APPENDIX A

Pre-Pilot Technical Memoranda

TM 1A: Pilot Discharge Characterization

TM 1B: Brine Toxicity Testing Plan

TM 1C: Environmental Review and Permitting

TM 2A: Intake System Evaluation and Desktop Study

TM 3A: Feedwater Quality Characterization

TM 3B: Prescreening and Pretreatment System Evaluation

TM 4A: Reverse Osmosis Technology Evaluation

TM 4B: Nanofiltration Evaluation

T E C H N I C A L   M E M O R A N D U M

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	**Pilot Discharge Characterization Technical Memorandum No. 1A**		
Prepared by:	Stefani Harrison, P.E.	**Reference:**	1481449/6.2.1
Reviewed by:	Charlie Bromley, P.E. Dawn Guendert	**Date:**	August 30, 2007

As discussed at the BARDP Kickoff Meeting and Workshop held on August 2, 2007, an important permitting issue to be resolved is the discharge of pilot plant water (brine plus permeate) from the proposed facilities. Surface release may require an NPDES permit, depending on discharge quantity and ability of site soils to absorb the water without overflow from the CCWD-owned site. Other options include discharge to the nearby sewer and discharge to a raw water canal for drinking water supply. An understanding of potential pilot plant liquid discharge is required as a first step in determining reuse and disposal options.

This memorandum will serve to briefly characterize the anticipated discharge water for the BARDP Pilot Study. It provides an overview of discharge components, anticipated quantity and quality of discharge flows, and potential dilution ratios achieved at the three discharge options. Values presented herein are preliminary and will be further refined during the course of the project.

Pilot Discharge Components

Normal operations of the pilot will involve raw water from Suisun Bay, taken from the end of Mallard Slough, and run through prescreening, two parallel trains of microfiltration (MF), and up to three parallel trains of reverse osmosis (RO) which receive a portion of the water produced by the MF trains (remaining MF water is not used and is overflowed). During the process, small quantities of process chemicals may be added in the treatment process, as indicated below. Several types of discharge water will be produced by the pilot plant:

1. Permeate: The plant permeate is expected to meet all drinking water regulations, and to

2. Process waste streams: Intermittent quantities of MF backwash and a steady stream of RO concentrate.

3. Cleaning waste streams: Low-volume cleaning waste streams will also be produced during routine MF and RO operation and maintenance procedures.

These discharge waters can be combined as needed for the purpose of discharge. If permeate and process waste streams are recombined, the product is essentially slightly cleaner but very similar to the water fed into the plant from Mallard Slough.

Anticipated Quantity of Discharge

When the pilot plant is operating, the quantities of each discharge component can be estimated as follows:

1. Permeate: A steady stream of 36 gpm (min) to 60 gpm (max) of permeate water is expected, comprised of approximately 12 gpm of permeate from each of the 3 RO units, plus some additional flows to allow for RO flux testing and equalization during MF backwashes. Average flows are expected to be approximately 48 gpm.

2. Process waste streams: A steady stream of 24 to 40 gpm, comprised primarily of RO concentrate plus some smaller intermittent volumes of MF backwash waste. Average flows are expected to be approximately 32 gpm.

3. Cleaning waste streams: Sporatic in nature, the cleaning waste streams will be on the order of magnitude of several hundred gallons every 30 to 60 days, depending upon the performance of the membranes, resulting in an equalized low-volume flow of approximately 10 gpd. It is likely that this waste will either be hauled offsite in chemical drums, or equalized and fed slowly into another waste stream.

The pilot plant is scheduled for one month of intermittent operations during startup and shakedown, and six months of stable operations. During startup, the pilot could be cycling on and off irregularly, depending upon problems encountered. During stable operations, the pilot is expected to run 24 hours per day, 7 days per week with short term scheduled outages for cleaning (a few hours, approximately once every month) and minor unplanned interruptions.

MWH expects to minimize discharge to the greatest extent possible. Actual flow will be proposed in the Experimental Plan and recommendations will be proposed to reduce flows where possible.

Anticipated Quality of Discharge

The discharge is expected to be a combination of Mallard Slough water, process chemicals, and potentially membrane cleaning products. The following sections provide a brief explanation of the water quality of each component.

Mallard Slough Water Quality

Mallard Slough water quality is tidally influenced, causing significant diurnal and seasonal variations. Mallard Slough water is characterized in Table 3-6 of the BARDP Pre-Feasibility

Report (2004). The range of TDS observed was 70 to 5737 mg/L from 1996 to 2000. Further data downloaded from the Department of Water Resources' Pittsburg Station (PTS) indicates a 90th percentile EC of 10,600 uS/cm observed from hourly data spanning 2004-2007. This converts to a TDS of approximately 6,800 mg/L (using a rule of thumb Delta correlation as follows: EC = TDS x 0.64)[1]. Analysis of daily data indicates that the tides can cause an order of magnitude variation, such that extremes are dampened over the tidal cycle. Based on the PTS data, the 95th percentile 24-hour average salinity is 6,440 mg/L TDS, and the 50th percentile 24-hour average salinity is 1,130 mg/L TDS.

Process Chemicals Added

MWH expects to minimize process chemicals added to the greatest extent possible. Actual chemicals and doses will be proposed in the Experimental Plan. Process chemicals would be added in a continuous stream with little variation, with the exception of coagulants which may only be added during storm and/or algae events. Some adjustments may be needed during pilot plant process optimization, but the changes are expected to have little or no impact on the overall water quality of the pilot discharge. The following process chemicals, all approved for use in drinking water treatment, may be used in this project:

Chemical	Purpose of Use	Point of Application in Process Train	Anticipated Dose Range (mg/L)	Notes
Scale inhibitors	To increase the solubility of sparingly soluble salts such as calcium and magnesium carbonates and sulfates. Additional chemicals may be used to target specific species, such as silica.	Upstream of RO	2 – 5 mg/L	ANSI-NSF 60 approved for drinking water
Coagulant (usually ferric chloride or ferric sulphate)	To aid in coagulation and enhance MF particulate removal rates	Upstream of MF	5 – 15 mg/L	Primarily used in open intake seawater RO during storm or algae events.

[1] Correlation between EC and TDS obtained from CalFed Water Quality Program Assessment Report, June 2005, pg. 2-12. Available online at http://calwater.ca.gov/content/Documents/WQP_Initial_Assessment_6_2005.pdf

Chemical	Purpose of Use	Point of Application in Process Train	Anticipated Dose Range (mg/L)	Notes
Acid (usually sulfuric acid)	To reduce pH for inhibition of scaling	Upstream of RO	40 – 50 mg/L as required to reduce pH to range 6 – 7	Used during membrane cleaning only
Pre-formed chloramines (optional)	To limit biofouling of MF and RO membranes and increase RO cleaning intervals	Upstream of MF	0.5 – 3	Bench scale testing will be needed to avoid oxidizing RO membranes. Only used if biofouling becomes an issue
Reducing agent (usually sodium metabisulfite); depending on chlorine dosage	To quench remaining free chlorine to protect the RO membranes	Upstream of RO	As needed to quench Cl. Generally 2 to 4 times higher than oxidizing agent.	Used after MF flux enhancement (daily)

Potential Cleaning Waste

If the pilot discharge is sent to a destination that can accept the membrane cleaning waste, then this could be flow-equalized at a minimal rate (say, 5 gpm or less) into the pilot discharge stream for disposal. If the pilot discharge is sent to a destination that cannot accept the cleaning waste, then the cleaning waste would need to be hauled offsite in chemical drums.

Daily flux enhancement of the MF membranes is typically performed to maximize membrane performance and increase MF cleaning intervals. The flux enhancement involves recirculating a highly chlorinated solution through the MF membranes to remove biological build-up. The target chlorine concentration for flux maintenance can be up to 300 or 400 mg/L, but the free chlorine residual decays through the recirculation process. Waste products from this daily operation could include 10 to 20 gallons of a 100 mg/L chlorine solution containing inactive biological solids (to be verified). If discharged to the environment, dechlorination would be practiced as previously described.

Chemical membrane cleaning procedures must be conducted periodically to reverse fouling. Typical procedures include a low-pH cleaning at pH 2-3 (potentially using citric acid) to remove mineral scale, and a high-pH cleaning at pH 10-11 (potentially using sodium hydroxide) to remove biological scale. The two flows are wasted into the same disposal tank and pH-neutralized. The remaining waste product is a neutral pH solution with significant concentrations of minerals and biological matter.

MWH's previous experience with membrane operations indicates that chemical cleaning procedures would need to be conducted on MF membranes approximately once every 30 to 40 days (producing less than 500 gallons for each MF pilot skid), and on RO membranes approximately once every six to twelve months (producing less than 500 gallons for each RO pilot skid). Chemical cleaning intervals can vary depending on changes in the feedwater source. The following cleaning chemicals may be used in this project:

Chemical Type	**Purpose of Use**	**Notes**
Acid (usually citric, phosphoric or hydrochloric acid)	Cleaning of solids and inorganic foulants from membrane surface	Periodic CIP of MF and RO membranes
Sodium hypochlorite	Cleaning of biological material from membrane surface	Periodic CEB and CIP of MF membranes and disc filter prescreen
Phosphates (tri-polyphosphae or similar)	Cleaning of membrane surface	Periodic CIP of MF and RO membranes
EDTA	Cleaning of membrane surface	Periodic CIP of MF and RO membranes
Specialty cleaning chemicals	Unusual deposits on membrane surfaces may be removed, off-line or off-site, using specific chemicals and treatments specified by the membrane manufacturers	Periodic MF or RO membrane cleaning
Membrane preservation and sterilization agents, such as hydrogen peroxide, acetic acid, and/or sodium bisulfite	Off line membranes must be sterilized and preserved. Sterilization may utilize hydrogen peroxide. In some cases acetic acid is also used to create peracetic acid. Preservation most commonly utilizes sodium bisulfite	

Potential Quality of Discharge Components

As a result, the pilot plant would continuously discharge the following during a typical period (not including cleaning waste):

Constituent	Unit	Permeate (assumes 99.8% rejection)	Process waste	Combined permeate & process waste
Flow	gpm	36 to 60	24 to 40	60 to 100
	mgd	0.05 to 0.09	0.03 to 0.06	0.09 to 0.14
TDS	mg/L (24 hour average, 95th percentile)	13	16100	6440
	mg/L (24 hour average, 50th percentile)	3	3325	1330
Scale Inhibitors	ppd (assuming 3 mg/L in 60 gpm RO feed)	0	5.5	2.2
Sulfuric Acid	ppd (assuming 30 mg/L in 60 gpm RO feed)	13.2	8.8	22
Sodium Metabisulfite	ppd (assuming 2 mg/L in 100 gpm MF filtrate)	0	6	2.4

These values do not include coagulant and coagulant solids since they would only be practiced only during infrequent high turbidity events. Also note that sodium metabisulfite will serve to bind the chloramine residual, such that neither chemical will be active in the pilot plant discharge, and the sulfuric acid would decrease the pH and not remain as an acid.

Anticipated Dilutions

There are four options currently under consideration for reusing or disposing of the pilot discharge:

- Send the combined permeate and process waste, without cleaning waste, to the Contra Costa Canal for integration into CCWD's raw water supply. The existing 30" pipe from Mallard Slough Pump Station, normally charged, would be used as the conduit, assuming the construction team could tap into that pipe in a manner acceptable to CCWD. Cleaning waste would be hauled offsite separately.
- Send the combined permeate, process waste, and cleaning waste, to the 30" VCP sewer main to be treated at the Delta Diablo Sanitation District (DDSD) wastewater treatment plant (WWTP). Given the diameter and slope of the pipe, it appears to have been designed to carry 1.7 mgd capacity for pipe flowing full. This would incur disposal fees from DDSD.
- Send the permeate to Contra Costa Canal for integration into CCWD's raw water supply. Send the process waste and cleaning waste to DDSD wastewater treatment plant (incurring disposal fees with DDSD).

- Send the combined permeate and process waste, without cleaning waste, to discharge into the drainage ditch on the south side of the pilot site (possibly requiring NPDES). Cleaning waste would be hauled offsite separately.

The following table presents the potential dilution ratios that could be achieved at each location:

	CCWD Canal		DDSD WWTP		CCWD / DDSD Combination				Pilot site discharge	
					CCWD		DDSD			
Dilution Scenario	Normal	Worst Case	Normal	Worst Case	Normal	Worst Case	Normal	Worst Case	Normal	Worst Case
Background flows (mgd)[1]	110	70	14.5	12.9	130	70	14.5	12.9	0	0
Discharge components	Permeate and process waste		Permeate, process waste, and cleaning waste		Permeate		Process waste and cleaning waste		Permeate and process waste	
Discharge flows (gpm)	80	100	80	100	48	60	32	40	80	100
Flowrate dilution ratio	**956:1**	**487:1**	**127:1**	**91:1**	**1882:1**	**811:1**	**316:1**	**225:1**	**None**	**None**
Background TDS (mg/L)[2]	224	300	800	1000	224	(3)	800	1000	n/a	n/a
Pilot discharge TDS (mg/L)	1330	6440	1330	6440	3	13	3325	16100	1330	6440
TDS % increase	**0.5%**	**4.2%**	**0.5%**	**6.0%**	**-0.1%**	(3)	**1.0%**	**6.7%**	**n/a**	**n/a**

1 Flows for CCWD and DDSD represent data from 2003-2006. Average flows for CCWD are 110 mgd on an average annual basis. Average flows from July-Dec are 130 mgd average, representing a greater flow and load dilution.
2 TDS for CCWD is based on EC data (monthly grabs) from 1/02 to 8/07, multiplied by CalFed multiplier of 0.64. TDS for DDSD is based on DDSD Recycled Water Project Mitigated Negative Declaration < http://www.ddsd.org/pdfs/ Antioch-AD.pdf > TDS for recycled water; assumes no removal of TDS during wastewater treatment. Data will be verified when Experimental Plan is prepared.
3 No data available yet; will be verified when Experimental Plan is prepared.

Recommendations

Based on the preferences of the BARDP Team and the desire to minimize pilot waste, it is recommended that the permeate be sent to CCWD and the process waste and cleaning waste be sent to DDSD. This solution will make maximum reuse of the pilot water with CCWD, while incurring minimal fees from DDSD for treatment of the waste. The next step in this process will be to enter into discussion with CCWD and DDSD to move forward with the recommended discharge plan.

T E C H N I C A L   M E M O R A N D U M

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	**Brine Toxicity Testing Plan** **Technical Memorandum No. 1B**		
Prepared by:	Jay Johnson, AMS Dane Hardin, AMS	**Reference:**	1481449
Reviewed by:	Dawn Guendert, MWH Charles Bromley, MWH	**Date:**	9/27/07

The Bay Area's four largest water agencies, the Contra Costa Water District (CCWD), the East Bay Municipal Utility district (EBMUD), the San Francisco Public Utilities Commission (SFPUC), and the Santa Clara Valley Water District (SCVWD), are jointly exploring a regional desalination project that could provide the region an additional water source, diversify the area's water supply, and foster long-term regional sustainability. The Bay Area Regional Desalination project (RDP) could consist of one or more desalination facilities, with an ultimate total capacity of up to 71 million gallons per day.

Following preparation of an Initial Feasibility Study, the RDP is proceeding with testing the operation and maintenance of a joint facility on a pilot scale. The Pilot Plant Study (PPS) will be located at CCWD's Mallard Slough Pumping Plant site near Pittsburg, CA, adjacent to the San Francisco Bay Estuary at Suisun Bay. The capacity of the PPS shall be approximately 100 gpm. Water from Mallard Slough will flow through the existing intake screen at the Mallard Slough Pump Station, then undergo potential pre-screening prior to treatment by microfiltration (MF) pretreatment followed by reverse osmosis (RO) treatment to produce potable water. After testing and analysis, it is the intent of the PPS to mix the permeate and RO concentrated brine streams for subsequent discharge to a viable disposal route. The PPS will run between June 2008 and January 2009. This test period was selected to capture both wet and dry season conditions, which are anticipated to reflect extreme physical and chemical conditions of both source water and receiving water.

One of the major potential issues associated with potential full-scale desalination operations is the discharge of the RO brine, backwash and concentrated brine streams. The potential effects of brine on local organisms involve both increased concentrations of ions (e.g., salinity or total dissolved solids) as well as more concentrated contaminants from the source water (e.g., pesticides or heavy metals). The location of the proposed Bay Area Regional Desalination Project is relevant to both of these potential brine effects.

Partitioning the brine effects between salinity and contaminant effects is necessary to determine the operational solutions needed to minimize them and requires a combination of different types of toxicity tests. Furthermore, these toxicity tests must be conducted in a manner that allows the differentiation of the source of the toxicity due to salinity and/or contaminants.

1.0 Brine Toxicity Testing Approach

As outlined in 40 CFR Part 136 (Guidelines Establishing Test Procedures for the Analysis of Pollutants), chronic toxicity screening of the PPS brine discharge will occur in two tiers of testing; initial testing for determining the most sensitive species and follow-up testing for both salinity and contaminant toxicity on the species determined to be the most sensitive. However, unlike routine toxicity testing for ongoing year-round operational discharges for NPDES compliance purposes, for which 40 CFR Part 136 is principally intended, the proposed brine toxicity testing of the PPS is focused on evaluating the potential toxicity of brine effluent during extreme conditions for both the source water (wet and dry seasons) as well as for the receiving water. Therefore, repeated monthly testing of the brine for determining the most sensitive species and quarterly toxicity testing will not be conducted. Rather, testing will focus on the environmental extremes that will be encountered during potential operations and the toxicity data will be used to fine-tune water treatment processes, facility siting and potential permitting requirements. Planned toxicity test results will provide LC50 data, which will be used to determine how much additional source water may be required to dilute the brine below toxic concentrations and, in combination with any modeling that might be done, the best location for the brine discharge. Moreover, if it is found that brine effects are due either to toxicity or salinity, operations can be adjusted throughout the year, in anticipation of seasonal variation in source water characteristics.

To this purpose, the brine toxicity testing will focus on seasonal and operational extremes in both source and intended receiving waters, which typically occur during the dry and wet seasons of the year. Dry-season conditions represent highest ambient salinities, whereas wet-season conditions represent highest contaminant concentrations associated with storm runoff. Two types of testing will be performed in each season.

1.1 Tier 1 Testing

Tier I testing will consist of an initial round of survival and growth testing of the brine using the following estuarine test organisms:

- the diatom (plant), *Thallassiosira pseudonana*
- the mysid shrimp (crustacean), *Americamysis bahia*, and
- the inland silversides (vertebrate), *Menidia beryllina*.

1.2 Tier 2 Testing

Tier 2 will consist of a follow-up round of testing, in which the most sensitive species identified in the Tier 1 testing will be tested for both salinity and potential contaminant toxicity. Comparison of test results between the 'salinity' and 'brine' tests will provide information on the toxicity source. Any reductions in survival and/or growth greater than that observed in the salinity tests can be attributed to organic and inorganic contaminants in the source water that have been concentrated along with the brine salts.

1.2.1 Salinity Toxicity Testing: Following Tier 1 testing, **w**ater samples of the desalination brine will be analyzed to identify the composition of major anions and cations present. In the laboratory, artificial "brine" will be created using de-ionized water and reagent-grade salts to duplicate the major ion composition and concentrations in the actual PPS brine. The most sensitive test organism in the Tier 1 test will be subjected to serial dilutions of the artificial brine to test for mortality and growth.

1.2.2 Brine Toxicity Testing: Concurrent with the salinity toxicity testing discussed above, the most sensitive species will be subjected to serial dilutions of the actual PPS brine discharge to test for effects on mortality and growth.

1.2.3 Reference Toxicity Testing: As an additional QA measure, a positive Control test (i.e., reference toxicant test) will be conducted concurrently with the salinity and brine toxicity testing.

1.3 Testing Protocols

All testing will be performed as described in the following US EPA toxicity testing manuals:

- *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms, First Edition* (EPA/600/R-95/136),
- *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms, Third Edition* (EPA-822-R-02-014).

1.4 Period of Testing:

Round 1: August-September 2008
Round 2: December2008-January 2009

2.0 Sample Collection

A sample of the brine discharge, representative of normal operations, will be collected from the PPS. For Tier 1 testing, this will involve the collection of one sample for the 7-day duration of the toxicity tests. For Tier 2 sampling, depending on the species being tested, either one sample will be collected and used for the entire test or collected every other day for the duration of the test. Upon collection, all samples will be stored and transported at 4˚C until delivered to the testing lab. Samples will be collected early enough in the day to allow testing to begin later the same day. Samples will be transported under chain-of-custody protocol.

3.0 Brine Test Treatments

The Lab Water Control media and the 100% brine will be used to prepare additional test treatments of 2.5%, 5%, 10%, 25%, and 50% brine.

4.0 QA/QC Measures

The toxicity testing will include standard QA/QC procedures to ensure that the test results are valid. Standard QA/QC procedures include the use of negative Lab Controls, positive Lab Controls, test replicates, and measurements of water quality during testing, as consistent with methods described in the US EPA testing guidelines The methods employed in this desalination brine testing program are detailed in standard guides and procedures maintained in the analytical laboratory.

The brine samples for the bioassay testing will be stored at ≤4°C and will be used within the established holding time period. All measurements of routine water quality characteristics will be performed as described in the Pacific EcoRisk Lab Standard Operating Procedures (SOPs). All biological testing water quality conditions will be within the appropriate limits. Laboratory instruments will be calibrated daily according to lab SOPs, and calibration data will be logged and initialed.

4.1 Negative Lab Control

The negative Lab Control will consist of clean water at the appropriate test salinity prepared using either:

- Reverse-osmosis, de-ionized water adjusted to the test salinity via addition of bioassay-grade artificial sea salts, or
- Pristine filtered natural seawater from the UC Granite Canyon Marine Laboratory, adjusted to the test salinity via addition of reverse-osmosis, de-ionized water.

4.2 Positive Lab Control

The accuracy of test organism response to toxic stress will be evaluated using positive Lab Controls (reference toxicant testing). The key test dose-response Effects Concentration (EC) point estimates determined for the test organisms will be compared to the reference toxicant test "typical response" ranges, to verify that these test species were responding to toxic stress in a typical fashion.

5.0 Routine Reporting

Reporting for each round of species screening testing will include the following, at a minimum, for each test.

- Sample date(s),
- Test initiation date,
- Test species,
- End point values for each dilution (e.g., number of young, growth rate, percent survival),
- No Observable Effects Concentration (NOEC) value(s) in percent brine or salinity,
- Inhibition Concentration (IC) and/or Effect Concentration (EC) point estimates [e.g., IC15, IC25, IC40, and IC50 values or EC15, EC25 ... etc.] in percent brine or salinity,
- TUc values (100/NOEC, 100/IC25, and 100/EC25),
- Mean percent mortality after 96 hours in 100% brine,
- Key EC and/or IC value(s) for reference toxicant test(s),
- Available water quality measurements (i.e., pH, D.O., temperature, conductivity, hardness, salinity, ammonia), and
- Evaluation of which of the tested species was the most sensitive

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	**Environmental Review and Permitting** **Technical Memorandum No. 1C**		
Prepared by:	Eric Zigas, ESA Charles Bromley, MWH CB	**Reference:**	1481449 / 6.2.1
Reviewed by:	Dawn Guendert, MWH Stefani Harrison, MWH	**Date:**	December 21, 2007

The proposed Pilot Plant Study (PPS) will need to comply with various state and Federal regulations and mandates, such as the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA). The work may also fall within the jurisdiction of agencies having permitting authority, such as the California Department of Health Services and the U.S. Army Corps of Engineers.

1.0 Background

The MWH Team has completed Subtask No. 1.2, Environmental Review, and Subtask No. 1.3, Permitting. Our findings are based on the following project considerations:

- Pilot plant permeate will be discharged to the Contra County Water District (CCWD) raw water transmission facilities at a location on, or immediately adjacent to, the Mallard Slough Pumping Station (MSPS).
- Pilot plant concentrate will be discharged into the Delta Diablo Sanitary District (DDSD) sanitary sewer, at an accessway located approximately 800-feet from the MSPS entry gate and within the access road.
- The pilot plant will be located entirely on the MSPS site, without impacting or infringing upon nearby wetlands.
- Feedwater will be obtained from the existing MSPS intake. New facilities will not be required.

2.0 Environmental Review

Findings associated with our environmental review are attached to this technical memorandum and are summarized in ESA's memorandum dated November 13, 2007. As indicated in the Initial

Study (IS) Checklist and Notice of Exemption (NOE), the PPS project falls within CEQA guidelines for a categorical exemption because it will have no significant environmental impact and because it falls into two classes of exempt categories:

- The PPS project will consist of several small research and utility infrastructure facilities.
- The purpose of the PPS is to collect basic data on desalination technology.

CCWD, is listed as the CEQA Lead Agency and will make necessary CEQA filings using the attached documents. These documents have been submitted separately to CCWD.

The PPS project does not fall under any NEPA environmental review requirements.

3.0 Permitting

Requirements have been considered for agencies which have jurisdiction over the PPS, including California Department of Fish & Game, California Department of Health Services, U.S. Army Corps of Engineers, Regional Water Quality Control Board, or others. As noted in the attached documents, the inclusion of environmentally sensitive project features and construction techniques has eliminated the need for permits from such agencies. Nor does the project fall within the jurisdiction of the California Coastal Commission or the San Francisco Bay Conservation and Development Commission.

Local permits will potentially be required, however, from the local building department, and from DDSD for concentrate discharge. Such permits will be pursued separately by the project team working in conjunction with the partner agencies.

4.0 Summary

This work has been prepared in accordance with the MWH scope of work for the BARDP, dated June 14, 2007. MWH is grateful for the assistance provided by Environmental Science Associates, particularly Eric Zigas and Maryann Hulsman. Subtask 1.2 and Subtask 1.3 are now completed, pending review comments or revisions needed for filing of the attached documents, and except as noted in Section 3.0 herein.

ESA Water

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memorandum

date November 13, 2007

to Charles Bromley, MWH
Fran Garland, CCWD

from Eric Zigas and Maryann Hulsman

subject Bay Area Regional Desalination Project - Initial Study Checklist and Categorical Exemption

Enclosed is the Initial Study checklist (IS) that ESA has prepared for the Bay Area Regional Desalination Project. We have prepared this IS to accompany a CEQA Categorical Exemption (CatEx) for the project.

Although it was initially expected that a Mitigated Negative Declaration (MND) would be necessary for the project, due to issues related to the intake system, the discharge methods, the infringement on adjacent wetlands, and potential visual impacts, we now recommend that a CatEx be filed instead of an MND. Our reasons for this recommendation are as follows:

- Originally, it was anticipated that the project would require construction of a new intake system. However, the project as currently planned would utilize the existing screens at the Mallard Slough Pumping Station by extending a pump into the existing wetwell behind the existing screens. Penetrations within the floor of the building may be used for this purpose. This eliminates potentially significant impacts associated with a new intake system.

- Until recently, several methods were under consideration for discharging both the product water and the waste water from the pilot plant study. Some of these methods would have potentially impacted biological resources and/or water quality. The currently planned method, however, is not expected to have any impact on biological resources in the area, since it sends the product water into an existing water system for treatment, and the waste water into an existing waste water disposal system. This eliminates potentially significant impacts associated with discharge.

- During the initial stages of project planning and design, it was unknown whether the project footprint would infringe upon and temporarily disturb adjacent wetlands, causing potentially significant impacts. Project design updates and changes have now made it possible to install the pilot treatment plant facilities without disturbing the wetlands.

- It was unknown initially whether there would be potentially significant visual impacts resulting from the project; however, analysis in the IS finds that the visual impacts of the project would be less than significant.

According to the CEQA Guidelines, Section 15300, certain projects can be exempt from the provisions of CEQA if they have been determined not to have a significant effect on the environment. The proposed pilot plant study falls into two of the classes of exempt projects: Class 6, Information Collection, and Class 3, New Construction or Conversion of Small Structures. CEQA Guidelines, Section 15306, defines Class 6 of exempt projects, which includes basic data collection, research, experimental management, and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource. These may be strictly for information gathering purposes, or as part of a study leading to an action which a public agency has not yet approved, adopted, or funded. CEQA Guidelines, Section 15303, defines Class 3 of exempt projects, which includes construction and location of limited numbers of new, small facilities or structures; installation of small new equipment and facilities in small structures; and the conversion of existing small structures from one use to another where only minor modifications are made in the exterior of the structure. This class includes water main, sewage, and other utility extensions.

ESA has prepared a Notice of Exemption (NOE) for the proposed project, to be filed with the County of Contra Costa. This NOE is also enclosed with this memo. Upon submittal, the NOE will be posted by the County clerk, and no further action is necessary on the part of the lead agency.

As a result of the evolution of the project definition, the project as proposed will not require any new permits. We have reviewed the permit requirements and conclude as follows:

- The intentional avoidance of wetlands and other jurisdictional water of the US obviates the need to file a 404(b)(1) permit application with the US Army Corps of Engineers
- The lack of an open water discharge obviates the need to file an NPDES permit application as well as a CWA 401 permit application
- Intake of water through the existing Mallard Slough Pump Station and delivery of the permeate to the CCWD raw water system for subsequent treatment will occur consistent with CCWD's existing water right at Mallard Slough, which obviates any need for a SWRCB permit application process
- The project location is not under the jurisdiction of either the California Coastal Commission or the SF Bay Conservation and Development Commission

Please review the enclosed NOE and IS, and submit your comments to Maryann Hulsman at mhulsman@esassoc.com. If you have any questions, please contact Maryann or Eric Zigas, both of whom can be reached at 415.896.5900. If there are no comments, CCWD should file the NOE with the County as soon as possible.

Thank you!

ENVIRONMENTAL CHECKLIST

Initial Study

1. Project Title:	Bay Area Regional Desalination Project (BARDP) Pilot Plant Study (PPS) at Mallard Slough
2. Lead Agency Name and Address:	Contra Costa Water District (CCWD) 1331 Concord Avenue Concord, CA 94520
3. Contact Person and Phone Number:	Marie Valmores 925-688-8132
4. Project Location:	The pilot plant would be located at CCWD's existing Mallard Slough Pump Station, which is located at the southern end of a 3,000-foot-long dredged intake channel adjacent to the Estuary at Suisun Bay in northern Contra Costa County. East ½ of Section 11, T2N, R1W, MDB&M Pittsburg, CA 38º 02' 07" N 121º 55' 42" W
5. Project Sponsor's Name and Address:	East Bay Municipal Utility District PO Box 24055 Oakland, CA 94623 In cooperation with: • Contra Costa Water District • San Francisco Public Utilities Commission • Santa Clara Valley Water District
6. General Plan Designation(s):	OS (Open Space) – Contra Costa County
7. Zoning Designation(s):	H-I (Heavy Industrial) – Contra Costa County

8. Description of Project:

The Bay Area's four largest water agencies -- the Contra Costa Water District, the East Bay Municipal Utility District, the San Francisco Public Utilities Commission, and the Santa Clara Valley Water District -- propose to construct and operate a pilot desalination plant at CCWD's existing Mallard Slough Pump Station near Pittsburg, California, in northern Contra Costa

County (see Figure 1). The pilot plant study (PPS) would be used to obtain additional data and help determine the optimal operations for a full-scale plant to be located in the San Francisco Bay Area. The data obtained from the PPS would also benefit others considering desalination in an estuarine environment.

The main objectives of the PPS are to:

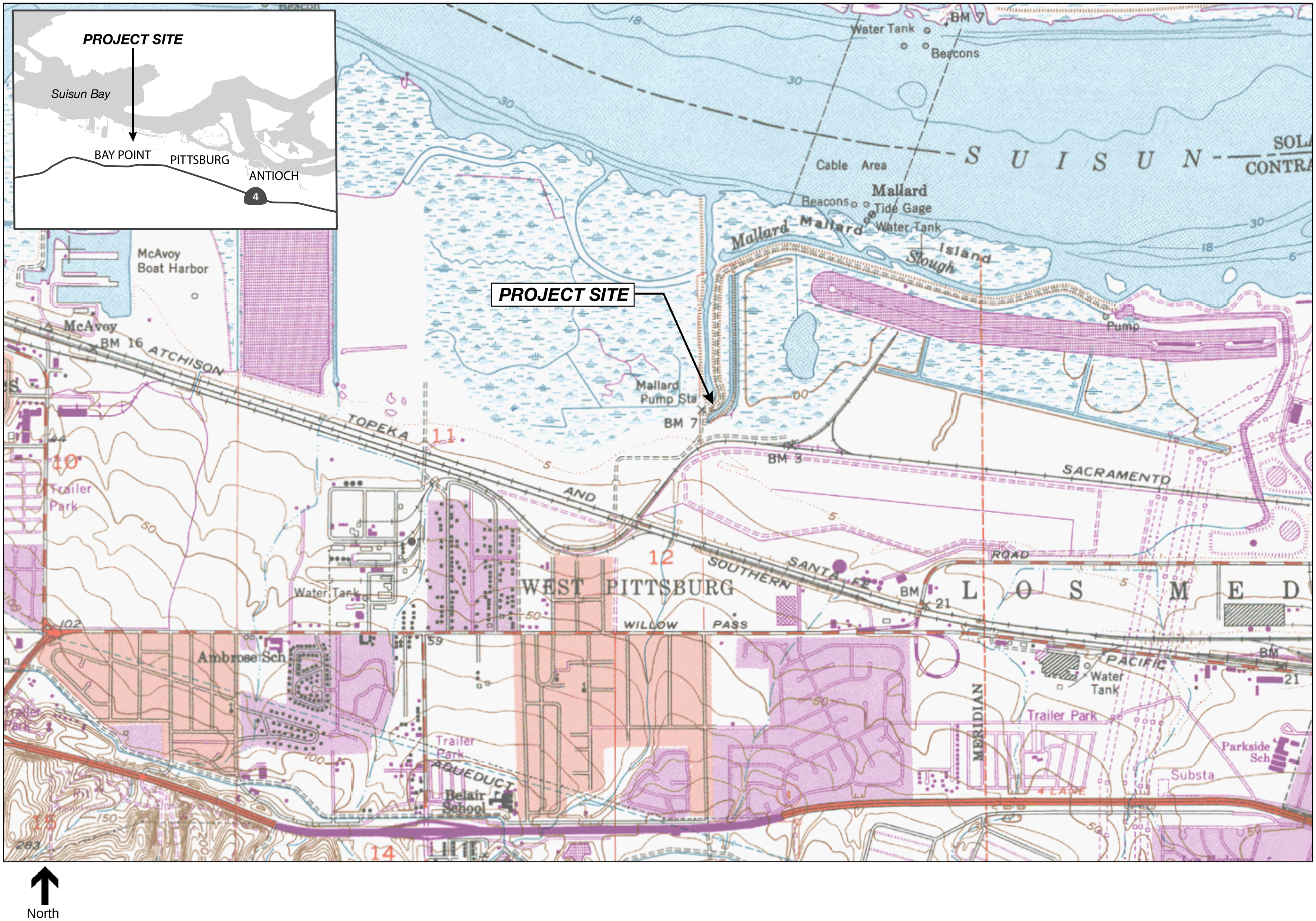
- Maximize the efficiency of operating and maintaining a regional desalination facility;
- Identify potential environmental impacts and evaluate methods to mitigate these potential impacts;
- Identify the preferred pre-treatment for this project;
- Identify the preferred reverse osmosis (RO) system configuration for this project; and
- Develop an information-sharing platform to share test data, methodologies and project information with other interested users in California.

The pilot plant is scheduled for one month of intermittent operations during startup (June 2008), and six months of stable operations (July through December 2008[1]). During stable operations, the pilot plant is expected to run 24 hours per day, 7 days per week, with short-term scheduled outages for cleaning (a few hours per cleaning, approximately once every month) and minor unplanned interruptions. The pilot plant would be dismantled and removed at the conclusion of the testing period.

Normal operations of the pilot plant would involve raw brackish water from the Delta being taken from the end of Mallard Slough and run through prescreening, microfiltration (MF), and RO treatment prior to discharge. Brackish water from the slough would travel through the intake to a temporary/mobile treatment plant, where it would undergo desalination processes. The desalinated water, as well as the waste stream from the desalination process, would then be released. The PPS at Mallard Slough would therefore have three primary components: an intake, treatment plant facilities, and a discharge (see Figure 2).

Intake: The existing Mallard Slough Pump Station is located at the end of a 3,000-foot-long channel running due south of Suisun Bay. The old Mallard Slough facility was replaced in 2002 with a new pump station that has a state-of-the-art fish screen and enables a withdrawal of up to 39.3 cubic feet per second (cfs). The screen's mesh size of 3/32 inches and low intake approach velocities are designed to eliminate the impingement of juvenile and adult fishes and to minimize the entrainment of larval fish. The facility is only used by CCWD during periods of very high Delta outflows (about 40,000 cfs or greater) when water quality meets CCWD's chloride standard of 65 milligrams per liter (mg/l) (normally occurring during the period of March through May). The performance of the new screen has been continuously monitored during pumping operations since 2002.

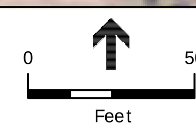
[1] Stable operations may extend into January 2009.



SOURCE: USGS

D207264-Bay Area Regional Desalination Project . 207264

Figure 1
Project Location



D207264-Bay Area Regional Desalination Project . 207264

Figure 2
Proposed Project Layout

SOURCES: CC Water (2007), MWH (2007, GlobeXplorer (2007), ESA (2007)

NOTE: Features are approximately located in relation to the underlying aerial map.
No proposed project components would be located on any wetlands.

The PPS would utilize the existing screens by extending a pump through an existing penetration into the Mallard Slough Pump Station wet well. When the pilot plant is operating, a steady stream of 60 gallons per minute (gpm) (minimum) to 100 gpm (maximum) of water is expected, accommodating up to 20 gpm for each of the three RO units, plus some additional flows to allow for RO flux testing and equalization during MF backwashes. Average flows are expected to be approximately 80 gpm. A pipe-penetration through the pump station wall, along with temporary pumping equipment, would also be required to deliver the water to the pilot plant.

Treatment: The pilot treatment plant facilities would consist of one trailer (approximately 40 by 8 feet footprint, approximately 10 feet high); two MF skids on pallets (each approximately 10 by 18 feet); a pre-screening unit (approximately 10 by 10 feet); a few holding tanks for flow equalization or blending; chemical tanks; an air compressor; and other miscellaneous appurtenances. These facilities would be enclosed within a fence, in an area of approximately 120 by 20 feet, although arrangement of the various features is flexible and the facilities would be arranged to optimally fit into the proposed project footprint.

The pilot treatment plant facilities would be located on a previously-disturbed area adjacent to the existing pump station, in a decomposed granite parking lot. The portion of the parking lot that would contain the treatment plant facilities (see Figure 1) is bordered to the northwest by wetlands, and an existing telephone pole is located within the parking lot at a point on the southwest edge of the proposed project footprint. The treatment plant facilities and the surrounding fence would be located so as to avoid both the wetlands and the telephone pole.

Minor amounts of chemicals would be used in the treatment process, and would be properly stored and contained on-site, consistent with local, state and federal regulations. Chemical storage is estimated to be less than 150 gallons, in containers up to 30-gallons in size. Site operations would include best management practices (BMPs) for storage and handling of these materials. Power would be provided directly from the existing electrical panel located inside the existing pump station.

Normal operations of the pilot plant would involve raw water from Mallard Slough being taken from behind the screens of the existing pump station at the end of Mallard Slough and run through prescreening, through two parallel trains of MF, and then up to three parallel trains of RO. Small quantities (less than 15 gallons per day) of process chemicals may be added in the treatment process.

Discharge: Two flow streams would be discharged from the PPS: a byproduct stream and a permeate, or product water, stream.

The byproduct stream would be discharged into the existing 30-inch-diameter VCP sewer main where it crosses the CCWD access road. The byproduct would be conveyed to the sewer main through approximately 800 feet of 2- to 3-inch-diameter temporary pipeline that would be laid within the existing CCWD access road. The byproduct would be treated at the Delta Diablo Sanitation District (DDSD) wastewater treatment plant (WWTP) with their normal sewer flows.

The permeate, or product water, that is generated by the pilot plant would be sent to Mallard Reservoir for integration into CCWD's untreated water supply for treatment. Since the Mallard Slough Pump Station is already connected to the untreated water system, product water from the PPS would be delivered to the untreated water system using the existing pipelines from the Pump Station. A small mechanical connection would be made either within the pump house or within the roadway. The existing pipeline would be tapped and a temporary tee and valve would be added. Pipe would be extending through the pump house to the location of this connection.

Daily flux enhancement of the MF membranes involves recirculating a chlorinated solution through the MF membranes to remove biological buildup. Additional chemical cleaning of the MF membranes would be conducted approximately once per month, involving use of a low pH cleaning solution to remove mineral scale and high pH cleaning to remove biological scale. When these cleaning wastes are deposited into the same container, the waste product is a pH neutral solution containing minerals and biological matter. All chlorinated wastes and other cleaning wastes would be hauled off-site twice per week for disposal.

The following table presents the potential dilution ratios that could be achieved at each location to which the permeate and byproduct are delivered. Because the flows are relatively low, the connection would not significantly impact the TDS levels of the treatment plant.

Dilution Scenario	CCWD		DDSD	
	Normal	Worst Case	Normal	Worst Case
Background flows (mgd) (1)	130	70	14.5	12.9
Discharge Components	Permeate		Process waste and cleaning waste	
Discharge flows (gpm)	48	60	32	40
Flowrate dilution ratio	1882:1	811:1	316:1	225:1
Background Total Dissolved Solids (TDS) (mg/L) (2)	224	(3)	800	1000
Pilot discharge TDS (mg/L)	3	13	3325	16100
TDS % increase	-0.1%	(3)	1.0%	6.7% (4)

1 Flows for CCWD and DDSD represent data from 2003-2006. Average flows for CCWD are 110 mgd on an average annual basis. Average flows from July through December are 130 mgd average, representing a greater flow and load dilution.

2 TDS for CCWD is based on EC data (monthly grabs) from 1/02 to 8/07, multiplied by CalFed multiplier of 0.64. TDS for DDSD is based on DDSD Recycled Water Project Mitigated Negative Declaration < http://www.ddsd.org/pdfs/ Antioch-AD.pdf > TDS for recycled water; assumes no removal of TDS during wastewater treatment. Data will be verified when Experimental Plan is prepared.

3 No data available yet; will be verified when Experimental Plan is prepared.

4 Even under "worst-case" conditions, the increase in TDS from the proposed project is well within the DDSD discharge permit.

9. Surrounding Land Uses and Setting. (Briefly describe the project's surroundings.)

The proposed project site is located adjacent to Mallard Slough. Land uses in the immediate vicinity include open space and industrial uses, with residential uses less than half a mile (approximately 2,000 feet south) away.

10. Other public agencies whose approval is required (e.g., permits, financing approval, or participation agreement. Indicate whether another agency is a responsible or trustee agency.)

There are no public agencies whose approval is required for the proposed project to be completed. A service contract would be entered into with the DDSD so that byproduct water can be discharged into the existing wastewater system.

Environmental Factors Potentially Affected

The proposed project could potentially affect the environmental factor(s) checked below. The following pages present a more detailed checklist and discussion of each environmental factor.

☐ Aesthetics	☐ Agriculture Resources	☐ Air Quality
☐ Biological Resources	☐ Cultural Resources	☐ Geology, Soils and Seismicity
☐ Hazards and Hazardous Materials	☐ Hydrology and Water Quality	☐ Land Use and Land Use Planning
☐ Mineral Resources	☐ Noise	☐ Population and Housing
☐ Public Services	☐ Recreation	☐ Transportation and Traffic
☐ Utilities and Service Systems	☐ Mandatory Findings of Significance	

DETERMINATION: (To be completed by Lead Agency)

On the basis of this initial study:

☐ I find that the proposed project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

☐ I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because revisions in the project have been made by or agreed to by the project proponent. A MITIGATED NEGATIVE DECLARATION will be prepared.

☐ I find that the proposed project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

☐ I find that the proposed project MAY have a "potentially significant impact" or "potentially significant unless mitigated" impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An ENVIRONMENTAL IMPACT REPORT is required, but it must analyze only the effects that remain to be addressed.

☐ I find that although the proposed project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier EIR or NEGATIVE DECLARATION pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier EIR or NEGATIVE DECLARATION, including revisions or mitigation measures that are imposed upon the proposed project, no further environmental documentation is required.

☒ I find that the proposed project COULD NOT have a significant affect on the environment, and because the proposed project qualifies as a Class 6 Exempt Facility, a CATEGORICAL EXEMPTION will be filed.

____________________	____________________
Signature	Date
____________________	____________________
Printed Name	For

Environmental Checklist

Aesthetics

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
1. AESTHETICS—Would the project:				
a) Have a substantial adverse effect on a scenic vista?	☐	☐	☒	☐
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway corridor?	☐	☐	☐	☒
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☒	☐
d) Create a new source of substantial light or glare which would adversely affect daytime or nighttime views in the area?	☐	☐	☒	☐

Discussion

a,c) The existing Mallard Slough Pump Station is located in an area that is largely natural and undeveloped. The pilot plant, intake, and discharge pipeline would be located within or directly adjacent to the existing, fenced facility, and therefore would not create a new point of interference within any scenic vista or change the existing visual character of the site. The Mallard Slough Pump Station is not located near any public roadways, pathways, or readily accessible waterways, and is therefore only occasionally subject to public views. The intake facilities would not be visible to any passersby outside of the pump station fence, and the pilot plant would only consist of one trailer and some other miscellaneous small equipment next to the existing pump station facilities. The discharge pipeline would be installed in the existing access road. In addition, all of the planned structures are temporary and would only be in place for approximately six to eight months. The impacts would be less than significant.

b) The proposed project is not located within a state scenic highway corridor. There would be no impact.

d) The proposed project would include one trailer and some other miscellaneous small equipment. These facilities would only add minimally to glare on the project site. There would be no day lighting of the site, and the night lighting would not be increased from what is already present at the pump station. Currently, downcast perimeter lighting linked to light sensors turns on at dusk and stays on all night. Also, as mentioned above, the project site is rarely part of a public viewshed. The impact would be less than significant.

Agricultural Resources

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
2. AGRICULTURAL RESOURCES In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of Conservation as an optional model to use in assessing impacts on agriculture and farmland. **Would the project:**				
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance, as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?	☐	☐	☐	☒
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☒
c) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland of Statewide Importance to non-agricultural use?	☐	☐	☐	☒

Discussion

a) The project site does not include any farmland. There would be no impact.

b) The project site is not zoned for agricultural use, and it is not subject to a Williamson Act contract. There would be no impact.

c) The proposed project would not cause changes that could result in conversion of farmland to non-agricultural use. There would be no impact.

Air Quality

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
3. AIR QUALITY Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. **Would the project:**				
a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☒	☐
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☒	☐

Issues (and Supporting Information Sources):		*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
c)	Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?	☐	☐	☒	☐
d)	Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☒	☐
e)	Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☒

Discussion

a–d) Construction activities associated with the proposed project would be minor and emissions during construction would be minimal. The pilot plant components would be prefabricated and would require on-site assembly. Some grading activity would be required to prepare the site for the pilot plant facilities. Grading would require the use of a bobcat or front-end loader, and grading activities would last approximately two days. Installation of the intake structure and other interior pump station connections would take up to one week. Installation of the discharge pipeline would require the use of a "ditch witch" or similar equipment, and would last approximately one week.

During operations, cleaning wastes would be hauled off-site in trucks up to twice per week. There are no other sources of air emissions during operation, since all equipment would be powered using electrical energy. While much of the electrical energy would likely be generated by burning fossil fuels that generate air emissions, electrical consumption would not be substantial due to the small size and limited duration of the facility. No new electrical-generating facilities would be required.

The impacts would be less than significant.

e) No objectionable odors would be created by the proposed project. There would be no impact.

Biological Resources

Issues (and Supporting Information Sources):	Potentially Significant Impact	Less Than Significant with Mitigation Incorporation	Less Than Significant Impact	No Impact
4. BIOLOGICAL RESOURCES— Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	☐	☒	☐
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	☐	☒	☐
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☐	☐	☒	☐
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☐	☐	☒	☐
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☒
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☒	☐

Discussion

a.1) Non-Marine Species

Since the proposed PPS at Mallard Slough would be constructed and operated entirely on an existing, unvegetated road/parking area which is sufficiently compacted and covered with gravel that it is currently driven on by vehicles, the project would not affect the habitat of any special-status species. The special-status species present or potentially present in the vicinity of the project area, as taken from the California Department of Fish and Game California Natural Diversity Database (CNDDB), the U.S. Fish and Wildlife Service (USFWS), and the California Native Plant Society (CNPS) rare plant database, are as follows:

<u>Plants</u>: Heartscale, big tarplant, Antioch Dunes evening-primrose, soft bird’s beak, Mason’s lilaeopsis, Suisun marsh aster, delta tule pea, delta mudwort

Invertebrates: vernal pool fairy shrimp, valley elderberry longhorn beetle, delta green ground beetle

Reptiles: Alameda whipsnake, giant garter snake

Amphibians: California tiger salamander, California red-legged frog

Birds: California clapper rail, California least tern, California black rail

Mammals: salt marsh harvest mouse

The construction and operation of the PPS would not affect the habitat of any of these species, since all activities would be restricted to the disturbed road/parking area, and would not enter into, or disrupt the nearby marsh in any way. The impact would be less than significant.

a.2) **Marine Species**

The special-status fish that are present or potentially present in the vicinity of the project area are: Steelhead, Chinook salmon, delta smelt, green sturgeon.

The existing CCWD Mallard Slough Pump Station is equipped with a state-of the-art fish screen with 3/32-inch mesh and low intake approach velocities to eliminate impingement of juvenile and adult fishes as well as to minimize entrainment of larval fish. The water intake system is designed to safely withdraw water from the slough at rates of up to 39.3 cfs. The PPS would utilize the existing screens by extending a pump through an existing penetration into the Mallard Slough Pump Station floor into a wet well. When the pilot plant is operating, a steady stream of 60 gpm (0.13 cfs) to 100 gpm (0.22 cfs) of water would be pumped to the RO filtration units. PPS operations would be conducted between June and December.

Any plankton in the water used for testing the pilot desalination process would be entrained with 100% mortality. Similarly, but to a much lesser degree, any larval or small fish in close proximity to the pump facility intake pipe can be expected to be entrained during PPS operations. The total number of larval and small fish as well as plankton biomass that is entrained can be expected to be fairly small - equal to or less than what may be entrained in the water-cooling system of an ocean-going ship transiting through the delta. The existing CCWD water intake system is designed to prevent fish impingement and reduce fish entrainment at flow rates up to 39.3 cfs. The PPS would be operating at flow rates several orders of magnitude lower (.13-0.22 cfs) further reducing the possibility of fish impingement and entrainment. It is anticipated that only larval stages of fish would be entrained.

The fish species of greatest concern that may be present in Mallard Slough are Delta and Longfin smelt. Delta smelt is a State and Federal listed threatened species and Longfin smelt is a species of special interest to both the State and Federal government. Both species have undergone significant population decline in the past few years and are considered an indicator species of the ecological health of the San Francisco Delta.

Although both species are known to be present in the Mallard Slough channel connecting Suisun Bay to the CCWD pump facility, neither species is expected to be present in the water supply channel during PPS operations in either significant numbers or during a critical life stage that would increase their entrainment. Both species frequently school together and inhabit the tidally influenced sloughs and channels of the Delta to spawn between December and June. Adults and juveniles then migrate back to the lower Delta and Bay where the salt water/freshwater interface is. This latter migration typically occurs between April and May. During the summer and fall months, the time period when PPS operations would be conducted, these fish typically inhabit more open water areas of the Delta and Suisun Bay. As part of the ongoing biological monitoring of the existing CCWD pump station, an entrainment study has been conducted during those months of the year in which the pumps are in use (January-May). Since 2002, no Delta or Longfin smelt have been entrained later than May (Mayer, pers. comm.). An additional entrainment study would be conducted during the PPS.

Brine created through the desalination process has the potential to elevate salinity and concentrate pollutants present in the original source water, effecting marine biota. The San Francisco Bay Basin Plan requires that controllable factors shall not increase TDS or salinity of surface waters, or contain concentrations of pollutants in amounts sufficient to negatively affect beneficial uses (RWQCB, 1995). However, discharge of brine for this pilot study is anticipated to be into existing sewer lines of the Delta Diablo Sanitation District. Therefore, there are no impacts to the local environment water quality posed by the pilot study.

Although the accidental spillage or release of desalination process chemicals could potentially migrate to the open water channel adjacent to the PPS test site and there affect marine biota, the use of stormwater containment and routine operational procedures would prevent any accidentally released brine waters or process chemicals from contacting channel water.

b) There is no riparian habitat at or near the site. Therefore, there is no impact to riparian habitat. Coastal brackish marsh is a sensitive plant community found in the vicinity of the project site; however, the project would not disturb, change, or adversely impact any part of the nearby coastal brackish marsh. The impact would be less than significant.

c) There are marsh wetlands, which are protected under Section 404 of the Clean Water Act, adjacent to the project area; but the proposed project would not interfere with these wetlands whatsoever. The wetlands are located to the West, South, and East of the existing pump station and surrounding parking area. The construction and operation of the PPS would take place on the disturbed parking area adjacent to the existing pump station. The intake for the PPS would utilize existing infrastructure from the pump station, and the discharge would be transported through a temporary pipeline that would be inserted in the existing road. None of these activities would result in any removal, fill, or hydrological interruption of the wetlands adjacent to the project area. The impact would be less than significant.

d) The project site is found within a pre-existing chain-link fence associated with the pump station. The fence is about seven feet tall, and has between 15 to 21 inches of barbed wire at the top. Access to the site by wildlife is therefore already limited. Additionally, since the area inside the fence, including the site where the PPS would be located, offers very little quality habitat for wildlife, it is unlikely that wildlife would use this site as a migration corridor or nursery site.

The construction of the PPS facilities and the process of digging a ditch down the access road for the temporary discharge pipeline would require some small heavy machinery (ditch-witch, bobcat), which would create an unnatural noise environment. However, this would not significantly impact wildlife in the area, given the short duration of the construction activities and the fact that they would be restricted to the disturbed road area. Operational noise from the PPS would not be any greater than the noise from the operation of the pump station, and therefore, would not have an increased or significant impact on wildlife. Likewise, the two truck trips in and out of the facility each week would not impact wildlife or wildlife habitat, since the truck would remain on the road, and drive at a reasonable speed.

There would be no day lighting of the site, and the night lighting would not be increased from what is already present at the pump station. Currently, downcast perimeter lighting linked to light sensors turns on at dusk and stays on all night.

The installment and operation of the PPS would not affect fish migration because this project would not have any effect on the movement of fish in the slough, and there would be no modification to the slough itself. There is an existing, state- of-the-art fish screen in place, and the flow of the intake water is low enough to prevent harm to fishes from the intake activities of this project. See the project description, above, for the specific proposed intake flow and process

The impact would be less than significant.

e) This project would not affect any trees, therefore the Contra Costa County Tree Preservation Ordinance does not apply. There would be no filling or dredging of the bay that would require a permit. Therefore, there are no conflicts with local policies and ordinances with respect to biological resources for this project. There would be no impact.

f) The land use of the project area would not change with the construction and operation of the PPS. The area that includes the project site is zoned “Heavy Industrial,” and is designated as “Open Space” in the East Contra Costa Habitat Conservation Plan (HCP). However, the East Contra Costa HCP does not specifically address this project or the project area in the section "Covered Activities," and the project does not fall within the "Urban Development Area," so the HCP does not apply to the project. The impact would be less than significant.

References

California Department of Fish and Game (CDFG), Wildlife Habitat and Data Analysis Branch, *California Natural Diversity Database*, data request for Honker Bay 7.5-minute USGS topographic quadrangle. Commercial version 3.1.0, 10/25/2007.

California Native Plant Society (CNPS), *Electronic Inventory of Rare and Endangered Plants of California, version 7-07d 10-18-07*, data request for the Honker Bay 7.5-minute USGS topographic quadrangle. Available online at: http://www.cnps.org/inventory, accessed October 25, 2007.

City of Pittsburg General Plan, Pittsburg 2020: A vision for the 21st Century. Section 2.5 Planning Subareas, October 2004.

Contra Costa County Redevelopment Agency, Bay Point Waterfront Strategic Plan EIR, prepared by Environmental Science Associates. April, 2006.

East Contra Costa County Habitat Conservation Plan/ Natural Community Conservation Plan October 2006.

Mayer, Dave, Tenera Environmental, email to Eric Zigas at ESA, October 23, 2007.

U.S. Fish and Wildlife Service (USFWS), List of Federal Endangered and Threatened Species that occur in or may be affected by projects in the Honker Bay 7.5 minute USGS quadrangle. Available online at:http://www.fws.gov/sacramento/es/spp_lists/ auto_list_form.cfm, accessed October 25, 2007.

Cultural Resources

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
5. CULTURAL RESOURCES— Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?	☐	☐	☐	☒
b) Cause a substantial adverse change in the significance of a unique archaeological resource pursuant to §15064.5?	☐	☐	☐	☒
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☒

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☒

Discussion

a) The project site is not located near any known historical resources. There would be no impact.

b–d) The project site is not located near any known archaeological resources. Construction activities would not include disturbance of any previously-undisturbed areas; minimal grading would be done on a swathe of decomposed granite parking lot, and some shallow trenching would be done to lay a 2- to 3-inch-diameter pipeline in the existing decomposed granite roadway. No excavation would be necessary. There would be no impact.

Energy

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
ENERGY—Would the project:				
a) Result in a substantial increase in overall per capita energy consumption?	☐	☐	☒	☐
b) Result in wasteful or unnecessary consumption of energy?	☐	☐	☒	☐
c) Require or result in the construction of new sources of energy supplies or additional energy infrastructure capacity the construction of which could cause significant environmental effects?	☐	☐	☒	☐
d) Conflict with applicable energy efficiency policies or standards?	☐	☐	☐	☒

Discussion

a) The proposed project would utilize about 30,000 kWh over the six-month period of operation. 30,000 kWh is equivalent to the amount of energy used by approximately 9 average California households over 6 months; it is not considered a substantial increase in overall per capita energy consumption. Also, this use of energy would be short-term. Additionally, this energy consumption would be offset in part by a corresponding decrease in energy use elsewhere in the CCWD water system, since the water produced by the pilot plant would replace water that would otherwise need to be pumped to a treatment plant.

b) The proposed project would utilize energy to produce water suitable for use in the CCWD water system, which is a valuable resource. The impact would be less than significant.

c) Although the proposed project would add slightly to the total load on energy infrastructure in the project region, this addition of use would be both temporary and negligible. The proposed project would not result in the construction of new sources of energy supplies or additional energy infrastructure. Energy would be supplied from the existing electrical panel located inside the existing pump station. The impact would be less than significant.

d) The proposed project would not conflict with any applicable energy efficiency policies or standards. There would be no impact.

Geology, Soils, and Seismicity

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
6. GEOLOGY, SOILS, AND SEISMICITY— Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? (Refer to Division of Mines and Geology Special Publication 42.)	☐	☐	☐	☒
ii) Strong seismic ground shaking?	☐	☐	☒	☐
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☒	☐
iv) Landslides?	☐	☐	☒	☐
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☒	☐
c) Be located on geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☒	☐
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☒	☐

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
e) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	☒

Discussion

a.i) No active faults have been mapped or identified in the project area (Geomatrix, 1998, as cited in Black and Veatch and EDAW, 1998). No surface rupturing is likely to occur at the proposed project site. There would be no impact.

a.ii–iv,c,d) Although it is not near an active fault, the project area is located within a region of California that is subject to groundshaking from several seismic sources. The vicinity of the project site is underlain by soft, poorly consolidated Bay Mud and associated fine-grained, organic-rich slough deposits (Geomatrix, 1998, as cited in Black and Veatch and EDAW, 1998). The soils in the area include potentially liquefiable soil types, with high shrink-swell potential. While the project site is relatively level, it is located near the banks of a waterway.

Due to the aforementioned factors, the project site is potentially susceptible to the effects of groundshaking and/or ground failure, including liquefaction, landslides, lateral spreading, and collapse. However, the proposed trailer would be relatively small and mounted on skids, pallets, or shallow slab-on-grade foundations. Although the facility could be damaged during a seismic event, it is unlikely that any serious damage or injury would result due to the modular nature of the construction and the occasional presence of humans at the pilot plant. The impacts would be less than significant.

b) The proposed project would not include disturbance or exposure of any previously-undisturbed areas, but it would include minimal grading in order to place the trailer containing the pilot plant and shallow trenching in order to lay pipeline; therefore, construction activities could result in the temporary exposure of soil to wind and water erosion. However, BMPs would be used to ensure that erosion is minimized. The impact would be less than significant.

e) The proposed project does not include septic tanks or alternative wastewater disposal systems. There would be no impact.

Hazards and Hazardous Materials

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
7. HAZARDS AND HAZARDOUS MATERIALS Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☒	☐
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☒	☐
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	☒
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	☐	☐	☐	☒
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☒
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☒	☐

Discussion

a,b) Pilot plant operations would require the storage and use of small quantities of process chemicals and cleaning chemicals. The process chemicals would include scale inhibitors (calcium and magnesium carbonates), coagulants (ferric chloride), sulfuric acid, reducing agents (usually sodium metabisulfite), and possibly chloramines. The usage of each of these chemicals is estimated to be less than 5 gallons per day, with a maximum of 30 gallons of each stored on-site at one time. Cleaning of the MF or RO membranes would occur approximately once a month and require various cleaning chemicals, including acid, sodium hypochlorite, phosphates, or specialty cleaning products. These chemicals would be stored on-site in containers less than 50 gallons in size.

Pilot plant operations would also require the transport of these chemicals, and transport routes could include passage through Bay Point and the City of Pittsburg, each of which include residential neighborhoods and disadvantaged communities.

Because hazardous materials transportation, storage, and use would be performed in accordance with applicable federal, state, and local laws and regulations, the potential impact of hazardous materials to the public or the environment is less than significant.

c) There are no schools within a 1/4-mile of the proposed project site. There would be no impact.

d) The proposed project site is not known to be a hazardous materials site. There would be no impact.

e) The proposed project is not located near any public airport. There would be no impact.

f) The proposed project is not located near a private airstrip. There would be no impact.

g) The proposed project would not interfere with an adopted emergency response plan or evacuation plan. There would be no impact.

h) The project site is located in a natural, undeveloped area. This area, however, is marshy and often partially inundated by water. Fire risk in the area is low.

Hydrology and Water Quality

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
8. HYDROLOGY AND WATER QUALITY—Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☒	☐
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☒
c) Substantially alter the existing drainage pattern of a site or area through the alteration of the course of a stream or river, or by other means, in a manner that would result in substantial erosion or siltation on- or off-site?	☐	☐	☒	☐

Issues (and Supporting Information Sources):	Potentially Significant Impact	Less Than Significant with Mitigation Incorporation	Less Than Significant Impact	No Impact
d) Substantially alter the existing drainage pattern of a site or area through the alteration of the course of a stream or river or, by other means, substantially increase the rate or amount of surface runoff in a manner that would result in flooding on- or off-site?	☐	☐	☒	☐
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☒	☐
f) Otherwise substantially degrade water quality?	☐	☐	☒	☐
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other authoritative flood hazard delineation map?	☐	☐	☒	☐
h) Place within a 100-year flood hazard area structures that would impede or redirect flood flows?	☐	☐	☒	☐
i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☒	☐
j) Expose people or structures to a significant risk of loss, injury or death involving inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☒

Discussion

a, f) Project construction would involve installing PPS facilities (with a total fenceline footprint of approximately 2,400 square feet) and approximately 800 feet of 2- to 3-inch-diameter temporary pipeline. The PPS facilities would be installed on a previously-disturbed area adjacent to the existing pump station near Mallard Slough, and the pipeline would be installed within the existing access road. Installation of the trailer would not involve substantial soil disturbance; therefore, water quality impacts from erosion or sedimentation would be minimal. Pipeline installation would involve excavation of a portion of the access road. The area of excavation, which would be no more than 3 feet wide, could cause erosion and sedimentation into the ditch and/or Mallard Slough, particularly due to the close proximity of the access road to waterways. However, CCWD or the construction contractor would implement erosion and stormwater control measures, or BMPs such as installation of a silt fence and site stabilization. Furthermore, given the scale of the project and the flat terrain, the impact would be less than significant.

Project construction would also involve the use of chemicals and solvents such as fuel and lubricating grease for motorized equipment. Inadvertent spill of such chemicals into the nearby waterways could cause an adverse water quality impact. However, the quantities of chemicals used during construction would be minimal. Further, CCWD would implement BMPs that would include practices for proper handling of chemicals, such as avoiding fueling at the construction site and avoiding overtopping during fueling and installing containment pans. The impact would be less than significant.

Given the small size of the project site (total of 2,400 square feet) and the temporary nature of the proposed facilities for the treatment plant, there would be negligible change in the stormwater runoff. The impact would be less than significant.

Water quality impacts from the six months of project operations would be predominantly associated with the wastewater discharge from the treatment process. As discussed in the project description, 60 to 100 gpm of raw water extracted from Mallard Slough would undergo MF and RO, generating approximately 48 gpm of permeate (product water) and 32 gpm of RO brine and MF backwash (wastewater).

The permeate would be conveyed to Mallard Reservoir and integrated with CCWD's untreated water supply, which is treated at the Bollman Water Treatment Plant. CCWD would monitor for certain parameters, including Electrical Conductivity/TDS and pH of permeate, and turbidity of permeate. (Significant variations would be cause for a contingency plan to terminate discharge.) Therefore, the permeate would not have adverse affects on water quality.

The wastewater would be conveyed to the DDSD WWTP for treatment and discharge. Prior to implementation, CCWD would enter into an agreement with DDSD for connection of the project pipeline with DDSD's collection pipeline network and to establish operational parameters and sampling requirements. CCWD would monitor the water quality of the wastewater discharge as required.

The impact would be less than significant.

b) The proposed project would not require withdrawal of groundwater. There would be no impacts to groundwater supplies or aquifers.

c) Construction activities could cause soil erosion and a temporary increase in stormwater runoff (see above). However, construction would be short-term and localized at the graded area at the Mallard Slough Pump Station. There would be no substantial change in runoff flow rates, nor would the project increase erosion or siltation off-site. The proposed treatment plant facilities would be built on an unpaved graded portion and would consist of temporary structures operating for six months. Neither the building structure nor the pipeline would substantially alter the existing drainage pattern of the site. There would be negligible change in the stormwater runoff on-site. There would be no alteration of streams or the existing drainage patterns that could result in substantial erosion or siltation. The impact would be less than significant.

d) Construction activities could cause soil erosion and temporary increase in stormwater runoff (see above). However, construction would be short-term. There would be no substantial change in runoff flow rates, nor would the project increase the potential for flooding. As stated above, there would be no alteration of streams or the existing drainage patterns. There would be no increased erosion, siltation, or flooding. The impact would be less than significant.

e) The proposed project would not add new pollutants or significantly change the stormwater runoff. The impact would be less than significant.

g,h,i) The project site lies in a 100-year flood zone with base flood elevation at seven feet (FEMA, 1987). The proposed project would be limited to short-term construction and six-month-long operations of pilot water treatment facilities within an existing graded property and would not involve development of residential housing. CCWD would not be required to obtain a floodplain permit for the proposed project from the Contra Costa County Public Works Department, since the proposed project is exempt[2]. The project facilities would not impede or redirect flood flows. The project would not subject people or structures to a substantial risk of flooding. The impact would be less than significant.

j) The proposed project would be located on a levee. Project construction along the levee could result in instability and expose workers to potential flooding hazards. However, standard engineering practices such as monitoring and interim stabilization would ensure that the impacts would be less than significant.

The influence of an ocean-borne tsunami wave would dissipate prior to reaching the project site, because of its distance from the Golden Gate in San Francisco Bay. Additionally, the chances of a tsunami generated east of the Golden Gate are very low because the fault structures in the Bay Area displace laterally. Seiches form in enclosed bodies of water. The risk from seiche is considered minimal because there are no enclosed water bodies in the immediate vicinity. The possibility of mudflow is minimal because the project site is relatively flat with no steep slopes. The proposed project would not exacerbate the risks to tsunami, seiche, or mudflows. No impact is expected.

References

FEMA, National Flood Insurance Program, Flood Insurance Rate Map, Unincorporated Contra Costa County, Community Panel Number 0600250120B, July 16, 1987.

[2] CCWD's water-related facility projects (as opposed to administrative facility projects) are exempt from local building ordinances under Government Code Section 53091. Since the pilot plant is for the production/generation of water, it would qualify for the exemption.

Land Use and Land Use Planning

Issues (and Supporting Information Sources):		*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
9.	**LAND USE AND LAND USE PLANNING—Would the project:**				
a)	Physically divide an established community?	☐	☐	☐	☒
b)	Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☒
c)	Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☒

Discussion

a) The proposed project is not located within an established community. There would be no impact.

b) The project site is designated as open space in the Contra Costa County General Plan, and is zoned for heavy industrial use. The proposed project would not change the land use at the project site, and would not conflict with any applicable land use plan, policy, or regulation. There would be no impact.

c) The proposed project would not conflict with any habitat conservation plan or natural community conservation plan. See Section 4, Biological Resources, for more details. There would be no impact.

Mineral Resources

Issues (and Supporting Information Sources):		*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
10.	**MINERAL RESOURCES—Would the project:**				
a)	Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	☐	☐	☐	☒
b)	Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	☒

Discussion

a,b) The proposed project would not result in the loss of availability of any known mineral resource or recovery site. Additionally, the proposed facilities are temporary and would therefore not interfere with future mineral resource recovery. There would be no impact.

Noise

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
11. NOISE—Would the project:				
a) Result in exposure of persons to, or generation of, noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☒	☐
b) Result in exposure of persons to, or generation of, excessive groundborne vibration or groundborne noise levels?	☐	☐	☒	☐
c) Result in a substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☒	☐
d) Result in a substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☒	☐
e) For a project located within an airport land use plan area, or, where such a plan has not been adopted, in an area within two miles of a public airport or public use airport, would the project expose people residing or working in the area to excessive noise levels?	☐	☐	☐	☒
f) For a project located in the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☒

Discussion

a–d) The nearest sensitive noise receptors to the proposed project site are residences that are located approximately 2,000 feet south of the site. The proposed pilot plant would be assembled on-site as temporary facilities, and the only construction equipment required would be a bobcat or front-end loader which would be used for approximately two days. Noise created by the construction equipment would for the most part be minimal, and construction equipment would be operated according to Contra Costa County noise standards. The air compressors that would be part of the pilot plant facilities are a potentially significant source of noise, but the distance between the pilot plant and any receptors (other than employees, who would wear appropriate ear protection as needed) is enough to attenuate the sound to an ambient level (Black and Veatch and EDAW, 1998). Operation of the rest of the pilot plant facilities would cause some noise on the project site, including noise from the use of air compressors in the treatment plant facilities, but this noise would be similar to and less than noise already created on the site during other times of year—the project would not substantially increase ambient noise levels on site or groundborne noise levels nearby. Additionally, the proposed project site is not located near any housing or places of employment, and would therefore not expose any persons other than CCWD employees or pilot plant operators to noise. The impacts would be less than significant.

e) The proposed project is not located near any public airport. There would be no impact.

f) The proposed project is not located near a private airstrip. There would be no impact.

References

Black and Veatch and EDAW, *Mallard Slough Pump Station Project Initial Study / Mitigated Negative Declaration*, prepared for Contra Costa Water District, August 7, 1998.

Population and Housing

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
12. POPULATION AND HOUSING— Would the project:				
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	☒
b) Displace substantial numbers of existing housing units, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒

Discussion

a) The proposed project is a pilot project and it would produce approximately 30 acre-feet of water over the 6-month period of operation. This 30 acre-feet of water would be used to replace an equal amount of raw water from one of CCWD’s other sources, and would therefore not create any new water for CCWD customer use during the period of operation. The proposed facilities are temporary and would be removed after the PPS is complete (approximately six months). The project therefore would not induce population growth either directly or indirectly. There would be no impact.

b,c) The proposed project would not displace any housing units or people. There would be no impact.

Public Services

Issues (and Supporting Information Sources):	Potentially Significant Impact	Less Than Significant with Mitigation Incorporation	Less Than Significant Impact	No Impact
13. PUBLIC SERVICES— Would the project:				
a) Result in substantial adverse physical impacts associated with the provision of, or the need for, new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times, or other performance objectives for any of the following public services:				
i) Fire protection?	☐	☐	☒	☐
ii) Police protection?	☐	☐	☒	☐
iii) Schools?	☐	☐	☐	☒
iv) Parks?	☐	☐	☐	☒
v) Other public facilities?	☐	☐	☐	☒

Discussion

a.i,ii) The proposed project would not require any additional fire or police protection, since it would be located at an existing facility. The impacts would be less than significant.

a.iii–v) The proposed project would not affect population or employment in the project area, would not lead to any changes that would necessitate the construction of schools, parks, or other public facilities. There would be no impact.

Recreation

Issues (and Supporting Information Sources):	Potentially Significant Impact	Less Than Significant with Mitigation Incorporation	Less Than Significant Impact	No Impact
14. RECREATION—Would the project:				
a) Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facilities would occur or be accelerated?	☐	☐	☐	☒
b) Include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?	☐	☐	☐	☒

Discussion

a, b) The proposed project would not affect population or employment in the project area, would not lead to any increase in the use of recreational facilities or require the construction of new recreational facilities. There would be no impact.

Transportation and Traffic

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
15. TRANSPORTATION AND TRAFFIC— Would the project:				
a) Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume-to-capacity ratio on roads, or congestion at intersections)?	☐	☐	☒	☐
b) Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?	☐	☐	☒	☐
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location, that results in substantial safety risks?	☐	☐	☐	☒
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☒
e) Result in inadequate emergency access?	☐	☐	☐	☒
f) Result in inadequate parking capacity?	☐	☐	☐	☒
g) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., conflict with policies promoting bus turnouts, bicycle racks, etc.)?	☐	☐	☐	☒

Discussion

a,b) The proposed project would not result in a permanent increase in traffic or change traffic patterns in the project area. During construction, approximately one to two vehicles would travel to and from the site each day, for approximately 180 days. During operations, only one to two operators would staff the trailer and two truck trips per week would be used to haul cleaning wastes off-site. Therefore, neither installation nor operation would exceed level of service standards or change traffic patterns in the area. The impacts would be less than significant.

c) The proposed project would not affect air traffic patterns. There would be no impact.

d) The proposed project would not increase traffic hazards. It would not result in changes to roadways, and it would not introduce incompatible uses into the project area roadways. There would be no impact.

e) The proposed project would not affect emergency access, since it would not obstruct any existing roadways. There would be no impact.

f) The proposed project would reduce the parking capacity for CCWD employees, their visitors, or plant operators at the Mallard Slough Pump Station, but parking capacity would still be adequate. There would be no impact.

g) The proposed project would not conflict with any adopted policies, plans, or programs supporting alternative transportation. There would be no impact.

Utilities and Service Systems

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
16. UTILITIES AND SERVICE SYSTEMS—Would the project:				
a) Conflict with wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☒	☐
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☒	☐
c) Require or result in the construction of new storm water drainage facilities, or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☒	☐
d) Require new or expanded water supply resources or entitlements?	☐	☐	☐	☒
e) Result in a determination by the wastewater treatment provider that would serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☒	☐
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☒
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☒

Discussion

a) The proposed project would not conflict with any wastewater treatment requirements of the Regional Water Quality Control Board. See Section 8, Hydrology and Water Quality, for more detail. The impact would be less than significant.

b,e) The proposed project consists of the construction of new temporary water treatment facilities at an existing water facility location, and involves the temporary delivery of up to 30 acre feet of water to an existing untreated water system for treatment. The project would also include temporary delivery of a waste stream to an existing sewer main and the existing Delta Diablo Sanitation District (DDSD) WWTP. The WWTP has sufficient capacity for this wastewater, and no new treatment facilities would be required. The impact would be less than significant.

c) The proposed project includes the placement of a small trailer and several other small pilot plant facilities that would slightly increase the amount of impermeable ground on the project site. However, this increase in impermeable ground would be negligible and would be absorbed into the permeable surface of the parking lot and roadway. The impact would be less than significant.

d) The proposed project consists of the construction of a pilot plant to test a potential source for new water supply resources. The CCWD already holds entitlements to pump water from this pump station. There would be no impact.

f,g) The proposed project would not create any solid waste. Therefore, the proposed project would not conflict with any federal, state, or local statutes related to solid waste, and it would not affect any local landfills. There would be no impact.

Mandatory Findings of Significance

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
17. MANDATORY FINDINGS OF SIGNIFICANCE— Would the project:				
a) Have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?	☐	☐	☒	☐

Issues (and Supporting Information Sources):	*Potentially Significant Impact*	*Less Than Significant with Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
b) Have impacts that would be individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.)	☐	☐	☒	☐
c) Have environmental effects that would cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☒	☐

Discussion

a) As discussed in the Biological Resources and Cultural Resources sections, the proposed project would not have any significant impacts on biological or cultural resources.

b) The proposed project would not have any impacts that would be cumulatively considerable. The impacts on air quality, hydrology, transportation, and utilities are less than significant to the point that they would not contribute to a cumulative impact.

c) The proposed project has not been found in this initial study to have effects that would cause substantial adverse effects on human beings, either directly or indirectly. It would potentially have less than significant effects on aesthetics, air quality, geology and soils, hazards and hazardous materials, hydrology, noise, public services, transportation, and utilities.

Notice of Exemption

To: Contra Costa County
Clerk's Office
555 Escobar Street
Martinez, CA 94553

From: Contra Costa Water District
P.O. Box H20
Concord, CA 94524

Project Title: Bay Area Regional Desalination Project Pilot Plant Study

Project Location: The pilot desalination plant would be located at Contra Costa Water District's existing Mallard Slough Pump Station, at the southern end of a 3,000 foot long dredged intake channel off Mallard Slough, adjacent to Suisun Bay in northern Contra Costa County, as shown on the attached maps.

Project Description: The project includes installation and operation of a 100-gallons-per-minute pilot desalination plant at CCWD's existing Mallard Slough Pump Station near Pittsburg, California, in northern Contra Costa County. The pilot plant study (PPS) would be used to obtain data and help determine the optimal operations for a full-scale plant to be located in the San Francisco Bay Area. The main objectives of the PPS are to maximize the efficiency of operating and maintaining a regional desalination facility; identify potential environmental impacts and evaluate methods to mitigate these potential impacts; identify the preferred pre-treatment for the regional facility; identify the preferred reverse osmosis (RO) system configuration for the regional facility; and develop an information-sharing platform to share test data, methodologies, and project information with other interested users in California.

The pilot plant would draw brackish water from the end of Mallard Slough through the existing Mallard Slough Pump Station intake structure and run the water through three treatment steps (prescreening, microfiltration [MF], and RO treatment) prior to discharge. The treatment facilities would consist of one trailer (approximately 40 by 8 feet); two MF skids on pallets (each approximately 10 by 18 feet); a pre-screening unit (approximately 10 by 10 feet); a few holding tanks for flow equalization or blending; chemical tanks; an air compressor; and other miscellaneous appurtenances. These facilities would be enclosed within a fence, in an area of approximately 120 by 20 feet. The treatment facilities would be located on a decomposed granite parking lot adjacent to the existing pump station.

At the end of the treatment process, desalinated water, as well as the waste stream, would be released. The desalinated water would be sent to Mallard Reservoir for integration into CCWD's untreated water supply for treatment and distribution. The waste stream from the PPS would be discharged into the existing 30-inch-diameter sewer main through approximately 800 feet of 2- to 3-inch-diameter temporary pipeline that would be laid within the existing CCWD access road. The byproduct would be treated at the Delta Diablo Sanitation District wastewater treatment plant with their normal sewer flows.

The PPS would be in operation from June 2008 through December 2008, although operations may be extended to January 2009. The PPS facilities would be removed at the conclusion of the pilot study.

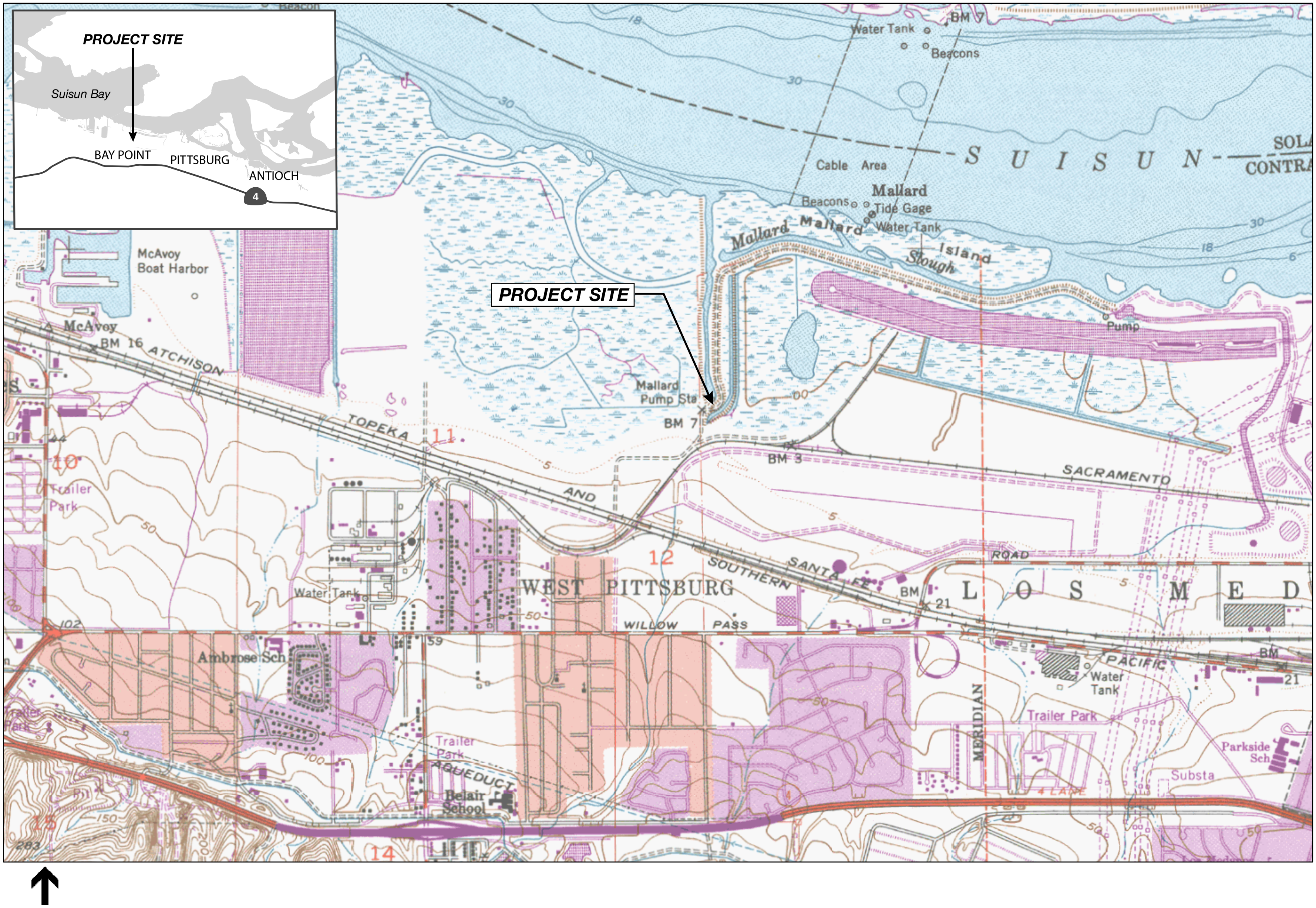
Name of Person or Agency Carrying Out Project: Contra Costa Water District, East Bay Municipal Utility District, San Francisco Public Utilities Commission, Santa Clara Valley Water District

Name of Public Agency Approving Project: Contra Costa Water District, East Bay Municipal Utility District, San Francisco Public Utilities Commission, Santa Clara Valley Water District

Reasons why project is exempt: The proposed project is categorically exempt under CEQA Guidelines Sections 15303 (Construction of Small Structures) and 15306 (Information Collection). The PPS will consist of several new small facilities for use in research and as utility infrastructure. The purpose of the project is collection of basic data on desalination technology as applied to local bay water. The PPS is designed to provide the information needed for the future design and construction of a full-scale bay water desalination plant. (The full-scale desalination plant has not yet been approved and will require completion of a project-level EIR.)

Contact Person: Marie Valmores, Associate Engineer, (925) 688-8132

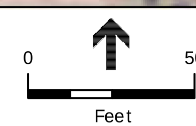
Signature: ______________________________ **Date:** ________________________
Frances I. Garland, Principal Planner



SOURCE: USGS

D207264-Bay Area Regional Desalination Project . 207264

Figure 1
Project Location



D207264-Bay Area Regional Desalination Project . 207264

Figure 2
Proposed Project Layout

SOURCES: CC Water (2007), MWH (2007, GlobeXplorer (2007), ESA (2007)

NOTE: Features are approximately located in relation to the underlying aerial map.
No proposed project components would be located on any wetlands.

TECHNICAL MEMORANDUM

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	**Intake System Evaluation and Desktop Study Technical Memorandum No. 2A**		
Prepared by:	Dawn Guendert David Mayer, PhD CB for	**Reference:**	1481449 / 6.2.2
Reviewed by:	Charles Bromley, P.E. Stefani Harrison, P.E.	**Date:**	August 30, 2007

The BARDP full scale facility, and the pilot facility to be implemented as part of the proposed testing at Mallard Slough, will require an effective and suitable intake system sufficient to supply desired feedwater while minimizing ecological impact. Available and practical alternatives must be carefully weighed in light of various project constraints, regulatory requirements, project schedule, and stakeholder considerations.

As the first step in the ocean water desalination process, the intake system is an important component of every ocean water desalination facility. Intake of water directly from the ocean usually results in loss of marine species as a result of impingement and entrainment. Impingement is when organisms collide with the screens at the intake, and entrainment is when the species are taken into the plant with the feedwater and killed during the plant processes. Impingement and entrainment impacts can be mitigated by the use of certain intake designs and technologies. Appropriately sized intake screens, as well as low velocity water flow are potential mitigation measures for open intake structures. Structures such as onshore intake wells or subsurface infiltration galleries have been proven highly effective.

As part of Task 2.0 of the EBMUD and MWH Agreement dated June 26, 2007, this technical memorandum has been prepared to evaluate potential technologies for the intake system for the BARDP, including use of the existing fish screen at Mallard Slough Pump Station for the proposed pilot plant, and to review the status of current seawater intake technologies around the world. In addition, a description of various intake technologies, both surface and subsurface is given, along with general information about the advantages and disadvantages of the various intake types.

1.0 Case Histories

Table 1-1 lists proposed and existing reverse osmosis desalination plants around the world, with a particular emphasis on California projects. The California plants listed include both proposed and existing plants regardless of size, but excludes units on offshore platforms. The international projects are those with capacities of 10 mgd or greater or have some feature that may be relevant to the BARDP. The table was created from information gathered from the Internet, Global Water Intelligence, personal communications, and seawater desalination papers by Water Ci (2006) and RBF (2004).

Existing California seawater desalination plants capacities range from 0.13 to 2.7 mgd. However plants with capacities of up to 65 mgd have been proposed in the State. The capacities of proposed and existing plants with surface water intakes range from 0.58 to 50 mgd. The capacities of proposed and existing plants with subsurface intakes range from 0.13 to 25 mgd, and the only large seawater desalination plants in California at this time that have proposed subsurface intakes are Long Beach (10 mgd) and Dana Point (25 mgd). Long Beach proposes to employ horizontally directionally drilled beach wells, while Dana Point proposes slant beach wells. West Basin is evaluating both open surface intake with passive wedgewire screens and subsurface seabed filtration.

The capacity of the international SWRO plants included in the Table range from 1 to 86 mgd. Ten of the 19 international desalination plants employ surface water intakes, some of which serve both thermal and membrane desalination facilities and which are co-located at power generating facilities. The operating plants with surface water intakes have capacities that range from 14.3 to 86 mgd, including the world's largest operational SWRO facility at Ashkelon, Israel. The capacity of the eight proposed or operating plants with subsurface intakes range from 1 to 52.8 mgd. However, the majority of the plants with subsurface intakes have capacities less than 20 mgd. The Barcelona desalination plant (52.8 MGD) has not been built but will become the largest facility that uses a subsurface intake. Of the nine international desalination plants that use subsurface intakes, two use a seabed filtration system while the others use some sort of beach well.

Two international seawater desalination facilities employ cylindrical, passive wedgewire screens. One is a 0.8 mgd SWRO facility in Fujairah UAE that reports several years of successful operation. The second installation is an 11 mgd thermal distillation desalination project in Qatar which was installed in 2001 and also reports successful operation.

Of all the seawater desalination plants surveyed (**Table 1-1**) the traditional open ocean surface water intakes have clearly been favored on most large-scale installations. This trend has apparently begun to shift in favor of passive intake arrangements or subsurface intakes with increasing concerns over impingement and entrainment and a desire to obtain feedwater with lower suspended solids concentrations.

Table 1-1. California and International Desalination Plant Intakes

Plant/Site Name	Location	Plant Size	Source	Type of Intake	Screening	Pretreatment	Discharge	Operational History/Permitting Issue/Notes	Source of Information	Proponent/ Water District	Contact Name	Contact #	Contact email	Web
	Arroyo Grande, CA	TBD	TBD	TBD	TBD	TBD	TBD	Feasibility Study	RBF	City of Arroyo Grande				
Diablo Canyon Power Plant	Avila Beach, CA	0.576 MGD	Seawater	Open intake, existing	NA	Dual media and multi media filters and cartridge filters	Existing cooling water outfall		Web	Pacific Gas & Electric Company				http://www.regionaldesal.com/documents.html
	Calleguas	18 MGD	Industrial	WWTP	NA	NA	Brine line to Reliant Energy Ormond Beach Power Plant outfall		RBF	Calleguas Municipal Water District				http://www.calleguas.com/index.html
	Cambria, CA	1 MGD	Seawater	Horizontal beach wells	None	NA	Exfiltration gallery	Water Supply Alternatives EIR in progress; beach well permitting; Desal EIR/EIS pending	RBF	Cambria Community Services District	Bob Gressens	805.927.6119		http://www.cambriacsd.org/ecm/Services/Engineering/desalination_project.html
Encina Power Plant	Carlsbad, CA	50 MGD	Waste Cooling Seawater	Open intake, existing; diversion from existing cooling water channel	Traveling water screen	Conventional	Existing cooling water outfall	Draft EIR out; FEIR 6/22; project on hold	RBF	San Diego County Water Authority	Bob Yamada	858.522.6744		http://www.sdcwa.org/
Encina Power Plant	Carlsbad, CA	50 MGD	Seawater	Open intake, existing; diversion from existing cooling water channel	Traveling water screen	Conventional or membrane filters	Existing cooling water outfall	Final EIR 6/12? NPDES permit 6/14	RBF	Poseidon Resources	Peter McLaggen			www.carlsbad-desal.com
	Catalina Island, CA	0.132 MGD	Seawater	Beach wells	None	None	Existing outfall (SCE Pebbly Beach Generating Station)	Ocasionally used		Southern California Edison/Avalon Community Services District				http://www.regionaldesal.com/documents.html
	Crockett, CA	1.5 MGD	Seawater	Open intake, existing	NA	NA	NA	Feasibility Study	RBF	San Francisco Public Utilities Commission/East Bay Municipal Utility District				http://www.ebmud.com/
Doheny State Beach	Dana Point, CA	25 MGD	Seawater	Slant wells	None	Fe/Mn removal ?	WWTP outfall		RBF	Municipal Water District of Orange County				www.mwdoc.com/desalfeasibilitystudies.htm
Scattergood Power Plant	El Segundo, CA	12 MGD	Waste Cooling Seawater and/or seawater	Open intake with velocity caps, existing	Traveling water screen	NA	Existing cooling water outfall	Feasibility Study RFP in process	RBF	Los Angeles Department of Water and Power				www.ladwp.com/ladwp/cms/ladwp001354.jsp
El Segundo Power Plant	El Segundo, CA	20 MGD	Seawater	Open intake with velocity caps, existing	Traveling water screen	TBD	Existing cooling water outfall	Feasibility Study RFP in process	RBF	West Basin Municipal Water District	Phil Lauri	310.660.6238		www.westbasin.com/pilotproject.html
San Pasqual Wastewater Reclaimation plant	Escondido, CA	5 MGD	Brackish	Conventional well	None	None	Evaporation ponds	Building a 150 gpm demonstration project.	RBF	City of San Diego	Paul Findley, RBF			http://www.sdcwa.org/
AES Power Plant	Huntington Beach, CA	50 MGD	Waste cooling seawater	Open intake with velocity caps, existing	None	Conventional	Existing cooling water outfall	EIR certified (litigated by Surfrider); CDP appealed	RBF	Poseidon Resources	Peter McLaggen			www.hbfreshwater.com
Haynes Generating Station	Long Beach, CA	10 MGD	Seawater	HDD beach wells	None	MF	Sub-sea bed drains	Pilot operating; subsurface demo in permitting; ultimate pending: uses a two pass multistage NF.	RBF	City of Long Beach				http://www.lbwater.org/desalination/desalination.html
	Marin, CA	10 MGD	Seawater	Open intake w/passive screens	Passive screens	Tested both conventional, MF, and UF	Studying combined brine and treated wastewater discharge	Pilot 2005; EIR in process	RBF/MWH	City of Marin				www.marinwater.org
	Marina, CA	2.7 MGD + 0.4 MGD Expansion	Brackish	Horizontal beach wells	None	Cartridge filters	Beach wells, and horizontal beach wells or beach wells for expansion	300K gpd operating; EIR certified; supplement in process; plant will add 0.4 MGD expansion. Possible Fort Ord service	RBF	Marina Coast Water District				http://www.mcwd.org/desal.html
Morro Bay Power Plant	Morro Bay, CA	0.83 MGD	Seawater or Brackish	Beach wells	None	NA	Existing cooling water outfall	To be used only during emergencies	Web	City of Morro Bay				http://www.morro-bay.ca.us/duke.html
LS Power Moss Landing Power Plant	Moss Landing, CA	10-18 MGD	Waste cooling seawater	Open intake, existing; diversion from waste cooling water system with equalization forbay	Traveling water screen not for I/E	MF	Existing cooling water outfall	PEA Submitted 7/14/05; CPUC EIR in process; Pilot Plant anticipated 1/07, NPDES permit for discharge for pilot plant received.	RBF/MWH	California American Water	Paul Findley, RBF			www.coastalwaterproject.com
National Marine Refractories	Moss Landing, CA	20-25 MGD	Seawater	Open intake, existing	Passive screens	Conventional or DAF	Existing cooling water outfall	Pilot Plant CDP appealed; Coastal Commission Permit was appealed	RBF	Pajaro/Sunny Mesa Community Services District				http://www.co.monterey.ca.us/lafco/MSR/North%20County%20MSR/Final%20Revised%20Draft%20N%20County%20MSR-2chapters4review.pdf
	Oceanside, CA	5-10 MGD	Seawater	TBD	None	NA	TBD	Phase II Feasibility Study	RBF	San Diego County Water Authority/Municipal Water District of Orange County	Bob Yamada	858.522.6744		http://www.sdcwa.org/ http://www.mwdoc.com/
US Navy Seawater Desalination Test Facility	Port Hueneme, CA	0.7 MGD	Seawater	Beach wells	NA	UF/MF	Existing outfall (diffusers on existing piers)	Pilot Plant						http://www.usbr.gov/pmts/water/media/pdfs/report012.pdf
Redondo Beach Generating Station	Redondo Beach , CA	20 MGD	Seawater	Open intake with velocity caps, existing	Traveling water screen	TBD	Existing cooling water outfall	Feasibility Study RFP in process	MWH	West Basin Municipal Water District	Phil Lauri	310.660.6238		www.westbasin.com/pilotproject.html
	San Francisco Bay	65 MGD	Seawater	TBD	NA	NA	Existing outfall	Phase II Feasibility Study (URS)	RBF	San Francisco Public Utilities Commission/East Bay Municipal Utility District				http://sfwater.org/detail.cfm/MC_ID/13/MSC_ID/165/MTO_ID/293/C_ID/2910
	Sand City, CA	0.3 MGD	Seawater	HDD Beach wells	None	NA	Vertical Beach wells	EIR certified; received $3 million in 2006 Prop 50	RBF	City of Sand City				http://www.sandcity.org/water/index.html
	Sand City, CA	3-7.5 MGD	Seawater	HDD Beach wells	None	NA	TBD	EIR not certified; project on hold	RBF	Monterey Peninsula Water Management District	Draby Furft			http://www.mpwmd.dst.ca.us/StPlan/StPlan_101705.htm
Charles Meyer Desalination Facility	Santa Barbara, CA	2.5 MGD	Seawater	Open intake, existing (0.5 mile offshore, abandoned outfall relined with HDPE)	NA	Primary and secondary horizontal media fiilters and cartridge filters	WWTP outfall (1.5 miles off shore)	Most of the plant's components have been disassembled.	Web	City of Santa Barbara				http://www.santabarbaraca.gov/Government/Departments/PW/DesalSum.htm
	Santa Cruz, CA	1-3 MGD	Brackish	Groundwater	None	NA	NA	Feasibility Study (RBF), Pilot study stage	RBF/MWH	Montara Water District				http://mwsd.montara.org/DraftWaterMasterPlan.PDF
	Santa Cruz, CA	2.5-4.5 MGD	Seawater	Open intake, existing	NA	NA	WWTP	EIR certified	RBF	City of Santa Cruz				www.ci.santa-cruz.ca.us
Big Bend Power Station	Tampa, FL	25 MGD	Waste Cooling Seawater	Open intake, existing; diversion from existing cooling water channel		Floc, SM gravity filter, precoat filter	Filter b/w settled, sludge to landfill. Brine blended with discharge from cooling system discharged into canal and further diluted into Tampa Bay.	To Be Commissioned November 2006	MWH	Tampa Bay Water				http://www.tampabaywater.org/watersupply/tbdesal.aspx
	Perth, Australia	38 MGD	Seawater	Offshore riser, onshore TWS		1-stage DM pressure filters	Offshore multi-port diffuser. Filter b/w clarified & centrifuged - sludge to landfill; conc blended & disch. to sea	To Be Commissioned November 2006		The Water Corporation				http://www.watercorporation.com.au/D/desalination.cfm

Gosford Wyong Water Supply Desalination Project	New South Wales, Australia	5.3 MGD	Seawater	Horizontal beach wells		Flocculation, dual media gravity filters, and 2 stage cartridge filters	Blended with wastewater plant effluent onshore, gravity discharge to sea via multiport diffuser.	Proposed	MWH	Wyong Shire Council				http://www.wyongsc.nsw.gov.au/
	Al Dur, Bahrain	11.9 MGD							Seawater Desalination "White Paper"					
	Antofagasta, Chile	13.7 MGD							Seawater Desalination "White Paper"					
Dhekelia	Dhekelia I, Cyprus	10.6 MGD	Seawater	Open intake w/passive screens		Dual media gravity filter	10 uni-directional diffusers, pipe buried/laid on seabed	Commissioned April 1997 (or To Be Commissioned June 2009?)		Caramondani Group will transfer to Water Development Department of the Ministry of Agriculture, Cyprus				http://www.cyprus.gov.cy/moa/wdd/wdd.nsf/79ba3338886beb78c2256cc5003e81cf/d9dd3467701044cdc2256e44003d7207?OpenDocument http://www.cyprus-mail.com/news/main.php?id=19011&archive=1
Larnaca	Larnaca, Cyprus	14.3 MGD	Seawater	Open sea, offshore		Dual media gravity filter		Commissioned May 2001		Water Development Department of the Ministry of Agriculture, Cyprus				http://www.moa.gov.cy/moa/wdd/Wdd.nsf/All/50189B849C08223BC2256DFD0032D1B2?OpenDocument http://www.water-technology.net/projects/larnaca/specs.html
	Marippaiyur, India	1 MGD		Seabed filtration system		Sodium hypochlorite and pressure media filters	To the ocean							
	Ashdod, Israel	21.7 MGD							Seawater Desalination "White Paper"					
Ashkelon Desalination Plant	Ashkelon, Israel	86 MGD	Seawater	Open sea, 1000m offshore		Dual media gravity filter	Filter b/w and concentrate discharge at shoreline adjacent to PP cooling water	Commissioned April/December 2005	MWH	Mekorot, gov't water company owned & operated by VID Desalination Company				http://www.water-technology.net/projects/israel/specs.html http://www.jr.co.il/articles/desalination.txt http://news.dow.com/dow_news/prodbus/2005/20050927c.htm
	Shomrad, Israel	21.7 MGD							Seawater Desalination "White Paper"					
Mamizu-Pia	Fukuoka, Japan	15.8 MGD	Seawater	Seabed filtration system		Sprialwound UF	Blended with wastewater plant effluent onshore, gravity discharge to sea via multiport diffuser.	Commissioned March 2005	MWH	Fukuoka Area Waterworks Association				http://www.city.fukuoka.jp/fan200609/page21.html http://www.nitto.com/company/release/05_01_06/index.html
	Okinawa, Japan	10.6 MGD							Seawater Desalination "White Paper"					
Ghar Lapsi SWRO	Malta	6.3 MGD	Seawater	Vertical beach wells					Seawater Desalination "White Paper"					
Pembroke Plant	Malta	14.3 MGD	Seawater	Beach Wells				Commissioned 1991	Seawater Desalination "White Paper"	Water Services Corporation, indep. body owned by gov't run by Malta Desalination Services				http://wbln0018.worldbank.org/water/bnwp.nsf/files/5malta.pdf/$FILE/5malta.pdf
Pemex Salina Cruz	Mexico	3.8 MGD	Seawater	Horizontal Beach Wells				Commissioned 1986		Pemex Salina Cruz Refinery				http://www.edsoc.com/Newsletter22.pdf
Hermosillo	Mexico	34 MGD	Brackish						Seawater Desalination "White Paper"					
Jubail IV	Saudi Arabia	24 MGD	Seawater	Open sea		Dual media gravity filter	Filter b/w blended with concentrate discharged to sea	Commissioned January 2006		operated by Saline Water Conservation Corporation				http://www.medrc.org/new_content/industry_news/Dec00/story2.html
	Buraydah, Saudi Arabia	24 MGD							Seawater Desalination "White Paper"					
	Medina/Yanbu II, Saudi Arabia	33.8 MGD						Start up 1998	Seawater Desalination "White Paper"					
	Yanbu - Medin III, Saudi Arabia	13.3 MGD							Seawater Desalination "White Paper"					
Tuas	Singapore	36 MGD	Seawater	Open sea, offshore		DAF, gravity filters	DAF float, filter b/w with conc; pipe laid on seabed, discharge angled for better mixing	Commissioned September 2005		Singapore Public Utilities Board				http://www.water-technology.net/projects/tuas/specs.html
	Alicante, Spain	63.4 MGD												
	Almeria, Spain	13.2 MGD							Seawater Desalination "White Paper"					
Barcelona	Barcelona, Spain	52.8 MGD	Seawater	HDD Beach wells				To be commissioned mid-2009		Aguas del Ter Llobregat				http://www.suez-environnement.com/en/espace_presse/communiques_de_presse/(offset)/6
Carboneras	Carboneras, Spain	31.7 MGD	Seawater	Open sea, 150m offshore, -13m		Degrit DM Pressure filter	Concentrate & filter b/w blended with PP cooling water	Commissioned July 2002		owned by RWE, a subsidiary of Thames Water				http://www.guardian.co.uk/spain/article/0,2763,1241636,00.html#article_continue
Bay of Palma	Mallorca, Spain	11 MGD	Seawater	Vertical Beach Well					Seawater Desalination "White Paper"	Ondeo-Degremont (private), EMAYA (municipal company)				www.watertime.net/docs/WP2/D35_Palma_de_Mallorca.doc
	Marbella, Spain	14.5 MGD							Seawater Desalination "White Paper"					
Cartagena I	Muricia, Spain	17.2 MGD	Seawater	HDD Beach wells		1-stage horiz pressure filter	Subsea outfall with mulitple diffusers	Commissioned 2000						
Cartagena II	Muricia, Spain	17.2 MGD	Seawater	Open intake		2-stage pressure filter	Subsea outfall with mulitple diffusers	Under Construction						
Point Lisas	Point Lisas, Trinadad and Tobago	30.0 MGD	Seawater	Open intake		Flocculation, sedimentation, and single stage deep bed media filters	Filter b/w settled, sludge to landfill; conc blended, discharge to ship channel	Commissioned March 2002		Water and Sewer Authority of Trinidad and Tobago (customer), Desalination Company of Trinidad and Tobago (owns & operates)				http://www.gewater.com/pdf/what_we_do/water_scarcity/CS1052EN.pdf
Fujairah	Fujairah, UAE	44.9 MGD	Seawater	Open sea, offshore riser		Dual media gravity filter	Blend with PP cooling water, discharge from channel at shoreline	Commissioned May 2004: hybrid SWRO and MSF		operated by Degremont				http://ww.pennnet.com/articles/article_display.cfm?article_id=227597

Key

Proposed/Uncompleted Plant	(yellow)
Operational Plant	

MWH

2.0 Surface Water Intakes

Surface water intakes draw water from a surface water body (ocean, bay, lagoon, etc.), and use screens or other devices to exclude a portion of the fish and other marine organisms from entering the feed flow stream to the downstream use. For seawater desalination plants that are co-located with seawater cooled power plants, the desalination plant feed water may be taken from the cooling water supply or discharge system. In this case, the surface water intake is the ower plant's cooling water intake.

Surface water intakes for seawater desalination plants are of two general types: 1) direct from a dedicated intake in the surface water body, or 2) indirect, i.e., from a cooling water system or some other conveyance system that derives water from a direct surface water intake. Design and permitting issues, as well as water quality characteristics associated with these two types of surface water intakes, are discussed in this section.

2.1 Direct Surface Water Intakes

Direct surface water intakes for seawater desalination plants will typically be equipped with a screen (sometimes other devices or systems are used) to exclude marine organisms from entering the desalination plant. The screen can be installed offshore, at the point of entry to the feed water conveyance pipe, or it can be installed on-shore, in which case, unscreened feed water flows by gravity to the screen via a pipe or channel. If the screen is mechanically cleaned, the screenings may be discharged back to the surface water, using carrier water in a return flow system. Alternatively, if permitted, the screenings may be collected, drained, and disposed.

2.2 Indirect Surface Water Intakes

Indirect surface water intakes draw prescreened water from another flow stream (usually once-through cooling (OTC) water to or from power plants). In order to protect downstream pumps and treatment processes, screens may be provided at the point of diversion, or prior to the pretreatment process at the desalination plant. Screenings from indirect surface water intakes are typically discharged back into the flow stream of the source water.

2.3 Surface Water Intake Considerations

Key issues for surface water intakes involve biological impacts and mitigation measures and water quality of the feedwater source.

2.3.1 Impingement and Entrainment

Although other systems have been investigated and occasionally used, the most practical way to prevent small marine organisms from entering the desalination plant feed water stream is though the use of screens. Marine life such as fish eggs and larvae, juvenile fish, and mature fish, may be affected by direct surface water intakes though impingement (on the screens) or entrainment (in pumps, piping, and processes upstream or downstream of the screens). Screens on surface water intakes must be carefully designed for a screen opening size that excludes fish eggs and larvae, that provides sweep flow and escape paths for any organism caught in the approach to the screen, and that has enough screen area to minimize approach velocity to the screens and flow velocity through the screen openings.

When the desalination plant feed water is taken from a power plant's OTC water supply system, the flow of water taken through the power plant's direct surface water intake system is increased, and the desalination operation now shares in any impingement and entrainment losses associated with the power plant's intake system. However, the power plant's intake flow of OTC water is typically not affected if the desalination plant feed water is taken from the heated OTC water before it is discharged to the ocean. For this reason, use of heated OTC water for feed water to the desalination plant may have a permitting advantage.

2.3.2 Water Quality

Other than a slight reduction in turbidity and algal content that may occur as a result of screening, the quality of water taken from direct surface water intakes will be the same as the source surface water. Monitoring systems are required to immediately detect and shut down the intake in the event of spills in the source water of oil or other contaminants that could make their way into the intake. Depending on the source, short-term fluctuations in turbidity and salinity may be expected as the result of the tidal cycle and/or weather. Seasonal fluctuations of temperature, salinity, and algal content may also occur. Algal blooms may affect operation of the screen and also water quality. Some algal blooms, classified as "red tides", result in the release of small amount of bio-toxin into the water, and the accumulation of this bio-toxin in shellfish can be a health hazard to marine animals (and humans) that eat the shellfish. This issue has attracted some recent attention from the California Department of Health Services regarding removal of this bio-toxin in the desalination process.

Similar to surface water intakes, the quality of water taken from cooling water systems will resemble the turbidity and algal content in the native source water. The lag between the time that water enters the power plant's system and when the water would be diverted into a desalination plant provides some time to detect and react to a spill event in the source water. For a heated cooling water system, desalination plant feed water should not be diverted from the system during and immediately after periods of heat treatment or chemical treatment of the cooling water system. During these periods, large amounts of biological growth in the cooling water system are sloughed.

The temperature of water taken from a heated OTC water discharge will be up to 25 degrees (Fahrenheit) warmer than the native source water. Also, the temperature may change rapidly, in a matter of minutes, as the power plant's output changes. The rapid change in temperature can cause operational problems for the desalination plant's reverse osmosis process. At least one other desalination project in California (Coastal Water Project at Moss Landing) is proposing to install an equalization basin for desalination plant feed water to mitigate this problem.

2.4 Types of On-Shore and Off-Shore Surface Water Intakes

The types of surface intakes available for desalination plants are briefly described below, and summarized in **Table 2-2.**

2.4.1 Behavioral Barrier Systems

Behavorial barrier systems employ sensory stimuli such as light or sound to induce marine life to avoid a open water intake and reduce overall impingement. Mechanisms that marine life use to respond to auditory and visual stimuli are not well understood and many responses appear to be species-specific. Therefore, behavioral barrier systems using light, bubbles, or sound to enhance fish avoidance or to attract them to a fish diversion system have been generally ineffective or inconclusive at reducing entrainment and impingement and are used infrequently (Shaw, 2005).

2.4.2 Velocity Caps

The cover placed over the vertical terminal of an offshore intake pipe is called a "velocity cap" (**Figure 2-1).** The cover converts vertical flow into horizontal flow at the intake entrance to reduce fish entrainment. It has been noted that fish will avoid rapid changes in horizontal flow and velocity cap intakes have been shown to provide 80-90% reduction in fish impingement at two California power stations, and a 50-62% impingement reduction versus a conventional intake at two New England power stations (EPA, 2001).

Table 2-2. Surface Intake Options

	Type of Intake	Description	Example	Maintenance	Impingement	Entrainment	Siting Criteria	Water Quality
OFFSHORE	**Behavior Systems**	Lights, bubbles, or sonic stimuli are used to keep fish from entering open intakes. Lights have also been used to attract fish to fish return systems.	San Onofre Nuclear Generating Station, Long Beach Generating Station, Redondo Beach Generating Station	Potentially high energy requirements	Moderate reductions possible in the impingement of specific species (pelagic schooling fish with swim bladders though not likely.	No reduction in entrainment.	Requires offshore power and air supply. Behavior avoidance systems must be deployed well upstream of intake point, i.e. 10 to 20 meters beyond offshore vertical riser.	Does not have the water quality benefits (reduced turbidity and organic carbon levels) of a filtration system provided by the subsurface intakes. Requires pretreatment.
OFFSHORE	**Velocity Caps**	A concrete cap placed on top of the intake which forces water to enter the intake perpendicularly to the intake pipe rather than inline with the pipe. There are three types: overhang, flush, and overhang with riser lip. Flush caps have a cap the same diameter as the intake pipe. Overhang caps have a cap with a larger diameter than the intake pipe. Overhang with riser lip have a cap with a larger diameter than the intake pipe and a lip on the riser.	El Segundo Generating Station, Redondo Generating Station, Scattergood Generating Station, Huntington Generating Station, San Onofre	No moving parts.	Has been reported to reduce entrapment and subsequent impingement by up to 90%.	No reduction in entrainment.	Vertical intake riser.	
OFFSHORE	**Passive Slotwire Screens**	Cylindrical screens constructed of wedgewire, which can be attached to the intake conduits, that eliminate impingement and significantly reduce or eliminate the entrainment of fish eggs and larvae	Marin, CA	Utilizes ambient cross-flow and air backwash system to keep the screens clean. No moving parts.	Eliminates impingement.	Reduces entrainment of fish eggs and larvae as a function of slot width of wedgewire by up to 95%.	Requires sweeping velocities and potentially large tracts of bottom area an that can be sacrificed or mitigated for habitat loss.	
OFFSHORE	**Aquatic Filter Barrier (Gunderboom)**	Consists of a full water depth microfiltration fabric suspended in the water column with a floats and weights. Air scour system can be added to periodically clean the filter. Unproven technology for marine environment.	Lovett Generating Station (fresh water), Arthur Kill Power Station (pilot test), El Segundo Generating Station (feasibility study)	Due to clogging/biofouling, requires frequent filter panel replacement. High maintenance cost.	Eliminates impingement; however useless if fabric tears or water flows over the top of the barrier, as field tests have shown to happen with some regular frequency. Use of barriers represent permanent loss of marine habitat enclosed by the barrier and anchoring system.	Significantly reduces entrainment up to 95%; however useless when barrier fails under field conditions. Use of barriers represent permanent loss of marine habitat enclosed by the barrier and anchoring system.	Wave protected settings, sweeping velocities and large tracts of bottom area that can be sacrificed or mitigated for habitat loss.	
ONSHORE	**Fish Barrier Net**	Consists of a wide mesh net placed in front of the intake.	Tested for 4 days at El Segundo.	No moving parts. Requires significant maintenance to prevent biofouling..	Can be effective at reducing impingement. Commonly used in many lake and some river intake settings. Susceptible to biofouling, velocity hotspots and debris clogging.	No reduction in entrainment.	Use restricted to relatively shallow embayments, inlets, lakes and rivers protected from high debris loading and wave energy. Not suitable for open ocean or conditions. Generally deployed on a seasonal basis due to maintenance and fouling issues.	
ONSHORE	**Fish Mesh Stationary Screens**			No moving parts. Requires significant maintenance to prevent biofouling..	Depending on mesh size and species of fish, fine mesh screens may reduces entrainment losses of and at the same time possibly increase impingement losses.	Some reduction in entrainment losses possible depending on life stages and mesh sizes. Impingement survival of these early larval life stages is generally low.	Shoreline intake location with requirements for potentially large amounts of land to achieve through screen velocities of 0.5 fps. Requires good sweeping flows parallel to screen face. Intake canals or conduits leading to screen must be avoided and depth of forebays minimized.	
ONSHORE	**Porous Dike**	Can be placed in front of an intake channel or pipe. Resembles a breakwater and acts as a physical and behavioral barrier.		No moving parts.	Eliminates impingement	Eliminates entrainment.	Shoreline intake locations with requirements for potentially large amounts of land to achieve low approach velocities of ~0.5 fps. Requires good sweeping flows parallel to dike face, and large tracts of bottom area that can be sacrificed or mitigated for habitat loss.	
ONSHORE	**Modified Vertical Traveling Water Screen with Fish Return**	Conventional traveling water screen with a collection bucket and spray system to return fish.	Arthur Kill Power Station, Dominion Power Surry Station	Requires much maintenance with continuous operation.	Has higher impingement survival rate than conventional screens, if fish return system is effective. Fish return systems often are associated with the establishment of predator feeding stations. Fish salvage efforts are only moderately successful for large adult fish, and less so for small and fragile stages.	No reduction in entrainment losses.	Locate in close proximity to fish return location in order to minimize transportation stresses.	
ONSHORE	**Fine Mesh Traveling Water Screens with Fish Return**	Conventional traveling water screen with fine mesh screen and spray system to return fish.	Big Bend Power Plant, Brunswick Power Plant	Requires much maintenance with continuous operation. Finer meshes require more maintenance.	Depending on mesh size and species of fish, fine mesh screens may reduces entrainment losses of and at the same time possibly increase impingement losses.	Some reduction in entrainment losses possible depending on life stages and mesh sizes. Impingement survival of these early larval life stages is generally low.	Avoid areas of high debris loading (e.g. seaweed) that would create screen hotspots and significantly reduce survival of smaller life stages, offsetting any potential reduction in entrainment benefits.	
ONSHORE	**Dual Flow and Centerflow Traveling Water Screens with Fish Return System**	Traveling water screens with intake screens inline with the water flow. Due to increased intake screen surface area, smaller mesh can be used.		Requires much maintenance with continuous operation.	High survival rate for impinged organisms.	No reduction in entrainment losses.	Large footprint of equipment and intake structure requires potentially large amounts of shoreline land and offshore bottom habitat.	
ONSHORE	**Single Entry Cup and Double Entry Drum Screens**	Circular screen with a single solid horizontal shaft which rotates slowly. Diameter of the circular screen can range from 5 to 65 ft.		Requires much maintenance with continuous operation.	High survival rate for impinged organisms.	No reduction in entrainment losses.	Large footprint of equipment and intake structure.	

*Information gathered from RBF (2005) and Southern California Edison (1975)

It has been shown that the relationship of the vertical opening (x) to the length of horizontal entrance (1.5x) can be optimized to create a uniform flow and improve a fish's ability to react. As with all intake configurations, there are many design issues that must be considered, and the performance of a velocity cap may vary in still water versus areas subject to tidal cross-flows.

Velocity caps are currently employed at the cooling water intakes at a number of generating stations in California. Velocity caps can be very effective in minimizing impingement impacts, but are ineffective in limiting entrainment of marine organism into the intake pipeline. Once inside the intake pipeline, entrained organisms are subject to in-pipe predation, and mortality rapidly occurs.

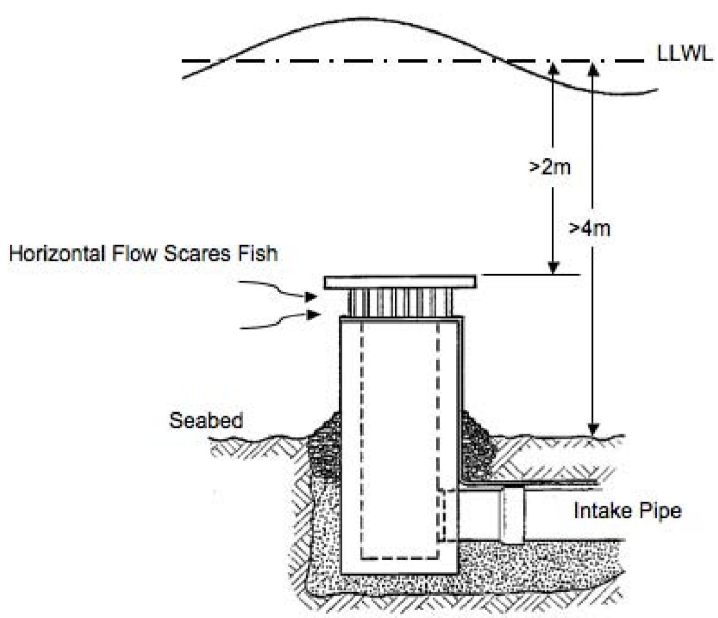


Figure2-1. Velocity Cap Intake

2.4.3 Passive Screens

Another technology with the potential to reduce impingement and entrainment is the passive screen. An intake arrangement utilizing slotted screens constructed of trapezoidal-shaped "wedgewire" is illustrated in **Figure 2-2**. The cylindrical screens have openings ranging from 0.5 millimeters (mm) to 10 mm are usually oriented on a horizontal axis with screens sized to maintain a velocity of less than 15 centimeter per second (cm/s) (0.5 feet per second, fps) to minimize debris and marine life impingement. Passive screens are best-suited for areas where an ambient cross-flow current is present, and air backwash system is usually recommended to clear screens if debris accumulations do occur. As with all submerged equipment, material selections should reflect the corrosion and biofouling potential of seawater.

Passive wedgewire screens are a well-proven technology in fresh-water applications and have a proven ability to reduce impingement and entrainment. Their effectiveness is related to: (1) a sufficiently small slot size to physically block passage of the smallest life stages to be protected; (2) low through-flow velocity to minimize the hydraulic zone of influence in which passive or weak organisms can be entrained; and, (3) an adequate "sweeping" velocity passing across the screen to carry organisms along and away from the screen. Recent studies have indicated that 0.5 and 1.0 mm wedgewire screens have the capability to physically exclude marine organisms enough to meet EPA's 316(b) entrainment reduction performance standard under many of the conditions studied.

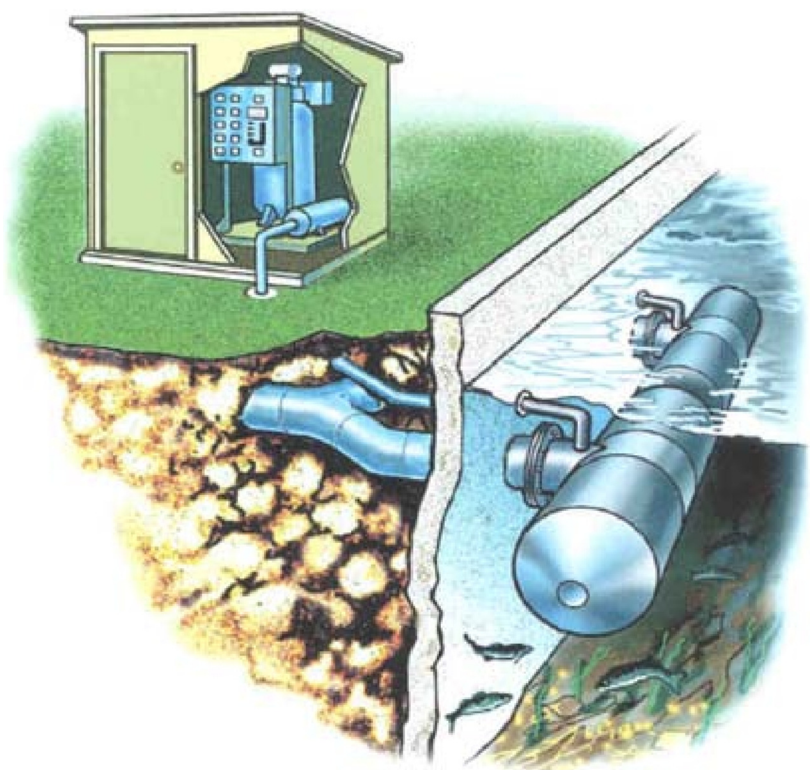


Figure 2-2. Passive Screen Intake

The standard method for back flushing debris from the intake screen is an air-burst system (**Figure 2-3**). **Figure 2-4** illustrates how a measured air-burst forces debris away and scours the screen surface for highly efficient cleaning. A variety of controls for the air-burst system are available, including manual, automatic timers and headloss activated. In addition to the air-burst, periodically the intake screen will need to be inspected and cleaned manually by a diver.

Figure 2-3 : Diagram of Air-burst System

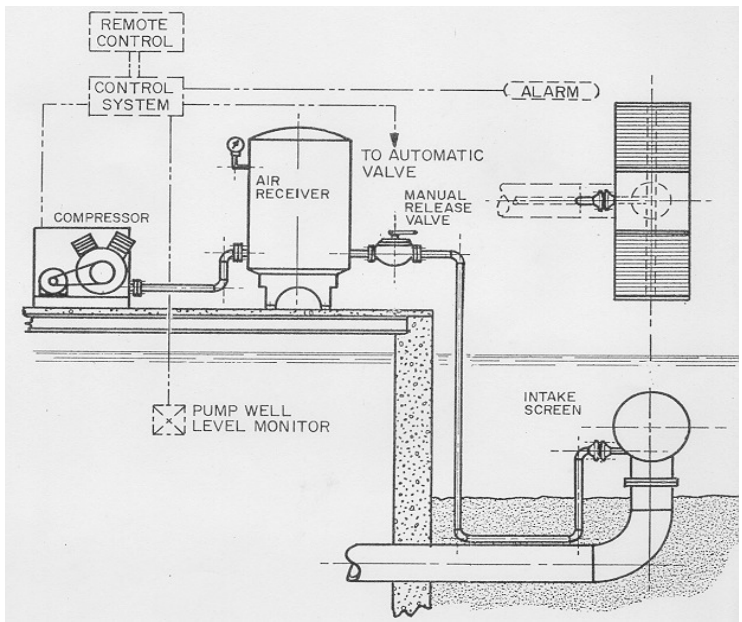
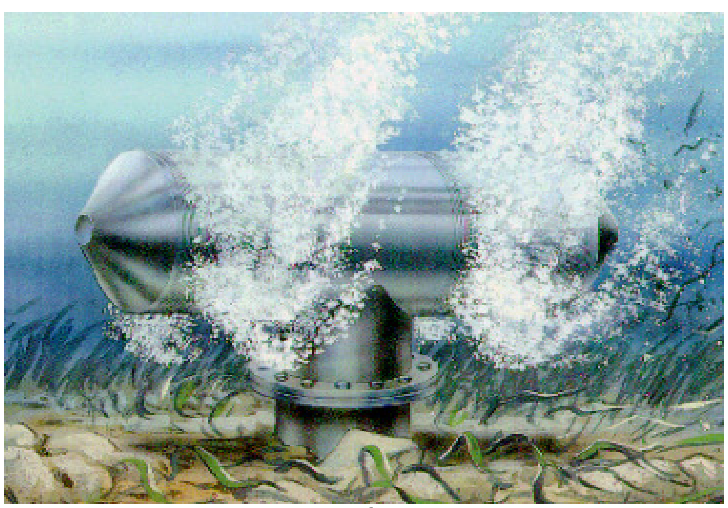


Figure 2-4 : Illustration of Air-burst



Passive wedgewire screens are considered to be one of the more promising technologies available for reducing impingement mortality and entrainment. EPA used existing effectiveness data for passive wedgewire screens, in part, in its justification of the current performance standards for impingement and entrainment reduction, and wedgewire screens are the only technology currently pre-approved for reducing impingement and entrainment at cooling water intake systems in freshwater rivers under the rule (Alden Research Laboratory, 2005).

Design and configuration issues that need to be resolved for full scale application of this technology include construction details to secure the screen to resist storm surges; design, construction and long term protection of the gravity pipeline(s) to convey the screened water on-shore; materials of construction to resist fouling due to growths of marine animals and plants on the screen; and access for periodic inspection, cleaning and replacement, and/or provision of an adequate and reliable backwash system.

2.4.4 Aquatic Filter Barriers

Another recent technology, designed to address both impingement and entrainment, is the aquatic filter barrier. The aquatic filter barrier is a semi-permeable mat of polyester fibers that will allow water through the filter mats while excluding aquatic organisms.

An aquatic filter barrier commercially available is the Marine Life Exclusion System (MLES) manufacturered by Gunderboom, Inc. and illustrated in **Figure 2-5.** A full-depth, porous filter fabric with openings ranging from 0.4mm to 5mm is placed at the entrance to an intake structure and suspended by a floating boom and anchored to the seabed. The system is sized to provide enough surface area to have a through-flow velocity low enough to avoid impingement of marine life or debris.

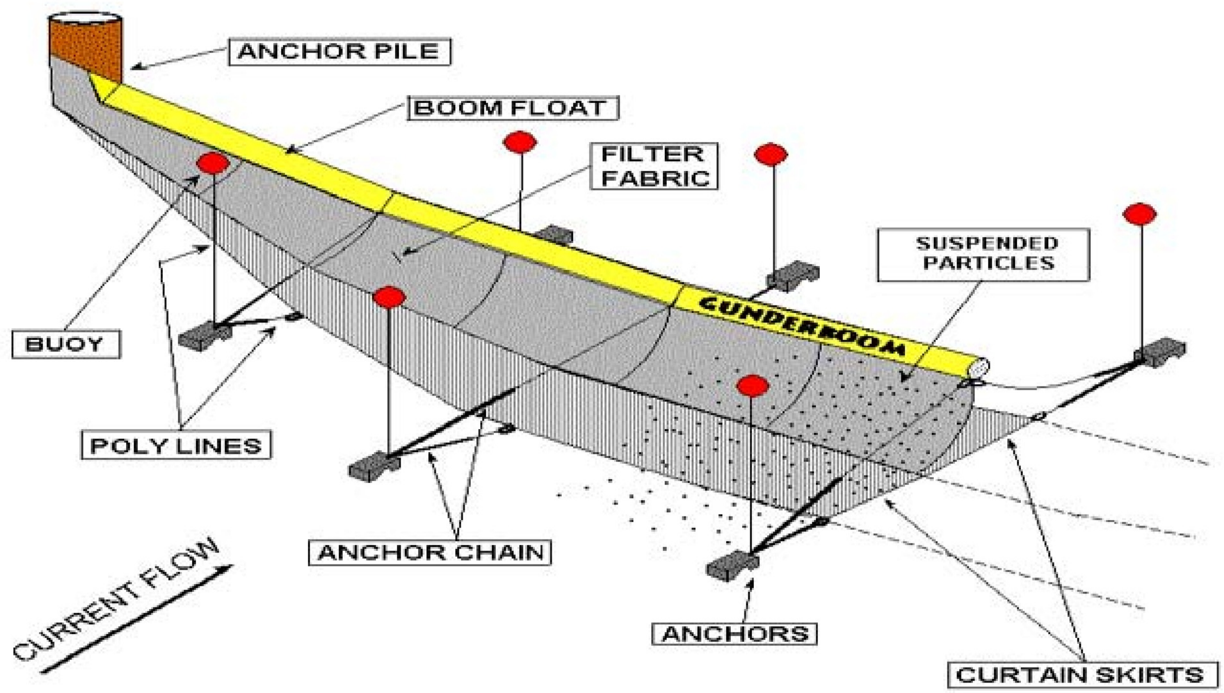


Figure 2-5. Aquatic Filter Barrier

Aquatic filter barriers have been tested in several facilities (Lovett Generating Station and Arthur Kill Power Station) and there has only been limited application of this technology. Currently there are no installations in an open ocean marine environment similar to California's coast (Shaw, 2005). An open marine environment would make an aquatic filter barrier not only hard to construct and maintain but would also become a navigation hazard (Shaw, 2005).

In addition, resistance to bio-fouling is a major concern. Bio-fouling can reduce the permeablility of the fabric to water and damage the material. Testing of the aquatic filter barrier material in a pond showed that the fabric can be quickly fouled, with permeability reduced to close to 97 percent on the panel tested and that use of the air-burst system actually enhanced bio-fouling (Henderson 2005).

A demonstration of the Gunderboom MLES was required for Contra Costa Power Plant to comply with a Habitat Conservation Plan; however, it has never been implemented since it has since been determined to be infeasible (CEC 2005).

2.4.5 Fish Barrier Net

A fish barrier net consists of wide mesh netting that is placed in front of the intake. Fish barrier nets have been used at several large power plants pulling water from embayments, inlets, lakes, and rivers, but will be difficult to construct and maintain in an open marine environment (Shaw, 2005). In 1972, Southern California Edison (1975), the owners of the El Segundo Generating Station at the time, installed a prototype net at El Segundo but removed it after only four days due to an inadequate anchoring system.

2.4.6 Fish Mesh Stationary Screens

Fish mesh stationary screens consists of mesh screening set across an intake. These units are typically installed on riverbanks or shoreline. There are no moving parts involved in this intake option so a good sweeping flow is required to keep the screens clean. Fish mesh stationary screens may improve entrainment but could increase impingement.

2.4.7 Traveling Water Screens

Traveling water screens have been employed on seawater intakes since the 1890's. Almost all cooling water intake structures in California utilize traveling screens. The screens are equipped with revolving wire mesh panels with openings typically ranging form one inch or less. Most facilities' intakes are 3/8-inch mesh or smaller.

As the wire mesh panels revolve out of the flow, a high-pressure water spray removes accumulated debris, washing it into a trough for further disposal. The screens can be located onshore, at the end of a channel or forebay that extends out beyond the surf zone, or at the end of a pipe that extends out into the sea, terminating in a vertical "velocity cap" inlet. **Figure 2-6** displays different intake configurations using traveling water screens.

A modified traveling water screen with fish return (Ristroph Screen) is a modification of a conventional traveling water screen in which screen panels are fitted with fish buckets that collect fish and lift them out of the water where they are gently sluiced away prior to debris removal with a high pressure spray (**Figure 2-7**). At one New York seawater intake, the 24-hour survival of conventional screens averaged 15% compared with 79-92% survival rates for Ristroph Screens.

A review of 10 similar sites reported that Ristroph modifications improved impingement survival 70-80% among various species. Ristroph Screens may be effective for improving the survival of impinged marine life, but they do not affect entrained organisms.

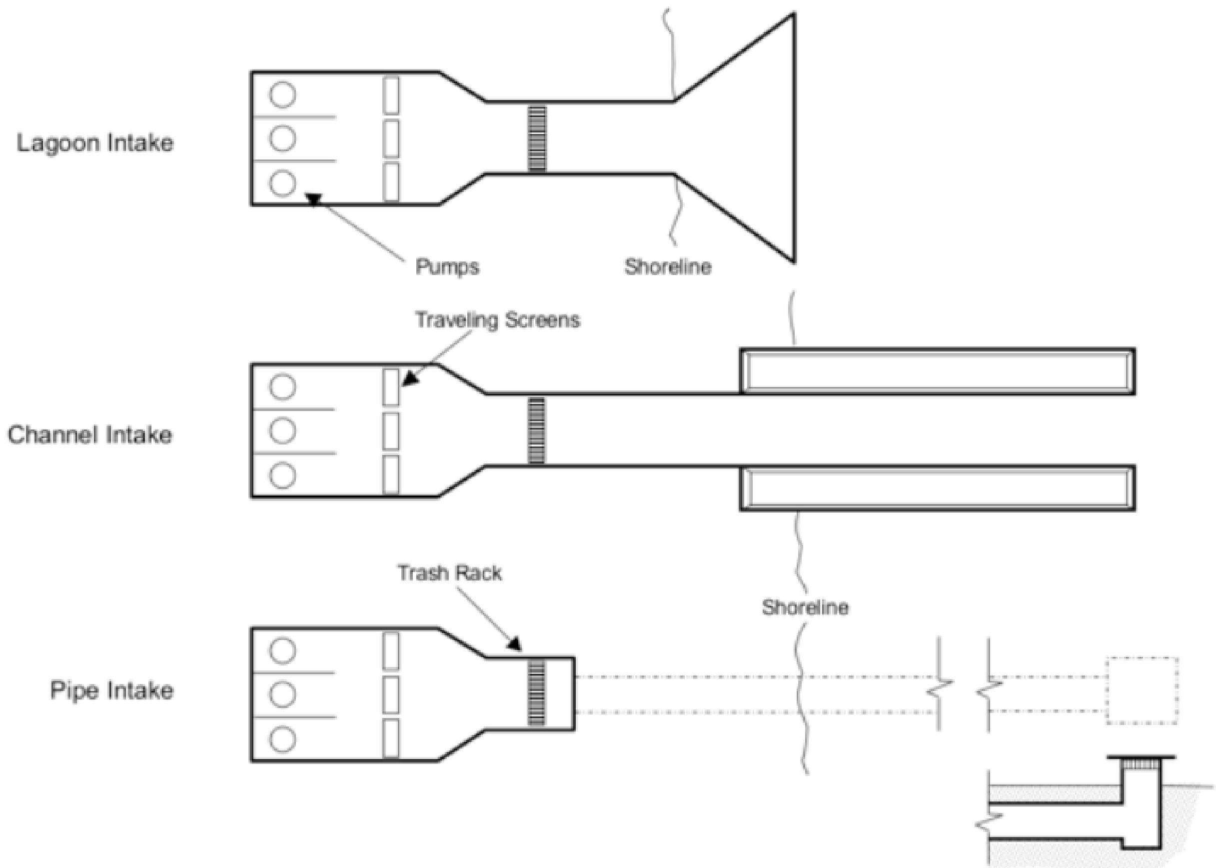


Figure 2-6. Surface Water Intake Alternatives

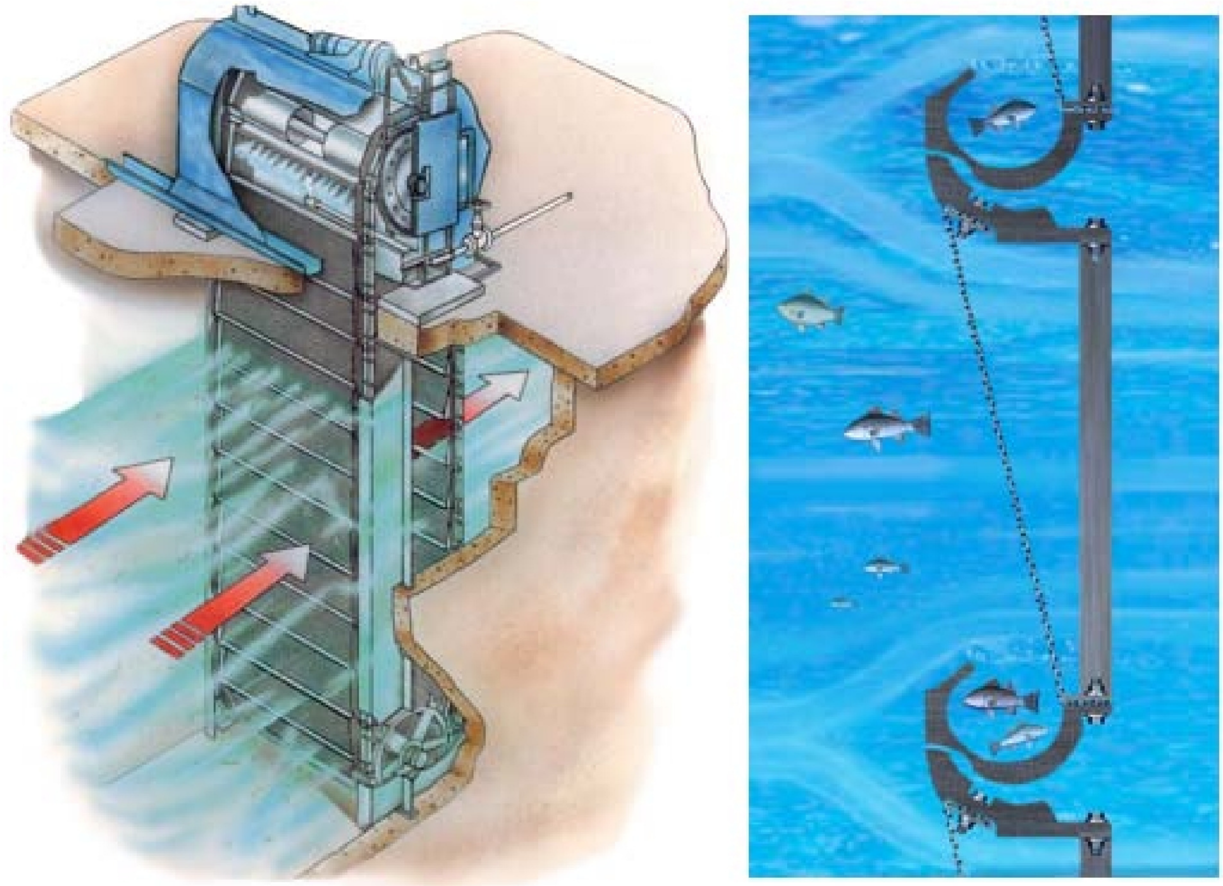


Figure 2-7. Ristroph Screen

Fine mesh screens have successfully reduced entrainment of eggs, larvae, and juvenile fish at some intake locations where traveling water screens have been outfitted with mesh having openings ranging from 0.5 mm to 5 mm, reducing entrainment by up to 80%. Fine mesh screens may result in operational problems due to the increased amount of debris removed along with the marine life, and in some locations, the fine mesh is only utilized seasonally, during periods of egg and larval abundance.

Rotating drum screens, dual flow and centerflow traveling water screens with fish return system, typically operate in either a single entry/double exit or double entry/single exit configuration, are another variation of traveling water screen that are commercially available. However, an example application of this technology for use as a seawater intake is not known.

All traveling water screens alternatives have been eliminated from the desalination plant intake consideration. Traveling water screens located onshore do not meet the entrainment criteria due to losses in the intake pipe. If a traveling water screen is moved offshore to the head of the intake, the entrainment criteria might be met, but the high maintenance and construction cost make this option not feasible.

3.0 Survey of Subsurface Intake Types

Subsurface intakes are differentiated from surface intakes in that they derive ocean water from sediments either under the seafloor, or adjacent to the coast. Because the intake water travels through either native or artificially placed granular porous media, the water is filtered, which greatly simplifies pretreatment requirements for particulate matter, and also greatly reduces concerns regarding impingement and entrainment. The primary benefit of subsurface intakes is that there are no fish, eggs or other biological material trapped or killed during the intake process. A primary disadvantage is that their design is highly site-specific (depending on the hydrogeology of the site), and the industry experience with subsurface intakes is much less extensive.

3.1 Subsurface Intake Considerations

General characteristics of subsurface intakes that differentiate them from surface water intakes are summarized below.

3.1.1 Stability of Water Characteristics

Water characteristics (temperature, salinity, turbidity, silt density index) would be expected to vary much less rapidly that open ocean water. This generally makes subsurface intakes more favorable because there is little or no pretreatment needed, and removes the need for an equalization basin.

3.1.2 Influence of Fresh Water

With the potential exception of directionally drilled wells or seabed infiltration systems located directly under the seafloor, subsurface intakes will be affected by fresh water to some degree either from surface recharge or from injection in the adjacent area. The influence of fresh water will vary with location (lower salinity inland of the tidal zone), depth of extraction (higher salinity with depth), rate of extraction (high salinity with higher extraction rate), and time (greater salinity with length of extraction). **Figure 3-1** is a schematic diagram of a typical phreatic coastal groundwater system showing the mixing zone of fresh and salt water.

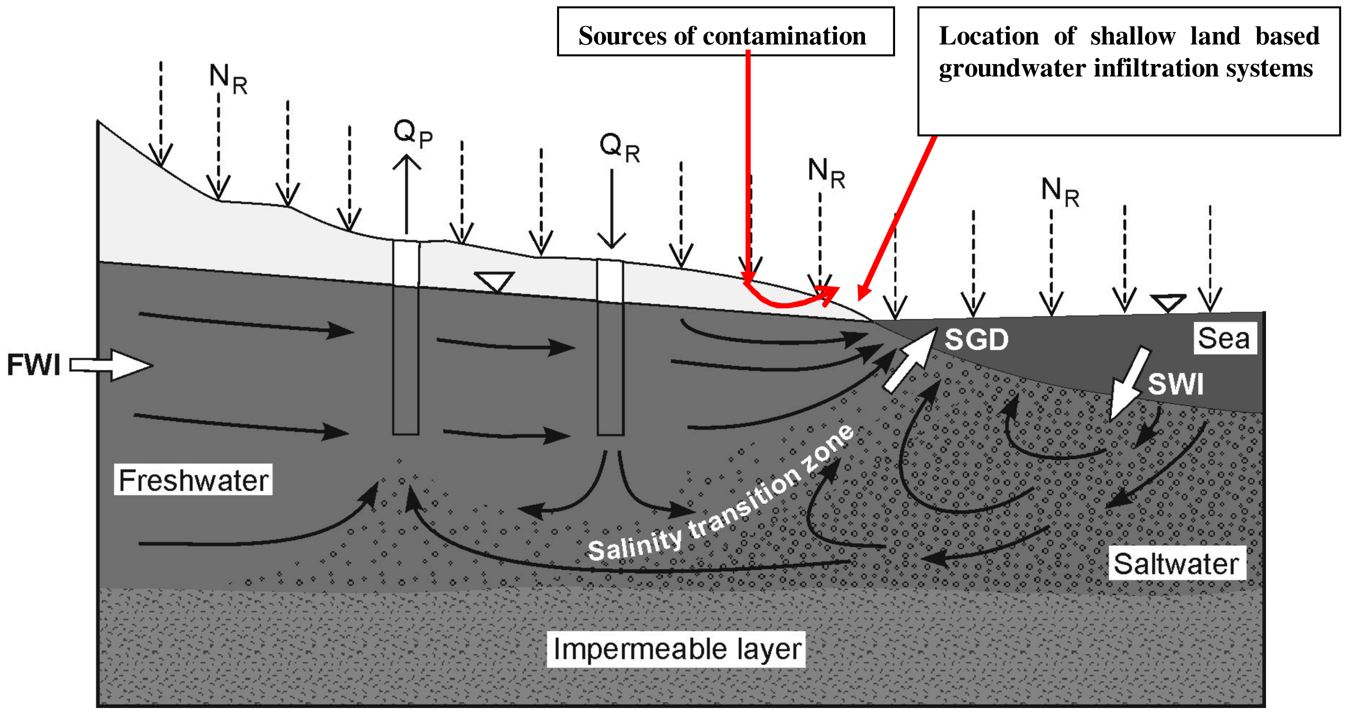


Figure 3-1: Schematic Diagram of a Typical Phreatic Coastal Groundwater System

The above schematic diagram shows fresh (potentially contaminated) groundwater and seawater flow patterns and salinity transition zone in a generalized cross-section of a phreatic coastal aquifer subject to pumping and artificial recharge. Natural recharge (N_R), pumping (Q_P) and artificial recharge (Q_R) rates and a freshwater inflow rate (FWI) at the inland boundary are the inland flow components which control the resulting submarine groundwater discharge (SGD), seawater inflow (SWI) and associated salinity transition zone. (Prieto, 2005)

3.1.3 Exposure to Groundwater Contamination

A shallow, high-rate subsurface intake system would be expected to change the local groundwater gradient causing groundwater to flow toward the intake system, potentially causing migration of contaminants to the intake. The risk of encountering contamination would be expected to be proportional to the degree of influence of fresh water at the intake. Naturally-occurring contamination is also possible, most commonly encountered are elevated concentrations of iron and manganese, which may necessitate additional pretreatment.

3.1.4 Beach Erosion and Changing Sea Levels

To reduce the influence of fresh water, it is most favorable to locate a subsurface intake as close as possible to the tidal zone. This means that design of subsurface intakes and appurtenant equipment must take into account erosion or deposition of beach sand, storm surge, and the potential impact of changing sea levels with time.

3.1.5 Space Requirement and Aesthetics

The coastal beach zone and adjacent environment will be very sensitive to the installation of additional structures (large diameter caissons), equipment, and associated service infrastructure (access roads, electrical supply equipment). Tall, aboveground concrete structures or piping that have a visual and aesthetic impact on the shoreline are not considered feasible.

3.1.6 Infrastructure and Pipelines

Given the relatively high volumes of seawater needed for the BARDP full-scale desalination plant, it is probable that multiple intakes (wells or collectors) would be required. This would necessitate the installation of multiple connecting pipelines and associated equipment. This is particularly true if the subsurface intakes are not co-located with the desalination plant for hydrogeologic or logistical reasons. As the name implies, subsurface intakes are located underground. Thus, routine maintenance for corrosion or plugging, or wholesale replacement of intakes, is more costly and complex than surface installations.

3.1.7 Pilot Study Requirements

The factors that affect maximum intake rate, expected water quality, and impact on the adjacent inland groundwater regime are very site specific and will vary greatly depending on the hydrogeology of the intake site. To evaluate the feasibility of a full-scale intake, extensive field efforts consisting of drilling, extraction testing, water quality sampling, bathymetry surveys, and pilot intake installation will be required. Based on this testing, groundwater modeling of a larger scale facility, or longer term operation is recommended only once the full-scale site has been selected.

3.2 Types of Subsurface Intakes

Table 3-1 summarizes the various types of subsurface intakes, which include wells, infitration galleries, and seabed filtration systems. These different subsurface intakes represent design variations that utilize the same principle: extracting filtered seawater originating from the seabed surface near the shoreline. Each of these intakes has its own advantages, capabilities, suitability, and cost-effectiveness for different site conditions. A brief description of each of the systems is given on the following pages.

Table 3-1. Subsurface Intake Options

Type of Intake	Description	Example	Hydraulic Capacity	Geological/ Hydrogeological	Construction	Maintenance	Entrainment/Impingement	Water Quality
Infiltration Galleries	Comprised of a trench filled with filter media (to a depth similar to a granular media filter) with vertical or horizontal collector wells equally spread along the trench. Trench has three layers of material. The first is a 3 to 6 ft layer of sand. Then a 4 to 6 ft layer of graded gravel pack surrounding the well collector screens. Finally a 20 to 30 ft layer of sand.		2.68 gpm per meter of drain and hydraulic conductivity of 2m/s (0.2 to 2.5 MGD per well)	Can be used when hydrogeological conditions are unfavorable to beach wells.	Required to be located on the seashore.	Media needs to be scraped off of the top of the filter periodically (6 to 12 months) and replaced.	Eliminates impingement and entrainment.	Many have higher concentrations of manganese and/or iron which require further pretreatment. Groundwater contamination in nearby aquifer can require additional pretreatment.
Seabed Filtration System	Comprised of an intake well connected to a slow sand filter constructed in the surf zone.	Dhekekial, Cypress (10.6 MGD); Marippaiyur, India (1 MGD); Fukuoka District RO Facility, Japan (15.8 MGD)	Surface loading rates range from 0.05 to 0.10 gpm/sq ft.		Excavation of the sea floor is necessary to install piping to connect intake wells.			
Horizontal Collector Wells (Ranney)	Comprised of a concrete caisson (10 to 30 diameter) that penetrates the ground surface with horizontal laterals that project out, up to 200 ft. Usually a vertical pump is used and is house above the caisson. There is a modified horizontal collector (Sonoma Method) which has a larger diameter radial collector that can extend out, up to 400 ft.	Cambria, CA (1 MGD); Pemex Salina Cruz, Mexico (3.8 MGD)	Higher yield (0.5 to 5.0 MGD).	Requires favorable geology and in high-permeability areas, can cause overdraft.	Requires pump house above the high tide level to avoid flooding the pump. But can be located further inland in developed areas to limit visual impact. No excavation, blasting, or dredging of seabed.	Little maintenance is required. Filter system can be cleaned with a backwash with air or water.		Low dissolved oxygen content which may require product water and concentrate to be reaerated. Reduce biofouling potential, membrane replacement, and cleaning frequency due to removal of colloidal, organic carbon, and suspended solids by natural prefilter. Minimizes anti-scaling and -fouling chemicals.
Horizontal Directional Drilled Wells	Uses horizontal directional drilling for the construction of the well. A single caison can have multiple horizontal directional drilled wells installed in it.	Long Beach , CA (10 MGD); Sand City, CA (0.3 MGD); Muricia, Spain (17.2 MGD); Barcelona, Spain (52.8 MGD)	Can extend the well furthest out to the ocean to expand capacity. But is untested for large plants. Higher yield (0.5 to 5.0 MGD).	Avoids affecting fresh water aquifers since the drains are below the seabed	Construction is difficult due to removal of drilling fluids, installation of well screen and gravel pack, need of favorable geology to avoid jamming the drill and hydraulic facturing, and still in developmental stage.			
Slant Wells	Similar to a conventional vertical well except the well is on an angle, 15 to 25 degree from horizontal. A single caison can have multiple slant wells installed in it.	Dana Point, CA (2.3 MGD)	Higher yield (0.5 to 5.0 MGD).		Moderately more complex than vertical wells.			
Conventional Vertical Wells	Identical to typical groundwater wells.	Ghar Lapsi, Malta (6.3 MGD); Bay of Palma, Mallorca, Spain (11 MGD)	Small yield (0.1 to 3 MGD).		No special construction requirements.			

*Information gathered from Peters and Pinto (2006) and Voutchkov (2006)

3.2.1 Infiltration Galleries

Infiltration galleries are constructed using a horizontal perforated pipe surrounded by a permeable filter pack installed in a trench. This type of installation is typically located along a long sand beach or similar permeable formation where hydrogeologic conditions may be less favorable for vertical or horizontal well systems. Vertical wells with pumps are installed at intervals along the infiltration gallery to withdraw the seawater from sumps as illustrated in **Figure 3-2**.

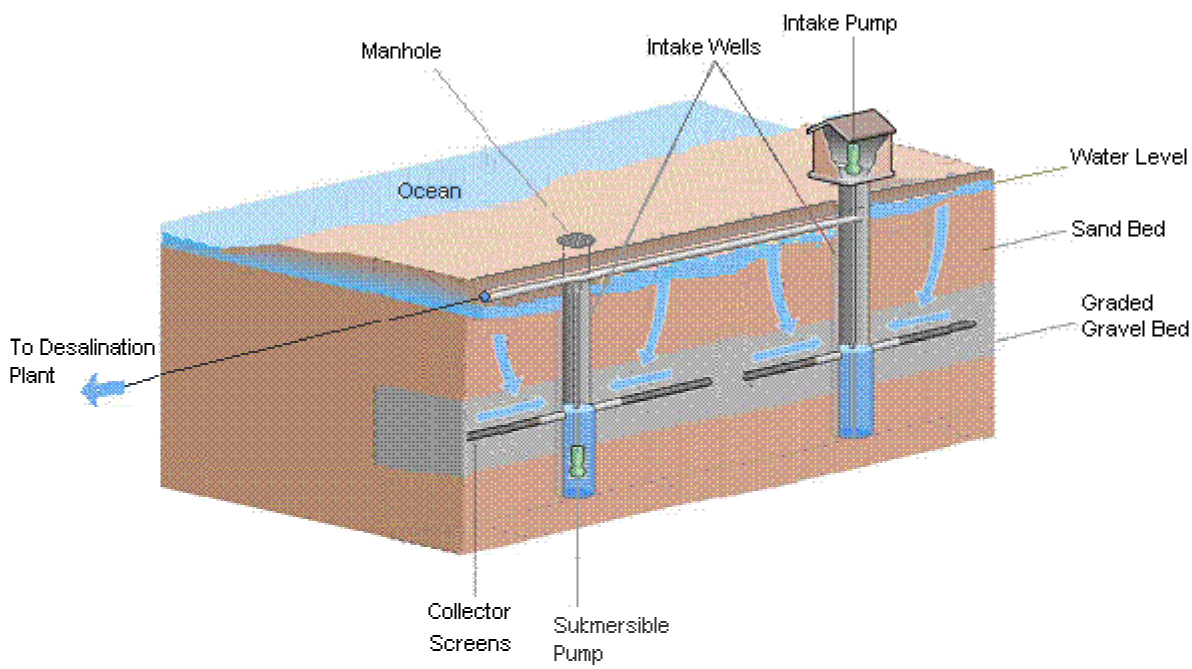


Figure 3-2. Typical Infiltration Gallery Section

A typical infiltration gallery section that is approximately 10 to 30 feet deep, 4 feet wide and 500 feet long is may have an intake capacity of up to 2.5 mgd (~ 1,800 gpm). The horizontal perforated pipe and surrounding filter pack is typically designed for inflow velocity of 0.1 feet per second (ft/s) or less. Available information for infiltration galleries installed in beach sands for small desalination plants have yielded an equilibrium discharge rate of 2.0 m^3/hr (8.8 gpm) or less per meter of drain (3.28 feet) based on a hydraulic conductivity of 2 m/sec or less.

The nature of infiltration galleries dictates that they must be located in a shallow permeable formation very near the coast - typically a sand beach. Removal and disposal of extensive quantities of earth material is required, which could result in environmental and aesthetic impacts during construction. A recent feasibility study prepared for a proposed 25 mgd seawater desalination facility to be located near Corpus Christi, Texas, concluded that horizontal infiltration galleries were not a feasible seawater intake alternative because the significant cost and land requirements make them impractical and economically infeasible (Turner Collier and Braden, 2004).

3.2.2 Seabed Filtration System

A seabed filtration intake system, shown in **Figure 3-3**, is essentially a submerged slow sand media filtration system located below the ocean floor in the near-shore zone. It is connected by a series of pipes to an intake pump station located on the shore.

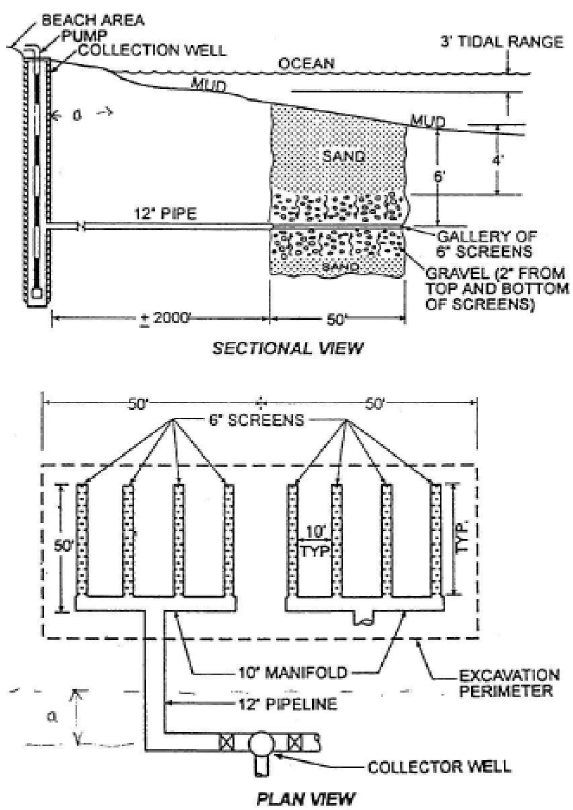


Figure 3-3. Typical Seabed Filtration System

The seabed filtration system would need to be located in a clean, sandy seafloor area to take advantage of the permeable nature and filtration ability of the sand. An area subject to silt and/or mud settling or significant bottom marine growth (e.g., algae) would quickly plug the seabed filtration system. To prevent damage to the filtration system, it also needs to be installed at a depth beneath which storm waves reach to prevent possible erosion and damage to the system.

Seabed filter beds can be designed using slow sand filter design criteria where the surface-loading rate is typically between 0.05 and 0.10 gpm/ft2. A series of perforated pipes or screens are installed in a grid in the sea floor to collect the filtered seawater. The ocean floor would need to be excavated to install an extensive network of pipes that connect the seabed filtration system to the intake pump station.

Site specific conditions may require removal of the natural sea floor material to several feet depth and installation of graded crushed stone with the original sand cover replaced to grade. In some applications, approximately one inch of sand is removed from the surface of the filter bed every six to 12 months to remove fine material plugging the near surface pores. After several years, the removed sand would be replaced with new sand to its original grade.

The largest seawater desalination facility with a seabed filtration intake system currently constructed is the 13.2 mgd Fukuoka District RO facility in Japan. The intake system is designed for a total intake flow of 27.2 mgd, covers approximately 312,000 square feet (7.12 acres) and the plant has been in operation since May 2005.

The intake system consists of a header/lateral pipe network buried in nine-feet deep trenches, excavated in the sandy seabed about 2,000-feet offshore in 40-feet of water and covering approximately seven acres. The perforated pipes are connected to shore by a single 62-inch diameter resin concentrate header. **Figure 3-4** shows the Fukuoka seabed infiltration intake plan view and **Figure 3-5** shows a section view.

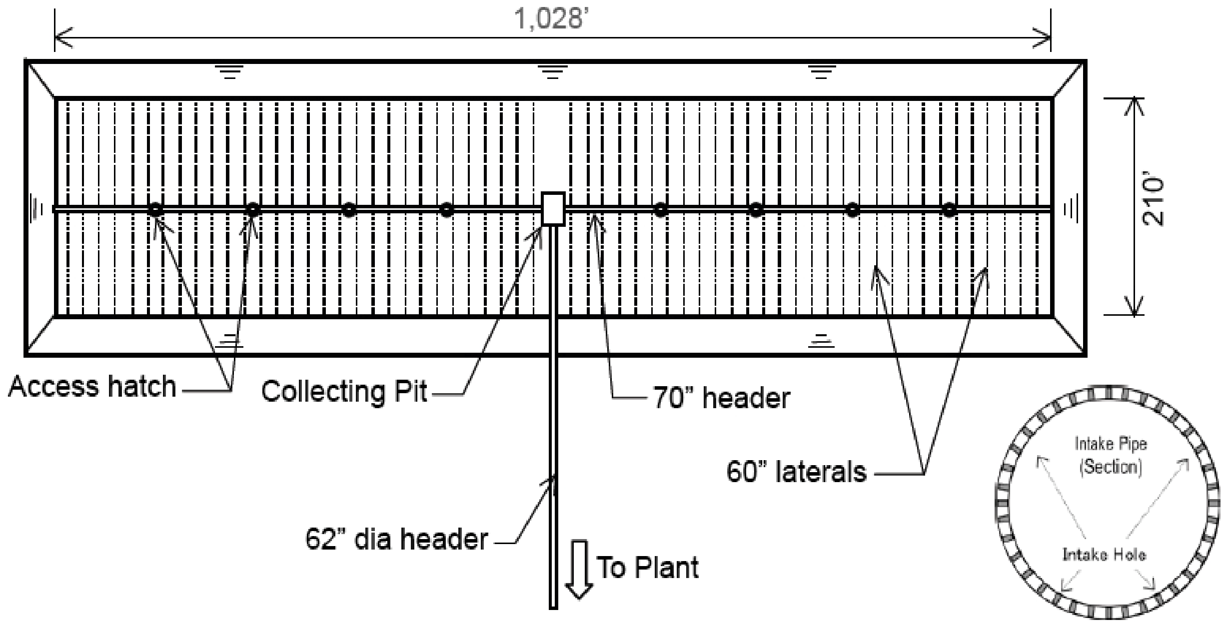


Figure 3-4: Fukuoka Seawater Intake Plan View

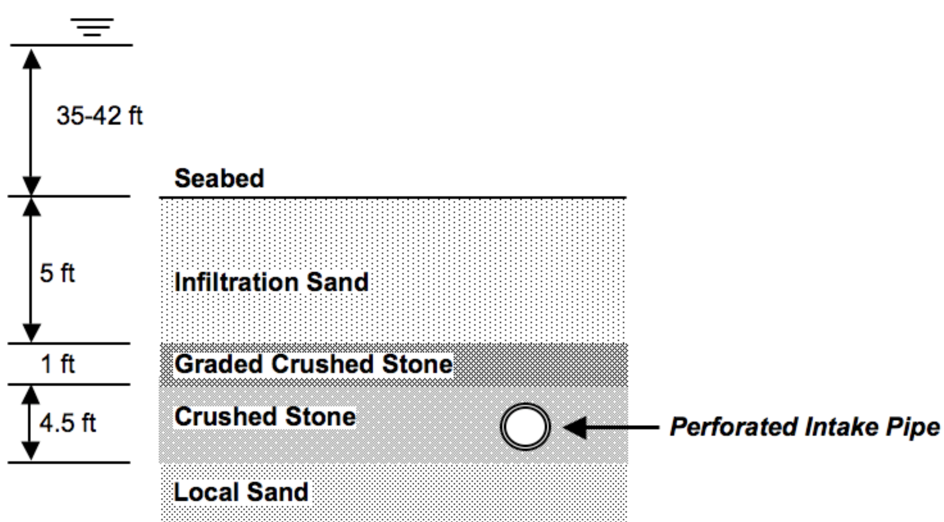


Figure 3-5: Fukuoka Section View

A one-year pilot study on an infiltration system with a plan area of approximately 800 ft^2 was conducted beginning in December 2000 and established the system could operate at infiltration rate of 81 to 196 gallons/ft^2/day.

The seabed infiltration intake has been in continuous operation since its start-up and the plant reports no increase in pressure drop. The system has been maintenance free to date and performed as shown in **Table 3-2**.

Table 3-2: Fukuoka Seabed Infiltration System Performance

	SDI	Color	Turbidity
Intake water	4.3 – 6.5	4	0.6
After infiltration	3 – 5	<1	0.3

Excavation of a large area of the ocean floor is needed to install a seabed filter system of adequate size to supply the full-scale desalination facility. This excavation would result in the complete removal of the entire benthic ecosystem, creating a significant temporary and permanent impact on the benthic marine organisms. The material removed would require disposal elsewhere, thus creating additional environmental impacts. The dredging of the sea floor and establishment of a layer filter bed would disrupt normal public use of the beach and surf zone in this area during construction and the periodic replacement of the layered filter media.

3.2.3 Horizontal Collector Wells

Collector wells, often referred to as "Ranney" well systems, shown in **Figure 3-6**, are constructed from a caisson sunk into the ground, using horizontal drilling to install a number of horizontal wells from the caisson, generally directed seaward. The horizontal wells are typically 6 to 12 inches in diameter and up to 200 feet in length. A modified method (Sonoma method), the horizontal collector lines can be extended to 400 feet. The width of the well screen slots is sized to maximize flow while retaining the grain-size of the formation material.

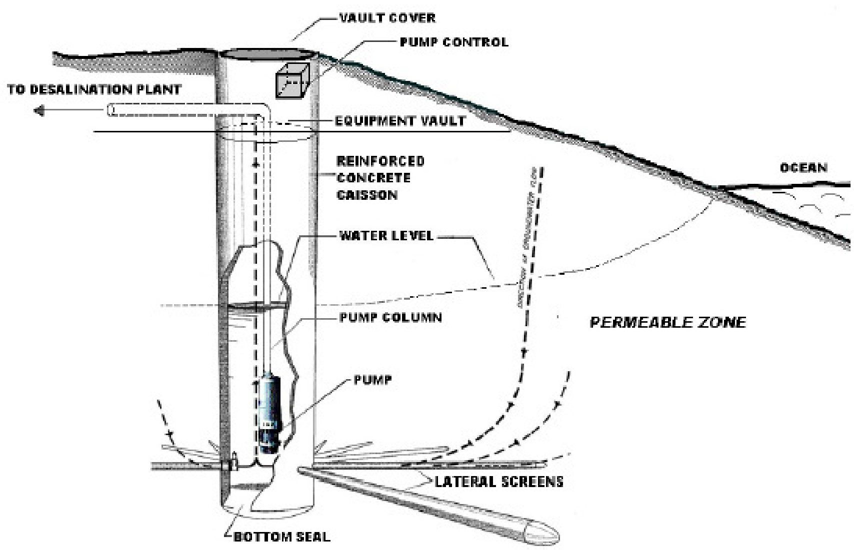


Figure 3-6. Typical Horizontal Collector Well

The horizontal wells convey raw seawater to the common caisson, which houses the pump mechanism. Reinforced concrete caissons, typically 15 foot or more in diameter, are sunk 30 to 150 feet deep into the ground to intercept the most productive aquifer zone. Since the laterals are placed horizontally within a productive zone of the aquifer, a higher rate of source water collection is generally possible than with vertical wells. Seawater collected in the caisson would then be pumped to the desalination facility through a pipeline system. The pump and associated equipment could be installed in an above-grade pump house or below-grade within the caisson as shown in **Figure 3-6**, depending on site-specific conditions. Given the dense development adjacent to the proposed full-scale sites, it may be difficult to obtain permission to install a number of collector well systems, pipelines and power lines due to the potential environmental and aesthetic impacts during construction, as well as the permanent aesthetic impacts of the well head related structures.

Based on available information, it is estimated that approximately one collector well system will be needed for every 5 mgd (~ 3,500 gpm) of RO feed water. Collector well use would require location of the caissons within approximately 500 feet of the shore. The number, location, and length of horizontal wells in each cluster and the capacity would depend on site specific geological conditions that could be obtained by a detailed hydrogeologic investigation to determine the hydraulic characteristics of the target formation. It may be assumed that each collector well system would require a collector area of approximately ½ acre.

The production capacity of some collector well systems may be lower than 5 MGD, requiring installation of additional collector well systems. Some disadvantages of this option include the requirement for a remote power source and the lateral well screens often experience plugging problems, necessitating installation of approximately 20 percent of extra capacity. Also construction, operation, power supply, and pipeline infrastructure could result in potential significant recreation, environmental and aesthetic impacts.

3.2.4 Horizontal Directional Drilled (HDD) Well Field

Horizontal directional drilling (HDD) techniques can be used to position a horizontal well within porous strata 10 to 15 feet under the seafloor as shown in **Figue 3-7**. Drilling can be accomplished by sonic, rotary, percussion, or jetting techniques. The advantages offered by HDD technology versus conventional trench installation techniques include: 1) minimized surface disturbance/impacts; 2) reduction in the quantity of excavated material; 3) accuracy of conduit placement and 4) backfill and compaction of open trenches is eliminated.

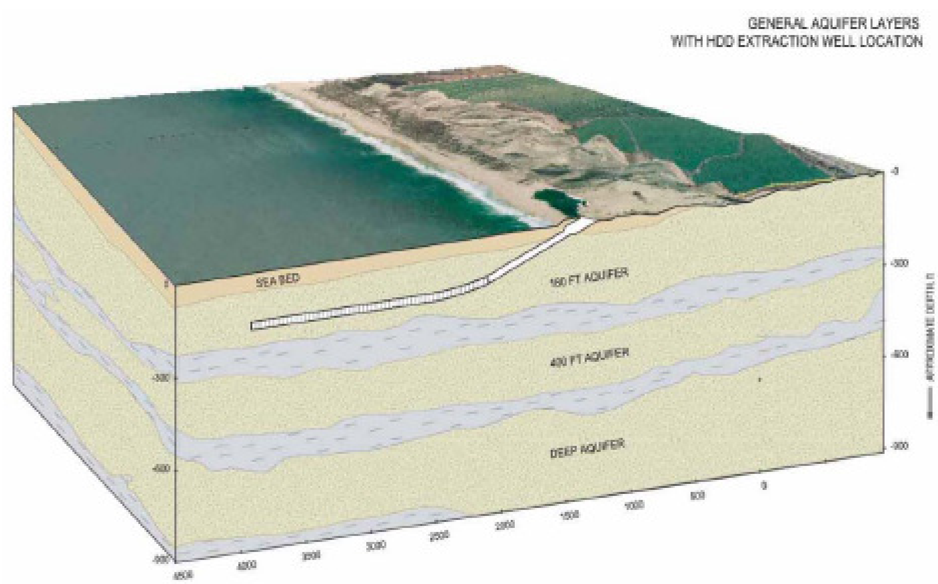


Figure 3-7. Illustration of HDD Intake Well

One HDD well field system investigated uses a relatively new type of porous polyethylene well pipe that acts as a well screen and packing all in one that does not require additional external media packing for long-term operation. The well screen and filter pack systems have a maximum diameter of 12 to 24 inches. Pre-packed well screens and filter mesh well screens that can be pulled over a slotted pipe are other options offered by several manufacturers. The key to using seabed filtration is to design the well screen and packing system so that the entrance velocity through the packing and screen does not exceed the prescribed maximum flow velocity for the adjacent formation materials. It should also be noted that conventional drilling mud or engineered fluids used for stabilizing the HDD open hole need to be avoided because residual drilling fluid within the filter pack and formation can and will foul membranes.

One advantage of this option is that there would be no beach construction.

An HDD well field system would have an intake velocity similar to an infiltration gallery, depending in part on the thickness and hydraulic conductivity of the shallow subsea sediments. In order to determine yield of seabed filtration wells and the feasibility of this option, site-specific test drilling and production pump tests are needed to determine the hydraulic characteristics of the formation materials. Multiple horizontal wells can be installed from the same origin within a caisson (**Figure 3-8**) in a similar manner to collector wells to supply higher production requirements. If it were assumed that one HDD well could produce approximately 3,000 gpm, then approximately 10 HDD wells constructed from multiple caissons might be required (depending on the number of wells per caisson) to supply the necessary feed water. An additional 20 percent standby capacity should be installed to account for well capacity decrease over time and also well downtime due to routine maintenance.

Each HDD well caisson should be constructed approximately 1,000 feet apart to prevent excessive hydraulic interference. Installation of the HDD seabed infiltration well system could result in potential significant environmental and aesthetic impacts during construction. The installation of a HDD system requires an approximately 150’ x 300’ work and lay down area for pipe and other equipment.

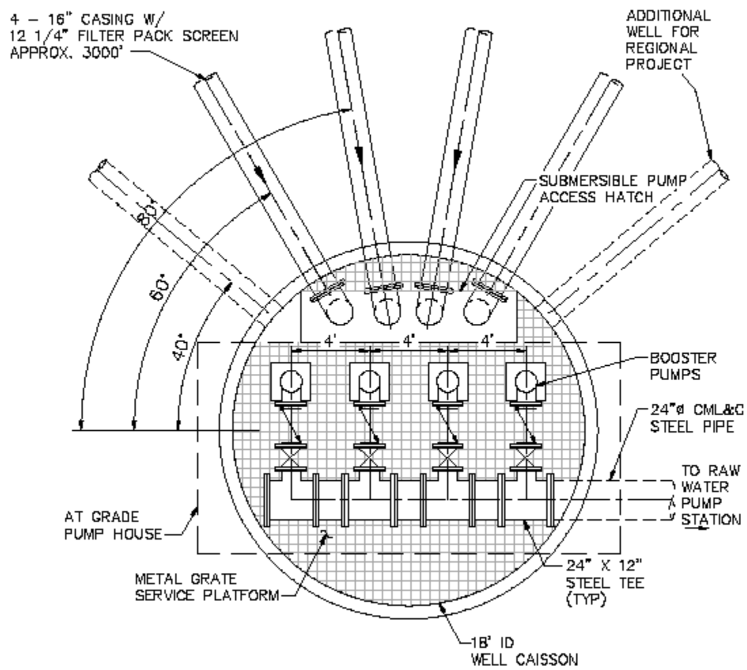


Figure 3-8. Plan View of HDD Well Caisson

3.2.5 Slant (Angled) Wells

A slant well or angled well, as illustrated in **Figure 3-9**, is similar to both vertical and horizontal directionally drilled (HDD) wells. This is because a slant well is nearly horizontal, yet constructed like a vertical well. The shallow-entry drill rig is angled approximately 15-25 degrees from the horizontal, and then drilled straight, unlike a HDD drill rig that gradually turns as it drills to achieve a horizontal well. The advantages offered by slant wells versus conventional trench installation techniques are similar to that of HDD wells, which include: 1) minimized surface disturbance/impacts; 2) reduction in the quantity of excavated material; 3) accuracy of conduit placement and 4) backfill and compaction of open trenches is eliminated.

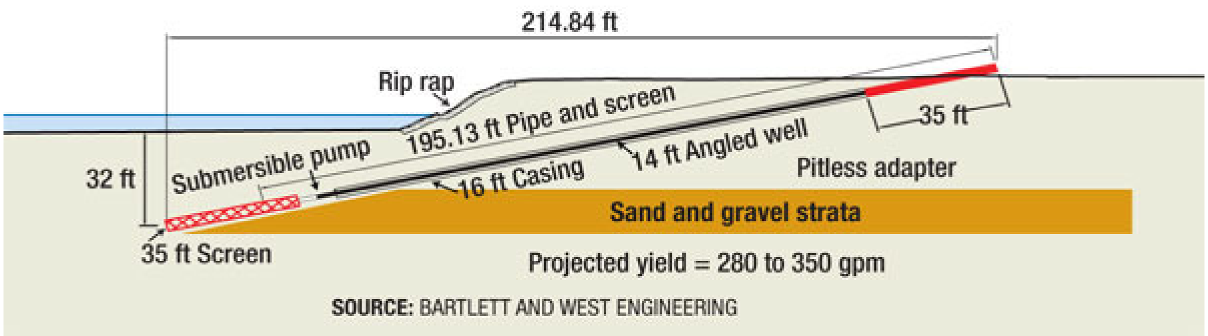


Figure 3-9. Illustration of a Slant (Angled) Intake Well

Similarly to an HDD well, a slant well could use a relatively new type of porous polyethylene well pipe that acts as a well screen and packing all in one that does not require additional external media packing for long-term operation. The well screen and filter pack system has a maximum diameter of up to 24 inches, but can probably be ordered larger. The key is to design the well screen and packing system so that the entrance velocity through the packing and screen does not exceed the prescribed maximum flow velocity for the adjacent formation materials.

The Municipal Water District of Orange County (MWDOC) plans to construct a desalination plant in south Orange County, and has proposed the use of slant wells at the mouth of San Juan Creek (MWDOC, 2006). To date, one test well has been constructed. This 12-inch well was drilled at an angle of 23 degrees below horizontal with a length of 350 feet in the spring of 2006 on Doheny Beach. The well was tested at a rate of 1,680 gpm and produce groundwater with a total dissolved solids concentration of approximately 2,600 mg/l. The construction cost of the test well was reported to be approximately $1.5 million. Future, deeper wells are estimated to have a design pumping rate of 2,000 to 3,000 gpm.

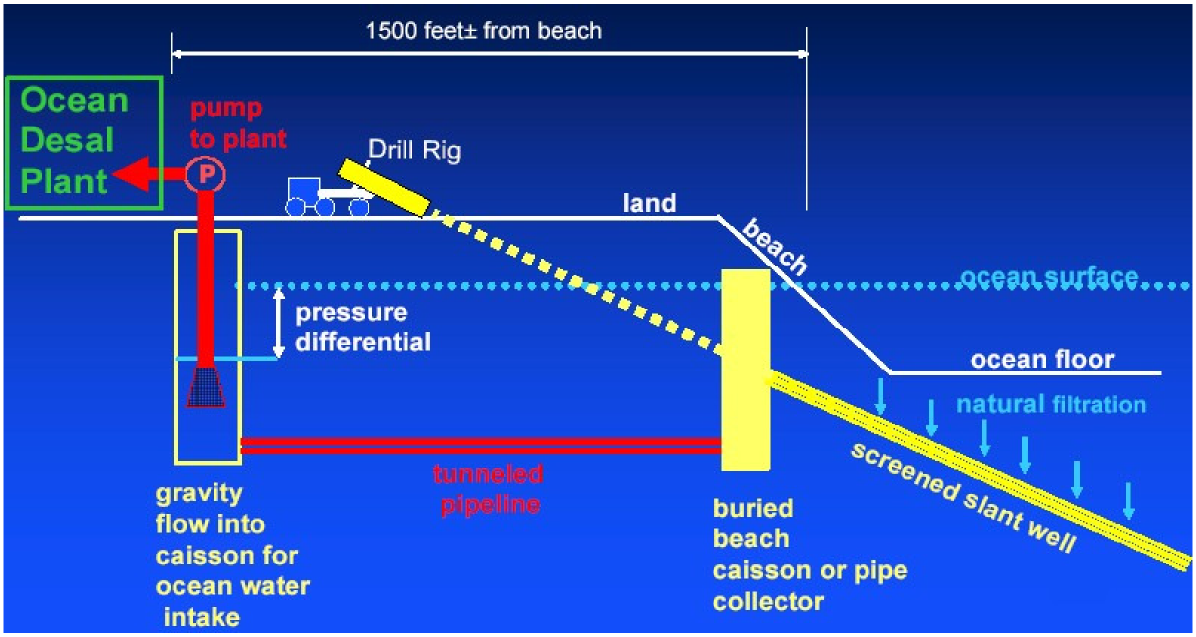


Figure 3-10. Illustration of Slant (Angled) Well Intake System

A slant well seabed filtration system would have an intake velocity similar to an infiltration gallery, depending in part on the thickness and permeability of the filter pack surrounding the well screen. In order to determine yield of seabed filtration wells and the feasibility of this option, site-specific test drilling and production pump tests are needed to determine the hydraulic characteristics of the formation materials. Multiple slant wells can be installed from the same origin within a caisson in a similar manner as the HDD wells illustrated in **Figure 3-10.** If it were assumed that one slant well can produce approximately 1,500 gpm, then approximately 20 slant wells would be required to supply the necessary feed water for the full scale system (42 mgd). An additional 20 percent standby capacity should be installed to account for well capacity decrease over time and also well downtime due to routine maintenance.

3.2.6 Conventional Vertical Wells

Vertical sea wells or beach wells are near-shore drilled vertical wells completed in a seawater source aquifer. Sea wells are generally of relatively small diameter (24 inches or less), and a maximum of 500 feet deep. Vertical sea wells are constructed of materials suitable for use in a seawater environment using stainless steel, or a non-metallic casing (typically, fiberglass reinforced pipe), well screens, and a stainless steel submersible or vertical turbine pump. The slot size of the well intake screens is selected to accommodate the grain-size of the aquifer formation. If necessary, an artificial gravel-pack filter is installed around the screen to enhance flow from fine formation material as shown in **Figure 3-11**.

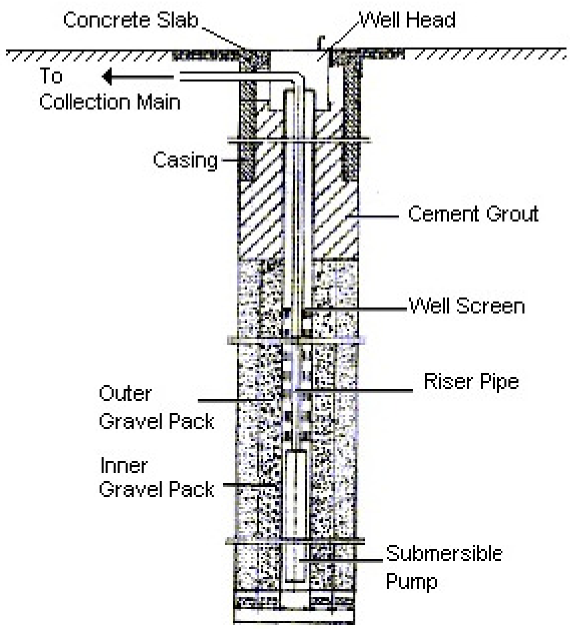


Figure 3-11. Typical Sea Well Installation (Schwartz, 2000)

There is the potential for significant environmental and aesthetic impacts during construction and immitigable aesthetic impacts of many well head related structures.

In order to determine individual well yields and the feasibility of this option, site-specific test drilling and aquifer pump tests are needed to determine the hydraulic characteristics of the aquifer zone and the spacing of the wells to prevent hydraulic interference. Assuming each well produced 2 mgd, approximately 72 wells would be required. The wells would need to be spaced approximately 500 feet apart, within 500 feet of the ocean. Therefore, approximately seven miles of shoreline would be needed to locate all the required wells. The actual production capacity of individual wells may be less than 2 mgd, necessitating installation of a larger number of wells over a larger distance. An additional 15 percent standby capacity would be installed to account for well capacity decrease over time and for well downtime due to routine maintenance.

Construction, operation, power supply, and pipeline infrastructure could result in significant recreation, environmental, and aesthetic impacts. For wells installed in the beach area, storm waves can erode the sand from wellheads and upper portions of well casings, which can potentially damage them and create an unsightly situation.

3.2.7 Porous Dike

A unique type of intake that might be considered a hybrid of surface water and subsurface intake is a "porous dike" (**Figure 3-12**). This type of intake involves intake of water behind a porous dike or berm that filters seawater. It could be located on the coastline, or involve a circular dike that surrounds a surface water intake such as the existing powerplant intakes. A porous dike would act as a physical and behavior barrier to aquatic organisms and would eliminate entrainment and reduce impingement (Wisconsin Electric Power LLC, 2002). Construction of the porous dike would involve large rip rap filter stone, protective armor stone, and core stone. Water flow velocity between the rocks would be around 0.2 feet per second. Care would need to be taken during design to ensure that waves do not overtop the porous dike.

A similar technology which is a hybrid of an infiltration gallery is to bury a well screen in an existing jetty or dike with a gravel and sand core. The flow capacity of a porous dike system is a function of the head difference between the ocean and the intake point, the permeability of the dike material, and the area of dike.

Figure 3-12. Porous Dike (Jetty)

4.0 Evaluation of the Existing Mallard Slough Pump Station Intake

CCWD operates three facilities that divert water form the Delta. Historically, Rock Slough with a diversion capacity of 350 cfs represented the District's main diversion facility. As part of the Los Vaqueros Project, CCWD built a facility at Old River near Highway 4 to divert water from the Delta. The third facility located at the end of a 3,000-foot channel running due south of Suisun Bay, known as Mallard Slough, enables a withdrawal of up to 39.3 cfs. The facility, which was modernized in 2002, is only used during periods of very high Delta outflows (about 40,000 cfs or greater) when water quality meets CCWD's chloride standard of 65 mg/l.

Although the Mallard Slough intake is small and only used under high Delta outflow conditions, it is an integral component of CCWD operations. CCWD has one license and one permit for Diversion and Use of Water issued by the SWRCB, which authorize CCWD to divert up to 26,780 AF per year at Mallard Slough. The FWS Biological Opinion (BO) for the Los Vaqueros Project requires CCWD to operate all three of its facilities (including Mallard Slough intake) and Los Vaqueros Reservoir as integrated system to minimize impacts to endangered species. The 1993 BO calls for monitoring at all three intakes to determine diversion of water at Rock Slough, Old River and Mallard Slough to minimize the take of Delta smelt during the spawning and rearing period. Additionally under the Los Vaqueros BO, CCWD is required to cease all diversion from the Delta for 30 days in the spring (no diversion) and is not allowed to divert water to Los Vaqueros storage (no fill) for a 45 day period in the winter or spring months.

The entrainment of larval fish at the Mallard Slough Pump station has been monitored during periods of diversion from 1998 to the present; samples were not collected in 2001 and 2002, during construction of a new intake. The old Mallard Slough intake was replaced in 2002 with a new pump station that has a state-of the-art fish screen. The screen's mesh size of 3/32 and low intake approach velocities are designed to eliminate the impingement of juvenile and adult fishes and to minimize the entrainment of larval fish. The performance of the new screen has been continuously monitored during pumping operations since 2002 by fishery biologists contracted to CCWD and Bureau of Reclamation. Studies to assess the degree of fish protection provided by the Mallard Slough intake screens, and as also required to gather data for integrated fish protection at CCWD's Old River and Rock Slough intakes that were initially conducted by the Department of Fish and Game, are currently conducted by Tenera Environmental in an ongoing, weekly monitoring effort during periods of facility pumping.

4.1 Entrainment Survey During Operation of Mallard Slough Pump Station

Entrainment samples of the Mallard Slough intake flow are collected weekly during each CCWD period of intake pumping, normally occurring during the period of March through May. In 1998, larval fish entrained at the Mallard Slough intake were sampled during June and July pumping, and again during June 2005. Samples of the larval fish (ichthyoplankton) passing through the screen are collected with a sieve net positioned in a discharge flow that is diverted from main intake flow to a side channel constructed for the purpose of sample collection. The entire diverted sampling flow is sieved through a net fabricated of 500-micron mesh and attached to a frame fitted to the cross-sectional width of the sampling channel. The diverted flow is sampled for 6-30 minute intervals during survey duration of six hours.

The majority of larval fish from the results of entrainment surveys of CCWD pumping during March, April and May from 1998 to 2006, including surveys in June and July mentioned above, are non-native species found throughout the southern Delta. The results of these surveys, which are summarized in **Table 4-1**, indicate a high degree of similarity in the species composition of entrained larval fish over the six-year period. Patterns of seasonal abundance for these species cannot be determined given the short three- month duration of most of the annual surveys. Delta smelt, the only sensitive species of fish collected in any of the Mallard Slough monitoring surveys, were collected in 2000 and in each annual survey from 2003 through 2005.

Results from length measurements of larval fish entrained by CCWD operation of the Mallard Slough intake indicate that the new 3/32-inch screens effectively exclude larval fish 20-mm in length and larger. The screens are proven 100 percent effective in preventing juvenile and adult fish from entering the intake flows. The length of the entrained fish larvae were generally less than 10 mm and ranged from 2.5 to 20.5 mm. The larger larvae were usually striped bass, and sculpins and gobies were commonly the smallest larvae.

TABLE 4-1. Species and annual presence of larval fish entrained at the CCWD Mallard Slough intake from 1998 to 2007.

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
American Shad	X									
Bigscale logperch	X	X	X			X	X	X	X	
Centrarchidae			X					X		
Common carp								X	X	
Cyprinid larvae			X							
Unid. Clinidae (Clinids)		X								
Unid. Cyprinidae (minnows)		X								

Delta smelt			X			X	X	X		
Fathead minnow	X									
Golden shiner								X		
Inland silverside	X	X						X		
Largemouth bass	X									
Lepomis spp.								X	X	
Longfin smelt		X	X			X	X		X	
Pomoxis spp.								X	X	
Prickly sculpin		X	X			X	X	X	X	
Sacramento splittail			X					X		
Sacramento sucker		X	X							
Staghorn sculpin		X								
Striped bass	X	X	X			X	X	X		
Threadfin shad	X						X	X	X	
Threespine stickleback	X	X	X							
Tridentiger spp.						X		X		
Yellowfin goby			X			X		X		
Number of Surveys	9	4	4*	0	0	5	2	11	4	0

* = night sampling effort

4.2 Fish Protection During Operation of Desalination Pilot Plant

Pumping feedwater for the pilot desalination plant from Mallard Slough during June through November will entrain very few if any larval fish, particularly in the late fall time period. The vast majority of fish living in the Delta and in the vicinity of Mallard Slough spawn in the winter and spring months, and nearly all of the area's spawning activity is completed by July. Among the low numbers of larval fish in the Mallard Slough area that could be entrained in the Fall and Winter, we would expect to see larval northern anchovy, inland silversides, and white catfish; we do not expect to collect any entrained listed species, such as delta smelt, which typically spawn in January through March, nor any salmonid species, because they would be to large in the Fall and Winter to pass through the 3/32 inch screen openings.

Although there is no reason to increase the level of fish protection of the existing Mallard Slough intake screen for pumping during July through November, it is feasible to test the ability of finer mesh screens to further reduce entrainment at the site. However, keeping in mind that the reason for not needing a higher level of fish protection is because there are few larval fish present in the Fall and Winter needing protection, this paucity of larval will compromise any screen tests results by small sample sizes of entrained and source water larvae. In addition since the results would be based on fall occurring species of larval fish, the results would not be readily transferable to other seasons in Mallard Slough or to localities in the region.

5.0 Recommendation of Appropriate Intake for the Pilot Plant Study

An ideal evaluation of an intake technology at the pilot plant would include the following objectives:

- Functionality (able to meet the impingement and entrainment requirements);
- Acceptable to permitting agencies;
- Scalable to 72 mgd product water;
- Transferability of data (both operational data and environmental impact data gathered at the pilot site would be transferable to the full-scale site);
- Cost-effective at pilot-scale and full-scale.

The MWH Team believes the water quality and aquatic habitat variability along this reach of the Delta is too dramatic to enable data transferability. Regulators are unlikely to consider data from the Mallard Slough site transferable to any other location, even nearby, and will likely require additional intake studies once the full-scale location is selected. Additionally, a new open water intake system will likely require the following:

- Biological assessment to the U.S. Fish and Wildlife Service (USFWS) and to the National Marine Fisheries Service (NMFS) to address effects to species under their jurisdiction.
- Some form of take coverage from the California Department of Fish and Game (CDFG) under the California Endangered Species Act.
- Biological opinion from the USFWS and NMFS.
- Response to state concerns by CDFG.

Any or all of these requirements could substantially delay start-up of the pilot plant study.

For these reasons, our team has recommended the use of the existing Mallard Slough Pump Station intake for the pilot plant study. The existing intake is a state-of-the-art, fish screen that was constructed, licensed and permitted in 2002. Furthermore, while biological testing has only been conducted when the pump station has been operational, no species of concern has ever gotten through the existing intake screen and the intake screen has already been permitted for relevant biological takes.

The costs associated with the use of the existing intake screen would include a pipe-penetration through the Mallard Slough Pump Station floor into it wet well. Additionally, a pipe-penetration through the wall to deliver the water to the pilot plant would also be required, along with temporary pumping equipment.

6.0 Intake Performance – Entrainment and Source Water Monitoring

Entrainment sampling from the pilot plant intake and source water monitoring water sampling in the area of the intake will be conducted in the day and night during two seasons over a period of one year (four sampling events). This will be accompliahed regardless of intake selection.

The MWH Team will collect samples downstream of the screened feedwater intake to determine the number and kinds of entrained fish eggs and larvae that were not excluded by the existing intake screen. The sampling will produce results that can be augmented with or compared to results from Tenera's ongoing monitoring studies of Mallard Slough ichthyoplankton for the CCWD and the Interagency Ecological Programs's ichthyoplantion monitoring in the river channel offshore of Mallard Slough.

Source water sampling will be conducted four times during the study, concurrent with the entrainment sampling. This source water sampling will provide data to be used for the empirical transport modeling (ETM) and proportional entrainment estimates, although findings based on the ETM calculations can only be applied to the months of entrainment and source water sampling. The ETM requires a comple sample of species' annual cohort of larval production to assess the impact of proportional losses to the population. This assessment cannot be performed based samples from the summer and fall months only, particularly since this is a time of the year most species in the area of Mallard Slough have grown out of the larval stage. However, if there is no plan to operate the intake during any other time of the year, the proportional loss estimate based on source water and entrainment samples during these months are respresentative of intake impacts.

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I N T E R N A L M E M O R A N D U M

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	**Feed Water Quality Characterization Technical Memorandum No. 3A**		
Prepared by:	Mary Carr Portillo, P.E. MCP	**Reference:**	1481449/6.2.3
Reviewed by:	Stefani Harrison, P.E. Charlie Bromley, P.E. Dawn Guendert	**Date:**	November 21, 2007

This technical memo summarizes the feed water quality available for sample points in or near Mallard Slough and provides recommendations for additional pre-pilot water characterization sampling and analysis. In general, the water quality of the proposed source water is highly variable depending on tidal fluctuations and seasonal changes, with decreasing total dissolved solids (TDS) during spring runoff and increasing TDS during fall and winter months. Recommendations contained herein will focus on assuring sufficient data are available to evaluate and select pilot plant process options.

During pilot testing, source water quality will be monitored regularly to evaluate pilot processes and ongoing system performance. Recommended water quality data collection procedures for the pilot will be presented once pilot processes have been selected.

1.0 Available Water Quality Data

Existing water quality data is available from several sources for sample points in or near Mallard Slough:

- the Bay Area Regional Desalination Pre-feasibility Study and Feasibility Study,
- Contra Costa Water District (CCWD), and
- California Department of Water Resources (DWR) data collection.

The Pre-feasibility Study was published in 2003 and the Feasibility Study was published in July 2007. Both contain water quality data for Mallard Slough (1996-2000) provided by CCWD in **Table 1-1**. Source documents do not indicate how often or when, during the five year period, data was collected.

In addition CCWD provided MWH with Mallard Slough water quality data extending from 2001 to 2005, as shown in **Table 1-2**. As with the 2003 Pre-feasibility Study and the 2007 Feasibility Study, information is not available in the source document regarding sample period frequency and sampling methodology. Data are not available for TOC and for silica in the period from 2001 to 2005.

Table 1-1: Summary of Water Quality for Mallard Slough (1996-2000)

Constituent	unit	Max	Min	Avg
Turbidity	NTU	146	4.09	24.1
Calcium	mg/L	276	3.9	35.2
Magnesium	mg/L	190	5.6	78.7
Sodium	mg/L	1600	10	595.2
Chloride	mg/L	3100	13	766
Potassium	mg/L	200	1.2	20.2
Sulfate	mg/L	420	10	151.5
Nitrate	mg/L	3.7	0.23	1.56
Phosphate	mg/L	3.4	<0.2	0.31
Silica	mg/L	23	13	17
Hardness	mg/L	960	36	295
pH		8.4	6.22	7.67
Alkalinity	mg/L	82	22	61.61
Conductivity	uS/cm	9550	130	2792.2
TDS	mg/L	5737	70	2137.8
Ammonia	mg/L	0.25	<0.1	0.1
TOC	mg/L	5.7	0.5	2.7
Source: Feasibility Study – July 2007				

Table 1-2: Summary of Water Quality for Mallard Slough (2001-2005)

Constituent	unit	Max	Min	Avg
Turbidity	NTU	58.1	11.4	27.7
Calcium	mg/L	92	12	33
Magnesium	mg/L	258	7.5	73.3
Sodium	mg/L	1700	18	450
Chloride	mg/L	1260	16	349
Potassium	mg/L	69	2.2	19.3
Sulfate	mg/L	32	12.3	19.4
Nitrate	mg/L	2	<0.1	1.4
Phosphate	mg/L	<0.2	<0.2	<0.2
Silica	mg/L	No Data		
Hardness	mg/L	1140	62	345
pH		8.3	7.5	7.8
Alkalinity	mg/L	89	67	76.5
Conductivity	uS/cm	10230	220	2828
TDS	mg/L	7130	110	2448
Ammonia	mg/L	<0.1	<0.1	<0.1
TOC	mg/L	No Data		
Source: CCWD – September 2007				

When comparing these data, average values within the two data sets are fairly similar, with the exception of sodium, chloride and sulfate which are each observed to much less during the 2001 to 2005 period. Lower minimum values are consistently observed with the 1996 to 2000 data set, while maximum values are somewhat scattered. Major anion (chloride, sulfate) average and maximum values are substantially higher in the 1996 to 2000 data set. Alkalinity, hardness, conductivity, and TDS average and maximum values are consistently observed to be highest from 2001 to 2005. Turbidity and major cation (calcium, magnesium, sodium, and potassium) values do not present a clearly discernible pattern.

Data scatter may be due in part to variations in sampling location, time-of-year, time-of day, depth of measurement, and use of preservative within the sample containers. Units of measurement are not fully defined in the tables and source documents, particularly for such components as Sulfate (S or SO_4), Nitrate (N or NO_3), Phosphate (P or PO_4), Silica (Si or SiO_2), Hardness (as $CaCO_3$), Alkalinity (as $CaCO_3$), and Ammonia (N or NH_3)

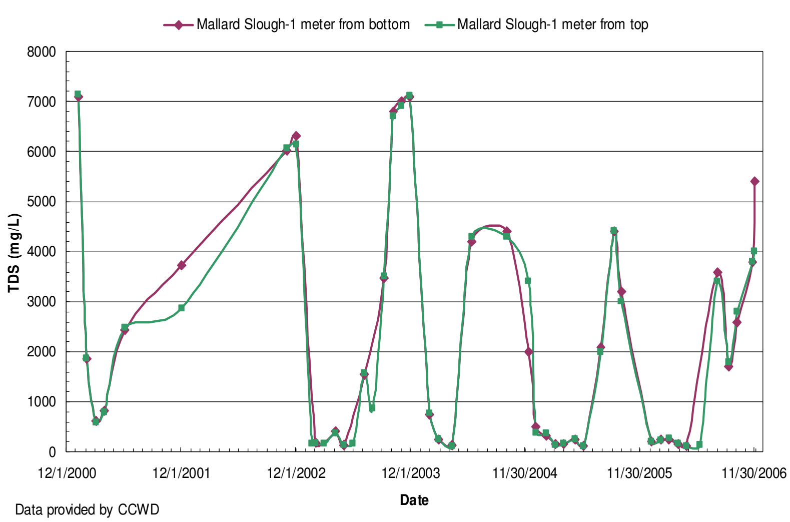
For these data to be completely understood, additional research and evaluation for number of samples, frequency, time period, dissolved solid constituents, and sampling/testing methodology may be necessary as the project moves forward into the proposed membrane evaluation activities.

1.1 Total Dissolved Solids, Mallard Slough

TDS is measured regularly throughout the year in Mallard Slough, as shown in **Figure 1-1,** at water depths one meter below the water surface and one meter above the slough bottom. Data provided by CCWD is from the five year period between 2001 through 2006.

Sample depth does not appear to make a significant difference in TDS. Peaks are generally observed in the fall and winter months and are attributed to tidal variations causing decreased TDS during spring run-off and increased TDS during the drier fall and winter months.

Figure 1-1: TDS for Mallard Slough (2001-2006)



Further analysis of the data has been performed to demonstrate percentile TDS distribution. Lower Mallard Slough TDS levels were observed in the years preceding 2000 as evidenced by **Table 1-3**.

Table 1-3: Percentile Distribution of TDS for Mallard Slough (2001-2006)

Percentile	TDS
	(mg/L)
Max	7130
95	6954
90	6304
75	3800
50	1540
25	230
10	140
Min	110

1.2 Total Dissolved Solids, Sacramento Delta

Hourly water quality data has also been provided by DWR from the California Data Exchange Center (CDEC) database Pittsburg station "PTS". Data presented in **Table 1-4** are converted from conductivity measurements using the Delta Wide Conversion Factor of 0.64 from the *CALFED Water Quality Program Assessment Report – June 2005*.

These data are understood to be representative of the delta/bay complex only. Tidal variations are quite evident and result in TDS levels much greater than observed in Mallard Slough, particularly in the higher percentile ranges.

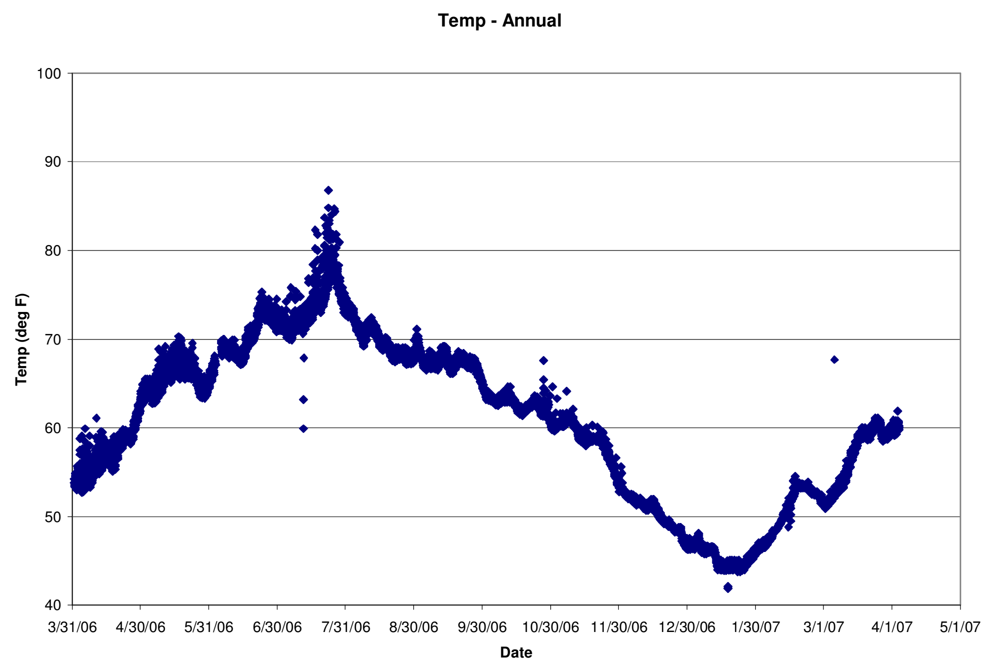
Table 1-4: Percentile Distribution of TDS for Pittsburg Site, near Mallard Slough (Jan. 2003 through Apr. 2007)

Percentile	TDS	24-hour TDS
	(mg/L)	(mg/L)
Max	22458	11188
95	10577	6438
90	8445	5479
75	4851	3143
50	1458	1134
25	292	199
10	152	98

1.3 Temperature

Sacramento delta water temperature as recorded at the PTS site is illustrated in **Figure 1-2**. Data are observed to vary between 43 deg F and 88 deg F throughout the year. Temperature is important with respect to membrane evaluations and it does not appear that data are specifically available for Mallard Slough water for the proposed period of pilot testing.

Figure 1-2: Temperature, Pittsburg Site (2006-2007)



2.0 Implications for the BARDP Pilot Study

Additional information is needed for key membrane design parameters (metals and physical characteristics) to assist in membrane selection and pilot system design. Additional water quality sampling of Mallard Slough water during wet and dry months will help close this data gap and provide assurance pilot configuration suitability for pretreatment as well as RO components. As a result, it is recommended to complete the following activities at up to two different seasonal periods:

1. Collect additional water quality parameters needed for the RO modeling software. Process selection will be made based on water quality data evaluation. At this time, MWH is considering several membrane options including low pressure UF/MF and high pressure RO. While, the low pressure UF/MF and high pressure RO process train provides an absolute barrier to solids, the dissolved solids removal is variable depending on which RO membrane is selected. Refer to **Table 2-1** for a list of suggested parameters. Suggested parameters would be measured concurrently with Recommendation No. 2 below.

Table 2-1: Supplemental Water Quality Parameters, Proposed

Metals	Physical Properties	Other
Iron	Conductivity	Ammonia
Barium	Turbidity	Algae
Strontium	pH	Hardness, total
Fluoride	Temperature	Bicarbonate
Phosphate		UVA
Boron		Carbon Dioxide (calculated)
Manganese		Silica
Selenium		Carbonate Alkalinity
Aluminum		Bicarbonate Alkalinity
		Total Organic Carbon
		Dissolved Organic Carbon
		Salinity, 24 hour profile
Note: All parameters are to be measured from a sample collected at Mallard Slough at the Mallard Slough Pumping Station intake screen.		

2. Collect algae, TOC and DOC water quality data to evaluate the pretreatment alternatives. Sampling would be performed once during the dry fall and winter season and once during the Spring run-off season, beginning immediately. Sampling during these two periods would be done over a 24 hour period with samples taken during low tide and high tide.

3. Collect E.Coli, Enterocci, and HPC to evaluate pretreatment alternatives and bio-fouling potential of membranes. Sampling would be done after start-up and successful integrity testing of pretreatment systems and prior to start-up of the RO system.

4. Collect data to develop a 24 hour tidal salinity profile (one sample per hour) in Mallard Slough, beginning immediately. Data will be compared to online hourly salinity data collected automatically at DWR's PTS station in the main delta waterway. The comparison will help identify differences in tidal ranges between the local pilot plant source water intake water quality and the potential full-scale intake water quality, and will help provide an understanding of hourly tidal influences in the slough.

5. Include temperature, turbidity, and conductivity measurements when sampling any of the above recommended parameters and throughout the pilot testing period.

It should be noted that parameters essential for preliminary process evaluation and selection will be further identified and evaluated during pilot testing.

Bay Area Regional Desalination
Mallard Slough Pump Station
Water Quality Sampling

TM 3A, Feedwater Quality Characterization, recommended the collection and analysis of Mallard Slough water quality for additional parameters that have not been characterized in the known set of data. These samples were recommended to be collected during high tide and low tide, and during periods of the year when snowmelt is high (wet season) and low (dry season).

Dry season sampling was conducted in December, 2007. MWH conducted water quality sampling at the Mallard Slough Pump Station located in Pittsburg, California. High tide samples were taken the morning of December 4, 2007 at approximately 10:30 AM. At that time a multiparameter probe was installed to collect continuous data for approximately two days. The site was revisited on the morning of December 6, 2007 (at approximately 8:00 AM for additional sampling at low tide. Analytical work was performed by MWH Labs in Monrovia, California.

This memorandum transmits the results of the dry season Mallard Slough water quality sampling, including high and low tide analyses, and two-day continuous monitoring. The first seasonal rain occurred on December 4, and up to 0.2 inches of rain fell during the sampling period. It is expected that this limited rainfall did not affect tidal patterns at Mallard Slough.

Additional sampling may be conducted in the Spring of 2008 during the wet season.

High Tide Sampling

High tide water samples were collected from Mallard Slough on December 4, 2007 from the area of the slough directly below the Mallard Slough Pump Station balcony and above the Pump Station screen. Samples were retrieved using a Masterflex Industrial Process Peristaltic Pump with a Masterflex I/P Standard Pump Head, both rented from Equipco Rental Services in Concord, California. Tygon Tubing, 3/16 x 3/8, was used through the pump head, and attached to 30 feet of Teflon Tubing, 3/16 x 1/4. Both tubes were brand new and sterile. A stainless steel weight was attached to end of the Teflon tubing and lowered over the balcony sidewall to 3 ft below the water surface, and remained there for the duration of sampling. The pump was then run for 2 minutes, completely flushing the tubing.

Initial sampling began at 10:21 AM and was completed at 10:45 AM. Following installation of a multiparameter probe, at 11:37 AM, a final sample was taken for TDS analysis. There was a high tide on December 4, 2007 at 11:19 AM. All samples were collected in bottles provided by MWH Labs. Preservatives were provided in the bottles as necessary for specific samples. Samples were sent overnight to MWH Labs on December 4, 2007.

Non-metal results provided by the lab are in Tables 1. Results from the metals scan are in Table 2.

Table 1. Mallard Slough Pump Station - High Tide Lab Results (Non-Metals)

	Units	
Algae	#/ml	130
Alkalinity in $CaCO_3$	mg/l	83
Bicarb. Alk as HCO_3	mg/l	100
Carbon Dioxide, Free	mg/l	3.3
pH		7.7
Specific Conductance	mS/cm	9.43
Total Hardness as $CaCO_3$	mg/l	1000
Turbidity	NTU	5.8
Fluoride	mg/l	0.23
Flouride (dissolved)	mg/l	0.22
Orthophosphate as P	mg/l	0.07
Orthophosphate as P (dissolved)	mg/l	0.07
Silica	mg/l	16
Ammonia Nitrogen	mg/l	ND
TDS - High Tide	mg/l	5680
UVA_{254}	cm^{-1}	0.099
TOC	mg/l	1.1
DOC - High Tide	mg/l	1.5

Table 2. Mallard Slough Pump Station - High Tide Lab Results (Metals)

	Units	Total	Dissolved
Aluminum	ug/l	230	ND
Antimony	ug/l	ND	ND
Arsenic*	ug/l	2.5	3.6
Barium	ug/l	55	50
Beryllium	ug/l	ND	ND
Boron	mg/l	0.82	0.8
Cadmium	ug/l	ND	ND
Calcium	mg/l	76	74
Chromium	ug/l	4	1.1
Copper	ug/l	2.2	ND
Iron	mg/l	0.4	ND
Lead	ug/l	ND	ND
Magnesium	mg/l	200	190
Manganese	ug/l	59	48
Nickel	ug/l	ND	ND
Potassium	mg/l	62	67
Selenium*	ug/l	20	33
Silicon	mg/l	7.4	
Silver	ug/l	ND	ND
Sodium	mg/l	1700	
Strontium	mg/l	1.2	1.2
Thallium	ug/l	ND	ND
Zinc	ug/l	ND	ND

*These metals have lower total concentrations than dissolved concentrations as generally insignificant effects of laboratory procedures are more significant for metals present in lower concentrations.

Low Tide Sampling

Low tide water samples were collected from Mallard Slough on December 6, 2007 at the same location as described above for high tide sampling on December 4, 2007. The equipment, personnel, and sampling methods were consistent with the previous sampling. Initial sampling began at 8:06 AM. and was completed at 8:11 AM. There was a low tide on December 6, 2007 at 6:10 AM.

Samples were sent overnight on December 6, 2007 to MWH Labs. Results provided by the lab are in Tables 3.

Table 3. Mallard Slough Pump Station – Low Tide Lab Results

	Units	
TDS	mg/L	6700
UVA_{254}	cm^{-1}	0.098
TOC	mg/L	1.2
DOC	mg/L	1.5

Continuous Data

A YSI Model 600XLM / 650 MDS Kit Datalogging Multiparameter Probe & Flow Cell was rented from Equipco Rental Sales Services in Concord, California. Equipco calibrated the probe on December 4, 2007. All parameters on the device were selected for analysis. This included temperature, conductivity, dissolved oxygen percent, resistivity, oxidation reduction potential, pH, pHmV, dissolved oxygen charge, and dissolved oxygen concentration.

The probe was initially dropped into Mallard Slough from the Pump Station balcony sidewall at 11:05am while attached to the handheld device. A reading was taken that demonstrated that the probe was sampling properly. While the readings appeared to be reasonable, the time on the device was behind by exactly two hours. Using the handheld, the probe was then programmed to take readings every minute beginning at 9:07 am, which would have an actual start time of 11:07 am. The probe was secured over the balcony sidewall, suspended at an elevation of 5.75 ft below the current water level.

Based on the drawings for the existing Mallard Slough Pump Station, the average high tide water level is 2.6 ft above sea level, and the average low tide water level is 2.24 ft below sea level. The top of the submerged screens directly below the pump station balcony is 3.85 feet below sea level. With the probe submerged 5.75 ft, the probe is expected to have been 0.7 ft above the screen at all times, and 5.75 ft below the water level during high tide, and 0.9 ft below the water level during low tide.

The probe was removed from the slough at 8:20 AM on December 6, 2007. Data was downloaded from the probe using EcoWatch software.

A summary of the readings taken by the probe is presented in Table 4.

Table 4. Summary of Mallard Slough Pump Station Probe Data

	Units	Min	Max	Avg
Conductivity	mS/cm	7.436	8.907	8.306
Dissolved Oxygen Charge (DO Charge)		51	56	54
Dissolved Oxygen Concentration (DO Conc)	mg/L	6.51	11.56	9.63
Dissolved Oxygen Percent (DO %)	%	63.3	110.6	93.1
pH		7.18	7.68	7.44
pHmV	mV	-44.2	-16.9	-31.4
Oxidation Reduction Potential (ORP)	mV	116	222	149
Resistivity*	Kohm-cm	0.11	0.13	0.12
Salinity*	ppt	5.6	6.77	6.29
Specific Conductivity*	mS/cm	9.908	11.816	11.022
Total Dissolved Solids* (TDS)	mg/L	6440	7681	7165
Temperature	C	11.56	12.49	12.09

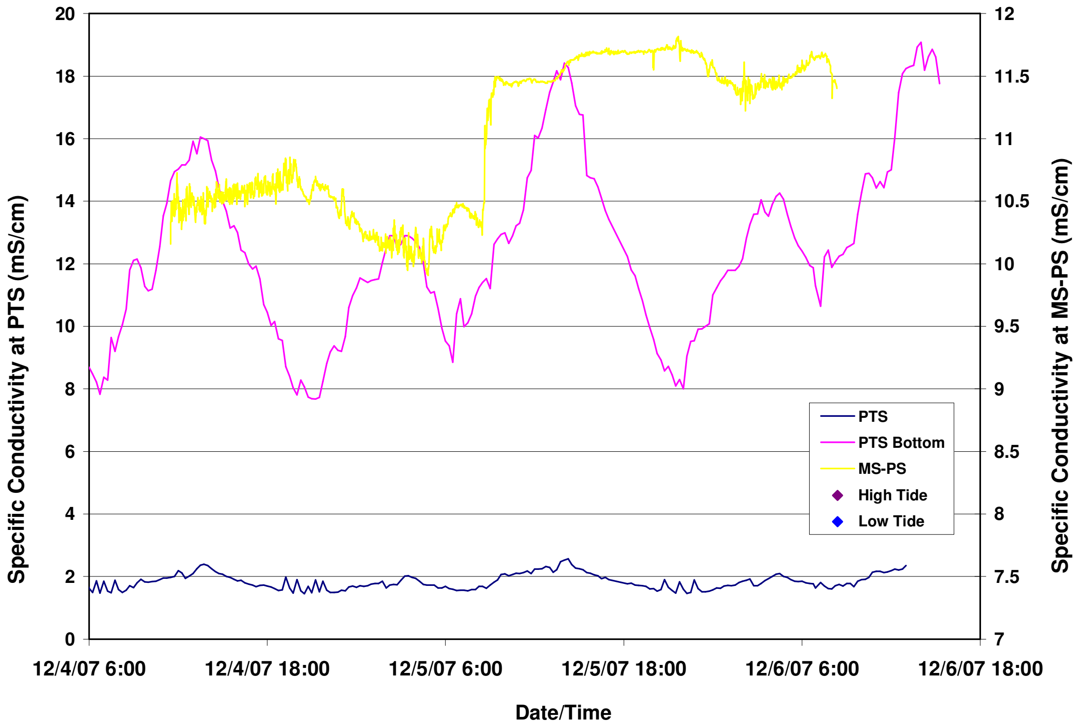
*Represents a calculated value. The probe is programmed to calculate these parameters from the measured conductivity, and they are therefore not measured directly. Specific conductivity is generated using the raw conductivity and temperature to correct to a specific conductance value compensated to 25^{o}C. Salinity is also determined using conductivity and temperature. TDS is converted directly from raw conductivity using a conversion factor of 0.65. Resistivity is converted directly from raw conductivity as it is the inverse of conductivity.

Results and Observations

Mallard Slough Pump Station Water Quality is Tidal, but Lags Behind Pittsburg Station

The continuous data collected at the Mallard Slough Pump Station (MSPS) is compared below to the data collected from the CDEC Pittsburg Station (PTS), located in the main channel of the Delta. Figure 1 compares specific conductivity at both stations, and Figure 2 compares temperatures at both stations. Both graphs indicate the high and low tides for the duration of the data.

Figure 1. Specific Conductivity Comparison
MS-PS and PTS

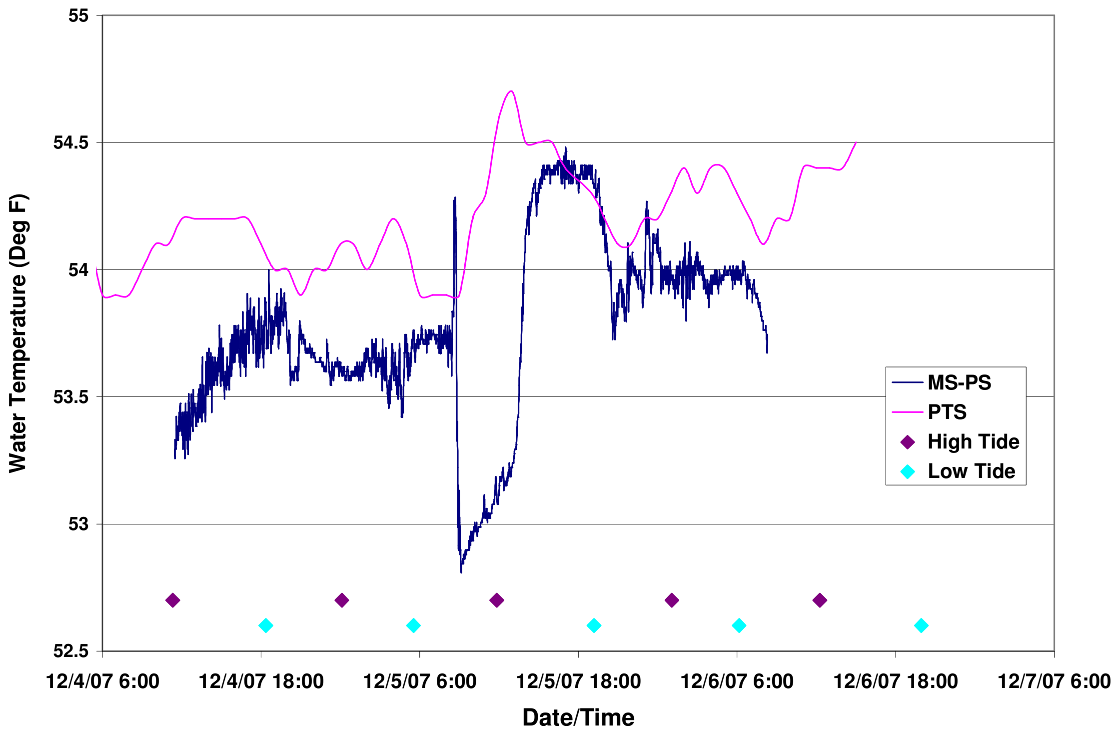


As shown in Figure 1, the specific conductivity at PTS clearly follows a tidal pattern, and roughly corresponds with the timing of high and low tide events with a lag of approximately 2 hours.

Specific conductivity at Mallard Slough Pump Station is significantly lower than specific conductivity at PTS. MS-PS specific conductivity ranged from 7.7 mS/cm to 9.9 mS/cm. PTS specific conductivity ranged from 11.8 mS/cm to 19.1 mS/cm. The specific conductivity at MS-PS follows a similar tidal pattern as at PTS, but has an overall lower salinity and a smaller magnitude of variation. Furthermore, there is a 7-hour delay from PTS to the tip of Mallard Slough where the probe was stationed. This illustrates the water quality buffering that occurs along the length of Mallard Slough when it is stagnant.

There appears to be an event around 8:00 AM on December 5, 2007 at the MS-PS that causes a sharp increase in specific conductivity. The same pattern was seen in all other parameters. The specific conductivity remains higher for the remainder of the sampling period. Specific conductivity at PTS also appears to be consistently higher following this time as well, with a less significant increase around 8:00 AM on December 5, 2007. There are no wind or storm events to explain this event. It is expected that the probe remained submerged. One possible explanation is a turnover of the shallow Mallard Slough.

Figure 2. Temperature Comparison
MS-PS and PTS



Higher temperatures are observed at PTS corresponding to high tides, demonstrating the greater influence of warmer seawater at high tide. Water temperatures at the mouth of the San Francisco Bay are typically higher than water temperatures in the Sacramento River at the Delta. Average temperatures at the Sacramento River at the Delta ranged from 45 ^{o}F to 49 ^{o}F for the duration of the sampling. Temperatures at the mouth of the San Francisco Bay averaged approximately 55 ^{o}F during that time[1]. The temperatures at MSPS and PTS exhibit the same tidal patterns and delays as salinity. There is an event around 8:00 am on December 5, 2007, that dramatically affects the temperature, as it did the specific conductivity.

Grab Samples for High Tide vs. Low Tide Are Similar

The parameters measured at MS-PS during both high tide and low tide are shown in Table 5. These values represent the measured results provided by MWH Labs, rather than the calculated values logged in the probe's data logger.

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[1] Water temperatures at the mouth of the San Francisco Bay are reported by the National Oceanic and Atmosphere Administation (NOAA). Water temperatures of the Sacramento River at the Delta are reported by the California Data Exchange Center (CDEC).

Table 5. MS-PS - High Tide and Low Tide Comparison

	Units	High Tide	Low Tide
TDS	mg/l	5680	6700
UVA254	cm-1	0.099	0.098
TOC	mg/l	1.1	1.2
DOC	mg/l	1.5	1.5

The TDS readings were18% higher during low tide. UVA, DOC, and TOC readings were approximately the same during both tidal conditions. This limited sample set could indicate that there is lower TDS at high tide, but the results from the continuous sampling show specific conductivity (and therefore TDS) to increase during high tides, and this is consistent with the understanding that there is a greater seawater influence during high tide.

Two possible explanations are offered for the discrepancy:

1) Throughout the time frame of the high and low tide samples, specific conductivity increased overall; low tide was sampled 45 hours following the high tide samples.
2) There is a nine hour tidal lag between high water level (high tide) and Mallard Slough salinity peak (as discussed above). Therefore, high tide sampling one hour before high tide is actually ten hours before the resulting salinity peak, and low tide sampling two hours after low tide is actually seven hours before the salinity trough. The tidal results do not actually represent the peaks and troughs of the salinity tidal cycle.

Probe vs. Lab Data:

Table 6 shows results for parameters that were analyzed using both the multiparameter probe and samples collected for the labs.

Table 6. Multiparameter Probe and Lab Sample Comparison

<table>
<tr><th rowspan="2"></th><th rowspan="2">Units</th><th colspan="3">Probe Continuous Data</th><th rowspan="2" colspan="2">Grab Samples</th></tr>
<tr><th>Min</th><th>Max</th><th>Avg</th></tr>
<tr><td>Specific Conductivity</td><td>mS/cm</td><td>9.908</td><td>11.816</td><td>11.022</td><td colspan="2">9.43</td></tr>
<tr><td rowspan="2">TDS (with 0.60 conv.)</td><td rowspan="2">mg/l</td><td rowspan="2">5969</td><td rowspan="2">7118</td><td rowspan="2">6640</td><td>High Tide</td><td>5680</td></tr>
<tr><td>Low Tide</td><td>6700</td></tr>
<tr><td>pH</td><td></td><td>7.18</td><td>7.68</td><td>7.44</td><td colspan="2">7.7</td></tr>
</table>

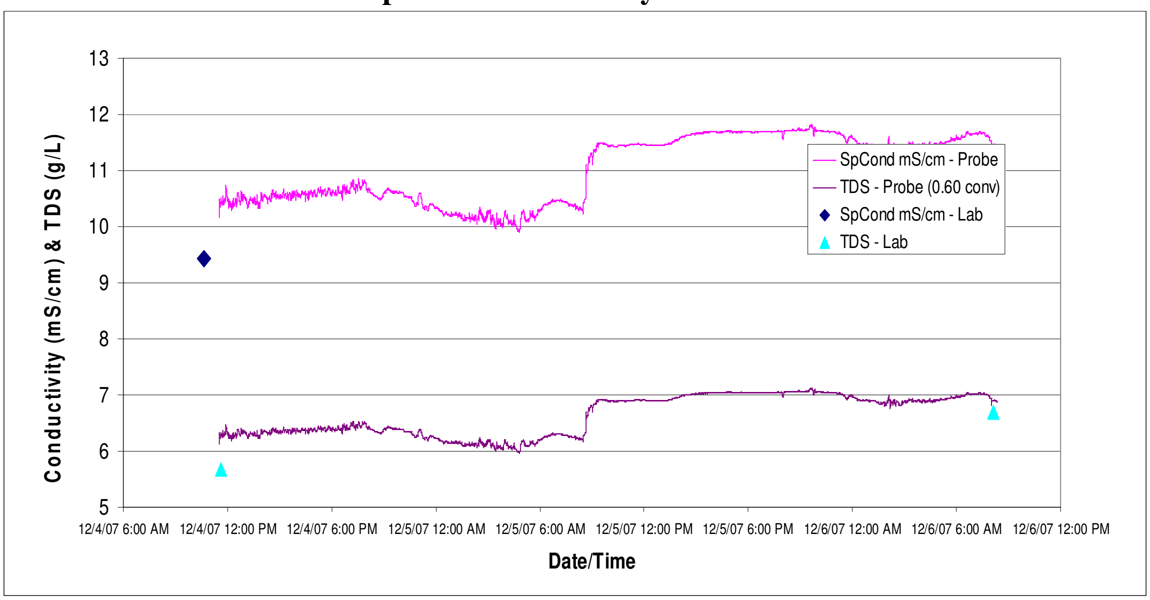
The TDS from the probe was calculated from the specific conductivity reading using a prescribed conversion factor. Therefore, TDS values from the probe's data logger cannot be directly compared to the TDS from the lab. The conversion factor used by the probe software was 0.65. Specific conductivity and TDS results from the lab indicate that 0.60

would be a more accurate conversion factor. Specific conductivity from the probe was therefore converted to TDS using the 0.60 conversion factor and those TDS values are compared to the lab results in Table 6 and Figure 3a.

The ratio between the high tide TDS values determined by the laboratory, and the specific conductance as reported by mutiparameter probe at the time of the high tide TDS sample collection, is 0.54. The corresponding ratio for low tide is 0.58. This is expected as the ratio typically increases at higher TDS concentrations such as those measured at low tide.

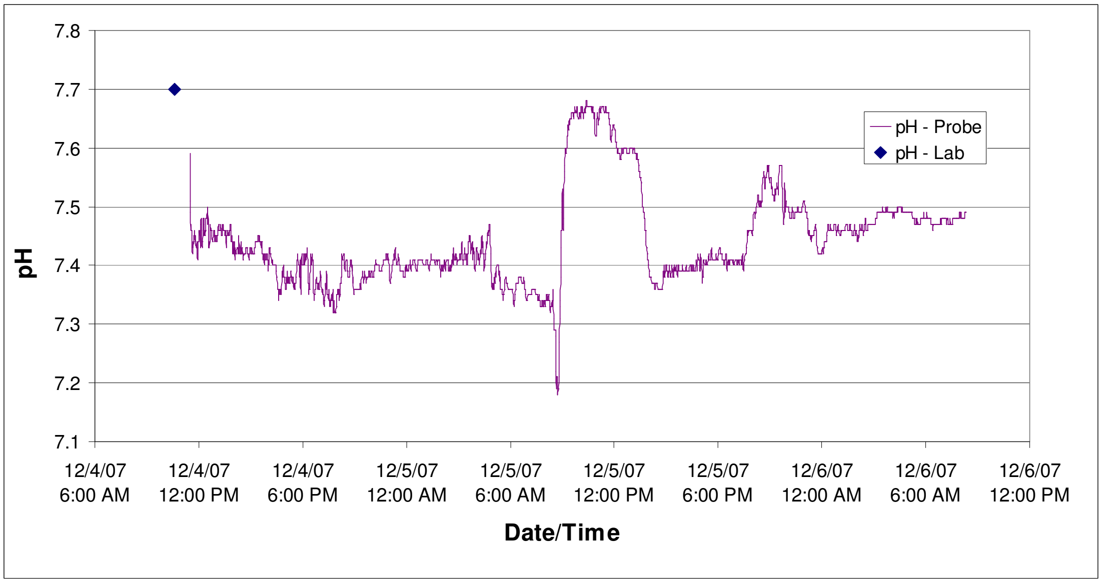
Figures 3a-3b show specific comparisons for the parameters measured both the probe and as lab samples.

Figure 3a. Multiparameter Probe and Lab Sample Comparison
Specific Conductivity and TDS



Specific conductivity and TDS were both measured slightly higher by the multiparameter probe than by the lab.

Figure 3b. Multiparameter Probe and Lab Sample Comparison
pH



There is no significant variation between the pH read by the probe and that measured by the lab.

T E C H N I C A L   M E M O R A N D U M

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	**Prescreening and Pretreatment System Evaluation** **Technical Memorandum No. 3B**		
Prepared by:	Stefani Harrison, MWH SDH Dawn Guendert, MWH	**Reference:**	1481449 / 6.2.3
Reviewed by:	Charlie Bromley, MWH Karla Kinser, MWH	**Date:**	December 21, 2007

The Bay Area Regional Desalination Project (BARDP) pilot study will evaluate low pressure membranes as a pretreatment step prior to the reverse osmosis (RO) process. Various types of membranes are available and have been considered by MWH for use by the partner agencies, including pressurized and submerged units. Findings and recommendations are presented in this technical memorandum, which has been prepared in accordance with the MWH scope of work dated June 14, 2007.

1.0 Prescreening

Prescreening will be included in the pilot design to protect all the membranes from debris in the Delta and Mallard Slough that may get through the intake screen. The anticipated technology to be employed for this purpose is in-line self-cleaning filters. These filters are installed in parallel, feeding a common header, and automated to backwash sequentially using the discharge pressure from the operating filters without interrupting the filtered water flow.

A variety of manufacturers make self-cleaning pumps, including Amiad, Hydac, and Tekleen. Specific manufacturer, model, and design specifications (such as pore size) will be determined during pilot design and the selection process will target meeting the needs of the selected pretreatment units.

2.0 Pretreatment Technologies

The RO process requires a high quality feedwater to minimize fouling, maximize membrane life and operate efficiently. The principle objective of pretreatment is to reduce the concentration of fouling constituents in the feed water to a level that will produce long-term stable performance that prolongs the life-span of the reverse osmosis (RO) membranes. Various pretreatment technologies are available, including conventional granular media filtration and low pressure membranes using polymeric or ceramic materials.

The most common parameter for determining the effectiveness of the pretreatment system to produce a feedwater suitable for an RO system is Silt Density Index (SDI), which is a measure of the of the rate at which colloidal and particulate fouling will occur for nanofiltration (NF) and RO systems. Most membrane manufacturers specify an upper limit SDI of 4 to 5, although for long-term stable performance the average SDI value should be below 3.

2.1 Conventional Pretreatment

Conventional pretreatment processes using granular media filters have proven to be effective in producing feedwater with SDI in the range of 3 to 4, for either brackish water or ocean water RO systems. However, conventional pretreatment processes do not represent a definite barrier to colloids and suspended particles, and the quality of feedwater produced can become highly dependent upon operations staff responding to changes in water quality and promptly adjusting chemical doses. As a result, product water quality can fluctuate significantly, negatively impacting the downstream RO process by increasing fouling rates and shortening membrane life.

2.2 Low Pressure Membrane Pretreatment

Alternatively, low-pressure membranes such as ultrafiltration (UF) and microfiltration (MF) membranes are an absolute barrier to particulate matter ranging from sub-micron size (UF) to micron size (MF). Most manufacturers have proven products which are capable of treating high turbidity water without experiencing an increase in filtered water turbidity. Potential benefits offered by membrane filtration pretreatment compared to conventional pretreatment methods are significant and include:

- Consistent product water quality regardless of the influent water quality
- Improved consistency of feedwater quality for the RO, in terms of lower suspended solids and colloidal material, lower SDIs (2-3 units), and less biological content, resulting in improved RO performance.
- Fewer RO membrane chemical cleanings, resulting in reduced chemical costs, disposal costs and less downtime.
- Reduction in fouling, resulting in reduced operating pressure and lower energy costs.
- Potential increase in RO system flux, resulting in a smaller footprint and lower capital costs, but subsequent trade-off in higher operating costs resulting form increased energy consumption.
- Lower overall chemical and sludge handling costs when compared to chemically intensive conventional pretreatments.

Membrane filtration has become an accepted water treatment technology for surface water treatment by regulatory and municipal water agencies, with competition and increasing numbers of installations helping to make membrane filtration cost competitive with conventional systems.

Low pressure membrane filtration is also recognized as the most efficient pretreatment for reverse osmosis in the treatment of brackish water, secondary sewage (for reuse applications) and ocean water desalination. Over the past several years, there have been a number of pilot studies in the United States with low pressure membrane systems as pretreatment for ocean water RO. One of the longest running pilot studies has been operating for close to five years, and is being operated by West Basin Municipal Water District at the NRG Generating Station in El Segundo, California. Other studies have been completed in Marin, California; Carlsbad, California, Tampa Bay, Florida; and San Patricio, Texas. In addition, two full-scale ocean water desalination plants utilizing low pressure membrane pretreatment (Yuhuan and Tuas) recently began operation.

2.3 Pretreatment Technology Selection

The full-scale BARDP will be a state-of-the-art facility utilizing innovative systems to effectively and efficiently produce a high quality water supply. As a result of the factors described herein, and because multiple manufacturers have developed commercially viable and proven MF/UF systems using advanced membrane technology, low pressure membranes are desired by EBMUD and the partner agencies, and are recommended for the Pilot Plant Study (PPS). MF/UF systems are capable of performing with lower chemical use, with low energy requirements, and are easily arranged on-site.

The balance of this document will evaluate MF/UF systems and will make recommendations for specific manufacturer systems to be considered for the PPS. This evaluation reflects the best information MWH has been thusfar able to develop during the course of the BARDP pilot testing study. Once the partner agencies have reviewed these recommendations, the Experimental Plan will be prepared with final technology selections.

3.0 Low Pressure Membrane Evaluation Objectives

The objective of this evaluation is to select two low pressure membrane systems as RO pretreatment for the BARDP pilot study. The purpose of the pilot testing is to identify and quantify operational variability from different physical configurations and flow patterns that are available in the pretreatment market. Therefore, the technologies selected for pilot-scale testing should reflect diverse configurations that could be employed at full scale, and the pilot testing experimental plan will be developed to compare operational requirements and benefits. The project will seek to make direct comparisons between MF/UF systems employing submerged vs. pressurized flow and inside-out vs. outside-in flow schemes.

The low pressure membrane systems for RO pretreatment must meet basic requirements, which can be grouped into two categories: water treatment objectives, and membrane performance objectives.

3.1 Water Treatment Objectives

Table 3-1 indicates the effluent water quality goals for the RO pretreatment. These goals must be met under varying influent water quality conditions including rain-driven turbidity spikes, tidal influences and seasonal changes, at 100% occurrence.

Table 3-1: RO Influent Water Quality Goals

Parameter	RO Influent Water Quality Goal
Silt Density Index (SDI)	<3.0
Turbidity (NTU)	<0.1
Particles larger than 2 microns	4-log removal
TOC	Partial TOC removal

3.2 Membrane System Performance Objectives

Table 3-2 indicates the low pressure membrane system performance goals. Overall average performance, vary with WQ conditions. These goals must be met under normal conditions, with some variation related to changing influent water quality conditions.

Table 3-2: UF/MF System Performance Goals

Parameter	System Performance Goals
Flux	30-50 gfd
Backwash interval	> 20 minutes
Chemically Enhanced Maintenance Wash Frequency	Maximum = daily
Chemical Clean-in-Place (CIP)	> 3 weeks
Recovery	> 92%

4.0 Low Pressure Membrane Systems

Low pressure membrane systems that have highly brackish and ocean water RO pretreatment experience at pilot-scale or full-scale, and that will be considered for the BARDP pilot study, are available from the following manufacturers:

- Pall Corporation
- Norit Americas, Inc.
- GE/Zenon Water Process Technologies
- Siemen/Memcor Water Technologies Corporation

Systems from the above listed manufacturers feature hollow-fiber membranes. There are two main physical configurations – skid mounted pressurized and submerged vacuum. Generally speaking, the same membranes can be used in either physical configuration, and the membrane process does not significantly change from one configuration to the other.

- In a skid mounted pressurized system, the membrane operates in a closed environment and feedwater is pressurized though the membrane units. Advantages of pressurized systems include flexibility to add additional residual pressure to meet specific applications, such as pretreatment for subsequent reverse osmosis, and ability to isolate individual membrane modules.
- In a submerged vacuum system, the membrane operates in an open tank design and the feedwater is drawn through the membranes under vacuum. Advantages of submerged systems includes capability to design for feedwater flow by gravity to the membrane tank, highly flexible for retrofitting of existing basins, and the open tank design allows for visual inspection for easy operation and maintenance.

Membrane systems also offer two different flow patterns – outside-in flow and inside-out flow. The backwash procedures for these two arrangements are significantly different, as described below.

- Outside-in flow indicates that the raw water is on the outside of the hollow fibers, and therefore the solids buildup occurs on the outside. In a backwash, clean water is sent through the membrane in the opposite direction of normal flow (inside-out), and small air bubbles are introduced to scour the fibers against each other.
- Inside-out flow indicates that the raw water is on the inside of the hollow fibers, and therefore the solids buildup occurs on the inside. In a backwash, clean water is sent through the membrane in the opposite direction of normal flow (outside-in), and air is not introduced as part of the backwash process.

A description of each commercially available hollow-fiber low pressure membrane system follows.

4.1 Pall Corporation

- The Pall Microza system is a skid mounted, pressure driven MF system. Each skid is composed of multiple 0.1 micron rated polyvinylidene fluoride (PVDF) hollow fiber membrane modules operating in an outside-in configuration mode. Backwash is achieved using a combined air/liquid scour. Pall Corporation has more than 100 Microza plants operating world-wide both for drinking water production from groundwater and surface water and wastewater reuse secondary effluent and has participated in a number of studies treating ocean water as pretreatment to reverse osmosis systems.
- To date, Pall Corporation has participated in nine ocean water desalination pilot studies around the world. Source water includes open ocean water intake, fresh water influence discharge from a power plant with high TOC, and tidal brackish river water. Pall has three full-scale ocean water systems in operation internationally (Belgium, UK, and Thailand).
- Pall Corporation is headquartered in New York and provides field support through service personnel located throughout the US.

Figure 4-1. Pall Pressurized MF Membranes

4.2 Norit Americas, Inc.

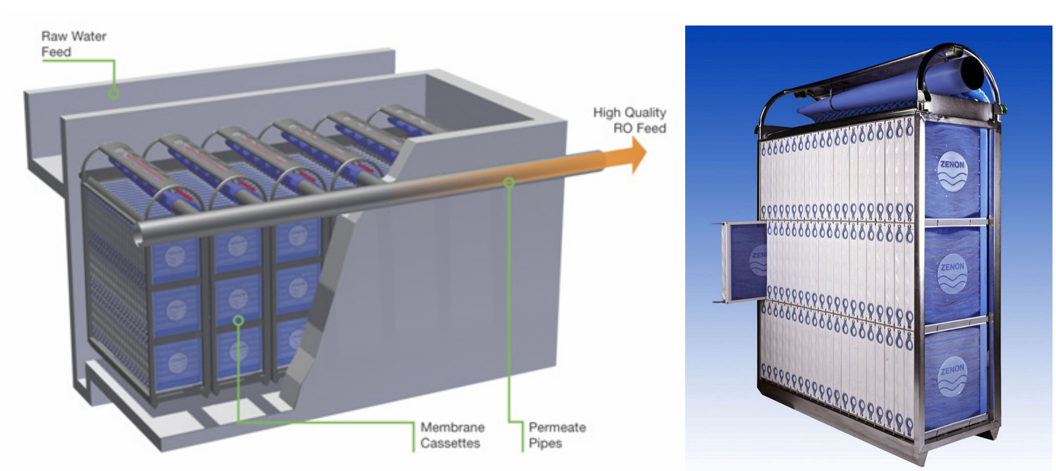
- The Norit system is a pressure driven UF system with polyethersulfone hollow fiber membrane modules housed in 8-inch diameter RO pressure vessels assembled on skids similar to a RO system. Norit offers the "Seaguard" UF membrane module, operating in an inside-out configuration with a fiber geometry specifically designed for ocean water pretreatment. Backwash is achieved using liquid only in reverse flow.
- To date, Norit has participated in 18 ocean water desalination pilot studies and has a 3-mgd UF system that has been operating as pretreatment to a 1-mgd RO system on a floating ocean water desalination plant at multiple locations within the U.A.E.
- Norit is a company based in the Netherlands and currently relies on representatives from other US based companies to install and provide field support for their UF systems

Figure 4-2. Norit Pressurized UF Membranes

4.3 GE/Zenon Water Process Technologies

- The Zenon system is an immersed membrane, vacuum driven UF membrane system that operates in an outside-in flow pattern. PVDF hollow fiber membranes horizontally oriented and potted at both ends into cassettes that are immersed directly into open process tanks. The cassettes are connected to permeate collection headers and aeration hoses. Permeate pumps apply a slight vacuum to the end of each membrane fiber. Backwash is achieved with a combined air/liquid scour.
- Zenon has participated in a number of ocean and brackish water desalination pilot studies, including West Basin, Tampa and Carlsbad. A 20-mgd Zenon UF system began operation treating ocean water as pretreatment to RO, at the Yuhan Power Plant in China in the summer of 2006.
- Zenon is headquartered in Oakville, Canada and is a division of GE. Zenon employs approximately 1400 people and provides field support through regional offices.

Figure 4-3. GE/Zenon Submerged UF Membranes



4.4 Siemens/Memcor Water Technologies

Memcor offers both their low pressure membrane system in both the skid mounted pressurized and submerged vacuum configurations.

- The Memcor submerged membrane system is a vacuum driven UF system that operates in an outside-in flow pattern. PVDF follow fiber membrane modules are horizontally immersed directly into an open process tank. The modules are connected to permeate collection headers and aeration hoses. Permeate pumps apply a slight vacuum to the end of each membrane fiber. Backwash is achieved with a combined air/liquid scour.
- The Memcor pressurized membrane system operates in the same manner as the submerged system with the exception that the feedwater is pushed through the membranes under pressure rather than pulled through the membranes under pressure.
- Memcor has participated in a number of ocean water desalination studies including San Diego, West Basin and Marin in California and San Patricio, Texas, and one full-scale ocean water application in China under contract but not yet installed.
- Memcor is headquartered in Massachusetts and is a division of Siemens. Memcor provides field support through their regional offices.

Figure 4-4. Siemens/Memcor Submerged UF Membranes

4.5 Ceramic Membrane Pretreatment

Ceramic membranes are not new and have been used in the pharmaceutical, food, and beverage industry in past years. Recent advances in fabrication and materials have led several manufacturers to develop systems which can be applied in larger-scale to the municipal water and wastewater treatment marketplace. Very few of these systems, however, are ready for full-scale deployment.

The unique characteristics of ceramic membranes – a porous ceramic microfiltration membrane surface typically matched with a sturdy monolithic ceramic substructure – provide a rugged, durable membrane that is highly resistant to operating pressure, heat, chemical attack, fouling, and mishandling. When compared to polymeric membranes, ceramics are characterized by high recovery, high flux and trans-membrane pressures, small mechanical footprint, long durations between cleanings, short cleaning periods, resistance to aggressive oxidants such as ozone, very long service life, and higher operating pressures. Operations are minimally affected by cold water temperatures.

Ceramic membrane systems are under development by an assortment of domestic and overseas manufacturers, and represent various developmental stages (e.g. prototype, pilot-level, full-scale production). Many of these companies were contacted by MWH while preparing this document. The only ceramic membrane currently that has been granted California Department of Health Services (CDHS) conditional approval for drinking water is the NGK ceramic MF membrane.

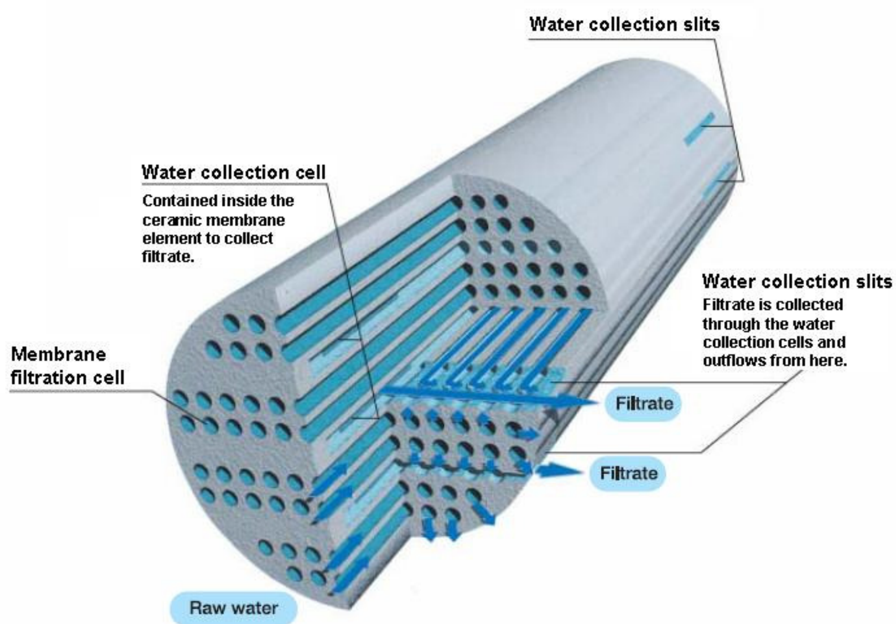
4.5.1 NGK Insulators, Ltd.

NGK is a Japanese ceramics manufacturing corporation with experience creating ceramic products for the electrical power industry. The firm produces a very robust membrane well suited to the municipal water treatment market, with research, development, and full-scale manufacturing capabilities located in Japan. Several full-scale WTPs are in operation in Japan utilizing fresh water as a feed source. MWH is conducting a pilot test of the NGK unit for a secondary wastewater effluent in Southern California. NGK has not yet developed membrane systems suitable for highly brackish and ocean water sources.

The membrane consists of multiple pressurized membrane elements approximately 1.5-meters in length and 3-cm in diameter, each of which is manufactured with ceramic material having a nominal pore size of 0.1 microns. The water is filtered from the inside-out and is collected in multiple channels throughout the membrane element where it is directed toward the filtrate side. Backwash is achieved using a high pressure (70 psi) water backwash from the filtrate side followed by a high pressure air burst (30 psi) down through the raw water channels within the membrane element.

In the USA, NGK is represented by the Kruger division of Veolia Water Systems in the USA. While developing this technical memorandum, MWH was informed by Kruger that the NGK system is not ready to be applied to a brackish or ocean water source, and that Kruger would be unwilling to participate in the BARDP PPS[1].

Figure 4-5. NGK Ceramic Membranes



4.5.2 Fairey Industrial Ceramics, Ltd.

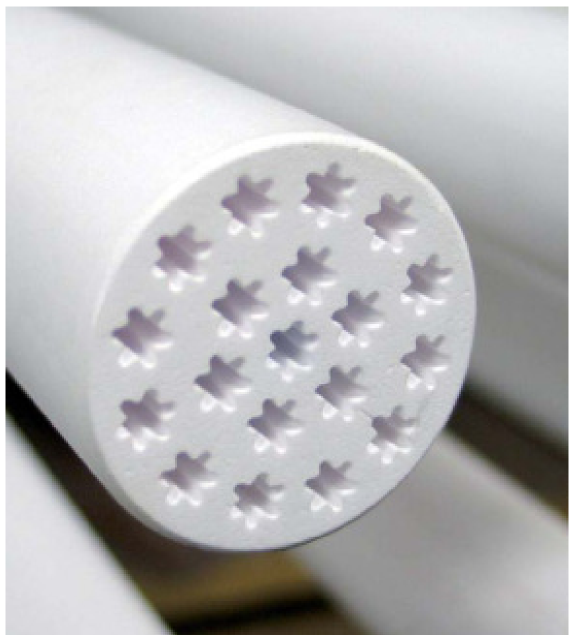
Fairey Industrial Ceramics is a membrane producer and supplier located in the UK. Typical applications involve the petroleum, pharmaceutical, food and beverage industry, and very small solids separation and water treatment systems for bilge water, laundry recycling, etc.

Membranes are available in 3 micron to 3.5 micron pore size, in modules varying from 0.6-meter to 1.2-meter and with varying configurations suited to the specific application. A cross-flow system is deployed, unlike the NGK unit, to assist in cleaning of the membrane surface.

[1] Personal communication between Charles Bromley- MWH and Nathen Myers - I. Kruger, Inc., Nov. 29, 2007.

While it is not believed that Fairey currently fabricates a membrane system for the filtration of large quantities of drinking water, such as would be required for the BARDP, their system may be suited to the small pilot scale flow rates associated with the PPS. Representatives have indicated a willingness to participate in the BARDP pilot study and that skid mounted systems capable of treating the pilot study flow rates could be made available. These systems, however, would have had no prior experience with highly brackish or ocean water supplies.

Figure 4-6. Fairey Ceramic Membranes



4.5.3 Other Ceramic Systems

Other manufacturers identified by MWH include the following:

Hilliard Corporation is company in New York that is interested in participating in pilot testing. They have systems installed at flow rates comparable to the pilot testing requirements and foresee the ability of expansion to large scale facilities because of the modular construction of their systems.

Lenntech Holding, B.V. is a manufacturer in the Netherlands with experience in pharmaceutical, chemical and semi-conductor industry. They are not currently pursuing large scale municipal water treatment projects.

Ceramem Corporation is a company in Massachusetts that primarily provides services to the U.S. government for research and development of ceramic membrane applications. They are not currently pursuing large scale municipal water treatment projects.

Pall Corporation already provides polymeric membrane systems. As previously discussed herein, and is currently looking to expand into ceramic membrane technology. Pall offers a system that has only been utilized in small scale applications. Pall is interested in participating in pilot testing.

4.5.4 Survey of Potential Ceramic Membrane Vendors

Mallard Slough feed water quality data was provided to Fairey, Hilliard, NGK/Kruger and Pall. Ceramem and Lenntech did not respond to initial contact. System data are provided in the following **Table 4-1** for the manufactures that may have the capability to provide pilot testing equipment.

Table 4-1. Ceramic Manufacturer Data

Information Requested	Fairey Industrial Ceramics	Pall Corporation
Element specifications		
model	19 Channel X 1200mm Star-Sep TM Ceramic cross flow Element	Membralox P19-60 element HCB Industrial Module
diameter	32 mm	
length	1200mm	1020mm
element surface area	0.33m2	20m2
elements per housing	Up to 300	Up to 60
number of channels	19	19-37
channel diameter	Star ID 2.8mm Star OD 4.6mm	3-6 mm
flow configuration	Cross-flow	
flow per element, maximum	3 m3/hr	
cross-flow pressure drop	1.6 bar	8 bar
material and coatings	Alumina	u alumina zirconia titania
pore size	0.2, 0.35, 0.5, 0.8 and 1.2 um	Up to 5um
pH	0.5 – 13.5	0-14
Temperature, maximum	140^{o}C	
Pressure, maximum	8 bar	10bar

4.5.5 Ceramic Membranes, Summary

While ceramic membranes are clearly a cutting edge technology with obvious application for the PPS, it is doubtful that any of the vendors, with the possible exception of NGK/Kruger, would be capable of providing a pilot skid suitable for Mallard Slough water by June 2008. The current state of the technology does not appear to warrant further consideration, particularly in view of minimal ceramic membrane experience with highly brackish water and ocean water.

Once the full scale BARDP site is identified by the partner agencies in the future after the PPS is completed, and if supplemental piloting is to be performed at that time, it will be worthwhile to reconsider ceramics. It is expected that technical advances will be achieved in the near future, and ocean water pilot skids will then be available, rendering this technology more readily available and suitable for use at any of the sites under consideration.

5.0 Low Pressure Membrane Systems Evaluation

A questionnaire was distributed to each of the four vendors to collect information on their technology, confirm that they are able to meet the water quality and operational goals, and determine the availability and specifications of pilot units for possible use at the BARDP pilot plant. The information is summarized in **Table 5-1** below.

Table 5-1: UF/MF Evaulation

Manufacturer:	Pall	Norit	GE/Zenon	Simens/Memcor
Membrane System				
Product name	Microza	Seaguard	ZeeWeed 1000	L20
Technology	MF membrane	UF membrane	UF membrane	UF membrane
Configuration	Pressurized	Pressurized	Submerged	Either(1)
Flow direction	Outside-In	Inside-Out	Outside-In	Outside-In
Backwash Mechanism	Air-Liquid	Liquid-Only	Air-Liquid	Air-Liquid
Can Water Quality Goals Be Met?	Y	Y	Y	Y
Can Performance Goals Be Met?	Y	Y	Y	Y
Typical Coagulant	Ferric Chloride, if required	Aluminum sulfate or ferric chloride, if needed	PACl or Ferric Chloride, if needed	none
Typical Coagulant Dose	10-15 ppm	0.5-1 ppm ferric (dose up to 6 ppm tolerated)	2-7 ppm as product (either coagulant)	N/A
Anticipated Flux	45 gfd	45-55 gfd	25-30 gfd	30-35 gfd
Pilot-scale unit(s)				
Available?	Y	Y	Y	Possible(1)
Lease agreement minimum timing	4-6 wks prior to June 2008, if available	2 wks prior to June 2008, if available	April 15, 2008	8-10 wks prior to June 2008

Manufacturer:	Pall	Norit	GE/Zenon	Simens/Memcor
Power Requirement for each major pump	3 HP	5 HP feed, 10 HP backwash, 5 HP compressor	3 HP	3 HP
Footprint	37"W x 172"L x 120"H, compressor 24"X x 48"L x 48"H	20' x 20' for all equipment	20'W x 20'L x 12'H	50" W x 90"L x 114"H, compressor 37"W x 75"L x 75"H
Weight	2200 lbs	4000 lbs (empty)	3200 lbs (empty)	TBD
Filtrate Flowrate	35-60 gpm	40-80 gpm	24 gpm maximum	15 gpm or more
Cost for intended pilot duration(2)	$43,000	$77,750 for up to 9 months	$80,000	$41,000
Monthly extension fee(2)	$8,000	$7,250	$7,500	$4,000
Field tech assistance with startup?	Y	Y	Y	Y
Field tech assistance with CIP?	Y	Y	via phone and remote access	Y
Closest field technician	Los Angeles	Cary, NC	1-2 hr flight (max 5 hr flight)	Daly City, Livermore
Online access	requires phone or Ethernet service	Strongly prefers Ethernet	requires phone	requires phone or Ethernet service

(1) Siemens/Memcor is considering the fabrication of a new skid to serve the PPS.[1]

(2) All costs are understood to be somewhat negotiable.

Table 5-2 below indicates specific items that are included or excluded from each manufacturer's scope of supply. Items marked with an "X" are items that would be provided by the manufacturer. Items marked with an "O" are items that the manufacturer *requires* the Owner to furnish.

[1] Personal communication between Stefani Harrison - MWH, John Kutilek – Siemens, and Mike Tooley - Misco Products, on Dec. 5, 2007.

Table 5-2: UF/MF Pilot Agreement Scope of Services

Item	Pall	Norit	Siemens	GE
Shipping to site	X	X		X
Offloading	O	X		O
Shelter		O		O
Potable water supply		O	O	O
Commissioning / Startup	X	X	X	X
Operator Training			X	X
Field visits		X		X
Remote Monitoring	X	X		X
Decommissioning	X			X
Return Shipping				X
Formal Report	X			
Equipment				
feed pump				O
feed tank		X (2 m^3)		
product storage tank		X (2 m^3)		
air compressor		X		O
feed strainer		X		

In addition to the above, the following common items will be excluded from the scope of services of any pilot unit supplier, and must be provided:

- Site preparation with a level area for the equipment skids
- Piping to/from pretreatment skid
- Phone line or internet connection for remote monitoring
- Electrical supply
- All process chemicals (coagulant, cleaning solutions, etc.), spill management, and disposal
- All water quality sampling and laboratory analyses

6.0 Results and Recommendations

The following differentiating observations are noted for each of the four systems evaluated:

- All four systems can meet the water quality and operational goals.
- Full-scale energy efficiencies and cost efficiencies will not be known until piloting is done, so the selection will need to be based on the intent to test various configurations and the requirement to provide sufficient feedwater for the RO system.
- Pall offers a pressurized membrane with the second highest flux rate and filtrate flow, but estimates the highest chemical doses. The pilot rental cost is relatively low.
- Norit has the only inside-out technology (pressurized), and can provide a pilot unit with the highest flux rate, the highest filtrate flow, and the lowest estimated coagulant dose. The unit has a relatively high energy consumption and a relatively high (but negotiable) rental cost.
- GE/Zenon offers a submerged membrane system that has a lower flux rate and filtrate flow, and slightly lower coagulant dose, than Pall's pressurized system. The pilot rental cost is relatively high.
- Siemens/Memcor has only one unit in its operational pilot fleet, and that unit is the smallest flowrate. It will shipped to Trinidad & Tobago in December for a project. Therefore, this unit would not be available for the BARDP project.

Based on these observations, it is recommended that the BARDP pilot plant include a Norit Seaguard pilot unit and a GE/Zenon ZeeWeed 1000 pilot unit. Using Norit and GE/Zenon would provide a basis for evaluating inside-out vs. outside-in flow as well as submerged vs. pressurized. The overall flow capacity of the two pretreatment units would be sufficient to feed up to three RO trains.

MWH will continue to gather availability and pricing information, so that final selection of pretreatment technology is developed in the Experimental Plan to be prepared under Task No. 1 for the PPS work. While selection must consider the range of available technologies (submerged, pressurized, inside-out, and outside-in), other objectives include:

- Providing sufficient flow to feed all RO units with two pretreatment skids
- Pilot skid availability and negotiated cost from vendors
- Potential schedule/availability of new pilot unit that Siemens/Memcor has offered to build for this project

The pilot testing experimental plan will be designed to collect enough information to determine which physical configuration and flow pattern would provide a more robust, energy-efficient, cost-efficient solution for pretreatment. To this end, the test plan will adjust operational variables to determine flux, recovery, operating pressure, rate of fouling, frequency and duration of all cleaning procedures (backwash, flux enhancement, and chemical cleaning), and specific flux recovery after cleaning procedures. Optimization adjustments will target maximizing filtrate quality and recovery, and minimizing chemical use and energy consumption under the varying tidal and seasonal conditions. With the six-month pilot testing duration spanning both the dry and wet seasons, this strategy will bracket the range of pretreatment technologies and how they respond to anticipated seasonal changes.

T E C H N I C A L   M E M O R A N D U M

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

Subject:	Reverse Osmosis (RO) Technology Evaluation Technical Memorandum No. 4A		
Prepared by:	Dawn Guendert, MWH Karla Kinser, P.E., MWH KK	**Reference:**	1481449/6.2.4
Reviewed by:	Stefani Harrison, P.E. MWH Charlie Bromley, P.E., MWH	**Date:**	January 3, 2008

This technical memorandum has been completed in accordance with the Bay Area Regional Desalination Project (BARDP) MWH scope of work dated June 14, 2007 to evaluate alternative reverse osmosis (RO) system configurations and membrane element types and to make recommendations for achieving pilot objectives. Parameters to be considered include finished water quality goals, operational aspects, and possible capital and operating costs. Desktop model-based analyses and review of data from previous desalination studies are used for the initial selection of RO system configurations and membrane elements. RO system design configurations will be representative of typical industry designs with the capability to accommodate site-specific conditions at Mallard Slough.

The primary goal for the pilot-scale RO system will be to evaluate and demonstrate sustainable operation under the range of conditions representative of Mallard Slough feedwater quality. Optimum conditions to be established include flux, recovery and chemical cleaning frequency. During the pilot study, flux and recovery will be varied to gauge the impact of these changes on performance and costs.

1.0 Pilot Plant Reverse Osmosis System Objectives

RO system objectives can be grouped into water treatment objectives and system performance objectives. Ultimate goal is to design a full scale RO system that provides the desired permeate flow, while minimizing feed pressure and membrane costs and maximizing permeate quality and recovery. These objectives will help guide the selection of the RO design configurations and membrane elements.

1.1 Generic Drinking Water Quality Specifications for Desalination of Bay-Delta Water

To initiate this evaluation of RO technology, it is necessary to broadly consider the finished water quality which the BARDP will need to meet at full-scale. **Table 1-1** summarizes the suggested components of a water quality specification for a RO system treating northern California Bay-Delta water, including the Mallard Slough feedwater being used for the BARDP pilot plant study (PPS). Lower targets are possible for source waters that contain less salinity and for second-pass treatment systems.

Table 1-1: Recommended Desalination Water Quality Specifications, Initial RO Evaluation

Parameter	Water Quality Target
Disinfection	**Comply with SWTR**
Virus removal and inactivation	4 – 6 log reduction
Giardia removal and inactivation	3 – 5 log reduction
Cryptosporidium removal and inactivation	2 – 4 log reduction
Permeate Water Quality	**Meet all State and Federal MCLs**
Total Dissolved Solids (TDS)	< 500 mg/L
Chloride (selected target level)	< 100 mg/L
Bromide	0.25 – 0.7 mg/L
Boron	0.5 – 1.0 mg/L
Disinfection By-Products	**Result in Stage 1 and Stage 2 DBP Rule Compliance**
Total Tri-Halomethanes (TTHM)	< 64 ug/L
Halo-Acetic Acids (HAA5)	< 48 ug/L

TTHM and HHA5 values are selected based on an assumed minimum 20% reduction below EPA drinking water requirements.

These assumptions are sufficient for developing piloting recommendations at this stage of the PPS. In addition to compatibility with existing partner agency drinking water quality, finished water quality targets at the full-scale will be further refined based on:

- further source water analysis,
- input from the partner agencies,
- aesthetics,
- compatibility with industrial standards, and
- suitability for agricultural purposes.

1.2 "Soft" Issues Associated with Desalinated Water

Besides the need to meet Federal, California, and agency-specific drinking water regulations, the ideal water quality goal also results from an analysis of what is sometimes referred to as the "soft" issues. These soft issues address consumer satisfaction with desalinated water as a new supply and are generally based upon the following specific issues:

- Water quality impacts on horticulture
- Industrial standards
- Consumer acceptance

Such issues apply only to the product water from the desalination treatment plant and are not a consequence of drinking water regulations, but will impact both potable water consumer and local industry satisfaction with the new water source nonetheless. Many of these soft issues can be addressed if the product water is introduced to the distribution system at a point that allows for adequate mixing and adequate dilution with the conventional water supplies utilized by the partner agencies.

1.2.1 Horticulture

Desalinated ocean water is high quality water from the perspective of total dissolved solids (TDS). However, there are still specific ions that are present in much higher concentrations in desalinated water and can have a negative impact on growth of certain forms of plant life.

The first of these ions is boron. Boron toxicity results from boron accumulation in the leaves of sensitive plants. While a drinking water standard does not exist as yet at the state or Federal level, the World Health Organization has chosen a finished water boron goal of 0.5 mg/L. An action level of 1.0 mg/L has been established in California. Boron concentrations between 0.5 and 1.0 mg/L may possibly impact many of the trees, plants and ornamentals that are commonly used in southern California landscapes. Typical treatment processes, including RO, provide minimal to moderate boron removal at ambient pH levels.

Increased levels of chloride and sodium ions present in desalinated water may also have noticeable effects upon plants following conversion to desalinated water within the distribution system. Chloride and sodium toxicity have very similar impacts on the health of plant life. The most common symptom is tip burn, but chloride or sodium toxicity can also result in tattered leaves, reduced leave size, reduced growth rates, yellowing of leaves in conifers and may be fatal in extreme cases.

1.2.2 Industry Standards

The level of chloride in the desalinated water can also an issue for industries served with the partner agencies' service areas. Industries use significant volumes of water for boilers and cooling towers, which typically have a water quality requirement of 100 mg/L or less chloride.

1.2.3 Aesthetics and Consumer Acceptance

The issue of consumer acceptance stems from taste and odor concerns. Depending on how the desalinated water is introduced to the distribution system, some consumers may be converted entirely from the conventional water supply to the new water supply. If these consumers remain on the new supply 100% of the time, following a transition period, the number of taste and odor complaints is not expected to be significant as a result of the conversion to the desalinated water. Complaints will become greater, however, if consumers are alternately switched from one supply to another.

As noted previously, a majority of these soft issues can be addressed by ensuring adequate blending and mixing with the local supply prior to distribution. However in the case where this is not an option, it is important from a water quality perspective that a system wide approach be engineered into the design to minimize the incidences of conversion from one supply to another.

1.3 Post Treatment Considerations

Post treatment of the RO permeate will most likely be necessary, as the resulting permeate is essentially a dilute solution of sodium chloride, devoid of hardness and alkalinity, and with an unstable pH. Calcium hardness and bicarbonate alkalinity must be added to the permeate, together with pH adjustment, to protect the distribution system and domestic plumbing from corrosion. If the water is introduced into an existing system with other sources of drinking water, it may be necessary to match the quality of the two waters. This may require additional action to further reduce chlorides.

Post treatment is also dependent on local practice, and may include disinfection, fluoridation and the use of corrosion inhibitor.

2.0 Review of Domestic RO Pilot Studies with High Salinity Surface Waters

While use of RO for high salinity surface water and ocean water desalination has been practiced on a wide scale outside of the United States for approximately 30 years, ocean water desalination for potable applications has been limited in capacity and number. However, as the cost for RO desalination treatment decreases as a result of efficiency improvements, and the need for alternative water supplies increases, the level of interest in ocean water desalination has grown, particularly in California and certain other coastal zones.

At this time in the United States, desalination is being evaluated with a critical focus on optimizing technologies and processes, for the purpose of designing systems for sustainable operation, cost minimization and compliance with finished water regulatory requirements. Additionally, some of the projects being considered are located in areas where ocean waters are under the influence of surface water. These sites are located in bays, estuaries, intra-coastal waterways, or at deltas of rivers.

The primary feedwater quality variations that influence the design at the Mallard Slough pilot study site are salinity and temperature. For this technical memorandum, three ocean water (two of which are under the influence of surface water) and one river water reverse osmosis desalination pilot studies completed in the United States (Florida, California and Massachusetts) were selected for review of their evaluation of seawater reverse osmosis (SWRO) membranes. The four studies represent a range of feedwater sources as shown in **Table 2-1**.

Table 2-1: Representative Case Studies

Client	Location	Feedwater Source
Tampa Bay Water	Anclote Power Station Holiday, FL	Ocean water under the influence of surface water. TDS: 13,000 to 36,400 mg/L.
West Basin Municipal Water District	El Segundo Generation Station, El Segundo, CA	Ocean water intake & discharge from power plant cooling system. TDS: 33,000 to 34,000 mg/L.
Marin Municipal Water District	North San Francisco Bay at pier at Marin Rod & Gun Club	Estuarine water body with influences from the ocean, rivers and bay discharges. TDS: 11,000 to 25,500 mg/L.
Town of Swansea	Tidal basin adjacent to a power plant	Brackish water from Tauton River at low tide & groundwater from the existing Vinnicum wellfield. TDS: <1,000 to 12,000 mg/L.

2.1 Actual versus Predicted Membrane System Water Quality

The West Basin and Marin pilot studies evaluated SWRO membrane elements from four membrane manufacturers: DOW/FilmTec Corp., Hydranautics Corp., Toray Membrane Inc. and Koch Membrane Systems. The Tampa Bay pilot study evaluated SWRO performance utilizing only the Toray membrane. The membrane manufacturer's membrane performance models were used to calculate the predicted permeate quality at the actual operating conditions. The actual TDS, sodium, chloride and boron concentrations from water quality data collected during the pilot studies were compared to the manufacturer's predicted performance at these conditions.

Review of the West Basin and Marin pilot study reports indicate that the actual results from the pilot studies were generally better than the manufacturer's modeled performance, with the exception of boron. Actual boron levels in the RO permeate were generally above the predicted levels. This is most likely a result of higher boron rejection membranes being relatively new, so less field data is available for refinement of the models to simulate field performance.

2.2 Impact of Seasonal and Tidal Variations on RO Performance

The source water for the BARDP pilot plant will be drawn from an existing open intake at the Mallard Slough Pump Station. The source water is a complex estuarine body of water with influences from the ocean, rivers and bay discharges. For mixed ocean water/surface water supplies, seasonal and tidal variations are expected to have a significant impact on process design, capital, and operation and maintenance costs. Therefore, awareness of the variability of these influential parameters and the typical duration of these events is important in the consideration of the design configuration of the RO pilot systems.

Both the Tampa Bay and Marin source waters are open ocean intakes with surface water influences resulting in a wide range of salinity, but even at its lowest salinity point, the source waters exceed the upper limit for brackish water membranes. Thus, both plants are designed with seawater membranes only. The source water for the Swansea project is being maintained at salinity levels not exceeding the brackish water limit of 8,000 mg/L, by withdrawing water only during two 6-hour periods around low tide and mixing with groundwater from an existing wellfield. Thus, the design for Swansea consists of brackish water membranes only.

Source water at Mallard Slough has a variable salinity (TDS) depending on season and tidal cycle, and turbidity, sediment and dissolved organic loads, of which all can potentially spike daily and/or seasonally. Water quality data has been characterized by MWH in Technical Memorandum No. 3A, and a portion of the data is briefly depicted in **Table 2-2** herein. Source water total dissolved solids (TDS) ranges from approximately 100 mg/L to 7,100 mg/L. This source water would be considered brackish water, which is typically defined as having TDS levels ranging from 3,000 mg/L to 10,000 mg/L (primarily sodium and chloride).

Table 2-2: Summary of Water Quality for Mallard Slough (2001-2006)

Constituent	unit	Max	Min	Avg
Turbidity	NTU	58.1	11.4	27.7
Calcium	mg/L	92	12	33
Magnesium	mg/L	258	7.5	73.3
Sodium	mg/L	1700	18	450
Chloride	mg/L	1260	16	349
Potassium	mg/L	69	2.2	19.3
Sulfate	mg/L	32	12.3	19.4
Nitrate	mg/L	2	<0.1	1.4
Phosphate	mg/L	<0.2	<0.2	<0.2
Silica	mg/L	No Data		
Hardness	mg/L	1140	62	345
pH		8.3	7.5	7.8
Alkalinity	mg/L	89	67	76.5
Conductivity	uS/cm	10230	220	2828
TDS	mg/L	7130	110	2448
Ammonia	mg/L	<0.1	<0.1	<0.1
TOC	mg/L	No Data		
Source: CCWD – September 2007				

Based on the existing water quality data, RO design configurations consisting of high rejection brackish water, or a combination of brackish water and seawater membranes in multiple configurations, are appropriate for the PPS.

Water quality influences are likely due to the adjacent estuary, and this indicates that a safety factor should be considered to account for potentially higher TDS during dry periods. Allowing for a potential 50 percent increase in salinity in the analysis of membranes and RO system design, the capability of a RO configuration with brackish water membranes only will consequently be exceeded. Benefits are derived from a design configuration that combines brackish water membranes in the first stage and seawater membranes in the second stage, or a RO design with seawater membranes only. A 50% increase in TDS is consistent with extreme conditions which may occur in the slough.

3.0 BARDP RO Technology Evaluation

Membrane elements typically used for pilot systems proposed for the BARDP are 4-inch diameter, 40-inch long, spiral-wound, high rejection, thin film composite material. The elements for a full-scale system, however, will likely be 8-inch diameter, 40-inch long, based on current technology. To select the preferred pilot scale configuration, it is therefore important to consider the probable configuration of the full-scale system and associated design parameters, major issues, and system sensitivities.

3.1 Approach

The approach MWH has followed for this evaluation involves the application of existing water quality data with RO manufacturer projection tools. These programs are desktop computer models developed to construct the proposed RO system. Feedwater quality is used to consider various RO elements and configurations, and to project the feed pressures, permeate water quality, scaling, and other sensitivities. The computer models are provided by all of the major RO element manufacturers, and enable rapid analysis with a high level of accuracy. The models are frequently updated by the manufacturers to incorporate full-scale test data. Key parameters are addressed below and are further defined in this document.

3.1.1 Flux

The average flux of the entire system, i.e. the system permeate flow rate related to the total active membrane area of the system, is a common system design parameter. Flux is controlled by the net driving pressure, water temperature and water permeation coefficient (Kw, which is also the water mass transfer coefficient). Water flux typically increases approximately 3 percent for each degree Fahrenheit increase. Based on the materials and construction, each membrane will have its own water permeation coefficient. Net driving pressure is the net applied pressure, which is the difference between the feed and permeate pressure, minus the average osmotic pressure. The design permeate flux affects the number of membrane elements installed, number of pressure vessels, manifold connections and the size of membrane skid.

3.1.2 Recovery

The recovery rate is the ratio of the permeate flow to the feedwater flow. The permeate recovery rate has the largest effect on capital an operating cost. The feed flow is inversely proportional to the design recovery rate; therefore the recovery rate directly affects the size and cost of all process equipment, chemical and power consumption. However, in RO systems, the recovery rate cannot be increased without consequences, as higher recovery results in higher average feed salinity, which results in higher osmotic pressure and increased permeate salinity. By balancing the capital and operating costs with scaling limits and water quality characteristics, the recovery is optimized to the highest percentage possible.

3.1.3 Stages/Array

A membrane array is the number of stages connected in series (concentrate from the prior stage is feedwater to the next stage) based on the design flux, capacity of each train and permeate recovery rate. Every stage consists of a certain number of pressure vessels, in parallel. The number of stages is a function of the planned recovery, the number of elements per vessel, and the source water quality. In general, the permeate recovery rate R is:

Single stage $\leq$ 50 percent

Two stage 50 < R $\leq$ 75 percent

Three stage > 75 percent

3.1.4 Single versus Two Pass

The most common RO system configuration is single pass, meaning permeate is produced from a RO membrane in one step. This configuration is widely used when the feedwater salinity is fresh or brackish, or when the permeate water quality goals can be met without the need to further reduce any specific analyte or group of analytes using RO or any other treatment process. In feedwaters with ocean water influence, the parameters that most influence the level of treatment required are chloride and boron.

3.2 Preliminary Analysis

The preliminary analysis based on the source water quality data shown in **Table 2-2**, which does not include boron, indicates that a chloride level of 100 mg/L could be met in a single pass without blending permeate with other drinking water sources prior to distribution. If additional water quality data currently being gathered from Mallard Slough indicates higher salinity or significant boron presence, or if another site is selected for the full-scale desalination facility that has greater ocean water influence, then part of the permeate may require additional treatment in the form of a second-pass RO system.

The flux and recovery rates recommended in **Table 3-1** represent the range typically applied on RO systems operating on similar source water. Flux and recovery may be varied during the pilot study because these parameters impact performance, capital costs and operational costs. On one hand, capital costs will generally decrease with higher flux and recovery, but on the other hand, operational costs will increase with higher flux and recovery (more power requirements and more chemical cleanings due to higher fouling rates).

Table 3-1: Initial RO Performance Criteria

Parameter	**Units**	**Performance Goals**
Chlorides	mg/L	< 100
Flux	Gfd	10 – 16
Recovery	percent	>75
Feed pressure	Psi	< 800 psi

Chemical Pretreatment	mg/L	Antiscalant and/or Acid Addition
Number of Passes	each	One
Permeate Flow	gpm	To be determined
Feed Salinity	mg/L	2,500 to 11,000
Feed Temperature	Deg F	50 to 80

Once major design criteria for the system were established, the RO manufacturers were selected. Based on a high level of global experience, recent experience in both brackish and seawater desalination, and a review of the aforementioned pilot studies, four membrane suppliers were selected for the subsequent evaluation

3.3 RO Membrane Element Selection

As previously noted, membrane elements for the PPS will be 4-inch diameter, 40-inch long, spiral-wound, high rejection, thin film composite material. Four membrane suppliers were considered for this evaluation:

- Dow/FilmTec Corp.
- Hydranautics Corp.
- Koch Membrane Systems
- Toray Membrane, Inc.

Each membrane manufacturer was provided source water quality data for Mallard Slough and worked closely with MWH to develop RO system models that would produce RO permeate with the chloride level not to exceed 100 mg/L. Alternative models were developed, based on a low feedwater salinity of approximately 2500 mg/L and high feedwater salinity of 7,200 mg/L to 11,000 mg/L; low feedwater temperature of 50°F; and high feedwater temperature of 80°F. The models included a range of seawater, brackish and nanofiltration membranes.

A review of the RO manufacturer's models led to the decision to limit the membrane selection to seawater and brackish water membranes. To meet the water quality target level for chloride, the use of nanofiltration membranes would have a significant impact on the flux and recovery, resulting in higher capital costs. NF membranes were effectively ruled out from further consideration.

A number of RO design configurations were then modeled and analyzed for the desktop evaluation. The RO membrane elements used in the RO design configurations evaluation are listed in **Table 3-2**.

Table 3-2: RO Membrane Manufacturer's Recommended System Configurations

RO Membrane Manufacturer	Elements	Membrane Type and Array	Membrane Cost Per Element*
DOW/Filmtec	Brackish: BW30-4040 XLE-440i Seawater: SW30XLE-400i SW30XLE-1200i	2 Stage Array: Seawater (all stages) OR Brackish (first stage) Seawater (second stage)	Brackish: 4-inch BW - $250 8-inch XLE440i - $600 Seawater: 4-inch SW - $400 8-inch SW - $700 16-inch SW - $3500
Toray	Brackish: TM720 Seawater: TM820L	3 Stage Array: Brackish (first 2 stages) Seawater (last stage)	Brackish: 4-inch $205 8-inch $450 (400 ft^2) 16-inch $1800 Seawater: 4-inch $225 8-inch $575 16-inch $2200
Hydranautics	Brackish: CPA3-LD Seawater: SWC5	3 Stage Array: Brackish (first 2 stages) Seawater (last stage)	Not Available
Koch	Brackish: 4820HR 4820XRCPA3-LD Seawater: 8822SS-365	2 Stage Array: Seawater (both stages) OR Brackish (first stage) Seawater (last stage)	Brackish: 4-inch $200 8-inch $505 Seawater: 8-inch $560

*Approximate cost per single element is based on information currently available from each vendor and is provided herein as a guideline only. Actual price will vary depending on the complete package of services requested from the vendor.

3.4 Major Issues Identified in RO System Evaluation

Different arrays identified for each RO manufacturer are summarized in **Table 3-2**. Results of the analyses showed the following major similarities of the systems:

1. Recovery is limited to a maximum of 80% as the salinity increases. If the TDS is between 8,000 and 11,000 mg/L, the last stage pressures rise significantly and will require a reduction in recovery of the system. Higher recoveries are possible at lower salinity levels. However, a formal recovery analysis based on scaling potential has not been possible since the water quality existing data is not complete. A full scaling analysis will be completed prior to the finalization of the pilot design and operation, based on the water quality data currently being collected.

2. Interstage boosting is needed on either the last stage, or between all stages. Boosting is necessary to accommodate the variations in salinity that are modeled herein.

3. Seven elements per vessel is the most optimum vessel arrangement.

4. Higher salinities in the feed water cause the pressure and permeate quality limits on the brackish elements to be reached. Seawater elements in general showed a better permeate quality, but would require a pressure penalty under lower salinity conditions.

5. Two stages may be possible for this array, but a three stage array may allow more flexibility in design, allow better permeate quality, and limit feed and interstage pressures. A full analysis of these interrelationships is identified for the pilot study and to confirm the staging arrangement of the pilot.

Overall, the single most important factor in this design is the variation in salinity of the feed water. If the variation or range is great, it will necessitate a more robust or complex design of the system. In addition, as the salinity increases beyond approximately 6,000 to 9,000 mg/L TDS, the system must be designed favoring seawater elements. Focusing on the variations and levels of the TDS and their effects on the pressures and permeate quality is the key to the pilot testing.

To further illustrate the differences in the design configurations, estimated specific energy use at 50^{o}F and 80^{o}F source water temperature, and 80% recovery for each design configuration are shown in **Table 3-3**. This table illustrates differences between the pressures required for the seawater membranes, even operating under brackish water conditions, and the pressures required for brackish elements.

Table 3-3: Projected Energy Use

RO Design Configuration	50^{o}F Source Water Temp.	80^{o}F Source Water Temp.

1st stage: high recovery brackish membrane 2nd: stage: high recovery brackish membrane	4.02 kWh/kgal*	3.33 kWh/kgal*
1st stage: seawater membrane 2nd stage: brackish membrane	8.06 kWh/kgal**	6.30 kWh/kgal**
1st stage: brackish membrane 2nd stage: seawater membrane	7.11 kWh/kgal**	5.75 kWh/kgal**
1st stage: seawater membrane 2nd stage: seawater membrane	7.18 kWh/kgal* 7.30 kWh/kgal**	4.84 kWh/kgal* 5.91 KWh/kgal**

*Based on average TDS 6,500 mg/L
** Based on average TDS 11,000 mg/L.

3.5 General Considerations for the BARDP PPS

The intent of the RO technology evaluation will be to compare and assess the differences in RO performance and permeate water quality of alternative RO design configurations. Main design parameters are flux, recovery and array configuration. A membrane system should be designed such that each element of the system operates within a frame of recommended operating conditions to minimize the fouling rate of the membrane and to exclude mechanical damage. These element operating conditions are limited by the maximum permeate flow rate, maximum recovery, the minimum concentrate flow rate and the maximum feed flow rate per element.

The use of pretreatment chemicals and the membrane chemical cleaning chemicals, along with the disposal of the waste streams, can be a significant operating cost. An objective during the pilot study will be to minimize the use of chemicals in the design process and the frequency of chemical cleanings.

All spiral-wound RO membranes have common configurations and typically have limited differences relative to water quality performance and potential fouling. Therefore, only one or two manufacturer's membranes will be selected for use on this project.

Performance criteria directly relates to capital and operating costs as well as the ability to meet finished water quality targets. The performance criteria established for the evaluation of RO design configurations and membrane elements include:

- productivity
- permeate water quality
- chemical cleaning requirements
- total water costs

Productivity is defined by the amount of treated water produced for a given pressure over a given time. Loss of productivity will be determined by assessing the rate of specific flux decline over time of operation. Flux decline is a function of feedwater quality, membrane type, and operational conditions.

Permeate water quality will be evaluated during the PPS to monitor RO membrane performance. MWH will work with the four partner agencies to develop appropriate finished water quality goals.

Periodic chemical cleanings may be required to restore losses in performance of the RO membranes due to fouling or scaling during the 6 to 8 month duration of the pilot study. The need for chemical cleaning of the RO membranes can be determined by monitoring for changes in one or more of the following parameters:

- 10 – 15% decrease in normalized permeate flow
- 10 – 15% increase in feed pressure
- 10% increase in normalized system differential pressure
- 30% increase in normalized salt passage

Chemical cleaning of the RO systems will be in accordance with the RO membrane manufacturer's instructions. The chemical cleanings will be documented in terms of types and quantity of chemicals required, pH of each cleaning solution, duration of chemical cleaning and overall downtime including rinse out period. Conductivity will be used to monitor rinse out steps. Flow and pressure data will be collected before the RO system is shut down for chemical cleaning and after the chemical cleaning is completed. The efficiency of the chemical cleaning will be evaluated by the recovery of specific flux compared to recoveries from previous chemical cleanings, if any.

Membrane aging deteriorates permeate water quality. Over extended periods of operation, the membrane performance will deteriorate due to surface damage (caused by: foulant deposition, oxidation, abrasion of the membrane material and the compounding effects of chemical cleanings). Typically, membrane fouling and salt passage will both increase with membrane age. Since, pilot studies are typically conducted over relatively short periods of time, the effect of membrane age on long-term performance cannot be obtained from the available pilot data. Therefore, information on "nominal" salt passage increment and fouling factors with membrane aging will be obtained from the selected membrane manufacturers.

Total water cost must include capital requirements and operating requirements. Operating conditions such as flux and recovery can be of importance relative to fouling and can be adjusted to ensure sustainability while minimizing costs. During the course of the PPS, operational variables would be adjusted to determine the rate of RO fouling; associated membrane cleaning frequencies; and the optimal design which maximizes permeate quality and recovery, and which minimizes chemical cleaning and energy consumption. In addition, the impact of seasonal and tidal effects and expected variations in the feedwater composition on the RO system performance will be assessed.

4.0 Recommendations

The BARDP pilot study will encompass six months in which the short-term and long-term operation of the MF/UF pretreatment and RO systems will be monitored. The analysis of the RO design configurations focused primarily on incorporation of all the parameters that influence the finished water quality with the goal of achieving a target level not exceeding 100 mg/L chloride in the RO permeate.

Each of the two RO systems proposed for the PPS will be comprised of a raw water booster pump, a cartridge filtration system, a high pressure pump, pressure vessels with 4-inch diameter membranes, chemical feed tank and pumping, and instrumentation. Interstage boosting will be evaluated for inclusion, based on the results of the sensitivity analysis. Seven element vessels are recommended for full-scale simulation.

Several design possibilities have been considered for treating the source water at Mallard Slough. In order to achieve a sufficiently robust pilot process for treating source water with a TDS potentially 50% higher than the current source water quality data indicates, and also to achieve a system that is representative of a design for a source water with potentially greater ocean water influence, the recommended design configurations to be considered are:

- 2-stage RO system design with brackish membranes in first stage and seawater membranes in second stage.
- 2-stage seawater membranes in both stages.

While two complete systems are recommended for the PPS, MWH will consider substituting another manufacturer's elements during the course of the piloting effort, if either the brackish-seawater or the seawater-seawater configurations show indication of failure.

Each RO system will be configured as a single pass, 2-stage RO system, consisting of a 2:1 array of pressure vessels, each pressure vessel containing seven membranes. Brine concentrate from the first stage will be boosted in pressure and then desalinated in a second stage. In a full-scale system, the final concentrate from the second stage could then be passed through an energy recovery device to recover residual pressure.

During the design and evaluation of the proposed pilot equipment, and with the additional water quality data currently being developed as part of Task No. 3 for dry weather and wet weather conditions, two stage and three stage arrays will be revisited. If it becomes apparent that there is an advantage or disadvantage of testing one over the other for this water, suggested modifications to this strategy will be brought forward to the partner agencies. In addition, more than one manufacturer will be considered for the pilot testing, to understand the effects of the permeate qualities and fouling potential of the water. However, it should be reiterated that the most important factor of this water is the salinity variation, and testing multiple manufacturers is a secondary issue.

Two stages are the preliminary selection for the pilot based on the model runs. As a rough rule, the number of stages decreases as salinity increases, which in turn reduces the recovery of the system. As feedwater is concentrated through the stages, the permeate quality degrades and the pressure needed to "push" the water through subsequent stages becomes prohibitive. In lower salinity water, such as may be encountered at Mallard Slough, three stages might be a more optimum approach. However, if the view is to collect beneficial data for a full-scale facility that is most likely to have water with higher salinities, and is closer to the seawater level, then a three-stage system will not be considered. Thus, MWH would take a careful look at how the data will be collected in a two stage array of the pilot system and determine how to best use this for scale-up, while at the same time collecting sufficient information to model the Mallard Slough water and to apply this data to the other full-scale sites under consideration.

Bay Area Regional Desalination Project
Pilot Study at Mallard Slough

DRAFT

Subject:	**Nanofiltration (NF) Evaluation** **Technical Memorandum No. 4B**		
Prepared by:	Mary Carr, P.E., MWH MCP	**Reference:**	1481449/6.2.4
Reviewed by:	Stefani Harrison, P.E. MWH Charlie Bromley, P.E., MWH	**Date:**	July 28, 2008

As requested by EBMUD and the partner agencies, a preliminary evaluation was conducted for potentially substituting nanofiltration (NF) membranes into RO Train No. 3, in lieu of brackish elements as is currently being implemented. The evaluation included gathering information from a recent desalination report for the Delta Diablo Sanitation District (DDSD) and from the ongoing City of Long Beach prototype project, and from process engineers with Dow/Filmtec and Nitto Denko/Hydranautics. MWH then ran pilot scale projections to determine projected operational and water quality performance using manufacturer RO element performance modeling software.

Previous Work by Others

In 2005 a report was prepared for DDSD evaluating Dow/Filmtec NF90 nanofiltration membranes in series with BW30 brackish RO membranes for seasonal salinity reduction for Sacramento Delta water. We contacted the consulting engineer (now retired) who prepared the paper study to confirm the specific membranes which were studied at that time.

The Long Beach Water Department Prototype Seawater Desalination Testing Facility is evaluating NF and RO side-by-side on seawater. Dow/Filmtec and Hydranautics have both provided membranes for the test but have not otherwise been involved in the actual on-site work. Dow/Filmtec provided the NF90 membrane. Hydranautics has provided the BW30 low pressure RO membrane. We briefly reviewed the February 2006 Long Beach test plan and spoke with applications engineers from each RO manufacturer.

Manufacturer Information

Hydranautics was contacted to discuss both the Long Beach Prototype project and to request a NF membrane recommendation for the BARDP pilot study. Three choices of NF membranes were recommended by Hydranautics. The new Hydranautics NanoBW membrane could be used but it is not yet currently part of their projection software. Consequently performance on the Mallard Slough source water cannot be firmly predetermined. The ESNA1 LF1 and ESNA1 LF2 nanofiltration membranes are available, with the LF2 model featuring the highest salt rejection of all three Hydranautics NF membranes. The NanoBW membrane features the lowest salt rejection of the three choices, and would be rejected on this basis even if it were incorporated into the projection software.

The Hydranautics BW30 low pressure RO membrane in use at Long Beach could be considered for the BARDP pilot; however, RO Train No. 1 already features a low pressure brackish RO element. MWH consequently elected to consider the ESNA1 LF2 for this project.

Dow/Filmtec was contacted to discuss the DDSD Report and Long Beach Prototype project (see above) and to request a NF membrane recommendation for the BARDP pilot study. Dow/Filmtec engineers recommended the NF90 nanofiltration membrane, which is the same membrane used for both of the above referenced studies. It has the highest salt rejection of Dow/Filmtec's NF membranes. Other choices, such as the NF210 and NF270, are looser membranes primarily used for color and hardness reduction and thus would not be suitable for the BARDP pilot test and would not meet finished water quality goals.

MWH Membrane Performance Projection Results

Membrane performance projections were conducted between the Dow/Filmtec NF90 and the Hydranautics ESNA1 LF2 membranes to evaluate proposed BARDP operating conditions and finished water quality under various operating and water quality conditions.

Design parameters for the NF projections which match the pilot conditions are summarized below:

- Average array flux: 14 gfd (highest flux allowable by Hydranautics software).
- Temperature: 50^{o}F (worst case).
- pH: 8.4 (worst case without acid addition).
- NF pilot configuration: single stage array, 6 element vessel.
- Element size: 4-inch.

Membrane operating conditions and performance were projected for four water quality scenarios as shown in **Table 1**. Minimum, Average and Maximum water quality data were previously developed for the project in Technical Memorandum No. 3A, dated November 21, 2007 and subsequently distributed to the partner agencies.

Assuming a maximum TDS of 11,000 mg/L which might be encountered during the pilot study (as determined based on a review of Suisun Estuary water quality data), an Adjusted Maximum water quality condition is also developed and modeled. A factor ranging from 1.5 to 2.0 is used to revise various anion and cation levels to achieve the desired 11,000 mg/L TDS level, so that performance projections can be adequately completed.

Table 1 – Water Quality

Parameter	Unit	Minimum	Average	Maximum	Adjusted Maximum
Ca	mg/L	3.9	35.2	276	400
Mg	mg/L	5.6	78.7	190	500
Na	mg/L	10	595.2	1600	2800
K	mg/L	1.2	20.2	200	300
NH_4	mg/L	0.1	0.1	0.2	0.4
CO_3	mg/L	0.22	1.3	3.14	8.42
HCO_3	mg/L	22	61.6	82	140
SO_4	mg/L	10	151.5	420	600
Cl [1]	mg/L	13 (19.38)	766 (1078)	3100 (3328)	6215 (6219)
NO_3	mg/L	.2	1.5	3.7	5
SiO_2	mg/L	13	17	23	23
TDS [1]	mg/L	70 (86)	2138 (2040)	5737 (6126)	10992 (10996)

Note 1: numbers in parentheses represent adjustments taken to achieve an appropriate ion balance.

Membrane performance and operating conditions are summarized in **Table 2**. Recovery was adjusted to the maximum value allowed by the projection software. Comparison of the two membranes shows that the Dow/Filmtec NF90 membrane has higher salt rejection than the Hydranautics ENSA1 LF2 membrane. Results also show that the Dow/Filmtec NF90 requires a higher feed pressure than the Hydranautics membrane. This demonstrates that the NF90 is a "tighter" NF membrane and is confirmed by the higher salt rejection capabilities.

Table 2 also illustrates that the BARDP finished water quality goals of 500 mg/L TDS can be met by both membranes, but only under certain water quality conditions. Recovery values shown in the table are generated by the manufacturer software and do not represent true full scale design values. All values in the table require pilot confirmation using the actual source water.

Findings

Because of the higher salt rejection capability, the Dow/Filmtec NF90 is an appropriate NF membrane to be pilot tested at the BARDP pilot facility, within RO Train No. 3 as has been previously targeted by MWH and partner agency staff. This membrane also has the capability of meeting other project finished water quality goals.

We anticipate that seven to eight of the Dow/Filmtec NF90 elements (six elements plus one or two spares) will be purchased and loaded into RO Train No. 3, depending on availability. These will replace the Toray brackish membranes which were previously recommended. We also anticipate that project cost will increase by a few thousand dollars, as NF membranes are normally more expensive than the proposed RO elements. Project delays and possibly other costs may be incurred if modifications to the high pressure pumps or control valves currently being purchased and installed on the pilot skids are required. This may result from the lower NF feed pressure, as compared to the brackish elements currently used as the basis of design. We will keep you informed should this occur.

Table 2 – Projected RO Performance and Operating Conditions

		Dow/Filmtec NF90				Hydranautics ENSA1 LF2			
	Unit	Min	Avg	Max	Adj. Max	Min	Avg	Max	Adj. Max
Recovery [1]	%	57	60	58	42	60	60	58	40
Feed Pressure	psi	87	124	198	260	69	94	146	201
Permeate TDS	mg/L	2.79	90	261	376	11	488	1444	2270

Note 1: Recovery values shown in the table are generated by the manufacturer software and do not represent true full scale design values.

Please review this matter at your earliest convenience. We will await your confirmation of this deviation in the project approach before proceeding further with substituting NF membranes for RO Train No. 3.