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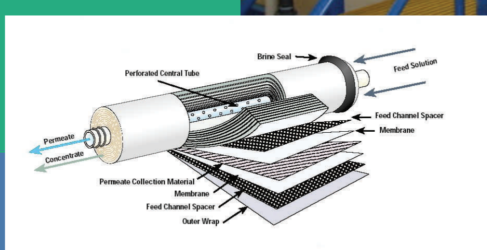
Desalination Program

Santa Cruz Water Department • Soquel Creek Water District

Seawater Reverse Osmosis Desalination Pilot Plant Tour

Santa Cruz, CA



December 2007

CDM

Tour Agenda

1. Introductions
2. Overview of the pilot plant program
3. Exterior equipment and tanks
4. Flocculation and sedimentation tanks
5. Granular media filters
6. Pressure ultra-filtration membrane system
7. Submerged ultra-filtration membrane system
8. Reverse osmosis membrane system
9. Remaining questions

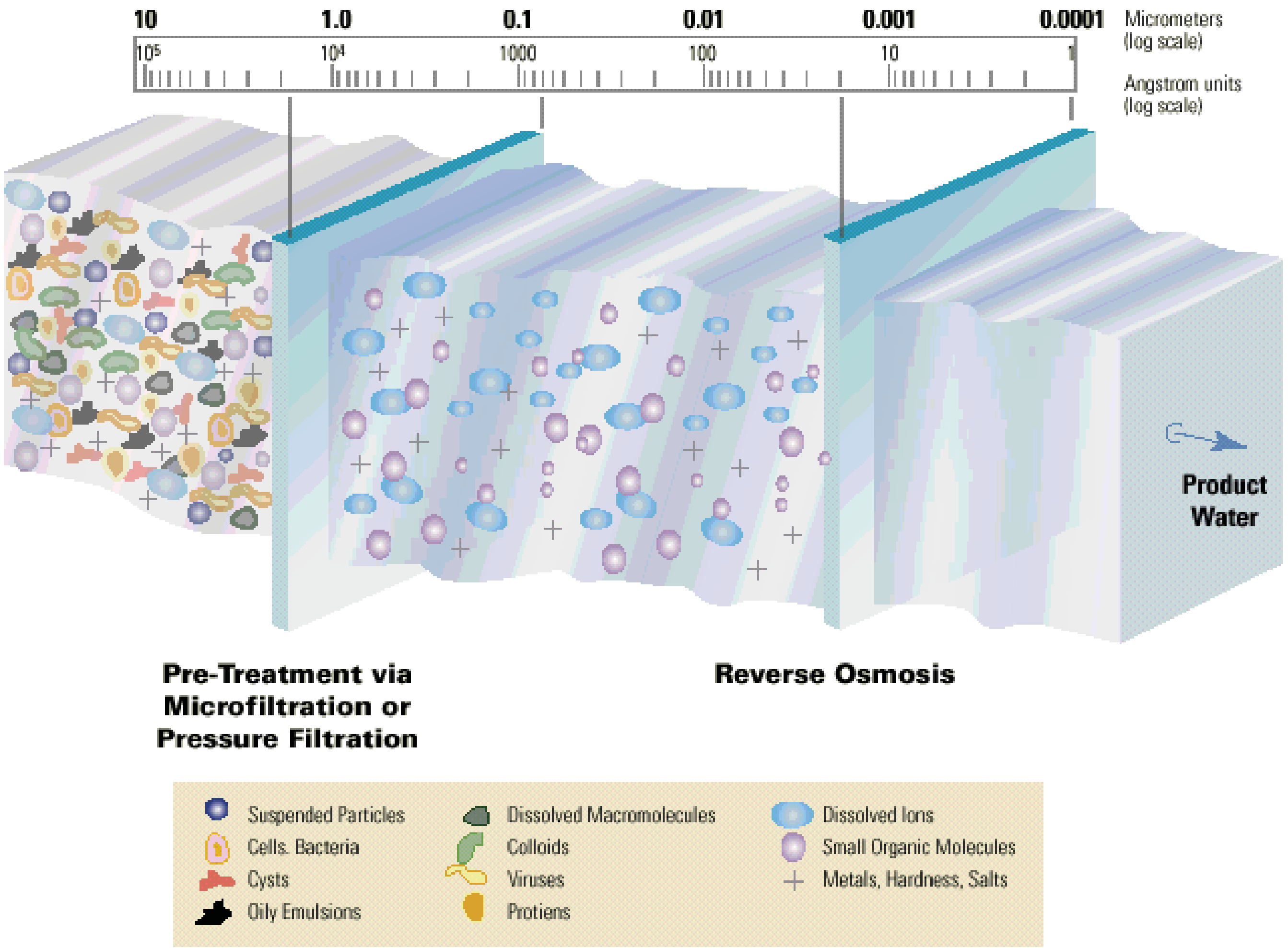
Objectives of the Pilot Plant Testing

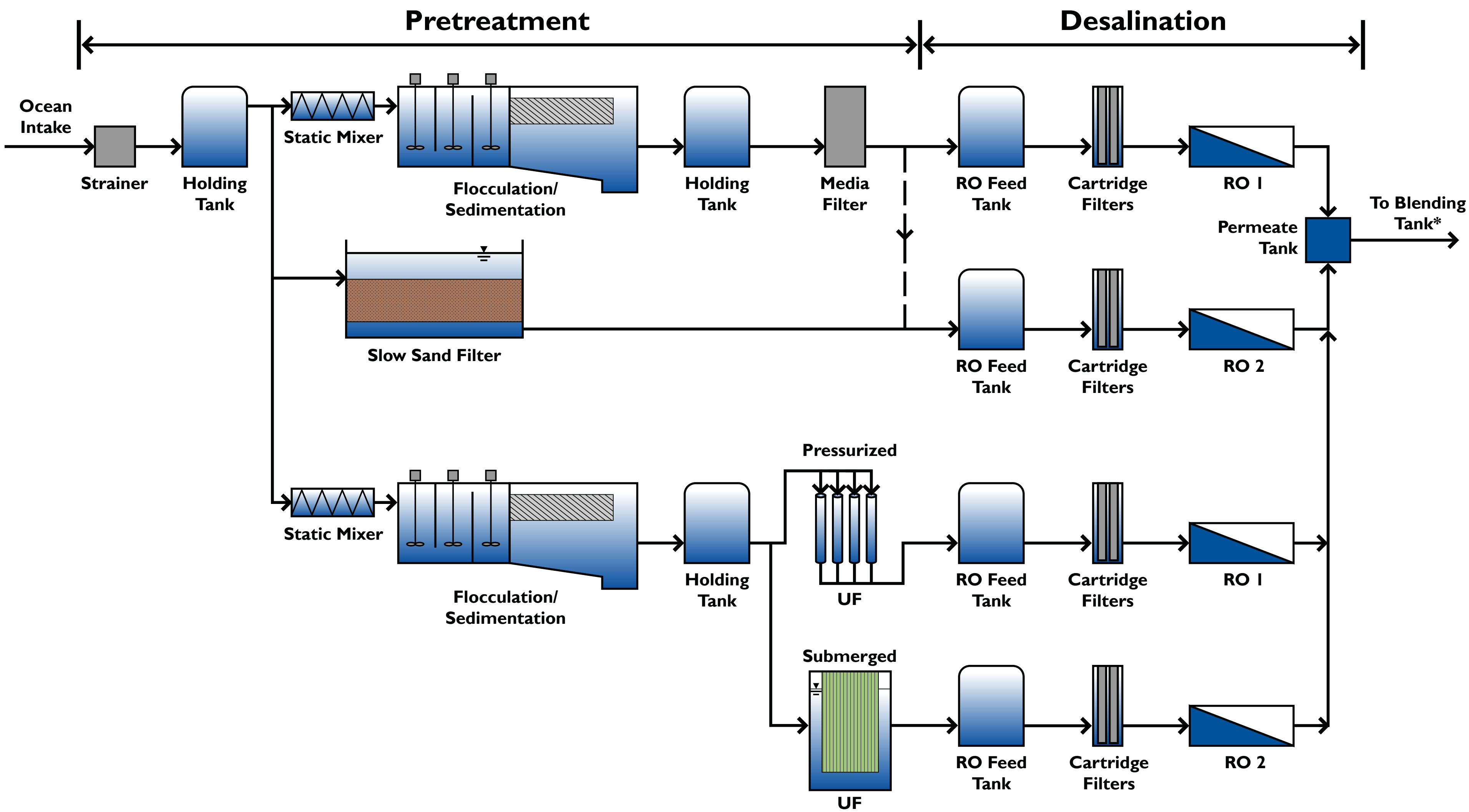
- Demonstrate innovative and cost-effective desalination technology
- Evaluate treatment alternatives and innovations
- Assess process alternatives based on reliability and expected life-cycle costs
- Provide data requested for regulatory approval and permitting
- 12 months of testing and water quality monitoring

Seawater Desalination Treatment

- **Pretreatment:** Incoming feedwater is screened, clarified and filtered to remove particulates and organic matter.
- **Desalination:** Feedwater is pumped into a closed container, to pressurize it against reverse osmosis membranes. Membranes inhibit the passage of dissolved salts while permitting the desalinated product water to pass through.

What is Removed from the Seawater?

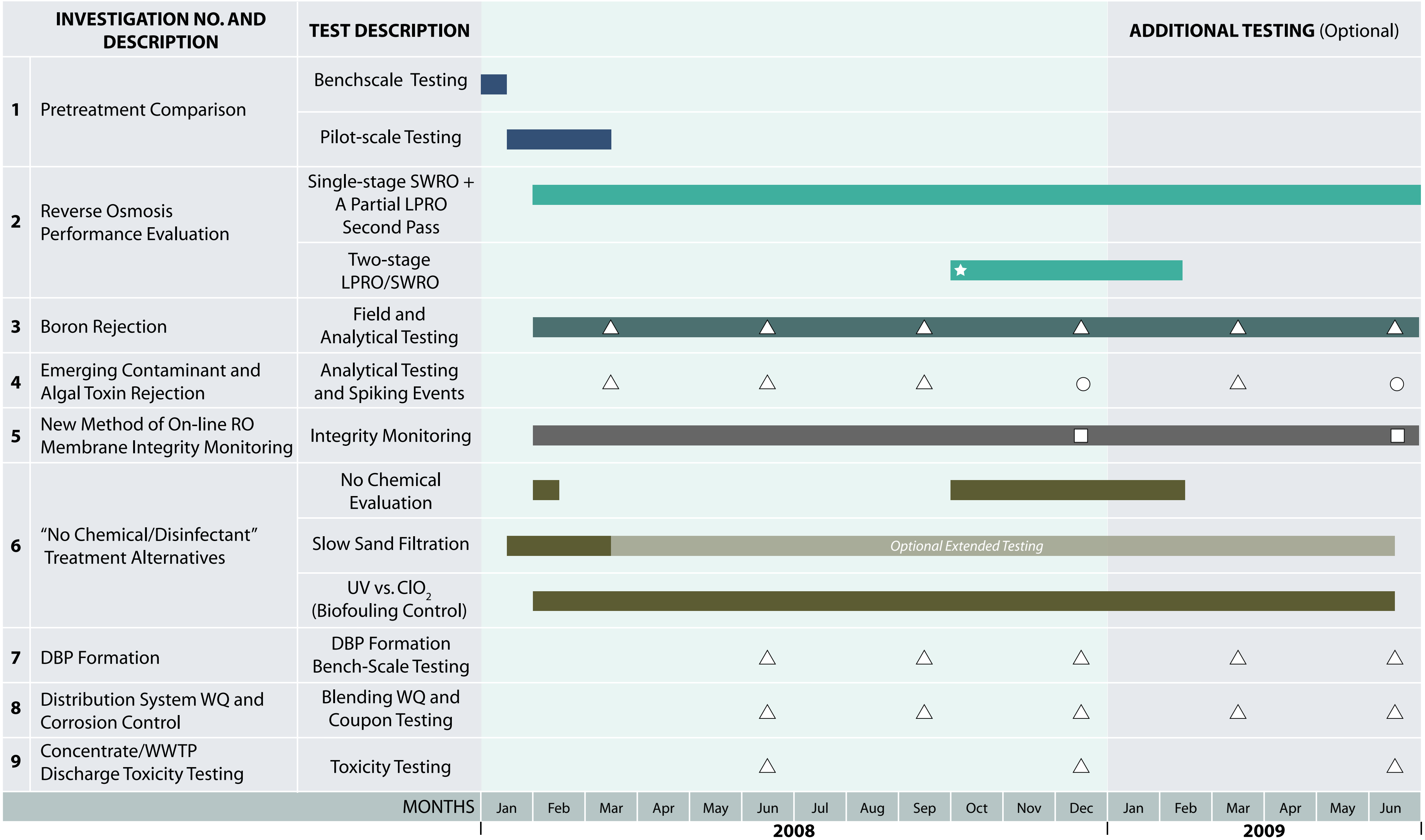




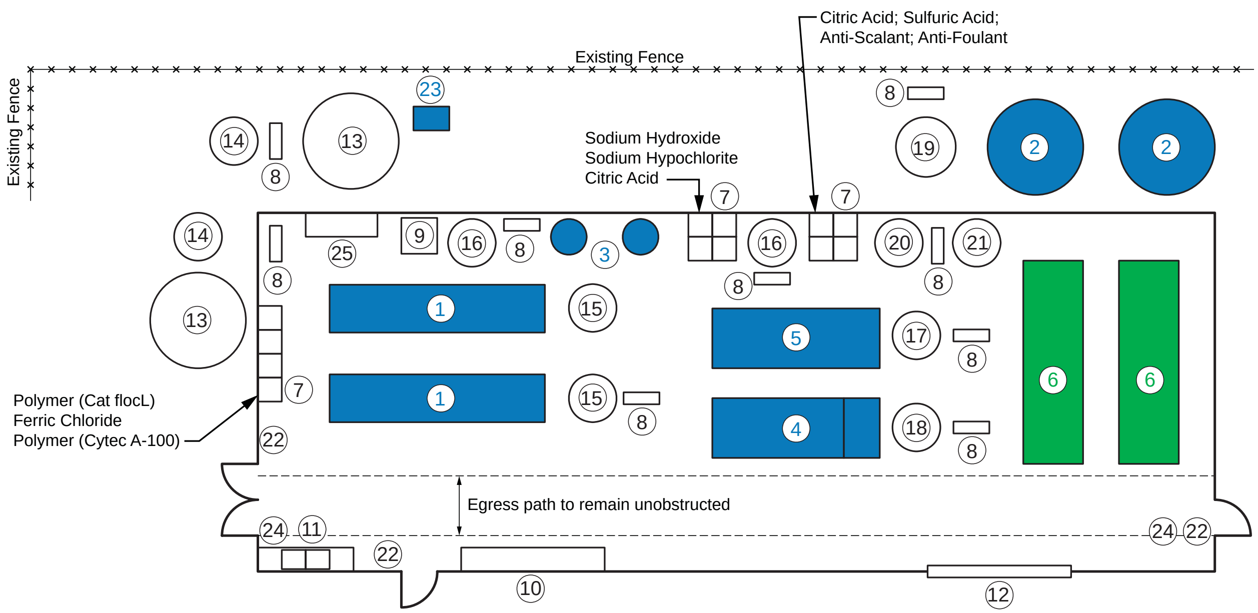
* RO Permeate and RO Concentrate are mixed in the blending tank and then discharged to the LML Seawater system

Pilot Plant Flow Schematic

(Chemical Addition and Pumping Equipment Not Shown)



Pilot Program Investigation Schedule



Legend

1. **Flocculation/Sedimetation Process**
2. **Slow Sand Filters (SSF) (8'Øx8'H)**
3. **Media Filters**
4. **Submerged Ultrafiltration System (Zenon)**
5. **Pressurized Ultrafiltration System (Norit)**
6. **SWRO Pilot Modules**
7. Chemical Dosing Equipment
8. Transfer Pumps
9. Air Compressor
10. MCC/Power Distribution Panel
11. Counter with Sink
12. Roll Up Door
13. Raw Water Tanks (8'Øx10'H)
14. Treatment Residuals Tanks (4'Øx10'H)
15. Clarified Water Tanks (4'Øx6 1/2'H)
16. Filtered Water Tank - Media Filter and/or SSF (4'Øx11'H)
17. Filtered Water Tank - MF (4'Øx11'H)
18. Filtered Water Tank - UF (4'Øx11'H)
19. Permeate/Concentrated Blending Tank (5'Øx11'H)
20. Permeate Tank (4'Øx6 1/2'H)
21. RO Cleaning Tank (3'Øx6 1/2'H)
22. Light Switch and Exit Signs
23. **Raw Water Strainer**
24. Fire Extinguisher (2A-10BC Portable)
25. Chlorine Dioxide Generator

Pilot Plant Equipment Layout

Strainer

Arkal Filter in normal filtration mode

The purpose of the strainer is to remove coarse solids (sediments, shell fragments, debris) and protect the desalination pretreatment systems. The pilot plant is equipped with an Arkal disc filter.

The key element of the filter is a plastic disc that is diagonally grooved on both sides to a specific size of 100 microns. A series of these discs are then stacked and compressed on a specially designed spine. When stacked, the groove on top runs opposite to the groove below, creating a filtration element with a statistically significant series of valleys and traps for solids. During the filtration process, the discs are tightly compressed by the force of a spring. Water passes through the stack of discs using an applied pressure of more than 20 psi. Filtration occurs as water travels through the grooves to the center element.

Slow Sand Filters

Slow Sand Filters in Salem, Oregon

Pilot Plant Slow Sand Filter Tank

The purpose of the slow sand filters is to remove organic matter and particulates from the seawater and thus reduce the risk of fouling on the seawater reverse osmosis (SWRO) membranes.

Slow sand filtration is a biological process that cleans water much the way the sandy bed of a river cleans and recharges an aquifer. Water passes through a three-foot layer of fine sand. On the top of the sand, an intense layer of microbes naturally develops. This layer lives by consuming whatever is passing through in the water. In a slow sand filter, this layer, called the *schmutzdecke*, is responsible for removing up to 99.99% of all bacteria, viruses, *Giardia*, and *Cryptosporidium*. It also removes suspended and colloidal particles and organic matter.

A benefit of slow sand filtration is that it requires no chemicals and uses only a fraction of the energy used by other pretreatment processes. A disadvantage is that it requires more land.

The pilot plant is equipped with two slow sand filters. Key design criteria for each filter:

- Feed flow: 8 – 12 gpm
- Filter media type and depth: sand with a total depth of 30 inches
- Filter diameter and area: 8 ft; 50 sq. ft.
- Filtration rate: 0.08 – 0.12 gallons per minute per square foot

Flocculation and Sedimentation Basins

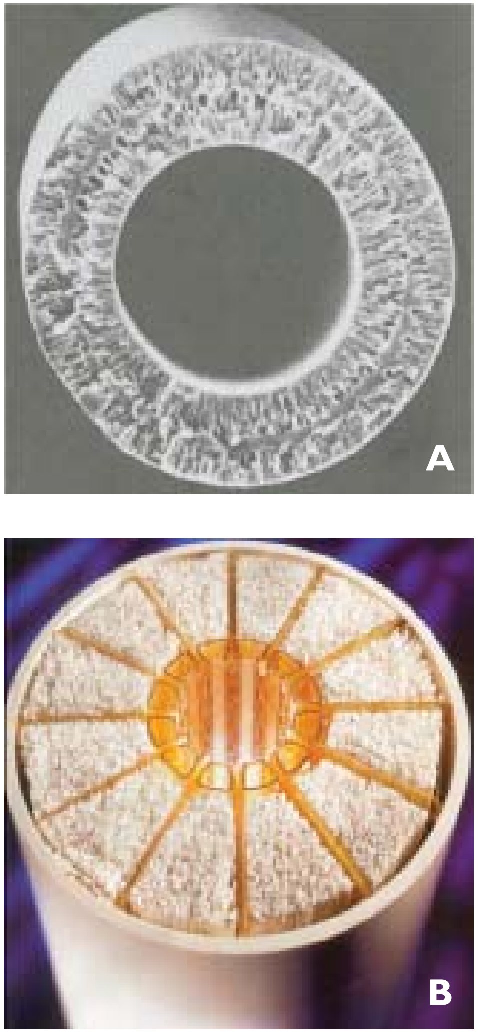
Treatment chemicals are injected into the water and rapidly mixed together as the water flows through a static mixer (baffled pipe element), forming "floc" particles, which resemble a discolored snowflake. The floc particles grow in size as they move through the 3 flocculation tanks, each equipped with a vertical shaft mixer. When the water reaches the sedimentation tank, the floc particles settle at the bottom. The cleaner water travels upward through inclined plates. This entire process takes about 60 minutes. This process not only removes suspended material, but also microbial contaminants that may be living within those particles. There are two trains of flocculation and sedimentation. The flow to each train is 15 - 25 gpm.

Granular Media Filters

The pilot plant is equipped with two pressure granular media filters. These filters receive water from the flocculation and sedimentation tanks and remove any remaining floc particles. Key design criteria for each filter:

- Feed flow: 15 – 25 gpm
- Feed pressure: 40 psi
- Filter media type and depth: sand and/or anthracite goal; total depth of 30 to 40 inches
- Filter diameter and area: 2 ft; 3.1 sq. ft.
- Filtration rate: 3 – 6 gallons per minute per square foot

Overview of Ultrafiltration Membranes



Hollow fiber membranes: (A) scanning electron microscope image of end view with macrovoids for water pasage, (B) example of a hollow fiber module.

The purpose of the ultrafiltration (UF) membranes is to remove organic matter and particulates from the seawater and thus reduce the risk of fouling on the seawater reverse osmosis (SWRO) membranes.

Hollow fiber polymeric UF membranes are most common. These hollow fibers have an inside diameter ranging from 0.4 to 1.0 millimeter (mm) and a wall thickness ranging from 0.07 to 0.6 mm. Each UF module contains thousands of membrane fibers that have millions of microscopic pores in each strand.

UF membranes provide a physical barrier, resulting in more complete removal of particles greater than 0.01 microns. UF membranes have been shown to provide more than 99.99% rejection of *Cryptosporidium, Giardia,* bacteria and virus.

Hollow fiber membranes are operated in either an inside-out or outside-in mode. During inside-out operation, the feed enters the fiber lumen and passes through the fiber wall to generate filtrate. During outside-in operation, the filtrate is collected in the fiber lumen after the feed is passed through the membrane.

Depending upon the way membrane modules are pressurized, they are available in two basic configurations: pressure vessel systems and submerged systems. Pressure systems are operated under positive pressure (between 3 to 35 psi) and submerged systems are under negative pressure (between -1 to -10 psi).

Pressure Ultra-Filtration Membranes

The pilot plant is equipped with a Norit pressure ultra-filtration (UF) membrane system. Key design criteria for the system:

- Feed flow and mode: 8-15 gpm; inside-out operation
- Feed pressure: 40 psi
- Membrane area: 377 or 753 sf. ft.
- Flux (filtration) rate: 20 – 60 gallons per square foot per day
- Membrane material: polyethersulfone (PES)
- Membrane pore size: 0.01 micron

Submerged Ultra-Filtration Membranes

The pilot plant is equipped with a Zenon submerged ultra-filtration (UF) membrane system. Key design criteria for the system:

- Feed flow and mode: 8-15 gpm; outside-in operation
- Feed pressure: -15 psi
- Membrane area: 600-1,800 sf. ft.
- Flux (filtration) rate: 12 – 36 gallons per square foot per day
- Membrane material: polyvinyl difluoride (PVDF)
- Membrane pore size: 0.02 micron

Reverse Osmosis System

The pilot plant is equipped with 2 custom fabricated reverse osmosis (RO) systems. Each system can test 2 different membranes, providing 4 RO trains for the pilot plant. Approximately 50% of the feedwater becomes potable water (permeate). Key design criteria for each RO train:

- Feed flow/permeate flow: 5.5 – 12 gpm; 2.8 – 4.4 gpm
- Feed pressure: 1000 psi
- No. of RO elements per train: 7
- Membrane surface area per element: 70-80 sq. ft.
- Design flux (filtration) rate: 8-12 gallons per square foot per day

View of Reverse Osmosis Membrane