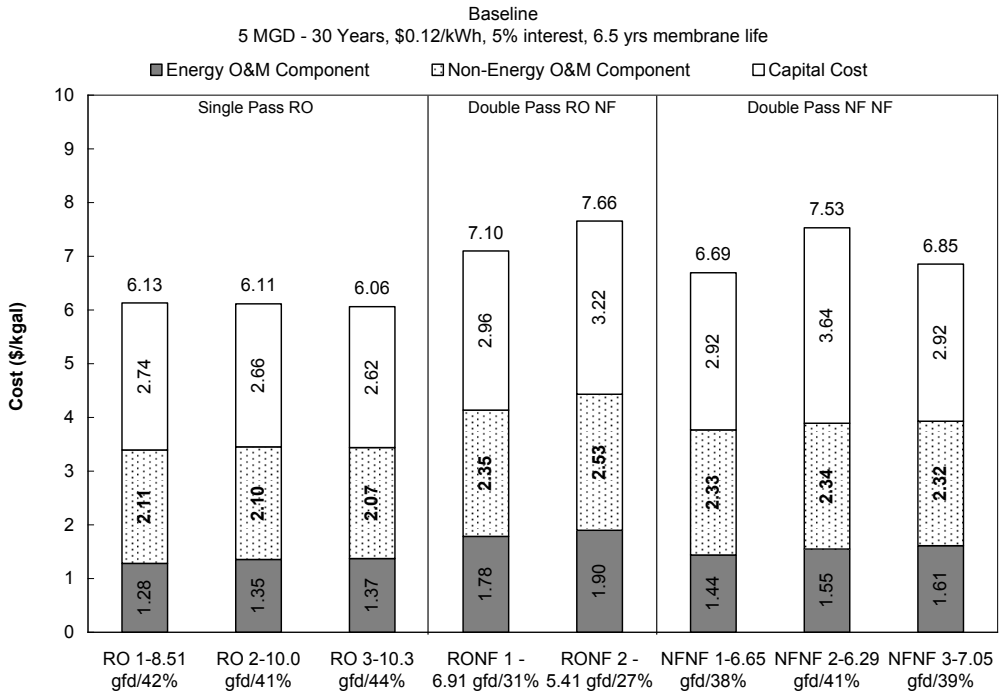


Figure 4.2. Baseline condition for 5-mgd NF^2 cost model.

The cost components were compared against estimates in Reclamation's Desalination and Water Purification Technology Road Map (Road Map) as a verification of the accuracy of the estimates. There is a lack of large United States-based seawater desalination facilities, and this document is arguably the most accurate source of desalination cost information that provides a compilation of survey information from around the world. According to the Road Map, the total cost is made up of energy (44 percent), capital (37 percent), and nonenergy (19 percent) components. Our analyses, as presented in **figure 4.3,** show a similar breakdown as shown in the Road Map. This provided a point of data verification that the analysis was accurate.

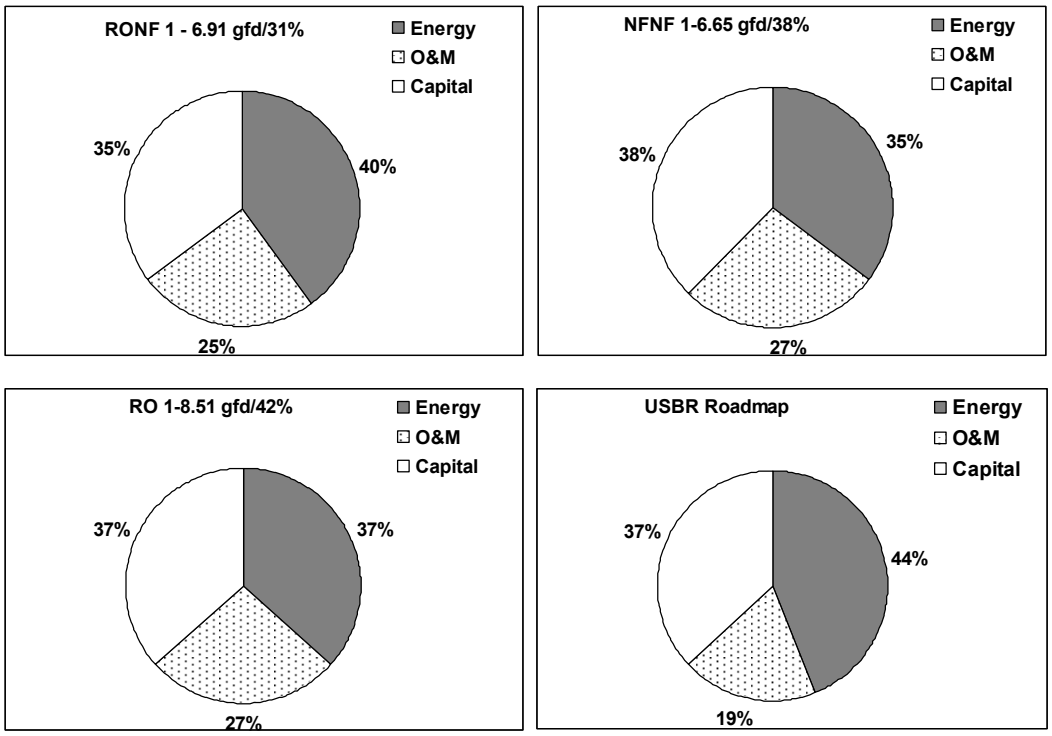


Figure 4.3. Comparison of cost components from baseline data and Reclamation's Road Map.

Sensitivity analysis is a commonly used tool to verify the cost dependence on various parameters. Many parameters can be used to generate various scenarios for sensitivity analysis. The following factors were identified from the cost component analysis as to provide the most meaningful information for planning purposes (**table 4.3**).

Table 4.3. Variables used for sensitivity analysis

Variable Changed	Effect
Project Life Decrease (25 years)	Capital cost
Interest Increase (6%)	Capital cost
Interest Decrease (4%)	Capital cost
Membrane Life Increase (10 years)	Nonenergy cost
Energy Increase ($0.15/kWh)	Energy cost

The project life determines the length of project financing, shorter term allows for less interest to be paid and decreases the annualized capital cost. The project life was decreased to 25 years, and **figures 4.4 and 4.5** show the cost results with the shorter project life at 50 and 5 mgd. Compared to the baseline conditions**,** the effect of this change is modest, increasing the product water cost by 3 to 4 percent, based on the facility size (**table 4.4**).

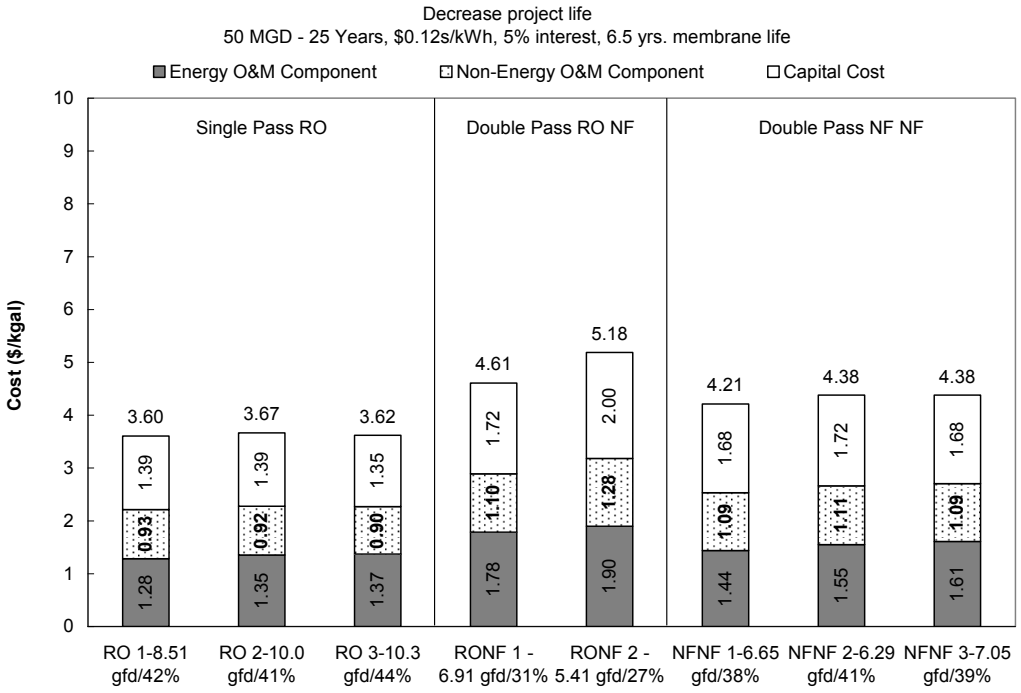


Figure 4.4. Project life decrease (25 years), 50 mgd.

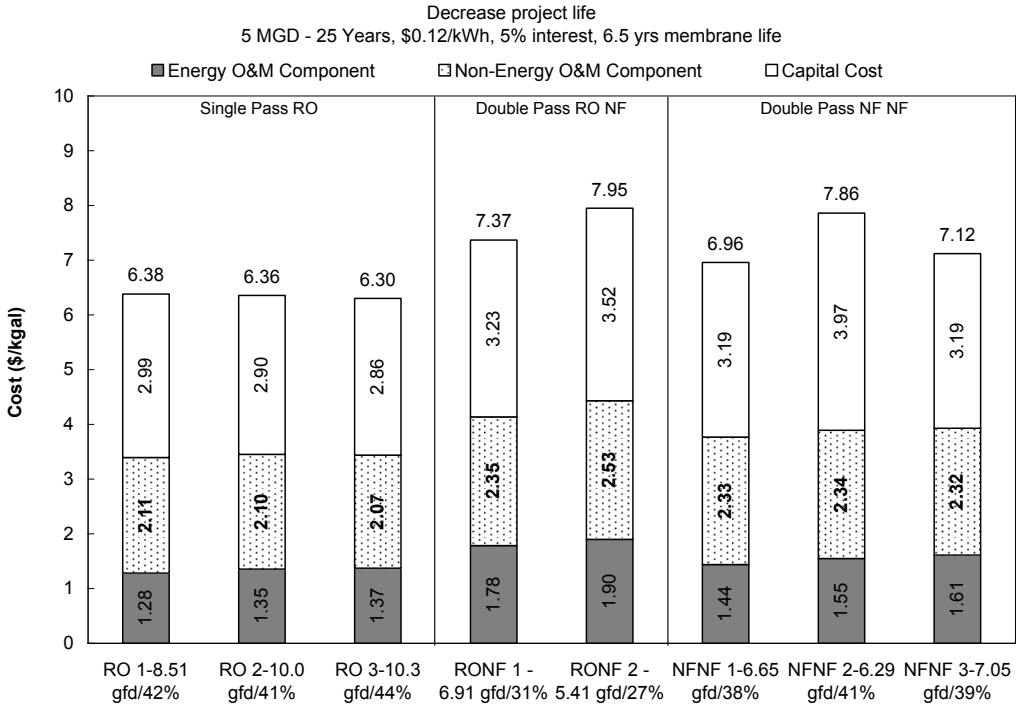


Figure 4.5. Project life decrease (25 years), 5 mgd.

Although the rate of debt financing may be low for public agencies (typically 5 percent or less), it can still vary. It is reasonable to assume that the interest rate may change 1 percent during the planning stages of the project. Analyses were performed to determine the effects of increasing and decreasing interest rates on the cost of product water (**figures 4.6 and 4.7)**. Increasing the finance rate from 5 to 6 percent resulted in a 4- to 6-percent cost increase, based on the facility size (**table 4.4**). Decreasing the finance rate from 5 to 4 percent (**figures 4.8 and 4.9**) resulted in a 4- to 5-percent decrease cost of product water, based on the facility size (**table 4.4**).

One nonenergy O&M factor that may impact the cost of product water is membrane life. Because the membranes were operated at a lower flux, membrane cleaning was minimized, and the membranes may extend past the industry-recognized replacement membrane life cycle of 5–7 years. The membrane life was extended to 10 years, and the sensitivity analyses are shown in **figures 4.10 and 4.11.** The resulting cost savings appear to be minimal, approximately 1 percent for both sizes of plants with different treatment processes (**table 4.4**).

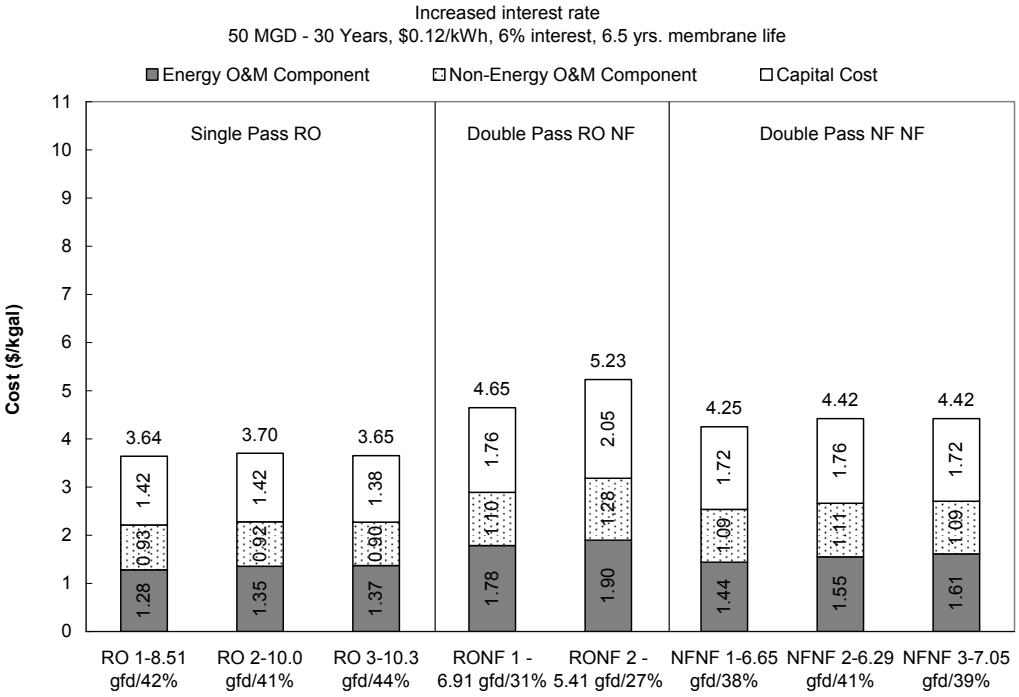


Figure 4.6. Interest increase (6%), 50 mgd.

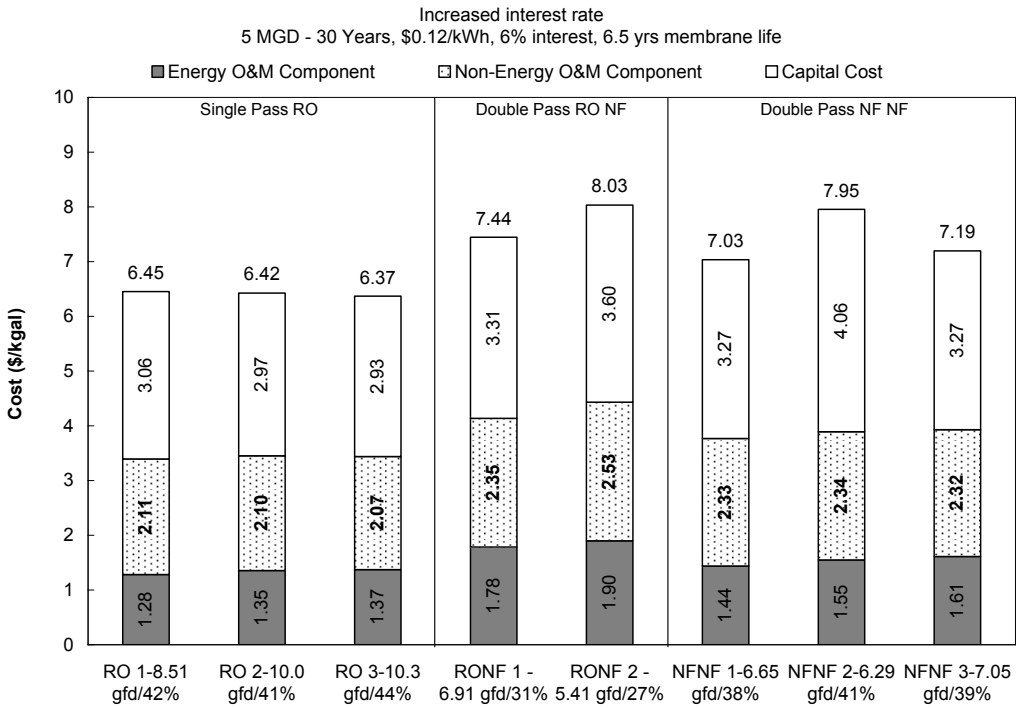


Figure 4.7. Interest increase (6%), 5 mgd.

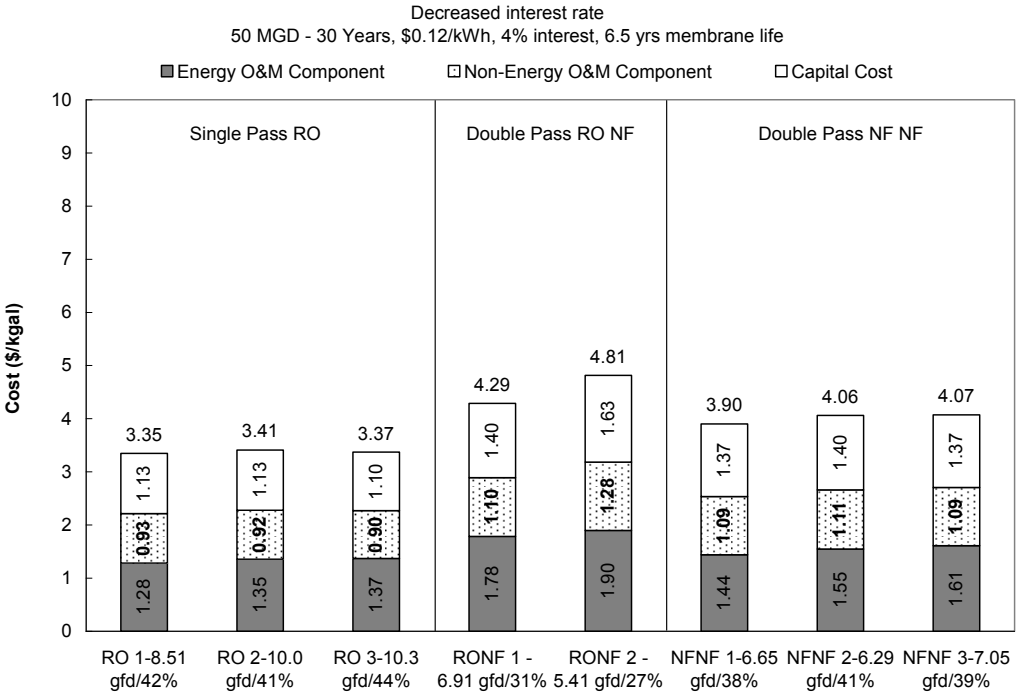


Figure 4.8. Interest decrease (4%), 50 mgd.

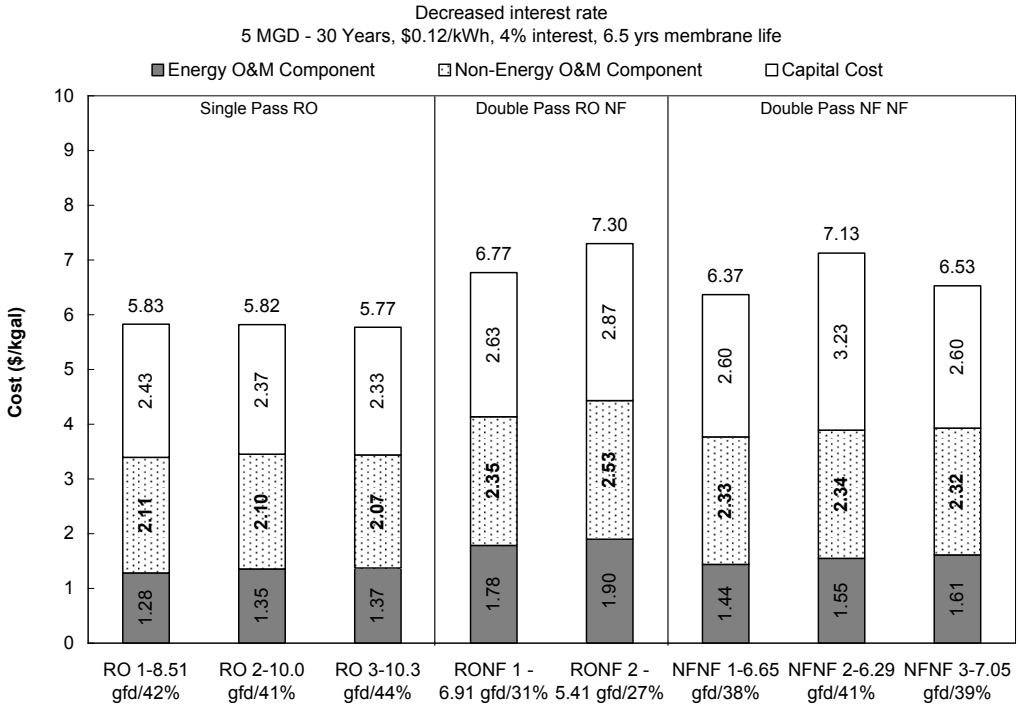


Figure 4.9. Interest decrease (4%), 5 mgd.

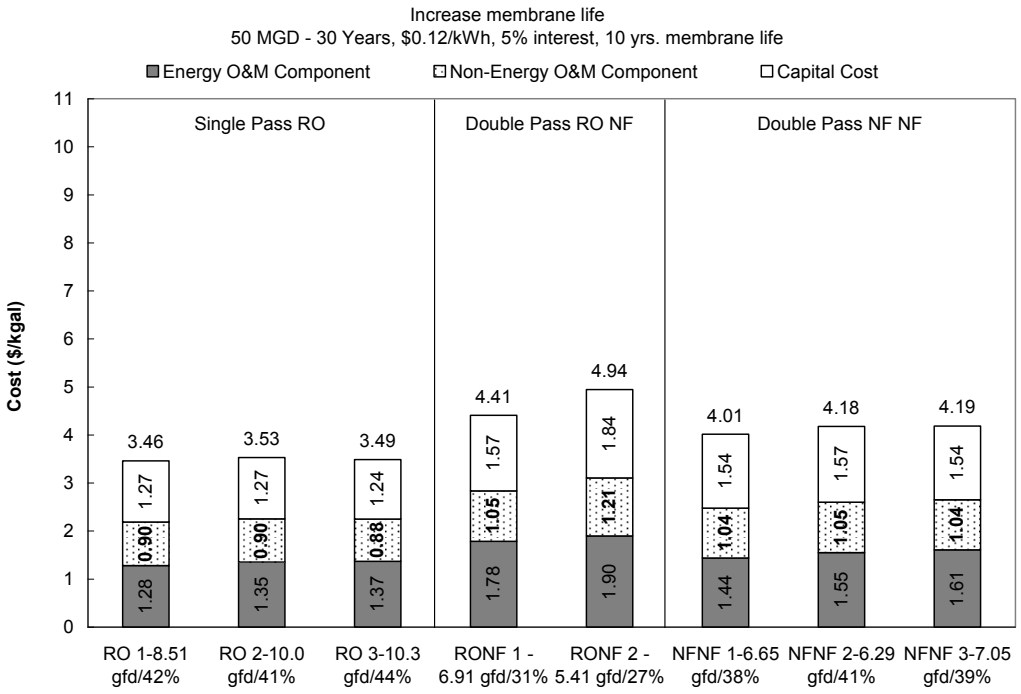


Figure 4.10. Membrane life increase (10 years), 50 mgd.

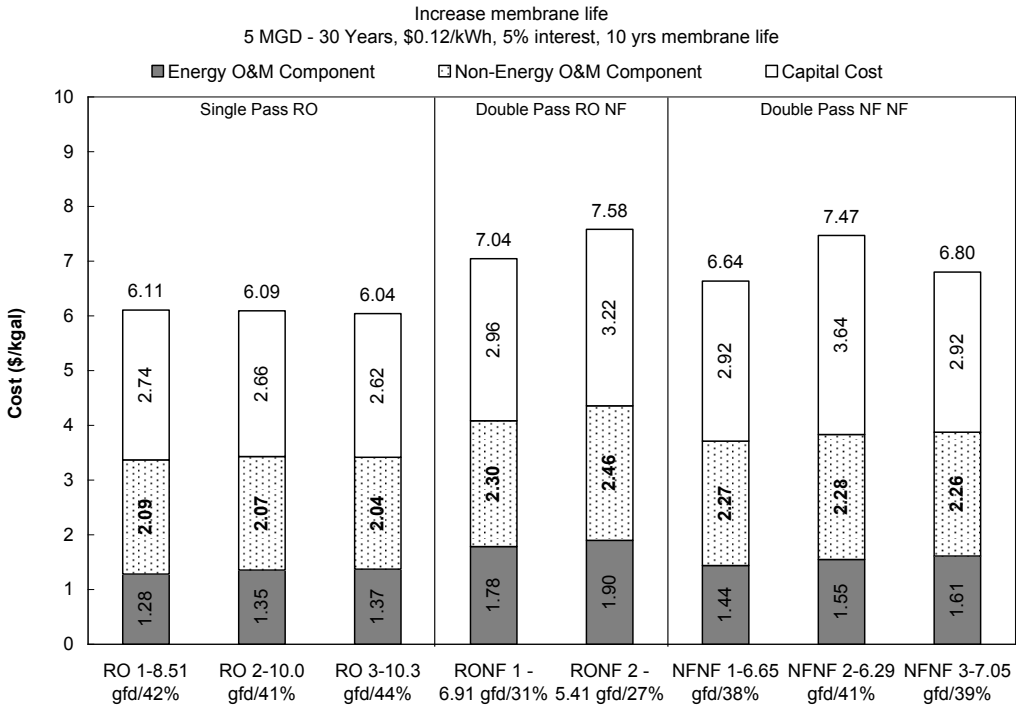


Figure 4.11. Membrane life increase (10 years), 5 mgd.

As shown in the Road Map, energy is the largest component of seawater desalination costs and a focal point in the Prototype research testing. It is expected that the desalination costs will be dramatically affected by changes in the energy costs. Although other parts of the United States may have electrical costs of $0.05/kWh, LBWD's current electrical rate is $0.12 kWh, and it is expected to increase to $0.15/kWh in the near future (**figures 4.12 and 4.13**). Analysis show that this increase of 25 percent in electrical cost will result in a 6–9-percent overall cost increase for the produced water, depending on the size of the facility (**table 4.4**).

Table 4.4 summarizes the overall and percent changes (**%Δ)** for each of the sensitivity analysis. Overall, the energy cost and interest rate resulted in the greatest impact on the product water costs. Other factors, such as increasing the membrane life and reducing the project life cycle, resulted in minimal impacts to the overall product water cost.

Inflation will occur over the life of the project, and it also impacts the overall cost of water production. The NF^2 cost model provides a snapshot of the cost at one point in time, and it is useful to perform analyses to determine how inflation affects the cost of the project over time. The cost of goods sold is commonly tracked as commodities and has historically shown an average of 3-percent increase over time (www.bls.gov).

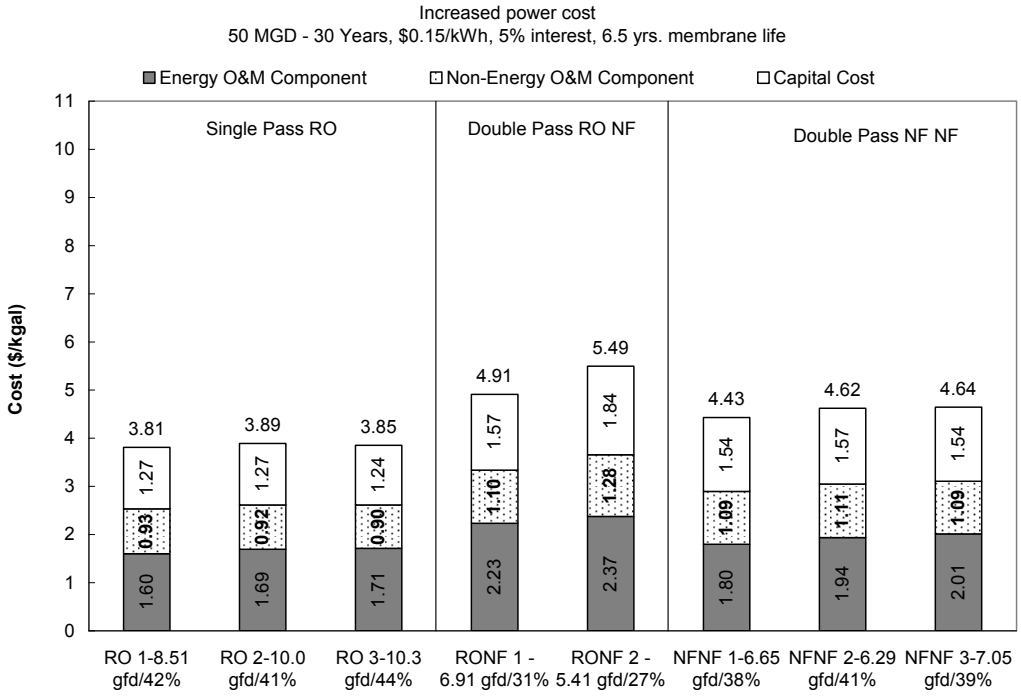


Figure 4.12. Energy increase ($0.15/kWh), 50 mgd.

Table 4.4. Summary table for NF^2 cost model sensitivity analysis

	Baseline	Project Life Decrease (25 yrs)		Interest Increase (6%)		Interest Decrease (4%)		Membrane Life Increase (10 years)		Energy Increase ($0.15/kWh)	
50 mgd		**Cost**	**%Δ**	**Cost**	**%Δ**	**Cost**	**%Δ**	**Cost**	**%Δ**	**Cost**	**%Δ**
RO 1 - 8.51 gfd/42%	$3.49	$3.60	3%	$3.64	4%	$3.35	4%	$3.46	0.8%	$3.81	9%
RO 2 - 10.0 gfd/41%	$3.55	$3.67	3%	$3.70	4%	$3.41	4%	$3.53	0.6%	$3.89	10%
RO 3 - 10.3 gfd/44%	$3.51	$3.62	3%	$3.65	4%	$3.37	4%	$3.49	0.6%	$3.85	10%
RONF 1 - 6.91 gfd/31%	$4.46	$4.61	3%	$4.65	4%	$4.29	4%	$4.41	1.2%	$4.91	10%
RONF 2 - 5.41 gfd/27%	$5.02	$5.18	3%	$5.23	4%	$4.81	4%	$4.94	1.5%	$5.49	9%
NFNF 1 - 6.65 gfd/38%	$4.07	$4.21	3%	$4.25	4%	$3.90	4%	$4.01	1.4%	$4.43	9%
NFNF 2 - 6.29 gfd/41%	$4.24	$4.38	3%	$4.42	4%	$4.06	4%	$4.18	1.4%	$4.62	9%
NFNF 3 - 7.05 gfd/39%	$4.24	$4.38	3%	$4.42	4%	$4.07	4%	$4.19	1.3%	$4.64	9%
5 mgd											
RO 1 - 8.51 gfd/42%	$6.13	$6.38	4%	$6.45	5%	$5.83	5%	$6.11	0.4%	$6.45	5%
RO 2 - 10.0 gfd/41%	$6.11	$6.36	4%	$6.42	5%	$5.82	5%	$6.09	0.3%	$6.45	6%
RO 3 - 10.3 gfd/44%	$6.06	$6.30	4%	$6.37	5%	$5.77	5%	$6.04	0.3%	$6.40	6%
RONF 1 - 6.91 gfd 31%	$7.10	$7.37	4%	$7.44	5%	$6.77	5%	$7.04	0.8%	$7.54	6%
RONF 2 - 5.41 gfd/27%	$7.66	$7.95	4%	$8.03	5%	$7.30	5%	$7.58	1.0%	$8.13	6%
NFNF 1 - 6.65 gfd/38%	$6.69	$6.96	4%	$7.03	5%	$6.37	5%	$6.64	0.8%	$7.05	5%
NFNF 2 - 6.29 gfd/41%	$7.53	$7.86	4%	$7.95	6%	$7.13	5%	$7.47	0.8%	$7.92	5%
NFNF 3 - 7.05 gfd/39%	$6.85	$7.12	4%	$7.19	5%	$6.53	5%	$6.80	0.7%	$7.26	6%

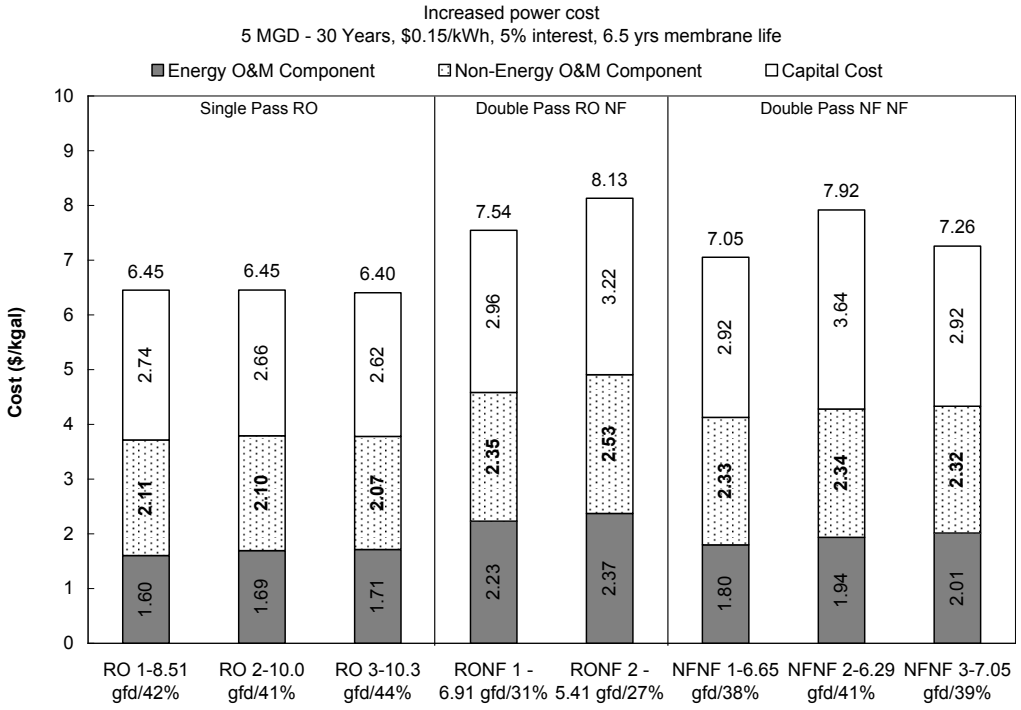


Figure 4.13. Energy Increase ($0.15/kWh), 5 mgd.

The cost of energy has increased steadily over time. To provide a more accurate projection for energy, regression analysis was performed for local energy cost data over the last 32 years. **Figure 4.14** shows the historical energy data for Los Angeles and Orange County, where the annual rate of inflation averaged 4 percent.

Inflationary commodity and power cost can be used to more accurately project the cost of producing desalinated water over the life of the project. Using the NF^2 cost model data and applying the rate of inflation for energy and nonenergy O&M components, a more accurate cost of water over the life of the project may be calculated. **Figures 4.15 and 4.16** show the annual costs, and the boxed numbers represent the cumulative cost over the life of the project. Assuming a project life of 30 years, the cost for product water will be twice as much as at the beginning of the project. Overall, the total cost of the product water for the 50-mgd RO-NF plant would be approximately $3.6 billion and approximately $3.2 billion for the NF^2 facility. The total cost for water produced from the 5-mgd RO-NF facility was valued at approximately $0.55 billion and approximately $0.51 billion for the NF^2 facility.

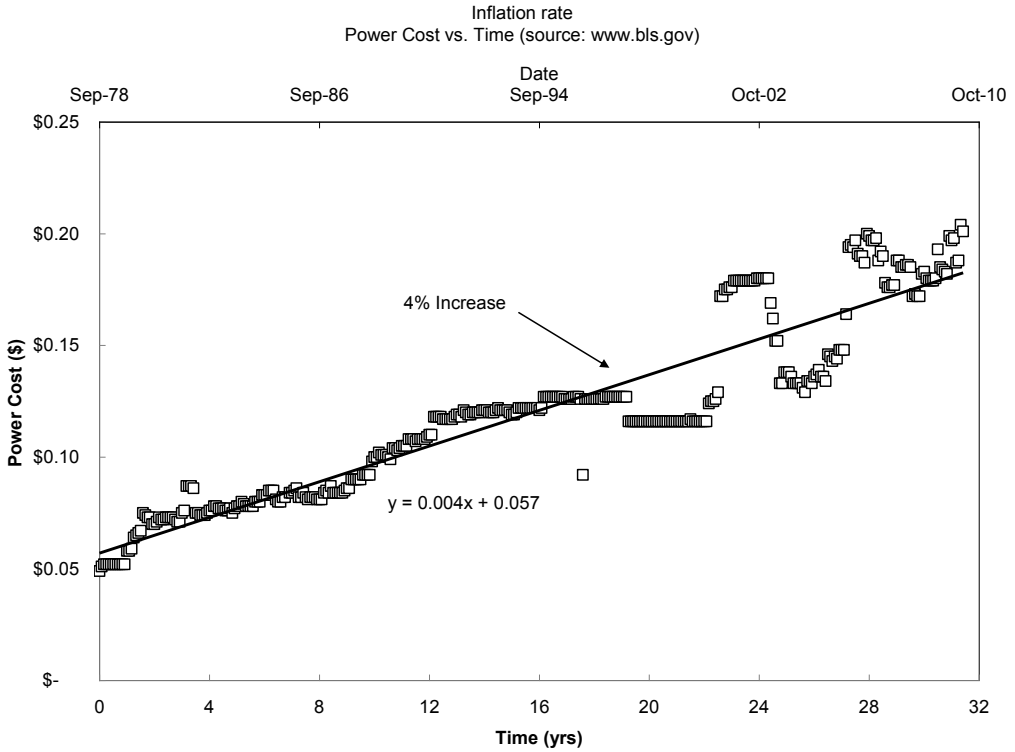


Figure 4.14. Inflation projection for energy from historical data.

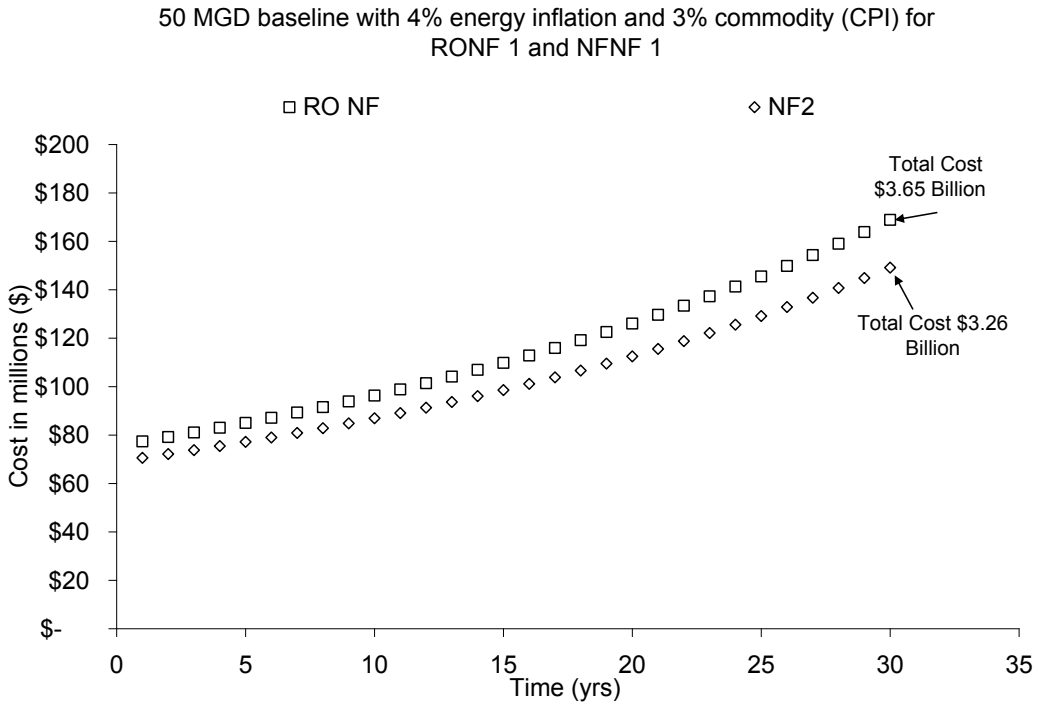


Figure 4.15. Inflation projections for 50 mgd.

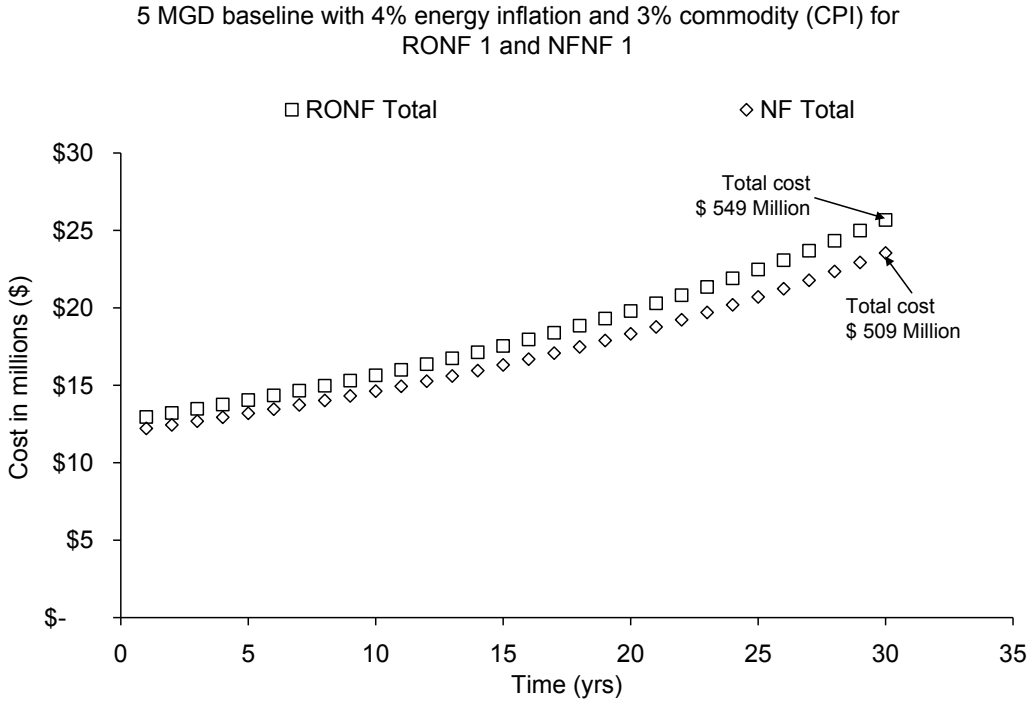


Figure 4.16. Inflation projections for 5 mgd.

4.3 Cost Analysis Summary

Cost analyses for full-scale plants were performed using a desalination NF^2 cost model (ADC, 2009) provided by Reclamation with parameters substituted from LBWD's Prototype performance data, where appropriate. The results indicated that the combined energy and capital components comprised over 80 percent of the total product water cost, which was consistent with the values presented in the Road Map. This confirmed the original goal of this research, which was to reduce the specific energy consumption while producing a water that meets all current and anticipated future drinking water regulations.

Among the processes tested in this facility that were able to meet all drinking water targets, the NF^2 process yielded the lowest cost ($4.07–$4.24/kgal for 50 mgd, $6.69–$7.53/kgal for 5 mgd), and the RO-NF process resulted in the highest cost ($4.46–$5.02/kgal for 50 mgd, $7.10–$7.66/kgal for 5 mgd). Although single-pass RO was tested, it could not reliably produce a water that met all drinking water regulations and goals (e.g., boron), and the data are presented for information only.

Various sensitivity analyses, including varying project life, finance rates, membrane life, energy, and plant size, were conducted to ensure that sufficient information is available for project planning purposes. In general, the average cost of product water for a 5-mgd facility was 53–78 percent more than a 50-mgd

facility, depending on the process selected. In addition to the plant size, the energy cost and finance rate also significantly impacted the overall product water cost. Other factors, including treatment plant life and membrane life, yielded minimal impacts on the product water costs. Cost analyses were conducted with inflation and showed that the cost of product water at the end of the 30-year project life was twice as much as at the beginning of the project. Regardless of the type of analyses, it was shown that the NF^2 process resulted in the lowest cost of product water meeting the drinking water regulations and goals.

5. Conclusions and Recommendations

5.1 Conclusions

This report summarizes the results of the comprehensive research effort at the LBWD's 300, 000-gpd Seawater Desalination Prototype Plant. Based on the test plan, the main objectives of this research were to: 1) demonstrate effectiveness of MF as a pretreatment process for NF/RO membranes; 2) demonstrate efficiency, reliability, and product water quality of NF^2 process; 3) compare NF^2 process (LBWD patented) with traditional seawater RO.

Results show that two-pass systems (whether RO-NF or NF^2) are necessary to meet all drinking water guidelines and goals, including boron. The full-scale desalination plant cost analysis was conducted using the Prototype performance data and the NF^2 cost model (ADC, 2009). These analyses confirmed the cost distribution provided in the Reclamation Road Map, where the energy and capital components constituted approximately 80 percent of the total cost. It also was shown that the product water from the NF^2 process cost less than the RO-NF process. Two plant sizes were evaluated (50 mgd and 5 mgd), and the product water cost for a 50-mgd plant ranges from \$4.07–\$4.24/kgal for NF^2 and \$4.46–\$5.02/kgal for RO-NF system. The produced water cost for a 5-mgd facility was higher, with the range of costs for NF^2 and RO-NF of \$6.69–\$7.53/kgal and \$7.10–\$7.66/kgal, respectively. These costs fall within the range of reported industry cost.

Other research efforts carried out in this facility included: 1) optimization of NF^2 process using different membrane configurations and mixed membranes; 2) feasibility and effectiveness of different biofouling control methods including UV and chlorine dioxide; 3) energy savings achieved by ER devices; 4) operational experience of desalination facility. Key conclusions of these tests are summarized below.

5.1.1 Effectiveness of MF as a Pretreatment Process for NF/RO Membranes

The MF system effectively reduced raw water turbidity to less than 0.2 NTU and the SDI to less than 1. SDI for pretreated waters to be fed to desalting membranes generally is required to be below 5. Different types of biological growth originally detected in the raw seawater were also effectively removed; however, periodic cleaning was necessary, and an increase in TMP increase usually indicated the need for a cleaning. TMP was dependent on the water production rate and the chlorine dosage. Higher chlorine dosage significantly decreased MF cleaning frequency. The balance between higher chlorine cost and membrane cleaning can be optimized for a specific plant.

5.1.2 Efficiency and Reliability of the NF^2 Process

Different recoveries were tested on the NF^2 pass 1. Approximately 40-percent recovery at pass 1 proved to be the optimal recovery in minimizing energy consumption. The 50^{th} percentile overall recovery on a cumulative curve of all tests performed for NF^2 process was approximately 30 percent. It was verified that the overall recovery was more significantly impacted by the pass 1 recovery than pass 2 recovery. Optimization of pass 1 is important to minimizing energy consumption. The facility experienced good influent water quality during the testing period, and no membrane scaling was observed after 2 years of operation, even without using antiscalent and sulfuric acid. Chemical usage was limited to chlorine (biofouling control) and sodium bisulfite (dechlorinate before the desalting membranes).

The NF^2 process operated reliably throughout the test and experienced similar system downtime compared to the RO process. The NF^2 process generated product water with TDS levels of approximately 200 mg/L, which is similar to the TDS of the drinking water currently in LBWD's system. The permeate also met the California boron goal of less than 1 mg/L (by raising the pH at pass 2). The NF^2 permeate water quality resulted in bromide levels less than 0.5 mg/L (75^{th} percentile). Other water quality parameters also meet the SDWA regulation.

5.1.3 Comparison of NF^2 Process with Traditional RO

As stated above, with the two-pass process, the NF^2 process produces very good permeate water quality that meets all drinking water regulation standards. A single-pass RO process can produce permeate water TDS and bromide levels similar to the NF^2 system. However, to meet the goal of less than 1 mg/L of boron, a second pass was also necessary for the RO process. The NF^2 process consumed less energy than the two-pass RO at a similar overall recovery.

5.1.3.1 Cost Analysis

This testing successfully demonstrated the comparable efficiency and reliability of the NF^2 process with RO in seawater desalination. The operation of the NF^2 process was optimized to minimize energy and chemical usage and maximize recovery. Cost data obtained in this analysis can be used as a guideline in the design of desalination plant.

Various sensitivity analyses, including varying project life, finance rates, membrane life, energy, and plant size, were conducted to ensure that sufficient information is available for project planning purposes. In general, the average cost of product water for a 5-mgd facility was 53–78 percent more than a 50-mgd facility, depending on the process selected. In addition to the plant size, the energy cost and finance rate also significantly impacted the overall product water cost. Other factors, including plant life cycle and membrane life cycle, yielded minimal impacts on the product water costs. Cost analyses were conducted with inflation and showed that the cost of product water at the end of the 30-year project life was twice as much as the beginning of the project. Regardless of the

type of analyses, it was shown that the NF^2 process resulted in the lowest cost of product water meeting the drinking water regulations and goals.

5.1.4 Other Objectives

5.1.4.1 Optimization of NF^2 Process

Energy optimization tests were conducted on Pass 1 of the NF^2 unit by varying the number of elements in series (five versus seven) and by incorporating different types of membranes in the same vessel, while maintaining the same permeate water quality. The permeate TDS for each configuration was below the secondary MCL of the SDWA. Testing NF(5) (five NF90 membranes in series) against NF(7) (seven NF90 membranes in series) did not indicate significant differences in energy consumption. However, placing more ULP RO membranes at the lead end of the vessel appeared to reduce energy consumption.

5.1.4.2 Effectiveness of Different Biofouling Control Methods

Two alternative disinfection methods were tested on microfiltered seawater. A 4-inch mobile membrane pilot skid was used as the control train. UV irradiation was applied at an intensity between 40–146.4 mJ/cm^2 on prefiltered water, which was fed to one train at the Prototype. The second alternative disinfectant tested was applying ClO_2 at a residual of at 0.5 ppm. When the influent seawater quality and the plant performance data were considered, the application of UV and ClO_2 did not appear to change the plant performance as compared to the baseline treatment (4-inch mobile skid).

5.1.4.3 Energy Savings Achieved by ER Devices

Tests were performed using the direct pressure exchanger as the energy recovery device. Although this device transfers energy through a direct interface of concentrate and the feed, the test results show no adverse effects on meeting the permeate TDS goal of below 500 mg/L. The results obtained from the Prototype showed average efficiencies in the range of 89–92 percent, although the manufacturer claimed an efficiency of greater than 95 percent for this device.

5.1.4.4 Operational Experience of Desalination Facility

The operation of a seawater desalination plant requires rigorous fabrication, quality control, constant coordination with project partners in the case of collocation with a power plant, and a diligent maintenance program. Exotic materials have long lead times for replacement parts; thus, it is prudent to have many of the exotic replacement parts on hand. Lastly, the operating environment is corrosive, and small problems can quickly lead to big problems. Staying proactive is the key to keeping these advance plants running. The many lessons learned can be integrated into the full-scale plant design. Water quality data collected throughout the facility (raw, permeate, concentrate, etc.) can be used during the permitting process.

6. References

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Table A1.1: 2006 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2006											
REPORTING PERIOD: APRIL - JUNE 2006											
Sampled Date:	**6/15/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
Turbidity	EPA 180.1	3.8	ND	0.15	3.4	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	24	ND	11	19	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	ND	DNQ	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	ND	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	ND	ND	DNQ	DNQ		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	NS	NS	NS	NS		1	0.003		NS	mg/L
Ammonia as N	WL/ EPA 350.1	0.17	DNQ	0.23	0.19			0.024		0.10	mg/L
Inorganics											
Antimony	WL/ EPA 200.8	ND	ND	ND	ND			0.26	0.5	2.5	µg/L
Arsenic	WL/ EPA 200.8	2.0	ND	4.2	2.0	36	69	0.33	2	2.0	µg/L
Beryllium	WL/ EPA 200.8	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	WL/ EPA 200.8	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	5.6	ND	8.8	28			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50	-	0.074		0.3	µg/L
Copper	WL/ EPA 200.8	7.6	ND	9.7	11	3.1	4.8	0.42	0.5	2.5	µg/L
Cyanide	WL/SM4500CN-F	ND	ND	ND	ND		1	0.31		1.0	µg/L
Lead	WL/EPA239.2	1.4	DNQ	ND	1.3	8.1	210	0.21	0.5	1.0	µg/L
Mercury	WL/ EPA 245.1	DNQ	DNQ	DNQ	DNQ		0.051	0.025	0.5	0.1	µg/L
Nickel	WL/ EPA 200.8	23	ND	44	48	8.2	74	0.7	1	4.0	µg/L
Selenium	WL/ EPA 200.8	ND	ND	2.2	ND	71	290	0.71	2	2.0	µg/L
Silver	WL/ S2150B	DNQ	ND	DNQ	ND		1.9	0.093	0.25	1.0	µg/L
Silver	WL/ EPA 200.8	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	WL/ EPA 180.1	DNQ	ND	DNQ	DNQ	81	90	3.6	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	6100	5	12,000	6200					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

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LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2006											
REPORTING PERIOD: APRIL - JUNE 2006											
Sampled Date:	**6/15/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
1,3-Dichloropropene (total)	WL/ EPA 524.2	NS	NS	NS	NS			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	DNQ	ND	0.12		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	0.33	1.3	3.2	5.2			0.04	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	0.21			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	DNQ	DNQ	0.52		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	0.27			0.40	2.00	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	0.18	DNQ	DNQ	0.37			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	0.24	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

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2nd Quarter in 2006											
REPORTING PERIOD: APRIL - JUNE 2006											
Sampled Date:	**6/15/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	ND	ND	ND		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	DNQ	DNQ	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.1: 2006 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2006											
REPORTING PERIOD: APRIL - JUNE 2006											
Sampled Date:	**6/15/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	DNQ	ND	ND		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
2,3,7,8-TCDD (Dioxin)	1613B	ND	ND	ND	ND		1.4E-08	0.543		5.00	pg/L

(+) = Detected above the daily and monthly average levels, will be resampled in the next quarter
(x) = Detected above the monthly average level, will be resampled in next quarter
DNQ, detected above the MDL but below the MRL
NS = Not Sampled, Sample was inadvertently not collected

Appendix A1
Table A1.2: 2006 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2006											
REPORTING PERIOD: JULY - SEPTEMBER 2006											
Sampled Date:	**7/27/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
Turbidity	EPA 180.1	1.2	DNQ	0.1	0.78	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	53	ND	98	54	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	DNQ	DNQ	ND	DNQ	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	ND	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	ND	ND	ND	DNQ		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	ND	ND	ND		1	0.003		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	0.14	DNQ	0.22	0.14			0.024		0.10	mg/L
Inorganics											
Antimony	WL/ EPA 200.8	ND	ND	ND	ND			0.26	0.5	2.5	µg/L
Arsenic	WL/ EPA 200.8	3.5	ND	7.5	3.6	36	69	0.33	2	2.0	µg/L
Beryllium	WL/ EPA 200.8	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	WL/ EPA 200.8	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	2.4	ND	5.8	2.4			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.074		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.5	ND	DNQ	1.3	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	WL/SM4500CN-F	ND	ND	ND	ND		1	0.31		1.0	µg/L
Lead	WL/EPA239.2	DNQ	ND	ND	DNQ	8.1	210	0.21	0.5	1.0	µg/L
Mercury	WL/ EPA 245.1	DNQ	DNQ	DNQ	DNQ		0.051	0.025	0.5	0.1	µg/L
Nickel	CRGL/ EPA 1640m	DNQ	ND	9.0	1.9	8.2	74	0.005	1	0.1	µg/L
Selenium	WL/ EPA 200.8	DNQ	ND	3.2	DNQ	71	290	0.71	2	2.0	µg/L
Silver	WL/ S2150B	DNQ	ND	ND	ND		1.9	0.093	0.25	1.0	µg/L
Thallium	WL/ EPA 200.8	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	WL/ EPA 180.1	DNQ	ND	DNQ	DNQ	81	90	3.6	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	6300	3	12,000	6400					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.2: 2006 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2006											
REPORTING PERIOD: JULY - SEPTEMBER 2006											
Sampled Date:	**7/27/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
1,3-Dichloropropene (total)	WL/ EPA 524.2	NS	NS	NS	NS			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	DNQ	ND	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	1.6	1.7	0.96			0.04	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	DNQ	DNQ	DNQ		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.40	2.00	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	DNQ	DNQ	ND			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	DNQ	DNQ			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.2: 2006 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2006											
REPORTING PERIOD: JULY - SEPTEMBER 2006											
Sampled Date:	**7/27/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	DNQ	DNQ	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.2: 2006 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2006											
REPORTING PERIOD: JULY - SEPTEMBER 2006											
Sampled Date:	**7/27/2006**	**Intake**	**Permeate**	**Concentrate**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**										
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND	DNQ	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
2,3,7,8-TCDD (Dioxin)	1613B	ND	ND	ND	ND		1.4E-08	0.543		5.00	pg/L

(+) = Detected above the daily and monthly average levels, will be resampled in the next quarter
(x) = Detected above the monthly average level, will be resampled in next quarter
DNQ, detected above the MDL but below the MRL
NS = Not Sampled, Sample was inadvertently not collected

Appendix A1
Table A1.3: 2006 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM 4th Quarter in 2006 **REPORTING PERIOD: OCTOBER - DECEMBER 2006**											
Sampled Date:	**12/5/06-12/5/06**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**						
Turbidity	LB EPA 180.1	0.526	NS	DNQ	0.502	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	86	NS	47	105	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	DNQ	NS	DNQ	DNQ	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	DNQ	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	0.05	ND	ND	ND		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	NS	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	NS	ND	ND		1	0.003		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	DNQ	ND	DNQ	DNQ			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	0.1	2.5	ND	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	1.5	ND	2.6	1.6	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	0.42	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III ^	CALC.	0.46	NS	NS	0.85			NA		1.0	µg/L
Chromium-VI ^	CRG/ SM 3500 Cr D	ND	NS	NS	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.9	0.62	2.3	2.7	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide ^	CRG/SM4500CN-E	ND	NS	NS	ND		1	0.005		1.0	µg/L
Lead	CRG/ EPA 1640	0.27	ND	ND	0.24	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.025	0.5	0.1	µg/L
Nickel	CRGL/ EPA 1640m	0.64	4.6	2.2	0.95	8.2	74	0.005	1	0.1	µg/L
Selenium	CRGL/ EPA 1640m	ND	4.1	ND	ND	71	290	0.71	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.093	0.25	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	4.2	ND	5.1	4.4	81	90	3.6	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	6079	NS	NS	6030					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.3: 2006 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2006											
REPORTING PERIOD: OCTOBER - DECEMBER 2006											
Sampled Date:	**12/5/06-12/5/06**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**						
1,3-Dichloropropene (total)	WL/ EPA 524.2	NS	NS	NS	NS			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	ND	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	DNQ	0.71	DNQ			0.04	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	DNQ	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	ND	ND	DNQ		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.40	2.00	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	DNQ	DNQ	DNQ	DNQ			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	DNQ	DNQ			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.3: 2006 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2006											
REPORTING PERIOD: OCTOBER - DECEMBER 2006											
Sampled Date:	**12/5/06-12/5/06**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**						
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	DNQ	DNQ	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.3: 2006 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2006											
REPORTING PERIOD: OCTOBER - DECEMBER 2006											
Sampled Date:	**12/5/06-12/5/06**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**						
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND	DNQ	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Tertiary butyl alcohol	WL/EPA 524.2	ND	NS	NS	ND			0.78		2	µg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	NS	ND	ND			0.06		3	µg/L
Acute Toxicity ^	WL/ EPA821-R-02	NS	NS	NS	100						%Survival
2,3,7,8-TCDD (Dioxin)	WL/ EPA 1613B	ND	NS	ND	ND		1.4E-08	0.543		5.00	pg/L

^ = Sampled on 12/14/2006
(+) = Detected above the daily and monthly average levels, will be resampled in the next quarter
(x) = Detected above the monthly average level, will be resampled in next quarter
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled, no flow during sampling time (will monitor when site becomes operational)

Appendix A1
Table A1.4: 2007 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2007											
REPORTING PERIOD: JANUARY - MARCH 2007											
Sampled Date:	**1/25/2007**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	NS	NS	NS	NS	50	75	0.04		0.1	NTU
Total suspended solids ^	SM 2540D	6	ND	69	21	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	DNQ	DNQ	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	ND	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	ND	ND	ND	ND		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	NS	ND	ND	NS	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	NS	NS	NS	NS		1	0.003		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	DNQ	ND	0.13	DNQ			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	ND	DNQ	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	ND	2.3	1.7	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	2.1	ND	ND	3.1			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.8	ND	1.5	1.7	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	ND	ND	ND	ND		1	0.005		1.0	µg/L
Lead	CRG/ EPA 1640	DNQ	ND	ND	DNQ	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.025	0.5	0.1	µg/L
Nickel	CRGL/ EPA 1640m	DNQ	DNQ	1.6	6.1	8.2	74	0.005	1	0.1	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.093	0.25	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	4.4	ND	5.8	4.1	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	5700	4	11,000	5700					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.4: 2007 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2007											
REPORTING PERIOD: JANUARY - MARCH 2007											
Sampled Date:	**1/25/2007**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	ND	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	1.9	DNQ	3.4	6.2			0.04	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	ND	DNQ	DNQ		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.40	2.00	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	DNQ	DNQ	ND	1.2			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	DNQ	DNQ			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.4: 2007 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2007											
REPORTING PERIOD: JANUARY - MARCH 2007											
Sampled Date:	**1/25/2007**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	0.21	ND	DNQ	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.4: 2007 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2007											
REPORTING PERIOD: JANUARY - MARCH 2007											
Sampled Date:	**1/25/2007**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	DNQ			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	DNQ	DNQ	DNQ	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	ND	ND	ND			0.06		3	µg/L

^ TSS for Intake and Effluent, sampled on 1/24/07
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled, Sample was inadvertently not collected

Appendix A1
Table A1.5: 2007 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2007											
REPORTING PERIOD: APRIL - JUNE 2007											
Sampled Date:	**4/11/07-4/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	1.6	0.1	0.14	1.88	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	23	ND	26	25	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	DNQ	ND	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	ND	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	0.06	DNQ	0.05	DNQ		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	ND	ND	ND		1	0.030		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	0.15	ND	0.15	0.1			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	ND	ND	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	ND	DNQ	DNQ	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	ND	ND	2.0	2.7			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	2.84	ND	3.80	3.77	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	ND	ND	ND	ND		1	0.005		1.0	µg/L
Lead	CRG/ EPA 1640	DNQ	ND	ND	DNQ	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.025	0.5	0.1	µg/L
Nickel	CRGL/ EPA 1640m	0.7	ND	2.9	2.3	8.2	74	0.005	1	0.1	µg/L
Silver	CRGL/ EPA 1640m	DNQ	DNQ	ND	ND	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.093	0.25	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	DNQ	ND	DNQ	DNQ	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	5000	4	6,700	5100					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.5: 2007 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2007											
REPORTING PERIOD: APRIL - JUNE 2007											
Sampled Date:	**4/11/07-4/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	0.57	0.56		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	2.2	0.99	40	36			0.04	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	DNQ	DNQ	5.5	6.1		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	1.5	0.37			0.40	2.00	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	0.91	1.2	1.0	0.9			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.5: 2007 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2007											
REPORTING PERIOD: APRIL - JUNE 2007											
Sampled Date:	**4/11/07-4/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	DNQ	DNQ	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.5: 2007 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2007											
REPORTING PERIOD: APRIL - JUNE 2007											
Sampled Date:	**4/11/07-4/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND	ND	ND		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	ND	ND	ND			0.06		3	µg/L

Effluent exceeded the monthly average value for copper. Weekly monitoring scheduled to be in compliance.
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled, Sample was inadvertently not collected

Appendix A1
Table A1.6: 2007 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2007											
REPORTING PERIOD: JULY - SEPTEMBER 2007											
Sampled Date:	**7/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	3.91	0.13	0.22	2.41	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	114	ND	92	126	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	ND	ND	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	ND	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	ND	DNQ	DNQ	DNQ		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	ND	ND	ND		1	0.030		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	ND	ND	ND	ND			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	ND	ND	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	ND	2.1	DNQ	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	DNQ	ND	DNQ	1.06			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.69	ND	1.20	2.26	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	ND	ND	ND	ND		1	0.005		1.0	µg/L
Lead	CRG/ EPA 1640	DNQ	ND	ND	DNQ	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.025	0.5	0.1	µg/L
Nickel	CRGL/ EPA 1640m	0.4	ND	0.5	0.91	8.2	74	0.005	1	0.1	µg/L
Silver	CRGL/ EPA 1640m	ND	DNQ	ND	ND	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.093	0.25	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	DNQ	ND	DNQ	DNQ	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	5300	ND	9,100	5600					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

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Table A1.6: 2007 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2007											
REPORTING PERIOD: JULY - SEPTEMBER 2007											
Sampled Date:	**7/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	DNQ	ND	DNQ	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	41	8.7	11	20			0.11	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	2.5	0.63	0.77	1.2		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	0.55	DNQ	DNQ			0.04	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	1.2	ND	ND			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.6: 2007 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2007											
REPORTING PERIOD: JULY - SEPTEMBER 2007											
Sampled Date:	**7/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	DNQ	ND	DNQ	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	DNQ	DNQ	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

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Table A1.6: 2007 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2007											
REPORTING PERIOD: JULY - SEPTEMBER 2007											
Sampled Date:	**7/12/07**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	5.7	DNQ	DNQ	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Toxicity (Acute)	WL/EPA 821	100	NA	NA	100						% Survival
Methyl tert butyl ether	WL/EPA 524.2	ND	ND	ND	ND			0.06		3	µg/L

Effluent exceeded the monthly average value for TSS. Weekly monitoring scheduled to be in compliance.
DNQ, detected above the MDL but below the MRL
NA = Not Applicable

Appendix A1
Table A1.7: 2007 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2007											
REPORTING PERIOD: OCTOBER - DECEMBER 2007											
Sampled Date:	**10/11/07-11/29/07**										
Constituent/ Parameters	**Method**	**Intake M-INF**	**Permeate M-INTA**	**Concentrate M-INTB**	**Plant Effluent M-001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	1.14	0.1	0.1	3.01	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	39	ND	21	44	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	1.2	ND	DNQ	ND	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	5.7	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	DNQ	ND	ND	0.11		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	ND	ND	ND		1	0.030		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	0.12	0.08	0.18	0.09			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	ND	DNQ	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	ND	2.6	DNQ	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	DNQ	ND	2.8	16			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	NA	NA	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.52	ND	1.50	**5.63**	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	NS	NS	NS	ND		1	0.005		1.0	µg/L
Lead	CRG/ EPA 1640	DNQ	ND	ND	0.66	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.025	0.5	0.1	µg/L
Nickel	CRGL/ EPA 1640m	0.5	ND	2.1	**9.77**	8.2	74	0.005	1	0.1	µg/L
Silver	CRGL/ EPA 1640m	DNQ	ND	ND	ND	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.093	0.25	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	DNQ	ND	DNQ	DNQ	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	4800	3	12,000	5100					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L

Appendix A1
Table A1.7: 2007 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2007											
REPORTING PERIOD: OCTOBER - DECEMBER 2007											
Sampled Date:	**10/11/07-11/29/07**										
Constituent/ Parameters	**Method**	**Intake M-INF**	**Permeate M-INTA**	**Concentrate M-INTB**	**Plant Effluent M-001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	ND	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	0.69	10	85			0.11	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	ND	DNQ	6		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND	ND	ND			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L

Appendix A1
Table A1.7: 2007 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2007											
REPORTING PERIOD: OCTOBER - DECEMBER 2007											
Sampled Date:	**10/11/07-11/29/07**										
Constituent/ Parameters	**Method**	**Intake M-INF**	**Permeate M-INTA**	**Concentrate M-INTB**	**Plant Effluent M-001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	DNQ	DNQ	ND		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	DNQ	DNQ	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L

Appendix A1
Table A1.7: 2007 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2007											
REPORTING PERIOD: OCTOBER - DECEMBER 2007											
Sampled Date:	**10/11/07-11/29/07**										
Constituent/ Parameters	**Method**	**Intake M-INF**	**Permeate M-INTA**	**Concentrate M-INTB**	**Plant Effluent M-001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND	DNQ	ND		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
2,3,7,8-TCDD (Dioxin)	WL/ EPA 1613B	ND	ND	ND	ND		1.4E-08	0.543		5	pg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	ND	ND	ND			0.06		3	µg/L

Effluent exceeded the monthly average value for copper and nickel. Weekly monitoring scheduled to be in compliance.
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled
2,3,7,8-TCDD (Dioxin) and Hardness sampled on 11/29/07 for all 4 sites

Appendix A1
Table A1.8: 2008 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2008											
REPORTING PERIOD: JANUARY - MARCH 2008											
Sampled Date:	**1/31/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	0.17	DNQ	0.1	0.25	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	49	ND	106	61	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	ND	ND	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	ND	ND	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	ND	ND	ND	ND		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	DNQ	ND	ND	ND		1	0.030		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	0.18	DNQ	0.14	0.34			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	ND	ND	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	ND	3.9	DNQ	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	ND	ND	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	DNQ	ND	5.8	DNQ			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.1	ND	1.67	0.98	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	ND	ND	ND	ND		1	0.005		1.0	µg/L
Lead	CRG/ EPA 1640	DNQ	ND	ND	ND	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.01	0.02	0.1	µg/L
Nickel	CRGL/ EPA 1640m	DNQ	ND	2.6	DNQ	8.2	74	0.005	1	0.1	µg/L
Silver	CRGL/ EPA 1640m	DNQ	ND	DNQ	DNQ	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.02	0.04	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	DNQ	ND	DNQ	DNQ	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	5800	4	12,000	5800					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.8: 2008 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2008											
REPORTING PERIOD: JANUARY - MARCH 2008											
Sampled Date:	**1/31/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	ND	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	0.55	18	8.2			0.11	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	ND	0.59	DNQ		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND	ND	ND			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.8: 2008 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2008											
REPORTING PERIOD: JANUARY - MARCH 2008											
Sampled Date:	**1/31/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	DNQ	DNQ	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.8: 2008 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2008											
REPORTING PERIOD: JANUARY - MARCH 2008											
Sampled Date:	**1/31/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND	ND	ND		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	ND	ND	ND			0.06		3	µg/L

Effluent exceeded the monthly average value for copper and nickel. Weekly monitoring scheduled to be in compliance.
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled

Appendix A1
Table A1.9: 2008 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2008											
REPORTING PERIOD: APRIL - JUNE 2008											
Sampled Date:	**5/22/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	0.85	NS	NS	1.9	50	75	0.04		0.1	NTU
Total suspended solids	SM 2540D	38	NS	NS	54	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	NS	NS	ND	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	NS	NS	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	DNQ	NS	NS	DNQ		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	NS	NS	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	NS	NS	DNQ		1	0.030		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	0.18	NS	NS	0.16			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	NS	NS	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	NS	NS	DNQ	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	NS	NS	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	NS	NS	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	DNQ	NS	NS	4.5			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	NS	NS	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	2.3	NS	NS	8.4	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	ND	NS	NS	7		1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	DNQ	NS	NS	2	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	NS	NS	ND		0.051	0.01	0.02	0.1	µg/L
Nickel	CRGL/ EPA 1640m	0.8	NS	NS	9	8.2	74	0.005	1	0.1	µg/L
Silver	CRGL/ EPA 1640m	DNQ	NS	NS	DNQ	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	ND	NS	NS	ND		1.9	0.02	0.04	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	NS	NS	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	4.46	NS	NS	11	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	5500	NS	NS	5400					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	NS	NS	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	NS	NS	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	NS	NS	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	NS	NS	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	NS	NS	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	NS	NS	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	NS	NS	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	NS	NS	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	NS	NS	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.9: 2008 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2008											
REPORTING PERIOD: APRIL - JUNE 2008											
Sampled Date:	**5/22/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	NS	NS	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	NS	NS	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	NS	NS	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	NS	NS	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	NS	NS	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	NS	NS	DNQ		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	NS	NS	20			0.11	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	NS	NS	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	NS	NS	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	NS	NS	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	NS	NS	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	NS	NS	2.1		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	NS	NS	1.7			0.04	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	NS	NS	ND			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	NS	NS	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	NS	NS	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	NS	NS	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	NS	NS	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	NS	NS	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	NS	NS	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	NS	NS	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	NS	NS	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	NS	NS	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	NS	NS	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.84	10	10	µg/L

Appendix A1
Table A1.9: 2008 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2008											
REPORTING PERIOD: APRIL - JUNE 2008											
Sampled Date:	**5/22/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	NS	NS	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	NS	NS	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	NS	NS	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	NS	NS	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	NS	NS	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	NS	NS	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	NS	NS	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	NS	NS	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	NS	NS	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	NS	NS	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	NS	NS	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	NS	NS	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	NS	NS	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	NS	NS	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	NS	NS	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	NS	NS	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	NS	NS	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	NS	NS	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	NS	NS	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	NS	NS	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	NS	NS	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	NS	NS	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	NS	NS	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	NS	NS	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	NS	NS	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	NS	NS	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.9: 2008 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2008											
REPORTING PERIOD: APRIL - JUNE 2008											
Sampled Date:	**5/22/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	NS	NS	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	NS	NS	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	NS	NS	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	NS	NS	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	NS	NS	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	NS	NS	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	NS	NS	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	NS	NS	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	NS	NS	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	NS	NS	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	NS	NS	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	NS	NS	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	DNQ	NS	NS	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	NS	NS	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	NS	NS	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	NS	NS	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	NS	NS	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	NS	NS	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	NS	NS	ND		0.00075	0.12	0.5	0.5	µg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	NS	NS	ND			0.06		3	µg/L

Effluent exceeded the monthly average value for copper, nickel and TSS, and daily value for cyanide. Weekly monitoring scheduled to be in compliance.
Quarterly cyanide sampled date: 6/12/08; Mercury sampled date: 6/19/2008
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled-Out of Service

Appendix A1

Table A1.10: 2008 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2008											
REPORTING PERIOD: JULY - SEPTEMBER 2008											
Sampled Date:	**7/3/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	LB EPA 180.1	2.45	NS	NS	3.93	50	75	0.04		0.1	NTU
Total suspended solids *	SM 2540D	33	NS	NS	32	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	NS	NS	ND	10	15	1		5	mg/L
BOD_5 20°C	WL/SM 5210B	ND	NS	NS	ND	20	30	3.0		10	mg/L
MBAS	WL/SM5540 C	ND	NS	NS	ND		0.5	0.023		0.05	mg/L
Settleable Solids	SM2450F	ND	NS	NS	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	SM4500-S= D	ND	NS	NS	ND		1	0.030		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	0.1	NS	NS	DNQ			0.024		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	ND	NS	NS	ND			0.26	0.5	2.5	µg/L
Arsenic	CRG/ EPA 1640m	DNQ	NS	NS	DNQ	36	69	0.33	2	2.0	µg/L
Beryllium	CRG/ EPA 1640m	ND	NS	NS	ND			0.18	0.5	0.5	µg/L
Cadmium	CRG/ EPA 1640m	ND	NS	NS	ND	9.3	42	0.12	0.25	0.5	µg/L
Chromium-III	CALC.	DNQ	NS	NS	DNQ			NA		1.0	µg/L
Chromium-VI	WL/ EPA 218.6	ND	NS	NS	ND	50		0.025		0.3	µg/L
Copper	CRGL/ EPA 1640m	2.04	NS	NS	3.35	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CRG/SM4500CN-E	ND	NS	NS	9		1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	DNQ	NS	NS	DNQ	8.1	210	0.21	0.5	1.0	µg/L
Mercury	CRG/ EPA 245.7 m	ND	NS	NS	ND		0.051	0.01	0.02	0.1	µg/L
Silver	CRGL/ EPA 1640m	1.3	NS	NS	1.29	8.2	74	0.005	1	0.1	µg/L
Selenium	CRGL/ EPA 1640m	DNQ	NS	NS	DNQ	71	290	0.01	2	2.0	µg/L
Silver	CRGL/ EPA 1640m	DNQ	NS	NS	DNQ		1.9	0.02	0.04	1.0	µg/L
Thallium	CRGL/ EPA 1640m	ND	NS	NS	ND		6.3	0.053	1	1.0	µg/L
Zinc	CRGL/ EPA 1640m	DNQ	NS	NS	DNQ	81	90	0.005	1	10	µg/L
Total Hardness (as CaCO3)	EPA 200.7	6100	NS	NS	6100					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	NS	NS	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	NS	NS	ND			0.09	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	NS	NS	ND		11	0.09	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	NS	NS	ND		42	0.05	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	NS	NS	ND		3.2	0.08	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	NS	NS	ND			0.11	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	NS	NS	ND			0.07	2	0.5	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	NS	NS	ND		99	0.08	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	NS	NS	ND		39	0.03	1	0.5	µg/L

Appendix A1
Table A1.10: 2008 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2008											
REPORTING PERIOD: JULY - SEPTEMBER 2008											
Sampled Date:	**7/3/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	NS	NS	ND			0.1	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	NS	NS	ND			0.18	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	NS	NS	ND			0.27	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	NS	NS	ND			0.11	2	5.0	µg/L
Benzene	WL/EPA 524.2	ND	NS	NS	ND		1	0.09	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	NS	NS	ND		46	0.08	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	NS	NS	4.1			0.11	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	NS	NS	ND		4.4	0.14	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	NS	NS	ND			0.09	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	NS	NS	ND			0.11	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	NS	NS	ND			0.06	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	NS	NS	DNQ		34	0.04	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	NS	NS	ND			0.04	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	NS	NS	ND			0.14	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	NS	NS	ND			0.13	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	NS	NS	ND			0.04	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	NS	NS	ND		8.85	0.07	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	NS	NS	ND			0.09	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	NS	NS	ND		81	0.10	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	NS	NS	ND			0.08	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	NS	NS	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.32	10	10	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	NS	NS	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.80	2	5	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	NS	NS	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	NS	NS	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	NS	NS	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.84	10	10	µg/L

Appendix A1
Table A1.10: 2008 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2008											
REPORTING PERIOD: JULY - SEPTEMBER 2008											
Sampled Date:	**7/3/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	NS	NS	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	NS	NS	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	NS	NS	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	NS	NS	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	NS	NS	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	NS	NS	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	NS	NS	ND			6.7	10	5	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	NS	NS	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	NS	NS	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	NS	NS	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	NS	NS	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	NS	NS	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	NS	NS	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	NS	NS	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.16		10	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	NS	NS	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	NS	NS	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	DNQ	NS	NS	DNQ		5.9	0.21	5	5.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	NS	NS	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	NS	NS	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	NS	NS	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	DNQ	NS	NS	DNQ			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	NS	NS	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	NS	NS	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	NS	NS	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	NS	NS	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	NS	NS	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	DNQ	NS	NS	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	NS	NS	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	NS	NS	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	NS	NS	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.10: 2008 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2008											
REPORTING PERIOD: JULY - SEPTEMBER 2008											
Sampled Date:	**7/3/08**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	NS	NS	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	NS	NS	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	NS	NS	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	NS	NS	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	NS	NS	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	NS	NS	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	NS	NS	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	NS	NS	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	NS	NS	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	NS	NS	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	NS	NS	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	NS	NS	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	NS	NS	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	DNQ	NS	NS	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	NS	NS	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	NS	NS	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	NS	NS	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	NS	NS	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	NS	NS	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	NS	NS	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	NS	NS	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	NS	NS	ND		0.00075	0.12	0.5	0.5	µg/L
Methyl tert butyl ether	WL/EPA 524.2	ND	NS	NS	ND			0.06		3	µg/L

Effluent exceeded the monthly average value for copper, and daily value for cyanide. Weekly monitoring scheduled to be in compliance.
Total suspended solids * sampled on 7/10/2008
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled-Out of Service

Appendix A1
Table A1.11: 2008 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2008											
REPORTING PERIOD: OCTOBER - DECEMBER 2008											
Sampled Date:	**10/9/08**	**Intake M-**		**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**Permeate**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	WL EPA 180.1	3.5	DNQ	0.12	1.6	50	75	0.04		0.1	NTU
Total suspended solids	LB/SM 2540D	30	ND	85	41	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	DNQ	ND	ND	10	15	2		5	mg/L
BOD_5 20°C	WL/SM 5210B	DNQ	ND	ND	DNQ	20	30	0.1		2	mg/L
MBAS	WL/SM5540 C	ND	ND	ND	ND		0.5	0.023		0.05	mg/L
Settleable Solids	LB/SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	LB/SM4500-S= D	DNQ	DNQ	DNQ	ND		1	0.01		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	DNQ	ND	DNQ	DNQ			0.048		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	0.16	ND	0.14	0.07			0.01	0.5	0.015	µg/L
Arsenic	CRG/ EPA 1640m	1.4	ND	2.9	1.4	36	69	0.01	2	0.015	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.005	0.5	0.01	µg/L
Cadmium	CRG/ EPA 1640m	0.025	ND	0.05	0.025	9.3	42	0.005	0.25	0.01	µg/L
Chromium-III	CALC.	0.38	ND	1.4	0.47			0.025		0.05	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.005		0.3	µg/L
Copper	CRGL/ EPA 1640m	1.9	ND	2.50	2	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CAL/335.2	ND	DNQ	DNQ	ND		1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	0.44	ND	0.07	0.31	8.1	210	0.005	0.5	0.01	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.01	0.02	0.02	µg/L
Silver	CRGL/ EPA 1640m	0.4	ND	1.1	0.59	8.2	74	0.005	1	0.01	µg/L
Selenium	CRGL/ EPA 1640m	0.02	ND	DNQ	DNQ	71	290	0.01	2	0.015	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.02	0.04	0.04	µg/L
Thallium	CRGL/ EPA 1640m	DNQ	ND	DNQ	DNQ		6.3	0.005	1	0.01	µg/L
Zinc	CRGL/ EPA 1640m	3.2	ND	4.1	1.2	81	90	0.005	1	0.01	µg/L
Total Hardness (as CaCO3)	EPA 200.7	5900	3.1	11,000	5600					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.18	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.22	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.36	2	1	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.32	2	1	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.21	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.19	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.3	2	2	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.14	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.15	1	0.5	µg/L

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Table A1.11: 2008 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2008											
REPORTING PERIOD: OCTOBER - DECEMBER 2008											
Sampled Date:	**10/9/08**	**Intake M-**		**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**Permeate**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.17	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.35	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.44	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.27	2	2.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.15	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	DNQ	DNQ		46	0.13	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	2.5	53	22			0.17	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.18	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.16	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	DNQ	4.6	1.6		34	0.19	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	DNQ			0.18	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.21	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.26	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.18	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.18	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	5	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	2	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.11: 2008 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2008											
REPORTING PERIOD: OCTOBER - DECEMBER 2008											
Sampled Date:	**10/9/08**	**Intake M-**		**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**Permeate**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	10	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		5	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	DNQ	ND	ND	DNQ		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	310	8.2	81	DNQ		5.9	0.21	5	4.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	DNQ	DNQ	DNQ	DNQ			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	DNQ	DNQ	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.11: 2008 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
4th Quarter in 2008											
REPORTING PERIOD: OCTOBER - DECEMBER 2008											
Sampled Date:	**10/9/08**	**Intake M-**		**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**Permeate**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	DNQ	ND	DNQ	DNQ		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Acute Toxicity		NA	NS	NS	NA						% Survival
2,3,7,8-TCDD (Dioxin) + Congenres -17		NA	NS	NS	NA		1.4E-08				TEF
Methyl tert butyl ether	WL/EPA 524.2	ND	ND	ND	ND			1.1		3	µg/L

DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled-Out of Service

Appendix A1
Table A1.12: 2009 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2009											
REPORTING PERIOD: JANUARY - MARCH 2009											
Sampled Date:	**1/8/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	WL EPA 180.1	**1.1**	**0.11**	**0.16**	**1.6**	50	75	0.04		0.1	NTU
Total suspended solids	LB/SM 2540D	**45**	ND	**79**	**35**	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	ND	ND	10	15	2		5	mg/L
BOD_5 20°C	WL/SM 5210B	**DNQ**	**DNQ**	**DNQ**	**DNQ**	20	30	0.1		2	mg/L
MBAS	WL/SM5540 C	**DNQ**	ND	**0.08**	**DNQ**		0.5	0.023		0.05	mg/L
Settleable Solids	LB/SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	LB/SM4500-S= D	ND	ND	ND	ND		1	0.01		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	ND	ND	ND	**DNQ**			0.048		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	**0.1**	**DNQ**	**0.21**	**0.12**			0.01	0.5	0.015	µg/L
Arsenic	CRG/ EPA 1640m	**1.3**	ND	**2.2**	**1.3**	36	69	0.01	2	0.015	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.005	0.5	0.01	µg/L
Cadmium	CRG/ EPA 1640m	**0.023**	ND	**0.04**	**0.02**	9.3	42	0.005	0.25	0.01	µg/L
Chromium-III	CALC.	**0.29**	ND	**0.48**	**0.49**			0.025		0.05	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.005		0.3	µg/L
Copper	CRGL/ EPA 1640m	**1.2**	**0.09**	**1.7**	**2.6**	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CAL/335.2	ND	ND	ND	ND		1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	**0.2**	ND	**0.03**	**0.27**	8.1	210	0.005	0.5	0.01	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.01	0.02	0.02	µg/L
Silver	CRGL/ EPA 1640m	**0.5**	ND	**0.96**	**1.3**	8.2	74	0.005	1	0.01	µg/L
Selenium	CRGL/ EPA 1640m	**DNQ**	ND	ND	ND	71	290	0.01	2	0.015	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.02	0.04	0.04	µg/L
Thallium	CRGL/ EPA 1640m	ND	ND	ND	ND		6.3	0.005	1	0.01	µg/L
Zinc	CRGL/ EPA 1640m	**1.6**	**6.4**	**7.6**	**1.5**	81	90	0.005	1	0.01	µg/L
Total Hardness (as CaCO3)	EPA 200.7	**5700**	**ND**	**11,000**	**5000**					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.18	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.22	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.36	2	1	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.32	2	1	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.21	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.19	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.3	2	2	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.14	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.15	1	0.5	µg/L

Appendix A1
Table A1.12: 2009 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2009											
REPORTING PERIOD: JANUARY - MARCH 2009											
Sampled Date:	**1/8/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.17	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.35	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.44	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.27	2	2.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.15	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	ND	**1.2**		46	0.13	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	**6.3**	**19**	**16**			0.17	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.18	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	**DNQ**	ND	ND			0.16	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	**1.4**			0.17	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	**0.67**	**1.4**	**2.2**		34	0.19	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.21	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.26	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.18	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.18	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	5	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	2	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.12: 2009 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2009											
REPORTING PERIOD: JANUARY - MARCH 2009											
Sampled Date:	**1/8/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	10	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		5	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	ND	**DNQ**	ND		5.9	0.21	5	4.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.12: 2009 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
1st Quarter in 2009											
REPORTING PERIOD: JANUARY - MARCH 2009											
Sampled Date:	**1/8/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND	ND	ND		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L

DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled-Out of Service

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Table A1.13: 2009 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2009											
REPORTING PERIOD: APRIL - JUNE 2009											
Sampled Date:	**4/10/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	WL EPA 180.1	**2.3**	**DNQ**	**0.15**	**2.0**	50	75	0.04		0.1	NTU
Total suspended solids	LB/SM 2540D	**59**	ND	**78**	**46**	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	ND	ND	10	15	2		5	mg/L
BOD_5 20°C	WL/SM 5210B	**DNQ**	ND	**DNQ**	**DNQ**	20	30	0.1		2	mg/L
MBAS	WL/SM5540 C	**DNQ**	ND	**DNQ**	**DNQ**		0.5	0.023		0.05	mg/L
Settleable Solids	LB/SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	LB/SM4500-S= D	ND	ND	ND	ND		1	0.01		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	**0.11**	ND	**DNQ**	**DNQ**			0.048		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	**0.1**	**0.11**	**0.31**	**0.15**			0.01	0.5	0.015	µg/L
Arsenic	CRG/ EPA 1640m	**1.4**	**0.03**	**1.9**	**1.2**	36	69	0.01	2	0.015	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.005	0.5	0.01	µg/L
Cadmium	CRG/ EPA 1640m	**0.03**	**DNQ**	**0.05**	**0.04**	9.3	42	0.005	0.25	0.01	µg/L
Chromium-III	CALC.	**0.39**	ND	**0.57**	**0.49**			0.025		0.05	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.005		0.3	µg/L
Copper	CRGL/ EPA 1640m	**1.7**	**0.59**	**2.2**	**2.6**	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CAL/335.2	ND	**DNQ**	**DNQ**	ND		1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	**0.4**	**0.01**	**0.03**	**0.35**	8.1	210	0.005	0.5	0.01	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.01	0.02	0.02	µg/L
Silver	CRGL/ EPA 1640m	**0.8**	**0.09**	**1.30**	**1.2**	8.2	74	0.005	1	0.01	µg/L
Selenium	CRGL/ EPA 1640m	**DNQ**	ND	**DNQ**	**DNQ**	71	290	0.01	2	0.015	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.02	0.04	0.04	µg/L
Thallium	CRGL/ EPA 1640m	**DNQ**	ND	ND	ND		6.3	0.005	1	0.01	µg/L
Zinc	CRGL/ EPA 1640m	**1.1**	ND	**8**	**4.5**	81	90	0.005	1	0.01	µg/L
Total Hardness (as CaCO3)	EPA 200.7	**5200**	**24**	**7,400**	**5100**					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.18	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.22	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.36	2	1	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.32	2	1	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.21	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.19	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.3	2	2	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.14	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.15	1	0.5	µg/L

Appendix A1
Table A1.13: 2009 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2009											
REPORTING PERIOD: APRIL - JUNE 2009											
Sampled Date:	**4/10/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.17	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.35	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.44	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.27	2	2.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.15	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	**DNQ**	ND		46	0.13	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	**15**	**28**	**17**			0.17	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.18	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	**DNQ**	ND	ND			0.16	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	**1.3**	**2.0**	**1.2**		34	0.19	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.21	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.26	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.18	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.18	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	5	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	2	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

Appendix A1
Table A1.13: 2009 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2009											
REPORTING PERIOD: APRIL - JUNE 2009											
Sampled Date:	**4/10/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	10	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		5	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	ND	ND	ND		5.9	0.21	5	4.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.13: 2009 Quarter 2 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
2nd Quarter in 2009											
REPORTING PERIOD: APRIL - JUNE 2009											
Sampled Date:	**4/10/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	**DNQ**	**DNQ**	**DNQ**	**DNQ**		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L

Chrinium V1 and Cyanide sampled on 5/13/09
MBAS sampled on 4/22/09
DNQ, detected above the MDL but below the MRL
NA = Not Analyzed
NS = Not Sampled-Out of Service

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Table A1.14: 2009 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2009											
REPORTING PERIOD: JULY - SEPTEMBER 2009											
Sampled Date:	**7/9/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	WL EPA 180.1	**1.25**	**DNQ**	**DNQ**	**0.31**	50	75	0.04		0.1	NTU
Total suspended solids	LB/SM 2540D	**61**	**DNQ**	**82**	**47**	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	ND	ND	10	15	2		5	mg/L
BOD_5 20°C	WL/SM 5210B	**DNQ**	**DNQ**	**DNQ**	**DNQ**	20	30	0.1		2	mg/L
MBAS	WL/SM5540 C	**DNQ**	ND	**0.1**	**0.07**		0.5	0.023		0.05	mg/L
Settleable Solids	LB/SM2450F	ND	ND	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	LB/SM4500-S= D	ND	ND	ND	ND		1	0.01		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	ND	ND	ND	ND			0.048		0.10	mg/L
Inorganics											
Antimony	CRG/ EPA 1640m	**0.09**	ND	**0.15**	**0.12**			0.01	0.5	0.015	µg/L
Arsenic	CRG/ EPA 1640m	**1.2**	**0.03**	**1.7**	**1.2**	36	69	0.01	2	0.015	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND	ND	ND			0.005	0.5	0.01	µg/L
Cadmium	CRG/ EPA 1640m	**0.03**	ND	**0.05**	**0.03**	9.3	42	0.005	0.25	0.01	µg/L
Chromium-III	CALC.	**0.37**	ND	**0.42**	**0.40**			0.025		0.05	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	ND	ND	50		0.005		0.3	µg/L
Copper	CRGL/ EPA 1640m	**1.7**	**0.12**	**2.1**	**1.7**	3.1	4.8	0.01	0.5	0.02	µg/L
Cyanide	CAL/335.2	ND	ND	ND	ND		1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	**0.39**	ND	**0.02**	**0.12**	8.1	210	0.005	0.5	0.01	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	ND	ND		0.051	0.01	0.02	0.02	µg/L
Silver	CRGL/ EPA 1640m	**0.39**	**DNQ**	**0.62**	**0.59**	8.2	74	0.005	1	0.01	µg/L
Selenium	CRGL/ EPA 1640m	**DNQ**	ND	ND	ND	71	290	0.01	2	0.015	µg/L
Silver	CRGL/ EPA 1640m	ND	ND	ND	ND		1.9	0.02	0.04	0.04	µg/L
Thallium	CRGL/ EPA 1640m	**0.01**	ND	**DNQ**	**DNQ**		6.3	0.005	1	0.01	µg/L
Zinc	CRGL/ EPA 1640m	**2.1**	**1.5**	**2.8**	**1.4**	81	90	0.005	1	0.01	µg/L
Total Hardness (as CaCO3)	EPA 200.7	**5,900**	**33**	**9,000**	**5,900**					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND	ND	ND					0.400	MF/L
Volatile Organic Chemicals											
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND	ND	ND		11	0.18	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND	ND	ND		42	0.22	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.36	2	1	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.32	2	1	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND	ND	ND		3.2	0.21	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.19	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND	ND	ND			0.3	2	2	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND	ND	ND		99	0.14	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND	ND	ND		39	0.15	1	0.5	µg/L

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Table A1.14: 2009 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2009											
REPORTING PERIOD: JULY - SEPTEMBER 2009											
Sampled Date:	**7/9/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND	ND	ND			0.17	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND	ND	ND			0.35	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND	ND	ND			0.44	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND	ND	ND			0.27	2	2.0	µg/L
Benzene	WL/EPA 524.2	ND	ND	ND	ND		1	0.15	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	ND	**DNQ**	**DNQ**		46	0.13	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	**DNQ**	**22**	**45**	**25**			0.17	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND	ND	ND		4.4	0.18	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.16	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	**1.6**	**2.6**	**1.6**		34	0.19	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND	ND	ND			0.17	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND	ND	ND			0.21	2	0.5	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND	ND	ND		8.85	0.26	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND	ND	ND			0.15	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND	ND	ND			0.18	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND	ND	ND		81	0.18	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND	ND	ND			0.18	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals											
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	5	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND	ND	ND		0.54	0.35	1	1.0	µg/L
1,3-dichlorobenzene	WL/ EPA 625/8270	NS	NS	NS	NS			0.36	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.80	2	2	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.84	10	10	µg/L

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Table A1.14: 2009 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2009											
REPORTING PERIOD: JULY - SEPTEMBER 2009											
Sampled Date:	**7/9/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND	ND	ND			6.7	10	10	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.16		5	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	ND	ND	ND		5.9	0.21	5	4.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND	ND	ND		0.81	0.003	0.01	0.01	µg/L

Appendix A1
Table A1.14: 2009 Quarter 3 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM											
3rd Quarter in 2009											
REPORTING PERIOD: JULY - SEPTEMBER 2009											
Sampled Date:	**7/9/09**	**Intake M-**	**Permeate**	**Concentrate M-**	**Plant Effluent M-**						
Constituent/ Parameters	**Method**	**INF**	**M-INTA**	**INTB**	**001**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Fluoranthene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	**DNQ**	**DNQ**	**DNQ**	**DNQ**		8.1	0.23	5	2.0	ng/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND	ND	ND		0.00075	0.12	0.5	0.5	µg/L

DNQ, detected above the MDL but below the DLR

Appendix A

Table A1.15: 2009 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
4th Quarter in 2009									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**10/22/09-10/29/09**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	WL EPA 180.1	**0.29**	**1.9**	50	75	0.04		0.1	NTU
Total suspended solids	LB/SM 2540D	**33**	**35**	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	10	15	2		5	mg/L
BOD_5 20^oC	WL/SM 5210B	**DNQ**	ND	20	30	0.1		2	mg/L
MBAS	WL/SM5540 C	**DNQ**	**DNQ**		0.5	0.023		0.05	mg/L
Settleable Solids	LB/SM2450F	ND	ND	0.1	0.3	0.10		0.10	mL/L
Sulfides	LB/SM4500-S= D	ND	ND		1	0.01		0.05	mg/L
Ammonia as N	WL/ EPA 350.1	**DNQ**	**0.3**			0.048		0.10	mg/L
Inorganics									
Antimony	CRG/ EPA 1640m	**0.18**	**0.16**			0.01	0.5	0.015	µg/L
Arsenic	CRG/ EPA 1640m	**1.3**	**1.3**	36	69	0.01	2	0.015	µg/L
Beryllium	CRG/ EPA 1640m	ND	ND			0.005	0.5	0.01	µg/L
Cadmium	CRG/ EPA 1640m	**0.023**	**0.053**	9.3	42	0.005	0.25	0.01	µg/L
Chromium-III	CALC.	**0.19**	**0.38**			0.025		0.05	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	50		0.005		0.3	µg/L
Copper	CRGL/ EPA 1640m	**1.3**	**1.54**	2.3	5.8	0.01	0.5	0.02	µg/L
Cyanide	CAL/335.2	ND	ND	0.39	1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	**0.24**	**0.31**	8.1	210	0.005	0.5	0.01	µg/L
Mercury	CRG/ EPA 245.7 m	ND	ND	0.051	0.102	0.01	0.02	0.02	µg/L
Nickel	CRGL/ EPA 1640m	**0.35**	**0.54**	5.9	15	0.005	1	0.01	µg/L
Selenium	CRGL/ EPA 1640m	**0.02**	ND	71	290	0.01	2	0.015	µg/L
Silver	CRGL/ EPA 1640m	**0.15**	**0.15**		1.9	0.02	0.04	0.04	µg/L
Thallium	CRGL/ EPA 1640m	**DNQ**	**DNQ**		6.3	0.005	1	0.01	µg/L
Zinc	CRGL/ EPA 1640m	**3.4**	**2.9**	81	90	0.005	1	0.01	µg/L
Total Hardness (as CaCO3)	EPA 200.7	**6400**	**2200**					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND					0.400	MF/L
Volatile Organic Chemicals									
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND		11	0.18	1	0.5	µg/L
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND		42	0.22	2	0.5	µg/L

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Table A1.15: 2009 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
4th Quarter in 2009									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**10/22/09-10/29/09**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND			0.36	2	1	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND			0.32	2	1	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND		3.2	0.21	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND			0.19	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND			0.3	2	2	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND		99	0.14	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND		39	0.15	1	0.5	µg/L
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND			0.17	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND			0.35	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND			0.44	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND			0.27	2	2.0	µg/L
Benzene	WL/EPA 524.2	ND	ND		1	0.15	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	**2.3**		46	0.13	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	**120**			0.17	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND		4.4	0.18	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND			0.16	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND			0.18	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	**0.94**			0.17	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	**9.6**		34	0.19	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND			0.18	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND			0.17	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND			0.21	2	0.5	µg/L
Tert-butyl Alcohol (TBA)	WL/ EPA 524.2	ND	ND			0.47		2.0	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND		8.85	0.26	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND			0.18	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND		81	0.18	2	0.5	µg/L
Vinyl Chloride	WL/ EPA 524.2	ND	ND			0.18	2	0.5	µg/L

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Table A1.15: 2009 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
4th Quarter in 2009									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**10/22/09-10/29/09**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Non-Volatile Synthetic Organic Chemicals									
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND		0.049	0.32	10	5	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND		0.54	0.35	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND			0.80	2	2	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND			0.84	10	10	µg/L
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND			6.7	10	10	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND			0.0017	0.02	0.02	µg/L
Anthracene	WL/ EPA 625/8270	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND		0.00054	0.7	5	5	µg/L

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Table A1.15: 2009 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
4th Quarter in 2009									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**10/22/09-10/29/09**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND		0.049	0.16		5	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	**0.02**	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	ND		5.9	0.21	5	4.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND		0.81	0.003	0.01	0.01	µg/L
Fluoranthene	WL/ EPA 625/8270	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND		0.00077	0.15	1	1.0	µg/L
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND		8.9	0.36	1	1.0	µg/L

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Table A1.15: 2009 Quarter 4 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
4th Quarter in 2009									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**10/22/09-10/29/09**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND		8.1	0.23	5	2.0	µg/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND		0.00075	0.12	0.5	0.5	µg/L
Toxicity - acute	ABC/EPA600-R-95-136	100	96	>70%					%survival
Toxicity - chronic-topsmelt	ABC/EPA600-R-95-136	1.00	1.00	≤ 1.0					TUc
Toxicity - chronic-kelp germination	ABC/EPA600-R-95-136	1.00	>1.00*	≤ 1.0					TUc
Toxicity - chronic-sea urchin	ABC/EPA600-R-95-136	1.00	1.00	≤ 1.0					TUc

* "The percent germination in this test was between 86.4 and 90.0 %. Given that these germination values exceed the acceptablility criteria for controls, ≥ 70%, we see no indication that this test exhibits a significant biological or ecological impact. Tu

DNQ, detected above the MDL but below the DLR

Appendix A

Table A1.16: 2010 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
1st Quarter in 2010									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**1/13/10**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Turbidity	WL EPA 180.1	**0.98**	**0.56**	50	75	0.04		0.1	NTU
Total suspended solids	LB/SM 2540D	**51**	**35**	50	75	5		5	mg/L
Oil and Grease	WL/EPA 1664	ND	ND	10	15	2		5	mg/L
BOD_5 20°C	WL/SM 5210B	DNQ	DNQ	20	30	0.1		2	mg/L
MBAS	WL/SM5540 C	**0.059**	**0.069**		0.5	0.023		0.05	mg/L
Settleable Solids (SS)	LB/SM2450F	ND	ND	0.1	0.3	0.10		0.10	mL/L
Ammonia as N	WL/ EPA 350.1	ND	ND			0.048		0.10	mg/L
Inorganics									
Antimony	CRG/ EPA 1640m	**0.06**	**0.09**			0.01	0.5	0.015	µg/L
Arsenic	CRG/ EPA 1640m	**1.8**	**1.8**	36	69	0.01	2	0.015	µg/L
Beryllium	CRG/ EPA 1640m	**0.033**	**0.03**			0.005	0.5	0.01	µg/L
Cadmium	CRG/ EPA 1640m	**0.03**	**0.031**	9.3	42	0.005	0.25	0.01	µg/L
Chromium-III	CALC.	**0.38**	**0.53**			0.025		0.05	µg/L
Chromium-VI	WL/ EPA 218.6	ND	ND	50		0.005		0.3	µg/L
Copper	CRGL/ EPA 1640m	**1.9**	**1.8**	2.3	5.8	0.01	0.5	0.02	µg/L
Cyanide	CAL/335.2	ND	ND	0.39	1	0.6		3.0	µg/L
Lead	CRG/ EPA 1640	**0.43**	**0.26**	8.1	210	0.005	0.5	0.01	µg/L
Mercury	CRG/ EPA 245.7 m	ND	**0.02**	0.051	0.102	0.01	0.02	0.02	µg/L
Nickel	CRGL/ EPA 1640m	**0.41**	**0.67**	5.9	15	0.005	1	0.01	µg/L
Selenium	CRGL/ EPA 1640m	ND	ND	71	290	0.01	2	0.015	µg/L
Silver	CRGL/ EPA 1640m	ND	ND		1.9	0.02	0.04	0.04	µg/L
Thallium	CRGL/ EPA 1640m	ND	**DNQ**		6.3	0.005	1	0.01	µg/L
Zinc	CRGL/ EPA 1640m	**3.7**	**4**	81	90	0.005	1	0.01	µg/L
Total Hardness (as CaCO3)	EPA 200.7	**6000**	**5700**					1.0	mg/L
Asbestos	WL/EPA100.1/.2	ND	ND					0.400	MF/L
Volatile Organic Chemicals									
	10/22/2009	**INF-001**	**EFF-001**						
1,1,1-Tirichloroethane	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
1,1,2,2-Tetrachloroethane	WL/ EPA 524.2	ND	ND		11	0.18	1	0.5	µg/L

Appendix A

Table A1.16: 2010 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
1st Quarter in 2010									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**1/13/10**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,1,2-Trichloroethane	WL/ EPA 524.2	ND	ND		42	0.22	2	0.5	µg/L
1,3-Dichlorobenzene (1,3-DCB)	WL/ EPA 524.2	ND	ND			0.36	2	1	µg/L
1,4-Dichlorobenzene (1,4-DCB)	WL/ EPA 524.2	ND	ND			0.32	2	1	µg/L
1,1-Dichloroethane	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
1,1-Dichoroethene (1,1-DCE)	WL/ EPA 524.2	ND	ND		3.2	0.21	2	0.5	µg/L
1,2,4-Trichlorobenzene	WL/ EPA 524.2	ND	ND			0.19	5	0.5	µg/L
1,2-Dichlorobenzene (1,2-DCB)	WL/ EPA 524.2	ND	ND			0.3	2	2	µg/L
1,2-Dichloroethane (1,2-DCA)	WL/ EPA 524.2	ND	ND		99	0.14	2	0.5	µg/L
1,2-Dichloropropane	WL/ EPA 524.2	ND	ND		39	0.15	1	0.5	µg/L
1,3-Dichloropropene (total)	WL/ EPA 524.2	ND	ND			0.17	1	0.5	µg/L
2-chloroethyl vinyl ether	WL/ EPA 624	ND	ND			0.35	1	1.0	µg/L
Acrolein	WL/ EPA 624	ND	ND			0.44	5	5.0	µg/L
Acrylonitrile	WL/ EPA 624	ND	ND			0.27	2	2.0	µg/L
Benzene	WL/EPA 524.2	ND	ND		1	0.15	2	0.5	µg/L
Bromodichoromethane	WL/ EPA 524.2	ND	**0.21**		46	0.13	2	0.5	µg/L
Bromoform	WL/ EPA 524.2	ND	**19**			0.17	2	0.5	µg/L
Carbon Tetrachloride (CTC)	WL/ EPA 524.2	ND	ND		4.4	0.18	2	0.5	µg/L
Chlorobenzene	WL/ EPA 524.2	ND	ND			0.16	2	0.5	µg/L
Chloroethane	WL/ EPA 524.2	ND	ND			0.18	2	0.5	µg/L
Chloroform	WL/ EPA 524.2	ND	**0.2**			0.17	2	0.5	µg/L
Dibromochloromethane	WL/ EPA 524.2	ND	**1.6**		34	0.19	2	0.5	µg/L
Dibromomethane	WL/EPA 524.2	ND	ND			0.18	2	0.5	µg/L
Dichloromethane (DCM)	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
Ethylbenzene	WL/ EPA 524.2	ND	ND			0.17	2	0.5	µg/L
Methyl Bromide(Bromomethane)	WL/ EPA 524.2	ND	ND			0.21	2	0.5	µg/L
Tert-butyl Alcohol (TBA)	WL/ EPA 524.2	ND	ND			0.47		2.0	µg/L
Tetrachloroethylene (PCE)	WL/ EPA 524.2	ND	ND		8.85	0.26	2	0.5	µg/L
Toluene	WL/ EPA 524.2	ND	ND			0.15	2	0.5	µg/L
trans-1,2-Dichloroethylene	WL/ EPA 524.2	ND	ND			0.18	1	0.5	µg/L
Trichloroethylene (TCE)	WL/ EPA 524.2	ND	ND		81	0.18	2	0.5	µg/L

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Table A1.16: 2010 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
1st Quarter in 2010									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**1/13/10**	**Intake INF-001**	**Plant Effluent**	**Monthly Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Constituent/ Parameters	**Method**								
Vinyl Chloride	WL/ EPA 524.2	ND	ND			0.18	2	0.5	µg/L
Non-Volatile Synthetic Organic Chemicals									
1,12-benzoperylene, same as benzo (g,h,i) perylene	WL/ EPA 625/8270	ND	ND			0.31	5	5	µg/L
1,2,5,6-dibenzanthracene, same as dibenzo (a,h) anthracene	WL/ EPA 625/8270	ND	ND		0.049	0.32	10	5	µg/L
1,2-diphenylhydrazine	WL/ EPA 625/8270	ND	ND		0.54	0.35	1	1.0	µg/L
2,4,6-trichlorophenol	WL/ EPA 625/8270	ND	ND		6.5	0.88	10	10	µg/L
2,4-dichlorophenol	WL/ EPA 625/8270	ND	ND			0.77	5	5	µg/L
2,4-dimethylphenol	WL/ EPA 625/8270	ND	ND			0.80	2	2	µg/L
2,4-dinitrophenol	WL/ EPA 625/8270	ND	ND			5	5	10	µg/L
2,4-dinitrotoluene	WL/ EPA 625/8270	ND	ND		9.1	0.4	5	5	µg/L
2,6-dinitrotoluene	WL/ EPA 625/8270	ND	ND			0.24	5	5	µg/L
2-chloronaphthalene	WL/ EPA 625/8270	ND	ND			0.26	10	5	µg/L
2-chlorophenol	WL/ EPA 625/8270	ND	ND			0.71	5	5	µg/L
2-Methyl-4,6-Dinotrophenol	WL/ EPA 625/8270	ND	ND			0.33	5	5	µg/L
2-nitrophenol	WL/ EPA 625/8270	ND	ND			0.84	10	10	µg/L
3,3'-dichlorobenzidine	WL/ EPA 625/8270	ND	ND		0.077	0.3	5	5	µg/L
3-Methyl-4-Chlorophenol	WL/ EPA 625/8270	ND	ND			0.40	1	1.0	
4,4'-DDD	WL/ EPA 608	ND	ND		0.00084	0.003	0.05	0.050	µg/L
4,4'-DDE	WL/ EPA 608	ND	ND		0.00059	0.0025	0.05	0.050	µg/L
4,4'-DDT	WL/ EPA 608	ND	ND		0.00059	0.0031	0.01	0.010	µg/L
4-bromophenyl phenyl ether	WL/ EPA 625/8270	ND	ND			0.23	5	5	µg/L
4-chlorophenyl phenyl ether	WL/ EPA 625/8270	ND	ND			0.24	5	5	µg/L
4-nitrophenol	WL/ EPA 625/8270	ND	ND			6.7	10	10	µg/L
Acenaphthene	WL/ EPA 625/8270	ND	ND			0.31	1	1	µg/L
Acenaphthylene	WL/ EPA 625/8270	ND	ND			0.26	10	5	µg/L
Aldrin	WL/ EPA 608	ND	ND		0.00014	0.0015	0.005	0.0050	µg/L
Alpha-BHC	WL/ EPA 608	ND	ND		0.013	0.0018	0.01	0.01	µg/L
Alpha-endosulfan	WL/ EPA 608	ND	ND			0.0017	0.02	0.02	µg/L

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Table A1.16: 2010 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
1st Quarter in 2010									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**1/13/10**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Anthracene	WL/ EPA 625/8270	ND	ND			0.28	10	5	µg/L
Benzidine	WL/ EPA 625/8270	ND	ND		0.00054	0.7	5	5	µg/L
Benzo(a) anthracene	WL/ EPA 625/8270	ND	ND		0.049	0.19		5	µg/L
Benzo(a)pyrene	WL/ EPA 625/8270	ND	ND		0.049	0.2	10	10	µg/L
Benzo(b) fluoranthene	WL/ EPA 625/8270	ND	ND		0.049	0.16		5	µg/L
Benzo(k) fluoranthene	WL/ EPA 625/8270	ND	ND		0.049	0.23	10	10	µg/L
Beta-BHC	WL/ EPA 608	ND	ND		0.046	0.0031	0.005	0.0050	µg/L
Beta-endosulfan	WL/ EPA 608	ND	ND			0.0019	0.01	0.01	µg/L
Bis (2-ethylhexyl) phthalate (same as di(2-ethylhexyl) phthalate	WL/ EPA 625/8270	ND	ND		5.9	0.21	5	4.0	µg/L
Bis(2-chloroethoxy) methane	WL/ EPA 625/8270	ND	ND			0.40	5.00	5	µg/L
Bis(2-chloroethyl) ether	WL/ EPA 625/8270	ND	ND		1.4	0.46	1	1.0	µg/L
Bis(2-chloroisopropyl) ether	WL/ EPA 625/8270	ND	ND			0.48	2	2.0	µg/L
Butyl benzyl phthalate	WL/ EPA 625/8270	ND	ND			0.29	10	5	µg/L
Chlordane	WL/ EPA 608	ND	ND		0.00059	0.08	0.1	0.1	µg/L
Chrysene	WL/ EPA 608	ND	ND		0.049	0.25	10	5	µg/L
Delta-BHC	WL/ EPA 608	ND	ND			0.0025	0.005	0.0050	µg/L
Dieldrin	WL/ EPA 608	ND	ND		0.00014	0.0021	0.01	0.01	µg/L
Diethyl phthalate	WL/ EPA 625/8270	ND	ND			0.23	2	2.0	µg/L
Dimethyl phthalate	WL/ EPA 625/8270	ND	ND			0.26	2	2.0	µg/L
Di-n-butyl phthalate	WL/ EPA 625/8270	ND	ND			0.53	10	5.0	µg/L
Di-n-octyl phthalate	WL/ EPA 625/8270	ND	ND			0.28	10	5.0	µg/L
Endosulfan sulfate	WL/ EPA 608	ND	ND			0.008	0.05	0.050	µg/L
Endrin	WL/ EPA 608	ND	ND		0.81	0.0028	0.01	0.01	µg/L
Endrin aldehyde	WL/ EPA 608	ND	ND		0.81	0.003	0.01	0.01	µg/L
Fluoranthene	WL/ EPA 625/8270	ND	ND			0.16	1	1.0	µg/L
Fluorene	WL/ EPA 625/8270	ND	ND			0.28	10	5.0	µg/L
Heptachlor	WL/ EPA 608	ND	ND		0.00021	0.0017	0.01	0.01	µg/L
Heptachlor Epoxide	WL/ EPA 608	ND	ND		0.00011	0.0019	0.01	0.01	µg/L
Hexachlorobenzene	WL/ EPA 625/8270	ND	ND		0.00077	0.15	1	1.0	µg/L

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Table A1.16: 2010 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
1st Quarter in 2010									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**1/13/10**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
Hexachlorobutadiene	WL/ EPA 625/8270	ND	ND		50	0.41	1	1.0	µg/L
Hexachlorocyclopentadiene	WL/ EPA 625/8270	ND	ND			5	5	10	µg/L
Hexachloroethane	WL/ EPA 625/8270	ND	ND		8.9	0.36	1	1.0	µg/L
Indeno(1,2,3-cd) pyrene	WL/ EPA 625/8270	ND	ND		0.049	0.32	10	10	µg/L
Isophorone	WL/ EPA 625/8270	ND	ND			0.33	1	1.0	µg/L
Lindane (Gamma BHC)	WL/ EPA 608	ND	ND		0.053	0.0021	0.02	0.020	µg/L
Napththalene	WL/ EPA 625/8270	ND	ND			0.35	1	1.0	µg/L
Nitrobenzene	WL/ EPA 625/8270	ND	ND			0.37	1	1.0	µg/L
n-Nitrosodimethylamine (NDMA)	WL/ EPA 1625M	ND	ND		8.1	0.23	5	2.0	µg/L
N-nitrosodi-n-propylamine	WL/ EPA 625/8270	ND	ND		1.4	0.41	5	5.0	µg/L
N-nitrosodiphenylamine	WL/ EPA 625/8270	ND	ND		16	0.23	1	1.0	µg/L
Pentachlorophenol	WL/ EPA 625/8270	ND	ND		8.2	0.56	5	5.0	µg/L
Phenanthrene	WL/ EPA 625/8270	ND	ND			0.25	5	5.0	µg/L
Phenol	WL/ EPA 625/8270	ND	ND			0.3	1	1.0	µg/L
Polychlorinated Biphenyls	WL/ EPA 608	ND	ND		0.00017	0.04 - 0.15	0.5	0.50	µg/L
Pyrene	WL/ EPA 625/8270	ND	ND			0.16	10	5	µg/L
Toxaphene	WL/ EPA 608	ND	ND		0.00075	0.12	0.5	0.5	µg/L
TCDD Dioxins EQ	WL/ EPA 1613 M	**0.6317**	**0.6656**	1.4E-08	2.8E-08	Equivalent	Equivalent		µg/L
				TEF		**INF-001**	**EFF-001**		
2,3,7,8- tetra CDD	WL/ EPA 1613 M	<0.519	<0.507	1.0					
1,2,3,7,8- penta CDD	WL/ EPA 1613 M	<0.546	<0.561	1.0					
1,2,3,4,7,8 hexa CDD	WL/ EPA 1613 M	<0.549	<0.510	0.1					
1,2,3,6,7,8 hexa CDD	WL/ EPA 1613 M	<0.6	<0.523	0.1					
1,2,3,7,8,9 hexa CDD	WL/ EPA 1613 M	<0.661	<0.532	0.1					
1,2,3,4,6,7,8 hepta CDD	WL/ EPA 1613 M	2.69	2.57	0.01		0.0269	0.02570		
Octa CDD	WL/ EPA 1613 M	11.3	12.4	0.0001		0.00113	0.00124		
2,3,7,8 tetra CDF	WL/ EPA 1613 M	1.49	1.43	0.1		0.149	0.14300		
1,2,3,7,8 penta CDF	WL/ EPA 1613 M	<0.525	<0.587	0.05					
2,3,4,7,8 penta CDF	WL/ EPA 1613 M	0.909	0.991	0.5		0.4545	0.49550		
1,2,3,4,7,8 hexa CDF	WL/ EPA 1613 M	<0.512	<0.581	0.1					

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Table A1.16: 2010 Quarter 1 Water Quality Monitoring and Reporting for NPDES

LONG BEACH SEAWATER DESALINATION RESEARCH FACILITY MONITORING AND REPORTING PROGRAM									
1st Quarter in 2010									
NEW PERMIT REPORTING PERIOD: Effective August 15, 2009									
Sampled Date:	**1/13/10**	**Intake INF-**	**Plant**	**Monthly**					
Constituent/ Parameters	**Method**	**001**	**Effluent**	**Ave.**	**Daily Max.**	**MDL**	**ML**	**DLR**	**Units**
1,2,3,6,7,8 hexa CDF	WL/ EPA 1613 M	<0.535	<0.607	0.1					
2,3,4,6,7,8 hexa CDF	WL/ EPA 1613 M	<0.522	<0.592	0.1					
1,2,3,7,8,9 hexa CDF	WL/ EPA 1613 M	<0.531	<0.603	0.1					
1,2,3,4,6,7,8 hepta CDF	WL/ EPA 1613 M	<1.63	<2.21	0.01					
1,2,3,4,7,8,9 hepta CDF	WL/ EPA 1613 M	<0.55	<0.531	0.01					
Octa CDF	WL/ EPA 1613 M	1.35	1.18	0.0001		0.000135	0.00012		
TCDD TEQ						**0.6317**	**0.6656**		

*TCDD Dioxins- Intake water credit applies.

DNQ, detected above the MDL but below the DLR

Appendix A2

Table A2.1: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 1/18/2008-2/14/2008											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 5	24,000	428	8.36	0.03	7.61E-05	43%	79%	10.11	12.54
	NF^2 pass 2		8,000		17.86	1.04	2.61E-06	70%	99%		
	NF^2 overall		32,000		N/A	N/A	N/A	34%	100%		
North	SWRO	SWC3+ × 7	22,400	393	8.51	0.02	9.16E-07	42%	100%	9.02	11.10

Water Quality Constituent		**unit**	**MDL**	**Raw**	**T1P2**	**T2P1**
General WQ	T	°C	N/A	14.0		
	T-alk	mg/L	3.08	79.50	16.84	2.58
	Turbidity	NTU	0.05*	2.25	0.10	0.20
	TDS	mg/L	1*	32502	45	136
	TSS	mg/L	N/A	121	0	0
	Hardness	mg/L	N/A	5922	0.84	0.85
	SDI	N/A	N/A	0.07	0.05	0.06
	Na	mg/L	0.32	10110	17.84	52.55
	Ca	mg/L	0.38	430	0.35	0.30
	K	mg/L	0.11	398	0.73	2.73
	Mg	mg/L	0.72	1182	0.72	0.64
	F	mg/L	0.007	0.321	0.007	0.007
	Br	mg/L	0.21	75.83	0.21	0.37
	Cl	mg/L	0.24	17521	21.20	81.10
	B	mg/L	0.29	4.78	0.86	0.92
	Si	mg/L	0.54	0.54	0.54	0.54
	NH3-N	mg/L	0.06	0.08	0.06	0.06
	NO_3^--N	mg/L	0.05	3.75	0.05	0.09
	NO_2^--N	ug/L	3.9	12.7	4.4	4.0
	OPO_4	mg/L	0.04	0.04	0.04	0.04
	PO_4	mg/L	0.14	0.14	0.14	0.14
	SO_4	mg/L	0.56	2532	0.46	28.36
	S^{2-}	mg/L	0.004	0.004	0.004	0.005

Appendix A2

Table A2.1: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P2	T2P1
Metal	Ag	ug/L	0.02	0.04	0.04	0.04
	Al	ug/L	13	121	13	130
	As	ug/L	0.06	1.41	0.06	0.16
	Ba	ug/L	0.02	9.10	0.02	0.02
	Be	ug/L	0.02	0.02	0.02	0.02
	Cd	ug/L	0.02	0.04	0.02	0.02
	Cr	ug/L	0.05	0.44	0.05	0.05
	Cu	ug/L	0.16	1.67	0.16	0.16
	Fe	ug/L	6.8	114	6.8	6.8
	Hg	ug/L	0.01	0.01	0.01	0.01
	Li	mg/L	0.01	0.01	0.01	0.01
	Mn	ug/L	0.1	5.8	0.1	0.1
	Ni	ug/L	0.08	0.45	0.08	0.08
	Pb	ug/L	0.03	0.28	0.03	0.03
	Sb	ug/L	0.03	0.13	0.03	0.03
	Se	ug/L	0.06	0.02	0.06	0.06
	Th	ug/L	0.03	0.01	0.03	0.03
	Zn	ug/L	2.3	3.8	1.9	1.8
Organic	TOC	mg/L	0.1	0.3	0.1	0.1
	UV 254	abs, cm-1	N/A	0.046	0.020	0.017
DBPs	BCAA	ug/L	0.169	0.169	0.169	0.169
	BDCM	ug/L	0.146	0.146	0.146	0.146
	CHBr3	ug/L	0.265	0.265	2.380	0.691
	CHCl3	ug/L	0.395	0.395	0.395	0.395
	DBAA	ug/L	0.161	0.161	0.161	0.161
	DBCM	ug/L	0.207	0.207	0.626	0.207
	DCAA	ug/L	0.464	0.464	0.464	0.464
	HAA5	ug/L	1*	1	1	1
	MBAA	ug/L	0.321	0.321	0.321	0.321
	MCAA	ug/L	0.601	0.601	0.601	0.601
	TTHM	ug/L	0.05	0.05	2.84	0.64
	TCAA	ug/L	1*	1	1	1

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Table A2.1: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P2	T2P1	
Microbes	Crypto	P/100 ml	0.09*	0.09	0.09	0.09	
	Giardia	P/100 ml	0.09*	0.32	0.09	0.09	
	Male-Specific Coliphage	P/100 ml	1*	1	1	1	
	Coliaphage	P/100 ml	1*	1	1	1	
	HPC	cfu/ml	1*	323	4	20	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1;
#first pass configuration
South-first stage: 5 NF90 elements in each vessel, there were 12 vessels, no second stage
North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.2: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 2/19/2008-3/20/2008											
Operational data		**First Pass Configuration[#]**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 7	30,400	466	6.65	0.02	6.06E-05	46%	79%	9.62	13.97
	NF^2 pass 2		8,000		19.55	0.36	2.47E-06	75%	99%		
	NF^2 overall		38,400		N/A	N/A	N/A	38%	100%		
North	SWRO	SWC3+ × 7	22,400	443	10.28	0.02	9.40E-07	44%	100%	10.34	12.28
Water Quality Constituent			**unit**	**MDL**	**Raw**	**T1P2**	**T2P1**				
General WQ	pH		N/A	N/A	8.13	9.46	6.36				
	T		°C	N/A	15.9						
	T-alk		mg/L	3.08	116	14.48	3.75				
	Turbidity		NTU	0.05*	1.89	0.20	0.31				
	TDS		mg/L	1*	33272	159	202				
	TSS		mg/L	N/A	39.00	0.00	0.00				
	Hardness		mg/L	N/A	6054	0.68	1.89				
	SDI		N/A	N/A	0.10	0.04	0.04				
	Na		mg/L	0.32	10717	75.33	65.93				
	Ca		mg/L	0.38	433	0.37	0.33				
	K		mg/L	0.11	424	2.32	3.38				
	Mg		mg/L	0.72	1208	0.72	0.72				
	F		mg/L	0.007	0.480	0.007	0.002				
	Br		mg/L	0.21	90.10	0.51	0.60				
	Cl		mg/L	0.24	19073	68.80	106				
	B		mg/L	0.29	4.73	1.35	1.08				
	Si		mg/L	0.54	0.67	0.54	0.54				
	NH3-N		mg/L	0.06	0.08	0.06	0.06				
	NO_3^--N		mg/L	0.05	0.68	0.05	0.05				
	NO_2^--N		ug/L	3.9	3.9	3.9	3.9				
	OPO_4		mg/L	0.04	0.06	0.04	0.04				
	PO_4		mg/L	0.14	0.14	0.14	0.14				
	SO_4		mg/L	0.56	2612	0.56	0.56				
	S^{2-}		mg/L	0.004	0.006	0.004	0.004				

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Table A2.2: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P2	T2P1
Metal	Ag	ug/L	0.02	0.04	0.04	0.04
	Al	ug/L	13	140	13	130
	As	ug/L	0.06	1.37	0.13	0.35
	Ba	ug/L	0.02	8.60	0.02	0.02
	Be	ug/L	0.02	0.02	0.02	0.02
	Cd	ug/L	0.02	0.03	0.02	0.02
	Cr	ug/L	0.05	0.39	0.05	0.05
	Cu	ug/L	0.16	2.14	0.16	0.53
	Fe	ug/L	6.8	122.0	6.8	6.8
	Hg	ug/L	0.01	0.01	0.01	0.01
	Li	mg/L	0.01	0.01	0.01	0.01
	Mn	ug/L	0.1	5.1	0.1	0.1
	Ni	ug/L	0.08	0.45	0.08	0.08
	Pb	ug/L	0.03	0.38	0.03	0.03
	Sb	ug/L	0.03	0.12	0.03	0.03
	Se	ug/L	0.06	0.02	0.06	0.06
	Th	ug/L	0.03	0.02	0.03	0.03
	Zn	ug/L	2.3	5.3	2.3	2.3
Organic	TOC	mg/L	0.1	0.4	0.1	0.1
	UV 254	abs, cm-1	N/A	0.022	0.009	0.013
DBPs	BCAA	ug/L	0.169	0.169	0.169	0.169
	BDCM	ug/L	0.146	0.146	0.146	0.146
	CHBr3	ug/L	0.265	0.265	1.283	0.758
	CHCl3	ug/L	0.395	0.395	0.395	0.395
	DBAA	ug/L	0.161	0.161	0.161	0.161
	DBCM	ug/L	0.207	0.207	0.207	0.207
	DCAA	ug/L	0.464	0.464	0.464	0.464
	HAA5	ug/L	1*	1	1	1
	MBAA	ug/L	0.321	0.321	0.321	0.321
	MCAA	ug/L	0.601	0.601	0.601	0.601
	TTHM	ug/L	0.05	0.05	1.18	0.65
	TCAA	ug/L	1*	1	1	1

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Table A2.2: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P2	T2P1	
Microbes	Crypto	P/100 ml	0.09*	0.09	0.09	0.09	
	Giardia	P/100 ml	0.09*	0.09	0.09	0.09	
	Male-Specific Coliphage	P/100 ml	1*	1	1	1	
	Coliaphage	P/100 ml	1*	1	1	1	
	HPC	cfu/ml	1*	118	2	40	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1;
#first pass configuration
South-first stage: 5 NF90 elements in each vessel, there were 12 vessels, second stage: 2 elements in each vessel, there were 8 vessels
North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.3: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 7/31/2008-8/15/2008											
Operational data		**First Pass Configuration[#]**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 5	24,000	281	5.62	0.05	3.88E-05	36%	84%	8.27	11.16
	NF^2 pass 2		8,000		11.97	0.15	1.03E-05	70%	96%		
	NF^2 overall		32,000		N/A	N/A	N/A	28%	99%		
North	SWRO	SWC3+ × 7	22,400	295	6.01	0.02	1.21E-06	37%	99%	8.86	11.17
Water Quality Constituent			**unit**	**MDL**	**Raw**	**T1P2**	**T2P1**				
General WQ	pH		N/A	N/A	8.05	8.52	6.17				
	T		°C	N/A		23.8					
	T-alk		mg/L	3.08	106	10.77	7.40				
	Turbidity		NTU	0.05*	1.66	0.18	0.16				
	TDS		mg/L	1*	33163	208	307				
	TSS		mg/L	N/A	41.00	0.67	0.00				
	Hardness		mg/L	N/A	6264	N/A	N/A				
	SDI		N/A	N/A	0.26	0.04	0.04				
	Na		mg/L	0.32	10819	86.67	78.67				
	Ca		mg/L	0.38	441	0.38	0.38				
	K		mg/L	0.11	439	0.11	0.11				
	Mg		mg/L	0.72	1278	0.72	0.72				
	F		mg/L	0.007	0.61	0.01	0.01				
	Br		mg/L	0.21	116	0.21	0.21				
	Cl		mg/L	0.24	19065	118	108				
	B		mg/L	0.29	4.83	1.60	1.13				
	Si		mg/L	0.54	0.54	0.54	0.54				
	NH3-N		mg/L	0.06	0.11	0.07	0.06				
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05				
	NO_2^--N		ug/L	3.9	3.9	3.9	9.0				
	OPO_4		mg/L	0.04	0.04	0.04	0.04				
	PO_4		mg/L	0.14	0.14	0.14	0.14				
	SO_4		mg/L	0.56	2640	0.56	0.56				
	S^{2-}		mg/L	0.004	0.003	0.003	0.004				

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Table A2.3: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P2	T2P1
Metal	Ag	ug/L	0.02	0.04	0.04	0.04
	Al	ug/L	13	159	13	130
	As	ug/L	0.06	1.41	0.11	0.11
	Ba	ug/L	0.02	N/A	0.11	0.21
	Be	ug/L	0.02	0.02	0.02	0.02
	Cd	ug/L	0.02	0.02	0.02	0.02
	Cr	ug/L	0.05	0.50	0.05	0.05
	Cu	ug/L	0.16	1.99	0.16	0.16
	Fe	ug/L	6.8	123	6.8	6.8
	Hg	ug/L	0.01	0.01	0.01	0.01
	Li	mg/L	0.01	0.01	0.01	0.01
	Mn	ug/L	0.1	4.3	0.3	0.2
	Ni	ug/L	0.08	0.47	0.08	0.08
	Pb	ug/L	0.03	0.48	0.03	0.05
	Sb	ug/L	0.03	0.10	0.03	0.03
	Se	ug/L	0.06	0.06	0.06	0.06
	Th	ug/L	0.03	0.03	0.03	0.03
	Zn	ug/L	2.3	4.1	2.3	2.3
Organic	TOC	mg/L	0.1	0.4	0.2	0.2
	UV 254	abs, cm-1	N/A	0.018	0.003	0.003
DBPs	BCAA	ug/L	0.169	0.169	0.169	0.169
	BDCM	ug/L	0.146	0.146	0.146	0.146
	CHBr3	ug/L	0.265	0.265	18.000	5.733
	CHCl3	ug/L	0.395	0.395	0.395	0.395
	DBAA	ug/L	0.161	0.161	0.161	0.161
	DBCM	ug/L	0.207	0.207	1.567	0.395
	DCAA	ug/L	0.464	0.464	0.464	0.464
	HAA5	ug/L	1*	1	1	1
	MBAA	ug/L	0.321	0.321	0.321	0.321
	MCAA	ug/L	0.601	0.601	0.601	0.601
	TTHM	ug/L	0.05	0.05	19.33	6.00
	TCAA	ug/L	1*	1	1	1

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Table A2.3: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P2	T2P1	
Microbes	Crypto	P/100 ml	0.09*	0.09	0.09	0.09	
	Giardia	P/100 ml	0.09*	0.09	0.09	0.09	
	Male-Specific Coliphage	P/100 ml	1*	1	1	1	
	Coliaphage	P/100 ml	1*	1	1	1	
	HPC	cfu/ml	1*	84	19	71	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1;
#first pass configuration
South-first stage: 5 NF90 elements in each vessel, there were 12 vessels, no second stage
North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.4: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 8/23/2008-9/5/2008											
Operational data		**First Pass Configuration[#]**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 5	24,000	428	8.36	0.03	7.61E-05	43%	79%	10.11	12.54
	NF^2 pass 2		8,000		17.86	1.04	2.61E-06	70%	99%		
	NF^2 overall		32,000		N/A	N/A	N/A	34%	100%		
North	SWRO pass 1	SWC3+ × 7	22,400	282	6.91	0.02	1.24E-06	42%	100%	9.14	9.92
	SWRO pass 2		8,000		15.86	N/A	N/A	82%	N/A		
	SWRO overall		22,400		N/A	N/A	N/A	34%	N/A		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**T1P1**	**T1P2**	**T2P1**	**T2P2**		
General WQ	pH		N/A	N/A	8.02	7.65	10.09	7.95	7.71		
	T		°C	N/A	22.9						
	T-alk		mg/L	3.08	106	105	15.40	2.60	9.80		
	Turbidity		NTU	0.05*	1.64	0.13	0.16	0.21	0.57		
	Conductivity		umhos/cm	N/A	46200	7480	399	439	8.23		
	TDS		mg/L	1*	34493	312	249	144	0		
	TSS		mg/L	N/A	20.77	0.20	0.00	0.13	0.00		
	Na		mg/L	0.32	10438	1655	75.80	22.47	0.32		
	Ca		mg/L	0.38	425	0.38	0.38	0.38	0.38		
	K		mg/L	0.11	441	77.50	2.14	1.01	0.11		
	Mg		mg/L	0.72	1266	5.13	0.72	0.72	0.72		
	F		mg/L	0.007	0.250	0.007	0.007	0.007	0.007		
	Br		mg/L	0.21	95.23	15.60	0.21	0.32	0.21		
	Cl		mg/L	0.24	18283	2595	95.17	38.40	0.24		
	B		mg/L	0.29	4.71	4.97	0.82	0.82	0.65		
	Si		mg/L	0.54	0.54	0.54	0.54	0.54	0.54		
	NH3-N		mg/L	0.06	0.08	0.06	0.06	0.06	0.06		
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.25	0.05		
	NO_2^--N		ug/L	3.9	3.9	6.0	3.3	4.7	3.9		
	OPO_4		mg/L	0.04	0.04	0.04	0.04	0.04	0.04		
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14	0.14		
	SO_4		mg/L	0.56	2569	7.48	0.56	0.56	0.56		
	S^{2-}		mg/L	0.004	0.004	0.004	0.004	0.004	0.004		

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Table A2.4: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P1	T1P2	T2P1	T2P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	0.04	
	Al	ug/L	13	106	13	13	91	13	
	As	ug/L	0.06	0.96	0.06	0.15	0.06	0.06	
	Ba	ug/L	0.02	3.76	0.02	0.02	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.03	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.30	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	1.38	0.16	0.16	0.16	0.16	
	Fe	ug/L	6.8	380.6	6.8	6.8	6.8	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.16	0.01	
	Li	mg/L	0.01	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	2.7	0.1	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.29	0.08	0.08	0.08	0.08	
	Pb	ug/L	0.03	0.33	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.06	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.03	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	0.03	0.03	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	0.02	
	V	ug/L	0.341	0.341	0.341	0.341	0.341	0.341	
	Zn	ug/L	2.3	1.9	2.3	2.3	4.9	2.3	
Organic	TOC	mg/L	0.1	0.4	0.0	0.1	0.1	0.1	
	UV 254	abs, cm-1	N/A	0.013	N/A	0.006	0.007	N/A	
	DOC	mg/L	N/A	0.33	N/A	0.20	0.15	N/A	
	AOC	ug/L acetate	1*	10	N/A	2	N/A	N/A	
DBPs	BCAA	ug/L	0.169	0.169	N/A	0.169	0.169	N/A	
	BDCM	ug/L	0.146	0.146	N/A	0.146	0.146	N/A	
	CHBr3	ug/L	0.265	0.265	N/A	11.600	1.040	N/A	
	CHCl3	ug/L	0.395	0.395	N/A	0.395	0.395	N/A	
	DBAA	ug/L	0.161	0.161	N/A	0.161	0.161	N/A	
	DBCM	ug/L	0.207	0.207	N/A	0.754	0.207	N/A	
	DCAA	ug/L	0.464	0.464	N/A	0.464	0.464	N/A	
	MBAA	ug/L	0.321	0.321	N/A	0.321	0.321	N/A	
	MCAA	ug/L	0.601	0.601	N/A	0.601	0.601	N/A	
	TTHM	ug/L	0.05	0.05	N/A	12.10	1.45	N/A	

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Table A2.4: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P1	T1P2	T2P1	T2P2	
Microbes	Total direct counts	cells/ml	2*	210	N/A	2100	1500	N/A	
	mHPC	cfu/100 ml	2*	189	N/A	300	104	N/A	
	HPC	cfu/ml	1*	100	N/A	1	12	N/A	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit

South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2

#first pass configuration

South-first stage: 5 NF90 elements in each vessel, there were 12 vessels, no second stage

North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.5: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 9/12/2008-9/15/2008											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 5	24,000	50	6.68	0.03	0.00	42%	83%	10.13	12.29
	NF^2 pass 2		8,000		13.65	0.16	0.00	80%	95%		
	NF^2 overall		32,000		N/A	N/A	N/A	37%	99%		
North	SWRO pass 1	SWC3+ × 7	22,400	69	5.41	0.02	0.00	35%	99%	10.96	12.43
	SWRO pass 2		8,000		11.47	N/A	N/A	75%	N/A		
	SWRO overall		22,400		N/A	N/A	N/A	27%	N/A		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**T1P1**	**T1P2**	**T2P1**	**T2P2**		
General WQ	T		°C	N/A	22.2						
	T-alk		mg/L	3.08	112	8.80	16.80	5.30	3.20		
	Turbidity		NTU	0.05*	1.06	0.05	0.10	0.11	0.08		
	Conductivity		umhos/cm	N/A	39600	6850	461	315	7.00		
	TDS		mg/L	1*	34320	0	438	218	0		
	TSS		mg/L	N/A	6.45	0.40	0.00	0.00	0.00		
	Na		mg/L	0.32	10756	1826	106	82.40	3.08		
	Ca		mg/L	0.38	443	3.80	1.65	0.38	0.38		
	K		mg/L	0.11	437	85.70	4.80	4.70	0.11		
	Mg		mg/L	0.72	1255	5.90	0.72	0.72	0.72		
	F		mg/L	0.007	0.007	0.007	0.007	0.007	0.007		
	Br		mg/L	0.21	91.50	17.90	0.21	0.21	0.21		
	Cl		mg/L	0.24	18858	2874	151	111	0.24		
	B		mg/L	0.29	N/A	5.37	0.78	1.45	0.95		
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05	0.05		
	NO_2^--N		ug/L	3.9	3.9	6.0	3.9	3.9	8.0		
	OPO_4		mg/L	0.04	0.04	0.04	0.04	0.04	0.04		
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14	0.14		
	SO_4		mg/L	0.56	2613	0.56	0.56	0.56	0.56		

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Table A2.5: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P1	T1P2	T2P1	T2P2
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	0.04
	Al	ug/L	13	13	13	13	13	13
	As	ug/L	0.06	0.06	0.06	0.06	0.06	0.06
	Ba	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	0.05
	Cu	ug/L	0.16	0.16	0.16	0.16	0.16	0.16
	Fe	ug/L	6.8	6.8	6.8	6.8	6.8	6.8
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	0.01
	Li	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
	Mn	ug/L	0.1	0.1	0.1	0.1	0.1	0.1
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	0.44
	Ni	ug/L	0.08	0.08	0.08	0.08	0.08	0.08
	Pb	ug/L	0.03	0.03	0.03	0.03	0.03	0.03
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	0.03
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	0.06
	Th	ug/L	0.03	0.03	0.03	0.03	0.03	0.03
	U	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	V	ug/L	0.341	0.341	0.341	0.341	0.341	0.341
	Zn	ug/L	2.3	14.3	18.8	29.4	27.3	25.4
Organic	TOC	mg/L	0.1	0.4	0.1	0.2	0.2	0.3

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit

South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2

#first pass configuration

South-first stage: 5 NF90 elements in each vessel, there were 12 vessels, no second stage

North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.6: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 10/1/2008-10/10/2008											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 5	24,000	207	6.29	0.03	4.30E-05	45%	83%	10.25	12.27
	NF^2 pass 2		8,000		15.35	0.15	1.36E-05	78%	95%		
	NF^2 overall		32,000		N/A	N/A	N/A	41%	99%		
North	SWRO pass 1	SWC3+ × 7	22,400	189	8.44	0.02	9.07E-07	46%	100%	11.39	11.78
	SWRO pass 2		8,000		19.07	0.09	2.92E-05	83%	97%		
	SWRO overall		30,400		N/A	N/A	N/A	37%	100%		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**T1P1**	**T1P2**	**T2P1**	**T2P2**		
General WQ	pH		N/A	N/A	8.01	7.95	10.34	5.61	5.63		
	T		°C	N/A	N/A	21.3			N/A		
	T-alk		mg/L	3.08	107	14.50	17.15	3.60	3.10		
	Turbidity		NTU	0.05*	1.72	0.09	0.14	0.11	0.09		
	TDS		mg/L	1*	33795	5260	510	220	51		
	TSS		mg/L	N/A	7.40	0.00	0.00	0.00	0.00		
	Na		mg/L	0.32	10393	1870	109	49.20	1.02		
	Ca		mg/L	0.38	418	3.67	0.83	0.30	0.38		
	K		mg/L	0.11	420	85.45	4.66	2.61	0.06		
	Mg		mg/L	0.72	1220	7.21	0.72	0.72	0.72		
	F		mg/L	0.007	0.582	0.025	0.007	0.007	0.006		
	Br		mg/L	0.21	80.25	16.15	1.05	0.42	0.21		
	Cl		mg/L	0.24	18404	2942	157	75.75	0.90		
	B		mg/L	0.29	4.73	4.82	0.76	1.00	0.67		
	NH3-N		mg/L	0.06	0.06	0.06	0.06	0.06	0.06		
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05	0.05		
	NO_2^--N		ug/L	3.9	3.9	8.5	6.0	3.9	3.9		
	OPO_4		mg/L	0.04	0.04	0.04	0.04	0.04	0.04		
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14	0.14		
	SO_4		mg/L	0.56	2549	9.68	0.56	0.64	0.56		
	S^{2-}		mg/L	0.004	0.004	0.004	0.004	0.004	0.004		

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Table A2.6: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P1	T1P2	T2P1	T2P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	0.04	
	Al	ug/L	13	85	7	13	72	72	
	As	ug/L	0.06	1.67	0.06	0.23	0.06	0.04	
	Ba	ug/L	0.02	7.66	0.13	0.02	0.07	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.03	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.25	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	1.03	1.19	0.16	0.16	0.32	
	Fe	ug/L	6.8	827	30.5	6.8	6.8	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	
	Li	mg/L	0.01	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	3.1	0.3	0.1	0.2	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.26	1.60	0.08	1.55	0.05	
	Pb	ug/L	0.03	0.23	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.05	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.04	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	0.02	0.03	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	2.4	2.3	2.3	2.3	2.3	
Organic	TOC	mg/L	0.1	0.4	0.1	0.07	0.2	0.1	
DBPs	BDCM	ug/L	0.146	0.146	0.146	0.146	0.146	0.146	
	CHBr3	ug/L	0.265	0.265	7.633	6.633	1.933	1.083	
	CHCl3	ug/L	0.395	0.395	0.395	0.395	0.395	0.395	
	DBCM	ug/L	0.207	0.207	0.704	0.604	0.207	0.207	
	TTHM	ug/L	0.05	0.05	8.025	7.025	1.825	0.975	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit

South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2

#first pass configuration

South-first stage: 5 NF90 elements in each vessel, there were 12 vessels, no second stage

North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.7: NF vs. RO Operational Data and Water Quality

NF vs. RO											
Testing Period: 12/6/2008-12/17/2008											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
North	SWRO	SWC3+ × 7	22,400	186	8.95	0.03	8.40E-07	37%	100%	7.38	11.09
Water Quality Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T2P1**				
General WQ	pH		N/A	N/A	7.76	6.37	5.58				
	T		°C	N/A		14.34					
	T-alk		mg/L	3.08	111	80.80	4.10				
	Turbidity		NTU	0.05*	1.47	0.06	0.22				
	TDS		mg/L	1*	33080	32060	271				
	TSS		mg/L	N/A	5.80	8.90	0.05				
	Na		mg/L	0.32	10419	10518	41.20				
	Ca		mg/L	0.38	441	436	0.38				
	K		mg/L	0.11	423	436	2.26				
	Mg		mg/L	0.72	1001	1226	0.72				
	F		mg/L	0.007	0.583	0.570	0.007				
	Br		mg/L	0.21	83.75	71.00	0.27				
	Cl		mg/L	0.24	18997	18465	63.25				
	B		mg/L	0.29	4.48	N/A	0.85				
	Si		mg/L	0.54	0.73	0.54	0.54				
	NH3-N		mg/L	0.06	0.06	0.06	0.06				
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05				
	NO_2^--N		ug/L	3.9	3.9	3.9	3.9				
	OPO_4		mg/L	0.04	0.04	0.04	0.04				
	PO_4		mg/L	0.14	0.14	0.14	0.14				
	SO_4		mg/L	0.56	2551	2598	0.56				
	S^{2-}		mg/L	0.004	0.004	0.004	0.004				

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Table A2.7: NF vs. RO Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	MF permeate	T2P1
Metal	Ag	ug/L	0.02	0.04	0.04	0.04
	Al	ug/L	13	13	13	13
	As	ug/L	0.06	0.06	0.06	0.06
	Ba	ug/L	0.02	5.51	0.02	2.87
	Be	ug/L	0.02	0.02	0.02	0.02
	Cd	ug/L	0.02	0.02	0.02	0.02
	Co	ug/L	0.02	0.02	N/A	0.02
	Cr	ug/L	0.05	0.05	0.05	0.05
	Cu	ug/L	0.16	0.16	0.16	0.16
	Fe	ug/L	6.8	1751	1125	6.8
	Hg	ug/L	0.01	0.21	0.00	0.01
	Li	mg/L	0.01	0.01	0.01	0.01
	Mn	ug/L	0.1	1.6	0.1	2.2
	Mo	ug/L	0.44	0.44	N/A	0.44
	Ni	ug/L	0.08	0.08	0.08	0.08
	Pb	ug/L	0.03	0.03	0.03	0.03
	Sb	ug/L	0.03	0.03	0.03	0.03
	Se	ug/L	0.06	0.06	0.06	0.06
	Th	ug/L	0.03	0.03	0.03	0.03
	U	ug/L	0.02	0.02	N/A	0.02
	Zn	ug/L	2.3	2.3	2.3	2.3
Organic	TOC	mg/L	0.1	0.3	0.4	0.2
	UV 254	abs, cm-1	N/A	0.013	0.000	0.000
	DOC	mg/L	N/A	0.50	N/A	0.15
	AOC	ug/L acetate	1*	12	N/A	5
Microbes	Total direct counts	cells/ml	2*	527000	N/A	48500
	mHPC	cfu/100 ml	2*	3000	N/A	2000
	ATP	ng/L	1*	45	N/A	6
	HPC	cfu/100ml	1*	N/A	N/A	2440

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
North Train-Train 2; T2P1: Train 2 Pass 1;
#first pass configuration
North-first stage: 5 SWC3+ elements in each vessel, there were 8 vessels; second stage: 2 SWC3+ elements in each vessel, there were 8 vessels

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Table A2.8: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 1/30/09-3/31/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 × 5	20,000	882	7.22	0.03	5.52E-05	39%	82%	9.61	13.55
	NF^2 pass 2		8,000		11.06	0.15	4.03E-06	58%	98%		
	NF^2 overall		28,000		N/A	N/A	N/A	28%	100%		
North	NF^2 pass 1	NF90 × 7	19,600	553	6.82	0.03	3.19E-05	33%	89%	9.19	13.08
	NF^2 pass 2		8,000		11.47	-0.09	1.42E-06	69%	98%		
	NF^2 overall		27,600		N/A	N/A	N/A	27%	100%		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**T1P1**	**T1P2**	**T2P1**	**T2P2**		
General WQ	pH		N/A	N/A	8.03	7.65	6.88	6.91	6.92		
	T		°C	N/A	16.5	16.5	16.8	16.6	16.8		
	T-alk		mg/L	3.08	112	8.23	3.75	12.45	2.03		
	Turbidity		NTU	0.05*	1.22	0.11	0.09	0.11	0.08		
	Conductivity		umhos/cm	N/A	N/A	7635	218	4785	123		
	TDS		mg/L	1*	34267	6290	330	2880	271		
	TSS		mg/L	N/A	6.08	0.63	0.03	0.38	0.00		
	Na		mg/L	0.32	10704	1712	36.98	1167	27.50		
	Ca		mg/L	0.38	427	26.40	0.38	1.63	0.38		
	K		mg/L	0.11	464	85.55	1.75	61.05	1.40		
	Mg		mg/L	0.72	1230	84.40	0.72	5.08	0.72		
	F		mg/L	0.007	0.607	0.007	0.007	0.007	0.007		
	Br		mg/L	0.21	99.25	15.55	0.33	12.30	0.28		
	Cl		mg/L	0.24	18867	2850	56.15	1814	41.38		
	B		mg/L	0.29	4.72	3.72	2.17	3.52	2.24		
	Si		mg/L	0.54	0.54	0.54	0.54	0.54	0.54		
	NH3-N		mg/L	0.06	0.06	0.06	0.06	0.06	0.06		
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.12	0.07		
	NO_2^--N		ug/L	3.9	3.9	3.9	3.9	3.9	3.9		
	OPO_4		mg/L	0.04	0.10	0.04	0.04	0.04	0.04		
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14	0.14		
	SO_4		mg/L	0.56	2563	166	0.56	3.97	0.56		
	S^{2-}		mg/L	0.004	0.004	0.004	0.004	0.004	0.004		

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Table A2.8: NF^2 Optimization Test Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	T1P1	T1P2	T2P1	T2P2
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	0.04
	Al	ug/L	13	228	214	13	13	13
	As	ug/L	0.06	0.06	0.06	0.06	0.06	0.06
	Ba	ug/L	0.02	10.97	28.89	1.58	4.89	1.88
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	0.05
	Cu	ug/L	0.16	6.42	0.16	0.16	0.16	0.16
	Fe	ug/L	6.8	1835	16.7	6.8	6.8	6.8
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	0.01
	Li	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
	Mn	ug/L	0.1	5.4	0.1	0.1	0.1	0.1
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	0.44
	Ni	ug/L	0.08	1.95	0.08	0.08	0.08	0.08
	Pb	ug/L	0.03	1.82	0.03	0.03	0.03	0.03
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	0.03
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	0.06
	Th	ug/L	0.03	0.03	0.03	0.03	0.03	0.03
	U	ug/L	0.02	0.02	0.02	0.02	0.02	0.02
	Zn	ug/L	2.3	23.1	2.3	2.3	2.3	2.3
Organic	TOC	mg/L	0.1	0.6	0.3	0.1	0.2	0.2
	UV 254	abs, cm-1	N/A	0.024	0.008	0.002	0.005	0.003
Microbes	Domoic acid	ug/L	0.002	0.002	N/A	N/A	0.002	0.002

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit

South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2; North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2

#first pass configuration

South-first stage: 5 NF90 elements in each vessel, there were 10 vessels, no second stage

North-first stage: 5 NF90 elements in each vessel, there were 7 vessels; second stage: 2 NF 90 elements in each vessel, there were 7 vessels

Appendix A2

Table A2.9: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 6/30/09-7/20/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	ULP(NE400) x 2 + NF90 x 5	19,600	882	7.22	0.03	5.52E-05	39%	82%	9.61	13.55
	NF^2 pass 2		8,000		11.06	0.15	4.03E-06	58%	98%		
	NF^2 overall		27,600		N/A	N/A	N/A	28%	100%		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T1P1**	**T1P2**			
General WQ	pH		N/A	N/A	7.65	7.75	6.81	7.67			
	T		°C	N/A	20.5	19.7	20.9	21.0			
	T-alk		mg/L	3.08	110	103.60	9.33	6.77			
	Turbidity		NTU	0.05*	1.89	0.09	0.11	0.08			
	Conductivity		umhos/cm	N/A	48950	49033	4763	143			
	TSS		mg/L	N/A	8.38	10.97	0.93	0.10			
	Na		mg/L	0.32	10443	10217	783	24.93			
	Ca		mg/L	0.38	374	368	1.49	0.38			
	K		mg/L	0.11	405	385	33.77	1.09			
	Br		mg/L	0.21	227	235	30.20	0.48			
	Cl		mg/L	0.24	19247	19043	2393	40.17			
	B		mg/L	0.29	3.75	3.76	2.79	1.99			
	Si		mg/L	0.54	0.95	1.63	1.51	1.66			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05			
	NO_2^--N		ug/L	3.9	9.5	3.9	5.3	3.9			
	OPO_4		mg/L	0.04	0.04	0.04	0.04	0.04			
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14			
	SO_4		mg/L	0.56	2531	2518	6.08	0.56			
	S^{2-}		mg/L	0.004	0.003	0.004	0.004	0.004			

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Table A2.9: NF^2 Optimization Test Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	MF permeate	T1P1	T1P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	
	Al	ug/L	13	170	13	13	13	
	As	ug/L	0.06	0.06	0.06	0.06	0.06	
	Ba	ug/L	0.02	6.89	6.42	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	0.16	0.16	0.16	0.16	
	Fe	ug/L	6.8	1049	745	6.8	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	3.1	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.08	0.08	0.08	0.08	
	Pb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	0.03	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	4.3	2.3	2.3	2.3	
Organic	TOC	mg/L	0.1	1.6	1.4	0.2	0.2	
	UV 254	abs, cm-1	N/A	0.033	0.017	0.013	0.015	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2
#first pass configuration
first stage: 2 ULP elements followed by 3 NF90 elements in each vessel, second stage: 2 NF90 elements in each vessel; there were 7 vessels in each stage; Ultravilot (UV) applied as biofouling control method

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Table A2.10: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 7/22/09-8/20/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	ULP(NE400) x 1 + NF90 x 6	19,600	612	5.31	0.03	2.63E-05	33%	89%	10.97	15.59
	NF^2 pass 2		8,000		9.58	0.17	4.93E-06	71%	97%		
	NF^2 overall		27,600		N/A	N/A	N/A	27%	100%		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T1P1**	**T1P2**			
General WQ	pH		N/A	N/A	7.90	7.48	8.56	9.11			
	T		°C	N/A	21.3	22.2	22.8	22.5			
	T-alk		mg/L	3.08	110	103	17.28	12.00			
	Turbidity		NTU	0.05*	1.04	0.07	0.06	0.06			
	Conductivity		umhos/cm	N/A	48700	48500	5385	233			
	TSS		mg/L	N/A	8.98	4.90	0.23	0.03			
	Na		mg/L	0.32	9173	9349	972	36.48			
	Ca		mg/L	0.38	341	343	1.45	0.38			
	K		mg/L	0.11	339	337	42.33	1.62			
	Br		mg/L	0.21	181	175	16.13	0.60			
	Cl		mg/L	0.24	16797	16934	1510	54.73			
	B		mg/L	0.29	3.78	3.72	2.85	2.00			
	Si		mg/L	0.54	0.54	0.54	0.54	0.54			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05			
	NO_2^--N		ug/L	3.9	8.1	3.9	5.7	5.7			
	OPO_4		mg/L	0.04	0.14	0.15	0.17	0.10			
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14			
	SO_4		mg/L	0.56	2284	2304	5.06	0.56			
	S^{2-}		mg/L	0.004	0.004	0.004	0.004	0.004			

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Table A2.10: NF^2 Optimization Test Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	MF permeate	T1P1	T1P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	
	Al	ug/L	13	143	13	13	13	
	As	ug/L	0.06	0.06	0.06	0.06	0.06	
	Ba	ug/L	0.02	7.02	6.06	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	0.16	0.16	0.16	0.16	
	Fe	ug/L	6.8	1002	735	6.8	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	1.4	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.08	0.08	0.08	0.08	
	Pb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	0.03	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	2.3	2.3	2.3	2.3	
Organic	TOC	mg/L	0.1	2.2	1.8	0.3	0.2	
	UV 254	abs, cm-1	N/A	0.038	0.024	0.012	0.015	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2
#first pass configuration
first stage: 1 ULP elements followed by 4 NF90 elements in each vessel, second stage: 2 NF90 elements in each vessel; there were 7 vessels in each stage; UV applied as biofouling control method

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Table A2.11: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 8/21/09-10/15/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	NF90 x 5 + ULP (NE400) x 2	19,600	1070	5.16	0.03	2.27E-05	33%	90%	11.38	16.26
	NF^2 pass 2		8,000		8.90	0.18	4.02E-06	N/A	98%		
	NF^2 overall		27,600		N/A	N/A	N/A	26%	100%		
Water Quality Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T1P1**	**T1P2**			
General WQ	pH		N/A	N/A	7.81	7.39	6.85	7.63			
	T		°C	N/A	21.5	22.3	22.8	22.8			
	T-alk		mg/L	3.08	111	105	9.40	8.23			
	Turbidity		NTU	0.05*	0.94	0.09	0.06	0.07			
	Conductivity		umhos/cm	N/A	49913	49338	4163	137			
	TSS		mg/L	N/A	7.12	4.71	0.36	0.05			
	Na		mg/L	0.32	9656	9798	878	35.31			
	Ca		mg/L	0.38	374	374	1.63	0.38			
	K		mg/L	0.11	371	371	42.75	1.60			
	Br		mg/L	0.21	113	112	11.88	0.37			
	Cl		mg/L	0.24	17905	17900	1412	53.81			
	B		mg/L	0.29	3.70	3.78	2.98	2.33			
	Si		mg/L	0.54	1.36	1.25	1.08	0.96			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05			
	NO_2^--N		ug/L	3.9	5.4	3.9	3.9	3.9			
	OPO_4		mg/L	0.04	0.06	0.05	0.40	0.07			
	PO_4		mg/L	0.14	0.14	0.14	0.28	0.14			
	SO_4		mg/L	0.56	2328	2352	6.87	0.56			
	S^{2-}		mg/L	0.004	0.004	0.007	0.008	0.006			

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Table A2.11: NF^2 Optimization Test Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	MF permeate	T1P1	T1P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	
	Al	ug/L	13	62	13	13	13	
	As	ug/L	0.06	0.06	0.06	0.06	0.06	
	Ba	ug/L	0.02	6.40	5.97	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	0.16	0.16	0.16	0.16	
	Fe	ug/L	6.8	922	755	125	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	1.4	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.08	0.08	0.08	0.08	
	Pb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	0.89	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	2.3	2.3	2.3	2.3	
Organic	TOC	mg/L	0.1	1.8	1.5	0.2	0.2	
	UV 254	abs, cm-1	N/A	0.036	0.036	0.018	0.016	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2
#first pass configuration
first stage: 5 NF90 elements in each vessel, second stage: 2 ULP elements in each vessel; there were 7 vessels in each stage; UV applied as biofouling control method

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Table A2.12: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 10/22/09-1/28/10											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
South	NF^2 pass 1	ULP (NE400) x 1 + NF90 x 6 (with ClO_2)	19,600	1536	6.50	0.03	2.32E-05	34%	92%	9.53	13.67
	NF^2 pass 2		8,000		10.79	0.17	2.45E-06	63%	99%		
	NF^2 overall		27,600		N/A	N/A	N/A	26%	100%		

Water Quality Constituent		**unit**	**MDL**	**Raw**	**MF permeate**	**T1P1**	**T1P2**
General WQ	pH	N/A	N/A	7.85	7.20	6.84	7.65
	T	°C	N/A	15.9	16.1	17.1	17.0
	T-alk	mg/L	3.08	104	99.13	8.41	6.37
	Turbidity	NTU	0.05*	0.80	0.08	0.06	0.06
	Conductivity	umhos/cm	N/A	49906	49619	3666	56.92
	TDS	mg/L	1*	N/A	N/A	N/A	N/A
	TSS	mg/L	N/A	8.00	5.52	0.17	0.09
	Na	mg/L	0.32	9838	9884	695	10.71
	Ca	mg/L	0.38	396	395	0.38	0.38
	K	mg/L	0.11	393	392	35.80	0.54
	Br	mg/L	0.21	249	240	16.62	0.22
	Cl	mg/L	0.24	18506	18588	1131	15.30
	B	mg/L	0.29	3.74	3.71	2.50	1.61
	Si	mg/L	0.54	0.54	0.54	0.54	0.54
	NO_3^--N	mg/L	0.05	0.05	0.05	0.05	0.05
	NO_2^--N	ug/L	3.9	17.6	3.9	3.9	4.0
	OPO_4	mg/L	0.04	0.09	0.06	0.06	0.05
	PO_4	mg/L	0.14	0.14	0.14	0.14	0.14
	SO_4	mg/L	0.56	2543	2573	1.15	0.56
	S^{2-}	mg/L	0.004	0.004	0.004	0.006	0.008

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Table A2.12: NF^2 Optimization Test Operational Data and Water Quality

Water Quality Constituent		unit	MDL	Raw	MF permeate	T1P1	T1P2	
Metal	Ag	ug/L	0.02	0.04	0.08	0.04	0.04	
	Al	ug/L	13	115	13	17	13	
	As	ug/L	0.06	1.17	1.13	0.15	0.10	
	Ba	ug/L	0.02	7.66	7.16	0.81	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.25	2.90	0.16	0.10	
	Cu	ug/L	0.16	2.17	0.54	0.25	1.28	
	Fe	ug/L	6.8	969	857	21.8	8.9	
	Hg	ug/L	0.01	0.04	0.04	0.02	0.02	
	Mn	ug/L	0.1	2.8	0.4	0.3	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.45	2.28	0.35	0.15	
	Pb	ug/L	0.03	0.46	0.05	0.04	0.07	
	Sb	ug/L	0.03	0.04	0.12	0.03	0.03	
	Se	ug/L	0.06	0.19	0.25	0.06	0.06	
	Th	ug/L	0.03	0.23	1.18	0.58	0.61	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	15.2	11.7	14.8	8.9	
Organic	TOC	mg/L	0.1	1.3	1.4	0.2	0.1	
	UV 254	abs, cm-1	N/A	0.037	0.027	0.028	0.027	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
South Train-Train 1; T1P1: Train 1 Pass 1; T1P2: Train 1 Pass 2
#first pass configuration
first stage: 1 ULP element followed by 4 NF90 elements in each vessel, second stage: 2 NF90 elements in each vessel; there were 7 vessels in each stage, ClO_2 applied as biofouling control method

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Table A2.13: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 4/1/09-9/18/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
North	NF^2 pass 1	NF90 × 7 (with ClO_2)	19,600	3002	5.00	0.02	4.38E-05	29%	81%	11.15	15.52
	NF^2 pass 2		8,000		9.34	-0.07	3.50E-06	71%	95%		
	NF^2 overall		27,600		N/A	N/A	N/A	26%	99%		
Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T2P1**	**T2P2**			
General WQ	pH		N/A	N/A	7.78	7.40	7.18	7.49			
	T		°C	N/A	20.1	21.4	21.2	21.5			
	T-alk		mg/L	3.08	116	109	11.43	8.12			
	Turbidity		NTU	0.05*	1.37	0.09	0.07	0.07			
	Conductivity		umhos/cm	N/A	48267	48500	9093	673			
	TSS		mg/L	N/A	8.62	5.93	0.75	0.15			
	Na		mg/L	0.32	10138	10112	1841	126			
	Ca		mg/L	0.38	378	377	5.41	0.37			
	K		mg/L	0.11	408	403	81.11	5.04			
	Br		mg/L	0.21	175	153	24.71	1.91			
	Cl		mg/L	0.24	18404	18246	2933	203			
	B		mg/L	0.29	4.03	3.97	3.57	2.72			
	Si		mg/L	0.54	0.73	0.80	0.71	0.59			
	NH3-N		mg/L	0.06	0.06	N/A	0.06	0.06			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.50	0.05			
	NO_2^--N		ug/L	3.9	8.1	3.9	3.9	3.9			
	OPO_4		mg/L	0.04	0.08	0.10	0.06	0.06			
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14			
	SO_4		mg/L	0.56	2438	2443	20.92	1.19			
	S^{2-}		mg/L	0.004	0.004	0.004	0.004	0.004			

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Table A2.13: NF^2 Optimization Test Operational Data and Water Quality

Constituent		unit	MDL	Raw	MF permeate	T2P1	T2P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	
	Al	ug/L	13	96	13	13	19	
	As	ug/L	0.06	0.45	0.06	0.06	0.06	
	Ba	ug/L	0.02	6.59	6.00	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	0.16	0.16	0.16	6.79	
	Fe	ug/L	6.8	1032	786	6.8	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	1.7	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.08	0.08	0.08	0.95	
	Pb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	0.03	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	2.7	3.0	2.8	3.2	
Organic	TOC	mg/L	0.1	1.5	1.3	0.1	0.1	
	UV 254	abs, cm-1	N/A	0.035	0.023	0.008	0.011	
Microbes	Total direct counts	cells/ml	2*	1545600	N/A	N/A	4305	
	mHPC	cfu/100 ml	2*	4786	N/A	N/A	215	
	ATP	ng/L	1*	2529	N/A	N/A	24	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2
#first pass configuration
first stage: 5 NF 90 elements in each vessel, second stage: 2 NF90 elements in each vessel; there were 7 vessels in each stage,
ClO_2 applied as biofouling control method

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Table A2.14: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 9/18/09-10/15/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
North	NF^2 pass 1	NE90 × 7 (with ClO_2)	19,600	210	5.09	0.03	2.64E-05	30%	87%	9.63	13.46
	NF^2 pass 2		8,000		10.52	-0.35	2.45E-06	74%	97%		
	NF^2 overall		27,600		N/A	N/A	N/A	29%	100%		
Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T2P1**	**T2P2**			
General WQ	pH		N/A	N/A	7.68	7.07	7.31	7.52			
	T		°C	N/A	20.7	21.8	21.6	22.1			
	T-alk		mg/L	3.08	110	104	10.60	8.63			
	Turbidity		NTU	0.05*	0.72	0.10	0.07	0.07			
	Conductivity		umhos/cm	N/A	49725	49375	4435	285			
	TSS		mg/L	N/A	5.53	4.03	0.50	0.13			
	Na		mg/L	0.32	9572	9693	1024	34.43			
	Ca		mg/L	0.38	372	369	3.74	0.38			
	K		mg/L	0.11	371	365	40.48	1.47			
	Br		mg/L	0.21	116	118	13.50	0.38			
	Cl		mg/L	0.24	17684	17798	1567	51.73			
	B		mg/L	0.29	3.69	3.81	3.15	2.41			
	Si		mg/L	0.54	1.57	1.34	0.94	1.25			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05			
	NO_2^--N		ug/L	3.9	3.9	3.9	3.9	2.9			
	OPO_4		mg/L	0.04	0.06	0.06	0.04	0.04			
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14			
	SO_4		mg/L	0.56	2317	2314	7.84	0.56			
	S^{2-}		mg/L	0.004	0.006	0.011	0.011	0.011			

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Table A2.14: NF^2 Optimization Test Operational Data and Water Quality

Constituent		unit	MDL	Raw	MF permeate	T2P1	T2P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	
	Al	ug/L	13	23	13	13	13	
	As	ug/L	0.06	0.06	0.06	0.06	0.06	
	Ba	ug/L	0.02	6.12	5.97	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.05	0.05	0.05	0.05	
	Cu	ug/L	0.16	0.16	0.16	0.16	0.16	
	Fe	ug/L	6.8	798	723	6.8	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	0.1	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.08	0.08	0.08	0.08	
	Pb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Sb	ug/L	0.03	0.03	0.03	0.03	0.03	
	Se	ug/L	0.06	0.06	0.06	0.06	0.06	
	Th	ug/L	0.03	1.76	0.03	0.03	0.03	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	2.3	2.3	2.3	2.3	
Organic	TOC	mg/L	0.1	1.9	1.5	0.2	0.2	
	UV 254	abs, cm-1	N/A	0.047	0.025	0.017	0.019	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2
#first pass configuration
first stage: 5 NE90 elements in each vessel, second stage: 2 NE90 elements in each vessel; there were 7 vessels in each stage,
ClO_2 applied as biofouling control method

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Table A2.15: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 10/22/09-12/19/09											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
North	NF^2 pass 1	ULP (NE400) x 1 + NF90 x 4	20,000	584	7.71	0.04	6.21E-05	38%	81%	9.84	14.00
	NF^2 pass 2		8,000		11.68	-0.05	3.32E-06	61%	96%		
	NF^2 overall		28,000		N/A	N/A	N/A	31%	99%		
Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T2P1**	**T2P2**			
General WQ	pH		N/A	N/A	7.88	6.94	7.20	7.70			
	T		°C	N/A	16.3	17.0	17.2	17.0			
	T-alk		mg/L	3.08	105	99.11	7.96	5.54			
	Turbidity		NTU	0.05*	0.70	0.07	0.07	0.07			
	Conductivity		umhos/cm	N/A	49813	49471	8524	410			
	TSS		mg/L	N/A	7.24	5.07	0.74	0.04			
	Na		mg/L	0.32	9773	9758	1764	73.73			
	Ca		mg/L	0.38	386	386	0.63	0.38			
	K		mg/L	0.11	386	385	91.33	3.70			
	Br		mg/L	0.21	181	176	36.18	1.59			
	Cl		mg/L	0.24	17790	17952	2847	118			
	B		mg/L	0.29	3.77	3.79	3.06	2.43			
	Si		mg/L	0.54	0.54	0.53	0.54	0.54			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05			
	NO_2^--N		ug/L	3.9	11.2	3.9	3.9	29.5			
	OPO_4		mg/L	0.04	0.09	0.08	0.06	0.05			
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14			
	SO_4		mg/L	0.56	2502	2535	1.65	0.56			
	S^{2-}		mg/L	0.004	0.004	0.005	0.006	0.014			

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Table A2.15: NF^2 Optimization Test Operational Data and Water Quality

Constituent		unit	MDL	Raw	MF permeate	T2P1	T2P2	
Metal	Ag	ug/L	0.02	0.04	0.04	0.04	0.04	
	Al	ug/L	13	61	13	13	13	
	As	ug/L	0.06	0.32	0.33	0.06	0.06	
	Ba	ug/L	0.02	7.53	7.22	0.02	0.02	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.02	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.15	0.09	0.05	0.05	
	Cu	ug/L	0.16	2.52	0.60	4.38	0.16	
	Fe	ug/L	6.8	880	792	9.9	6.8	
	Hg	ug/L	0.01	0.01	0.01	0.01	0.01	
	Mn	ug/L	0.1	1.0	0.1	0.1	0.1	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.18	1.43	0.08	0.08	
	Pb	ug/L	0.03	0.07	0.07	0.03	0.03	
	Sb	ug/L	0.03	0.05	0.06	0.03	0.03	
	Se	ug/L	0.06	0.08	0.09	0.06	0.06	
	Th	ug/L	0.03	0.10	0.11	2.60	0.69	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	14.1	10.0	7.9	10.3	
Organic	TOC	mg/L	0.1	1.6	1.6	0.1	0.2	
	UV 254	abs, cm-1	N/A	0.016	0.007	0.018	0.018	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2
#first pass configuration
first stage: 1 ULP element followed by 4 NF90 elements in each vessel, there were 10 vessels; no second stage

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Table A2.16: NF^2 Optimization Test Operational Data and Water Quality

NF^2 Optimization Test											
Testing Period: 12/28/09-1/28/10											
Operational data		**First Pass Configuration#**	**Membrane Area (ft2)**	**Total Time (hr)**	**Flux (gfd, 25°C)**	**Kw (gfd/psi)**	**Ks (cm/sec)**	**Recovery**	**% Rejection**	**Realistic Power (kwhr/kgal)**	**Actual Power (kwhr/kgal)**
North	NF^2 pass 1	ULP (NE400) x 2 + NF90 x 3	20,000	364	7.10	0.04	4.56E-05	35%	85%	9.59	13.63
	NF^2 pass 2		8,000		11.38	-0.06	3.97E-06	64%	95%		
	NF^2 overall		28,000		N/A	N/A	N/A	29%	99%		
Constituent			**unit**	**MDL**	**Raw**	**MF permeate**	**T2P1**	**T2P2**			
General WQ	pH		N/A	N/A	7.82	7.45	6.59	7.78			
	T		°C	N/A	15.5	15.2	16.7	17.0			
	T-alk		mg/L	3.08	104	99.15	9.65	7.00			
	Turbidity		NTU	0.05*	0.89	0.08	0.07	0.07			
	TDS		umhos/cm	N/A	50000	49767	7170	410			
	TSS		mg/L	N/A	8.77	5.97	0.87	0.20			
	Na		mg/L	0.32	9903	10010	1432	77.39			
	Ca		mg/L	0.38	405	404	0.38	0.38			
	K		mg/L	0.11	401	399	81.98	4.06			
	Br		mg/L	0.21	316	304	37.15	2.34			
	Cl		mg/L	0.24	19223	19225	2265	125			
	B		mg/L	0.29	3.71	3.63	3.02	2.35			
	Si		mg/L	0.54	0.54	0.54	0.54	0.54			
	NO_3^--N		mg/L	0.05	0.05	0.05	0.05	0.05			
	NO_2^--N		ug/L	3.9	24.0	3.9	3.9	3.9			
	OPO_4		mg/L	0.04	0.09	0.04	0.04	0.04			
	PO_4		mg/L	0.14	0.14	0.14	0.14	0.14			
	SO_4		mg/L	0.56	2583	2611	0.56	0.56			
	S^{2-}		mg/L	0.004	0.004	0.004	0.004	0.004			

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Table A2.16: NF^2 Optimization Test Operational Data and Water Quality

Constituent		unit	MDL	Raw	MF permeate	T2P1	T2P2	
Metal	Ag	ug/L	0.02	0.04	0.12	0.04	0.04	
	Al	ug/L	13	169	13	60	13	
	As	ug/L	0.06	2.03	1.93	0.06	0.16	
	Ba	ug/L	0.02	7.79	7.09	0.02	0.15	
	Be	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cd	ug/L	0.02	0.02	0.02	0.02	0.10	
	Co	ug/L	0.02	0.02	0.02	0.02	0.02	
	Cr	ug/L	0.05	0.34	5.72	0.17	0.55	
	Cu	ug/L	0.16	1.83	0.49	0.16	0.16	
	Fe	ug/L	6.8	1058	922	15.8	11.5	
	Hg	ug/L	0.01	0.07	0.07	0.04	0.03	
	Mn	ug/L	0.1	4.7	0.7	0.3	0.2	
	Mo	ug/L	0.44	0.44	0.44	0.44	0.44	
	Ni	ug/L	0.08	0.73	3.13	0.20	0.33	
	Pb	ug/L	0.03	0.85	0.03	0.09	0.15	
	Sb	ug/L	0.03	0.03	0.18	0.03	0.15	
	Se	ug/L	0.06	0.30	0.40	0.06	0.06	
	Th	ug/L	0.03	0.36	2.24	0.73	1.62	
	U	ug/L	0.02	0.02	0.02	0.02	0.02	
	Zn	ug/L	2.3	16.3	13.3	8.9	16.9	
Organic	TOC	mg/L	0.1	1.0	1.2	0.1	0.1	
	UV 254	abs, cm-1	N/A	0.057	0.048	0.045	0.044	

Note: MDL: Method dection limit; all samples with non detectables were reported as the MDL values; *report limit
North Train-Train 2; T2P1: Train 2 Pass 1; T2P2: Train 2 Pass 2
#first pass configuration
first stage: 2 ULP elements followed by 3 NF90 elements in each vessel, there were 10 vessels in first stage, no second stage

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U N I V E R S I T Y O F N E W H A M P S H I R E

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Long Beach Water District (LBWD)
Collimated Beam Testing Report
Desalination Pilot Plant Influent Samples

INTRODUCTION

The purpose of this study was to determine through collimated beam testing the delivered UV Dose needed to control marine heterotrophic plate count bacteria. A dose is needed for the UV reactor that will be specified and put into service to test its effects on reducing membrane fouling at the LBWD Desalination Pilot Plant. Samples were collected by LBWD personnel and shipped via express mail to the UV Research Laboratory at the University of New Hampshire (UNH). These samples were tested for UV percent transmittance and marine heterotrophic plate counts (MHPCs). Samples were then prepared and tested using a seven point collimated beam test in accordance with USEPA protocols to determine the UV dose response of the marine HPCs using both a low pressure high output (LPHO) UV and a medium pressure (MP) UV collimated beam device.

STUDY OBJECTIVES

The study had four objectives:

a. Determine the relative concentrations of marine HPCs in the desalination pilot plant influent and following membrane filters at the pilot plant.
b. Determine the UV transmittance of the desalination pilot plant influent and following membrane filters at the pilot plant.
c. Determine through collimated beam dose response testing the UV dose needed to reduce the concentrations of marine HPCs in the pilot plant influent in order to minimize the potential for biofouling as a cause for desalination membrane (nanofiltration in series) fouling.
d. Determine if there was any significant difference between the marine HPC responses to LPHO UV lamps versus MP UV lamps.

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MATERIALS AND METHODS

The first set of samples from LBWD, one marked MF Raw and one marked MF Permeate, were received at UNH on August 18, 2006. Unfortunately the samples were delayed due to express mail problems and arrived warm. It was decided to run some preliminary tests on these samples to determine UV transmittance values and get initial levels of marine HPCs. The UV transmittance levels were reasonable but the marine HPC data after 24 and 48 hour counts were erratic and unreliable. The MF Raw sample had a percent UV transmittance of 95% and did not appear to contain any solids or turbidity at all. Therefore, after discussions with LBWD it was determined that there was a microstrainer on the influent line prior to the sampling of the MF Raw which explained the lack of solids or turbidity. A second sampling was requested and this time samples of MF Raw Pre-Strainer and MF Permeate were collected and shipped. These samples arrived within 24 hours at the UNH laboratories on August 24, 2006. These samples were immediately analyzed for UV transmittance and marine HPCs. Based on preliminary results the MF Raw Pre-Strainer sample was determined to have the highest marine HPC values and was used for the collimated beam testing.

Marine HPC (MHPC) Determinations – Method 9215 D. Heterotrophic Plate Count – Membrane Filter Method as published in Standard Methods for the Examination of Water and Wastewater (Appendix A) was used in this study with the following modifications. The growth media chosen was Difco™ Marine Agar 2216 to select for marine bacteria. Sample sizes of 100 mL were passed through 47-mm, 0.45 micron gridded membrane filters. For preliminary marine HPC testing, filters were placed on the marine agar and incubated at 20^{o}C for 24 and 48 hours. For the collimated beam testing, filters were placed on the agar and incubated at 20^{o}C for 48 hours in an effort to quantify the largest number of bacteria possible. All plating was done in duplicate for this study. Dilutions were established to produce plates with between 20 and 200 colonies present. The detection limit for this method is therefore determined to be 20 colony forming units (cfu) per 100 mL. All standard microbiological quality assurance and quality control procedures were used as defined in Section 9020 of Standard Methods.

Collimated Beam Tests - All collimated beam studies followed the procedures and protocols established in the USEPA Draft UV Disinfection Guidance Manual (Appendix B) with the exception that marine HPCs were substituted for the test organism. The LPHO studies were performed using an Infilco Degremont Inc., Richmond, VA, LPHO Collimated Beam Device. The Petri Factor for the LPHO Device averaged 0.97 and did not go below 0.95 during the testing. MP studies were performed with a Calgon Carbon, Pittsburgh, PA, MP Collimated Beam Device. The MP device had a modified collimation tube to insure that the Petri Factor did not go below 0.90 during the study and it averaged 0.93 throughout the testing.

UV Transmittance Testing – All UV transmittance testing was performed using a research grade Hitachi 2000 Dual Beam UV Visible Spectrophotometer. Given the

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relatively high UVT of the LBWD samples, matching 10-cm cells were used and the results normalize to percent transmittance per centimeter. The spectrophotometer was zeroed with high quality Type 1 Super-Q™ laboratory water. All samples were analyzed in duplicate for this study.

RESULTS

Table 1 contains the results of the preliminary testing for percent UV transmittance (UVT) and MHPCs on all four samples received from LBWD. These data show that the UVT of all samples is relatively high and ranges from 95.1 to 96.8%. The MHPC data was erratic for the first sampling event on August 18, 2006 likely due to shipping problems and resulting contamination. The August 18, 2006 data will not be discussed further and not used to draw any final conclusions. The MF Raw – Pre Strainer sample of August 24, 2006 had the highest MHPC counts of 5×10^5 cfu/100 mL. As expected the MF Permeate had lower levels of MHPCs and based on this single sampling event it appears the MF filter was able to remove about 99.9% of the MHPCs. Based on wanting the highest number of MHPCs and the very favorable UVT of 96.1%, all remaining testing was performed on the MF Raw Pre-Strainer (MFRPS) sample. For completeness, the UV scan for the MFRPS is shown in Figure 1 and the UV scan for the MF Permeate is shown in Figure 2. For MP UV reactor design purposes, the UV Scan shown in Figure 2 would be representative of the UV transmittance as a function of wavelength for the water that would be entering the UV reactor (i.e., MF Permeate).

Table 1. Results of Preliminary Analyses for LBWD Samples.

Sample Location	Sampling Date	Replicate Number	%UVT (per cm)	MHPCs* cfu/100 mL)
MF Raw	August 18, 2006	A	96.0	4.0E+02
		B	96.2	1.9E+03
		Mean	96.1	1.15E+03
MF Permeate	August 18, 2006	A	96.4	21
		B	96.5	110
		Mean	96.5	6.6E+01
MF Raw Pre-Strainer	August 24, 2006	A	95.5	5.1E+05
		B	96.2	4.8E+05
		Mean	96.1	5.0E+05
MF Permeate	August 24, 2006	A	96.8	5.1E+02
		B	96.6	5.0E+02
		Mean	96.4	5.05E+02

* Incubated at 20°C for 48 hours. Detection Limit is 20 cfu/100 mL.

Figure 1. UV Scan for the MFRPS Sample Collected August 24, 2006

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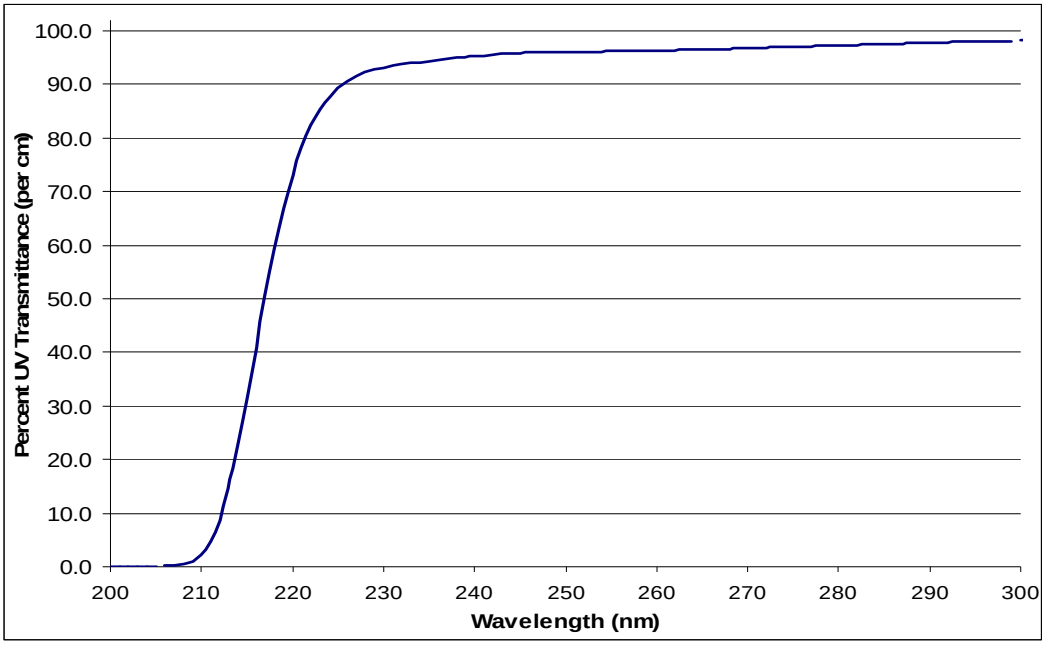
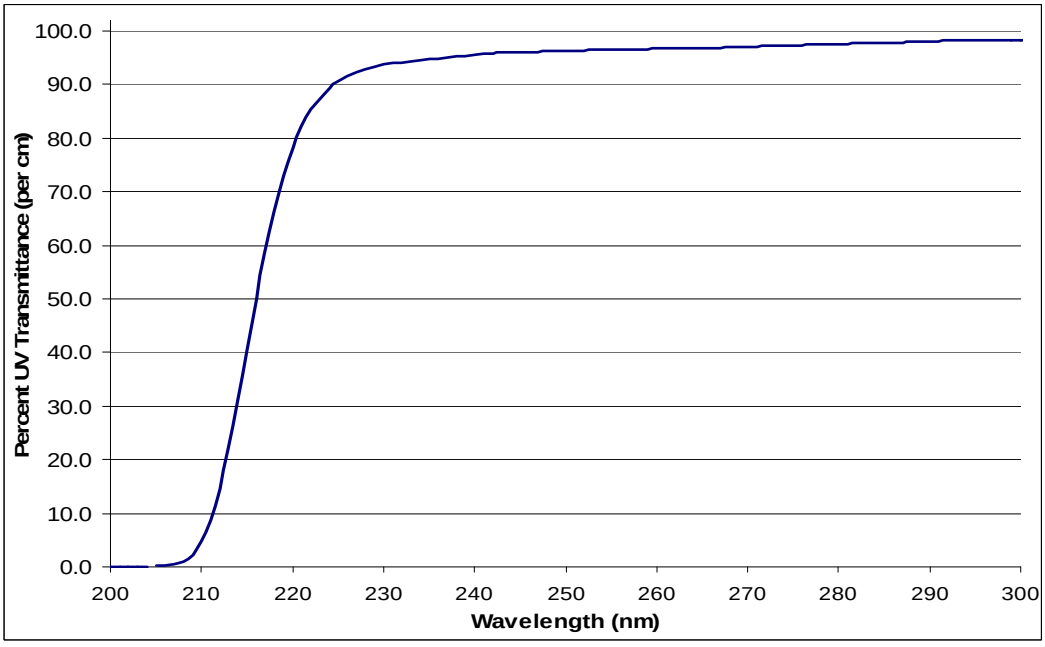


Figure 2. UV Scan for the MF Permeate Sample Collected August 24, 2006



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Results for the collimated beam studies are shown in Figure 3 for the LPHO Lamp type (IDI Unit) and Figure 4 for the MP Lamp Type (Calgon Unit). These data show similar trends in performance and indicate a delivered UV Dose of 40 mJ/cm^2 will reduce the MHPCs to below their method detection limit of 20 cfu/ 100 mL but a delivered UV Dose of 60 mJ/cm^2 is required to reduce the MHPCs to the point where zero colonies are detected on the marine agar plates.

Figure 5 shows a comparison of the collimated beam results for LPHO and MP (diamond symbols). The collimated beam conditions displayed on Figures 3 and 4 are based on the UVDGM protocols which use dose correction spreadsheets developed by Bolton and Linden. These dose correction spreadsheets are structured to determine the required dosing time needed in a collimated beam unit to deliver a UV dose which based on the action spectrum relative to DNA and normalized to an essentially monochromatic at 254nm low pressure UV collimated beam unit. One could then argue the reason the LPHO and the MP units produce results that are not statistically different is because of this normalization. Therefore, also shown on Figure 5 are a series of data points generated for contact times with the MP collimated beam unit that are 5% and 10% below the contact times determine by the Bolton and Linden spreadsheets. The hypothesis is that if the MP unit produces equivalent reductions of MHPCs at these reduced times then there is empirical evidence that the MP lamp system might perform better on marine bacteria than the LPHO system. However, the resulting data shows that performance of the MP unit when the times are reduced by 5% (squares) and 10% (triangles) declines. Therefore, there is no observed difference between the MP lamp system and the LPHO lamp system for these collimated beam tests.

Figure 3. Collimated Beam Results for the LPHO Lamp System (IDI).

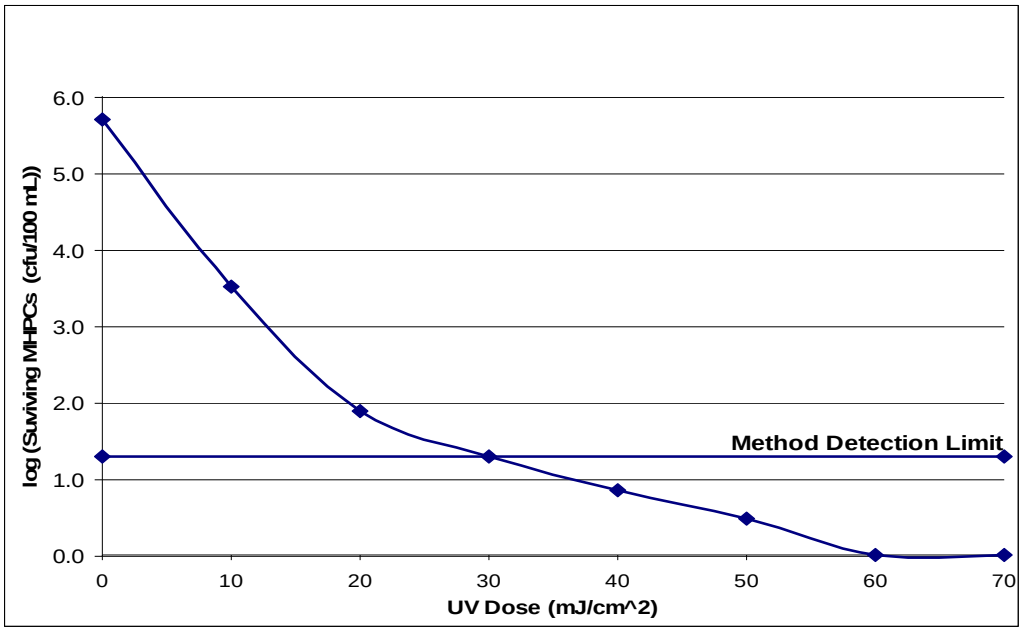

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Figure 4. Collimated Beam Results for the MP Lamp System (Calgon).

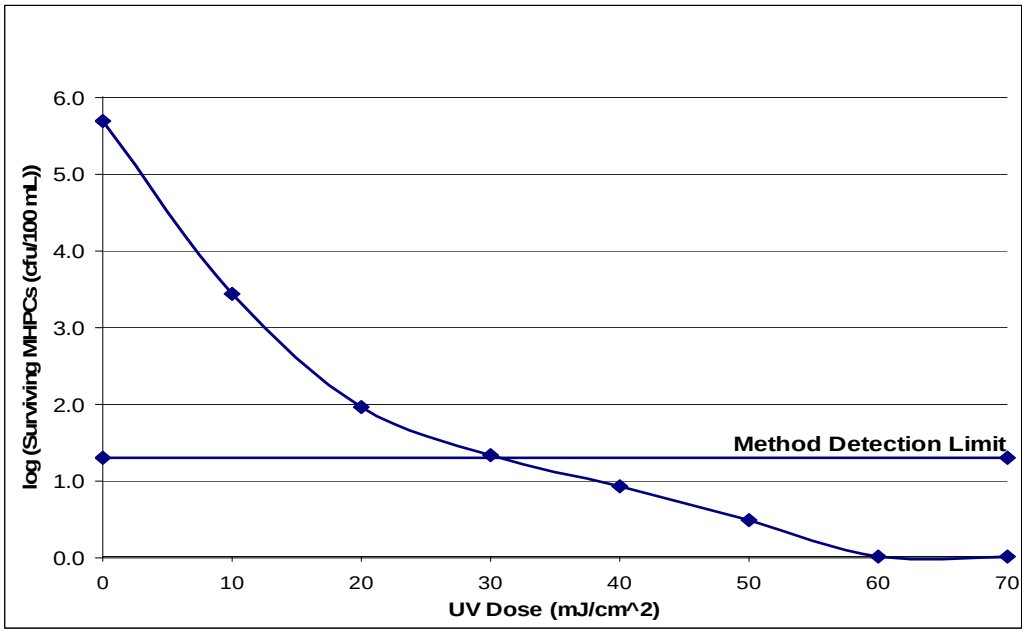
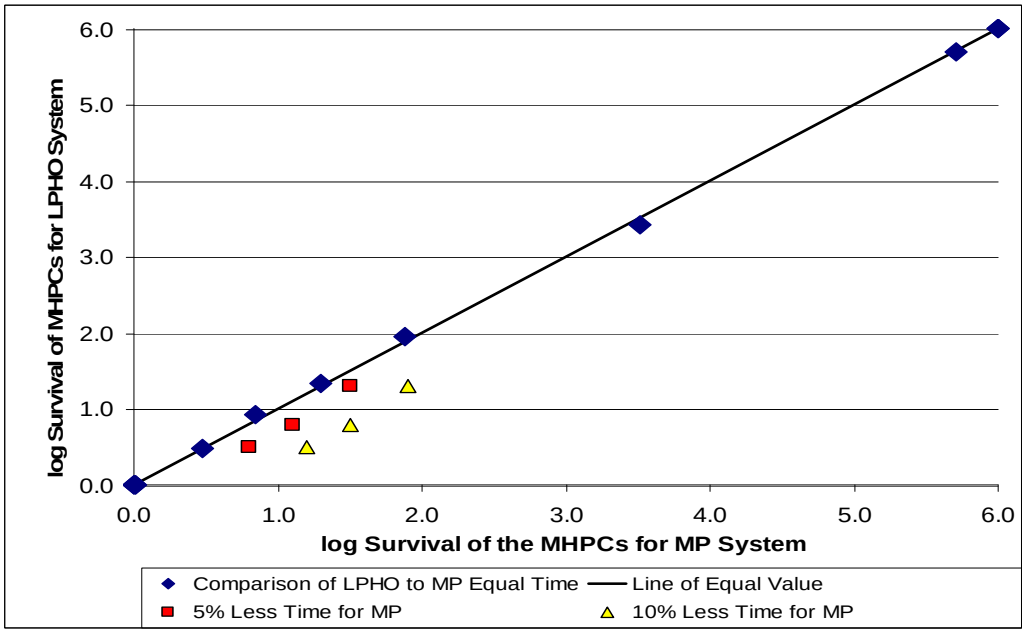


Figure 5. Comparison of MP and LPHO Lamp System Results.



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CONCLUSIONS AND RECOMMENDATIONS

Based upon the August 24, 2006 samples analyzed for MHPCs the concentration in the MF Raw – Pre Strainer was on the order of 10^5 cfu/100 mL. The concentration of MHPCs in the MF Permeate was on the order of 10^2 cfu/100 mL. A brief review of the literature on marine bacterial concentrations, has shown that MHPCs are on the order of 10^5 cfu/100 mL. When MHPC techniques are compared to more intensive and expensive methods of bacterial enumeration it is reported that MHPCs detect between f0.1 to 1% of the total viable bacterial present. Therefore, total marine bacteria are often found to be on the order of 10^7 to 10^8 cfu/100 mL.

Based upon the relationship between MHPCs and total viable bacterial concentrations, it was conservative to use samples from the MF Raw – Pre Strainer location for the collimated beam studies. By doing this the MHPCs measured should compare well with the actual total viable bacterial concentrations present in the MF permeate since the membrane filters remove about 99.9% (3-logs) of the bacteria in their influent.

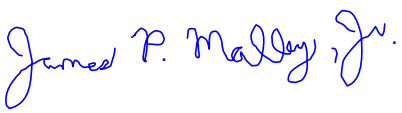
Analysis of the August 24, 2006 samples for UVT at 254nm shows that the UVT of the MF Permeate (the influent for the proposed UV reactor) is in the range of 96% and this value was not significantly altered by the strainer or the membrane filter. UVT is primarily influenced by dissolved organic matter therefore, it is not surprising that neither the strainer nor the membrane filter significantly altered the UVT of the samples.

The collimated beam studies indicate that a delivered UV dose of 40 mJ/cm^2 reduced the MHPCs to below the detection limit of 20 cfu/100 mL and that 60 mJ/cm^2 resulted in no colonies on the MHPC assays. There was no significant difference between LPHO and MP lamp technologies in achieving theses levels of MHPCs.

Based upon the goal of the pilot testing to determine if UV disinfection can reduce the rate of desalination membrane system (dual nanofilters in series) fouling it is conservative to apply a high enough UV dose to remove all measurable MHPC bacterial colonies. If this conservative value reduces the rate of membrane fouling, additional testing can be used to optimize the UV dose. However, if this conservatively high UV dose is not found to improve the rate of membrane system fouling then it is prudent to conclude that this is not a practical application of UV disinfection technology for LBWD.

Please contact me for questions regarding this study or for additional information.

Sincere Regards,



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Appendix C

Table C1.1: Single Pass RO Cost Analysis for 50 MGD Plant

Single Pass RO 50 MGD

Plant Utilization Factor	95%

	Scenario 1	Scenario 2	Scenario 3
Flux, GFD	8.51	10.02	10.28
Recovery	42.0%	41.0%	44.0%
Raw Water Flow, MGD	119.0	122.0	113.6
Finished Water Flow, MGD	50	50	50
PUMPING POWER			
Raw Water Pumping TDH, ft H2O	200	200	200
Raw Water Pumping Efficiency	80%	80%	80%
Raw Water Pumping Power, kW-hr	93,560	95,840	89,300
MF pumping specific power kW-hr/kgal	0.25	0.25	0.25
MF pumping power kW-hr/day	29,286	30,000	27,955
RO/PX Booster Pump Specific Power, kW-hr/kgal	7.14	7.68	8.00
RO/PX Booster Pump Power, kW-hr/day	356980	384110	399910
Permeate Lift Pumping TDH, ft H2O	40	40	40
Permeate Lift Pumping Efficiency	80%	80%	80%
Permeate Lift Pumping Power, kW-hr	7,860	7,860	7,860
Finished Water Pumping TDH, ft H2O	200	200	200
Finished Water Pumping Efficiency	80%	80%	80%
Finished Water Pumping Power, kW-hr	39,300	39,300	39,300
Motor Efficiency	95%	95%	95%
Total Treatment Pumps Specific Power kWh/kgal	10.10	10.69	10.87
CHEMICAL CONSUMPTION			
Prechlorination MF BW, mg/L	2.5	2.5	2.5
Prechlorination MF BW, lbs/day	2480	2540	2370
Dechlorination Pre RO, mg/L	5	5	5
Dechlorination Pre RO, lbs/day	4960	5080	4740
Base Post Treatment, mg/L	44	44	44
Base Post Treatment lbs/day	18320	18320	18320
Carbon Dioxide, mg/L	16	16	16
Carbon Dioxide, lbs/day	6670	6670	6670
Chlorine (Disinfection), mg/L	2	2	2
Chlorine (Disinfection), lbs/day	840	840	840
MISC. UNITS			
No of MF Module	123	126	117
No of MF membranes	11,070	11,340	10,530
Cartridge Filter Loading Rate, gpm/10-inch	4	4	4
Cartridge Filter Length, inches/filter	40	40	40
No. of Cartridge Filters, No.	5200	5300	5000
Cartridge Filter Replacement Frequency, Hours	1000	1000	1000
RO Element Membrane Area, Ft2	400	400	400
RO Elements Per Vessel, No.	7	7	7
No. of Vessels per Train	350	297	290
No. of Trains	6	6	6
No. of Membranes	14689	12475	12160
Membrane Life, Years	6.5	6.5	6.5
Clean in Place Frequency, Times Per Year	6	6	6
Clean in Place Cost, $ per cleaning	$ 15,000	$ 15,000	$ 15,000
Labor, No. of Operators	35	35	35
OPERATIONS COST SUMMARY			
Flux, GFD	8.51	10.02	10.28
Recovery	42%	41%	44%
POWER COSTS			
Raw Water Pumping, $/yr	$ 4,097,928	$ 4,197,792	$ 3,911,340
MF Pumping, $/yr	$ 1,218,579	$ 1,248,300	$ 1,163,189
RO/PX Booster Pumping, $/yr	$ 14,853,938	$ 15,982,817	$ 16,640,255
Permeate Lift Pumping, $/yr	$ 344,268	$ 344,268	$ 344,268
Finished Water Pumping, $/yr	$ 1,721,340	$ 1,721,340	$ 1,721,340
CHEMICAL COSTS			
Prechlorination, $/yr	$ 1,031,928	$ 1,056,894	$ 986,157
Dechlorination, $/yr	$ 515,964	$ 528,447	$ 493,079
Base, $/yr	$ 317,623	$ 317,623	$ 317,623

Appendix C

Table C1.1: Single Pass RO Cost Analysis for 50 MGD Plant

	Scenario 1	Scenario 2	Scenario 3
Carbon Dioxide, $/yr	$ 92,513	$ 92,513	$ 92,513
Chlorine (Disinfection), $/yr	$ 349,524	$ 349,524	$ 349,524
MISC UNITS			
MF Filter Replacement $/yr	$ 720,000	$ 737,000	$ 684,000
Cartridge Filters, $/yr	$ 865,488	$ 882,132	$ 832,200
Membrane Replacement, $/yr	$ 1,242,882	$ 1,055,581	$ 1,028,884
Clean-in-Place, $/yr	$ 90,000	$ 90,000	$ 90,000
Solids Disposal	$ 940,000	$ 940,000	$ 940,000
Maintenance, $/yr	4,685,967	4,629,761	4,508,771
CO2 Reduction	1,000,000	1,000,000	1,000,000
Misc Expenses (e.g., Utilities)	$ 721,738	$ 713,117	$ 695,281
Labor, $/yr	$ 3,582,862	$ 3,582,862	$ 3,582,862
Energy O&M COST			
$/year	$ 22,236,052	$ 23,494,517	$ 23,780,392
$/kgal	$ 1.28	$ 1.36	$ 1.37
Non-Energy O&M COST			
$/year	$ 16,156,488	$ 15,975,453	$ 15,600,892
$/kgal	$ 0.93	$ 0.92	$ 0.90
TOTAL O&M COST			
$/year	$ 38,392,540	$ 39,469,970	$ 39,381,284
$/kgal	$ 2.21	$ 2.28	$ 2.27
CAPITAL COST SUMMARY	Jun-09		
ENR CCI	8578		
Flux, GFD	8.51	10.02	10.28
Recovery	42%	41%	44%
Intake/Intake Pump Station	$ 7,757,400	$ 7,757,400	$ 7,757,400
Prechlorination System MF BW	$ 454,200	$ 454,200	$ 454,200
MF Feed Tank	$ 2,480,159	$ 2,540,650	$ 2,367,424
MF Feed Pump	$ 3,125,939	$ 3,181,974	$ 3,020,545
MF Membranes	$ 7,195,500	$ 7,371,000	$ 6,844,500
MF Modules	$ 26,014,500	$ 26,649,000	$ 24,745,500
Dechlorination System Pre RO	$ 506,000	$ 506,000	$ 506,000
MF Filtrate Tank	$ 2,450,980	$ 2,264,493	$ 2,480,159
MF Transfer Pump/filtered water lift station	$ 7,227,400	$ 7,403,700	$ 6,898,900
Acid Addition System Pre RO	$ 3,666,700	$ 3,666,700	$ 3,666,700
Cartridge Filters	$ 5,862,200	$ 6,005,200	$ 5,595,800
Pass 1 HP Pumps	$ 7,420,008	$ 7,983,918	$ 8,312,329
RO Membranes	$ 8,078,731	$ 6,861,277	$ 6,687,743
RO Skids	$ 17,934,783	$ 15,232,036	$ 14,846,790
Energy Recovery	$ 5,929,844	$ 6,179,206	$ 5,465,122
PX Booster Pumps	$ 1,349,105	$ 1,349,105	$ 1,349,105
Base for Boron Removal Pre RO	$ 431,400	$ 431,400	$ 431,400
Pass 2 HP Pumps			
Chlorination System	$ 282,000	$ 282,000	$ 282,000
Carbon Dioxide System	$ 1,261,500	$ 1,261,500	$ 1,261,500
Building	$ 25,130,900	$ 25,130,900	$ 25,130,900
Electrical	$ 18,517,890	$ 18,272,179	$ 17,743,262
Instrumentation/Control	$ 15,431,575	$ 15,226,816	$ 14,786,052
Transfer Pump Station	$ 515,300	$ 515,300	$ 515,300
Permeate Flush System	$ 279,600	$ 279,600	$ 279,600
Process Piping	$ 6,211,300	$ 6,211,300	$ 6,211,300
Yard Piping	$ 1,752,600	$ 1,752,600	$ 1,752,600
Clean-in-Place System	$ 224,900	$ 224,900	$ 224,900
Lime System	$ 431,400	$ 431,400	$ 431,400
Ground Storage Tank	$ 3,372,800	$ 3,372,800	$ 3,372,800
High Service Pumping Station	$ 2,698,300	$ 2,698,300	$ 2,698,300
Site Work	$ 4,270,300	$ 4,270,300	$ 4,270,300
Subtotal	$ 188,265,212	$ 185,767,155	$ 180,389,832
Engineering & CM (25%)	$ 47,066,303	$ 46,441,789	$ 45,097,458
Permitting	$ 10,000,000	$ 10,000,000	$ 10,000,000
CO2 Reduction	$ 20,000,000	$ 20,000,000	$ 20,000,000
Contractor Overhead & Profit (10%)	$ 18,826,521	$ 18,576,716	$ 18,038,983
Contingencies (15%)	$ 28,239,782	$ 27,865,073	$ 27,058,475
Total Capital Cost	**$ 312,397,818**	**$ 308,650,733**	**$ 300,584,747**

Appendix C

Table C1.1: Single Pass RO Cost Analysis for 50 MGD Plant

	Scenario 1	Scenario 2	Scenario 3
Reclamation Estimate Worksheet Allowance			
Subtotal 1	**$188,265,212**	**$185,767,155**	**$180,389,832**
Mobilization	$9,400,000	$9,300,000	$9,000,000
Subtotal 1 with Mobilization	**$197,665,212**	**$195,067,155**	**$189,389,832**
Escalation to Notice to Proceed (NTP), at 4% per year, for a period of 36 months	$2,334,788	-$67,155	$610,168
Subtotal 2 = Subtotal 1 with Mobilization + Escalation to NTP	**$200,000,000**	**$195,000,000**	**$190,000,000**
Escalation During Construction, at 4% per year, from NTP to mid-point of construction for a period of 24 months	$0	$0	$0
Subtotal 3 = Subtotal 2 + Escalation During Construction	**$200,000,000**	**$195,000,000**	**$190,000,000**
Design Contingencies	$20,000,000	$15,000,000	$20,000,000
APS = Allowance for Procurement Strategies (if applicable), Note: Type of solicitation assumed is Request for Proposal (RFP)	$0	$0	$0
CONTRACT COST	**$220,000,000**	**$210,000,000**	**$210,000,000**
Construction Contingencies	$40,000,000	$50,000,000	$40,000,000
FIELD COST	**$260,000,000**	**$260,000,000**	**$250,000,000**
Non-Contract Costs	$50,000,000	$50,000,000	$50,000,000
CONSTRUCTION COST	**$310,000,000**	**$310,000,000**	**$300,000,000**
Permitting	**$10,000,000**	**$10,000,000**	**$10,000,000**
CO2 Reduction	**$20,000,000**	**$20,000,000**	**$20,000,000**
Total Cost	**$340,000,000**	**$340,000,000**	**$330,000,000**

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Table C1.2: Double Pass RONF Cost Analysis for 50 MGD Plant

Double Pass RO 50 MGD

Plant Utilization Factor	95%

	Scenario 1 (II-4N) 8/23/08)		Scenario 2 (II-5N) (9/12/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
Flux, GFD	6.91	15.89	5.41	11.47
Recovery	42.0%	82.0%	35%	75%
Raw Water Flow, MGD	134.2	61.0	173.8	66.7
Finished Water Flow, MGD	61.0	50	66.7	50
PUMPING POWER				
Raw Water Pumping TDH, ft H2O	200		200	
Raw Water Pumping Efficiency	80%		80%	
Raw Water Pumping Power, kW-hr	105,470		136,590	
MF pumping specific power kW-hr/kgal	0.25		0.25	
MF pumping power kW-hr/day	33,014		42,757	
RO/PX Booster Pump Specific Power, kW-hr/kgal	9.29	1.71	9.81	1.29
RO/PX Booster Pump Power, kW-hr/day	464680	85530	490400	64690
Permeate Lift Pumping TDH, ft H2O		40		40
Permeate Lift Pumping Efficiency		80%		80%
Permeate Lift Pumping Power, kW-hr		7,860		7,860
Finished Water Pumping TDH, ft H2O		200		200
Finished Water Pumping Efficiency		80%		80%
Finished Water Pumping Power, kW-hr		39,300		39,300
Motor Efficiency	95%	95%	95%	95%
Total Treatment Pumps Specific Power kWh/kgal	9.44	2.70	9.51	2.29
CHEMICAL CONSUMPTION				
Prechlorination MF BW, mg/L	2.5		2.5	
Prechlorination MF BW, lbs/day	2800		3620	
Dechlorination Pre RO, mg/L	5		5	

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Table C1.2: Double Pass RONF Cost Analysis for 50 MGD Plant

	Scenario 1 (II-4N) 8/23/08)		Scenario 2 (II-5N) (9/12/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
Dechlorination Pre RO, lbs/day	5590		7240	
Base Post Treatment, mg/L		44		44
Base Post Treatment lbs/day		18320		18320
Carbon Dioxide, mg/L		16		16
Carbon Dioxide, lbs/day		6670		6670
Chlorine (Disinfection), mg/L		2		2
Chlorine (Disinfection), lbs/day		840		840
MISC. UNITS				
No of MF Module	123		147	
No of MF membranes	11,070		13,230	
Cartridge Filter Loading Rate, gpm/10-inch	4		4	
Cartridge Filter Length, inches/filter	40		40	
No. of Cartridge Filters, No.	5900		7600	
Cartridge Filter Replacement Frequency, Hours	1000		1000	
RO Element Membrane Area, Ft2	400	400	400	400
RO Elements Per Vessel, No.	7	7	7	7
No. of Vessels per Train	525	187	734	259
No. of Trains	6	6	6	6
No. of Membranes	22061	7867	30807	10898
Membrane Life, Years	6.5	6.5	6.5	6.5
Clean in Place Frequency, Times Per Year	6	6	6	6
Clean in Place Cost, $ per cleaning	$ 15,000	$ 15,000	$ 15,000	$ 15,000
Labor, No. of Operators	35		35	
OPERATIONS COST SUMMARY				
Flux, GFD	6.91	15.89	5.41	11.47
Recovery	42.0%	82.0%	35.0%	75.0%
POWER COSTS				
Raw Water Pumping, $/yr	$ 4,619,586	$ -	$ 5,982,642	$ -
MF Pumping, $/yr	$ 1,373,724	$ -	$ 1,779,125	$ -

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Table C1.2: Double Pass RONF Cost Analysis for 50 MGD Plant

	Scenario 1 (II-4N) 8/23/08)		Scenario 2 (II-5N) (9/12/08)	
	Pass 1	Pass 2	Pass 1	Pass 2
RO/PX Booster Pumping, $/yr	$ 19,335,335	$ 3,558,903	$ 20,405,544	$ 2,691,751
Permeate Lift Pumping, $/yr	$ -	$ 344,268	$ -	$ 344,268
Finished Water Pumping, $/yr	$ -	$ 1,721,340	$ -	$ 1,721,340
CHEMICAL COSTS				
Prechlorination, $/yr	$ 1,165,080	$ -	$ 1,506,282	$ -
Dechlorination, $/yr	$ 581,500	$ -	$ 753,141	$ -
Base, $/yr	$ -	$ 317,623	$ -	$ 317,623
Carbon Dioxide, $/yr	$ -	$ 92,513	$ -	$ 92,513
Chlorine (Disinfection), $/yr	$ -	$ 349,524	$ -	$ 349,524
MISC UNITS				
MF Filter Replacement $/yr	$ 720,000		$ 860,000	
Cartridge Filters, $/yr	$ 981,996		$ 1,264,944	
Membrane Replacement, $/yr	$ 1,866,670	$ 665,634	$ 2,606,759	$ 922,138
Clean-in-Place, $/yr	$ 90,000	$ 90,000	$ 90,000	$ 90,000
Solids Disposal	$ 1,106,000		$ 1,106,000	
Maintenance, $/yr	$ 5,074,886.10	$ 603,947.19	$ 5,980,360.06	$ 725,991.95
CO2 Reduction	$ 1,000,000.00		$ 1,000,000.00	
Misc Expenses (e.g., Utilities)	$ 758,450	$ 105,962	$ 887,517	$ 124,889
Labor, $/yr	$ 3,582,862	$ -	$ 3,582,862	$ -
Energy O&M COST				
$/year	$ 25,328,645	$ 5,624,511	$ 28,167,311	$ 4,757,359
$/kgal	$1.46	$0.32	$1.22	$0.27
Non-Energy O&M COST				
$/year	$ 16,927,443	$ 2,225,203	$ 19,637,865	$ 2,622,679
$/kgal	$0.80	$0.13	$0.85	$0.15
TOTAL O&M COST				
$/year	$ 42,256,088	$ 7,849,714	$ 47,805,175	$ 7,380,038
$/kgal	$2.00	$0.45	$2.07	$0.43
CAPITAL COST SUMMARY	1995	2006	1995	2006

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Table C1.2: Double Pass RONF Cost Analysis for 50 MGD Plant

	Scenario 1 (II-4N) 8/23/08)		Scenario 2 (II-5N) (9/12/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
ENR CCI	5524.15	7629.95	5524.15	7629.95
Flux, GFD	6.91	15.89	5.41	11.47
Recovery	42.0%	82.0%	35.0%	75.0%
Intake/Intake Pump Station	$ 8,432,000		$ 8,432,000	
Prechlorination System MF BW	$ 823,200		$ 823,200	
MF Feed Tank	$ 2,795,925		$ 3,621,032	
MF Feed Pump	$ 3,125,939		$ 3,575,754	
MF Membranes	$ 7,195,500		$ 8,599,500	
MF Modules	$ 26,014,500		$ 31,090,500	
Dechlorination System Pre RO	$ 534,100		$ 534,100	
MF Filtrate Tank	$ 2,795,925		$ 3,621,032	
MF Transfer Pump/filtered water lift station	$ 8,813,900		$ 11,563,800	
Acid Addition System Pre RO	$ 5,473,900		$ 5,473,900	
Cartridge Filters	$ 7,149,100		$ 9,379,500	
Pass 1 HP Pumps	$ 9,658,606		$ 10,193,209	
RO Membranes	$ 12,133,352	$ 4,326,621	$ 16,943,931	$ 5,993,897
RO Skids	$ 26,936,042	$ 9,605,098	$ 37,615,527	$ 13,306,452
Energy Recovery	$ 7,231,517	$ 942,591	$ 10,632,823	$ 1,431,342
PX Booster Pumps	$ 1,349,105	$ 1,349,105	$ 1,349,105	$ 1,349,105
Base for Boron Removal Pre RO	$ 431,400		$ 431,400	
Pass 2 HP Pumps		$ 1,777,784		$ 1,344,614
Chlorination System		$ 282,000		$ 282,000
Carbon Dioxide System		$ 1,261,500		$ 1,261,500
Building	$ 25,130,900		$ 25,130,900	
Electrical	$ 20,218,081		$ 24,176,437	
Instrumentation/Control	$ 16,848,401		$ 20,147,031	
Transfer Pump Station		$ 515,300		$ 515,300
Permeate Flush System		$ 279,600		$ 279,600
Process Piping	$ 6,211,300		$ 6,211,300	

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Table C1.2: Double Pass RONF Cost Analysis for 50 MGD Plant

	Scenario 1 (II-4N) 8/23/08)		Scenario 2 (II-5N) (9/12/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
Yard Piping	$ 1,752,600		$ 1,752,600	
Clean-in-Place System	$ 224,900		$ 224,900	
Lime System		$ 431,400		$ 431,400
Ground Storage Tank		$ 3,372,800		$ 3,372,800
High Service Pumping Station		$ 2,698,300		$ 2,698,300
Site Work	$ 4,270,300		$ 4,270,300	
Subtotal	$ 205,550,493	$ 26,842,097	$ 245,793,781	$ 32,266,309
Engineering & CM (25%)	$ 51,387,623	$ 6,710,524	$ 61,448,445	$ 8,066,577
Permitting	$ 10,000,000		$ 10,000,000	
CO2 Reduction	$ 20,000,000		$ 20,000,000	
Contractor Overhead & Profit (10%)	$ 20,555,049	$ 2,684,210	$ 24,579,378	$ 3,226,631
Contingencies (15%)	$ 30,832,574	$ 4,026,315	$ 36,869,067	$ 4,839,946
Total Capital Cost	**$ 338,325,740**	**$ 40,263,146**	**$ 398,690,671**	**$ 48,399,463**
Reclamation Estimate Worksheet Allowance				
Subtotal 1	**$205,550,493**	**$26,842,097**	**$245,793,781**	**$32,266,309**
Mobilization	$10,500,000	$1,350,000	$12,500,000	$1,600,000
Subtotal 1 with Mobilization	**$216,050,493**	**$28,192,097**	**$258,293,781**	**$33,866,309**
Escalation to Notice to Proceed (NTP), at 4% per year, for a period of 36 months	$3,949,507	-$192,097	$1,706,219	$133,691
Subtotal 2 = Subtotal 1 with Mobilization + Escalation to NTP	**$220,000,000**	**$28,000,000**	**$260,000,000**	**$34,000,000**
Escalation During Construction, at 4% per year, from NTP to mid-point of construction for a period of 24 months	$0	$0	$0	$0
Subtotal 3 = Subtotal 2 + Escalation During Construction	**$220,000,000**	**$28,000,000**	**$260,000,000**	**$34,000,000**
Design Contingencies	$20,000,000	$3,000,000	$20,000,000	$3,000,000

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Table C1.2: Double Pass RONF Cost Analysis for 50 MGD Plant

	Scenario 1 (II-4N) 8/23/08)		Scenario 2 (II-5N) (9/12/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
APS = Allowance for Procurement Strategies (if applicable), Note: Type of solicitation assumed is Request for Proposal (RFP)	$0	$0	$0	$0
CONTRACT COST	**$240,000,000**	**$31,000,000**	**$280,000,000**	**$37,000,000**
Construction Contingencies	$50,000,000	$6,000,000	$60,000,000	$8,000,000
FIELD COST	**$290,000,000**	**$37,000,000**	**$340,000,000**	**$45,000,000**
Non Contract Costs	$50,000,000	$8,000,000	$70,000,000	$9,000,000
CONSTRUCTION COST	**$340,000,000**	**$45,000,000**	**$410,000,000**	**$54,000,000**
Permitting	**$10,000,000**		**$10,000,000**	
CO2 Reduction	**$20,000,000**		**$20,000,000**	
Total Cost	**$370,000,000**	**$45,000,000**	**$440,000,000**	**$54,000,000**

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Table C1.3: Double Pass NFNF Cost Analysis for 50 MGD Plant

Double Pass NF 50 MGD

Plant Utilization Factor	95%

	Scenario 1(II-2S) (2/19/08)		Scenario 2 (II-6S) (10/01/08)		Scenario 3 (II-4S) (8/23/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**	**Pass 1**	**Pass 2**
Flux, GFD	6.65	19.55	6.29	15.35	7.05	15.17
Recovery	46%	75%	45%	78%	44%	80%
Raw Water Flow, MGD	128.3	66.7	128.3	64.1	129.5	62.5
Finished Water Flow, MGD	66.7	50	64.1	50	62.5	50
PUMPING POWER						
Raw Water Pumping TDH, ft H2O	200		200		200	
Raw Water Pumping Efficiency	80%		80%		80%	
Raw Water Pumping Power, kW-hr	100,800		100,860		101,810	
MF pumping specific power kW-hr/kgal	0.25		0.25		0.25	
MF pumping power kW-hr/day	31,552		31,574		31,868	
NF/PX Booster Pump Specific Power, kW-hr/kgal	6.64	1.61	6.99	2.18	7.39	2.26
NF/PX Booster Pump Power, kW-hr/day	332000	80420	349440	108890	369650	113020
Permeate Lift Pumping TDH, ft H2O		40		40		40
Permeate Lift Pumping Efficiency		80%		80%		80%
Permeate Lift Pumping Power, kW-hr		7,860		7,860		7,860
Finished Water Pumping TDH, ft H2O		200		200		200
Finished Water Pumping Efficiency		80%		80%		80%
Finished Water Pumping Power, kW-hr		39,300		39,300		39,300
Motor Efficiency	95%	95%	95%	95%	95%	95%
Total Treatment Pumps Specific Power kWh/kgal	6.57	2.60	7.11	3.17	7.63	3.25
CHEMICAL CONSUMPTION						
Prechlorination MF BW, mg/L	2.5		2.5		2.5	
Prechlorination MF BW, lbs/day	2680		2680		2700	
Dechlorination Pre NF, mg/L	5		5		5	
Dechlorination Pre NF, lbs/day	5350		5350		5400	
Base Post Treatment, mg/L		44		44		44
Base Post Treatment lbs/day		18320		18320		18320
Carbon Dioxide, mg/L		16		16		16
Carbon Dioxide, lbs/day		6670		6670		6670
Chlorine (Disinfection), mg/L		2		2		2

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Table C1.3: Double Pass NFNF Cost Analysis for 50 MGD Plant

	Scenario 1(II-2S) (2/19/08)		Scenario 2 (II-6S) (10/01/08)		Scenario 3 (II-4S) (8/23/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**	**Pass 1**	**Pass 2**
Chlorine (Disinfection), lbs/day		840		840		840
MISC. UNITS						
No of MF Module	112		112		117	
No of MF membranes	10,080		10,080		10,530	
Cartridge Filter Loading Rate, gpm/10-inch	4		4		4	
Cartridge Filter Length, inches/filter	40		40		40	
No. of Cartridge Filters, No.	5600		5600		5700	
Cartridge Filter Replacement Frequency, Hours	1000		1000		1000	
NF Element Membrane Area, Ft2	400	400	400	400	400	400
NF Elements Per Vessel, No.	7	7	7	7	7	7
No. of Vessels per Train	597	152	607	194	528	196
No. of Trains	6	6	6	6	6	6
No. of Membranes	25063	6394	25478	8143	22163	8240
Membrane Life, Years	6.5	6.5	6.5	6.5	6.5	6.5
Clean in Place Frequency, Times Per Year	6	6	6	6	6	6
Clean in Place Cost, $ per cleaning	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000
Labor, No. of Operators	35		35		35	
OPERATIONS COST SUMMARY						
Flux, GFD	6.65	19.55	6.29	15.35	7.05	15.17
Recovery	46.0%	75.0%	45.0%	78.0%	44.0%	80.0%
POWER COSTS						
Raw Water Pumping, $/yr	$ 4,415,040	$ -	$ 4,417,668	$ -	$ 4,459,278	$ -
MF Pumping, $/yr	$ 1,312,886	$ -	$ 1,313,774	$ -	$ 1,326,035	$ -
NF/PX Booster Pumping, $/yr	$ 13,814,520	$ 3,346,276	$ 14,540,198	$ 4,530,913	$ 15,381,137	$ 4,702,762
Permeate Lift Pumping, $/yr	$ -	$ 344,268	$ -	$ 344,268	$ -	$ 344,268
Finished Water Pumping, $/yr	$ -	$ 1,721,340	$ -	$ 1,721,340	$ -	$ 1,721,340
CHEMICAL COSTS						
Prechlorination, $/yr	$ 1,115,148	$ -	$ 1,115,148	$ -	$ 1,123,470	$ -
Dechlorination, $/yr	$ 556,534	$ -	$ 556,534	$ -	$ 561,735	$ -
Base, $/yr	$ -	$ 317,623	$ -	$ 317,623	$ -	$ 317,623
Carbon Dioxide, $/yr	$ -	$ 92,513	$ -	$ 92,513	$ -	$ 92,513
Chlorine (Disinfection), $/yr	$ -	$ 349,524	$ -	$ 349,524	$ -	$ 349,524
MISC UNITS						
MF Filter Replacement $/yr	$ 655,000		$ 655,000		$ 684,000	

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Table C1.3: Double Pass NFNF Cost Analysis for 50 MGD Plant

	Scenario 1(II-2S) (2/19/08)		Scenario 2 (II-6S) (10/01/08)		Scenario 3 (II-4S) (8/23/08)	
	Pass 1	Pass 2	Pass 1	Pass 2	Pass 1	Pass 2
Cartridge Filters, $/yr	$ 932,064		$ 932,064		$ 948,708	
Membrane Replacement, $/yr	$ 2,120,686	$ 541,019	$ 2,155,828	$ 689,050	$ 1,875,341	$ 697,226
Clean-in-Place, $/yr	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000
Solids Disposal	$ 1,106,000		$ 1,106,000		$ 1,106,000	
Maintenance, $/yr	5,036,459	553,870	5,059,425	631,942	4,952,512	634,627
CO2 Reduction	$ 1,000,000.00		$ 1,000,000.00		$ 1,000,000.00	
Misc Expenses (e.g., Utilities)	$ 759,738	$ 97,227	$ 762,643	$ 108,533	$ 746,231	$ 109,076
Labor, $/yr	$ 3,582,862	$ -	$ 3,582,862	$ -	$ 3,582,862	$ -
Energy O&M COST						
$/year	$ 19,542,446	$ 5,411,884	$ 20,271,640	$ 6,596,521	$ 21,166,450	$ 6,768,370
$/kgal	$ 0.85	$ 0.31	$ 0.91	$ 0.38	$ 0.98	$ 0.39
Non-Energy O&M COST						
$/year	$ 16,954,490	$ 2,041,776	$ 17,015,504	$ 2,279,185	$ 16,670,859	$ 2,290,589
$/kgal	$ 0.73	$ 0.12	$ 0.77	$ 0.13	$ 0.77	$ 0.13
TOTAL O&M COST						
$/year	$ 36,496,936	$ 7,453,661	$ 37,287,144	$ 8,875,705	$ 37,837,308	$ 9,058,959
$/kgal		$ 0.43	$ 1.68	$ 0.51	$ 1.75	$ 0.52
CAPITAL COST SUMMARY	1995	2006	1995	2006	1995	2006
ENR CCI	5524.15	7629.95	5524.15	7629.95	5524.15	7629.95
Flux, GFD	6.65	19.55	6.29	15.35	7.05	15.17
Recovery	46.0%	75.0%	45.0%	78.0%	44.0%	80.0%
Intake/Intake Pump Station	$ 8,432,000		$ 8,432,000		$ 8,432,000	
Prechlorination System MF BW	$ 823,200		$ 823,200		$ 823,200	
MF Feed Tank	$ 2,672,101		$ 2,673,908		$ 2,698,864	
MF Feed Pump	$ 2,923,166		$ 2,923,166		$ 3,020,545	
MF Membranes	$ 6,552,000		$ 6,552,000		$ 6,844,500	
MF Modules	$ 23,688,000		$ 23,688,000		$ 24,745,500	
Dechlorination System Pre RO	$ 534,100		$ 534,100		$ 534,100	
MF Filtrate Tank	$ 2,672,101		$ 2,673,908		$ 2,698,864	
MF Transfer Pump/filtered water lift station	$ 8,798,600		$ 8,648,200		$ 8,623,600	
Acid Addition System Pre RO	$ 5,473,900		$ 5,473,900		$ 5,473,900	
Cartridge Filters	$ 7,136,600		$ 7,014,600		$ 6,994,700	
Pass 1 HP Pumps	$ 6,900,786		$ 7,263,285		$ 7,683,360	
NF Membranes	$ 13,784,461	$ 3,516,624	$ 14,012,882	$ 4,478,827	$ 12,189,716	$ 4,531,971

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Table C1.3: Double Pass NFNF Cost Analysis for 50 MGD Plant

	Scenario 1(II-2S) (2/19/08)		Scenario 2 (II-6S) (10/01/08)		Scenario 3 (II-4S) (8/23/08)	
	Pass 1	Pass 2	Pass 1	Pass 2	Pass 1	Pass 2
NF Skids	$ 30,601,504	$ 7,806,905	$ 31,108,597	$ 9,942,997	$ 27,061,170	$ 10,060,976
Energy Recovery	$ 6,721,082	$ 1,431,342	$ 6,728,529	$ 1,211,135	$ 6,831,403	$ 1,073,506
PX Booster Pumps	$ 1,349,105	$ 1,349,105	$ 1,349,105	$ 1,349,105	$ 1,349,105	$ 1,349,105
Base for Boron Removal Pre RO	$ 431,400		$ 431,400		$ 431,400	
Pass 2 HP Pumps		$ 1,671,570		$ 2,263,333		$ 2,349,177
Chlorination System		$ 282,000		$ 282,000		$ 282,000
Carbon Dioxide System		$ 1,261,500		$ 1,261,500		$ 1,261,500
Building	$ 25,130,900		$ 25,130,900		$ 25,130,900	
Electrical	$ 20,050,093		$ 20,150,493		$ 19,683,111	
Instrumentation/Control	$ 16,708,411		$ 16,792,078		$ 16,402,593	
Transfer Pump Station		$ 515,300		$ 515,300		$ 515,300
Permeate Flush System		$ 279,600		$ 279,600		$ 279,600
Process Piping	$ 6,211,300		$ 6,211,300		$ 6,211,300	
Yard Piping	$ 1,752,600		$ 1,752,600		$ 1,752,600	
Clean-in-Place System	$ 224,900		$ 224,900		$ 224,900	
Lime System		$ 431,400		$ 431,400		$ 431,400
Ground Storage Tank		$ 3,372,800		$ 3,372,800		$ 3,372,800
High Service Pumping Station		$ 2,698,300		$ 2,698,300		$ 2,698,300
Site Work	$ 4,270,300		$ 4,270,300		$ 4,270,300	
Subtotal	$ 203,842,610	$ 24,616,445	$ 204,863,350	$ 28,086,297	$ 200,111,631	$ 28,205,635
Engineering & CM (25%)	$ 50,960,652	$ 6,154,111	$ 51,215,838	$ 7,021,574	$ 50,027,908	$ 7,051,409
Permitting	$ 10,000,000		$ 10,000,000		$ 10,000,000	
CO2 Reduction	$ 20,000,000		$ 20,000,000		$ 20,000,000	
Contractor Overhead & Profit (10%)	$ 20,384,261	$ 2,461,645	$ 20,486,335	$ 2,808,630	$ 20,011,163	$ 2,820,563
Contingencies (15%)	$ 30,576,391	$ 3,692,467	$ 30,729,503	$ 4,212,945	$ 30,016,745	$ 4,230,845
Total Capital Cost	**$ 335,763,915**	**$ 36,924,668**	**$ 337,295,026**	**$ 42,129,445**	**$ 330,167,446**	**$ 42,308,452**
Reclamation Estimate Worksheet Allowance						
Subtotal 1	**$203,842,610**	**$24,616,445**	**$204,863,350**	**$28,086,297**	**$200,111,631**	**$28,205,635**
Mobilization	$10,000,000	$1,250,000	$10,000,000	$1,400,000	$10,000,000	$1,400,000
Subtotal 1 with Mobilization	**$213,842,610**	**$25,866,445**	**$214,863,350**	**$29,486,297**	**$210,111,631**	**$29,605,635**
Escalation to Notice to Proceed (NTP), at 4% per year, for a period of 36 months	-$3,842,610	$133,555	-$4,863,350	-$486,297	-$111,631	$394,365
Subtotal 2 = Subtotal 1 with Mobilization + Escalation to NTP	**$210,000,000**	**$26,000,000**	**$210,000,000**	**$29,000,000**	**$210,000,000**	**$30,000,000**

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Table C1.3: Double Pass NFNF Cost Analysis for 50 MGD Plant

	Scenario 1(II-2S) (2/19/08)		Scenario 2 (II-6S) (10/01/08)		Scenario 3 (II-4S) (8/23/08)	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**	**Pass 1**	**Pass 2**
Escalation During Construction, at 4% per year, from NTP to mid-point of construction for a period of 24 months	$0	$0	$0	$0	$0	$0
Subtotal 3 = Subtotal 2 + Escalation During Construction	**$210,000,000**	**$26,000,000**	**$210,000,000**	**$29,000,000**	**$210,000,000**	**$30,000,000**
Design Contingencies	$30,000,000	$2,000,000	$30,000,000	$3,000,000	$20,000,000	$3,000,000
APS = Allowance for Procurement Strategies (if applicable), Note: Type of solicitation assumed is Request for Proposal (RFP)	$0	$0	$0	$0	$0	$0
CONTRACT COST	**$240,000,000**	**$28,000,000**	**$240,000,000**	**$32,000,000**	**$230,000,000**	**$33,000,000**
Construction Contingencies	$40,000,000	$6,000,000	$40,000,000	$7,000,000	$50,000,000	$6,000,000
FIELD COST	**$280,000,000**	**$34,000,000**	**$280,000,000**	**$39,000,000**	**$280,000,000**	**$39,000,000**
Non-Contract Costs	$60,000,000	$7,000,000	$60,000,000	$8,000,000	$50,000,000	$8,000,000
CONSTRUCTION COST	**$340,000,000**	**$41,000,000**	**$340,000,000**	**$47,000,000**	**$330,000,000**	**$47,000,000**
Permitting	**$10,000,000**		**$10,000,000**		**$10,000,000**	
CO2 Reduction	**$20,000,000**		**$20,000,000**		**$20,000,000**	
Total Cost	**$370,000,000**	**$41,000,000**	**$370,000,000**	**$47,000,000**	**$360,000,000**	**$47,000,000**

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Table C1.4: Double Pass RONF Cost Analysis for 5 MGD Plant

Single Pass RO 5 MGD

Plant Utilization Factor	95%

	Scenario 1	Scenario 2	Scenario 3
Flux, GFD	8.51	10.02	10.28
Recovery	42.0%	41.0%	44.0%
Raw Water Flow, MGD	11.9	12.2	11.4
Finished Water Flow, MGD	5	5	5
PUMPING POWER			
Raw Water Pumping TDH, ft H2O	200	200	200
Raw Water Pumping Efficiency	80%	80%	80%
Raw Water Pumping Power, kW-hr	9,360	9,590	8,930
MF pumping specific power kW-hr/kgal	0.25	0.25	0.25
MF pumping power kW-hr/day	2928.6	3000.0	2795.5
RO/PX Booster Pump Specific Power, kW-hr/kgal	7.14	7.68	8.00
RO/PX Booster Pump Power, kW-hr/day	35700	38420	40000
Permeate Lift Pumping TDH, ft H2O	40	40	40
Permeate Lift Pumping Efficiency	80%	80%	80%
Permeate Lift Pumping Power, kW-hr	790	790	790
Finished Water Pumping TDH, ft H2O	200	200	200
Finished Water Pumping Efficiency	80%	80%	80%
Finished Water Pumping Power, kW-hr	3,930	3,930	3,930
Motor Efficiency	95%	95%	95%
Total Treatment Pumps Specific Power kWh/kgal	10.10	10.70	10.87
CHEMICAL CONSUMPTION			
Prechlorination MF BW, mg/L	2.5	2.5	2.5
Prechlorination MF BW, lbs/day	250	260	240
Dechlorination Pre RO, mg/L	5	5	5
Dechlorination Pre RO, lbs/day	500	510	480
Base Post Treatment, mg/L	44	44	44
Base Post Treatment lbs/day	1840	1840	1840
Carbon Dioxide, mg/L	16	16	16
Carbon Dioxide, lbs/day	670	670	670
Chlorine (Disinfection), mg/L	2	2	2
Chlorine (Disinfection), lbs/day	90	90	90
MISC. UNITS			
No of MF Module	13	13	12
No of MF membranes	1,170	1,170	1,080
Cartridge Filter Loading Rate, gpm/10-inch	4	4	4
Cartridge Filter Length, inches/filter	40	40	40
No. of Cartridge Filters, No.	600	600	500
Cartridge Filter Replacement Frequency, Hours	1000	1000	1000
RO Element Membrane Area, Ft2	400	400	400
RO Elements Per Vessel, No.	7	7	7
No. of Vessels per Train	35	30	29
No. of Trains	6	6	6
No. of Membranes	1469	1248	1216
Membrane Life, Years	6.5	6.5	6.5
Clean in Place Frequency, Times Per Year	6	6	6
Clean in Place Cost, $ per cleaning	$ 15,000	$ 15,000	$ 15,000
Labor, No. of Operators	15	15	15

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Table C1.4: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1	Scenario 2	Scenario 3
OPERATIONS COST SUMMARY			
Flux, GFD	8.51	10.02	10.28
Recovery	42%	41%	44%
POWER COSTS			
Raw Water Pumping, $/yr	$ 409,968	$ 420,042	$ 391,134
MF Pumping, $/yr	$ 121,858	$ 124,830	$ 116,319
RO/PX Booster Pumping, $/yr	$ 1,485,477	$ 1,598,656	$ 1,664,400
Permeate Lift Pumping, $/yr	$ 34,602	$ 34,602	$ 34,602
Finished Water Pumping, $/yr	$ 172,134	$ 172,134	$ 172,134
CHEMICAL COSTS			
Prechlorination, $/yr	$ 104,025	$ 108,186	$ 99,864
Dechlorination, $/yr	$ 52,013	$ 53,053	$ 49,932
Base, $/yr	$ 31,901	$ 31,901	$ 31,901
Carbon Dioxide, $/yr	$ 9,293	$ 9,293	$ 9,293
Chlorine (Disinfection), $/yr	$ 37,449	$ 37,449	$ 37,449
MISC UNITS			
MF Filter Replacement $/yr	$ 76,000	$ 76,000	$ 70,000
Cartridge Filters, $/yr	$ 99,864	$ 99,864	$ 83,220
Membrane Replacement, $/yr	$ 124,288	$ 105,558	$ 102,888
Clean-in-Place, $/yr	$ 90,000	$ 90,000	$ 90,000
Solids Disposal	$ 188,000	$ 188,000	$ 188,000
Maintenance, $/yr	991,627	979,861	965,683
CO2 Reduction	$ 100,000	$ 100,000	$ 100,000
Misc Expenses (e.g., Utilities)	$ 169,753	$ 168,488	$ 165,941
Labor, $/yr	$ 1,590,594	$ 1,590,594	$ 1,590,594
Energy O&M COST			
$/year	$ 2,224,039	$ 2,350,264	$ 2,378,589
$/kgal	$1.28	$1.36	$1.37
Non-Energy O&M COST			
$/year	$ 3,664,807	$ 3,638,248	$ 3,584,766
$/kgal	$2.11	$2.10	$2.07
TOTAL O&M COST			
$/year	$ 5,888,846	$ 5,988,512	$ 5,963,355
$/kgal	$3.40	$3.45	$3.44
CAPITAL COST SUMMARY	Jun-09	Jun-09	Jun-09
ENR CCI	8578	8578	8578
Flux, GFD	8.51	10.02	10.28
Recovery	42%	41%	44%
Intake/Intake Pump Station	$ 2,482,368	$ 2,482,368	$ 2,482,368
Prechlorination System MF BW	$ 145,344	$ 145,344	$ 145,344
MF Feed Tank	$ 248,016	$ 254,065	$ 236,742
MF Feed Pump	$ 477,816	$ 486,359	$ 461,746
MF Membranes	$ 760,500	$ 760,500	$ 702,000
MF Modules	$ 2,749,500	$ 2,749,500	$ 2,538,000
Dechlorination System Pre RO	$ 161,920	$ 161,920	$ 161,920
MF Filtrate Tank	$ 245,098	$ 245,098	$ 226,449
MF Transfer Pump/filtered water lift station	$ 722,800	$ 740,400	$ 689,900
Acid Addition System Pre RO	$ 1,751,648	$ 1,751,648	$ 1,751,648
Cartridge Filters	$ 586,300	$ 600,600	$ 559,600
Pass 1 HP Pumps	$ 742,042	$ 798,579	$ 831,420
RO Membranes	$ 807,873	$ 686,128	$ 668,774
RO Skids	$ 1,793,478	$ 1,523,204	$ 1,484,679

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Table C1.4: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1	Scenario 2	Scenario 3
Energy Recovery	$ 592,984	$ 617,921	$ 546,512
PX Booster Pumps	$ 596,282	$ 431,713	$ 431,713
Base for Boron Removal Pre RO	$ 138,048	$ 138,048	$ 138,048
Pass 2 HP Pumps			
Chlorination System	$ 90,240	$ 90,240	$ 90,240
Carbon Dioxide System	$ 403,680	$ 403,680	$ 403,680
Building	$ 8,041,888	$ 8,041,888	$ 8,041,888
Electrical	$ 3,548,097	$ 3,496,662	$ 3,434,679
Instrumentation/Control	$ 2,956,747	$ 2,913,885	$ 2,862,232
Transfer Pump Station	$ 164,896	$ 164,896	$ 164,896
Permeate Flush System	$ 89,472	$ 89,472	$ 89,472
Process Piping	$ 1,242,260	$ 1,242,260	$ 1,242,260
Yard Piping	$ 771,144	$ 771,144	$ 771,144
Clean-in-Place System	$ 71,968	$ 71,968	$ 71,968
Lime System	$ 138,048	$ 138,048	$ 138,048
Ground Storage Tank	$ 809,472	$ 809,472	$ 809,472
High Service Pumping Station	$ 863,456	$ 863,456	$ 863,456
Site Work	$ 1,878,932	$ 1,878,932	$ 1,878,932
Subtotal	$ 36,072,318	$ 35,549,397	$ 34,919,232
Engineering & CM (25%)	$ 9,018,079	$ 8,887,349	$ 8,729,808
Permitting	$ 10,000,000	$ 10,000,000	$ 10,000,000
CO2 Reduction	$ 2,000,000	$ 2,000,000	$ 2,000,000
Contractor Overhead & Profit (10%)	$ 3,607,232	$ 3,554,940	$ 3,491,923
Contingencies (15%)	$ 5,410,848	$ 5,332,410	$ 5,237,885
Total Capital Cost	**$ 66,108,477**	**$ 65,324,095**	**$ 64,378,848**
Reclamation Estimate Worksheet Allowance			
Subtotal 1	**$36,072,318**	**$35,549,397**	**$34,919,232**
Mobilization	$1,850,000	$1,800,000	$1,750,000
Subtotal 1 with Mobilization	**$37,922,318**	**$37,349,397**	**$36,669,232**
Escalation to Notice to Proceed (NTP), at 4% per year, for a period of 36 months	$1,077,682	-$349,397	$330,768
Subtotal 2 = Subtotal 1 with Mobilization + Escalation to NTP	**$39,000,000**	**$37,000,000**	**$37,000,000**
Escalation During Construction, at 4% per year, from NTP to mid-point of construction for a period of 24 months	$0	$0	$0
Subtotal 3 = Subtotal 2 + Escalation During Construction	**$39,000,000**	**$37,000,000**	**$37,000,000**
Design Contingencies	$3,000,000	$4,000,000	$3,000,000
APS = Allowance for Procurement Strategies (if applicable), Note: Type of solicitation assumed is Request for Proposal (RFP)	$0	$0	$0
CONTRACT COST	**$42,000,000**	**$41,000,000**	**$40,000,000**
Construction Contingencies	$9,000,000	$8,000,000	$8,000,000
FIELD COST	**$51,000,000**	**$49,000,000**	**$48,000,000**
Non-Contract Costs	$10,000,000	$10,000,000	$10,000,000
CONSTRUCTION COST	**$61,000,000**	**$59,000,000**	**$58,000,000**
Permitting	**$10,000,000**	**$10,000,000**	**$10,000,000**
CO2 Reduction	**$2,000,000**	**$2,000,000**	**$2,000,000**
Total Cost	**$73,000,000**	**$71,000,000**	**$70,000,000**

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Table C1.5: Double Pass RONF Cost Analysis for 5 MGD Plant

Double Pass RONF 5 MGD

Plant Utilization Factor	95%

	Scenario 1		Scenario 2	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
Flux, GFD	6.91	15.89	5.41	11.47
Recovery	42.0%	82.0%	35%	75%
Raw Water Flow, MGD	13.4	6.1	17.4	6.7
Finished Water Flow, MGD	6.1	5.0	6.7	5.0
PUMPING POWER				
Raw Water Pumping TDH, ft H2O	200		200	
Raw Water Pumping Efficiency	80%		80%	
Raw Water Pumping Power, kW-hr	10,550		13,660	
MF pumping specific power kW-hr/kgal	0.25		0.25	
MF pumping power kW-hr/day	3,301		4,276	
RO/PX Booster Pump Specific Power, kW-hr/kgal	9.29	1.71	9.81	1.29
RO/PX Booster Pump Power, kW-hr/day	46470	8560	49040	6470
Permeate Lift Pumping TDH, ft H2O		40		40
Permeate Lift Pumping Efficiency		80%		80%
Permeate Lift Pumping Power, kW-hr		790		790
Finished Water Pumping TDH, ft H2O		200		200
Finished Water Pumping Efficiency		80%		80%
Finished Water Pumping Power, kW-hr		3,930		3,930
Motor Efficiency	95%	95%	95%	95%
Total Treatment Pumps Specific Power kWh/kgal	9.44	2.71	9.51	2.29
CHEMICAL CONSUMPTION				
Prechlorination MF BW, mg/L	2.5		2.5	
Prechlorination MF BW, lbs/day	280		370	
Dechlorination Pre RO, mg/L	5		5	

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Table C1.5: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1		Scenario 2	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
Dechlorination Pre RO, lbs/day	560		730	
Base Post Treatment, mg/L		44		44
Base Post Treatment lbs/day		1840		1840
Carbon Dioxide, mg/L		16		16
Carbon Dioxide, lbs/day		670		670
Chlorine (Disinfection), mg/L		2		2
Chlorine (Disinfection), lbs/day		90		90
MISC. UNITS				
No of MF Module	13		15	
No of MF membranes	1,170		1,350	
Cartridge Filter Loading Rate, gpm/10-inch	4		4	
Cartridge Filter Length, inches/filter	40		40	
No. of Cartridge Filters, No.	600		800	
Cartridge Filter Replacement Frequency, Hours	1000		1000	
RO Element Membrane Area, Ft2	400	400	400	400
RO Elements Per Vessel, No.	7	7	7	7
No. of Vessels per Train	53	19	73	26
No. of Trains	6	6	6	6
No. of Membranes	2206	787	3081	1090
Membrane Life, Years	6.5	6.5	6.5	6.5
Clean in Place Frequency, Times Per Year	6	6	6	6
Clean in Place Cost, $ per cleaning	$ 15,000	$ 15,000	$ 15,000	$ 15,000
Labor, No. of Operators	15		15	
OPERATIONS COST SUMMARY				
Flux, GFD	6.91	15.89	5.41	11.47
Recovery	42.0%	82.0%	35.0%	75.0%
POWER COSTS				
Raw Water Pumping, $/yr	$ 462,090	$ -	$ 598,308	$ -
MF Pumping, $/yr	$ 137,372	$ -	$ 177,912	$ -

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Table C1.5: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1		Scenario 2	
	Pass 1	Pass 2	Pass 1	Pass 2
RO/PX Booster Pumping, $/yr	$ 1,933,617	$ 356,182	$ 2,040,554	$ 269,217
Permeate Lift Pumping, $/yr	$ -	$ 34,602	$ -	$ 34,602
Finished Water Pumping, $/yr	$ -	$ 172,134	$ -	$ 172,134
CHEMICAL COSTS				
Prechlorination, $/yr	$ 116,508	$ -	$ 153,957	$ -
Dechlorination, $/yr	$ 58,254	$ -	$ 75,938	$ -
Base, $/yr	$ -	$ 31,901	$ -	$ 31,901
Carbon Dioxide, $/yr	$ -	$ 9,293	$ -	$ 9,293
Chlorine (Disinfection), $/yr	$ -	$ 37,449	$ -	$ 37,449
MISC UNITS				
MF Filter Replacement $/yr	$ 76,000		$ 88,000	
Cartridge Filters, $/yr	$ 99,864		$ 133,152	
Membrane Replacement, $/yr	$ 186,667	$ 66,563	$ 260,676	$ 92,214
Clean-in-Place, $/yr	$ 90,000	$ 90,000	$ 90,000	$ 90,000
Solids Disposal	$ 221,200		$ 221,200	
Maintenance, $/yr	1,011,528	104,767	1,099,757	116,969
CO2 Reduction	$ 100,000		$ 100,000	
Misc Expenses (e.g., Utilities)	$ 172,531	$ 16,999	$ 185,664	$ 18,891
Labor, $/yr	$ 1,590,594	$ -	$ 1,590,594	$ -
Energy O&M COST				
$/year	$ 2,533,079	$ 562,918	$ 2,816,775	$ 475,953
$/kgal	$ 1.20	$ 0.32	$ 1.22	$ 0.27
Non-Energy O&M COST				
$/year	$ 3,723,146	$ 356,972	$ 3,998,938	$ 396,717
$/kgal	$ 1.76	$ 0.21	$ 1.73	$ 0.23
TOTAL O&M COST				
$/year	$ 6,256,226	$ 919,890	$ 6,815,713	$ 872,670
$/kgal	$ 2.96	$ 0.53	$ 2.95	$ 0.50

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Table C1.5: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1		Scenario 2	
	Pass 1	Pass 2	Pass 1	Pass 2
CAPITAL COST SUMMARY	1995	2006	1995	2006
ENR CCI	5524.15	7629.95	5524.15	7629.95
Flux, GFD	6.91	15.89	5.41	11.47
Recovery	42.0%	82.0%	35.0%	75.0%
Intake/Intake Pump Station	$ 2,698,240		$ 2,698,240	
Prechlorination System MF BW	$ 263,424		$ 263,424	
MF Feed Tank	$ 279,593		$ 362,103	
MF Feed Pump	$ 477,816		$ 546,384	
MF Membranes	$ 760,500		$ 877,500	
MF Modules	$ 2,749,500		$ 3,172,500	
Dechlorination System Pre RO	$ 170,912		$ 170,912	
MF Filtrate Tank	$ 279,593		$ 362,103	
MF Transfer Pump/filtered water lift station	$ 881,400		$ 1,156,400	
Acid Addition System Pre RO	$ 1,751,648		$ 1,751,648	
Cartridge Filters	$ 715,000		$ 938,000	
Pass 1 HP Pumps	$ 965,902		$ 1,019,321	
RO Membranes	$ 1,213,335	$ 432,662	$ 1,694,393	$ 599,390
RO Skids	$ 2,693,604	$ 960,510	$ 3,761,553	$ 1,330,645
Energy Recovery	$ 723,152	$ 94,259	$ 1,063,282	$ 143,134
PX Booster Pumps	$ 431,713	$ 431,713	$ 431,713	$ 431,713
Base for Boron Removal Pre RO	$ 138,048		$ 138,048	
Pass 2 HP Pumps		$ 177,924		$ 134,482
Chlorination System		$ 90,240		$ 90,240
Carbon Dioxide System		$ 403,680		$ 403,680
Building	$ 8,041,888		$ 8,041,888	
Electrical	$ 3,503,949		$ 3,889,646	
Instrumentation/Control	$ 2,919,957		$ 3,241,372	
Transfer Pump Station		$ 164,896		$ 164,896
Permeate Flush System		$ 89,472		$ 89,472

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Table C1.5: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1		Scenario 2	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
Process Piping	$ 1,242,260		$ 1,242,260	
Yard Piping	$ 771,144		$ 771,144	
Clean-in-Place System	$ 71,968		$ 71,968	
Lime System		$ 138,048		$ 138,048
Ground Storage Tank		$ 809,472		$ 809,472
High Service Pumping Station		$ 863,456		$ 863,456
Site Work	$ 1,878,932.00		$ 1,878,932.00	
Subtotal	$ 35,623,477	$ 4,656,332	$ 39,544,735	$ 5,198,629
Engineering & CM (25%)	$ 8,905,869	$ 1,164,083	$ 9,886,184	$ 1,299,657
Permitting	$ 10,000,000		$ 10,000,000	
CO2 Reduction	$ 4,000,000		$ 4,000,000	
Contractor Overhead & Profit (10%)	$ 3,562,348	$ 465,633	$ 3,954,473	$ 519,863
Contingencies (15%)	$ 5,343,522	$ 698,450	$ 5,931,710	$ 779,794
Total Capital Cost	**$ 67,435,215**	**$ 6,984,498**	**$ 73,317,102**	**$ 7,797,943**
Reclamation Estimate Worksheet Allowance				
Subtotal 1	**$35,623,477**	**$4,656,332**	**$39,544,735**	**$5,198,629**
Mobilization	$1,800,000	$230,000	$2,000,000	$260,000
Subtotal 1 with Mobilization	**$37,423,477**	**$4,886,332**	**$41,544,735**	**$5,458,629**
Escalation to Notice to Proceed (NTP), at 4% per year, for a period of 36 months	-$423,477	$13,668	$455,265	$41,371
Subtotal 2 = Subtotal 1 with Mobilization + Escalation to NTP	**$37,000,000**	**$4,900,000**	**$42,000,000**	**$5,500,000**
Escalation During Construction, at 4% per year, from NTP to mid-point of construction for a period of 24 months	$0	$0	$0	$0
Subtotal 3 = Subtotal 2 + Escalation During Construction	**$37,000,000**	**$4,900,000**	**$42,000,000**	**$5,500,000**
Design Contingencies	$4,000,000	$500,000	$4,000,000	$500,000

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Table C1.5: Double Pass RONF Cost Analysis for 5 MGD Plant

	Scenario 1		Scenario 2	
	Pass 1	**Pass 2**	**Pass 1**	**Pass 2**
APS = Allowance for Procurement Strategies (if applicable), Note: Type of solicitation assumed is Request for Proposal (RFP)	$0	$0	$0	$0
CONTRACT COST	**$41,000,000**	**$5,400,000**	**$46,000,000**	**$6,000,000**
Construction Contingencies	$8,000,000	$1,000,000	$9,000,000	$1,200,000
FIELD COST	**$49,000,000**	**$6,400,000**	**$55,000,000**	**$7,200,000**
Non-Contract Costs	$10,000,000	$1,300,000	$11,000,000	$1,400,000
CONSTRUCTION COST	**$59,000,000**	**$7,700,000**	**$66,000,000**	**$8,600,000**
Permitting	**$10,000,000**		**$10,000,000**	
CO2 Reduction	**$2,000,000**		**$2,000,000**	
Total Cost	**$71,000,000**	**$7,700,000**	**$78,000,000**	**$8,600,000**

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Table C1.6: Double Pass NFNF Cost Analysis for 5 MGD Plant

Double Pass NF 5 MGD

Plant Utilization Factor	95%	
	Scenario 1	
	Pass 1	**Pass 2**
Flux, GFD	6.65	19.55
Recovery	46%	75%
Raw Water Flow, MGD	12.8	6.7
Finished Water Flow, MGD	6.666666667	5
PUMPING POWER		
Raw Water Pumping TDH, ft H2O	200	
Raw Water Pumping Efficiency	80%	
Raw Water Pumping Power, kW-hr	10,080	
MF pumping specific power kW-hr/kgal	0.25	
MF pumping power kW-hr/day	3,155	
NF/PX Booster Pump Specific Power, kW-hr/kgal	6.64	1.61
NF/PX Booster Pump Power, kW-hr/day	33200	8050
Permeate Lift Pumping TDH, ft H2O		40
Permeate Lift Pumping Efficiency		80%
Permeate Lift Pumping Power, kW-hr		790
Finished Water Pumping TDH, ft H2O		200
Finished Water Pumping Efficiency		80%
Finished Water Pumping Power, kW-hr		3,930
Motor Efficiency	95%	95%
Total Treatment Pumps Specific Power kWh/kgal	6.57	2.60
CHEMICAL CONSUMPTION		
Prechlorination MF BW, mg/L	2.5	
Prechlorination MF BW, lbs/day	270	
Dechlorination Pre NF, mg/L	5	
Dechlorination Pre NF, lbs/day	540	
Base Post Treatment, mg/L		44
Base Post Treatment lbs/day		1840
Carbon Dioxide, mg/L		16
Carbon Dioxide, lbs/day		670
Chlorine (Disinfection), mg/L		2
Chlorine (Disinfection), lbs/day		90
MISC. UNITS		
No of MF Module	12	
No of MF membranes	1,080	
Cartridge Filter Loading Rate, gpm/10-inch	4	
Cartridge Filter Length, inches/filter	40	
No. of Cartridge Filters, No.	600	
Cartridge Filter Replacement Frequency, Hours	1000	
NF Element Membrane Area, Ft2	400	400

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Table C1.6: Double Pass NFNF Cost Analysis for 5 MGD Plant

	Scenario 1	
	Pass 1	**Pass 2**
NF Elements Per Vessel, No.	7	7
No. of Vessels per Train	60	15
No. of Trains	6	6
No. of Membranes	2506	639
Membrane Life, Years	6.5	6.5
Clean in Place Frequency, Times Per Year	6	6
Clean in Place Cost, $ per cleaning	$ 15,000	$ 15,000
Labor, No. of Operators	15	
OPERATIONS COST SUMMARY		
Flux, GFD	6.65	19.55
Recovery	46.0%	75.0%
POWER COSTS		
Raw Water Pumping, $/yr	$ 441,504	$ -
MF Pumping, $/yr	$ 131,289	$ -
NF/PX Booster Pumping, $/yr	$ 1,381,452	$ 334,961
Permeate Lift Pumping, $/yr	$ -	$ 34,602
Finished Water Pumping, $/yr	$ -	$ 172,134
CHEMICAL COSTS		
Prechlorination, $/yr	$ 112,347	$ -
Dechlorination, $/yr	$ 56,174	$ -
Base, $/yr	$ -	$ 31,901
Carbon Dioxide, $/yr	$ -	$ 9,293
Chlorine (Disinfection), $/yr	$ -	$ 37,449
MISC UNITS		
MF Filter Replacement $/yr	$ 70,000	
Cartridge Filters, $/yr	$ 99,864	
Membrane Replacement, $/yr	$ 212,069	$ 54,102
Clean-in-Place, $/yr	$ 90,000	$ 90,000
Solids Disposal	$ 221,200	
Maintenance, $/yr	978,133	99,760
CO2 Reduction	$ 100,000	
Misc Expenses (e.g., Utilities)	$ 171,519	$ 16,125
Labor, $/yr	$ 1,590,594	$ -
Energy O&M COST		
$/year	$ 1,954,245	$ 541,697
$/kgal	$0.85	$0.31
Non-Energy O&M COST		
$/year	$ 3,701,899	$ 338,630
$/kgal	$1.60	$0.20
TOTAL O&M COST		
$/year	$ 5,656,144	$ 880,327
$/kgal	$2.45	$0.51
CAPITAL COST SUMMARY	1995	2006

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Table C1.6: Double Pass NFNF Cost Analysis for 5 MGD Plant

	Scenario 1	
	Pass 1	**Pass 2**
ENR CCI	5524.15	7629.95
Flux, GFD	6.65	19.55
Recovery	46.0%	75.0%
Intake/Intake Pump Station	$ 2,698,240	
Prechlorination System MF BW	$ 263,424	
MF Feed Tank	$ 267,210	
MF Feed Pump	$ 446,898	
MF Membranes	$ 702,000	
MF Modules	$ 2,538,000	
Dechlorination System Pre RO	$ 170,912	
MF Filtrate Tank	$ 267,210	
MF Transfer Pump/filtered water lift station	$ 879,900	
Acid Addition System Pre RO	$ 1,751,648	
Cartridge Filters	$ 713,700	
Pass 1 HP Pumps	$ 690,079	
RO Membranes	$ 1,378,446	$ 351,662
RO Skids	$ 3,060,150	$ 780,691
Energy Recovery	$ 672,108	$ 143,134
PX Booster Pumps	$ 431,713	$ 431,713
Base for Boron Removal Pre RO	$ 138,048	
Pass 2 HP Pumps		$ 167,323
Chlorination System		$ 90,240
Carbon Dioxide System		$ 403,680
Building	$ 8,041,888	
Electrical	$ 3,489,105	
Instrumentation/Control	$ 2,907,588	
Transfer Pump Station		$ 164,896
Permeate Flush System		$ 89,472
Process Piping	$ 1,242,260	
Yard Piping	$ 771,144	
Clean-in-Place System	$ 71,968	
Lime System		$ 138,048
Ground Storage Tank		$ 809,472
High Service Pumping Station		$ 863,456
Site Work	$ 1,878,932	
Subtotal	$ 35,472,572	$ 4,433,788
Engineering & CM (25%)	$ 8,868,143	$ 1,108,447
Permitting	$ 10,000,000	
CO2 Reduction	$ 2,000,000	
Contractor Overhead & Profit (10%)	$ 3,547,257	$ 443,379
Contingencies (15%)	$ 5,320,886	$ 665,068
Total Capital Cost	**$ 65,208,859**	**$ 6,650,682**

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Table C1.6: Double Pass NFNF Cost Analysis for 5 MGD Plant

	Scenario 1	
	Pass 1	**Pass 2**
Reclamation Estimate Worksheet Allowance		
Subtotal 1	**$35,472,572**	**$4,433,788**
Mobilization	$1,750,000	$220,000
Subtotal 1 with Mobilization	**$37,222,572**	**$4,653,788**
Escalation to Notice to Proceed (NTP), at 4% per year, for a period of 36 months	-$222,572	$46,212
Subtotal 2 = Subtotal 1 with Mobilization + Escalation to NTP	**$37,000,000**	**$4,700,000**
Escalation During Construction, at 4% per year, from NTP to mid-point of construction for a period of 24 months	$0	$0
Subtotal 3 = Subtotal 2 + Escalation During Construction	**$37,000,000**	**$4,700,000**
Design Contingencies	$4,000,000	$400,000
APS = Allowance for Procurement Strategies (if applicable), Note: Type of solicitation assumed is Request for Proposal (RFP)	$0	$0
CONTRACT COST	**$41,000,000**	**$5,100,000**
Construction Contingencies	$8,000,000	$1,000,000
FIELD COST	**$49,000,000**	**$6,100,000**
Non-Contract Costs	$10,000,000	$1,300,000
CONSTRUCTION COST	**$59,000,000**	**$7,400,000**
Permitting	**$10,000,000**	
CO2 Reduction	**$2,000,000**	
Total Cost	**$71,000,000**	**$7,400,000**

Appendix D
Literature Review

D.1 Reverse Osmosis

D.1.1 Principles of RO

The principle of the membranes used in this project is based on reverse osmosis (RO) membrane principle. An RO membrane is a selective barrier between two phases (Mulder, 1991). The RO membrane process is a separation process which seperates a feed stream into two streams, a purified stream, which is known as "permeate" or "product" water, and a concentrated stream known as "brine" or "concentrate".

Chemical potential differences are the driving force for changes in aquatic systems. The presence of solutes reduces chemical potential, which increase entropy and decrease free energy (Cheryan, 1998). When two aqueous solutions of differing concentrations are separated by a semi-permeable membrane, the difference in chemical potential (i.e., free energy) causes water from the dilute phase to pass through the membrane to the more concentrated phase. This occurs until the difference in chemical potential is negligible, and this process is known as osmosis. The process of reverse osmosis relies on the principle of applying a hydraulic pressure to the concentrated solution to force water to flow into the dilute solution side.

D.1.2 Membrane types

There are four commonly used types of pressure-driven membranes: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse-osmosis (RO). MF and UF are known as filtration membranes and NF and RO are known as reverse osmotic membranes. The membranes are identified by the types of materials rejected. MF membranes (0.1 μm pore size) remove particles, sediment, algae, protozoa, and bacteria. UF membranes (0.01 μm pore size) remove small colloids and viruses. NF membranes (0.001 μm pore size) primarily reject dissolved organic matter and divalent ions, and RO membranes reject monovalent ions. In this project, seawater NF (SWNF) and seawater RO (SWRO) membranes were used to desalt the pretreated seawater while MF was used as part of the pretreatment process.

D.1.3 Process performance

The performance of the Prototype was determined by monitoring the selectivity of the membranes used which was based on the relative permeability of the solvent (water) and the solutes (salt and other contaminants) through the membrane (Mallevialle et al., 1996). The separation performance of RO membrane processes is defined by the water flux and solute rejection. Flux is commonly expressed in

terms of a volumetric water flux (J_w), where Q is the permeate flow rate, and A is the surface area of the membrane.

$$J_w = \frac{Q}{A} \tag{D.1}$$

Salt rejection, r_s is defined by the following equation.

$$r_s = 1 - c_p / c_f \tag{D.2}$$

The overall performance of RO membrane processes is defined by the product water quality and flow, which are functions of the water recovery (Y) via

$$Y = \frac{Q_p}{Q_f}, \tag{D.3}$$

According to Mulder, the energy consumption to pressurize a liquid from P_1 to P_2 is given by (Mulder, 1991):

$$E_{pump} = E_p = \frac{q_v \Delta P}{\eta_{pump}} \tag{D.4}$$

Where q_v is the flow rate (m^3/s) and ΔP is the pressure difference or pressure drop (N/m^2). The efficiency η of a pump is generally between $0.5 \leq \eta_{pump} \leq 0.8$. In the case of reverse osmosis, an energy recovery device (ERD) is utilized to recover part of the energy.

$$E_{ERD} = -\eta_{ERD} q_v \Delta P \tag{D.5}$$

The efficiency η of an energy recovery device is generally between $0.5 \leq \eta_{ERD} \leq 0.8$ as well. The specific energy consumption (SEC) is illustrated in the following equation:

$$SEC_{total} = SEC_{pump} - SEC_{ERD} \tag{D.6}$$

$$SEC_{pump} = \frac{Q_{feed} \cdot P_{feed}}{Q_{permeate} \cdot \eta_{pump}} = \frac{P_{feed}}{Y \cdot \eta_{pump}} \tag{D.7}$$

$$SEC_{ERD} = \frac{Q_{concentrate} \cdot P_{concentrate} \cdot \eta_{ERD}}{Q_{permeate}} = \left(\frac{1}{Y} - 1\right) P_{concentrate} \cdot \eta_{ERD} \tag{D.8}$$

D.1.4 Multi-pass system

This project implemented various process arrangements which had been made to improve NF and RO membrane performance, including multi-pass and multi-stage configurations. Typically, multi-stage configuration is used to achieve higher recovery by treating the concentrate stream in a second stage. The multi-pass approach allows higher product water quality to be produced by treating the permeate in a second pass. The schematics for a multi-stage and a multi-pass system are shown in **Figures D.1 and D.2,** respectively.

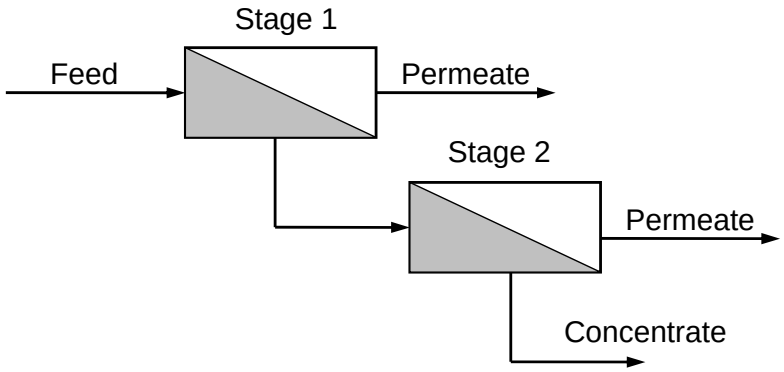

Figure D.1. Schematic of a multi stage system

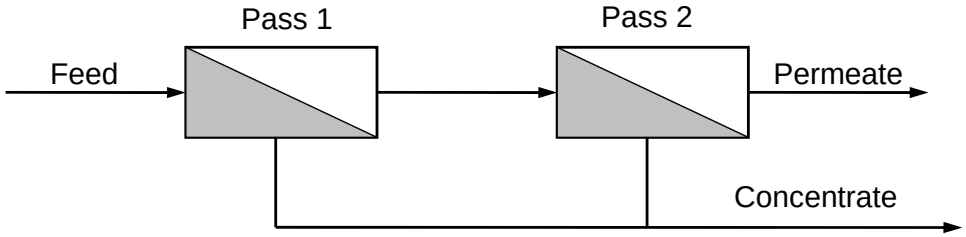

Figure D.2. Schematic of a multi pass system

The "Long Beach method" or NF^2 is an example of the multi-pass approach which makes use of SWNF membranes arranged in a two-pass configuration. Another feature of the NF^2 process is that the concentrate from the second pass is recycled and mixed with the seawater influent, which dilutes the feed water salinity and allows the system to operate at lower pressures. The lower pressures allow the use of lower-pressure fittings, piping, and vessels which may reduce materials cost (LBWD, 2006b).

The multi-pass approach also allows chemical addition to be made between the treatment processes, which results in enhanced removal of specific water quality constituents, including boron. Boron exists naturally in seawater as boric acid at ~4 mg/L, which is uncharged under normal seawater pH (~pH = 8) and passes through NF and RO membranes. The two-pass system allows calcium to be removed in the first pass, and base is added before the second pass to increase the

pH. The higher pH (above 9) transforms the boric acid to borate, which is more easily removed in the second pass.

D.2 Feed Water Quality

Seawater contains organics, bacteria, and dissolved salts, minerals, metals and gases. Problems associated with seawater desalination can be encountered in plant operation, permeate water quality, and concentrate discharge. The following sections will address each seawater component and the associated problems.

D.2.1 Inorganic (ionic composition)

Monitoring the salinity changes of the feed, permeate, and concentrate from the Prototype helps to determine the effectiveness of the system. Salinity is a measure of the mass of dissolved salts in a mass or volume of seawater. On the basis of evaporation method, salinity was defined as "the weight in grams of dissolved inorganic salts in one kilogram of seawater, when all bromides and iodides are replaced by an equivalent quantity of chlorides, and all the carbonates are replaced by equivalent quantity of oxides (Millero, 2006)." Salinity can be experimentally determined by the gravimetric method through drying and weighing of the salts, however, difficulties exist due to vaporization of bromine and chlorine gas and CO_2 from the bicarbonates and carbonates (Millero, 2006). A complete chemical analysis of seawater is the only reliable way to determine the true salinity of seawater (S_T, in parts per thousand). This method is too time-consuming for routine studies. The typical method for measuring salinity is by electrical conductivity by the use of a conductivity meter, corrected for temperature of a water sample.

In practical seawater applications, TDS can be calculated by using a conductivity meter and applying the following formula:

$$TDS = 0.67 \times \text{Conductivity } (\mu S/cm) \quad (D.9)$$

TDS is expressed as the concentration of ions in a liter of water, or the number of grams of dissolved solids in 1000 g of water. A 1000-g sample of seawater containing 34.7 g of dissolved material has a salinity of 34.7‰ (ppt, parts per thousand), or 3.47%, and the remaining 96.53% is pure water. Based on the Long Beach Prototype Test Plan, the raw seawater data show the influent TDS concentration is ~34,000 ppm (typically 32,000-35,000 ppm) (LBWD, 2006b).

Table D.1. Major ionic constituents (Horne, 1969)

Constituent	Concentration (g/L)
Cl^-	19.353
Na^+	10.760
SO_4^{2-}	2.712
Mg^{2+}	1.294

Ca^{2+}	0.413
K^{+}	0.387
HCO_3^-/CO_3^{2-}	0.142
Br^-	0.067
Sr^{2+}	0.008
F^-	0.001
$B(OH)_3$	0.026

Seawater contains all of the natural elements, but is dominated by relatively few ionic species (Pilson, 1998). The species shown in **Table D.1**, which comprise more than 99.9% of the mass of the total dissolved solids (TDS) in the ocean, are known as the major ions and are identified as dissolved species having a concentration in seawater of more than 1 ppm. Na^+ and Cl^- alone account for more than 85% of dissolved solids in seawater (Millero, 2006). Although salinity varies from location to location, the ratios of the major ions remain nearly constant, which holds true in oceans as well as for surface and deep waters. This observation is known as the "rule of constant proportions (Horne, 1969)." Exceptions to this rule exist for calcium, strontium, and bicarbonate ions because a small fraction of the total concentration of these species participates in biological reactions resulting in slight variation of ion/Cl^- ratios between surface and deep waters (Millero, 2006).

D.2.2 Minor and trace elements

At the Prototype, minor and trace elements were part of the water quality monitored in the feed water. Minor and trace elements in seawater are defined as those that occur in concentration less than 1 ppm, and vary slightly with location and depth in seawater. Morel and Price define trace element as those with concentration less than 0.1 μM (Morel and Price, 2003). Kennish defines trace elements to range between 0.05 and 50 μmol/kg (Kennish, 1994). Minor and trace ions are tightly linked to biological activity. Ions that vary in this fashion are referred to as "nutrient type" ions, because they are consumed by one or more types of organism. "Nutrient type" ions can be locally depleted if biological activity is high enough. A depletion of an element in surface waters and an enrichment at depth is called nutrient-type profile (Millero, 2006). **Table D.2** shows the common trace ions in seawater.

Table D.2. Common minor and trace elements in seawater (Horne, 1969)

Species	Concentration (mg/L)
Lithium	0.17
Rubidium	0.12
Phosphate	0.0 to 0.3
Barium	0.03
Aluminum	0.01
Iron	0.01

Zinc	0.01
Copper	0.003

Many trace elements are metals. Depending on the concentrations, elements classified as heavy metals can be either essential nutrients for marine life, or toxic if the levels are sufficiently high. For example, copper exists in natural seawater around 0.25 ppb, and is essential for many organisms (Hall and Anderson, 1999), but can be toxic to certain marine organisms when the levels exceed mg/L levels.

D.2.3 Dissolved gasses

The two most critical gases in seawater are oxygen and carbon dioxide. Oxygen concentration is generally uniform near the surface due to mixing by wind and other processes, and is controlled by exchange with atmosphere and microbial activity. Oxygen is most concentrated within the first 50 meters due to photosynthesis, and starts to drop due to biological processes and oxidation of organic matter between 50 and 100 meters below the photosynthesis zone (Horne, 1969; Sverdrup et al., 2003).

Carbon dioxide affects the pH values of seawater as recent increase in atmospheric $CO_{2(g)}$ has shifted the equilibrium of the carbonate buffer system and increased the acidity (decreased pH) of major oceans. The pH of seawater varies between 6.5 and 8.3, with an average slightly above pH 7.0 (Horne, 1969). The average pH of the Prototype feed water was at ~7.8.

D.2.4 Natural organics matter (NOM)

The natural organic matter at the Prototype was monitored by measuring the total organic carbon (TOC) which had the average of 1.0 mg/L. Organic compounds contain covalent carbon-carbon, carbon-hydrogen bonds, and often they can contain nitrogen and phosphorous or other atoms. Organic materials in seawater may act as food, toxins, and metal binding agents. They can also cause odors, inhibit the abiotic precipitation of calcium carbonate and reduce light penetration through the water (Kirchman, 2000). From an operational perspective, organic materials are classified as either dissolved organic matter (DOM) or particulate organic matter (POM), with DOM defined as all organic materials that pass through operational pore size of 0.45 μm filter, and POM defined as organic materials retained by such filters (Kirchman, 2000).

Table D.3. Levels of dissolved and particulate organic matter in seawater (Millero, 2006)

Source	Dissolved (μM)	Particulate (μM)
Surface	75-150	1-17
Deep	4-75	0.2-1.3
Coastal	60-210	4-83

Dissolved organic material in the oceans is often measured in terms of its carbon content, and is referred to as dissolved organic carbon (DOC). Typically, there is twice as much DOM by mass as DOC in seawater. The DOM concentration in seawater may be estimated by measuring DOC and multiplying by two. The same relationship applies to POM and POC. Suspended POC is frequently less than DOC, often by an order of magnitude (Millero, 2006). **Table D.3** shows the concentration of DOM and POM in typical natural waters (Millero, 2006).

D.2.5 Marine microbes

At the Prototype, most marine microbes were removed by the MF pretreatment so that they are not a major concern. Microorganisms are classified as prokaryotes (e.g. bacteria and cyanobacteria) or eukaryotes (e.g. algae and phagotrophic protests). Prokaryotes are organisms lacking cell nucleus and the other organelles found in eukaryotes. Prokaryotes are almost always unicellular (Kirchman, 2000). Bacteria and archaea are subdivision of prokaryotes. Most organisms are eukaryotes, whose cells are much more advanced and complex than those of prokaryotes. Eukarya also includes all algae (except "blue-green algae," called "cyanobacteria") (Castro and Huber, 1991; Kirchman, 2000). Cyanobacteria are prokaryotes which perform photosynthesis. Although commonly known as algae, blue-green algae are considered bacteria because they have a prokaryotic cellular organization. There are, however, similarities between blue-green algae and more complex primary producers like the seaweeds in the way that photosynthesis takes place, which is through the production of chlorophyll and chlorophyll a, and liberate gaseous oxygen.

Algae require warm temperature, sunlight, and nutrients to grow and reproduce, so they live in the upper 60 to 90 meters (200 to 300 feet) of ocean water. The upper layer of water is rich in oxygen, penetrated by sunlight, and warmer than water at lower levels. As algae and other organisms die, they fall to the bottom of the ocean, decay, and release the compounds from their cellular makeup. Under certain conditions, the nutrients can deplete the oxygen in the water (Horne, 1969).

Algae blooms occur when there is an explosive increase in algae cell density caused by events that upset the balance in the ocean. These events cause an excess of nutrients (particularly phosphorus and nitrogen) in waters, and higher concentrations of these nutrients cause increased growth of algae and green plants. This nutrient increase may be caused by human activities, including runoff from animal farms or fertilized croplands and lawns which change the concentration of nitrogen (Kyewalyanga et al., 1998; Platt et al., 1992), or atmospheric deposition of sulfur and nitrogen compounds or oxides derived from the burning of fossil fuel. These nutrients lead to blooms in coastal waters to a greater extent than in the open ocean. However, some nutrients flow into the open ocean by wind and ocean currents, and contribute to the formation of blooms. Other causes of algae bloom include stratification (Gallegos et al., 1983), turbulence (Lewis et al., 1984), light intensity and quality in the water column (Kyewalyanga et al., 1998), and size and diversity of phytoplankton species (Gallegos, 1992; Malone and Neale,

1981). Variations in photosynthesis and primary production in the ocean can also be related to temperature (Harding et al., 1986; Platt and Jassby, 1976; Tilstone et al., 1999). Temperature and salt concentration affect the density and movement of water. Cold water is denser and sinks from the surface causing a downwelling. The water at the surface is eventually replaced by water that has risen, or upwelled, from the bottom to the surface somewhere else in the ocean. The upwelling brings nutrient-rich waters to the top.

Some blooms are recognized by discoloration of water which results from high density of pigmented cells, and can be green, yellowish-brown, or red. Bright green blooms may also occur from cyanobacteria (Kirchman, 2000). The type of algae bloom that is more widely publicized is associated with the species that produce toxin harmful to animals that feed on the algae (harmful algae bloom), and/or algae that cause a tint in the water because of the photosynthetic pigments ("red tide"). Depending on the species present, a red tide may or may not be harmful.

D.3 Membrane Fouling

Fouling is defined as an undesirable change in separation performance due to accumulation of insoluble matter at membrane surface and/or within membrane pores (Koros et al., 1996). Because RO membrane pores are molecular in size, there is little evidence of internal fouling of RO membranes by insoluble matter. Therefore, it is commonly assumed that surface fouling phenomena dominate. Fouling can be classified into the following three key mechanisms based on the foulant materials matter (Schäfer et al., August, 2003; Trussell et al., 2005):

a. Scale formation: This results from heterogeneous crystallization of sparingly soluble mineral salts on the membrane surface, the foulant includes inorganic materials ($CaCO_3$, $CaSO_4$, SiO_2, $BaSO_4$, $SrSO_4$, $Al_xSi_yO_z$).
b. Cake (or gel) formation: This results from convective deposition of organics, colloidal, and microbial matter on the membrane surface, the foulant includes organic (humic acids, fulvic acids, biopolymers) and colloidal (clays, metal oxides, precipitates, biological macromolecules).
c. Biofilm formation: This results from growth, multiplication, and biopolymer exudation by viable, deposited microorganisms, the foulant includes microbial matter (bacteria, algae, cell debris).

Feed spacer entrapment may also cause membrane fouling. It was indicated by some researchers that microbial deposition was observed in spacer filled channels. Deposits of microbial cells appear at the leading edge of the spacer adjacent to the membrane surface, and more cells accumulate at the leading edge of these spacer filaments (Subramani, 2007).

Concentration polarization of rejected foulant matter increases the severity of surface fouling phenomena, especially for heterogeneous crystallization of minerals and adsorption of dissolved organic matter (Schäfer et al., August, 2003). In full-scale RO systems, cake formation occurs in lead elements, scale formation occurs in tail (lag) elements, and biofilm formation can occur throughout the system. All three fouling mechanisms result in flux decline, which can be compensated by increasing operational pressure but results in higher cost of product water. Additionally, algal blooms may result in an increased number of microorganisms (bacteria and algae) in the feed water, which may pass through the pretreatment process and deposit onto the membrane, which increases the biogrowth potential in the membrane modules (Ghayeni et al., 1996).

Fouling can decrease permeate flux and salt rejection. The salt concentration at the membrane surface increases significantly as fouling occurs because the back diffusion that transports salt away from the membrane is hindered by fouling. The permeate flux decline, coupled with an decrease in salt rejection on the membrane surface will result in an increase in the permeate salt concentration (Lee et al., 2004). Fouling also results in higher energy consumption because it enhances concentration polarization and increases osmotic pressure (Herzberg and Elimelech, 2007; Hoek et al., 2002). Fouling may also result in a higher cleaning frequency and a shorter membrane life. Membrane fouling can be detected by an increase in applied pressure, increase in differential pressure through the elements, decrease in product water quality, and slime formation in the system components.

Fouled membranes must be eventually cleaned by a combination of physical and chemical methods, which increases operating costs and decreases productivity due to process down-time, chemical consumption, and membrane degradation (Pilson, 1998). Pretreatment may be used to mitigate the problems associated with fouling, and will further be explained in Section 1.4.

D.4 Pretreatment Processes

D.4.1 Intake water quality

The intake water quality of the feed water at the Prototype is similar to the surface seawater intake because the intake line shared with Haynes Power Plant was located at six feet below the surface. Fukuhara et al tabulated the quality of the deep seawater in Kochi, Japan compared with surface seawater in **Table D.4** (Fukuhara, 2003). Suddhoo also compared surface water versus deep water (1000 m deep) in **Table D.5** (Suddhoo, 2006)**.**

Table D.4. Deep seawater quality (Kochi, Japan) in comparison with surface seawater (Fukuhara, 2003)

Parameter	Surface seawater (0m)	Deep seawater (-320m)
Temperature (°C)	16.2 - 24.9	8.1 - 9.8
Salinity (%)	3.37 - 3.48	3.43 - 3.44
DO (ppm)	6.4 - 9.5	4.1 - 4.8
NO_3-N (mM)	0.0 - 5.4	12.1 - 26.0

The advantages of deep seawater intake include the following:

- Low level of microorganisms and suspended matters.
- Low temperature with slight seasonal fluctuations
- Rich in nutrient level with several inorganic nutrients salts necessary for aquatic plant growth.

Table D.5. Key parameters of seawater (Suddhoo, 2006)

Parameter	Surface Sea Water[1]	Deep-Sea Water[2]
Temperature (°C)	27-28	5-6
Salinity (ppt)	34.7	34.3
pH	8.3	7.9
Dissolved Oxygen (mg/L)	6.7	3.8
Total Bacterial Count (CFU/mL)	25-257	1-13
Total Coliforms (CFU/mL)	0	0
Faecal Coliforms (CFU/mL)	0	0
Vibrio Species (CFU/mL)	0	0
Nitrate (mg/L)	0.015	0.39
Phosphate (mg/L)	<0.003	0.050
Ratio Nitrate / Phosphate	5	8
Ratio Nitrate / Nitrite	3	78
Silicate (mg/L)	<0.1	3.0
Ammonia (mg/L)	<0.01	<0.01

1 – at 3 km from the coast
2 – at 3 km from the coast and 1,000 m deep

Subsurface seawater, such as the type that is collected by beach wells, may result in a different water quality from open intakes. Depending on the location, beach well water may contain low levels of dissolved oxygen (DO) and difficult-to-treat compounds, especially when it is under the influence of contaminated groundwater. For example, the Morro Bay SWRO plant (CA) detected MTBE in its influent seawater from the beach well intake water because of an underground gasoline tank spill. Similar problems were observed at Santa Catalina Island (CA) 132,000 gpd (500 m^3/day) seawater desalination plant, using a beach well intake (Voutchkov, 2005). These concerns may be addressed using available

technologies such as activated carbon filtration, UV radiation, hydrogen peroxide oxidation, and ozonation. However, the additional treatments will add to the capital cost.

D.4.2 Particulate removal

The prototype uses MF process for its particulate removal. The success of a membrane-based desalination plant is very dependent on the pretreatment process (Jezowska et al., 2009; Pearce, 2007; Vedavyasan, 2007; Yang and Kim, 2009). Compared to conventional pretreatment, MF/UF processes can produce high quality waters, use less space, significantly reduce NF/RO membrane cleaning and replacement frequency (Jezowska et al., 2009; Pearce, 2007; Vedavyasan, 2007). MF and UF pretreatment is based on size exclusion, with MF removing particulate matter down to 0.1 μm, some dissolved/colloidal matter, and most pathogens except viruses. UF membranes remove particulates, pathogens, and colloids down to ~10-30 kDa molecular weight (~1-3 nm in size), some dissolved solutes, and most virus (Crittenden, 2005).

Multiple large-scale plants are in operation using MF/UF as pretreatments in locations such as the Netherlands, Belgium, Germany, Spain, Namibia, Singapore, Kuwait, and USA. An example includes the UF system installed at Sulaibiya, Kuwait with a nominal capacity of ~100 mgd (374,400 m^3/day) (Knops et al., 2007). The benefits of MF/UF pretreatment include reducing the overall cost, and improving the process reliability. The benefits are as follows (Pearce, 2007):

- Higher RO design flux and recovery may be possible
- Smaller footprint results in 33 percent saving in capital with UF
- RO membrane replacement reduced significantly
- Can treat feed water with poor and/or variability quality
- Avoid shutdown or operation without specific feed
- Reduced requirement for RO disinfection and cleaning
- Ensures consistent SDI to RO process

The capital cost of MF and UF pretreatment process may be higher than dual media filters (up to a factor of two), and the overall membrane system can exceed the conventional system by 20 to 50 percent, depending on flow rate, feed quality, and other factors (Pearce, 2007). Additionally, the cost of chemicals may increase due to cleaning requirement.

D.4.3 Scale inhibition

The Prototype did not utilize any scale inhibition process. Scaling is commonly prevented with the addition of antiscalant chemicals. Antiscalants allow membrane systems to operate at higher recoveries by increasing the saturation limits of specific ions before precipitation occurs. This process inhibits silica, sulfate, aluminum, and iron scale formation. Sodium hexametaphosphate (SHMP) is commonly used as an antiscalant, but it has limited ability to extend the supersaturation range and it adds phosphate compounds to the concentrate,

which causes disposal problems. As a result, SHMP has been displaced by polymeric compounds. Some operational limitations to antiscalants include high cost, hazardous chemical handling, and increased biofouling. In cases where scaling is excessive and antiscalants are ineffective, additional pretreatment, such as lime softening, may be required (Crittenden, 2005). Before antiscalants are included into a facility, site-specific analyses should be conducted to determine the cost benefits of operating at a lower recovery without the use of antiscalants, or operate at higher recoveries, but including the use of these chemicals.

D.4.4 Biogrowth control

D.4.4.1 Chlorination and dechlorination

Chlorination and dechlorination were incorporated into the Prototype process before and after the MF pretreatment system to reduce biofouling. Preoxidation is sometimes incorporated into the treatment process to improve removal of specific chemicals during treatment or to control biological growth. Chemical disinfection of water is traditionally limited to highly oxidizing, chlorine-containing chemicals including chlorine, combined chlorine, chlorine dioxide (Tanaka et al., 1994). Chlorine has been used as a disinfectant for cellulose acetate membrane (Vos et al., 1968), however, polyamide (PA) RO membranes are rapidly degraded by oxidizers, including chlorine. Chloramines (combined chlorine) can react with the bromide in seawater to form hypobromous acid, which also attacks PA membranes (Nawrocki and Bilozor, 1997; Wong, 1980). The reactions between chlorine and hypobromous acid on PA membranes are well documented (Glater et al., 1994; Glater et al., 1983). In addition to membrane oxidation, chlorine may also increase disinfection by-product (DBP) formation in the treatment process.

To prevent membrane degradation, dechlorination is used to remove residual disinfectants from feed water prior to desalting membrane processes. Dechlorination chemicals and processes include carbon adsorption, sodium metabisulfite, sodium bisulfite, sulfur dioxide, and hydrogen peroxide. Sodium bisulfite is commonly used to reduce the disinfectant residuals (Light et al., 1987), and is used at the Prototype Plant ensure that no chlorine is fed to the desalting membranes.

D.4.4.2 Ultraviolet (UV) disinfection

UV disinfection was utilized at the Prototype as one of the additional pretreatment used to disinfect after the MF process. UV disinfection is an alternative option when oxidizing chemicals cannot be used. Ultraviolet light uses electromagnetic radiation having a wavelength between 100 and 400 nm for disinfection (Crittenden, 2005). The photons in UV light react directly with the nucleic acids in the target organism. While the damage is not usually fatal to the organism, successful cell reproduction is inhibited. Depending on the dose, UV radiation can also cause more severe cell damage by breaking chains, causing DNA to crosslink with itself and with other proteins, and forming other byproducts.

Cellular reactivation is likely to occur in UV disinfection than with other disinfection methods.

D.4.4.3 Chlorine dioxide

Chlorine dioxide was one of the additional pretreatment used at the Prototype after MF pretreatment to prevent biofouling. Because free chlorine and chloramines may damage PA membranes, other chemical disinfection method may be needed to control biofouling. Although chlorine dioxide (ClO_2) has been used in conventional water treatment, its effect on the performance of NF and RO membranes operating in seawater environments is not well documented. The most important factor in the use of ClO_2 for membrane biofouling control is the prevention of the formation of free chlorine during ClO_2 production (Adams, 1990; Wise et al., 2004).

There are several reactions available in producing chlorine dioxide from chlorite. These include reactions with gaseous chlorine (Cl_2), aqueous chlorine (HOCl), or acid (usually HCl). The reactions are (Knops et al., 2007):

$$2NaClO_2 + Cl_2(g) \rightarrow 2ClO_2(g) + 2NaCl \quad (D.10)$$

$$2NaClO_2 + HOCl \rightarrow 2ClO_2(g) + NaCl + NaOH \quad (D.11)$$

$$5NaClO_2 + 4HCl \rightarrow 4ClO_2(g) + 5NaCl + 2H_2O \quad (D.12)$$

Chlorine dioxide generators are relatively simple mixing chambers, which are filled with media to generate hydraulic turbulence for mixing. A potential issue with the ClO_2 generation method is if free chlorine is present, the bromide in seawater will react with chlorine to produce hypobromous acid and hypobromite ion causing membrane degradation:

$$Br^- + HOCl \rightarrow HOBr + Cl^- \quad (D.13)$$

Trace amounts of free chlorine in ClO_2 may be attributed to the photolytic decay of chlorine dioxide or the original (unreacted) chlorine. Reaction of indene or other aromatic hydrocarbons with chlorine dioxide can be another pathway for the secondary formation of chlorine (Nawrocki and Bilozor, 1997). In addition to causing membrane degradation, hypobromous acid (HOBr) also interferes with the titrant used in amperometric titration method which is generally used to analyze chlorine dioxide.

D.5 Permeate Water Quality Goals

At the Prototype, permeate water quality was continuously monitored to ensure that the permeate water quality goals were met. TDS is the concentration of ions in water, generally expressed as mg of dissolved solids in 1 L of water. The Safe Drinking Water Act (SDWA) has a secondary Maximum Contaminant Level (MCL) for TDS at 500 mg/L (USEPA, 1996). Typical drinking water TDS concentration in LBWD's distribution system is in the range of 230 to 330 mg/L (LBWD, 2006a), and the TDS goal in the desalted water is to match these levels.

It is necessary for the membrane processes to produce similar TDS as LBWD's drinking water TDS levels. The typical water quality for the distribution system at Long Beach is shown in **Table D.6**.

Table D.6. Distribution water quality

Parameter	LBWD Distribution
pH	7.8-8.4
Alkalinity, mg/L as $CaCO_3$	73 – 136
Conductivity, µmhos/cm	423 – 803
TDS, mg/L	232-470
Sodium, mg/L	41- 87
Calcium, mg/L	26 - 41
Magnesium, mg/L	3 - 20
Chloride, mg/L	22-41
Sulfate, mg/L	25-152
Silica, mg/L	8.2 – 23.0
Boron, mg/L	0.14 – 0.17
Bromide, mg/L	0.49-0.65
TOC, mg/L	<2

Specific water quality constituents of concern in seawater include boron, bromide, and iodide (Harrison et al., 2007). Boron is naturally present in seawater at a range of 4 to 5 mg/L, and high levels of boron can cause toxicity in plants, including yellowing of leaves (Parks and Edwards, 2005). Boron has a pKa of 9.2; below pH 9.2, boron exists as boric acid (H_3BO_3) and can easily pass through membranes. Above pH 9.2, boron hydrolyzes to borate ion ($H_2BO_3^-$) and is easily rejected by membranes (Harrison et al., 2007). The World Health Organization (WHO) standard for boron is set at 0.5 mg/L and proposed to be changed to 2.4 mg/L (WHO, 2009). The California Notification Limit (CANL) is set at 1 mg/L. Although LBWD has not set a final internal water quality goal for boron, this research set 0.8 mg/L as the water quality objective which is at least 20 percent less than the CANL.

Seawater also has a typical bromide concentration of 65 to 67 mg/L (Harrison et al., 2007), which can rapidly react with monochloramine and accelerate its decay (Sohn et al., 2006; Trofe et al., 1980; Tseng et al., 2005). Bromide can also be incorporated into brominated disinfectant by products, which have a much higher risk factor than chlorinated DBPs (Sohn et al., 2006; USEPA, 1996). Iodide reacts similarly as bromide, and it can be present in seawater at concentrations up to 50 µg/L (Harrison et al., 2007). Currently, there is no regulation for bromide and iodide; however, based on earlier bench scale testing (Tseng et al., 2005), a bromide level below 0.5 mg/L is necessary to ensure the disinfectant stability.

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Appendix E
Optimization Modeling of Nanofiltration Membranes

Optimization modeling of nanofiltration membranes for seawater desalination: Scale up from pilot to prototype scale

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Introduction

- Desalination with SWRO membrane is energy intensive
- Long Beach Water Department (LBWD) identified NF membranes for seawater desalination
  - Loose skin layer but high rejection
  - Low energy cost
    - Operate at low feed pressure

Appendix E
Optimization Modeling of Nanofiltration Membranes

Introduction

- LBWD patented a two-pass nanofiltration (NF2) process for seawater desalination
- Extensive testing done at various scales
  - Pilot (9000 gpd)
    - 4” elements
      - Multiple configurations: 1-element, 2-element, and 4-element
  - Prototype (300,000 gpd)
    - 8” elements
      - 5-element configuration

Overall objectives of the prototype testing

- 1) Verify the NF2 process side-by-side with SWRO
  - water quality and operational parameters (e.g. pressure, energy, fouling, etc.)
- 2) Optimize the NF2 process overall through system optimization of different variables
  - including number of elements in each vessel, mixing membrane types within each vessel.

Specific Objectives

- Using LBWD experimental data, develop a "mechanistic" model using the pilot plant data to estimate prototype and full-scale performance
  - Scale-up from 4" to 8" element
- Identify optimum operating conditions
  - Flux and recovery
  - Water quality
- Optimize NF configuration including
  - Number of elements
  - Element types (combination of NF, ULPRO, BWRO, SWRO)

Model Development for first pass

Accounts for more than 80% energy consumption

Hypothesis: Membrane intrinsic parameters are independent of operating condition and can be used to scale-up performance

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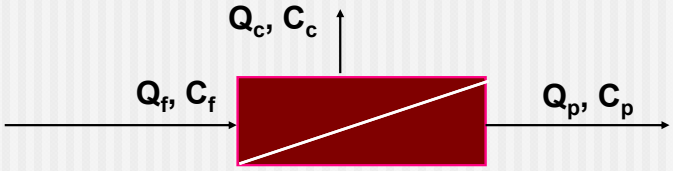
Appendix E
Optimization Modeling of Nanofiltration Membranes

Basics: Irreversible Thermodynamics Model



$$Jv = Lp[\Delta p - \Delta\Pi]$$

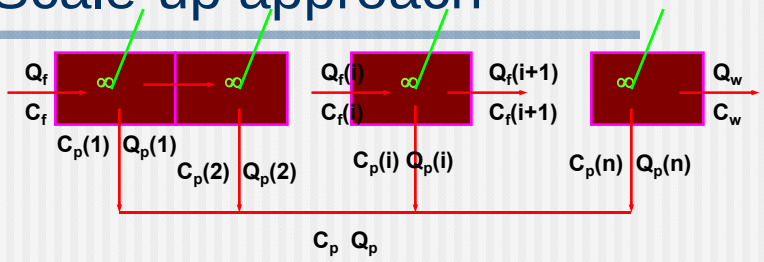
(Spiegler and Kedem 1966)

$$J_S = -P_M \Delta x\left(\frac{dc}{dx}\right) + (1-\sigma) J_V c$$

$$R = 1 - \frac{C_p}{C_m} = \frac{\sigma(1-F)}{(1-\sigma F)} \qquad \text{where } F = \exp\left(-\frac{1-\sigma}{P_M} J_v\right)$$

Three intrinsic parameters: Lp, σ, and P_M

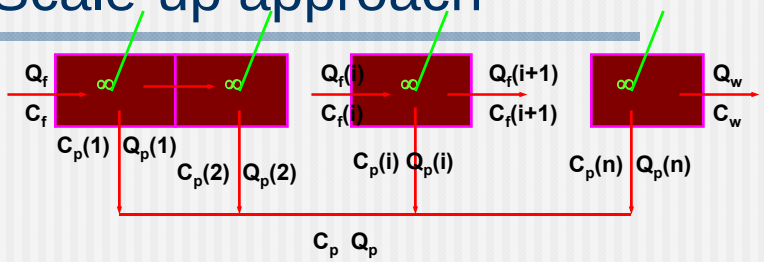
Scale-up approach



The need of a model that can account for
1. Increasing feed concentration
2. Reducing c/s flow velocity
3. Decreasing volumetric flux
4. Increasing osmotic pressure
5. Hydraulic losses in feed pressure

Appendix E
Optimization Modeling of Nanofiltration Membranes

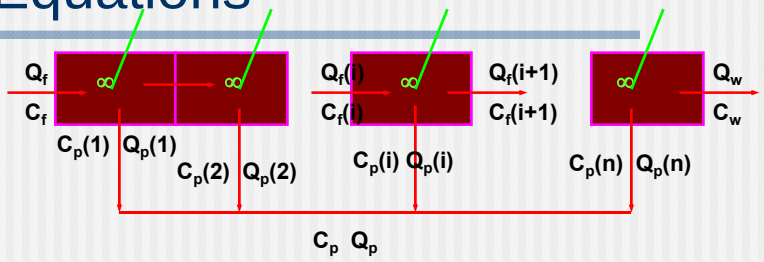
Scale-up approach



The need of a model that can account for
1.Increasing feed concentration
2.Reducing c/s flow velocity↑
3.Decreasing volumetric flux
4.Increasing osmotic pressure
5.Hydraulic losses in feed pressure

Hypothesis: Membrane intrinsic properties will not change regardless of the scale.

Model Development: Key Equations



$$Q_p = \sum_1^n Q_p(i)$$

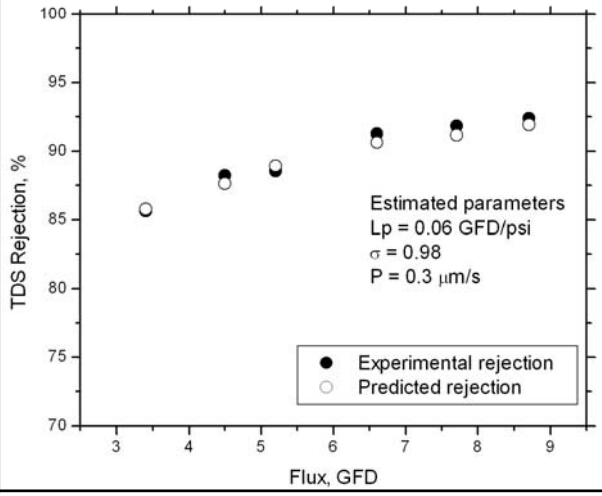
$$Q_p(i) = \frac{Lp[\Delta p(i) - \Delta\Pi(i)]A}{n}$$

$$C_p = \frac{\sum_1^n Q_p(i)C_p(i)}{Q_p}$$

$$R = 1 - \frac{(1-\sigma)\exp\left[\frac{J_v}{k}\right]}{(1-F)\sigma + (1-\sigma)\left[\frac{J_v}{k}\right]}$$

Model Calibration

Select data from 4" single element operations



Model Validation

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1-element results

Using Lp = 0.06 GFD/psi
σ = 0.98
P =0.3 μm/s

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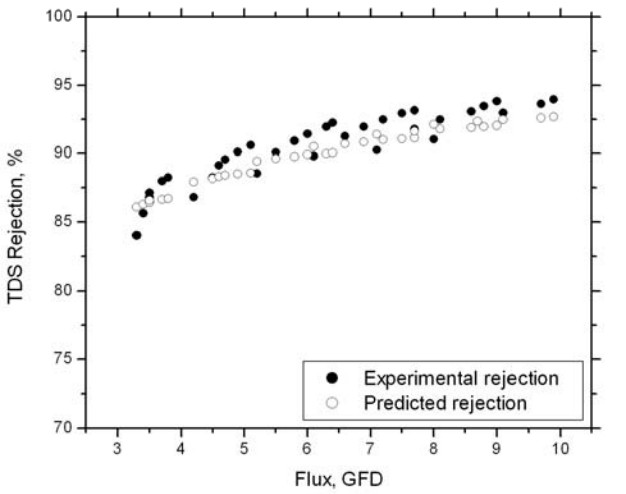
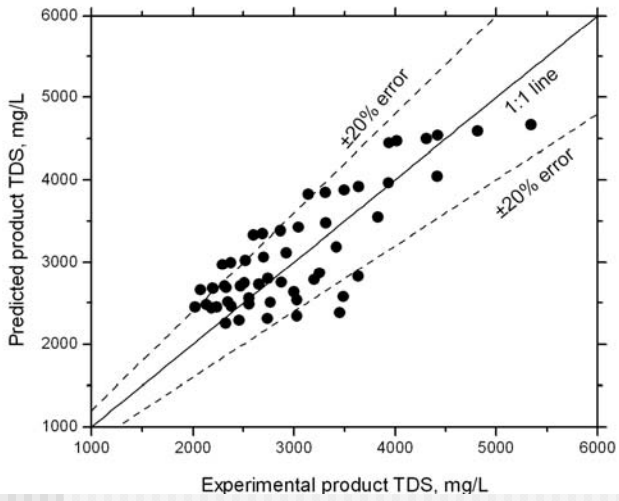
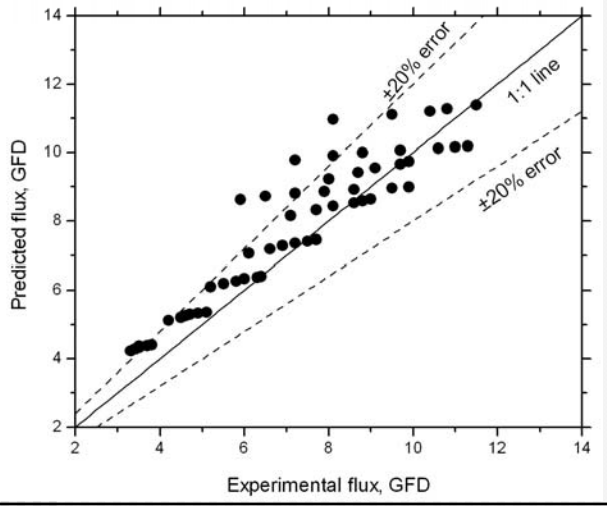
1-element
TDS Rejection



1-element
Permeate TDS concentration



1-element
Volumetric flux



Scale-up from 1-element to 2-element

All 4" element

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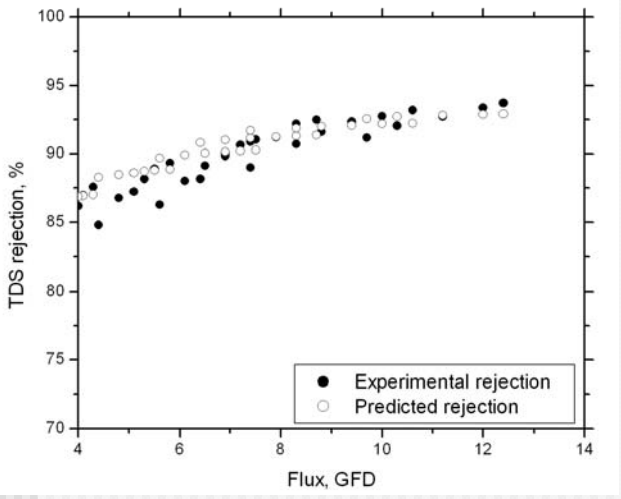
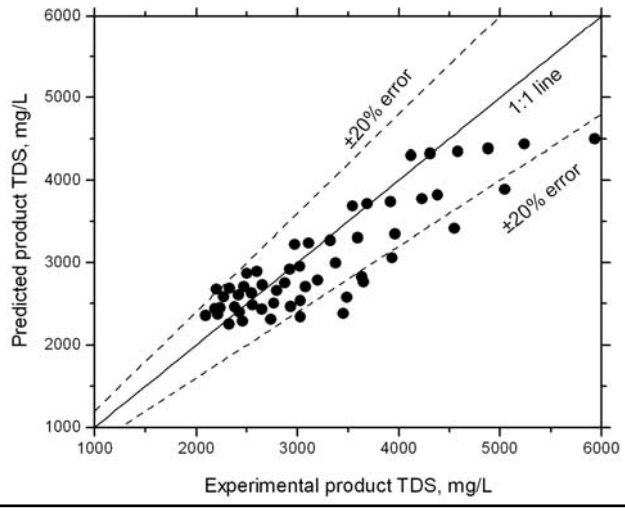
2-element

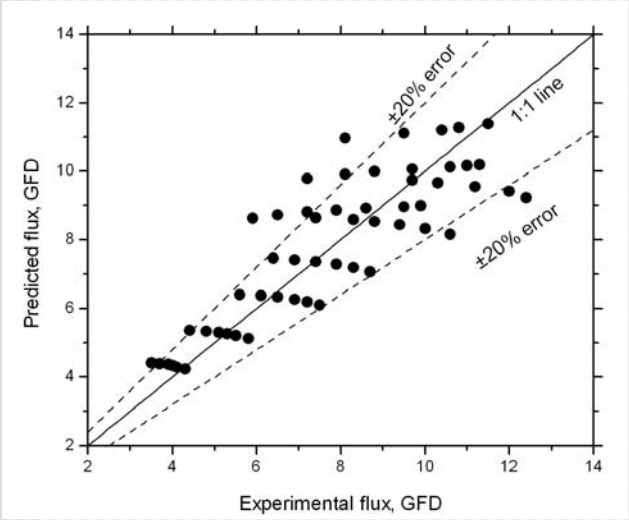
TDS rejection



2-element
Permeate TDS concentration



2-element
Volumetric flux



Scale-up from 1-element to 4-element

All 4” elements

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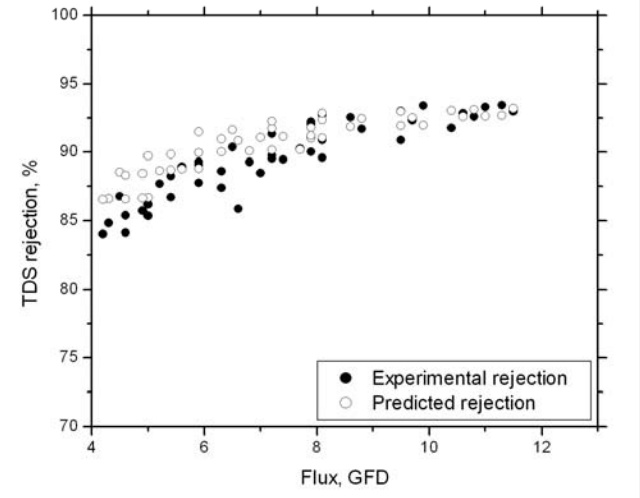
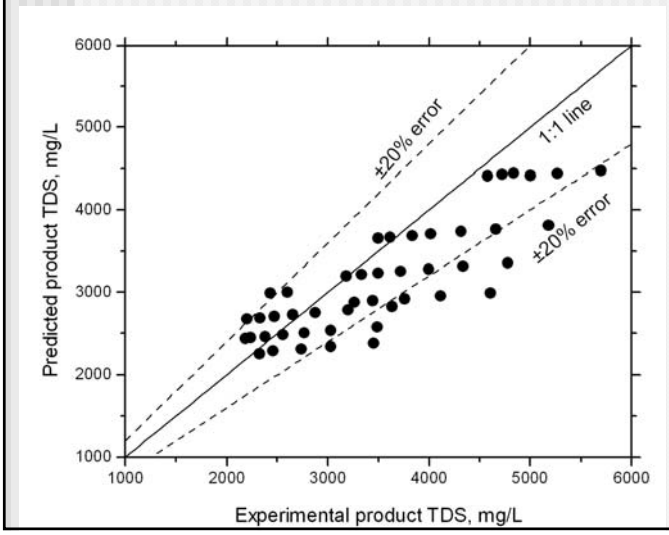
4-element

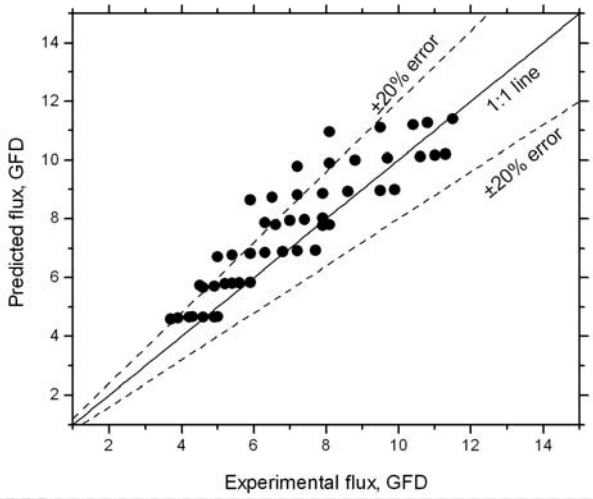
TDS rejection



4-element Permeate TDS



4-element Volumetric flux



Scale-up from 4” single element to 8” five element configuration

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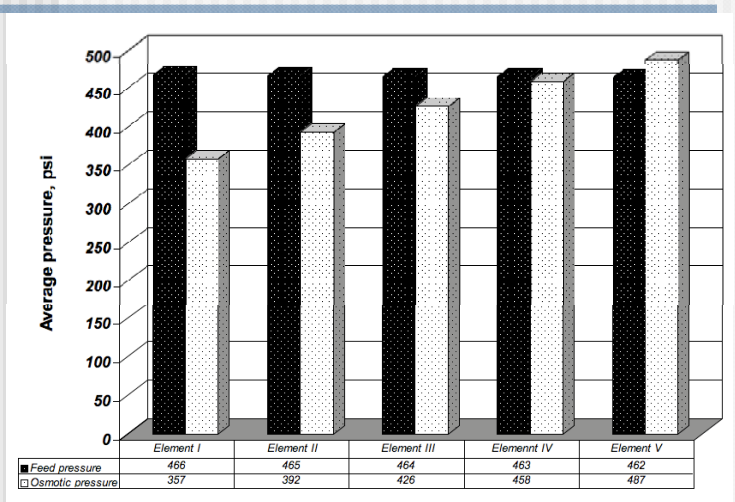
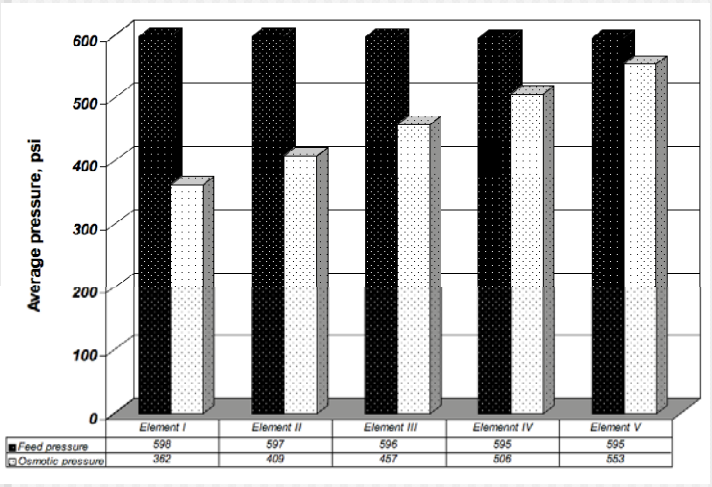
8” Results (Demo plant)

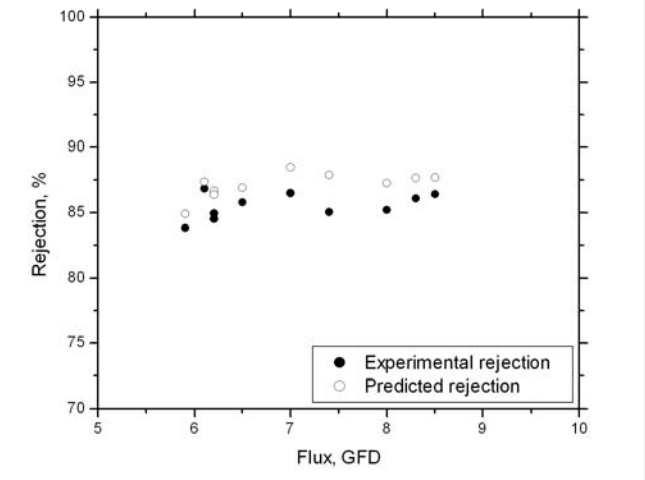


8” Results (Demo plant)



8” Results (Demo plant)

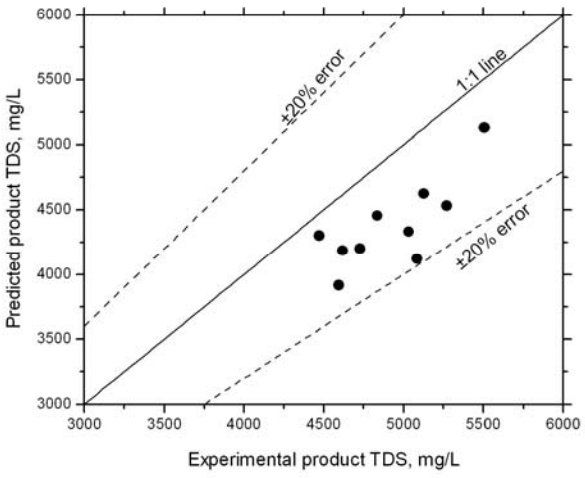
TDS rejection



Note: All data from experiments with feed pressure> osmotic pressure on last element

8” Results (Demo plant)

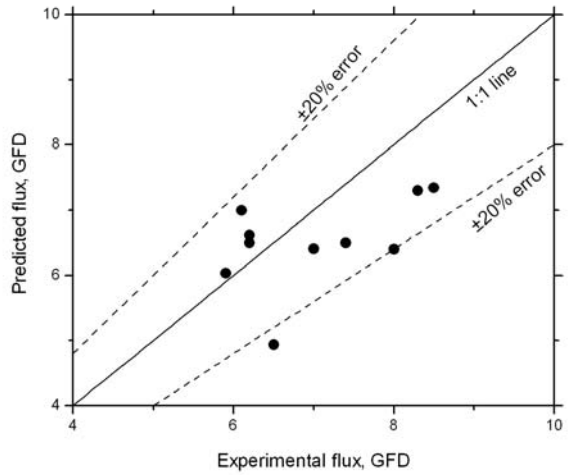
Permeate TDS



Note: All data from experiments with feed pressure> osmotic pressure on last element

8” Results (Demo plant)

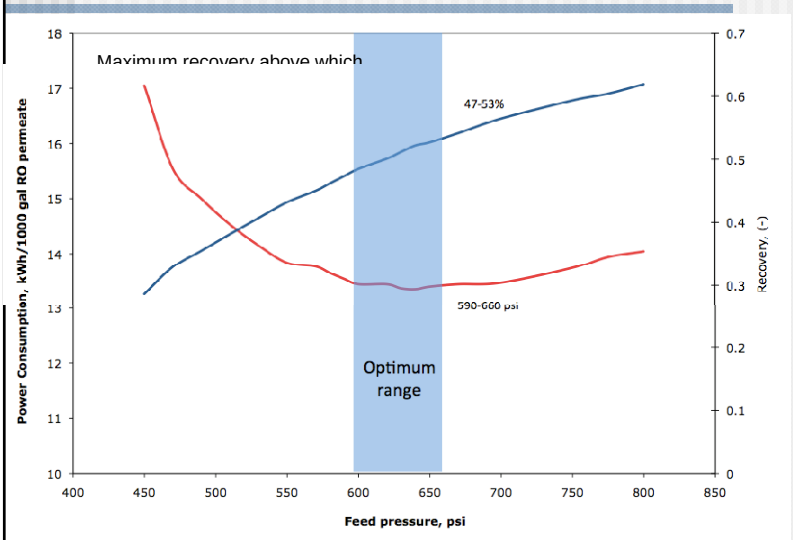
Permeate flux



Note: All data from experiments with feed pressure> osmotic pressure on last element

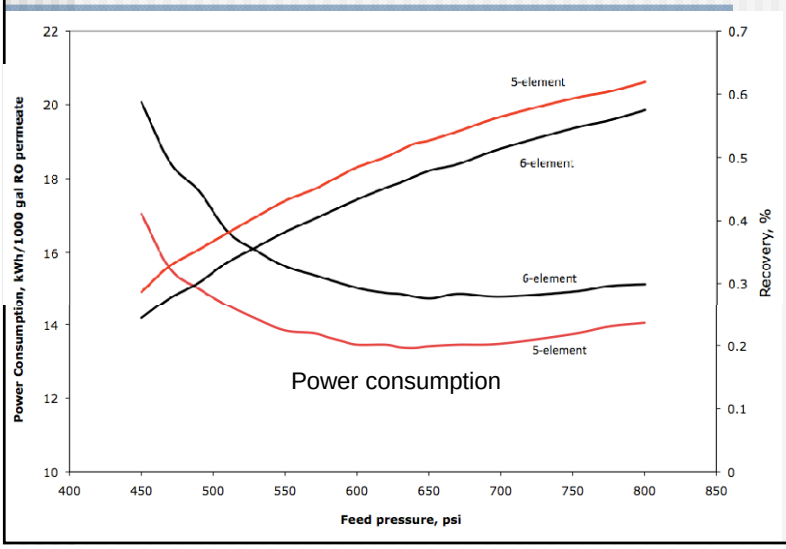
How high recovery can be?

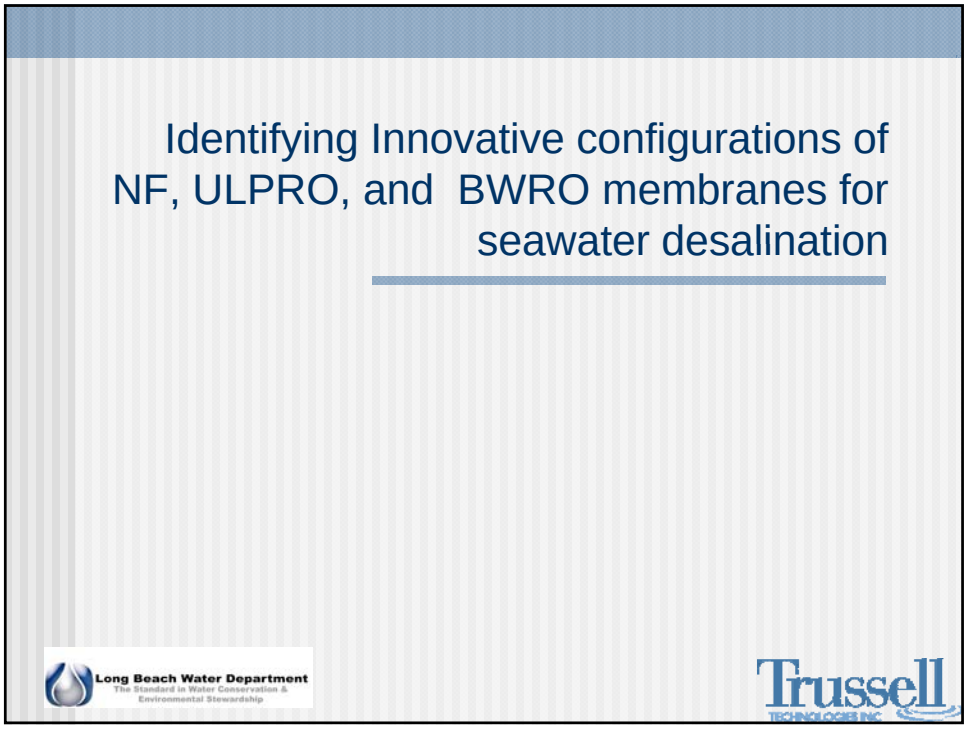
Dilemma: Recovery increases osmotic pressure but decreases kWh/1000 gal



Can six-element configuration reduce energy consumption?

Answer is NO.





Membrane intrinsic parameters

Membrane type	Lp, GFD/psi	Sigma	P, GFD/sec
NF	0.06	0.980	0.30
ULPRO	0.05	0.994	0.18
BWRO	0.044	0.996	0.11
SWRO	0.034	0.999	0.04

T = 20 ºC
A = 400 sq.ft
No. leaves = 21
Channel height = 30 mil
Leaf length = 90 cm
Feed TDS = 35,000 mg/L

Innovative configurations

All at 600 feed pressure and 45% recovery, ULPRO is Dow membrane LE 400

Configuration	Flux	Prod. TDS	kWh/1000 gal	Last element flow	Last element pressure	Ranking
NF-NF-NF-NF-NF	7.93	3965	14.49	13.5	585	
NF-NF-NF-NF-ULP	7.1	3688	14.49	12	588	
ULP-NF-NF-NF-NF	7.4	3681	14.49	12	588	2
ULP-ULP-NF-NF-NF	6.9	3330	14.49	11.7	591	1
NF-NF-NF-ULP-ULP	6.3	3306	14.49	10.7	591	3
ULP-ULP-ULP-NF-NF	6.3	2817	14.49	10.6	595	
NF-NF-ULP-ULP-ULP	5.6	2798	14.49	9.53	595	
BW-NF-NF-NF-NF	7.1	3771	14.49	12	587	
BW-BW-NF-NF-NF	6.2	3509	14.49	10.5	587	
BW-BW-BW-NF-NF	5.3	3092	14.49	8.96	593	

Innovative configurations

All at 45% recovery and 7 GFD flux, ULPRO is Dow membrane LE 400

Configuration	Pressure	Flux	Prod. TDS	kWh/1000 gal	Last elem flow	Last element pressure	Ranking
NF-NF-NF-NF-NF	573.9	7	4366	13.86	13	539.9	
NF-NF-NF-NF-ULP	593	7	3699	14.32	13.2	536	
ULP-NF-NF-NF-NF	588.9	7	3843	14.22	12	539.9	2
ULP-ULP-NF-NF-NF	604	7	3284	14.58	13.3	538	1
NF-NF-NF-ULP-ULP	612.7	7	2987	14.79	14.4	499.6	3
ULP-ULP-ULP-NF-NF	623	7	2857	15.04	13.5	535.2	
NF-NF-ULP-ULP-ULP	642.5	7	2336	15.51	12.6	565.5	
BW-NF-NF-NF-NF	597	7	3882	14.42	12	534.4	
BW-BW-NF-NF-NF	627.7	7	3200	15.15	13.5	522.8	
BW-BW-BW-NF-NF	667.5	7	2512	16.13	11.9	518.2	

Summary

- Membrane intrinsic parameters can be used to scale-up performance
- Optimal configuration for first pass NF is 5 elements per vessel
  - 6 element - energy cost is higher
  - 4 element - capital cost is prohibitive
- Alternative configuration could provide improvements in water quality without significant penalty on the energy consumption
    - ULP-ULP-NF-NF-NF

Acknowledgements

- Funding partners
  - US Bureau of Reclamation
  - LADWP
- Long Beach Water Department staff

See www.lbwater.org for more project information

Long Beach Water Department
Prototype Seawater
Desalination Testing Facility

Test Plan
February 2006

Appendix F
Prototype Test Plan

Appendix F
Prototype Test Plan

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Attachments

A – Process Schematic

Glossary

CDHS	California Department of Health Services
DWPR	Desalination and Water Purification Research and Development Program
ERD	Energy Recovery Device
ERI	Energy Recovery Incorporated
ESWTR	Enhanced Surface Water Treatment Rule
GPD	gallons per day
IESWTR	Interim Enhanced Surface Water Treatment Rule
LADWP	Los Angeles Water and Power
LBWD	Long Beach Water Department
MF	microfiltration
O&M	operation and maintenance
NF/NF	two-pass nanofiltration process
NTU	nephelometric turbidity unit
QA/QC	quality assurance and quality control
Reclamation	Bureau of Reclamation, U.S. Department of Interior
RO	reverse osmosis
SWRO	sea water reverse osmosis
TDS	total dissolved solids
VFD	variable frequency drive

Appendix F
Prototype Test Plan

1.0 Process and Objectives

1.1 Process

The Long Beach Water Department (LBWD) has developed and patented a two-pass nanofiltration process, called NF/NF, to desalinate seawater to drinking water quality. Over the last several years, the LBWD has been testing the hybrid desalination process in the 9000 gallons per day (GPD) pilot scale unit at its Groundwater Treatment Plant. The hybrid desalination process consists of a two-pass multistage nanofiltration membrane process that can achieve treated water salinity better than or at least as good as a conventional single-pass seawater reverse osmosis (SWRO) desalination process utilizing cellulose acetate or thin-film composite membranes, at a lower operating pressure and energy cost. The key component is the 2nd pass concentrate recycle loop that dilutes the feed water and makes the use of nanofiltration membranes feasible. In its simplest form, the process is shown in **Figure 1.1** below.

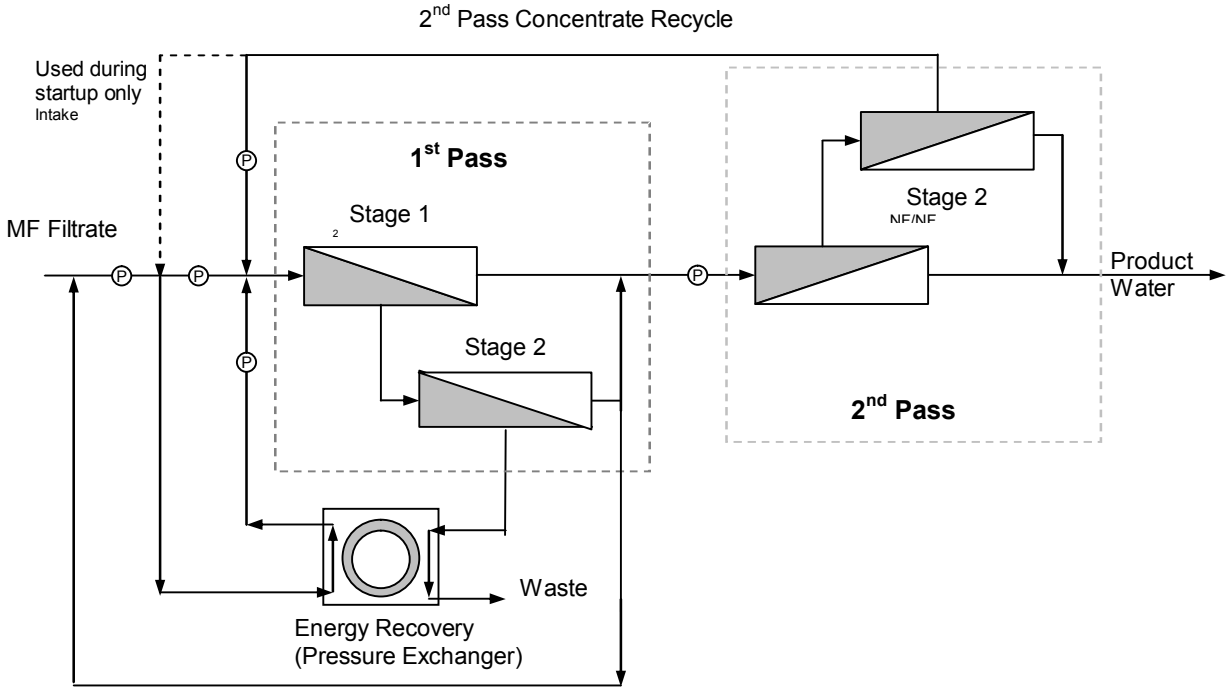


Figure 1.1: NF/NF Process Component Diagram

The next step in the development of the NF/NF process was to construct a 300,000 GPD prototype seawater desalination facility (prototype) to validate the performance results observed

during initial pilot testing directly against SWRO and to test the long-term operating characteristics of the hybrid desalination process. This document will outline the test program to be employed at the prototype facility. It was compiled by personnel from LBWD, Bureau of Reclamation (Reclamation), and Los Angeles Department of Water and Power (LADWP).

1.2 Objectives

The Primary Objectives of this program are to:

A) Operate an efficient pretreatment system
B) Demonstrate that the NF/NF process is efficient and reliable.
   - **Efficiency is** defined as:
     - Maximized recovery
     - Minimized energy usage
     - Minimized chemical usage
     - Minimized cleaning cycles

   - **Reliability** is defined as:
     - Minimized down time
     - Product water quality meets primary and secondary drinking water standards

C) Measure consistency of the long term performance on the NF/NF process

D) Compare the capital and direct O&M cost of the NF/NF against SWRO under the same feed water quality conditions.

E) Provide for Regulatory Acceptability
   - Demonstrate the system meets Surface Water Treatment Rule requirements
   - Obtain California Department of Health Services (DHS) approval for the process for full-scale drinking water production

F) Develop Design Criteria (for technology transfer) relating input water quality and operating parameters to unit performance that will allow plants to be designed locally and at other locations, and to permit optimization of plant operation.

The secondary objectives for the NF/NF system include:

G) Determine the ability of the NF/NF and SWRO systems to remove emerging contaminants (e.g. boron)

2.0 Background

2.1 Site location and description

The prototype is located at the LADWP Haynes Generating Station (**Figure 2.1**). The location for the prototype facility, within the generating station site, is near the station's entrance (just north of Westminster Avenue), adjacent to and east of the station's cooling water channel.

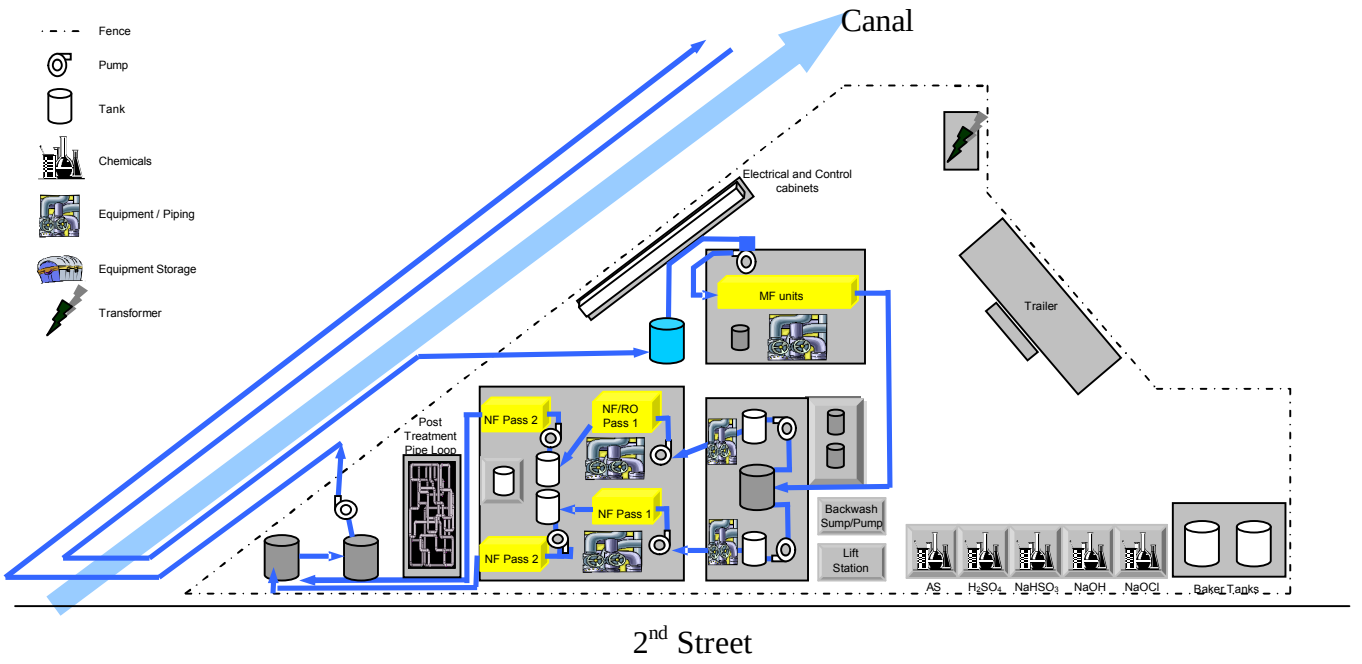


Figure 2.1: Site location and general layout

2.2 Water Composition

The source water for the prototype facility is seawater pumped from the Haynes Generating Station cooling water channel. The cooling water channel seawater intake is located within the Long Beach Marina, which is situated just west of the mouth of the San Gabriel River. The source water quality is characteristic of a coastal seawater off the coast of California. **Table 2.1** shows analyses of samples taken on two days in February 2003, one a dry day, one a rain day.

The dry day values are expected to be typical of values for that season. Rainy day samples may be unique, depending on the duration and intensity of the precipitation. It should be noted that salinity variations due to precipitation are strongly influenced by coastal currents and are site specific.

Seawater samples will be taken periodically during prototype testing to generate a database of compositions. This will allow prediction of the annual variation of seawater composition during dry weather and to estimate what kind of deviations in composition might be produced by precipitation.

Table 2.1 Haynes cooling channel seawater composition

Component	Unit	Dry Day Samples February 12, 2003					Rainy Day Samples February 2, 2003		
		High Tide	Mid Tide	Low Tide	Average	Max.	Low Tide	Mid Tide	High Tide
Primary Regulated Ions									
Arsenic	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Barium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, total	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, VI	mg/L	ND	ND	*NA*	*NA*	*NA*	*NA*	ND	ND
Copper	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Fluoride	mg/L	0.68	0.68	0.67	0.68	0.68	0.61	0.58	0.59
Lead	mg/L	ND	ND	ND	ND	ND	ND	0.051	0.051
Mercury	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ug/L	ND	ND	ND	ND	ND	ND	ND	ND
Other Ions									
Aluminum	mg/L	0.068	0.052	0.040	0.053	0.068	0.149	0.148	0.202
Ammonia	mg/L	0.11	0.09	0.1	0.1	0.11	0.09	0.09	0.09
Bicarbonate	mg/L	113	113	113	113	113	112	112	113
Boron	mg/L	3.9	3.9	3.8	3.9	3.9	4.3	4.2	4.1
Bromide	mg/L	60.9	59.3	59.2	59.8	60.9	50.9	50.9	51.2
Calcium	mg/L	409	410	415	411	415	439	802	444
Carbonate	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Chloride	mg/L	18,566	18,236	18,476	18,426	18,566	18,948	18,828	18,903
Hardness, total	mg/L	6,150	6,176	6,241	6,189	6,241	6,214	7,087	6,205
Hydrogen sulfide	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Iron, total	mg/L	ND	ND	0.1	0.1	0.1	0.1	ND	0.1
Iron, dissolved	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium	mg/L	1,246	1,251	1,246	1,254	1,264	1,243	1,235	1,238
Manganese	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Phosphate	mg/L	0.15	0.16	0.11	0.14	0.16	0.12	0.09	0.12
Potassium	mg/L	370	372	374	372	374	425	395	395
Silica (SiO2) total	mg/L	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Silica (Reactive)	mg/L	0.85	0.7	0.87	0.81	0.87	0.86	0.64	0.38
Silica (Dissolved)	mg/L	0.43	0.41	0.4	0.41	0.43	*NA*	*NA*	*NA*
Silver	µg/L	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	mg/L	9,961	9,999	10,085	10,015	10,085	10,117	10,056	10,037
Strontium	mg/L	*NA*	*NA*	*NA*	*NA*	*NA*	6.6	6.5	6.6
Sulfate	mg/L	2,342	2,316	2,347	2,335	2,347	2,383	2,363	2,374
Sulfide	mg/L	ND	ND	ND	ND	0	ND	ND	ND
Vanadium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	mg/L	ND	ND	ND	ND	ND	ND	ND	ND

ND = Not Detected
NA = Not Available

Table 2.1 (con't) Haynes cooling channel seawater composition

Component	Unit	Dry Day Samples February 12, 2003					Rainy Day Samples February 2, 2003		
		High Tide	Mid Tide	Low Tide	Average	Max.	Low Tide	Mid Tide	High Tide
Algae Count	Natural Units/mL	3,160	4,440	1,440	3,013	4,440	2,160	972	2,230
Color, apparent	Pt-Co	29	19	20	22.7	29	40	38	48
Color, true	Pt-Co	5	6	7	6	7	15	12	16
Conductance	µS/cm	50,300	50,400	50,700	50,500	50,700	50,100	49,800	47,300
TDS/ conductance		0.68	0.676	0.662	0.671	0.662	0.69	0.694	0.73
Heterotrophic Plate Count	cfu/mL	300	200	95	198	300	110	170	218
MTBE	mg/L	ND	ND	ND	*NA*	*NA*	ND	ND	ND
DOC	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Organic Carbon (Total)	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
DO	mg/L	8.68	8.45	8.77/8.17	8.57	8.68	8.15	8.12	7.66
pH (sampling)	unit	7.98	8.03	7.84	7.95	8.03	8.07	8.01	7.99
Plankton Counts	Natural Units/	<1	<1	<1	*NA*	*NA*	<1	<1	<1
Temperature (sampling)	^{o}C	17.5	17	16	16.8	17.5	15.2	15.3	16.3
Total Dissolved Solids (TDS)	mg/L	34,115	33,950	33,630	33,898	34,115	34,580	34,565	34,460
Total Algal Count	Cells/ 100mL	78,000	64,000	52,000	64,667	78,000	20,000	*NA*	6,200
Total Suspended Solids (TSS)	mg/L	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Turbidity	ntu	2.1	2	2	2	2.1	3.3	2.5	4.1
UV_{254}	cm^{-1}	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
TDS (calculated)		33,141	32,814	33,179	33,044	33,179	33,879	34,052	33,769
%Difference		3%	3%	1%	3%	3%	2%	1%	2%

ND = Not Detected
NA = Not Available

3.0 Treatment Process and Equipment

A general process schematic diagram for the prototype desalination treatment system is presented in **Figure 3.1**. A detailed process schematic is shown in **Attachment A**.

The major treatment components of the test facility include pressurized microfiltration (MF) pretreatment, followed by two parallel desalination trains. The south desalination train (Train 1) is configured for NF/NF with optional energy recovery. A north desalination treatment train (Train 2) will be initially operated as conventional SWRO with optional energy recovery. In general the entire prototype system will be operated as one entity with the option of operating either Train 1 or Train 2 by itself. After completion of the initial phases of testing, Train 2 will be reconfigured as a second NF/NF train. The prototype facility includes a product water post-treatment testing station. Post-treatment testing will evaluate the effects of desalinated seawater before post-treatment and after post-treatment. This will include corrosion effects on common distribution system materials. Guidelines will be developed to minimize corrosion effects for desalination facilities.

3.1 Pretreatment

The source water for the prototype facility is seawater diverted from the Haynes Generating Station cooling water channel. Trash racks at the channel intake screen the flow to remove coarse materials. The influent raw seawater is passed through 300 µm self-backwashing strainers prior to reaching the pretreatment process. The prototype facility will use a Pall MF system as pretreatment for the desalination processes. The MF system will remove particulates greater than 0.1 µm in size from the raw seawater and provide a low fouling potential water to the downstream desalting processes.

The MF is expected to operate up to 10% recycle and a minimum and maximum filtrate flow of 556 gpm and 660 gpm, respectively. MF filtrate is directed to the 10,000 gal MF filtrate storage tank, which is adequate to continually supply MF filtrate to both trains, while the MF process undergoes backwash. A bypass pipe is provided to allow the off-spec feed water to be returned to the channel via the Combined Effluent Tank. Filtrate water entering the MF filtrate storage tank must have the following specifications:

- Turbidity $\leq$ 0.2 NTU
- Silt Density Index $\leq$ 5.0

Water exiting the MF filtrate tank after de-chlorination must have the following specification:

- Chlorine Residual $\leq$ 0.1 mg/L (membrane dependent)

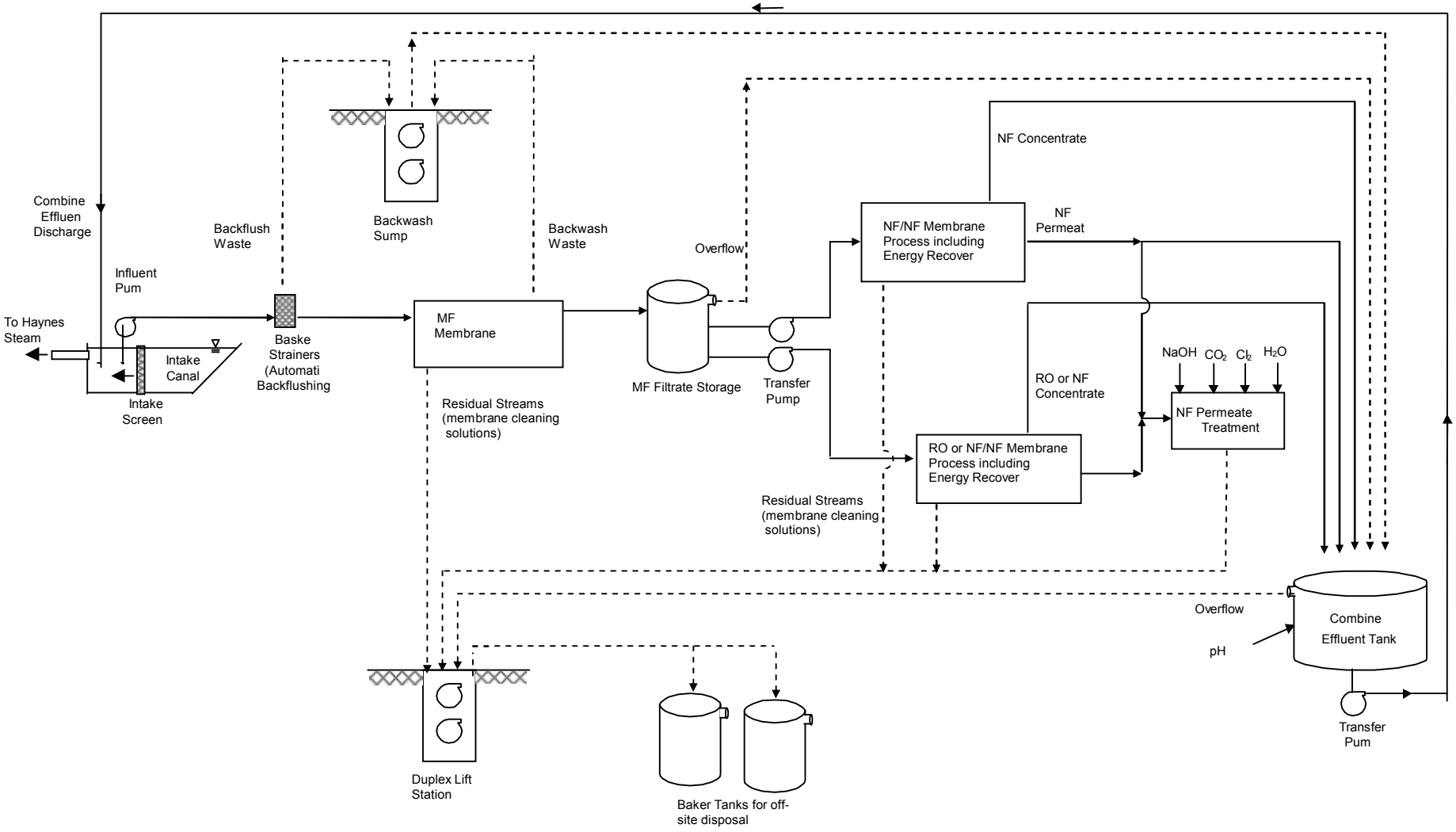
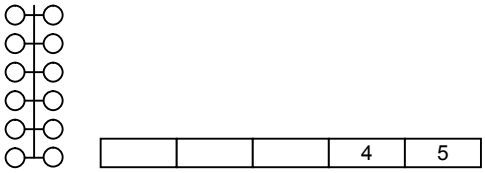


Figure 3.1 NF2 general process schematic

The MF system is backwashed at staggered intervals of approximately 15 to 60 minutes (currently 22 min.) and can be manually changed. Backwash frequency is based on how quickly head loss increases and the backwash cycle duration needed to restore the membrane. Source water quality changes and its effect on MF membrane performance will be considered. Chlorine will be used in the backwash water to assist in minimizing biogrowth on the membranes. Backwash water will be neutralized as required, and discharged to the Combined Effluent Tank. The MF system requires chemical cleaning with citric acid or sodium hydroxide/chlorine if fouling occurs. Fouling is recognized by a differential pressure exceeding 20 psi. Used cleaning chemical solutions are discharged to the on-site baker tanks after required neutralization.

Distinction is made between pretreatment equipment and desalination equipment at the NF/SWRO feed tank. One tank for each train has been provided to allow for limited short-term flow differences between the source water feed pumps and the low-pressure transfer pump. This permits a constant flow rate through the desalination process trains during microfiltration process backwashes. The MF filtrate water may be blended in the respective feed tanks with permeate from Pass 1 – Stage 2. As the tank fills, a high-level sensor signals that the NF/SWRO feed pumps for that respective train can be started. The NF/SWRO feed tank is provided with an overflow pipe leading to the Combined Effluent Tank.

3.2 Train 1: NF/NF Pass 1 – Stage 1



The NF/NF process is arranged in two passes, with the permeate from Pass 1 NF vessels being used as the feed water to the Pass 2 NF vessels. Under this treatment scheme, the total dissolved solids concentration of the MF pretreated water (approximately 34,000 mg/L) can be reduced to 340 mg/L or less when the TDS rejection in each NF pass is at least 90%.

Pass 1 performs the preliminary desalination of the seawater. This membrane stage consists of 12 vessels. They are operated in parallel (6 vessels per side), each capable of holding five membrane elements.

The Pass 1 Feed Pump fills the Pass 1 membrane rack at a minimum inlet pressure of about 50 psi to the Pass 1 High Pressure Pump. Capability to feed acid and scale inhibitor chemicals is provided in the system to control the scaling potential of the pretreated water. The two chemicals can be injected into the Pass 1 Feed Pump discharge. After chemical addition, the pretreated water passes through a 10 μm cartridge filter that provides protection for the NF membranes and ensures that chemicals added are well mixed with the feed water.

The Pass 1 High Pressure Pump is controlled by a variable frequency drive (VFD) and provides flow and operating pressure up to 600 psi for Pass 1. While the Pass 1 High Pressure Pump provides the flow and high pressure, the pressure is further refined through a pressure control valve on the discharge side of the high pressure pump. The combination of the VFD driven high pressure pump and pressure control valve allows the testing of specific pressure and flow. The value of 530 psi, used in the bench test unit is a reasonable starting value. However, to optimize the unit performance, we need data covering a range of values.

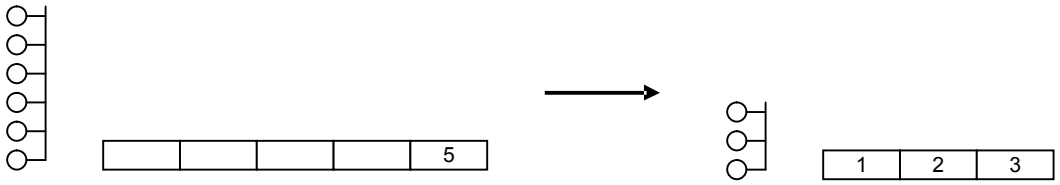
When the energy recovery device (ERD), an Energy Recovery Incorporated (ERI) isobaric chamber pressure exchanger, is not being employed, the recovery of Train 1 Pass 1 is controlled by a flow control valve on the discharge of Train 1 Pass 1 concentrate line. By limiting the flow out of the Pass 1, more recovery can be achieved. However, it is important to note that increasing recovery will result in higher required pressure and subsequently poorer product quality. When the ERD is used, concentrate from Pass 1, Stage 2 is discharged through the device to recover the available energy. The ERD can potentially transfer up to 97% of the Pass 1 pressure remaining in the concentrate stream. The feed flow into the ERD must equal the concentrate flow. An energy recovery booster pump on the discharge side of the ERD will boost the flow to overcome the Pass 1 High Pressure Pump Pressure. Consequently, the energy recovery booster pump will control the recovery of Pass 1 when the ERD is employed.

3.3 Train 1: NF/NF Pass 1 – Stage 2

The purpose of this portion of the system is to recover additional water from the still pressurized concentrate from Pass 1 – Stage 1 to increase the recovery of permeate of Pass 1. The Pass 1 – Stage 2 consists of eight vessels. They are operated in parallel (4 vessels per side), each capable of holding five membrane elements. Experience shows that after 3 membranes, the osmotic pressure is equal to the feed pressure and flow can not be obtained. The permeate from this section may be too high in salinity to be delivered to the Pass 2, but is less concentrated than the original feed (for full strength seawater), so it may be recycled to the Pass 1 Feedwater Tank. If the Stage 2 permeate TDS is not too high, it can be combined with the Stage 1 permeate.

Optimization of Pass 1, Stage 2, will be part of the model to be developed. The critical parameter is the dividing line between Stage 1 and Stage 2. This will be determined by calculation and confirmed by experiment. At this time, two membranes are in use (530 psi feed). This number may increase if TDS and corresponding feed pressures increase.

3.4 Train 1: NF/NF Pass 2 – Stage 1 & 2



Train 1: Pass 2 also consists of 2 stages; where Stage 1 consist of six vessels, each capable of holding five elements and Stage 2 consist of three vessels, each capable of holding three elements.

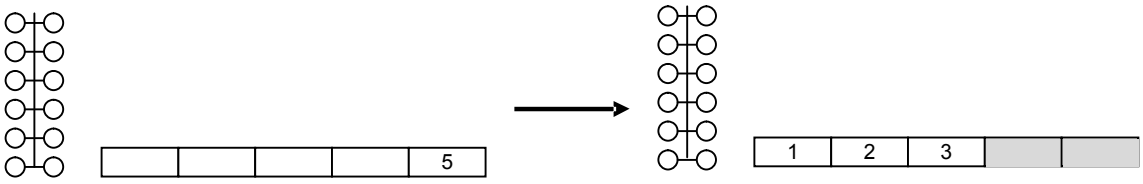
Permeate from the Pass 1 constitutes the feed for Pass 2. A VFD controls the Pass 2 High Pressure Pump. A control valve is located on the discharge side of the Pass 2 High Pressure Pump. Like Pass 1, the desired test flow and pressure is controlled with the combination of the two.

Based on pilot testing data, the final concentrate TDS from Pass 2 is still less than the raw seawater TDS, thus, it can be recycled to the Pass 1 feed. The final Pass 2 concentrate can be recycled to either the suction side of the Pass 1 High Pressure Pump or can be boosted through the Pass 2 booster pump to the discharge side of the Pass 1 High Pressure Pump. The latter will be the primary method of recycling the Pass 2 concentrate since this will allow the greatest energy recovery. Consequently, the recovery of Pass 2 is controlled by the amount of recycle to Pass 1.

The combined Pass 2 product TDS goal is 350 mg/L based on the LBWD existing distribution system TDS. It is a useful property of this process that the product salinity can be adjusted close to the desired value by configuration of the unit. To obtain a particular product salinity, the operating rejection of Stage 2 depends exclusively on the rejection of Pass 1 – Stage 1 and any contribution from Pass 1 – Stage 2. As the latter decreases, the former must increase. The operating pressure is determined by the membrane permeability and the desired water recovery.

3.5 Train 2: SWRO/NF – Stage 1 & 2

3.5.1 SWRO



Train 2 is initially configured as a conventional SWRO system. The SWRO system consists of two stages. The first stage and second stages have 12 vessels operated in parallel (6 vessels per side). Each vessel is capable of holding five membrane elements. Each second stage vessel is expected to hold from two to three elements. Using all eight second stage vessels, the second stage is an extension of the first stage that permits testing up to eight elements in series with sampling available after element 5.

Like Train 1, the Train 2 Feed Pump fills the SWRO membrane rack at a minimum inlet pressure of 50 psi to the SWRO High Pressure Pumps. Capability to feed acid and scale inhibitor chemicals is provided in the system to control the scaling potential of the pretreated water. The two chemicals can be injected into the SWRO Feed Pump discharge. After chemical addition, the pretreated water passes through a 10 μm cartridge filter that provides protection for the SWRO membranes and ensures that chemicals are well mixed with the feed water.

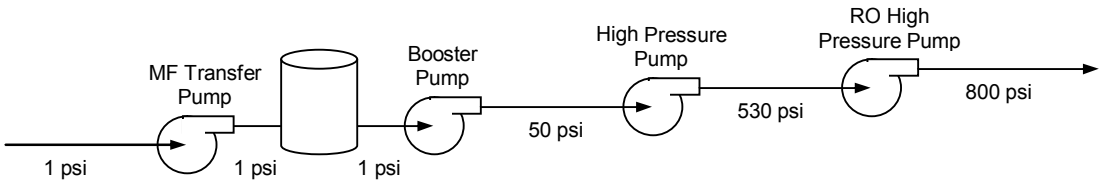


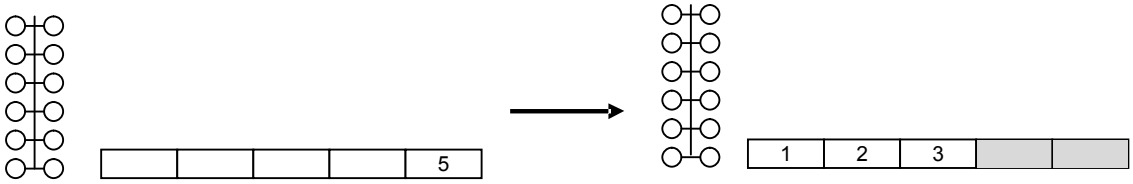
Figure 3.2: Membrane pumping system (energy recovery portion not shown)

There are two high pressure pumps for the SWRO train, staged in series. The SWRO High Pressure Pump 1 can increase the feed pressure to a maximum of 600 psi and the SWRO High Pressure Pump 2 can further increase the feed pressure up to a maximum of 1000 psi. Both SWRO High Pressure Pumps are controlled by a VFD and combined with a control valve on the discharge side of the SWRO High Pressure Pump 2 allows the testing of specific pressure and flow.

Traditional SWRO membrane systems typically operate at much higher pressures than NF membranes (up to 1,000 psi). As compared with the NF/NF process, conventional SWRO is a one pass process, with recovery ranging from 40 to 50 percent. For SWRO membranes to achieve product water quality comparable to the NF/NF process, the overall salt rejection has to be greater than 99% in the single pass.

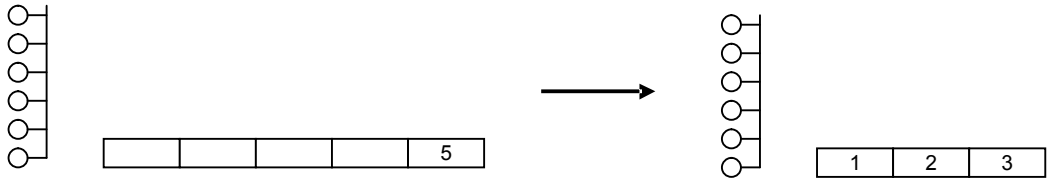
After the initial phase of testing comparing the performance of the NF/NF process with SWRO with respect to product water quality and overall system efficiency, the second treatment train will be reconfigured as a second NF/NF system for the remainder of testing. A bypass section of pipe is installed on the discharge of SWRO High Pressure Pump 1 to bypass SWRO High Pressure Pump 2 after the initial phase of testing. Regardless of whether Train 2 is operated as SWRO or as a second NF/NF train, recovery control is identical to that of Train 1.

3.5.2 NF



After the initial phase of testing comparing the performance of the NF/NF process with SWRO with respect to product water quality and overall system efficiency, the second treatment train will be reconfigured as a second NF/NF system for the remainder of testing. A bypass section of pipe is installed on the discharge of SWRO High Pressure Pump 1 to bypass SWRO High Pressure Pump 2 after the initial phase of testing. Regardless of whether Train 2 is operated as SWRO or as a second NF/NF train, recovery control is identical to that of Train 1. See section 3.2 to 3.4 for a description of NF/NF operation.

3.6 Train 2: NF/NF Pass 2 – Stages 1 & 2



Train 2: Pass 2 is nearly identical to Train 1: Pass 2 with the exception that Pass 2 – Stage 2 consists of six vessels, each capable of holding three elements. The basic operating capability of Train 2: Pass 2 is identical to that of Train 1.

3.7 Energy Recovery

The concentrate stream from Pass 1 – Stage 2 will consist of 45% to 55% of the feed volume of water at a pressure of several hundred psi. This represents energy that can be recovered and returned to the process.

Historically, the commonly used means of energy recovery was a Pelton wheel turbine. However, more recently developed units like the Pressure Exchanger (PX) operate more efficiently. Manufacturer performance projections for the PX indicate 20% greater energy recovery than can be achieved with a Pelton wheel turbine.

The Pressure Exchanger technology has been developed by Energy Recovery, Inc. The PX utilizes the principle of positive displacement to allow low-pressure pretreated seawater to be pressurized directly by the high-pressure concentrate stream from the desalination process. The device uses a cylindrical rotor with longitudinal ducts to transfer the pressure energy from the

concentrate stream to the feed stream. The rotor spins inside a sleeve between two end covers with ported openings for low-pressure and high-pressure.

The low-pressure side of the rotor fills with seawater. The high-pressure side of the rotor fills with concentrate, which discharges the seawater at a higher pressure than the inlet pressure. The pressure exchanger pressurizes 45% to 55% of the Pass 1 Stage 1 feedwater to 95% of the pressure required. A booster pump provides the additional 5% of the pressure required. There is some inefficiency in the PX recognized by a small amount of salt transfer from the concentrate to the feed (1 to 2%) (**Figure 3.3**) and friction loss.

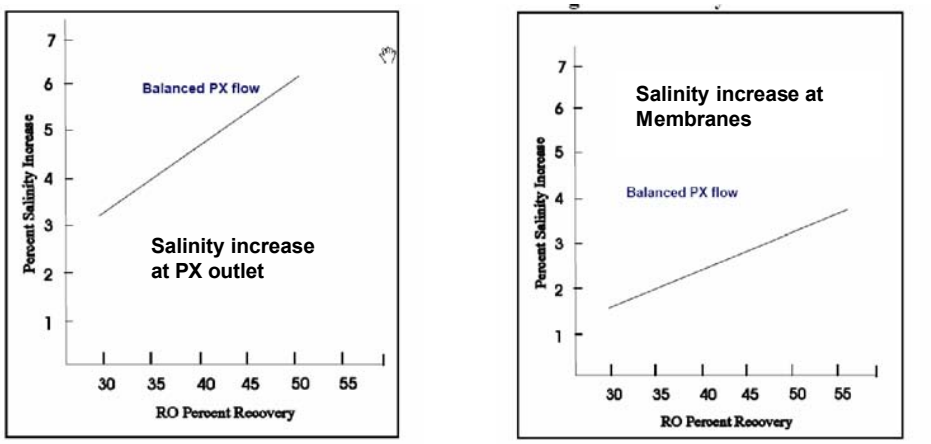


Figure 3.3: Salinity increase from the PX

3.8 Post Treatment

A portion of the product water stream from either Train 1 or Train 2 can be directed to the post-treatment system for evaluation of the effects of desalinated seawater on distribution system components. Post treatment equipment consists of chemical dosing systems for sodium hypochlorite (for disinfection), blend water (source of calcium), sodium hydroxide and carbon dioxide (both for pH adjustment). A chlorine contact loop with adjustable residence time (depending on the settings of multiple valves) follows addition of sodium hypochlorite. The corrosivity and pH of the product stream can then be adjusted through the addition of sodium hydroxide and carbon dioxide. Three evaluation stations will be used to evaluate the effects of the following water samples on common distribution system materials:

- Desalinated seawater before post-treatment
- Desalinated seawater after post-treatment
- Normal distribution system water

Post treatment results from the RO and NF systems will be compared. More detailed post treatment tests will be performed during later NF only testing.

The treatment system has 2 major goals, the reduction in viable pathogen content and the reduction in TDS. Pathogen reduction in this design is achieved through physical barriers (ultra filter (UF) membranes, cartridge filters, and reverse osmosis (RO) membranes) and oxidation (ultraviolet light (UV) and chloramines) (**Table 9.1**). TDS reduction is achieved through physical removal using RO membranes.

3.9 Pathogen Removal

Table 9.1: Log inactivation/removal credit provided from a regulatory standpoint

	Treatment Credit							Required Credit		
	200 μm Strainer	UF	Cartridge Filter	NF Pass 1	NF Pass 2	Chlorine	Total	SDWA [2]	Additional LT2 ESWTR [3]	Total
Giardia	-	4	0	0	0	3		3.0	N/A	
Total Credit	0	4	4	4	4	7	**7.0**	3.0	3.0	**3.0**
Viruses	-	2	0	0	0	4		3.0	N/A	
Total Credit	0	2	0	0	0	6	**6.0**	3.0	3.0	**3.0**
Cryptosporidium	-	4	0	0	0	0		3.0	2.5	
Total Credit	0	4	4	4	4	4	**4.0**	3.0	5.5	**5.5**

1 - RO is not given credit due to variability in the membrane surface and insufficient ability to integrity check. However, actual removal of all organisms is expected to be at least 3.0 log removal.
2 – SDWA = Safe Drinking Water Act
3 – LT2 ESWTR = Long Term 2 Enhance Surface Water Treatment Rule
4 – Additional credits may be needed due to diversion of wastewater before the chlorine contact basin

3.10 Chemical Addition

Chemical metering pumps are used to supply treatment chemicals to various system processes. The prototype facility will include chemical addition systems for the following:

- Sodium Hypochlorite prior to the MF for major cleaning only
- Sodium Hypochlorite to the MF backwash water to enhance backwash
- Sodium Hydroxide to the MF clean-in-place (CIP) process
- Sodium Bisulfite to the MF filtrate for dechlorination
- Sulfuric Acid to the Train 1 & 2 feed separately to reduce scaling
- Scale Inhibitor to the Train 1 & 2 feed separately to reduce scaling

- CIP Feed Solution of sodium hydroxide or Citric Acid to Trains 1 & 2 - Pass 1 & 2 separately for membrane cleaning
- Sodium Hydroxide to Train 1 & 2 Pass 2 feed separately for increased Boron removal
- Sodium Hypochlorite to Post Treatment system for distribution system disinfectant residual simulation
- Sodium Hydroxide to Post Treatment system for distribution system pH adjustment
- Carbon Dioxide to Post Treatment system for distribution system recarbonation
- Sodium Bisulfite to the combined effluent to remove any free chlorine before discharge
- Sodium Hydroxide to the combined effluent to ensure proper pH in the discharge water

3.11 Online Instrumentation

The following online instrumentation is included in the prototype facility:

- Alkalinity
- Conductivity
- Differential pressure
- Energy usage
- Flow
- Hardness
- Oxidation/Reduction potential
- pH
- Pressure
- Temperature
- Turbidity

4.0 Test Program

4.1 General Plan

A summary of the proposed project phases and their goals is shown in **Table 4.1**. The timeline for implementing the phases is shown in **Table 4.2**.

Table 4.1: Testing phases

Phase	Goal
1 System Startup	100% operational equipment with calibrated and verified instrumentation
2 Process Validation	Obtain data from the RO & NF/NF process for comparison purposes
3 NF/NF Optimization	Convert the RO system to an NF/NF system and optimize the process
4 Regulatory Approval	Provide the necessary data for the final approval of the NF/NF process for seawater desalination by CDHS
5 Report	Analyze remaining data and finish reporting, etc.

Table 4.2: Testing phase timeline

		2005	2006												2007		
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
	Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	System Startup																
2	Process Validation																
3	NF/NF Optimization																
4	Regulatory Approval																
5	Report																

Table 4.3 combines the objectives with the plan on how to accomplish each objective. Specific goals are shown where relevant along with the phase in which each objective will be accomplished.

Table 4.3: Objectives, plan to accomplish objectives, goals, and relevant phases

Objective	Description	Detail	How to Accomplish Objective	Phase	Threshold	Goal	Estimated Optimum
A	Operate and efficient pretreatment system		SDI	2,3	5 (max)	<4	3
			Turbidity (NTU)	2,3	0.2 (max)	<0.2	0.05
			Flux (GFD)	2,3			30
B	Demonstrate that the NF/NF process is efficient and reliable	Efficiency	Maximize Recovery	2,3	30% (min.)	>35%	40%
			Minimize Energy Usage	2.3			
			Minimize Chemical Usage - Sulfuric Acid	2,3			
			Scale Inhibitor	2,3			
			Minimize MF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year
			Minimize NF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year
		Reliability	Minimize down time *	2	95% operational time	>95% operational time	
			Meet Primary Standards by obtaining data on all likely contaminants	2	100% of the time	100% of the time	
			Meet Secondary Standards by obtaining data on all likely contaminants	2	99% of the time	100% of the time	
C	Measure consistency of the long term performance on the NF/NF process		Demonstrate that changes in feed water do not substantially change the product water quality by recording feed and product water quality data	2			
			Demonstrate that initial performance levels are maintained (e.g. constant flux) and equipment (e.g. membranes) meet their projected lifespan	2			
D	Compare the Capital and O&M Cost of the NF/NF and RO system under the same usage conditions			2			
E	Regulatory Acceptability	SWTR	(see Objective **B**)	2,3,4			
		DHS	Work toward approval for treatment process	2,3,4			
F	Develop Design Criteria (for technology transfer) relating input water quality and operating parameters to unit performance		Develop a mathematical model to determine the most influential design parameters	2,3,4,5			
G	Determine the ability of each system to remove Boron	NF/NF	Measure boron and utilize the sodium hydroxide addition pt. between Pass 1 and Pass 2	2,3			
		RO		2			

* "down time" is not counted in the following situations:
-equipment failure where standard redundant equipment, not included here, would allow for maintenance. A design flaw with the NF/NF system could be an exception.
-shutdown for vacations and facility tours

During testing, the primary contact persons for the cooperating organizations are shown in **Table 4.4**.

Table 4.4: Contact Personnel

Organization	Primary Contact
LBWD	Tai Tseng or Robert Cheng
LADWP	Alvin Bautista
Reclamation	Frank Leitz

4.1.1 2005 AWWARF Study Recommendations

The 2005 AWWARF study entitled "A Novel Approach to Seawater Desalination Using Dual-Staged nanofiltration Process" makes a series or recommendations for further testing. These recommendations are re-phrased and detailed below:

1. Verify where the majority of desalting is taking place.
   The predictive model suggested that most of the desalting occurs within the first four elements in Stage 1 and the first three elements in Stage 2.
2. Determine the optimal distribution of membranes to obtain the best recovery/rejection relationship
   Generally, the conditions that result in low overall energy required included using tighter membrane in Stage 1 (94 percent rejection) and looser membrane in Stage 2 (84 percent rejection)
3. Determine the critical pressure point where salt rejection is optimized
   After a critical pressure was exceeded for some salts, rejection decreased in bench and pilot tests. Below this critical point, convection dominated and permeate water quality improved with increasing pressure. Once the critical point was reached, diffusion dominated and permeate water quality deteriorated with further increases in pressure.
4. Determine the fouling potential and most appropriate cleaning techniques
   Surface analysis of used membranes indicated organic fouling, diatoms (high in silica), and localized scale deposits (Si, Fe, Al, Ca)
5. Determine the most appropriate cross flow velocity
   Increasing the cross flow velocity improved flux and rejection by decreasing the thickness of the CP layer. However, the cross flow may not be able to overcome the negative fouling effects of the high flux rates.
6. Determine impact of maintaining a high pH for corrosion control and its negative effects on chloramination
7. Determine how to control the effects of bromide
   Bromide exerts a chlorine demand and deplete the disinfectant residual. Bromamines can react with NOM from blended water to form brominated DBPs. Oxidation of NOM from the blending stream by chlorine was identified as a possible solution if the chlorination process does not form too many DBPs.

8. Determine the treated water quality needed for proper corrosion control
   This includes blending and pH adjustment
9. Investigate the options for alternative viral surrogates to MS-2 phage
   Virus surrogates would need to be <30 nm and/or molecular weight <100,000 amu.

4.1.2 Post Treatment

Post treatment is a critical step for high-pressure membrane applications for drinking water treatment. ***The desalinated water quality needs to be adjusted and/or blended to ensure that it meets finished water quality goals and also to minimize corrosion potential in the distribution system. The impact of various blending and/or disinfection scenarios on finished water quality and DBP formation will be evaluated at a bench-scale at LBWD laboratory. The corrosion potential of the NF/NF process permeate with and without chemical addition will be evaluated using test coupons and current potable water as reference. Post treatment will be evaluated throughout the testing program and the generated data will be used to recommend effective post treatment strategies for the full-scale system.

4.1.3 Energy Recovery

Testing will take place with and without energy recovery. The data will be used to minimize the energy consumption by the NF/NF process and enhance process economics. Following stabilization the remaining first half (time wise) of every test is run without energy recovery. Energy recovery is then implemented for the second half (Figure 4.1)

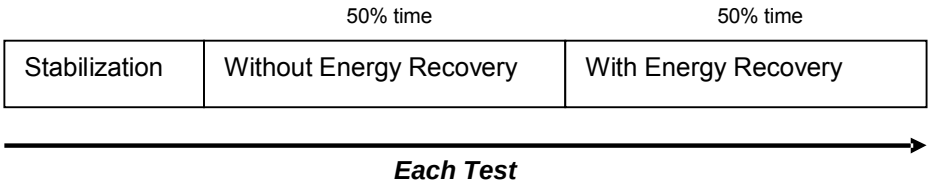


Figure 4.1: Energy recovery usage during each test

4.1.4 Membranes

The following membranes will be used during testing (Table 4.5):

Table 4.5: Membrane Selection

Type	Method	Model	Size	Surface Area	Salt Rejection	Max Feed Flow per Vessel	Max Pressure
MF	Pall		0.01 um	400 ft^2			
NF							
NF	Dow FIlmtec	NF90-400			85-95% NaCl >97% $MgSO_4$	70 gpm	600 psig
RO	Saehan	NE90					

4.1.5 Membrane Integrity Monitoring

A key factor to ensure the reliability of any membrane process is the monitoring of membrane integrity to ensure that adequate treatment is continuously being provided. The direct monitoring methods are typically applied directly to the membrane system and/or element to check its integrity. Indirect methods monitor a surrogate parameter in the membrane permeate and correlate it to membrane integrity. Several direct and indirect methods are available and some will be employed to monitor membrane integrity and overall treatment reliability and consistency (**Table 4.6 & Table 4.7**).

Method Type	Method	Employed	Frequency
Indirect	Online turbidity	Yes	Continuous
	Online particle-count	No	
Direct	Air Pressure Hold Test	Yes*	Once per month

Table 4.6: MF integrity monitoring methods

Method Type	Method	Employed	Frequency
Indirect	Online conductivity	Yes	Continuous
	Online sulfate	No	
	Online hardness	Yes	Continuous
Direct	Vacuum Hold Test	No	

Table 4.7: RO and NF integrity monitoring methods

4.1.6 Membrane Cleaning

Membrane cleaning should be minimized with thresholds, goals, and estimated optimum points shown below (**Table 4.8**).

Table 4.8: Membrane cleaning thresholds, goals, and estimated optimum points

Parameter	Phase	Threshold	Goal	Estimated Optimum
MF Backwash Cleaning Cycles *	2,3	1 per 15 min.	1 per 30 min.	1 per 30 min.
MF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year
NF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year

While minimized cleaning is the overall goal, it may not always be the goal of a specific test. Some tests may test the limits of the system where the limits is between scaling and not scaling, etc.

The treatment system is operated in a constant pressure / declining flux mode. Therefore, all indicators of required membrane cleaning are related to flux. Membrane cleaning indicators are established by the membrane manufacturers and are summarized below for both constant pressure and constant flux modes (**Table 4.9**).

Table 4.9: Membrane cleaning indicators and cleaning method details

Type	Membrane Manufacturer	Condition	Constant Pressure Mode Indicator for CIP	Constant Flux Mode Indicator for CIP	Cleaning Solution	Conc.	Duration
MF		Biological Fouling		TMP increase = 20%	NaOH		30 min.
			(if NaOH does not work)	(if NaOH does not work)	Add Sodium Hypochlorite		
		Scaling		NDP increase = 20%	Citric Acid		30 min.
		Scaling					
		Particle plugging		Feed – Retentate = 10 psi			
RO		Biological Fouling	Flux decline = *%	NDP increase = 20%	NaOH		
		Scaling	Flux decline = *%	NDP increase = 20%	Citric Acid		
		Particle plugging					
NF							

4.2 Phase 1: System Startup

The system startup involves the use of the separate "Testing and Start-up Plan". This phase includes initial startup and sufficient run time to ensure all equipment runs as specified. Plant operation staff will use this startup period to become familiar with proper operation of the system. If design modifications are needed, these will occur during this phase.

4.3 Phase 2: Process Validation

The process validation phase involves the operation of the NF/NF and RO systems for comparison purposes. This phase contains two distinct sub-phases (**Table 4.10**).

Table 4.10: "Process Validation" phase timeline

	Mar	Apr	May	Jun	Jul	Aug
Sub-phase	**4**	**5**	**6**	**7**	**8**	**9**
Optimization						
Validation						

The optimization sub-phase is a 3 month period where the SWRO and NF/NF systems will be optimized as far as possible. The first week of this sub-phase will involve a fast optimization where the system will set at expected optimum settings with adjustments as needed. Subsequent testing will be more methodic to obtain quality data points. This is followed by a 3 month period of validation testing where control settings are held constant. This data will be crucial for Objective A (reliability), B, and C.

The SWRO system will be run at standard operating conditions for a seawater treatment system for the given water quality and optimized to fit local conditions where needed. The NF/NF system will be run according to parameters developed during previous pilot testing. The matrix of parameters is shown below (**Table 4.11**).

Initial operating parameters are summarized in **Attachment A**. The results of this phase must indicate that the NF/NF process is at least reasonably close in performance to the RO system in order to proceed to the NF/NF Optimization Phase.

Table 4.11: "Process Validation" phase testing matrix

		Independent Variables		Dependent Variables	
	Parameter	**Estimated Optimum**	**Values to be tested**	**Estimated Optimum**	**Estimated Values**
UF	Membranes				
	Feed Pressure (psi)				
	Feed Flow (gpm)				
	Flux (gfd)				
NF Pass 1	Membranes				
	Feed Pressure (psi)	530	520 540 560 580		
	Feed Flow (gpm)		*** (+10%) *** (-10%)		
	Flux (gfd)				
	Recovery				
NF Pass 2	Membranes				
	Feed Pressure (psi)			***	*** *** *** ***
	Feed Flow (gpm)				*** (+10%) *** (-10%)
	Flux (gfd)				
	Recovery				
RO	Membranes				
	Feed Pressure (psi)	***	*** *** *** ***		
	Feed Flow (gpm)		*** (+10%) *** (-10%)		
	Flux (gfd)				
	Recovery				

4.3.1 Model Design

Reclamation will design an empirical model to analyze the data and determine which parameters are most influential. Data from this phase will be entered into the model as a starting point. This model will be essential for Phase 3.

4.4 Phase 3: NF/NF Optimization

Upon the completion of the validation phase, the Train 2 will be converted to an NF/NF system to initiate the NF/NF optimization phase. There does not currently exist a suitable experience and

models for NF membrane performance under the conditions employed in the NF/NF process, thus the optimization phase of this testing program will focus on this process. The optimization of the NF/NF will focus on several factors that should improve the process. These factors include:

- Membrane brands and suppliers
- Number of membrane elements per stage
- Feed pressure
- Feed flow
- Chemical dosage

This phase will provide critical design and operating parameters that are required for costing of the NF/NF process.

Model Development

The model designed in Phase 2 will use the independent and dependent variable data obtained in this phase to generate curves. These curves will indicate potential optimal operation points that should be tested in this iterative process. Parameters may be evaluated one at a time while keeping the parallel system as a reference. In some cases, multiple parameters may be changed at once to move in on the optimization point faster.

4.5 Phase 4: Regulatory Approval

Representative staff from the following regulatory agencies will be invited to key project meetings during the Validation, NF/NF Optimization, Regulatory Approval phases:

- California Department of Health Services (CDHS)
- Regional Water Quality Control Board

These regulatory authorities will also be frequently updated with data on the overall process performance and their comments on the system operation will be addressed (if possible) during the optimization phase. Towards the end of the NF/NF Optimization phase, specific regulatory testing requirements to approve the NF/NF process by the regulatory authorities will be identified and addressed in the subsequent testing phase.

The current CDHS accepted protocol for approving membrane filtration systems as "alternative filtration technology" under the Enhanced Surface Water Treatment Rule (ESWTR) requires the following:

- ***Giardia* Removal**: Demonstrate a minimum of 2-log removal of Giardia sized particles (e.g., 5 – 15 um).
- ***Cryptosporidium* Removal**: Demonstrate producing a time-weighted maximum turbidity in the permeate water of no more than 0.1 ntu.
- **Virus Removal**: Demonstrate a minimum of 1-log virus removal.

- **Operational Reliability**: Develop data for demonstrating the reliability of the membrane system, including membrane performance, permeate water quality, chemical cleaning residual die-away, membrane integrity monitoring, etc.
- **Quality Control**: Document a procedure for quality assurance and quality control sufficient to ensure the integrity of the data collection of the above requirements.

Preliminary discussions with CDHS staff indicated that the overall treatment train should meet the ESWTR requirements. Hence, the above requirements may need to be evaluated and addressed during the regulatory approval evaluation phase. The expected removal credit is shown below:

Table 4.12: Log inactivation/removal credit expected by the NF2 system

	Treatment Credit							Required Credit		
	300 μm Strainer	UF	Cartridge Filter	NF (Pass 1)	NF (Pass 2)	Chlorine	Total	SDWA [2]	Additional LT2 ESWTR	Total
Giardia	-	4	0	1	1	3		3.0	N/A	
Total Credit	0	4	4	5	6	9	**9.0**	3.0	3.0	**3.0**
Viruses	-	2	0	1	1	4		3.0	N/A	
Total Credit	0	2	2	3	4	8	**8.0**	3.0	3.0	**3.0**
Cryptosporidium	-	4	0	1	1	0		3.0	2.5	
Total Credit	0	4	4	5	6	4	**6.0**	3.0	5.5	**5.5**

1 – SDWA = Safe Drinking Water Act
2 – LT2 ESWTR = Long Term 2 Enhance Surface Water Treatment Rule

In addition, CDHS identified the following specific concerns regarding seawater desalination that will also need to be evaluated during this testing phase

- Boron
- Marine Biotoxins (Domoic Acid is the general surrogate for now)

The regulatory approval phase should provide the necessary data for the final approval of the NF/NF process for seawater desalination by CDHS.

4.5.1 Pathogen Challenge Testing

Pathogen challenge testing using microbial contaminants will not be included on this system due to the high cost associated with such testing at these flow rates. If pathogen challenge testing is needed, the pilot unit will be used.

4.6 Phase 5: Report

This phase will include analyzing remaining data and writing reports. The main project report will conform to Reclamation "Desalination and Water Purification Research and Development Program" (DWPR) report guidelines.

5.0 Quality Assurance / Quality Control

To ensure the data generated during the test period are representative and accurate, the following quality assurance and quality control (QA/QC) procedures will be implemented. Spreadsheet data collection forms are used to document the performance of the QA/QC procedures (LBWD) (**Attachment ***). Instruments will be calibrated on a periodic basis according to **Table 5.1**.

Table 5.1: Equipment calibration information

		Specification			Calibration Frequency	Test Parameter	Maximum Deviation from Test Parameter
	Equipment	1	2	Brand/ Model			
1	Pressure gauge	Manual			Yearly	20% of max.	5%
2	Pressure gauge	Electronic	Magnetic		Yearly		0.25
3	Flow meter	Manual			Never	-	-
4	Flow meter	Electronic			Yearly		5%
5	Temperature	Electronic			2 Years or B/E		5%
6	pH probe				Weekly	pH 4, 7, 10	-
7	Conductivity probe				Weekly		
8	ORP probe				Monthly		
9	Hardness	Online		Hach	Monthly		
10	Alkalinity	Online			Monthly		
11	Chlorine	Online					
12	Turbidity	Online			Yearly (Turbidty) Weekly (Flow)		
13	Turbidity	Manual			Weekly		
14	Power Meter				2 Years or B/E		
15	Chemical Pumps				Weekly		5%
16	Analog Signal				B/E & after 2 Mo.		

Calibration information in table 5.1 is also shown on the Calibration Schedule in **Attachment *.**

5.1 SCADA

Operating data acquired by the SCADA will be verified against online instrument readouts near the low end of expected operating values (pressures, flows, temperatures) and near the high end of expected operating values. All analog signals will be verified and adjusted if needed to ensure they are within 5% of the field calibrated value. Digital signals should not need calibration due to nature of the signal. SCADA system operating data will be compared against online instrument readouts at the beginning of testing, after 2 months, and near the end of testing.

6.0 Sampling and Analysis

6.1 Constituents to be Sampled

Table 6.1 shows the samples to be taken during the course of testing. Exact locations are detailed in **Attachment A**.

Table 6.1: Constituents to be sampled

Parameter		NF/NF and SWRO
Unregulated Constituents	General	Alkalinity Boron DOC Hardness * ORP pH * Silica (total) TDS * TSS
	Gases	-
	Cations (dissolved)	Ammonium (NH_4^+) Aluminum (Al^{+3}) Calcium (Ca^{+2}) Iron (Fe^{+2}) Magnesium (Mg^{+2}) Manganese (Mn^{+2}) Nickel (Ni) Phosphorous (total) (P) Potassium (K^+) Silver (Ag) Sodium (Na^+) Strontium (Sr^{+2}) Zinc (Zn^{+2})
	Anions (dissolved)	Bromide (Br^-) Chloride (Cl^-) Orthophosphate (PO_4^{-3}) Sulfate (SO_4^{-2}) * Sulfide

	Biological & fouling potential	Marine Biotoxins via Domoic Acid MS2 bacteriophage SDI
Regulated Primary Contaminants	Cations	Antimony (Sb) Arsenic (As) Asbestos Barium (Ba) Beryillium (Be) Cadmium (Cd) Chromium (total) (Cr) Copper (Cu) Lead (Pb) Mercury (inorganic) (Hg) Selenium (Se) Thallium (Tl)
	Anions	Fluoride (F^-) Nitrate (NO_3^-) (as N) Nitrite (NO_2^-) (as N)
	Radionuclide	-
	Disinfectants	Chlorine (free)
	DBP	HAA5 THM
	Biological & fouling potential	Turbidity Heterotrophic Plate Count Giardia Cryptosporidium

* = secondary limit

The following process data will be measure continuously:

- Flow
- Pressure
- Temperature
- Conductivity
- pH
- Hardness

6.2 Sample Timing

The short term tests are typically run from one Tuesday to the following Tuesday. Online equipment is measured continuously, but polled every 2 minutes.

For sampling, the beginning, middle and end of tests are defined as follows:

"Beginning" may mean one of two different times, depending on the type of test and should be taken at two different times. Those which will be compared to values at the end of the test should be taken early. Those which will be compared to other measurements and whose value would change if membrane properties change should be taken a day after the test starts.

"Middle" means Thursday or Friday.
"End" means the following Tuesday, before conditions are changed.

6.2.1 Storm Events

Because of the possibility that precipitation may affect the composition and quality of water in the intake to the demonstration unit and because the timewise relationship between precipitation and its effect on the feedwater is unknown, special procedures must be used to obtain samples during storm events. The proposed procedure, which may be refined with experience, is as follows. The only continuously monitored parameter that should be affected by precipitation is raw water conductivity (Sample port 5). When precipitation occurs, samples will be taken at the critical points:

- Feed Water to MF unit, SP-9
- Feed water to first pass NF, SP-55
- Permeate from first pass, SP-90
- Product from second pass, SP-116

Samples will be taken every half hour. The maximum effect of precipitation on the feed water will be considered to occur when the conductivity reaches a minimum. Sample #'s correspond to the sample port.

Sample 5 taken at the time closest to the time of the minimum will be analyzed. There is some lag time for this water to reach points further into the system because of the residence time in various feedwater tanks. Residence time in the piping and the pressure vessels will be ignored. When the active volume of these tanks is determined, the residence time for these tanks can be calculated.

Sample 9 taken nearest the time of minimum conductivity plus the residence time of the MF Feedwater Tank will be analyzed.

Sample 55 taken nearest the time of minimum conductivity plus the residence time of MF and Pass 1 Feedwater Tanks will be analyzed.

Sample 90 taken nearest the time of minimum conductivity plus the residence time of MF and Pass 1 Feedwater Tanks will be analyzed.

Sample 116 taken nearest the time of minimum conductivity plus the residence times of MF, Pass 1 and Pass 2 Feedwater Tanks will be analyzed.

7.0 Data Management

A database system developed by LBWD allows easy access to test data, including operations data, water quality data and chemical dosing data. The database allows for sorting and downloading of subsets of the data. Database management software such as Microsoft Access®, or other relational database software, including database software utilized by the SCADA, will be used for this purpose. Data recorded by hand on data sheets will be stored and recorded in spreadsheet format.

7.1 SCADA System

The prototype facility utilizes supervisory control and data acquisition (SCADA) using Industrial Sequel software. The SCADA system has the following functions:

- Data collection and storage
- Process monitoring and control
- Remote monitoring and control (limited to 128 tag points)
- Data trending
- Paging for alarms
- Automatic shutdown for alarms

7.2 Data Recording

7.2.1 Operational Data

Process operating data is recorded on data collection forms once each weekday as a quality control check on the data collected by the SCADA system. Data collection forms are located in **Attachment ***. Data from Industrial Sequel can be readily exported to spreadsheets for analysis.

7.2.2 Chemical Dosage Data

A spreadsheet based chemical dosing sheet created by LBWD assures accurate chemical doses are delivered to the system process flows (**Attachment ***). The dosing spreadsheet will allow chemical dilution factors in the appropriate flow range for each metering pump to be easily determined. Chemical metering pump flow rates will be verified on a weekly basis, or more frequently as required, to assure their reliable operation. Data collection forms will include date and time, feed tank concentration, target flow and dosage, and measured flow and dosage.

7.2.3 Chemical Cleaning Data

Spreadsheet data collection forms created by LBWD are available for recording the specifics related to chemical cleanings performed on each membrane test system (**Attachment ***). These

forms will document the date of cleaning, cleaning chemical doses, chemical solution contact times, temperatures, pressures and flows. Process flow, temperature and pressure data will be collected before and after cleaning to determine cleaning efficiency

7.2.4 Membrane Element Position

A spreadsheet based membrane element form developed by LBWD details the membrane element location (Attachment *). The data form includes:

- process name
- date of configuration change
- pressure vessel
- element position within the pressure vessel
- manufacturer
- model
- serial number
- hours of operation of each membrane element.

The form will be updated each time a change is made to the membrane element configuration.

7.2.5 Project Log Book

A permanently bound project log book will be maintained onsite in the staff trailer. The log book will be used for recording information, calculations, etc. not collected on prepared data collection forms. Each entry in the project log book will be dated and initialed by the operator making the entry.

7.3 Data Backup

All electronic data collected by the project SCADA will be backed up to an appropriate storage device at least once weekly during the operation of the test facility processes. Backup records will be maintained. Data maintained electronically on computers, will be backed up at least once weekly. Completed data collection forms should be copied once weekly and maintained at a separate location.

7.4 Data Distribution

The plots developed will be distributed to project team members on a weekly basis. Web-based project collaboration software developed by LBWD will be utilized to distribute updated project information, including plots to project team members.

7.5 Data Backup

All electronic data collected by the project SCADA will be backed up to an appropriate storage device at least once weekly during the operation of the test facility processes. Backup records

will be maintained. Data maintained electronically on computers, will be backed up at least once weekly. Completed data collection forms should be copied once weekly and maintained at a separate location.

7.6 Data Analysis

Some of the data, particularly those relating to meeting challenge tests are of a pass/fail sort and require little analysis. These need to be put into a proper format and the conditions under which the prototype passes need to be sorted from the conditions under which is does not. More complex analysis is required to establish the economic comparison of NF/NF with RO and development of a model for the NF/NF process itself.

The economic comparison of the two processes will take good technical judgment. An appropriate comparison of the two processes will be on the basis of life cycle costs. This will require assignment of cost of equipment, cost of power and cost of money.

The most difficult analysis is development of a functional model of the NF/NF process itself. If each vessel were to contain the same number of elements, we could do this analysis on a vessel-by-vessel basis. However, this would not necessarily lead to a unit with optimal performance.

The element is the basic unit for analysis. We begin with the assumption that all elements of a particular manufacturer and type are identical in performance. This is an incorrect assumption since the variability of nanofiltration membranes is well known. However, in the absence of individual element tests, it is the only practical assumption that we can use.

The independent variables that determine the performance of an element are temperature (T, °C), inlet pressure (P, psi), volumetric flow rate (Q, gallons per minute), and concentration of various species (Cx, mg/L). Since the rejection of various species varies widely, we will track each species separately. We will relate the output variables, product low, and product concentrations to these input variables by empirical relations to be developed.

Temperature is an independent variable over which we have no control. Over the course of the year the temperature of the raw water may vary over a 15° C range. Within the process, the biggest change in temperature, estimated to be about 1° C, is caused by inefficiencies of the high pressure pumps. Other than that, we can assume that the process is isothermal. For NF Pass 1 and SWRO, the values from instruments (**53**) for Train 1 and (**142**) for Train 2 will be used. For Pass 2, the values from instruments (**85**) for Train 1 and (**175**) for Train 2 will be used.

The major effect that change in temperature has is on the volumetric flux through the membranes. Flux will be normalized to 25° C using the equation:

$$Q_{25} = Q_T e^{-0.0239(T-25)} \qquad 7.1$$

A manufacturer suggested the flux correction factor (0.0235). This will be used until we have enough data to extract our own flux correction factor.

Runs will be made at four values of inlet pressure and four different values of feed water flow to each pass. These should be within the manufacturer's recommended limits and ideally they will encompass the optimum range of operation for the process. The purpose of having four values is to allow us to make a reasonably accurate determination of the relationship of dependant variables, flux and permeate concentration on the independent variables.

Each run will last for one week. This is to allow the operation of the prototype unit to come to steady state. The chemical analyses at the end of the run and the operating data over some period of time on the last day of the run will be used for the analysis. Only data from weeks without rain days will be used.

A certain amount of redundancy of flow and TDS measurements has been built into the unit. This redundancy is to provide a check on the validity of the data. This validity check will be performed ahead of any other analysis.

Since measurements are made only on performance of vessels, and we want to know performance of elements, some approximations have to be made. The pressure difference between the inlet and outlet of an element will be taken to be 1/n th of the pressure difference of the vessel containing n elements. While we know that the pressure difference of the 1st element should be greater than that of any downstream element because the flow is greater, we don't know how much greater. Since the inlet pressure is large compared to the pressure difference, the error introduces by this simplification is trivial.

Initially, we will assume that the permeate flux from each element and the rejection for each element is the same in a vessel. When some data are available, we may attempt to improve on this approximation.

8.0 Safety and Communications

8.1 Safety

Safety is the number one consideration at the project test site. All project staff working at the test site will be familiar with and follow the guidance of the Job Hazard Analysis (separate document developed by LBWD.

Table 8.1 Emergency Phone Numbers

Emergency	**Phone**
Fire, Police, Ambulance, Paramedics	911
Poison Control	800-332-6633

8.2 Project Staff

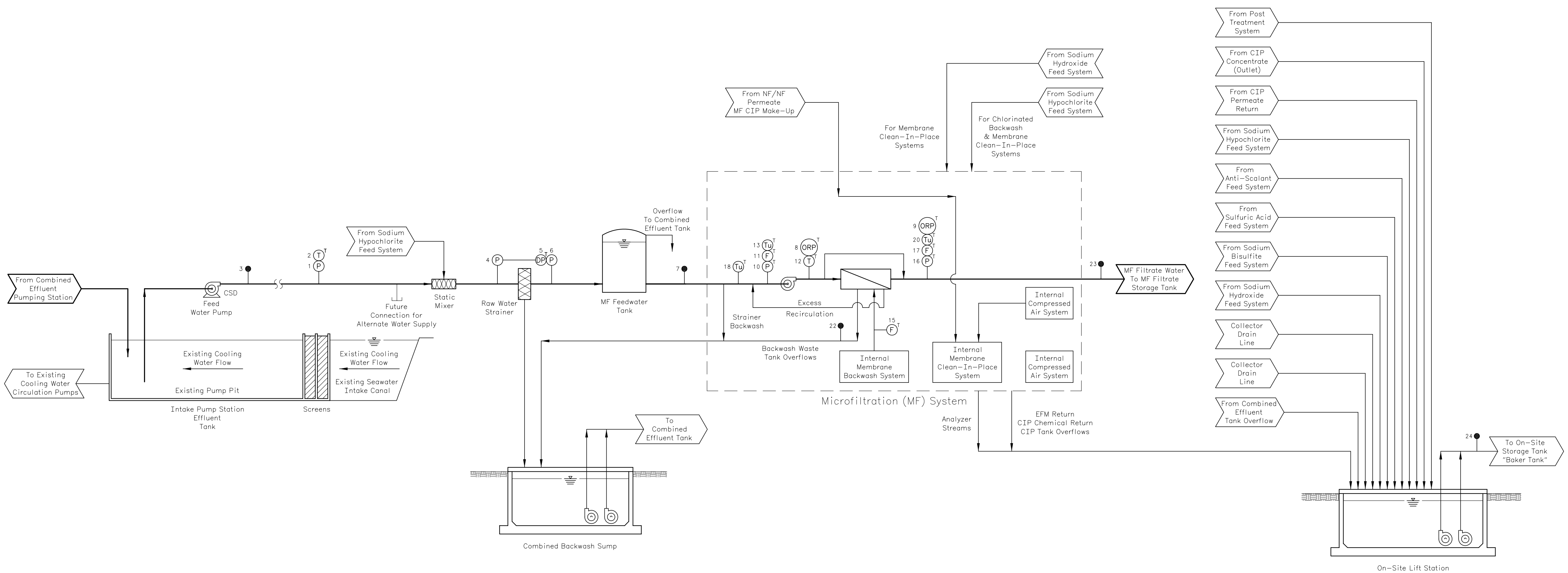
This project is a cooperative effort between LBWD, USBR, and LADWP. A steering Committee composed of representatives of these three organizations will provide overall management of the project.

Table 8.2 Contact Information

Appendix F
Prototype Test Plan

Name	Agency	Phone	Cell Phone	Fax	Email
Bautista, Alvin	LADWP	213-367-0800		213-367-1131	alvin.bautista@water.ladwp.com
Cheng, Robert	LBWD	562-570-2487		562-426-9625	robert_c_cheng@lbwater.org
Dundorf, Steve	Reclamation, Denver	303-445-2263	(303)349-7691	303-445-6354	sdundorf@do.usbr.gov
Jurenka, Robert	Reclamation, Denver	303-445-2254		303-445-6354	bjurenka@do.usbr.gov
Karimi, Ali	LADWP				ali.karimi@water.ladwp.com
Leitz, Frank	Reclamation, Denver	303-445-2255		303-445-6329	fleitz@do.usbr.gov
Leung, Eric	LBWD	562-570-2347		562-492-9631	eric_leung@lbwater.org
Tseng, Tai	LBWD	562-570-2472		562-426-9625	tai_tseng@lbwater.org
Vuong, Diem	LBWD		(562)508-0614	949-366-9174	diemvuong@hotmail.com
Wolfe, Dennis	Reclamation, Temecula	909-695-5310		909-695-5319	dwolfe@lc.usbr.gov
Wu	Theresa	562-570-2341			theresa_wu@lbwater.org

DRAWING 1



NOTES

1. This drawing was developed from the Montgomery Watson Harza August 2003 final submittal drawings.
2. Some process lines, valves, etc are not shown for clarity.
3. Potable water hardness and alkalinity must meet Pall's requirements to prevent $CaCO_3$/MgOH scaling during high pH cleaning.
4. High pressure and/or low flow sensors for pump overload protection are not shown, but are to be included.
5. Level sensors with transmitters for all tanks are not shown, but are to be included.
6. Hardness meters are not furnished by owner within furnished by owner box.

LEGEND

P – Pressure
C – Conductivity
F – Flow Rate
Cl – Chlorine
pH
T – Temperature
Tu – Turbidity
H – Hardness
Al – Alkalinity
DP – Difference Pressure
ORP – Oxidation/Reduction Potential
G – Generator
LC – Load Cell
VSD – Variable Speed Drive
CSD – Constant Speed Drive

Typical Main Process Flow
Process Flow
Future Use
Owner Furnished
Sensor
Transmitter
Sampling Port

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LONG BEACH WATER DEPARTMENT
NF/NF DEMONSTRATION UNIT
PROCESS FLOW SCHEMATIC

DESIGNED S. DUNDORF CHECKED F. LEITZ
DRAWN R.D. RODRIGUEZ TECH. APPR.
APPROVED
PEER REVIEWER

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
AutoCAD Rel. 16.0s	MEMBRANE PROCESS_NEW	JANUARY 27, 2006 13:20
DENVER, COLORADO	JANUARY 22, 2004	DRAWING 1

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DRAWING 2

Appendix F
Prototype Test Plan

F45

NF/NF SYSTEM

RO SYSTEM

Process Train 1

Process Train 2

Delineation Line

MF Transfer Pump

Pass 1 Feedwater Tank

Pass 1 Feed Pump

Pass 1 Feedwater Booster Pump

From Sulfuric Acid Feed System

From Anti-Scalant Feed System

Overflow and Drain To On-Site Lift Station

Cartridge Filter

Drain to On-site Lift Station

Pass 1 High Pressure Pump

SW RO High Pressure Pump

Booster Pump

PX Pressure Exchange

12 Vessels

8 Vessels

Stage 1

Stage 2

Pass 1

From Sodium Hydroxide Feed System

Pass 2 Feedwater Tank

Pass 2 Membrane Pressure Pump

Pass 2 Concentrate Booster Pump

3 Vessels

6 Vessels

Pass 2

Future Connection from Train 2, Pass 1

Future Connection to Train 2, Pass 2

Future Connection from Train 1, Pass 1

Future Connection to Train 1, Pass 2

To On-Site Lift Station

CIP Permeate Return

CIP Concentrate

CIP Concentrate Return

CIP Feed

To Combined Effluent Tank

To Post Treatment System

To NF/RO CIP Make-Up

To MF CIP Make-Up

To NF/RO CIP System

From Sodium Bisulfite (SBS) Feed System

From MF Filtration System

Static Mixer

Overflow To Combined Effluent Tank

MF Filtrate Storage Tank

8 Vessels

Indicates layout of pressure vessels (end view)

Indicates tests will be performed on 3 or 4 elements

Spacer (no element)

ELEMENT AND VESSEL CONFIGURATION KEY

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G – Generator
LC – Load Cell
VSD – Variable Speed Drive
CSD – Constant Speed Drive

Typical Main Process Flow
Process Flow
Future Use
Owner Furnished
Sensor
Transmitter
Sampling Port

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LONG BEACH WATER DEPARTMENT
NF/NF DEMONSTRATION UNIT
PROCESS FLOW SCHEMATIC

DESIGNED S. DUNDORF CHECKED F. LEITZ
DRAWN R.D. RODRIGUEZ TECH. APPR.
APPROVED
PEER REVIEWER

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
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DENVER, COLORADO	JANUARY 22, 2004	DRAWING 2

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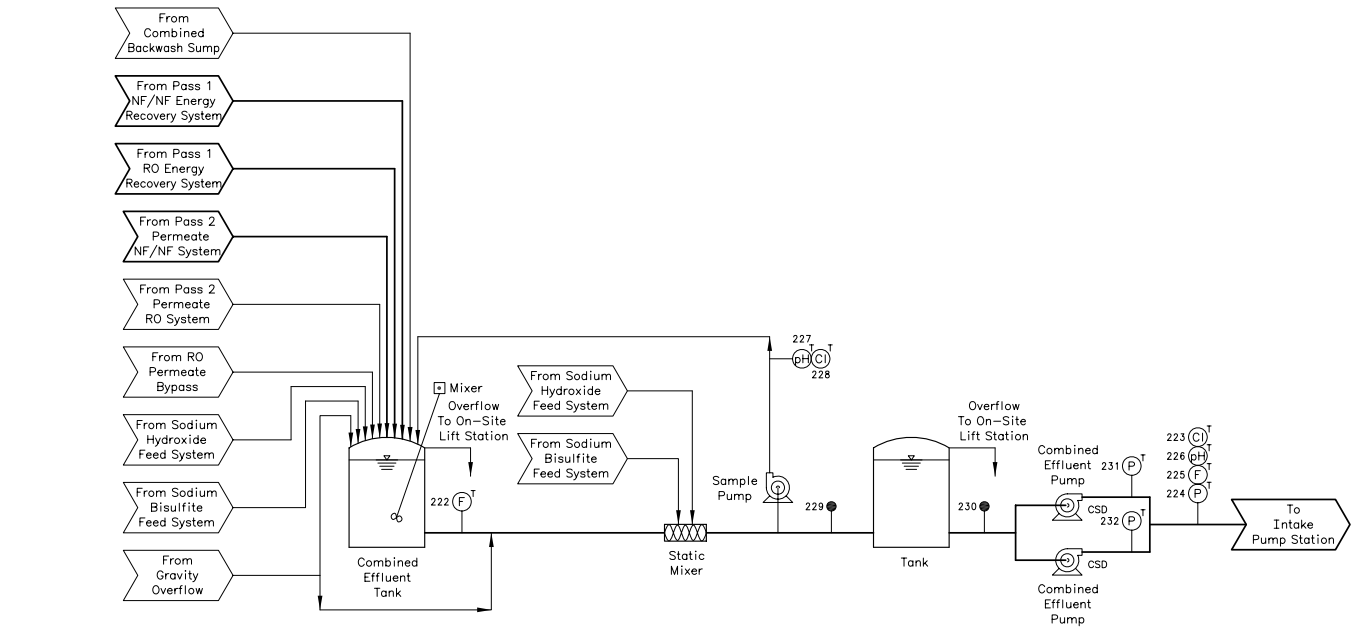

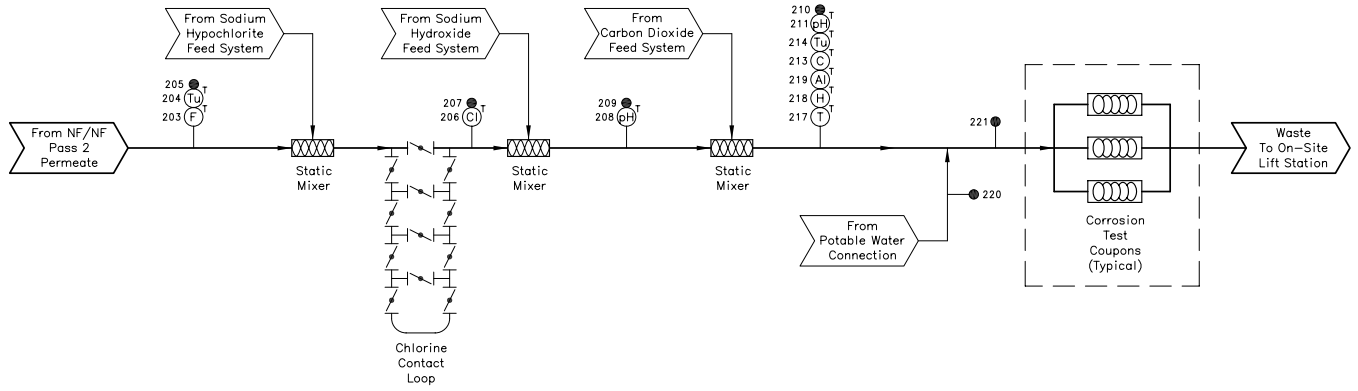

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CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
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