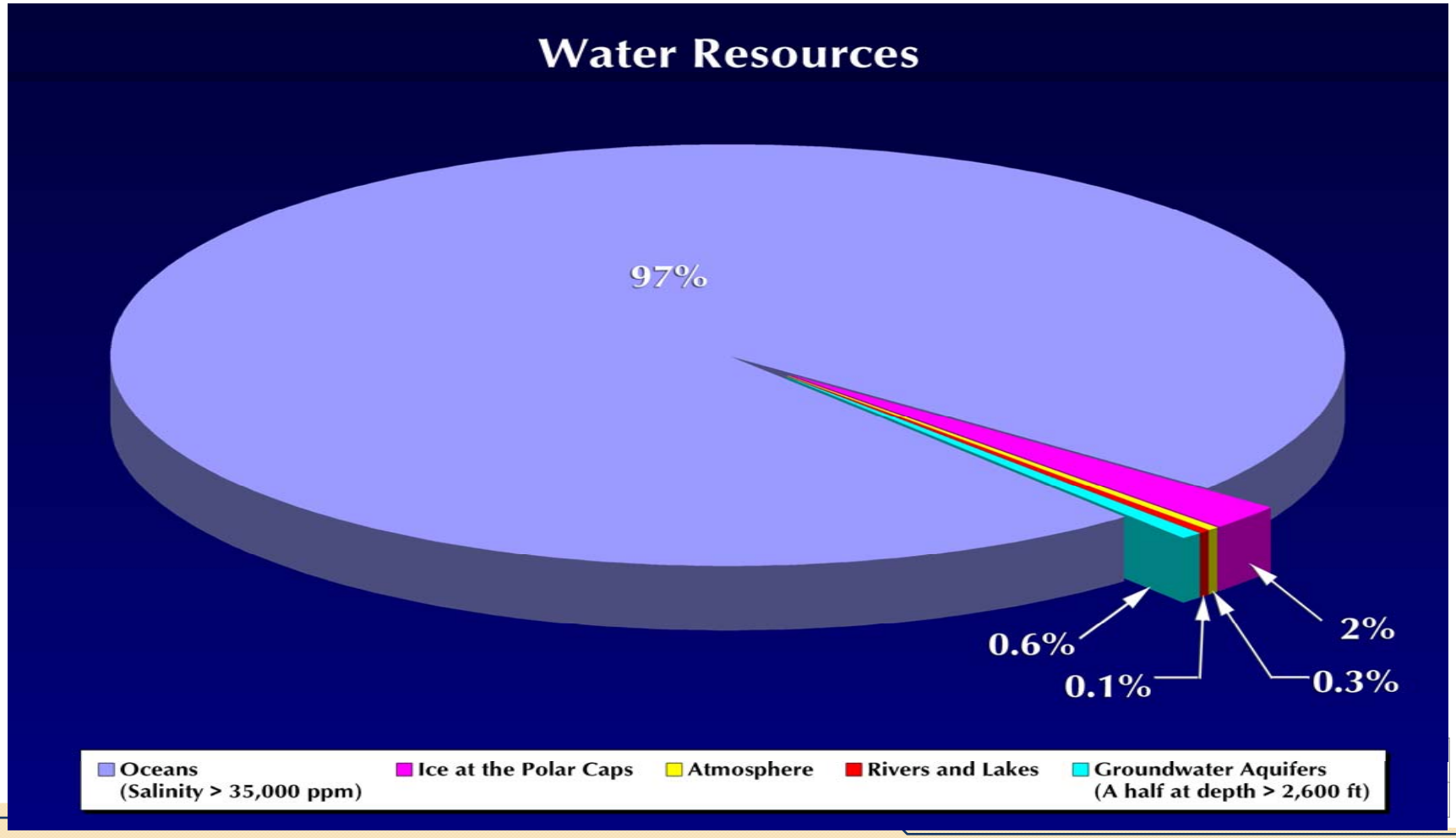
Advanced Membrane Technologies
Stanford University, May 07, 2008

Bay Water SWRO Desalination:
Challenges and Solutions

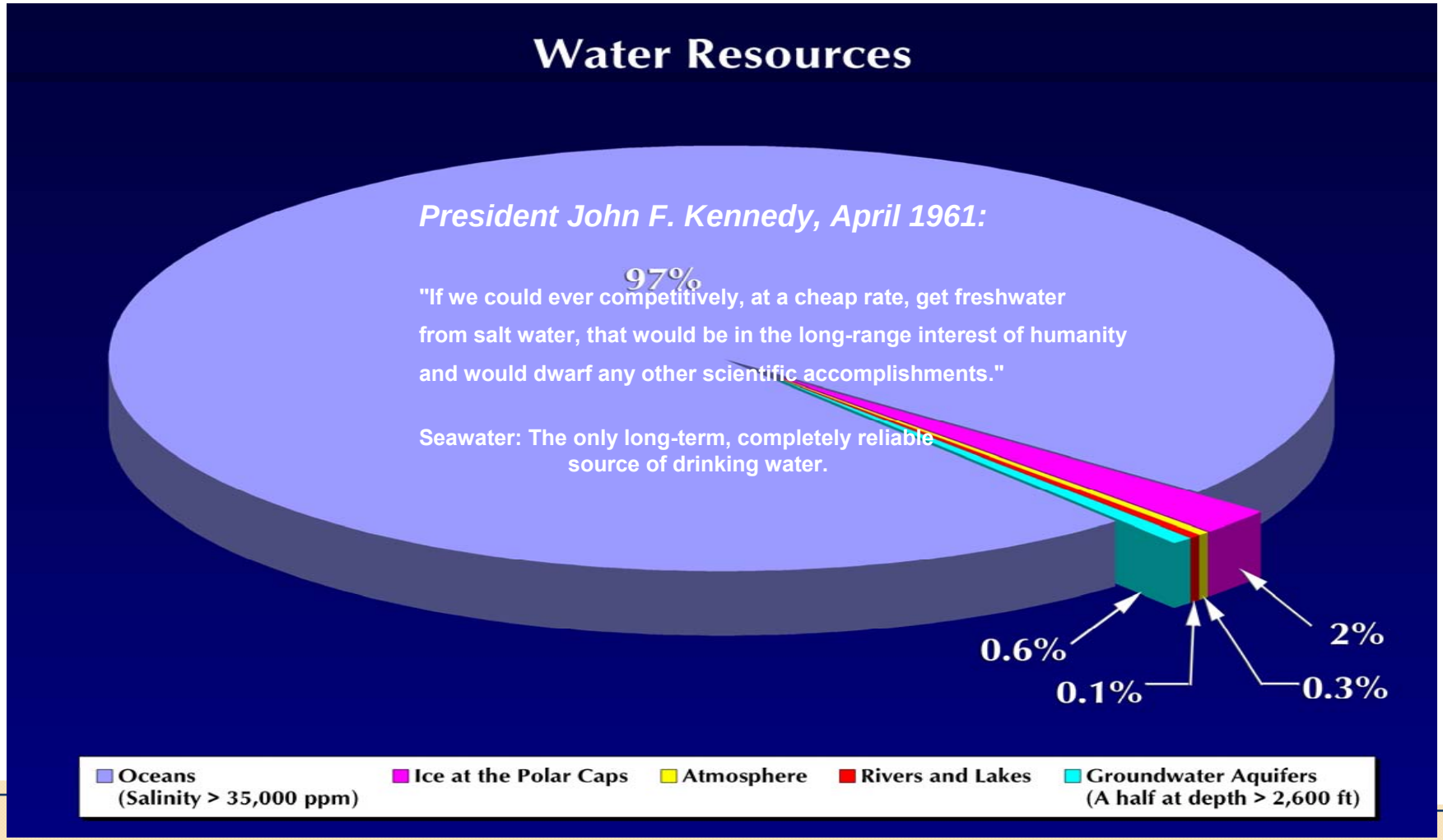
Val S. Frenkel, Ph.D.

Kennedy/Jenks Consultants
Engineers & Scientists
National Water Research Institute

SWRO Provides New Water Sources



SWRO Provides New Water Sources

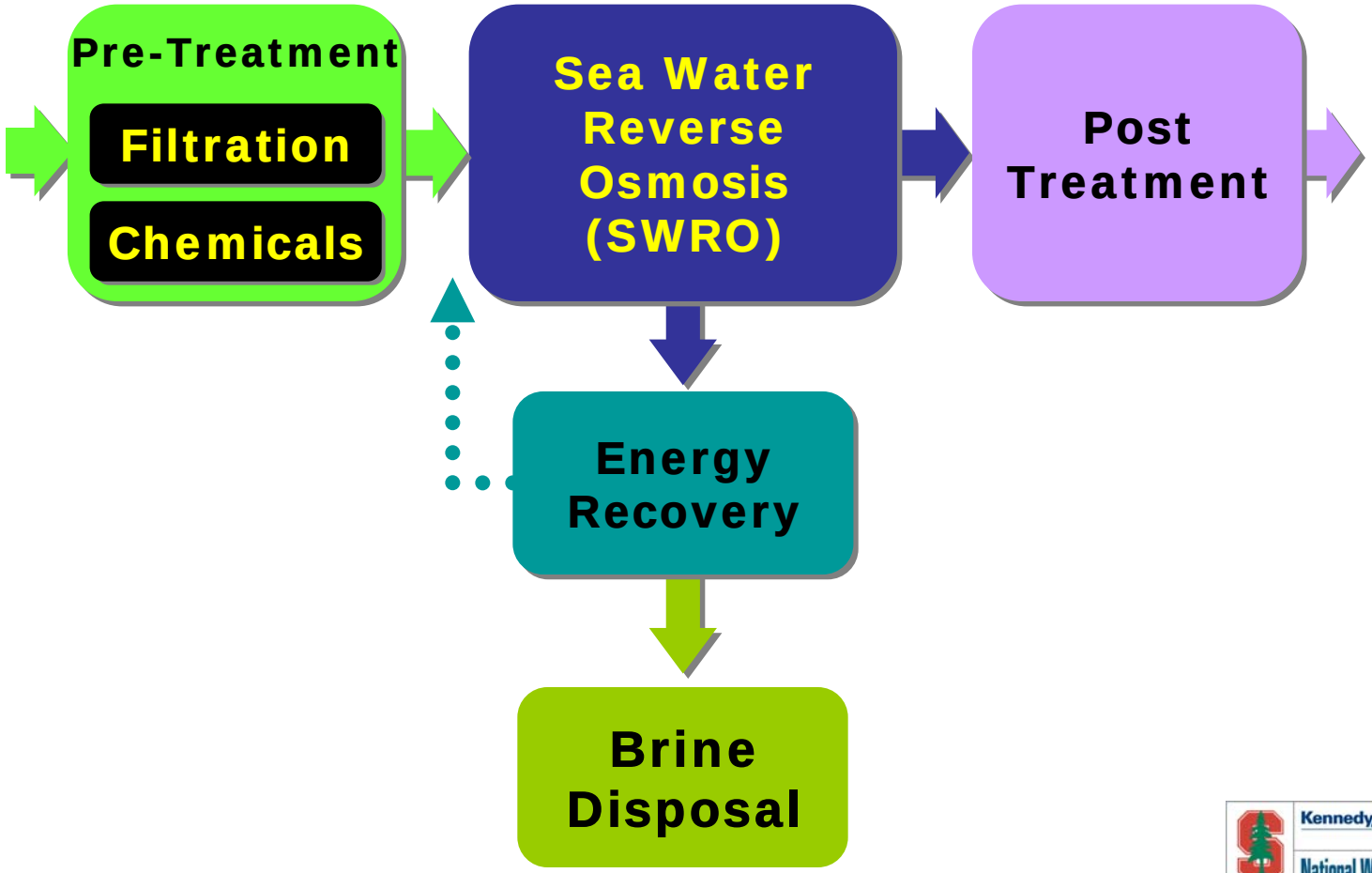


Desalination in 1990 and today

SWRO Advances:

- New commercial membrane pre-treatment – MF and UF
- Energy Recovery Devices from 30% energy savings up to 45%
- New SWRO membrane elements materials (TFC): higher porosity, more uniform pores, salt rejection up to 99.8%, 30% less energy
- New generation of chemicals, including Antiscalents, Dispersants and others, allowing operate SWRO at much higher recovery from 30% to 50% depending on chemistry and TDS
- SWRO membrane elements became commodity which led to reducing 8” x 40” element cost from ~ $ 2,000 to ~ $ 500.
- Overall reduction in capital cost and O&M makes SWRO acceptable standard in water desalination
- Number of SWRO plants overcomes thermal desalination

The Technical Desalting Process…



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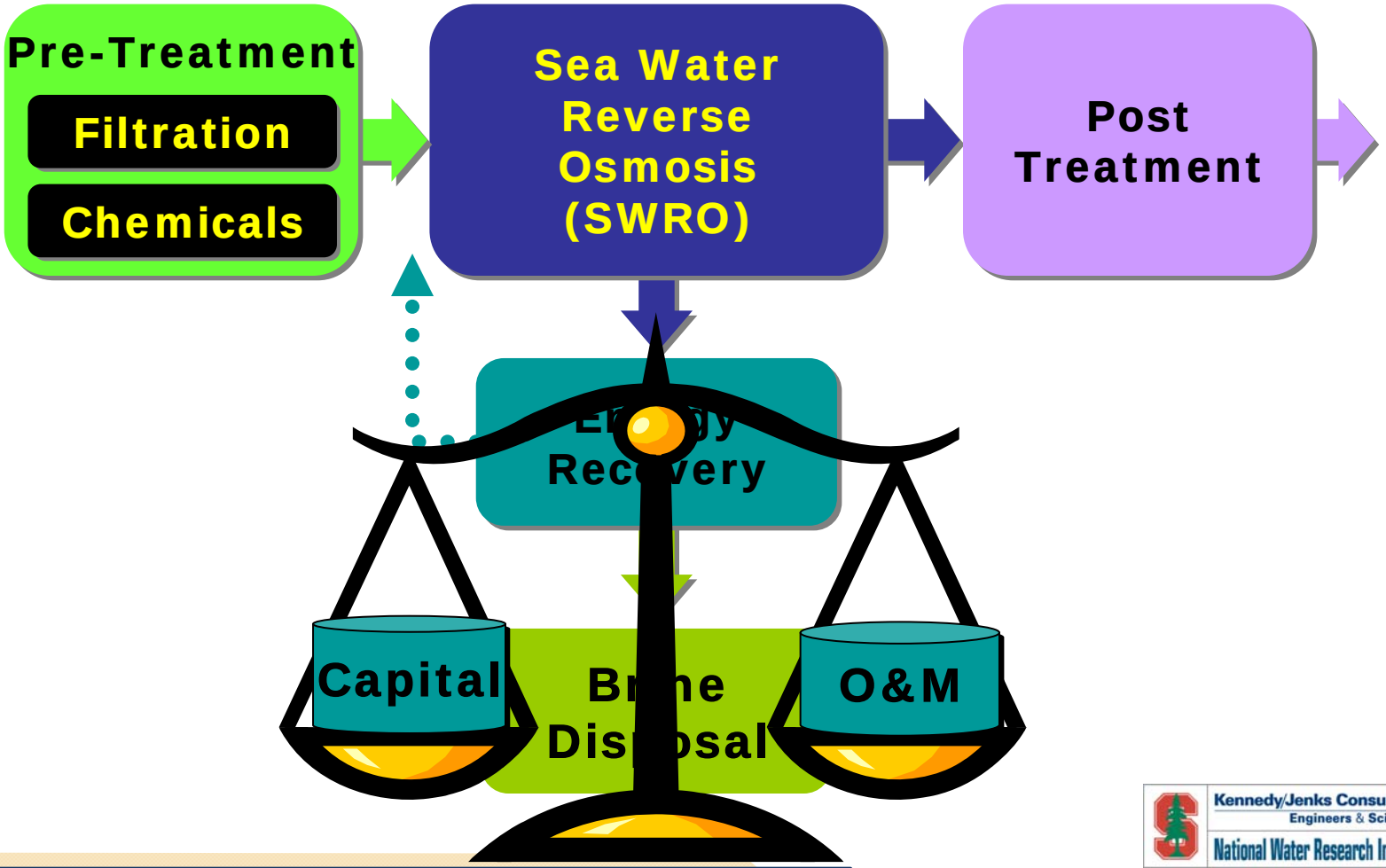
…Is Balanced On Cost Considerations



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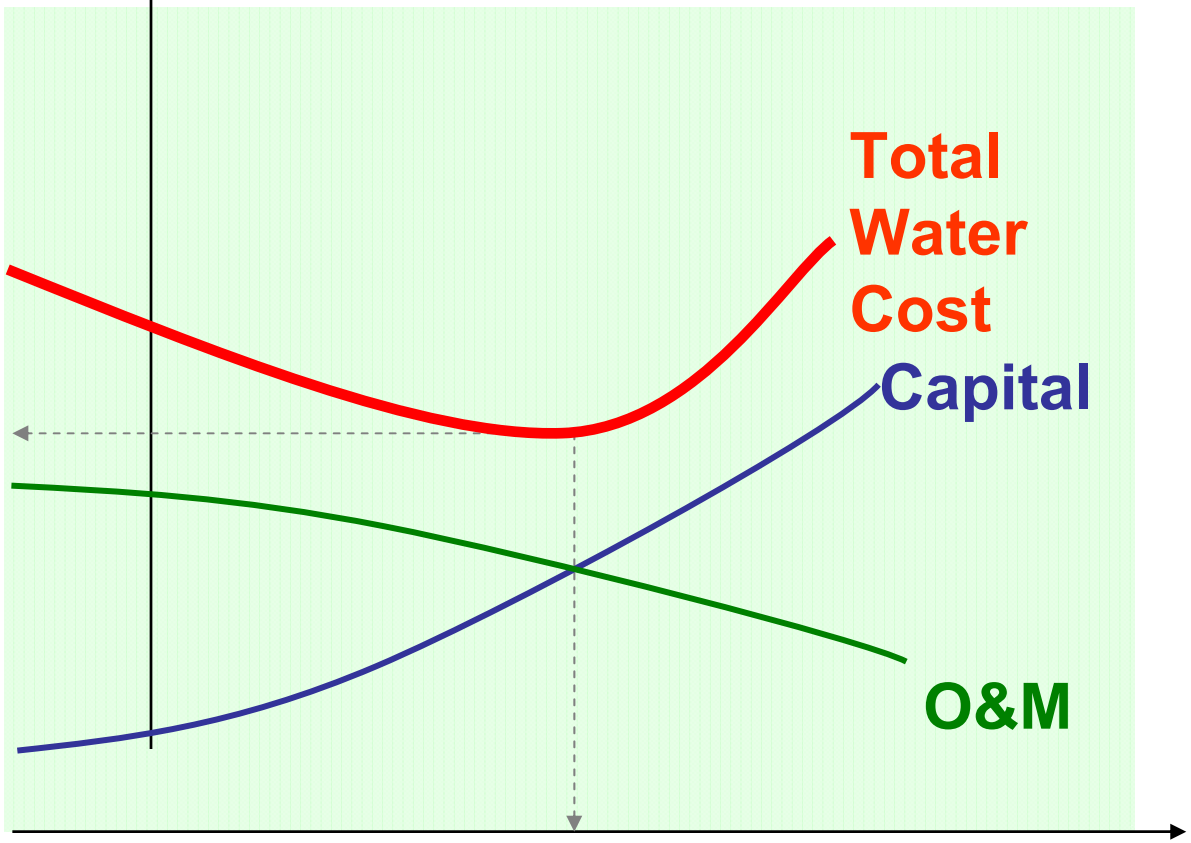
COST

Optimal Design Parameters Ensure the Lowest Cost of Water



Pilot plant program provides optimal performance data on the most critical process elements

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SWRO Pilot Study

Desalination Pilot Study Major Generic Objectives:

- Evaluate and pilot pre-treatment (local issues) for the DESALINATION process - saves capital and O&M
- Evaluate and prove product water quality including emerging contaminants
- Evaluate quality and discharge criteria for the brine
- Provide public outreach and educate residents on desalination technology and quality of the produced water

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SWRO Pilot Study

Desalination Pilot Study Benefits:

- Pilot study can save 5-10% of the **capital investment** and up to 20% of the **O&M** for the DESALINATION project
- Piloting technology provides smooth **startup, operation and commissioning** of the full scale system.
- Piloting provides complete picture on the **product water quality** major components and emerging contaminants, as well as on the **discharged brine**.

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MMWD SWRO Pilot Plant Objectives:

- Establish optimum operating conditions for both conventional and membrane pretreatment
- Determine which pretreatment system is best-suited for the SWRO process
- Demonstrate that SWRO can reliably desalt San Francisco Bay water
- Demonstrate that desalted seawater meets or exceeds state and federal drinking water standards
- Demonstrate the efficacy of the membrane process in removing trace compounds of concern
- Establish operating parameters for a 56,575 m3/d (15 mgd) full-scale facility
- Demonstrate that the desalinated water compares favorably with the low-TDS, low-sodium drinking water that MMWD customers currently supplied
- Conduct testing of pretreatment residuals to determine design of full-scale plant residuals handling and disposal
- Conduct a public outreach program to acquaint the public and media with the technology employed and the quality of the water produced

SWRO Pilot Plant Treated Water Quality Objectives:

The treated water quality objectives for the SWRO Pilot plant are based on:

- **Compliance with Federal and State regulatory requirements,**
- **Meeting MMWD's additional requirements for dissolved minerals (e.g., Sodium),**
- **Ensuring the treatment process can remove unregulated emerging contaminants, and**
- **Customer acceptance, i.e., taste.**

The treated water objectives to ensure compliance with the current and upcoming water quality regulations include the requirements of the following:

- **Surface Water Treatment Rule (SWTR),**
- **Interim Enhanced SWTR and Long-Term 2 Enhanced SWTR,**
- **Stage 1 and 2 Disinfectants and Disinfection By-Product Rules,**
- **Lead and Copper Rule,**
- **Boron Action Level,**
- **Total Coliform Rule, and**
- **The California Cryptosporidium Action Plan.**

MMWD has additional requirements to ensure that the water from the SWRO plant is chemically compatible with and comparable in quality to the District's other water sources.

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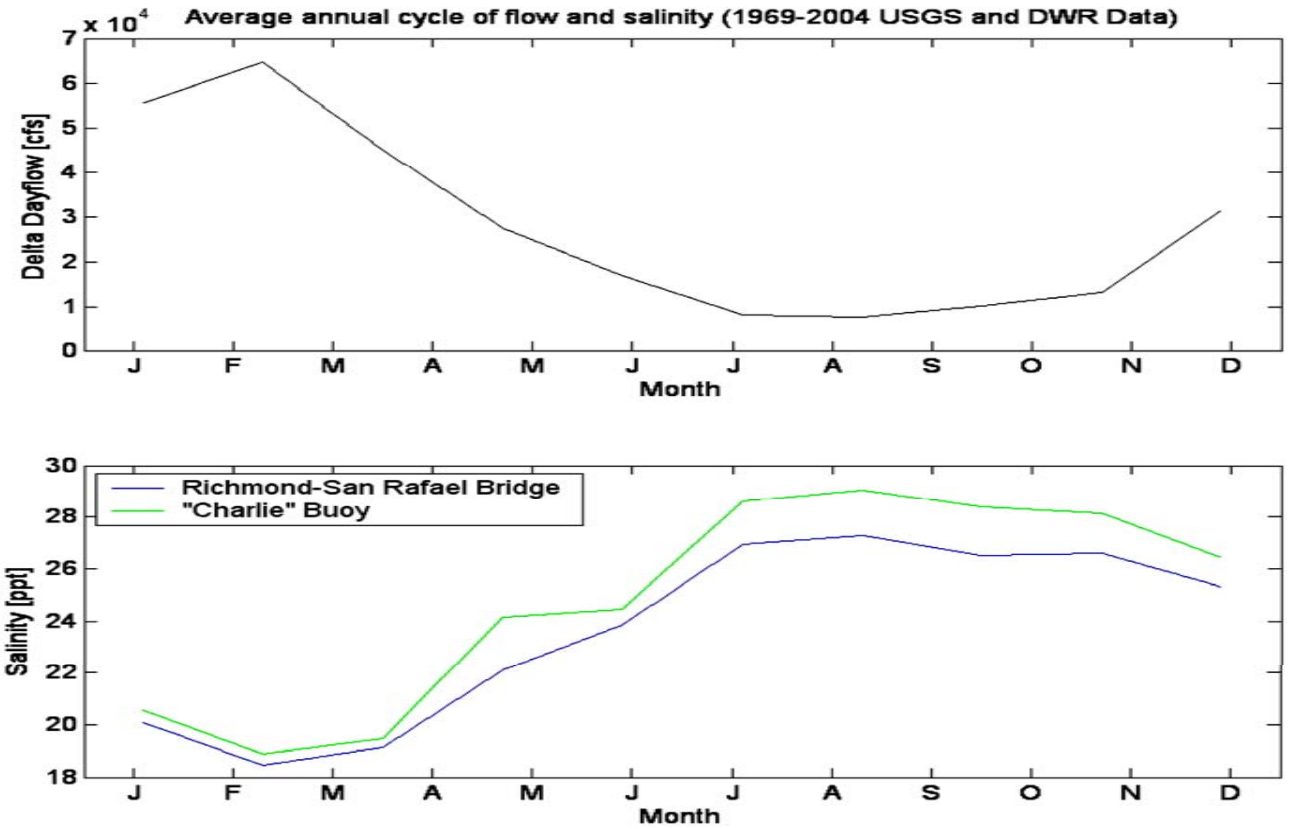
Variable Nature of Francisco Bay Water



There are daily and seasonal variations in salinity, suspended solids, and productivity levels in the North SF Bay

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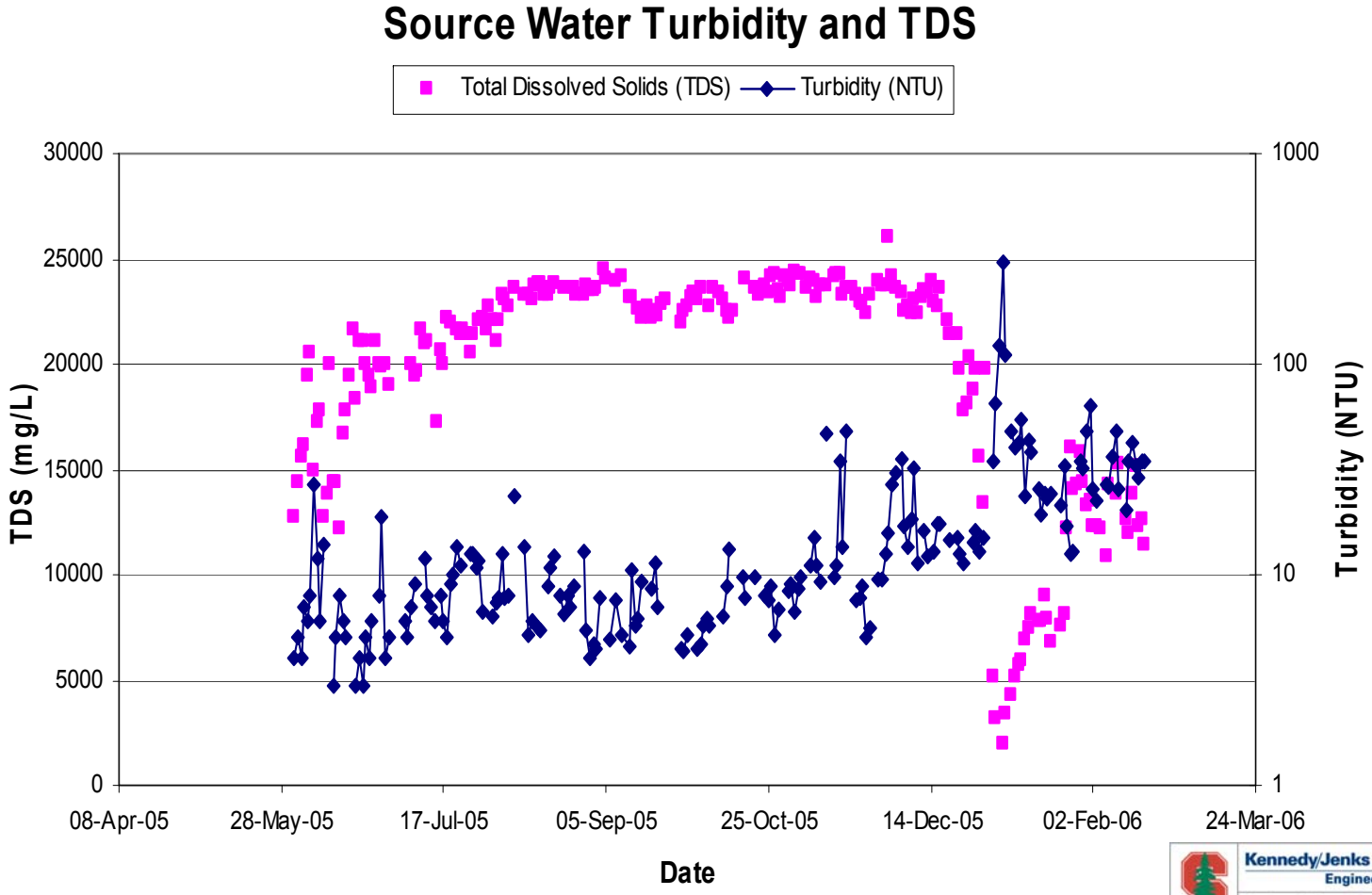
Salinity and Turbidity Vary Diurnally and Seasonally

MMWD Seawater Desalination Pilot Program



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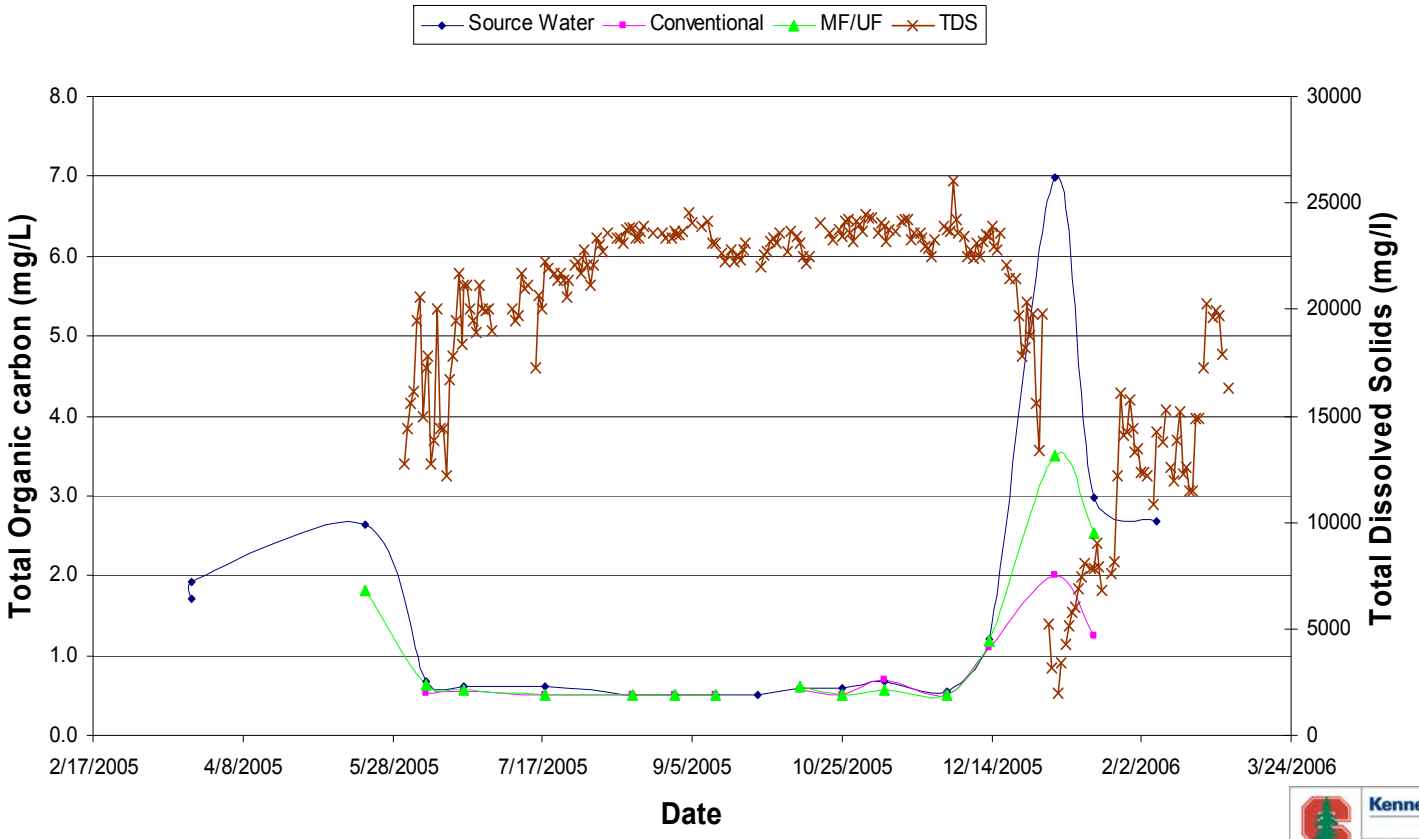
Source Water Organics Vary with Freshwater Runoff in Bay

MMWD Seawater Desalination Pilot Program
Source Water and Filtrate Total Organic Carbon (TOC)



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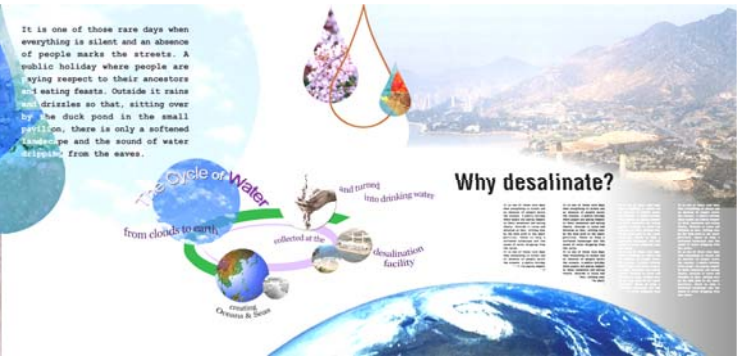
Demonstrating SWRO is a Viable, Reliable Water Supply Solution



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Team When Project Started……

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Team When Project Started……

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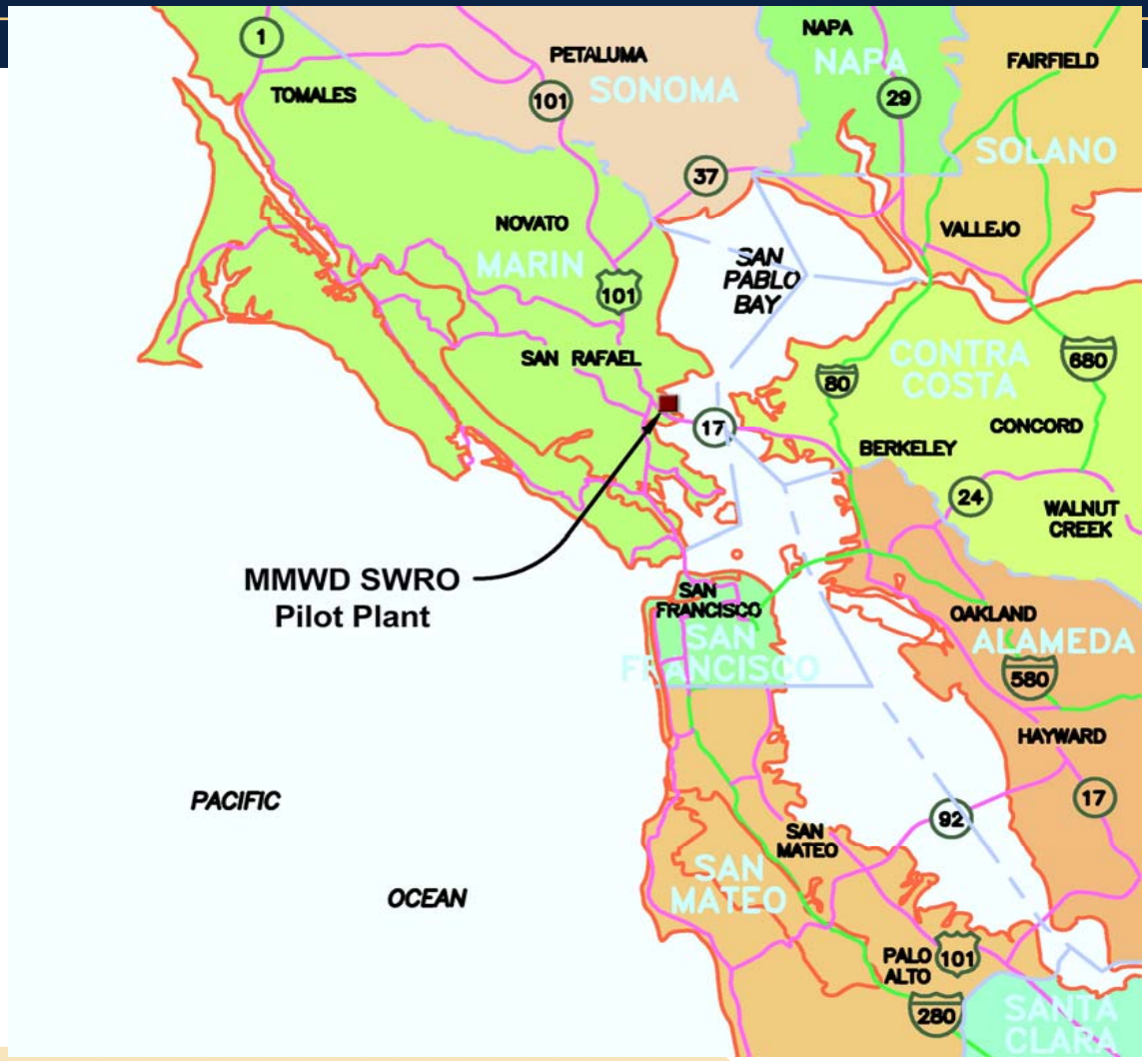
Site Location Map



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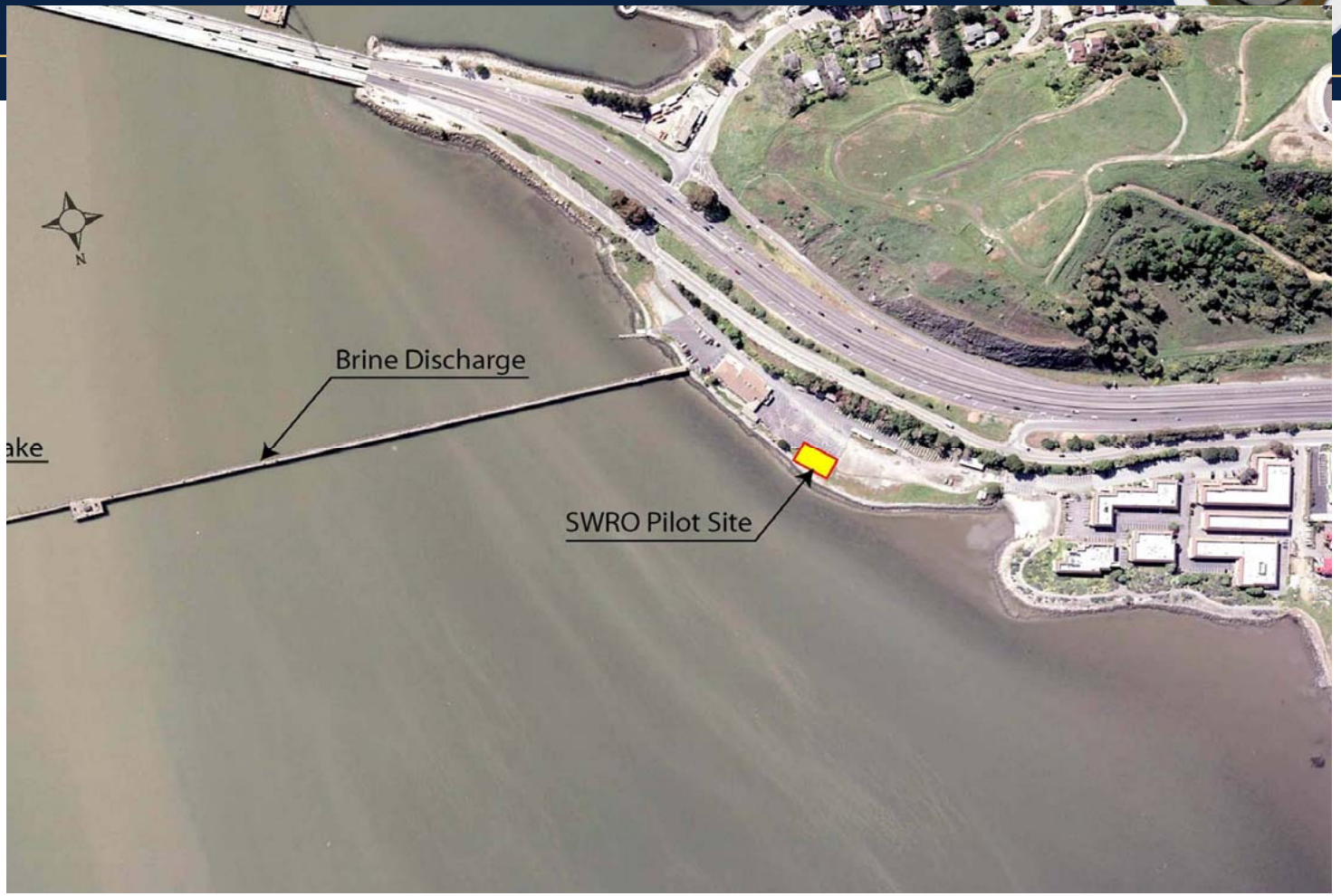
Site Location Map



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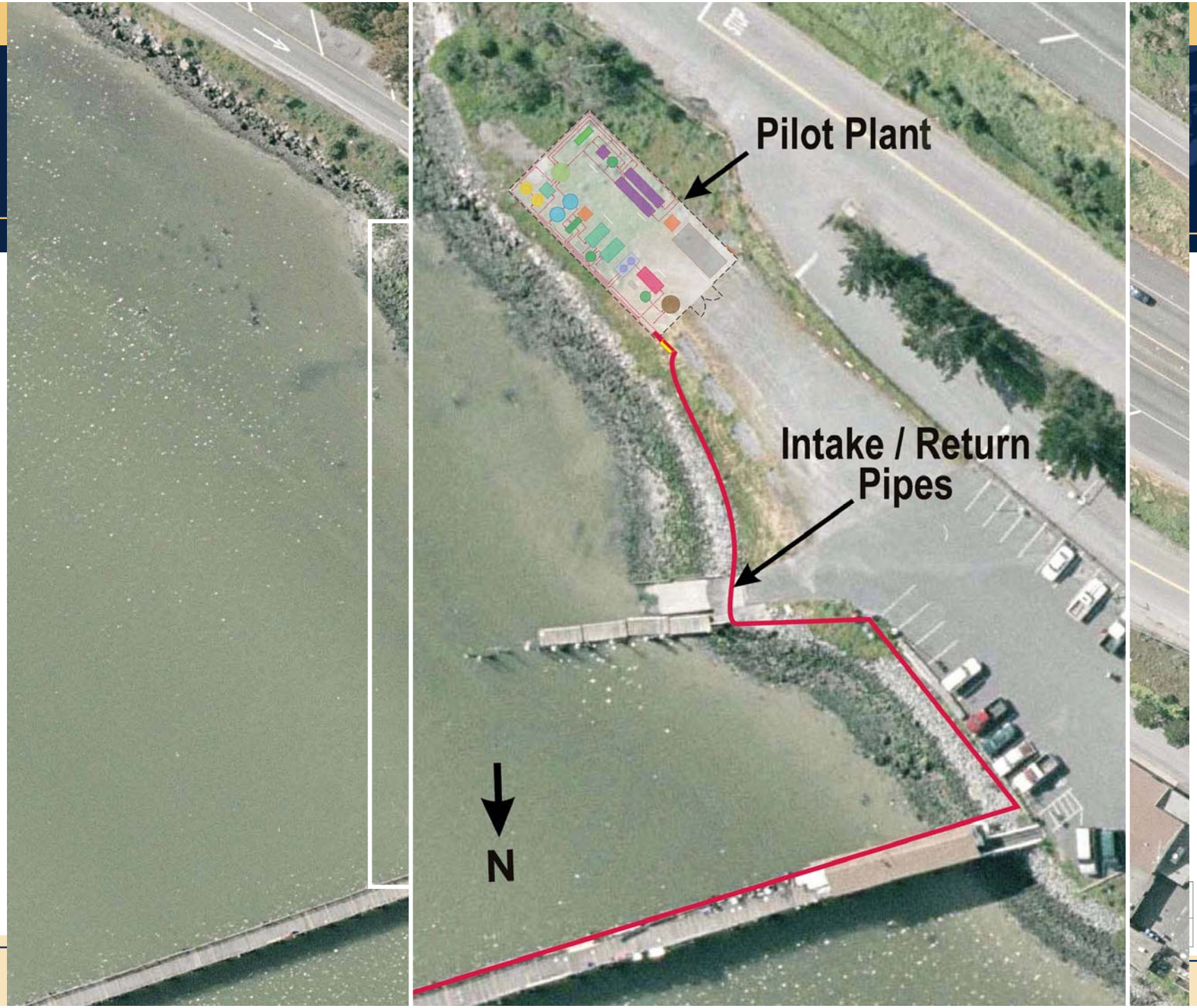
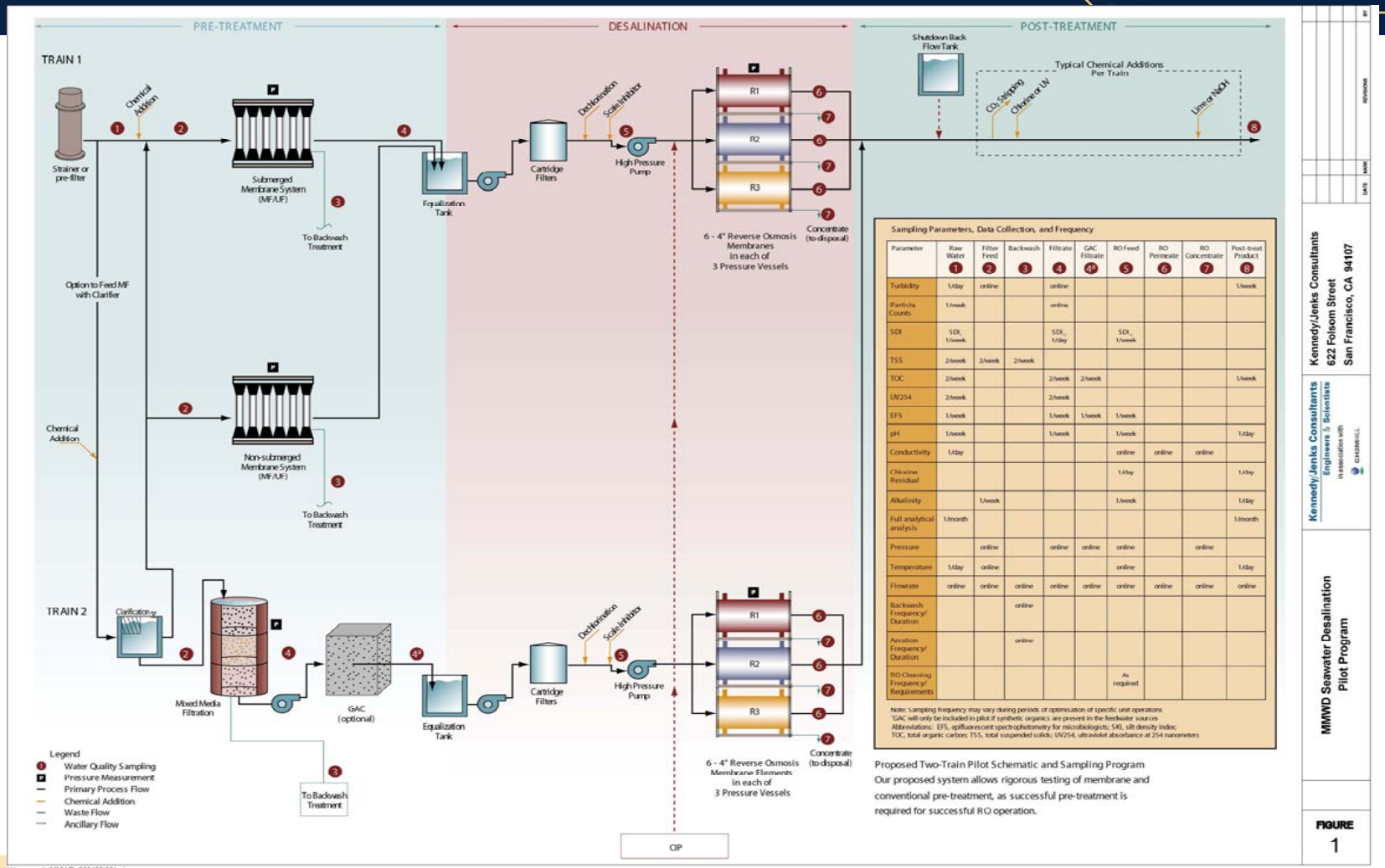
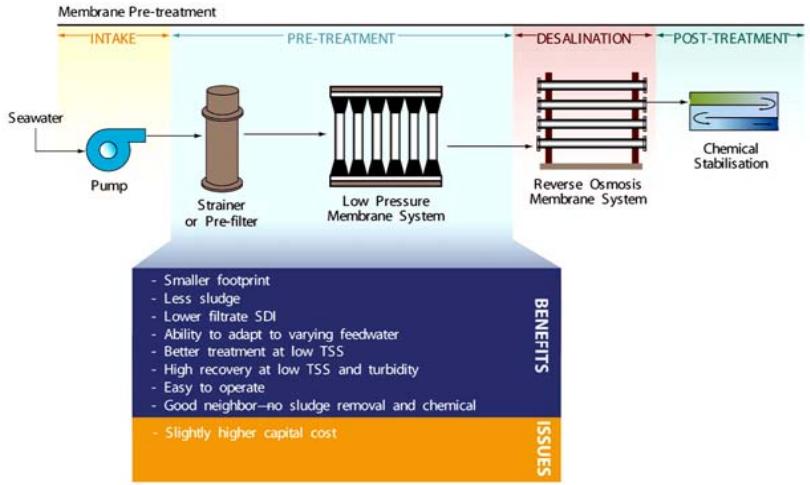
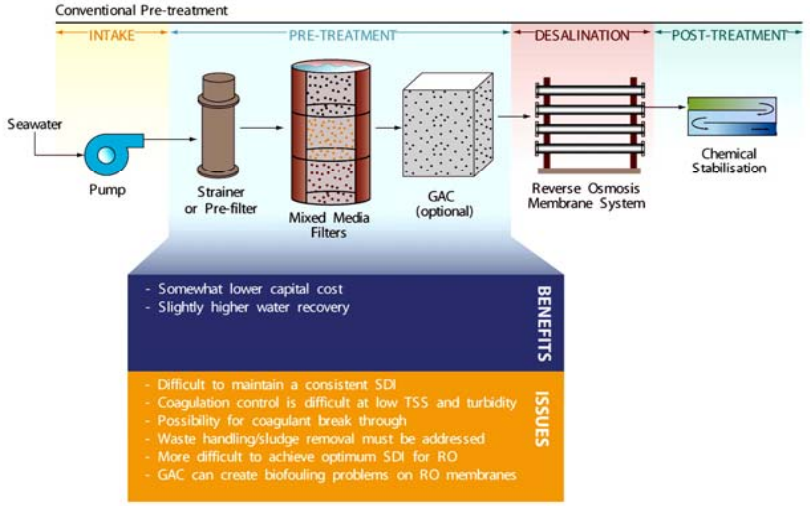

Pilot Plant
Intake / Return
Pipes
N

Pilot Process Flow Diagram - PFD



SWRO Pilot Program Configuration





- To ensure optimum data for comparison and design, we have two SWRO trains fed by three pretreatment units.
- This approach successfully demonstrated similar pretreatment for SWRO at many places around the world.

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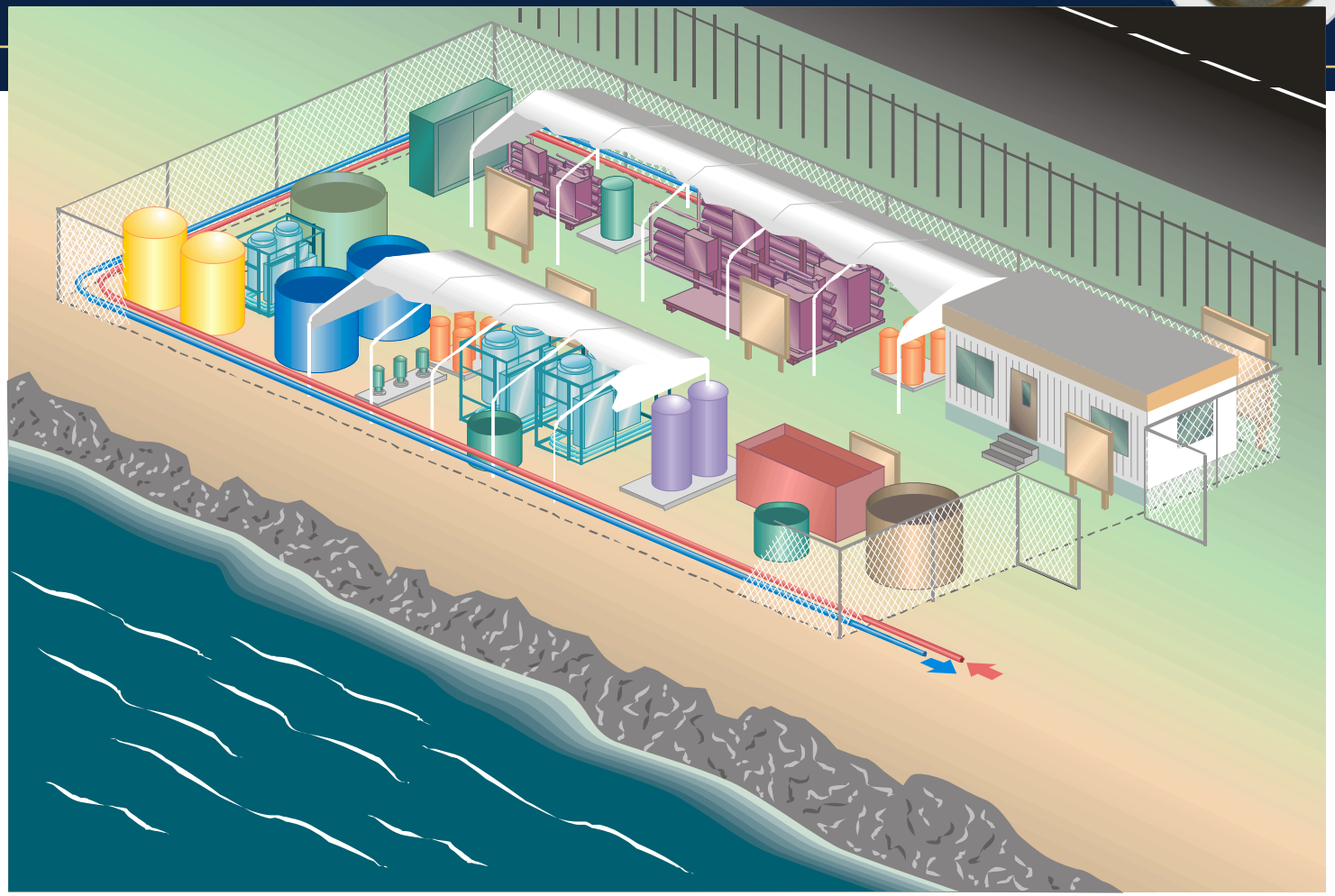
Pilot Plant General Layout



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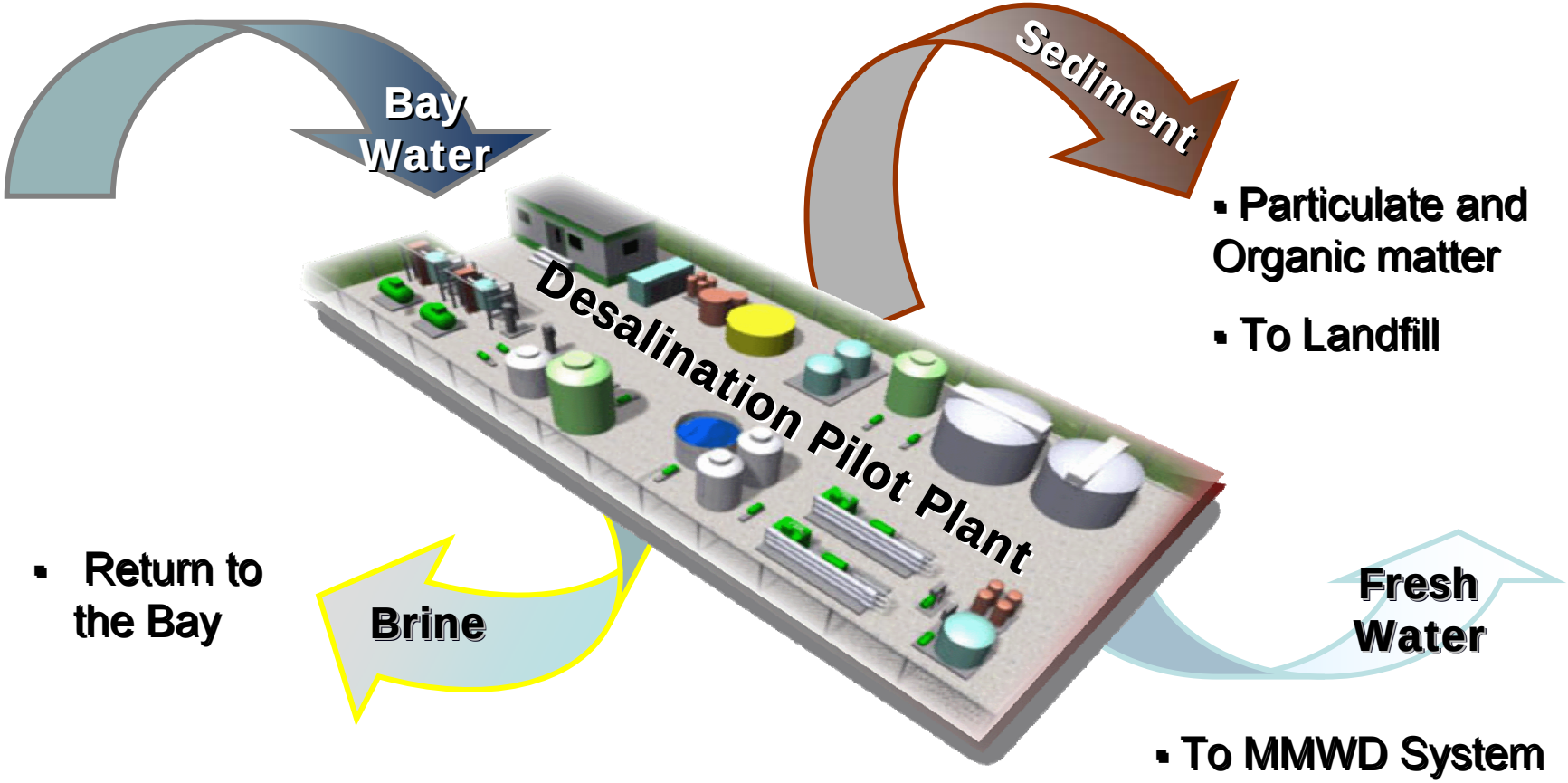
MMWD Desalination: From Bay Water to Drinking Water



- Particulate and Organic matter
- To Landfill
- Return to the Bay
- To MMWD System

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SWRO Pilot Intake 2,000 ft / 600 meters

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Intake Screening

- Designed to meet Federal and State criteria (316b) for fish protection
  - 3/32-inch openings
  - <0.3 fps velocity
  - airburst cleaning
- Removes large particles and debris

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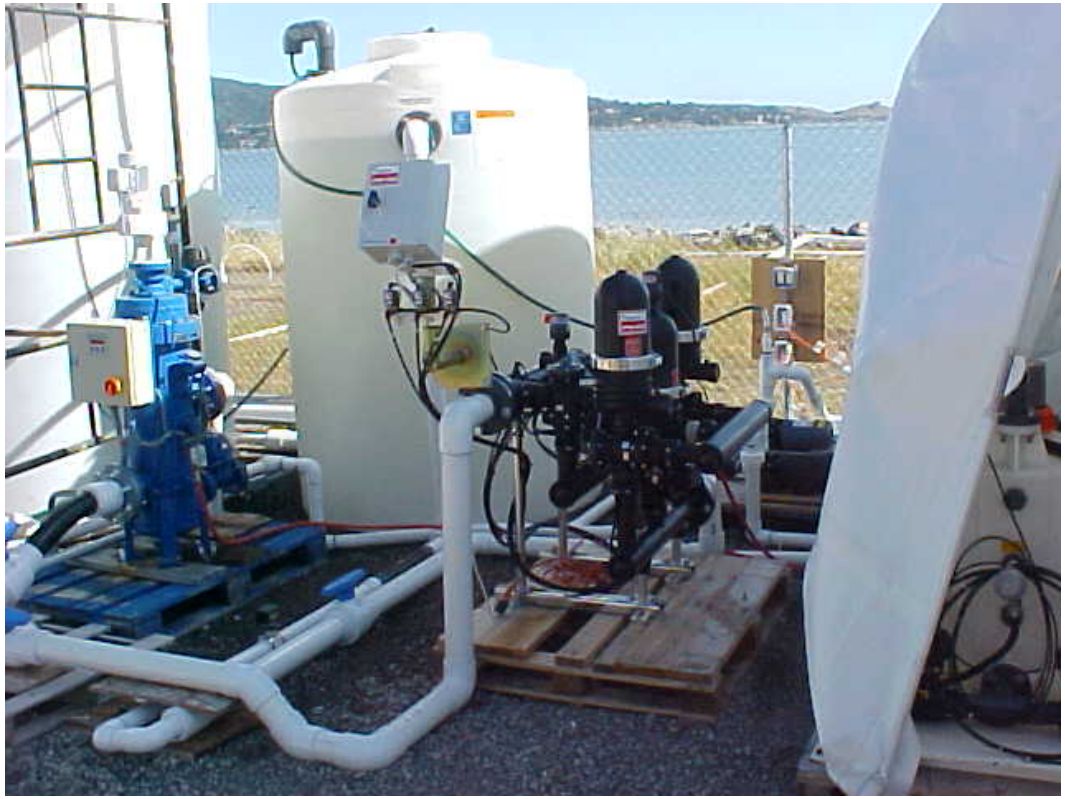
Feed Strainers Reduce Solids Loading and Protect MF/UF Systems



- Bollfilter - 100 micron Wedgewire Strainer
  - Stainless steel
  - Water backwash
- Arkal - 100 micron Disk Strainer
  - Plastic disks and body
  - Air or water backwash

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Disk strainer provides better water quality with easier maintenance

100 micron Wedgewire Strainer

100 micron Disk Strainer

- **Parallel 2-hr clogging capacity test of strainer effluent**
- **Disk Strainer effluent contained fewer solids**
- **Disk strainer permitted easy access to strainer elements**
- **Plastic materials for corrosion resistance**

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Membrane Pre-Treatment: MF & UF

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Conventional Pre-Treatment

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SWRO: 1st and 2nd Passes

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2nd Pass RO

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Post Treatment

Marin Independent Journal

50 CENTS

JUNE 20, 2005 MONDAY WWW.MARINIJ.COM

H_2O taste test

MMWD's desalinated bay water beats Marin competition

GULP: Stephanie Taubert of San Rafael tries one of the three samples of Marin Municipal Water District tap water, desalinated water and North Marin Water District tap water during a blind taste test at the IJ on Friday afternoon.

IJ photo/Jeff Vreeland

Tastings dispel desal's bad reputation

By Mark Prado
IJ reporter

Maybe drinking bay water is not such a bad idea after all.

Desalinated water scored on par and even better than Marin tap water, according an unscientific blind taste test conducted Friday outside the Independent Journal's Novato office building.

Unmarked samples of Marin Municipal Water District's desalinated water, Marin Municipal tap water and North Marin Water District's tap water were offered and testers were asked to rank the three water samples on a 1 to 3 scale, with 1 being the best, 3 the worst.

Fifty people, many of them Independent Journal employees, stopped by the test table and sipped from paper cups.

Of the 50 who sampled, 20 ranked the desalinated water as their top choice, with 18 preferring North Marin water and 12 indicating Marin Municipal tap as the best. Overall, desalinated water and North Marin water tallied 98 points, and Marin Municipal tap 103. The lower the score, the better taste of the water.

Stephanie Taubert pulled a wry face when told one of the three waters was cleaned San Pablo Bay water. After carefully tasting all three, she indicated the water marked with a yellow sticker was her favorite: the desalinated bay water.

"You're kidding! That's weird," she said, before her

See Taste, page A7

Which water tastes best?

At an unscientific blind taste test conducted at the front doors of the Marin IJ on Friday, random visitors and employees compared water samples from three Marin sources. Here are the results:

	A. North Marin Water District tap water from the IJ in Novato	B. Desalinated water from MMWD's pilot plant in San Rafael	C. MMWD tap water from a Terra Linda home
First place votes:	18	20	12
Total points*:	98	98	103
Comments:	"...tasted like nothing."	"If it smooth, it didn't have any lingering flavor."	"A metallic, unpleasant taste."

*Participants were asked to rate three samples 1-3 in order of preference. Lowest number indicates the winner.

IJ graphic

Pipeline project could soon die

By Mark Prado
IJ reporter

Plans for a pipeline to move water from Sonoma County to Marin could die if the Marin Municipal Water District does not renew a contract that expires at the end of the month.

The MMWD has a series of contracts with the Sonoma County Water Agency to provide it with water. Two contracts are locked in and provide Marin with up to 9,300 acre-feet annually. MMWD's demand for that water is 8,000 acre-feet annually.

A third contract provides MMWD with 5,000 acre-feet on an "as available" basis. MMWD now must decide if it wants to lock in those water rights at a cost of $6 million.

The 5,000 acre-feet would be used for a pipeline to tap water from the Russian River.

See Pipe, page A7

PIPE: Extension is sought

From page A1

But the project has been put on the back burner as the water district pursues desalination.

If MMWD does not renew the contract, the pipeline project is essentially dead.

"We would like an extension for at least two years," said Jared Huffman, president of the Marin Municipal Water District board of directors.

It would cost the district $200,000 for each year of an extension, officials said.

There will be a series of meetings to determine the issue. The Sonoma County Water Advisory Committee will meet next Monday, then the water agency's board meets Tuesday.

"Ideally everyone will agree on this, but we will have to wait and see what they say," said Elizabeth Emmett, spokeswoman for the Sonoma water district.

The Marin water district board will then hold a special meeting June 29.

Simply renewing the contract wouldn't mean the water from the Russian River would be available overnight, Huffman noted.

First, Marin would have to build a pipeline, and then Sonoma County would need facilities in place to deliver the water. The Sonoma facilities haven't been built and could take another 10 years to materialize.

"That is one reason we are asking for an extension," Huffman said. "Sonoma doesn't have everything together on their side. That's not our fault. We'd hate to commit $6 million to something that is under a huge cloud."

Beyond the physical issue of getting water from Sonoma, there are several legal ones as well. Environmental groups have sued, trying to halt water pulled from the Russian and Eel rivers because of concern about fish protection. Water from the Eel River is diverted into the Russian River.

The amount of water flowing from the rivers could be limited by the courts, preventing Marin from seeing an extra drop of water through the pipeline, Huffman noted.

"Whatever happens has to happen soon, because the curtain is coming down soon," Huffman said.

Contact Mark Prado via e-mail at mprado@marinij.com

TASTE: Desalinated water wins

From page A1

mouth went agape. "It just tasted a little sweeter; that's frightening. I'm very surprised."

Despite choosing bay water as the best tasting, she still wasn't sold on drinking desalinated water, an issue Marin Municipal officials realize they must overcome.

"It's not good news that I liked it. Do you know what is in the bay? Toxics and contaminants," she said. "I think I'll start buying bottled water."

David Glanbastiani also liked the desalinated brew.

"It is smooth; it didn't have any lingering flavor. It just tasted like bottled water," he said.

Glanbastiani described MMWD tap as having a "metallic, unpleasant taste" and North Marin's as having a "tap water taste."

But sampler Fred Conner thought the desalinated water had a "chemical and chlorine taste" and favored North Marin's "neutral" flavor.

Flora Mavrak favored the desalinated water because it was the only one to have a taste.

"There was a flavor; the other two tasted like nothing," she said.

The desalinated water was some of the first to come from the Marin Municipal Water District's $1.2 million pilot desalination plant at the Marin Rod and Gun Club site near the west end of the Richmond-San Rafael Bridge.

The pilot plant cleans water through a reverse osmosis process and microfilters.

Testing for the next nine months will determine if desalting bay water and pumping it to Marin homes is feasible. That could lead to construction of a $77 million, full-scale facility capable of producing at least 5 million gallons of water daily.

Although officials plan to arrange for the public to weigh in on the taste of desalinated water, they haven't yet formally organized taste testing.

Friday's informal Independent Journal test indicated desalinated water is off to a decent start.

"They are all good," said taster Ruth Mendoza. "The (desalinated water) had an interesting flavor that I liked."

Contact Mark Prado via e-mail at mprado@marinij.com

- Calcium and bicarbonate added to match stability and taste of current MMWD water
- Disinfection similar to current MMWD practices
- MMWD customers find taste of Desal water as good as water from local reservoirs

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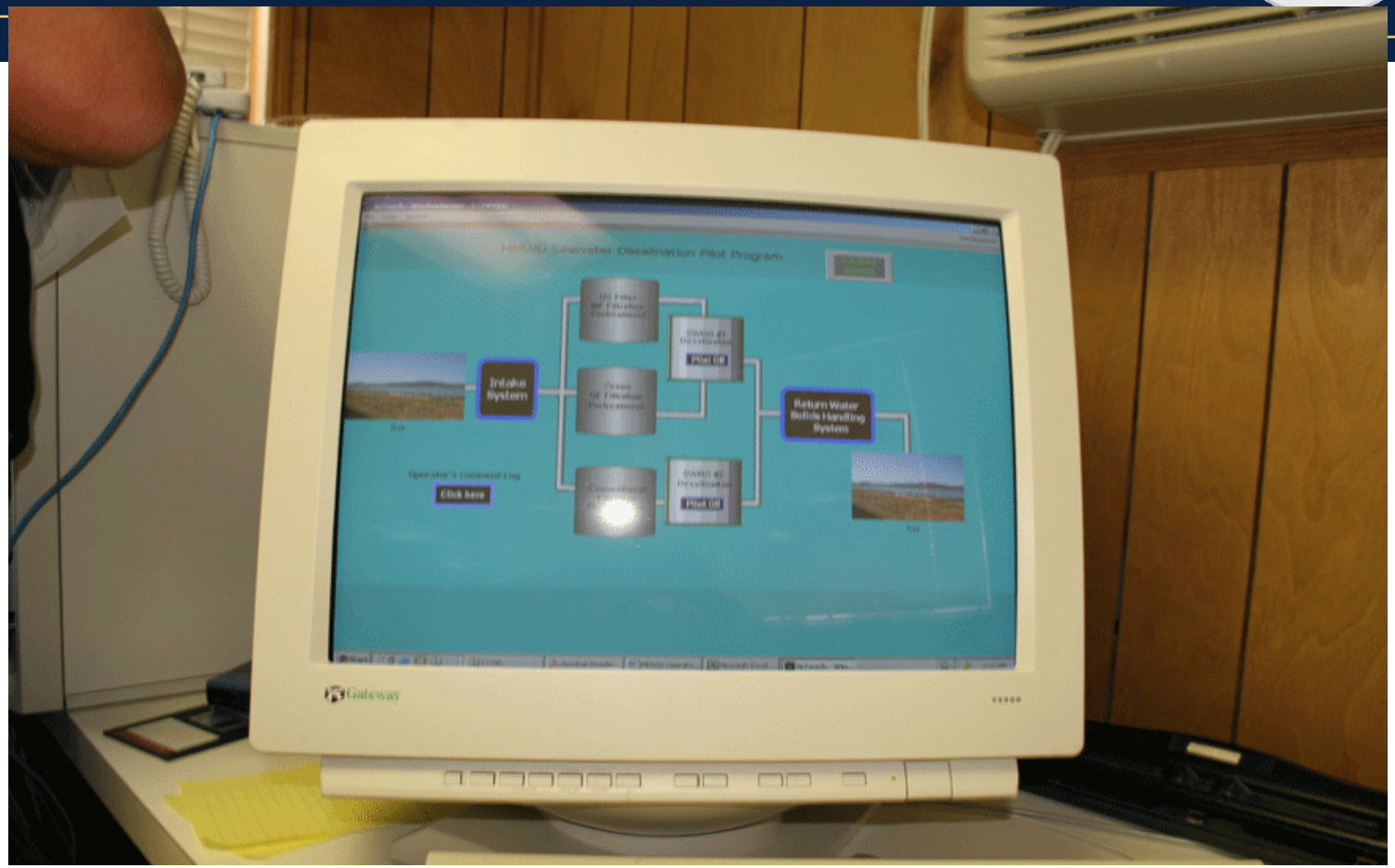
Pilot Automation: Master PLC Screen



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SWRO Pilot Site First Visitor

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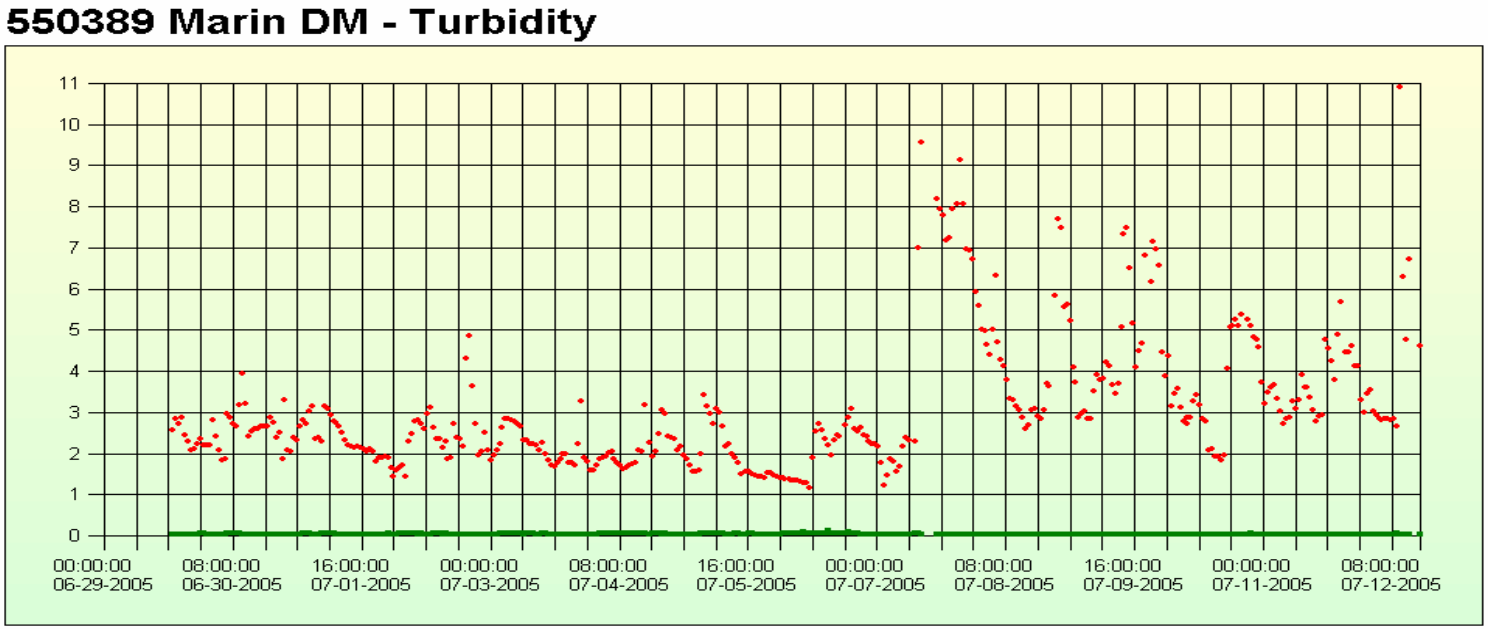
Proper Pretreatment Meets Challenges of SF Bay Water Quality Fluctuations



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COMMENTS:

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MF/UF Provides Better Solids Removal and lower SDI

	Conventional Filtered Water	MF Filtrate	UF Filtrate
Average Turbidity	0.09	0.06	0.05
Average SDI	3.88	2.64	2.57
SDI Standard Deviation	0.55	0.51	0.49

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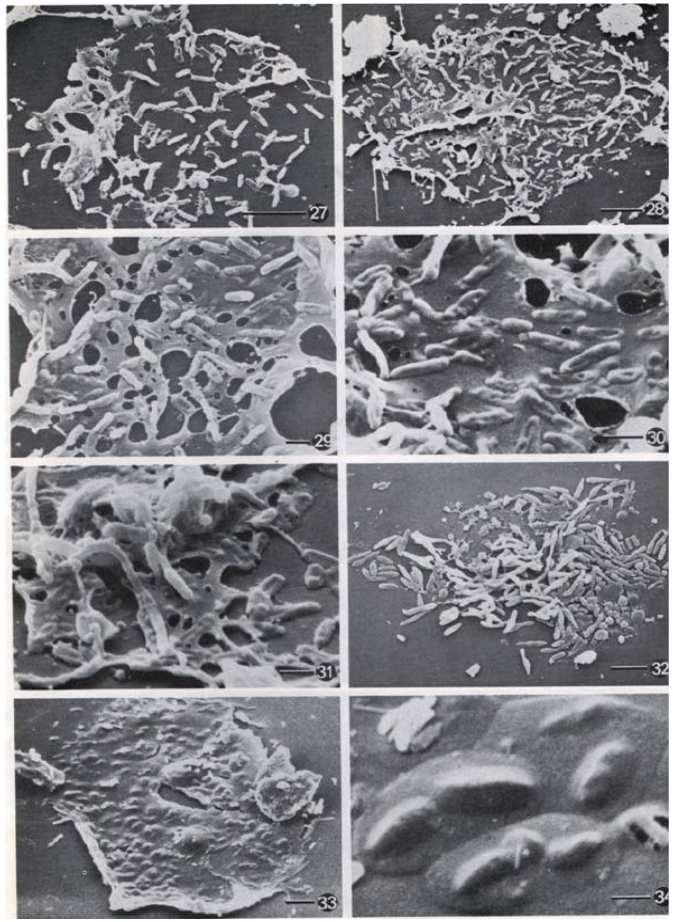
Types of SWRO membrane fouling



- Inorganic scale - control with antiscalant, system recovery
- Particulate fouling – minimize feed water turbidity and SDI
- Organic fouling – minimize feed water dissolved organics
- Biofouling – control with flux rate, shock Cl

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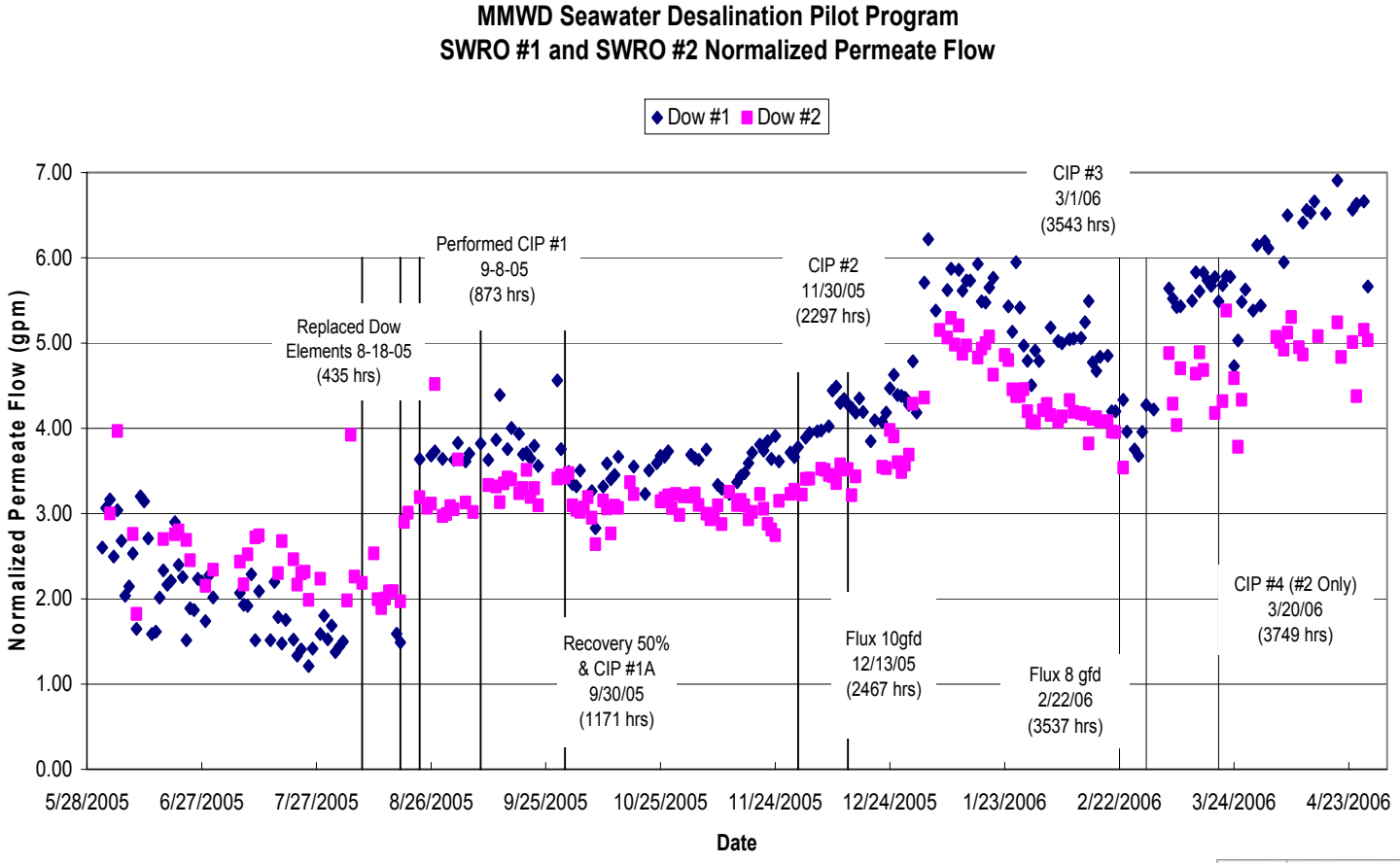
MF/UF SWRO has better permeate flow



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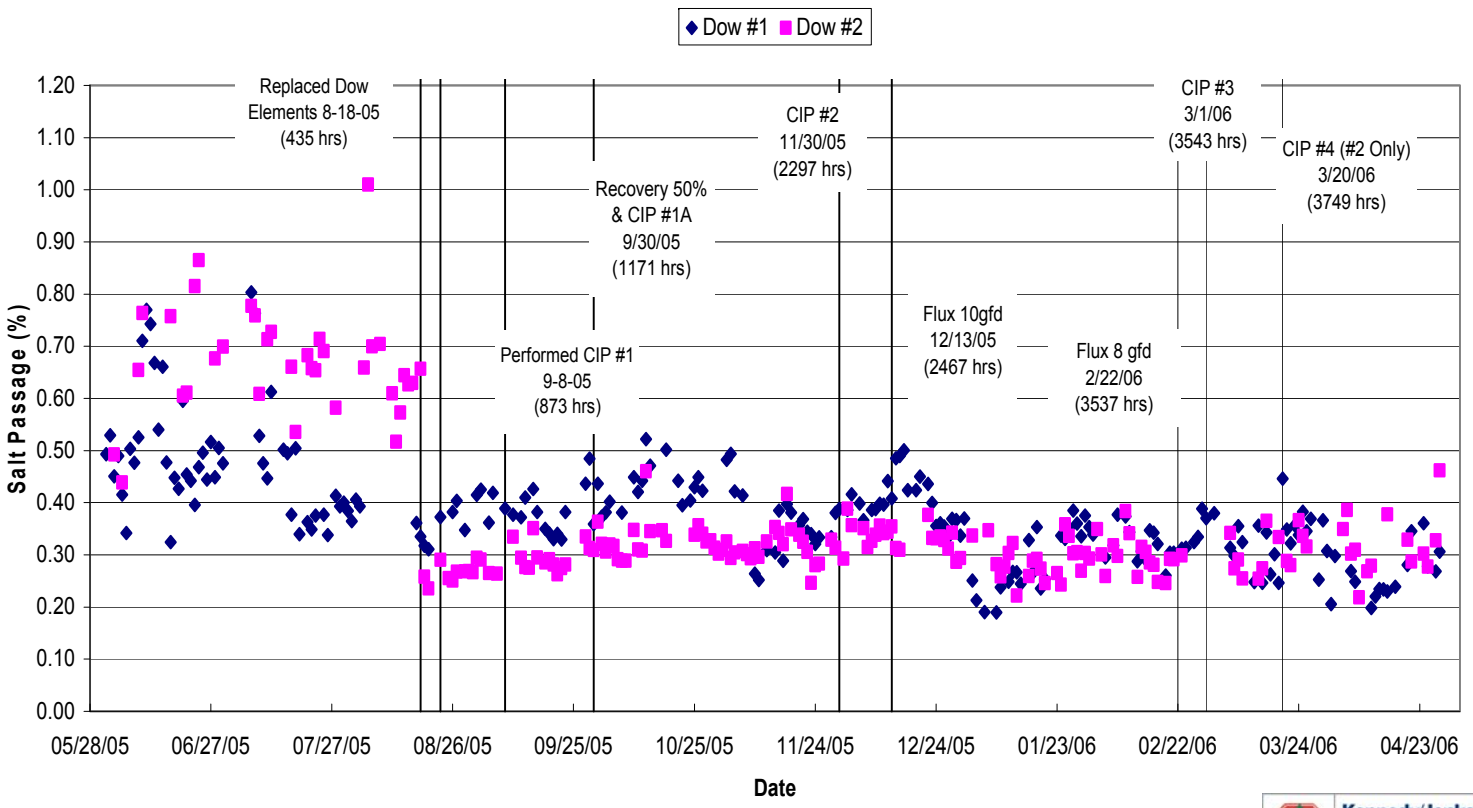
Both systems show similar salt passage



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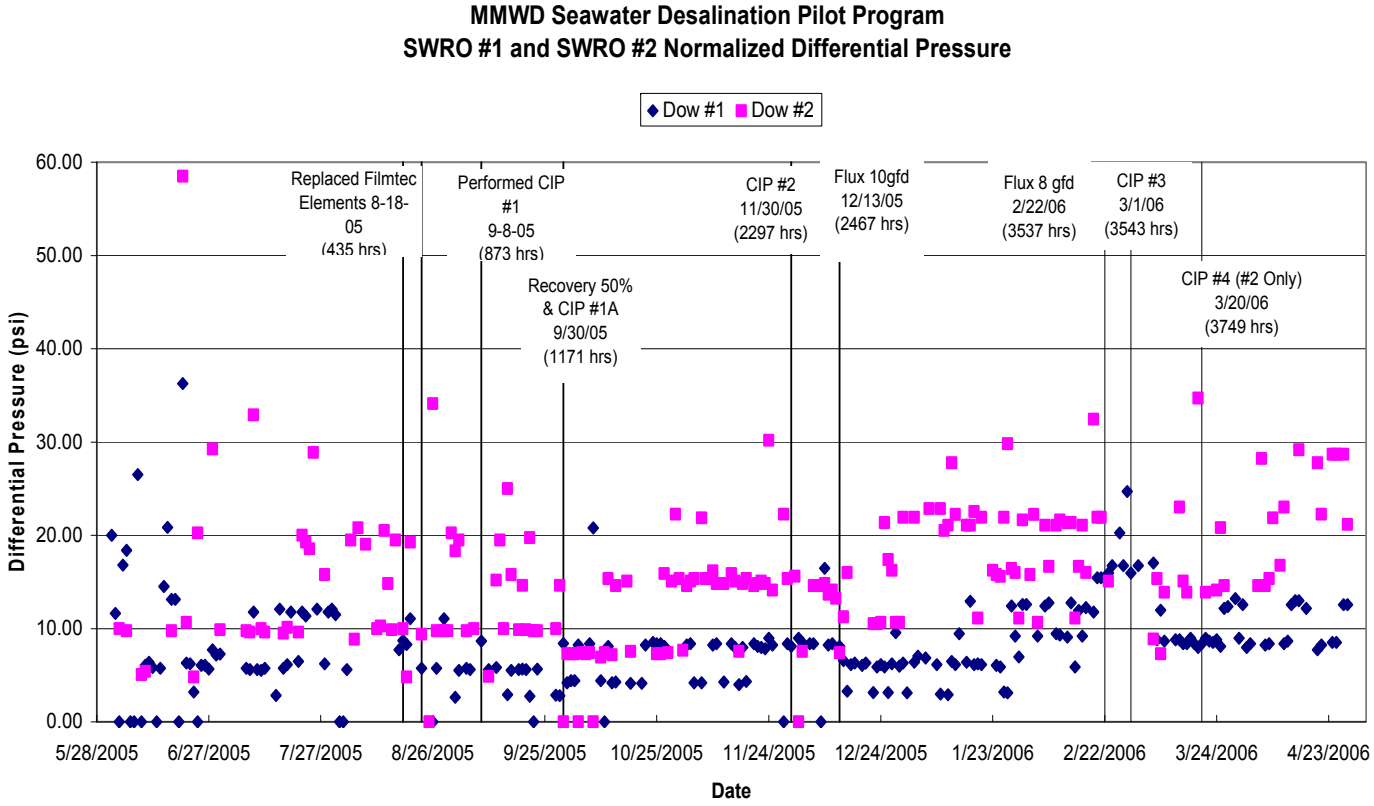
MF/UF SWRO has less fouling



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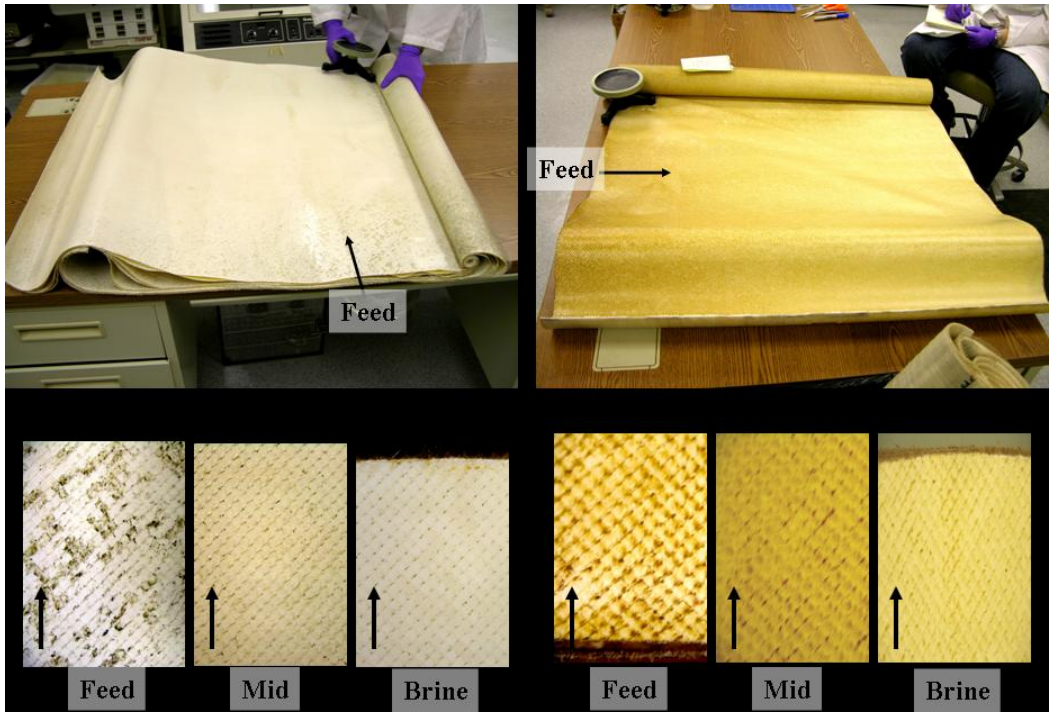
Autopsy confirmed MF/UF SWRO has less fouling



MF/UF Pretreatment

Conventional Pretreatment

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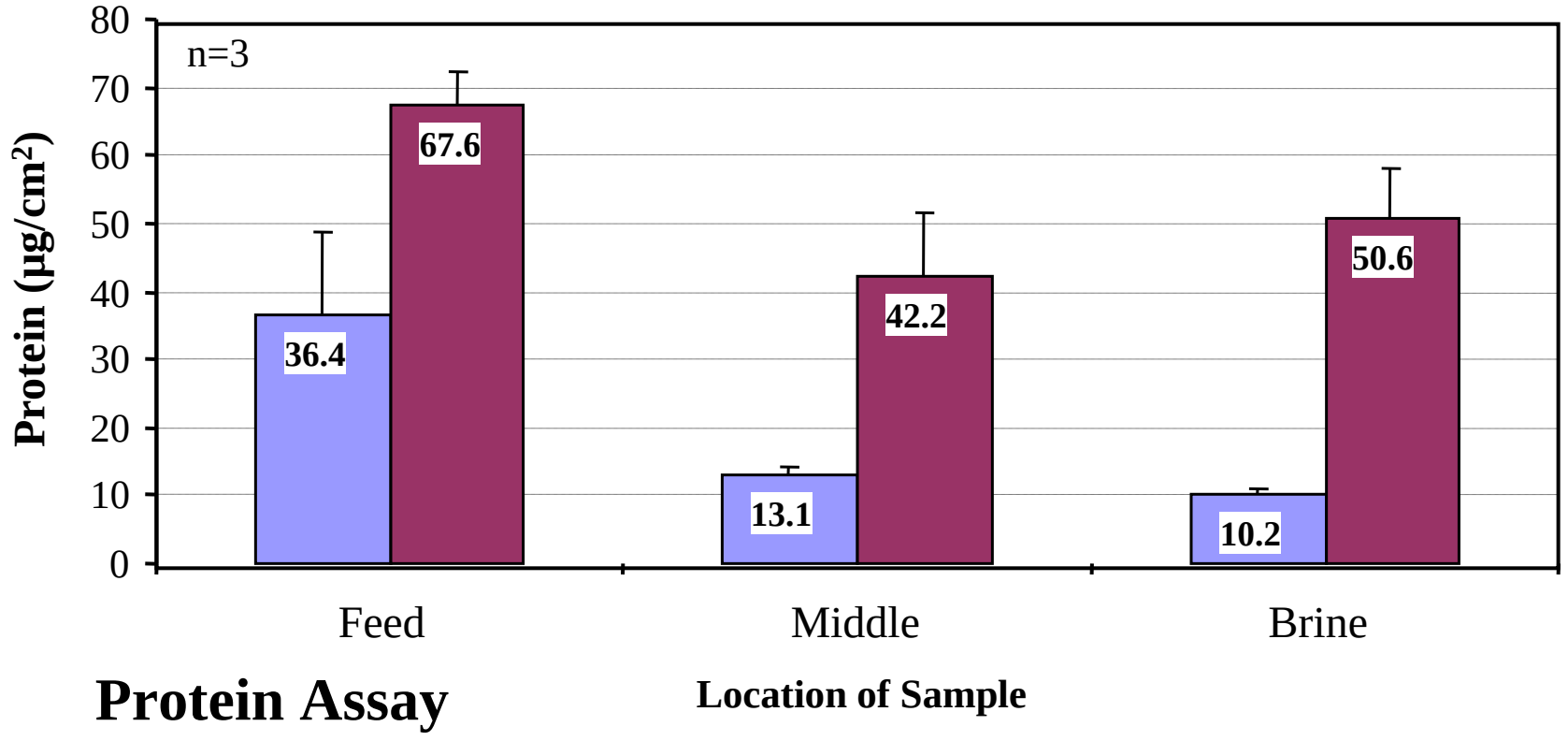
MF/UF SWRO had lower particulate and organic fouling



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MF/UF requires less area than conventional pretreatment

- **For 10 MGD MMWD Desal Facility**
- **Conventional Pretreatment**
  - **Flocculation ~ 3,000 sf**
  - **Clarifiers ~7,000 sf**
  - **Filters ~14,000 sf**
  - **WW Recovery ~7,000 sf**
  - Total Area ~31,000 sf
- **MF/UF Pretreatment**
  - **Strainers ~2,000 sf**
  - **Flocculation ~2,000 sf**
  - **Membrane Bldg ~8,000 sf**
  - **WW Recovery ~2,000 sf**
  - Total Area ~14,000 sf

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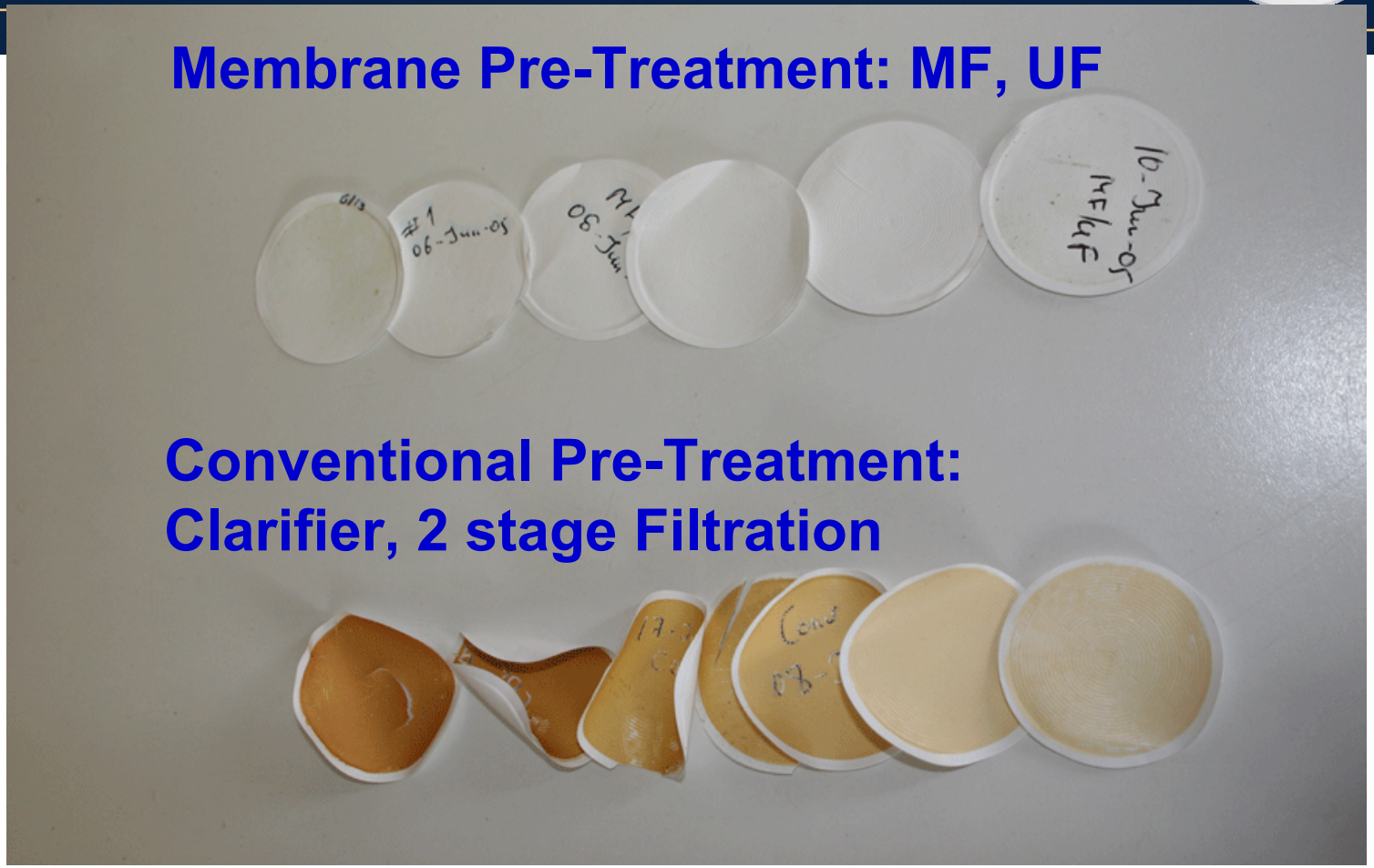
SWRO: Pre-Treatment Performance



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SWRO Membrane in Pressure Vessel

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SWRO Elements Performance

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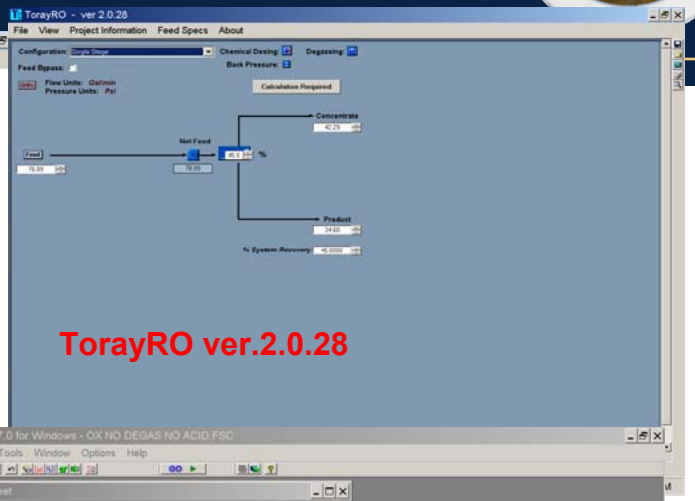
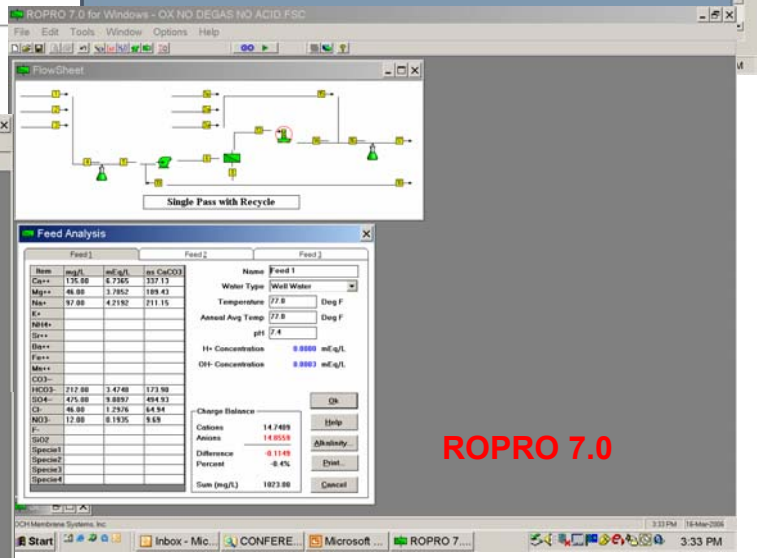


TorayRO ver.2.0.28



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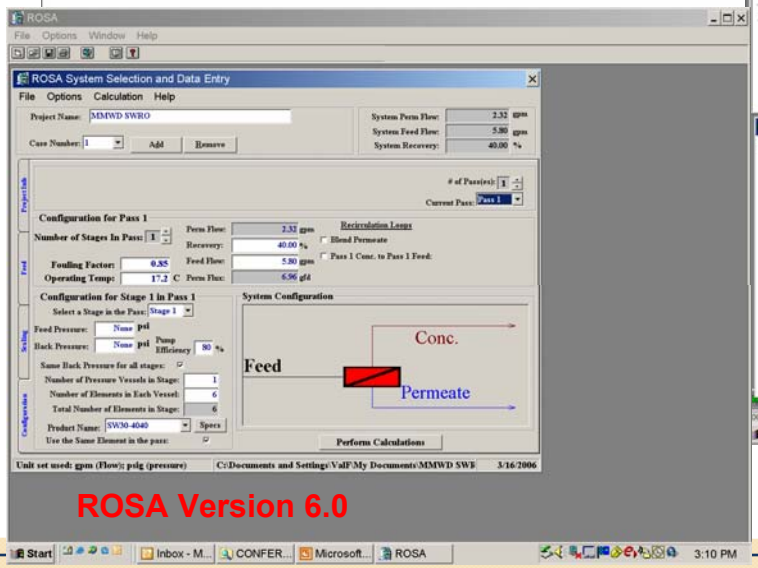

ROSA Version 6.0

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SWRO Elements Performance Evaluation:

-Salt Rejection, %
-Net Driving Pressure (Normalized), PSI
-Bio-Fouling/Scaling Rate
-Specific Ions Rejection (Boron, Emerging Contaminants), %

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SWRO Elements Performance

MMWD SWRO Pilot Project — Kennedy/Jenks Consultants

Membranes Information List

Train #	Membrane Brand	Membrane Model	Standard Salt Rejection, %	Active area of 1 element, ft2	Number of Element per Train	Total Membrane area per train, ft2	FLUX, GFD	Recovery %	Permeate Flow, gpm	Feed Flow, gpm	Brine Flow, gpm
1	TORAY	TM-810	99.80%	65	6	390	8	40	2.167	5.42	3.25
2	HYDRANAUTICS	SWC4+	99.80%	80	6	480	8	40	2.667	6.67	4.00
3	DOW Filmtec	SW30HR LE-4040	99.75%	85	6	510	8	40	2.833	7.08	4.25
TOTAL					18	1380			7.667	19.167	11.5

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SWRO Elements Performance

Contaminant	*% nominal rejection*	*Contaminant*	*% nominal rejection*
Aluminum	96-98	Ammonium	80-90
Bacteria	99+		
Boron	80-90 (up to 94)	Bromide	90-95
Cadmium	93-97	Calcium	93-98
Chloride	92-95	Chromate	85-95
Copper	96-98	Cyanide	85-95
Fluoride	92-95	Hardness Ca & Mg	93-97
Iron	96-98	Lead	95-98
Manganese	96-98	Magnesium	93-98
Mercury	94-97	Nickel	96-98
Nitrate	90-95	Orthophosphate	96-98
Phosphate	95-98	Polyphosphate	96-98
Potassium	93-97	Radioactivity	93-97
Silica	80-90	Silicate	92-95
Silver	93-96	Sodium	92-98
Sulfate	96-98	Thoisulfate	96-98
Zinc	96-98		

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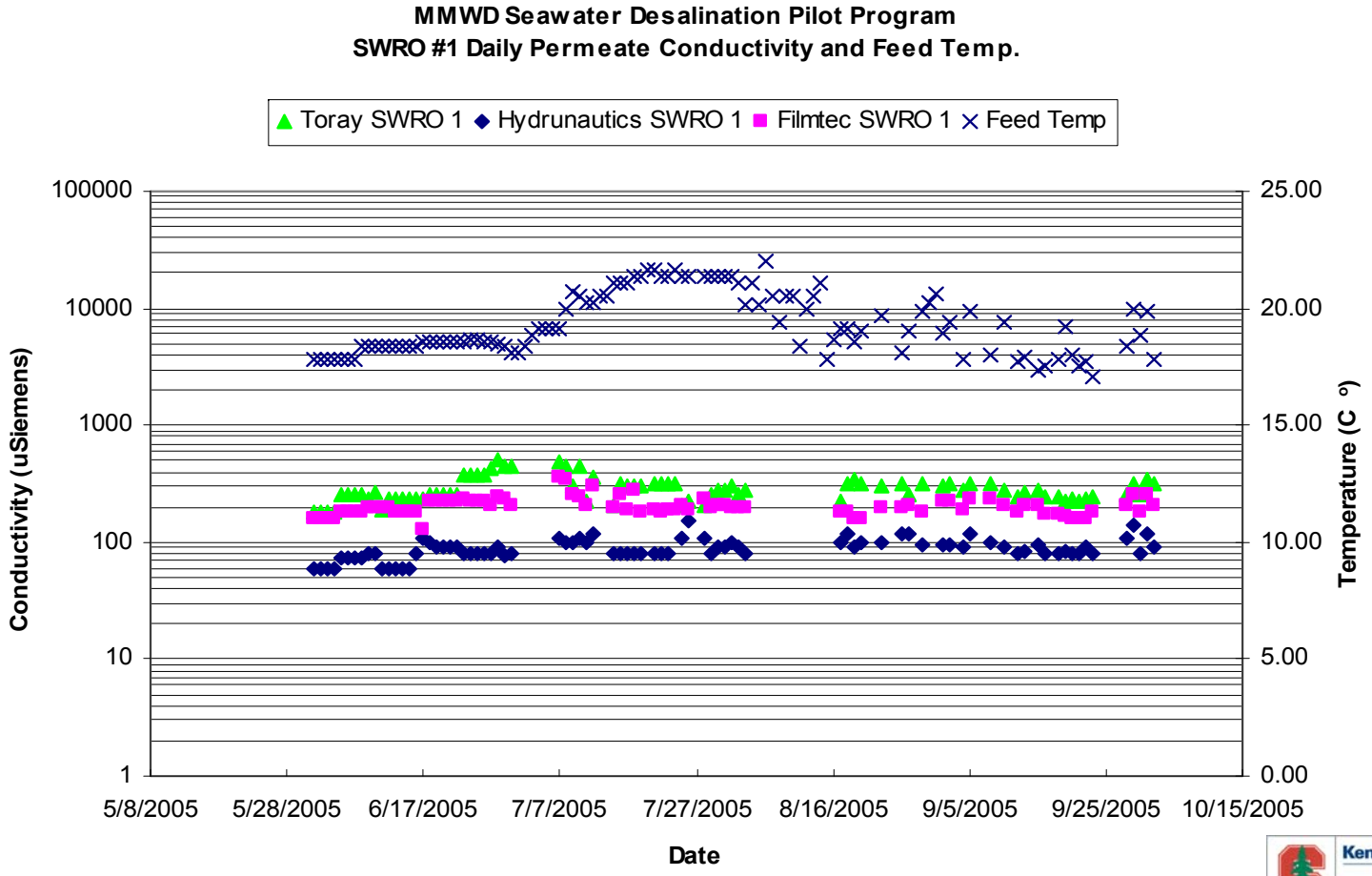

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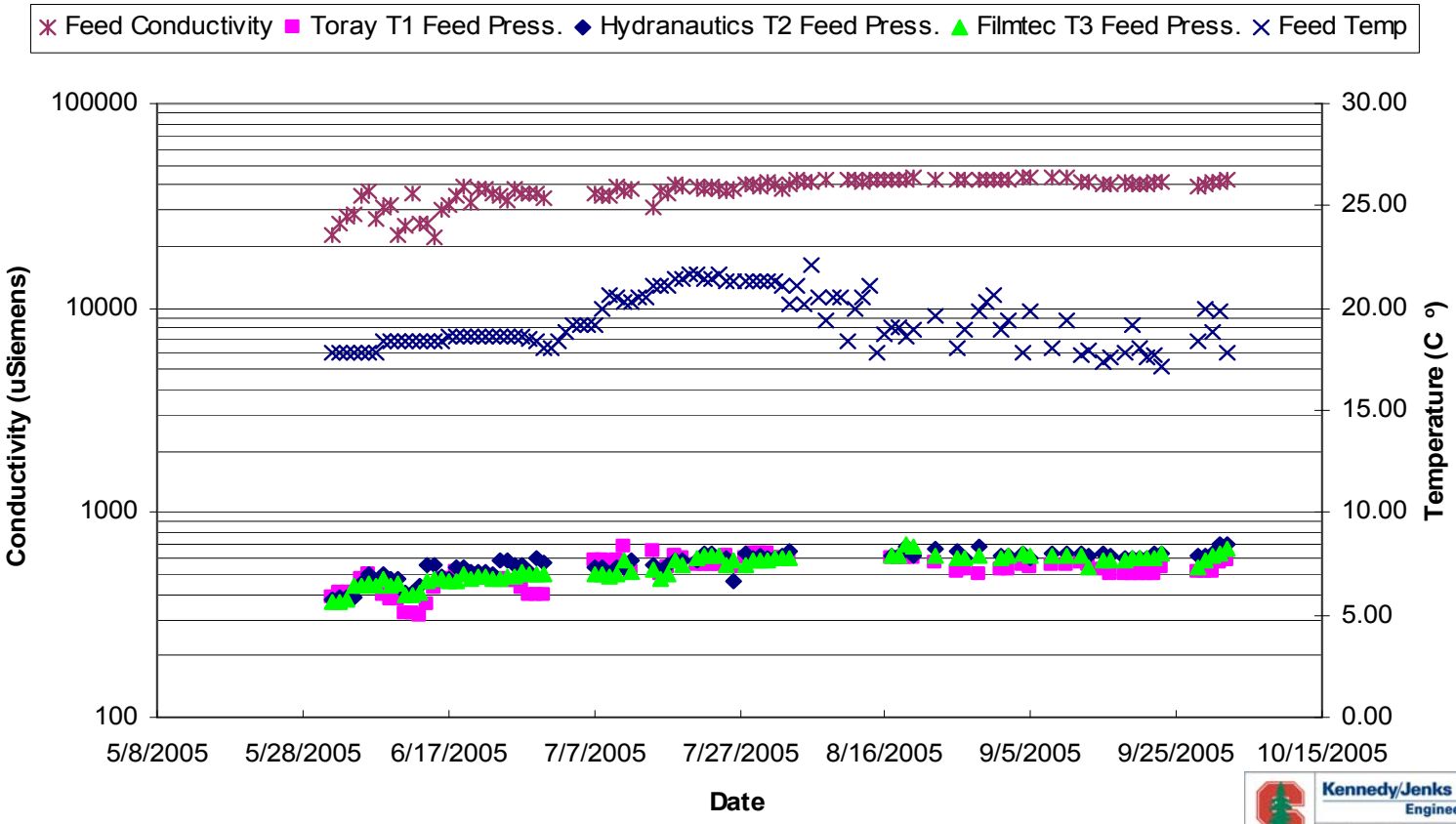
SWRO Elements Performance

MMWD Seawater Desalination Pilot Program
SWRO #1 Daily Feed Conductivity, Feed Pressure and Feed Temp.



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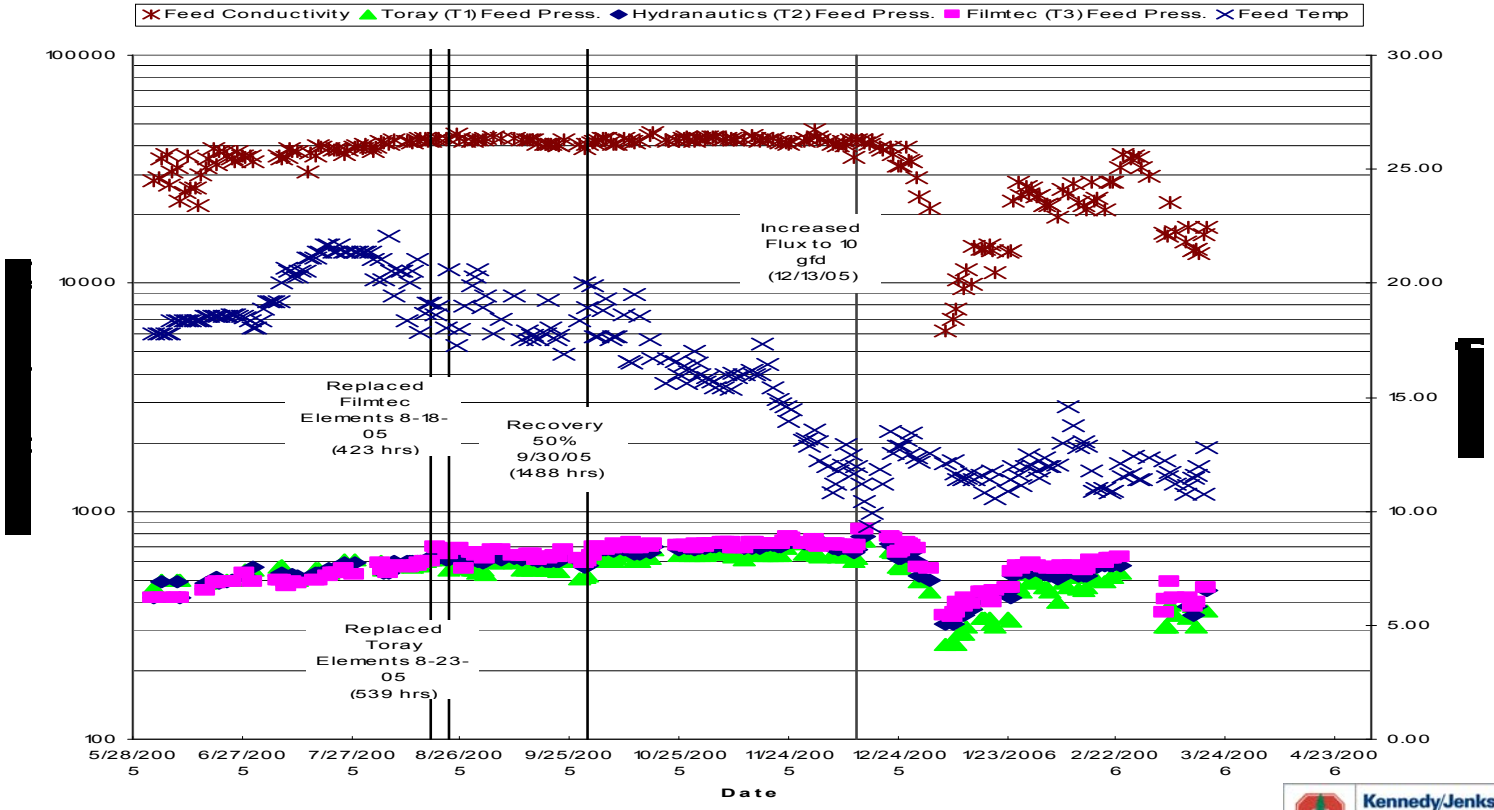
SWRO Elements Performance

MMWD Seawater Desalination Pilot Program
SWRO #2 Daily Feed Conductivity, Feed Pressure and Feed Temp.



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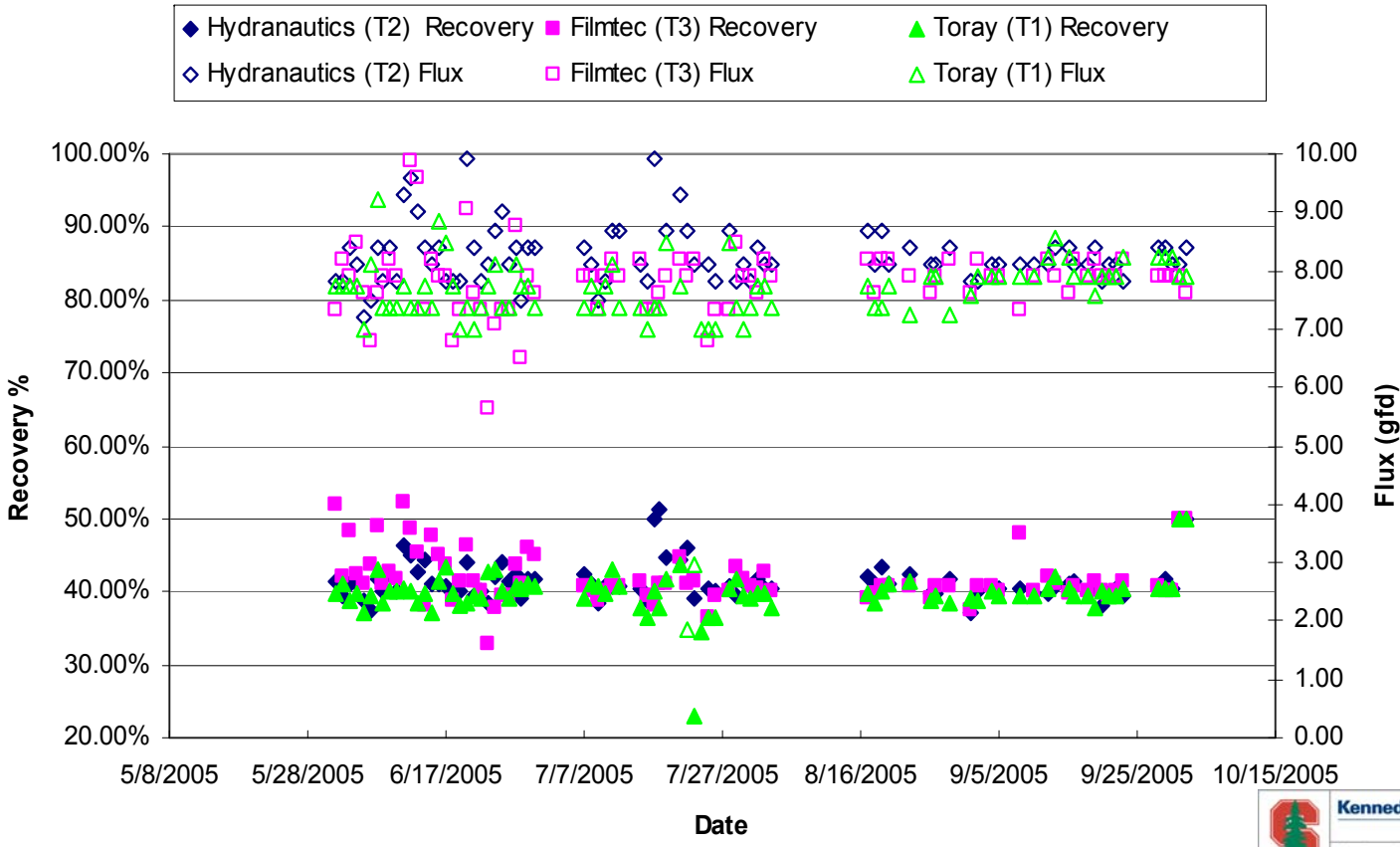
SWRO Elements Performance

MMWD Seawater Desalination Pilot Program
SWRO #1 Flux and Recovery



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SWRO Elements Performance Boron

World Health Organization (WHO) recommended guideline level of 0.5 mg/L

California Drinking Water Action Level for boron is 1.0 mg/L

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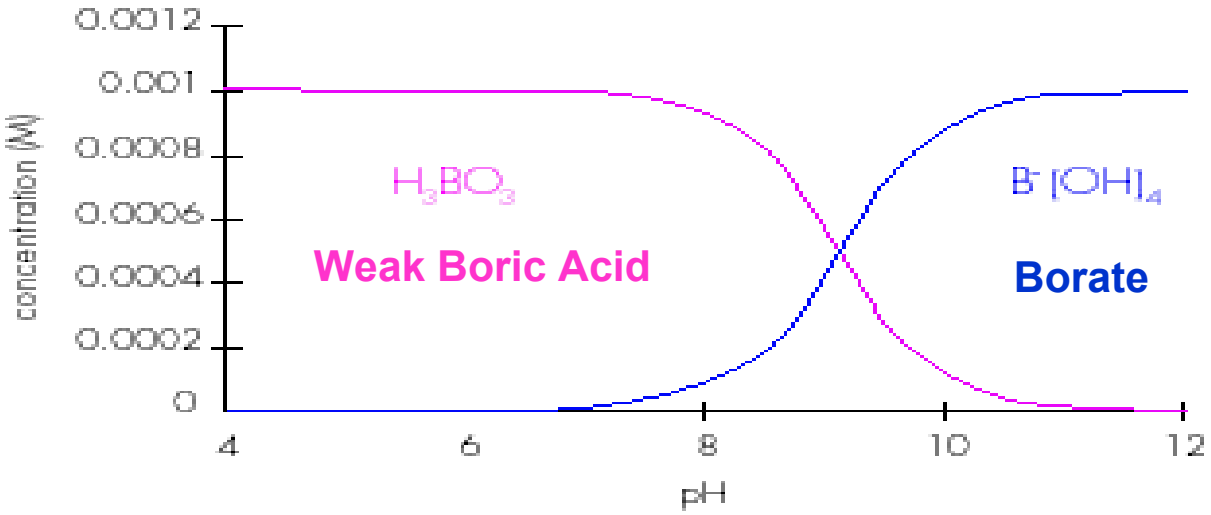
SWRO Elements Performance - Boron



$$B[OH]_3 + H_2O <-> B^-[OH]_4 + H^+$$

$$B(OH)_3 + NaOH \longleftrightarrow [B(OH)_4]^- + Na^+$$

$$2\ B(OH)_3 + [B(OH)_4]^- \longleftrightarrow [B_3O_3(OH)_4]^- + 3\ H_2O$$

1 mM boric acid behavior in aqueous solutions

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SWRO Monitoring

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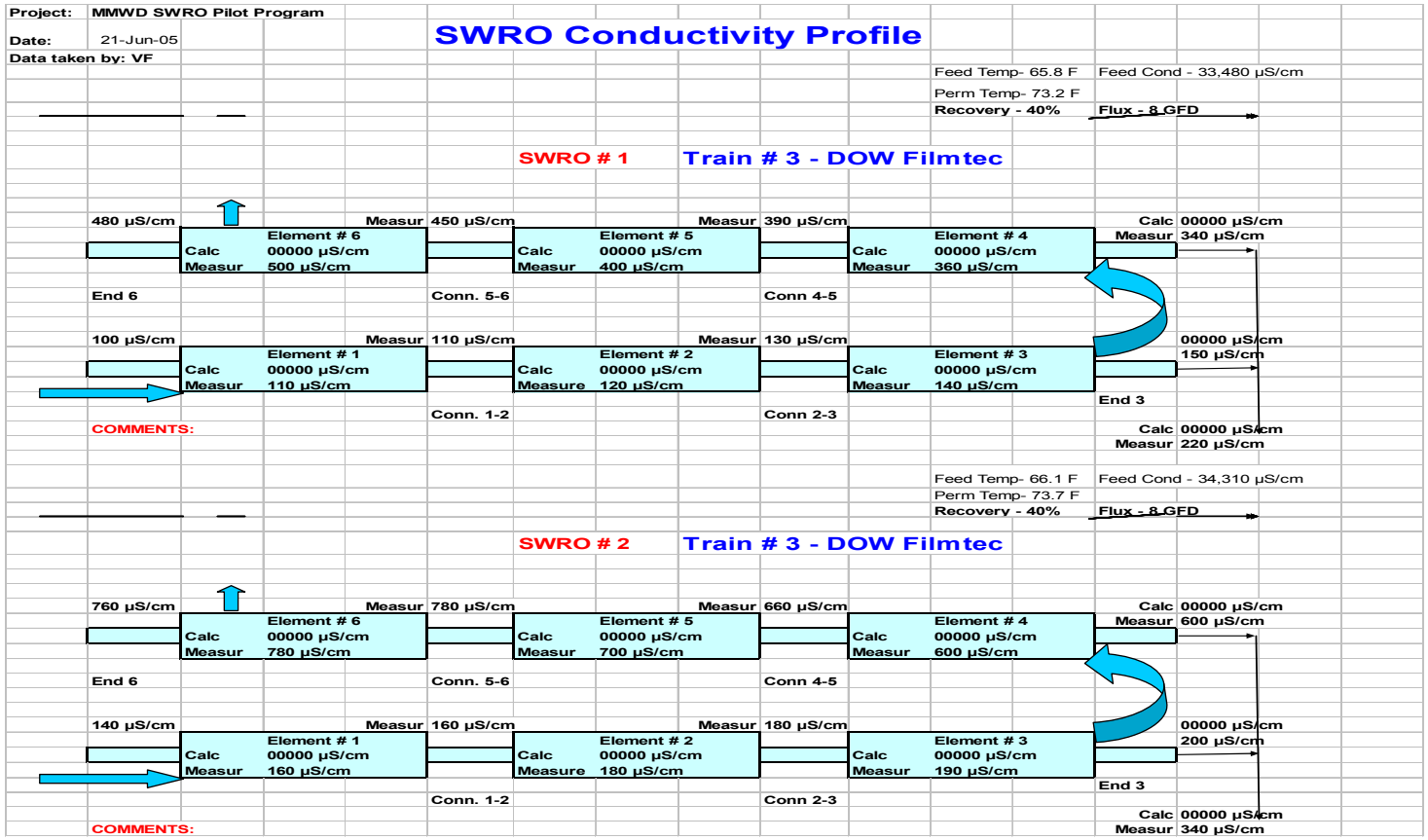
SWRO Probing by Catheters

SWRO Probing by Catheters



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SF Bay and Treated Water

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SUMMARY:

A well-designed pilot testing program is a valuable tool to answer questions on the performance of the technology, to confirm the high quality of the water produced, and to conduct environmental studies to ensure the viability of desalination. The pilot program described herein provided the following valuable benefits:

- Confirmed that desalinated water is safe to drink
- Educated customers and showed that desalinated water tastes good
- Conducted environmental studies to support the EIR process
- Evaluated the best available treatment technologies
- Determined design criteria and costs for a full scale facility

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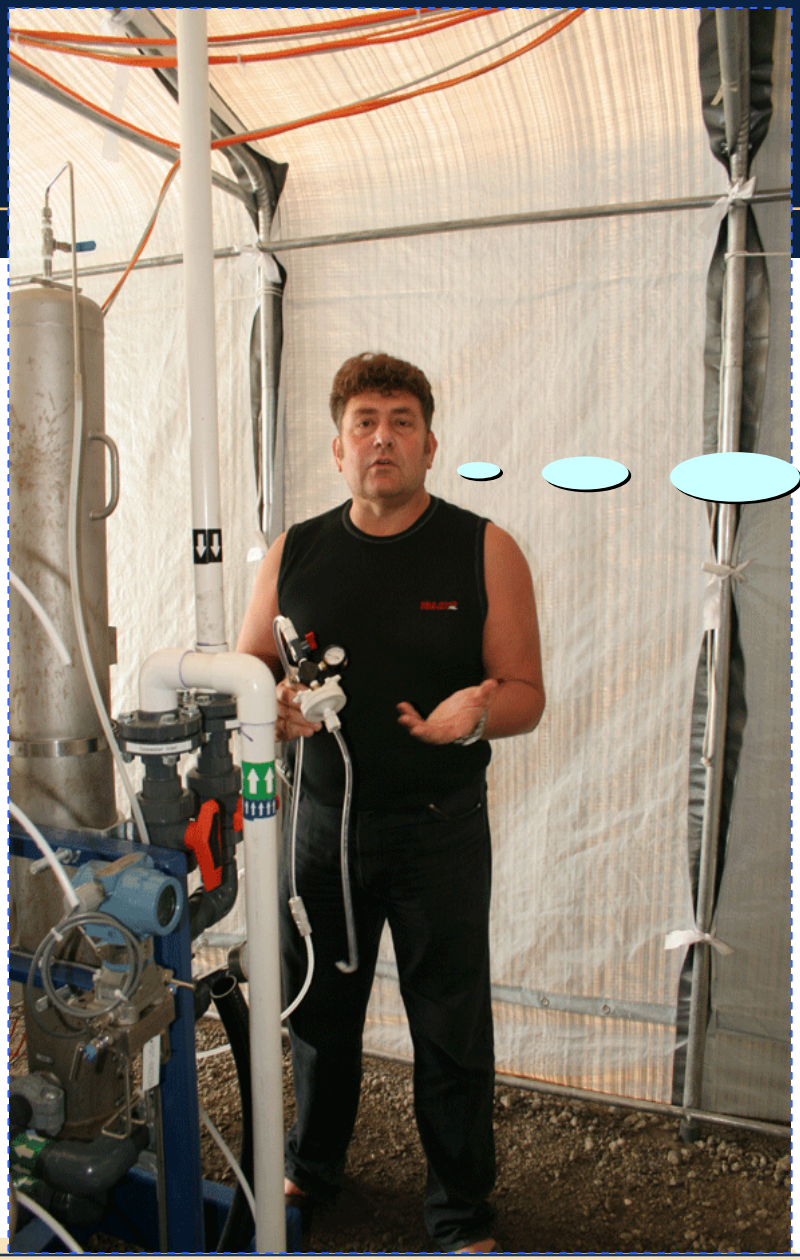

Questions?

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