Seawater Reverse Osmosis Design and Optimization

Nikolay Voutchkov, PE, BCEE

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Engineers & Scientists
National Water Research Institute

Typical Desalination Cost-of-Water Breakdown

Item	Percent of Total Cost of Water (*)
SWRO System	40 %
Energy	30 %
Intake, Discharge & Pretreatment	15 %
Other Costs	15 %
Total Cost of Water	100 %

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(*) Note: Percentage Could Vary Depending on Project-Specific Factors

Performance Optimization Focus

- **SWRO System Design & Operations;**
- **Energy Reduction;**
- **Intake & Discharge Configuration/Collocation;**

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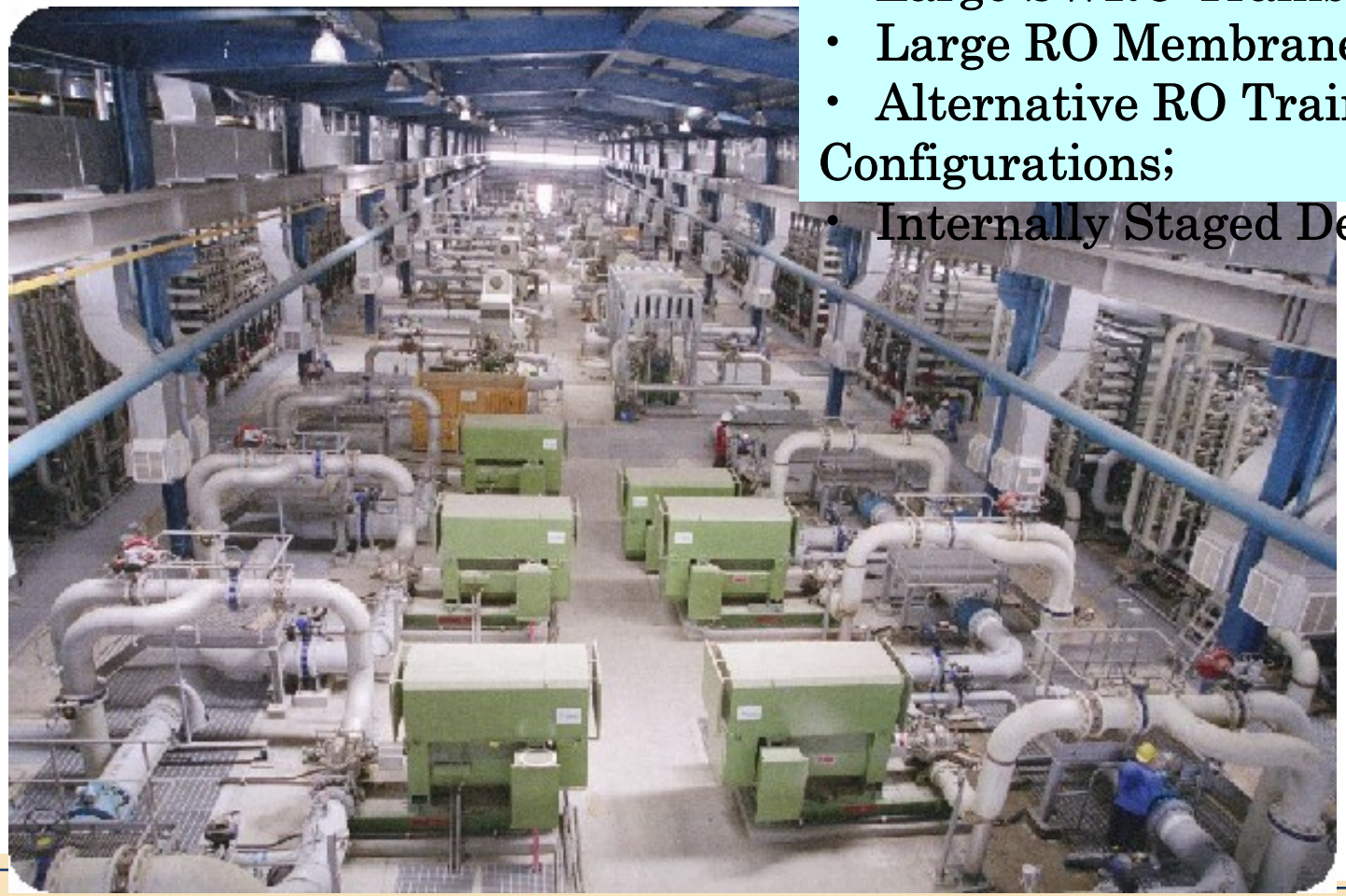
Optimizing RO System Performance – Size Matters!



- Large SWRO Trains;
- Large RO Membrane Elements;
- Alternative RO Train Configurations;
- Internally Staged Design.

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Trinidad SWRO Plant – the Largest SWRO Trains In Use – 5.5 MGD

Large SWRO Membrane Elements

16” RO Membrane Element

Large Size RO Membranes – Advantages

- Potential Space Savings – 10 to 15 %.
- Capital Cost Savings – 5 to 10 %.
- Total Cost of Water Savings – 4 to 6 %

Potential Disadvantages

- Loading Requires Special Equipment and Extra Space.
- Uneven Flow Distribution – Accelerated Fouling.
- Special Vessels Needed.

Standard 8” RO Membrane Element

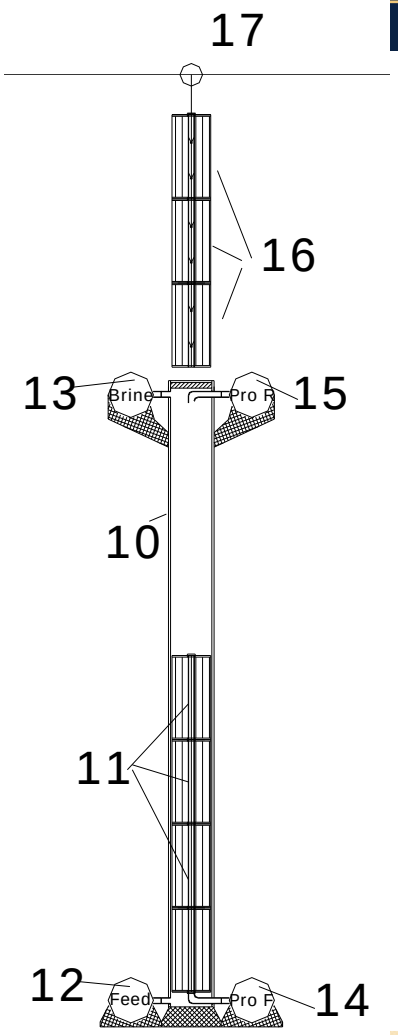
Large Element Space Savings Could Be Elusive!

Brackish Desalination Plant
Yuma, Arizona
12-inch RO Elements

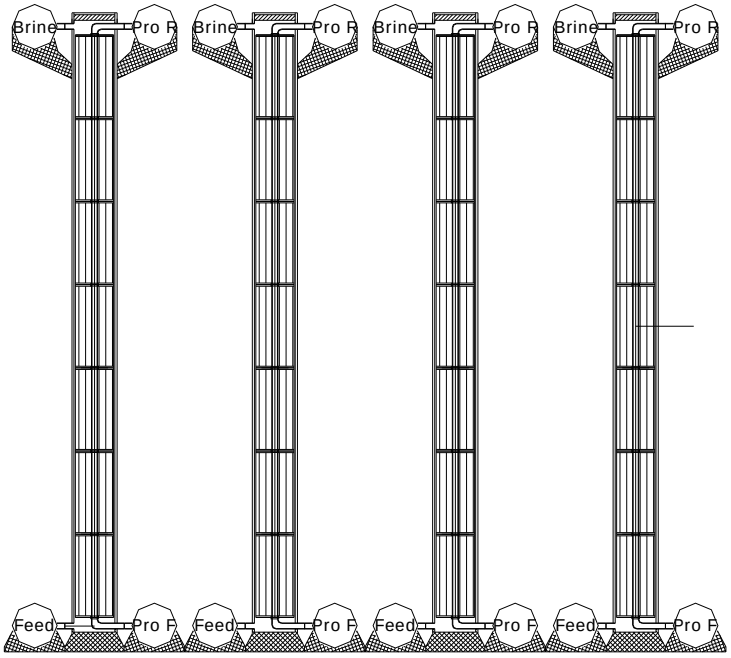
Large Space Needed For the Machine For Element Loading!

Large-Diameter SWRO Vessels in Vertical Position

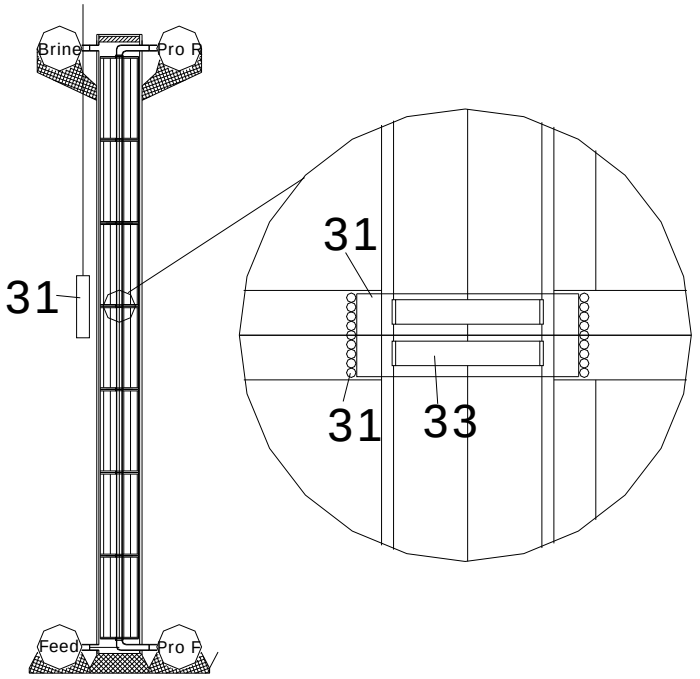
Easy Load



Vertically Positioned PV



Large & Smart Membranes



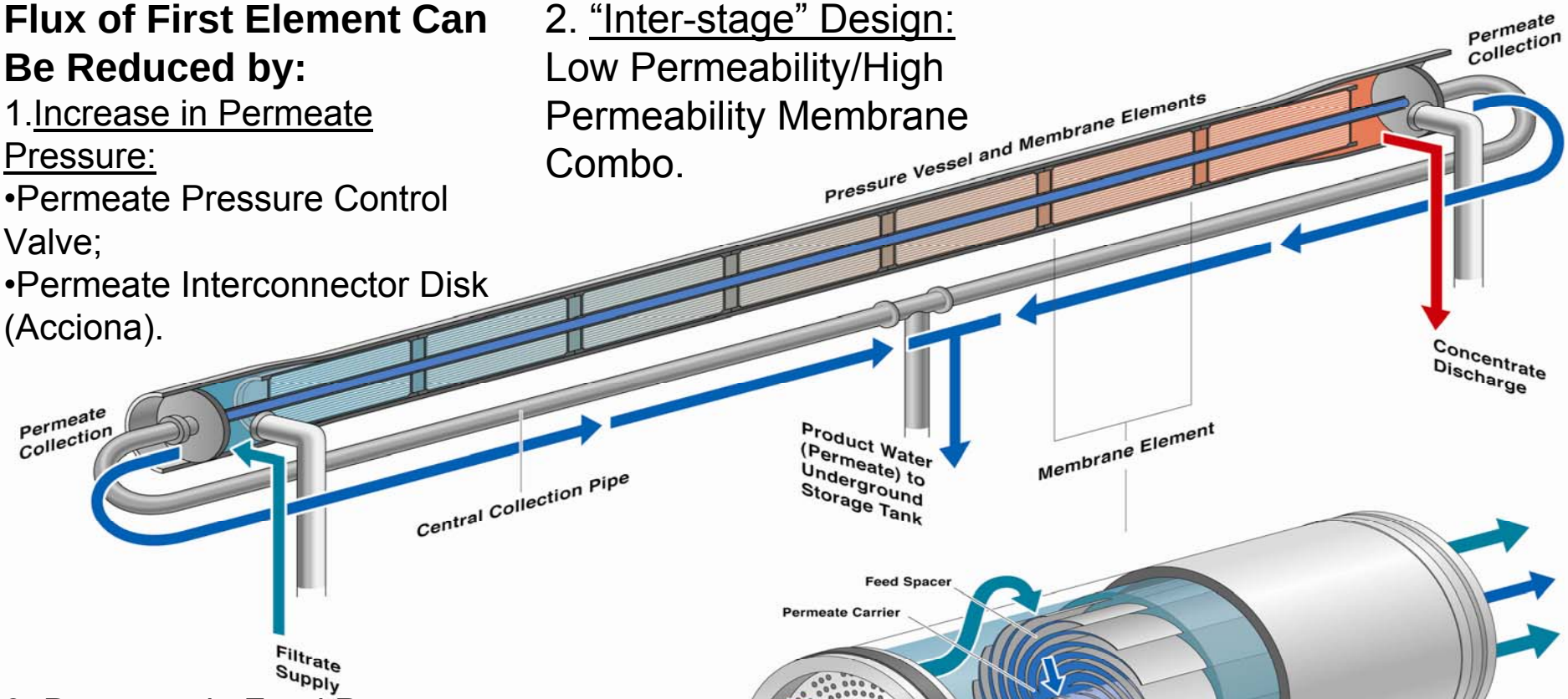
Source: IDE

Optimizing Performance by Redistributing Flux/Energy

Flux of First Element Can Be Reduced by:

1. Increase in Permeate Pressure:
- Permeate Pressure Control Valve;
- Permeate Interconnector Disk (Acciona).

2. "Inter-stage" Design: Low Permeability/High Permeability Membrane Combo.

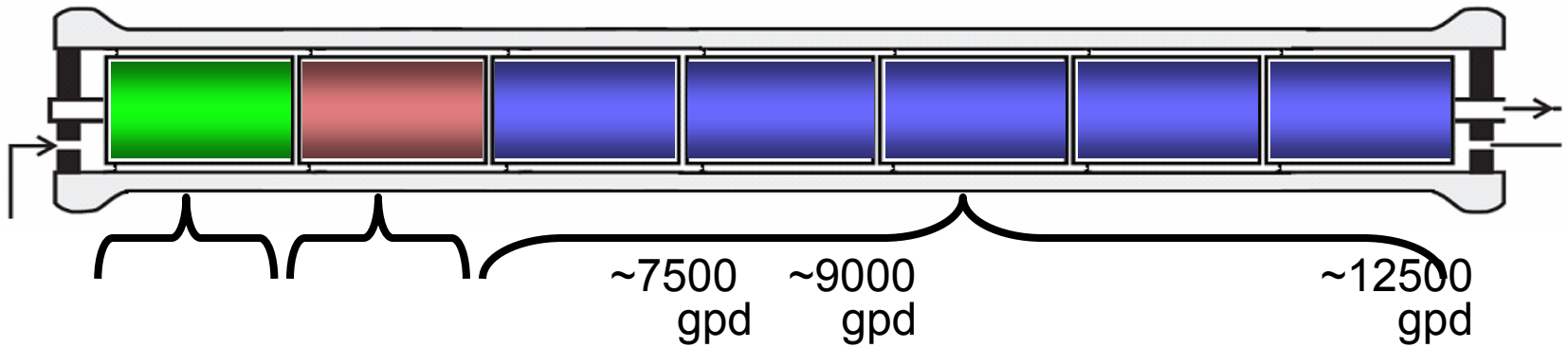


3. Decrease in Feed Pressure:
- Two Pass RO System w/ Interstage Booster Pump;
- "Nano-Nano" Configuration.

Flux is Proportional to the Difference of the Feed and Permeate Pressure

Internally Staged Design (1-1-5)

Element Flow at Standard Test Conditions



Compared to standard SWRO design, ISD SWRO offers:

- **Higher average permeate flux with same lead element flux;**
- **Good permeate quality;**
- **Energy Savings - 5% - 10%;**

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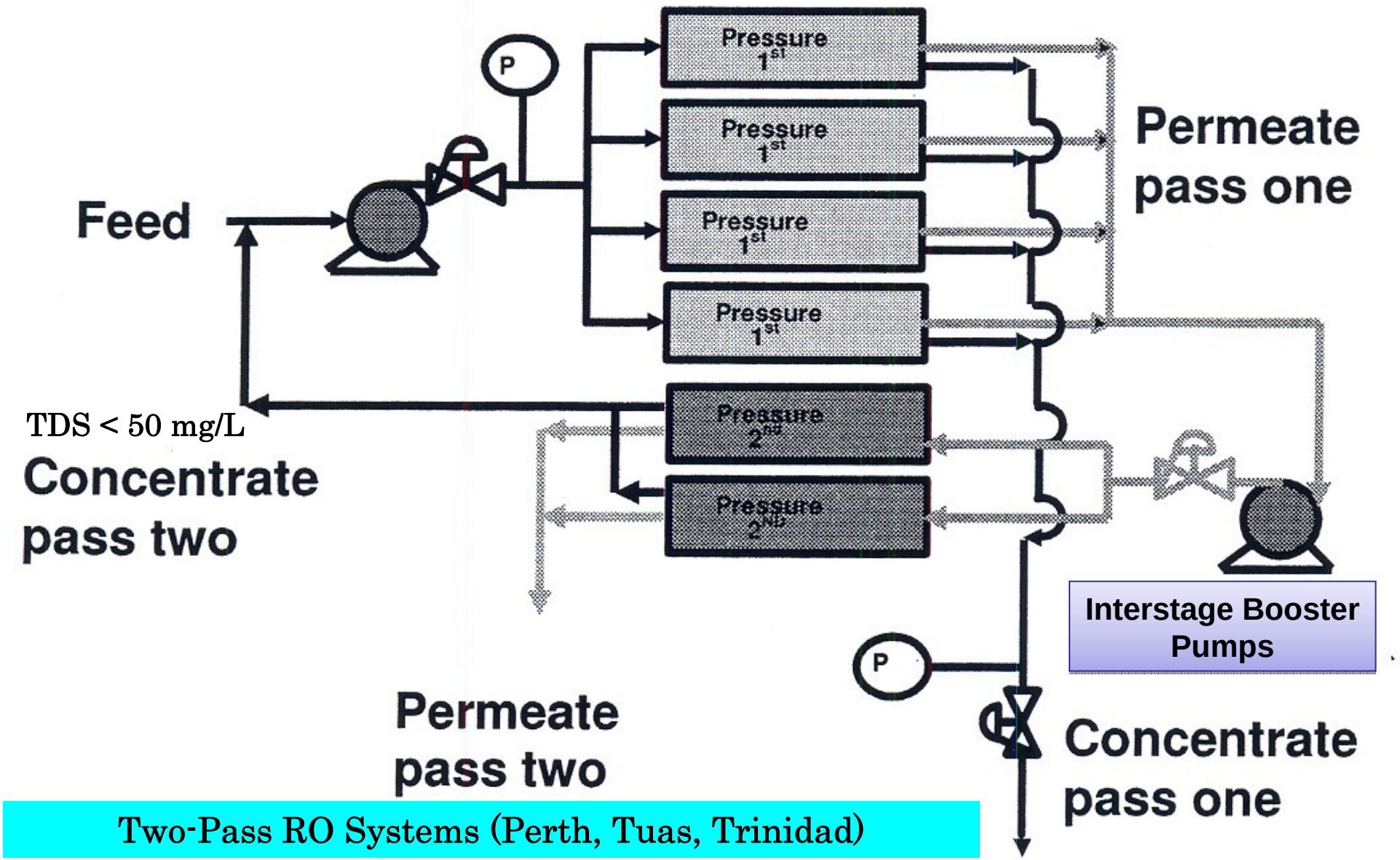
Courtesy: Dow Chemical

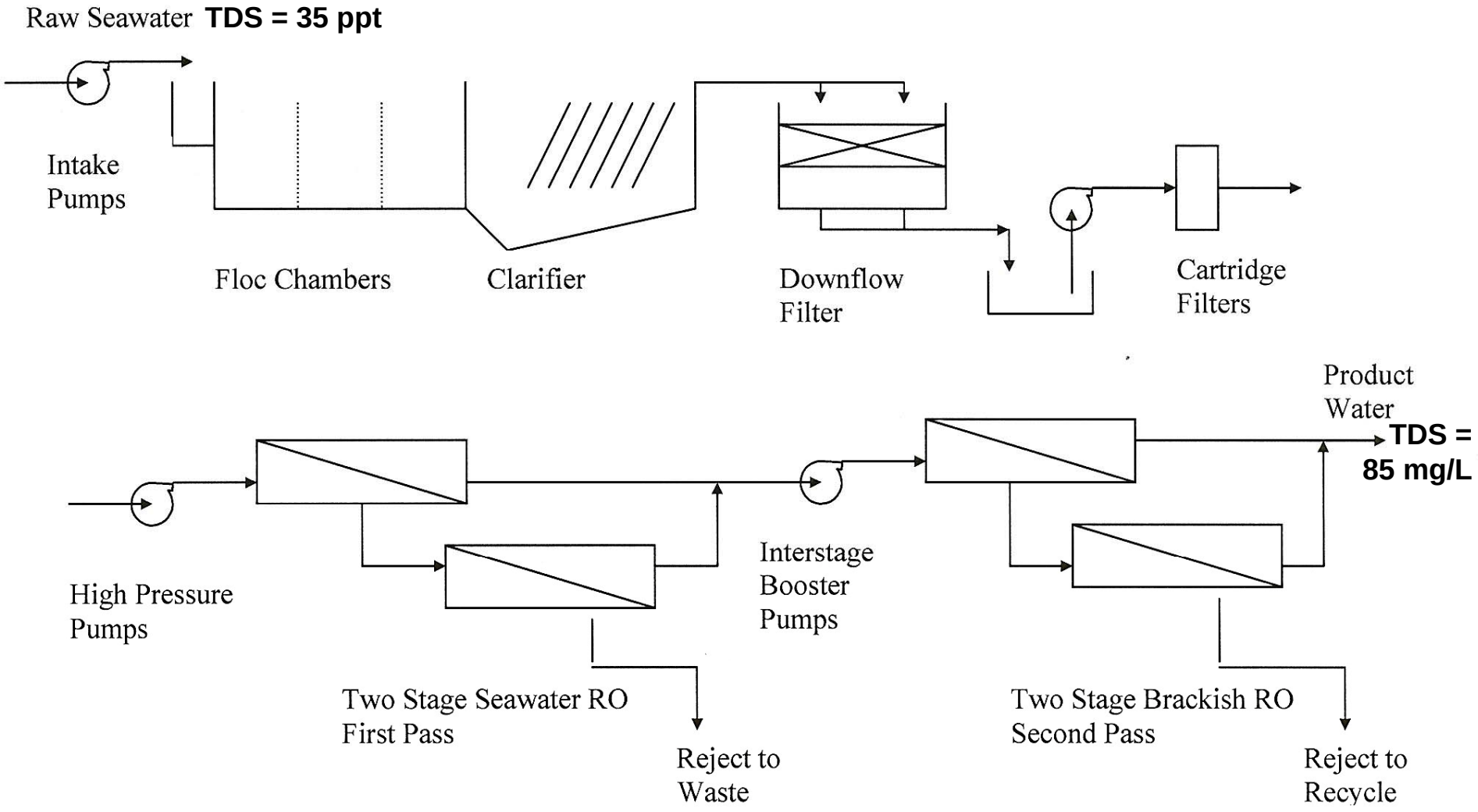
Two-Pass RO Systems



Two-Pass RO Systems (Perth, Tuas, Trinidad)

34 MGD Point Lisas SWRO Plant, Trinidad

Two Pass /Two-stage SWRO System



Reducing Power Use – A Hair Rising Challenge?

- Putting Power Use in Prospective;
- Improving Energy Recovery;
- Maximizing Pump Efficiency;
- Desalination Plant Collocation;
- Source Water Salinity & Energy.

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Putting Desalination Power Use In Prospective

Power Needed to Produce Drinking Water from Seawater for One Family for One Year is Over Two Times Lower than the Power Used by Family's Water Heater!

Treatment	Power Use (kWh/kgal)
Conventional Surface Water	0.8 to 1.6
Water Imports - Pumping	6.0 to 10.6
Reclamation Of Municipal Wastewater	3.0 to 5.0
Seawater Desalination	7.5 to 10.0

Reducing Energy for SWRO – Practical Solutions

- **Pressure Exchanger Energy Recovery**

  (35 to 40 % Energy Reduction);

- **Use of Alternative RO Membrane Vessel Configurations (10 to 15 % Energy Reduction);**

- **Application of Large RO Trains/Pumps (3 to 5 % Energy Reduction);**

- **Use of Warm Power Plant Cooling Seawater**

  (5 to 10% Energy Reduction).

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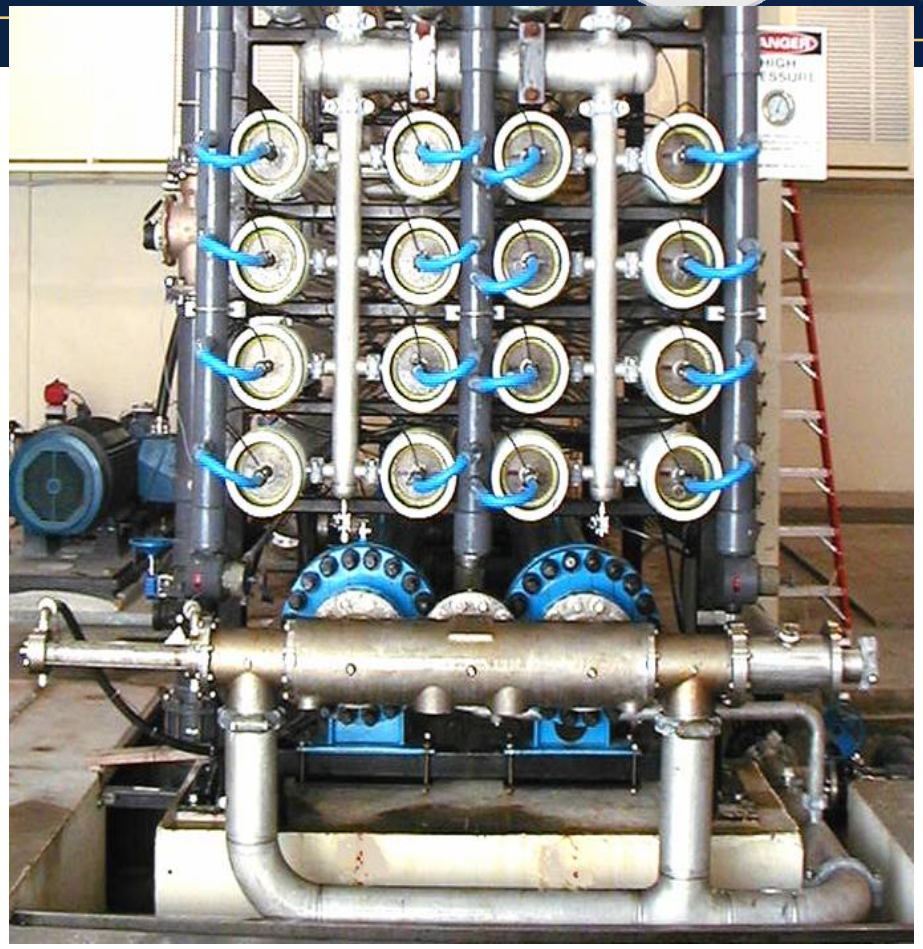
Improving Energy Recovery – Pressure Exchangers

Dhekelia, Cyprus SWRO Plant



Barbados SWRO Plant

5 to 15 % Better Recovery than Traditional Pelton Wheel Systems

Maximizing Pump Efficiency

- **Pump Efficiency ~**

  $n \times (Q/H)^{0.5} \times (1/H)^{0.25}$

Where:

n = pump speed (min^{-1});

Q = nominal pump capacity (m^3/s);

H = pump head (m).

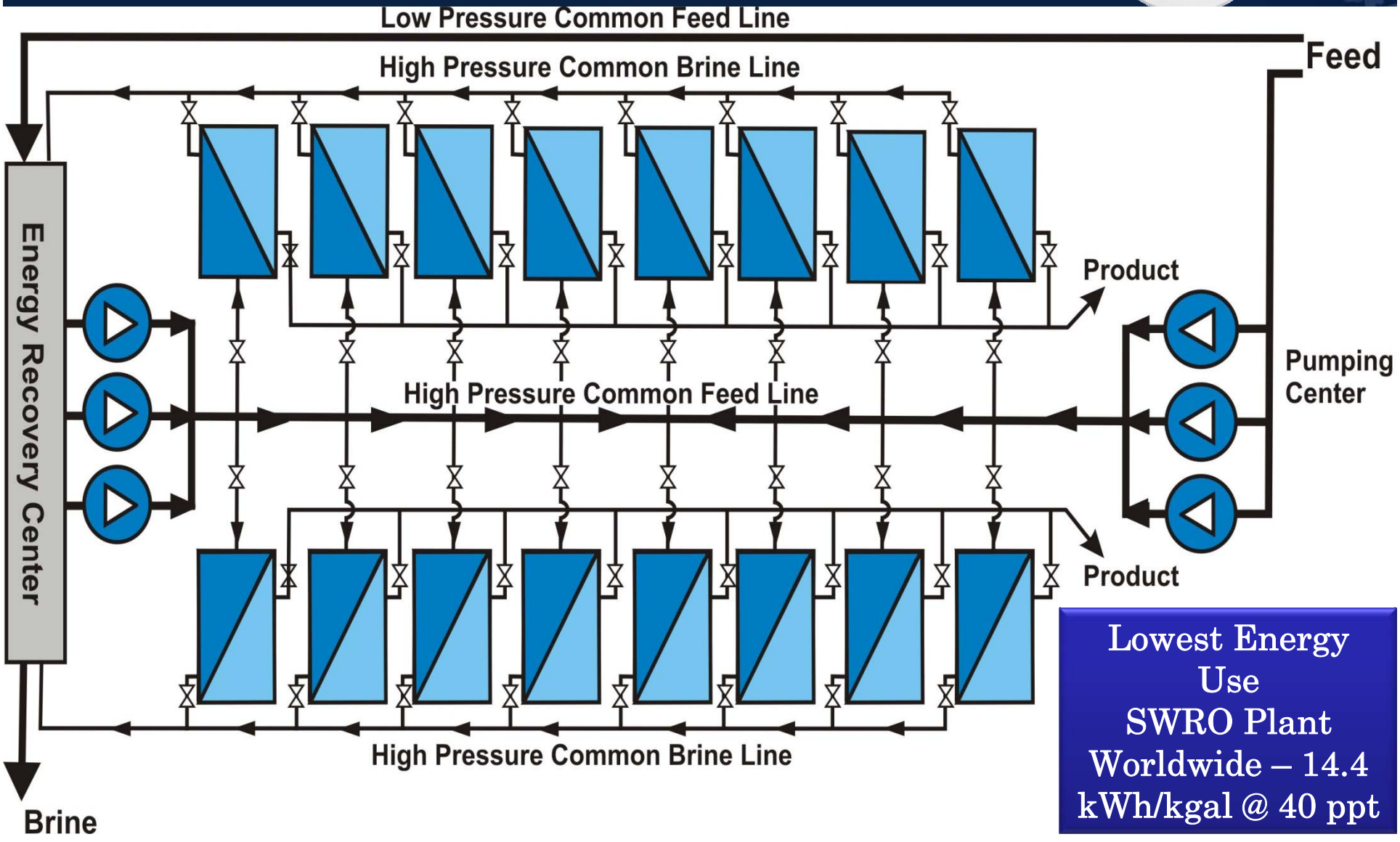
Pump Efficiency:

One Pump Per Train – 83 %

Carboneras, Spain & Perth –
One Pump per 2 RO Trains

Ashkelon, Israel –
Two Pumps per 16 RO Trains

Flattening the Pump Curve For Wide Range of Flows - The Three-Center Design



Lowest Energy Use SWRO Plant Worldwide – 14.4 kWh/kgal @ 40 ppt

Change in SWRO Plant Operations Paradigm!

Tri-Center Design

Delivers Varying

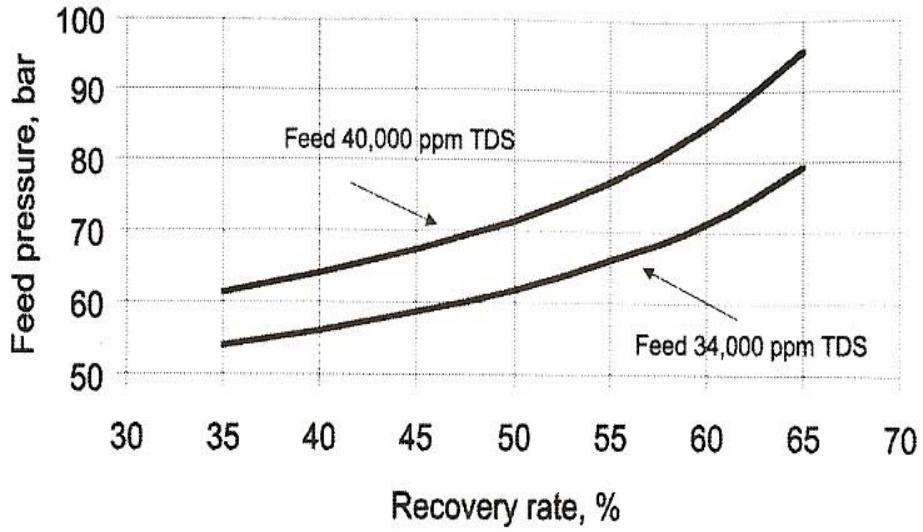
Flow by Change in

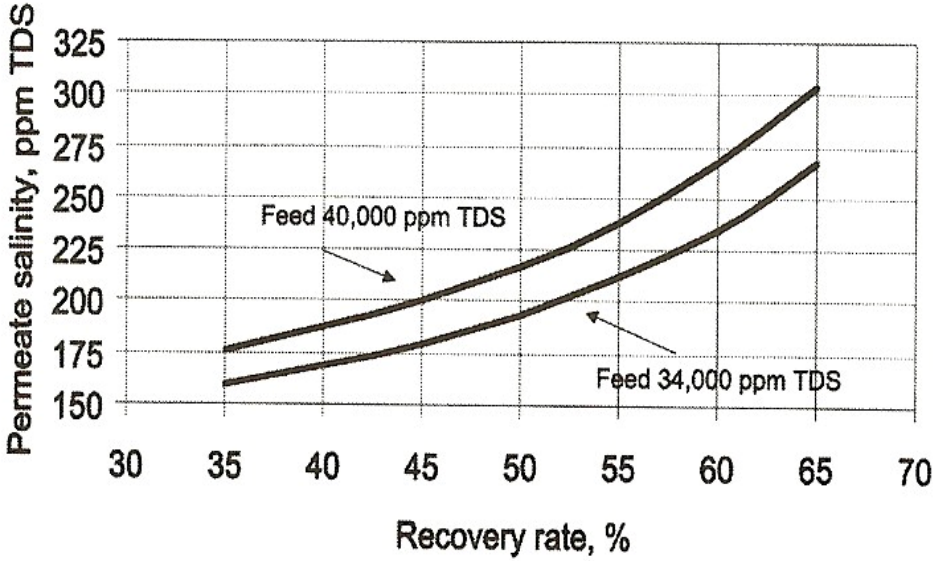
Recovery

Rather than

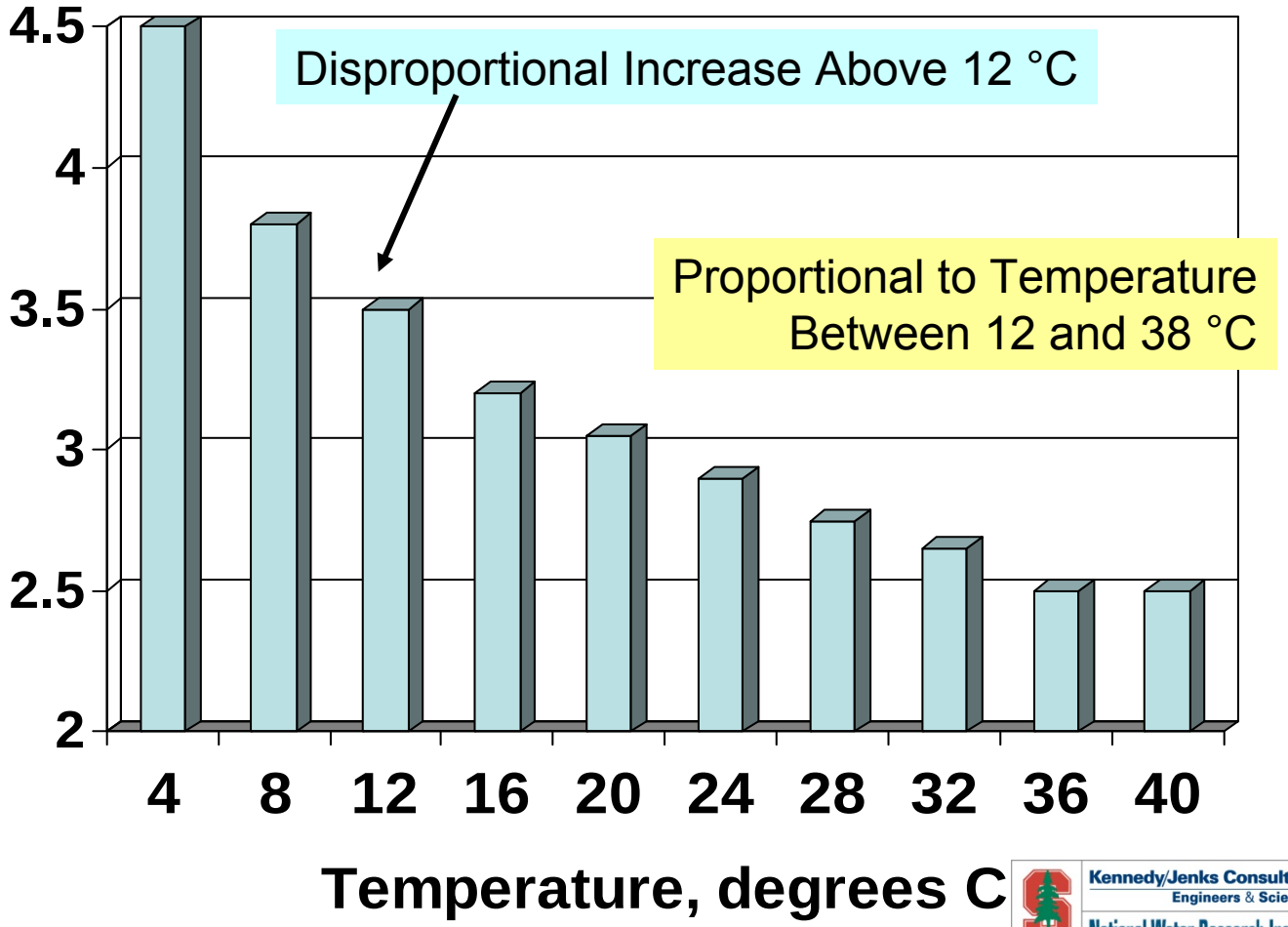
By Turning

RO Trains On & Off!





Energy Use and Temperature



- Use of Warm Water May Be Beneficial!
- Use of Intake Wells or Deep Intakes May Result in Energy Penalty!

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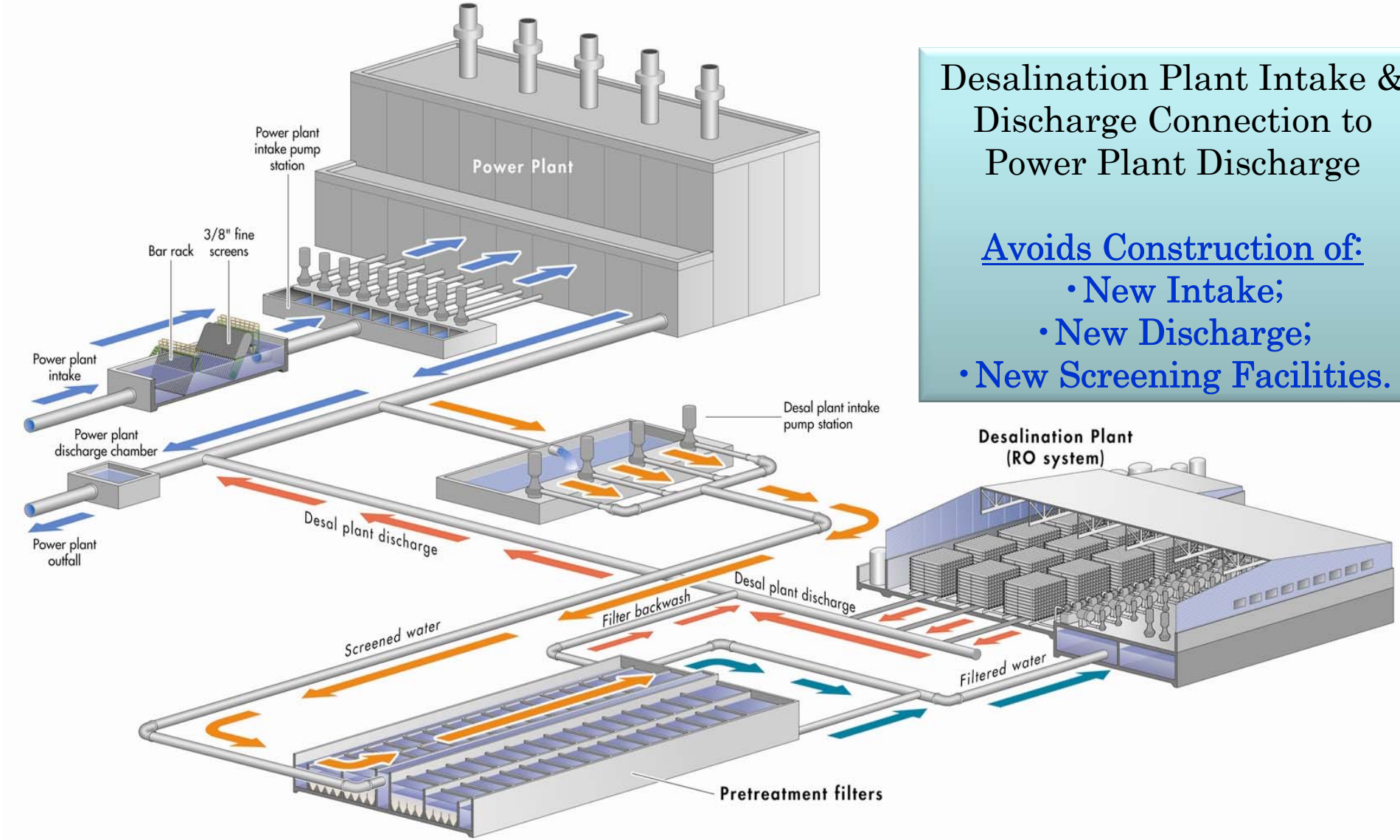
Collocation with Power Plant



Desalination Plant Intake & Discharge Connection to Power Plant Discharge

Avoids Construction of:

- New Intake;
- New Discharge;
- New Screening Facilities.

Potential Energy Benefits of Collocation

- **Reduced Intake and Discharge Pumping Costs (1-2% Power Savings).**
- **Power Cost Savings due to Warmer Source Water (5-15 % Power Use Reduction).**
- **Use of Power Plant "Spinning Reserve" Energy Where Available.**
- **Potential Avoidance of Power Grid Connection Charges/Power Tariff Fees.**

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Collocation – Capital Cost Savings

- **Avoidance of Construction of New Intake & Discharge Facilities – 10 to 50 % of Construction Costs;**
- **Avoidance of Construction & Operation of New Screening Facilities;**
- **Electrical System Cost Savings:**
  - **Lower or No Power Grid Use Tariff Charge;**
  - **Use of the "Spinning Reserve" of "Must Run" Power Plants.**

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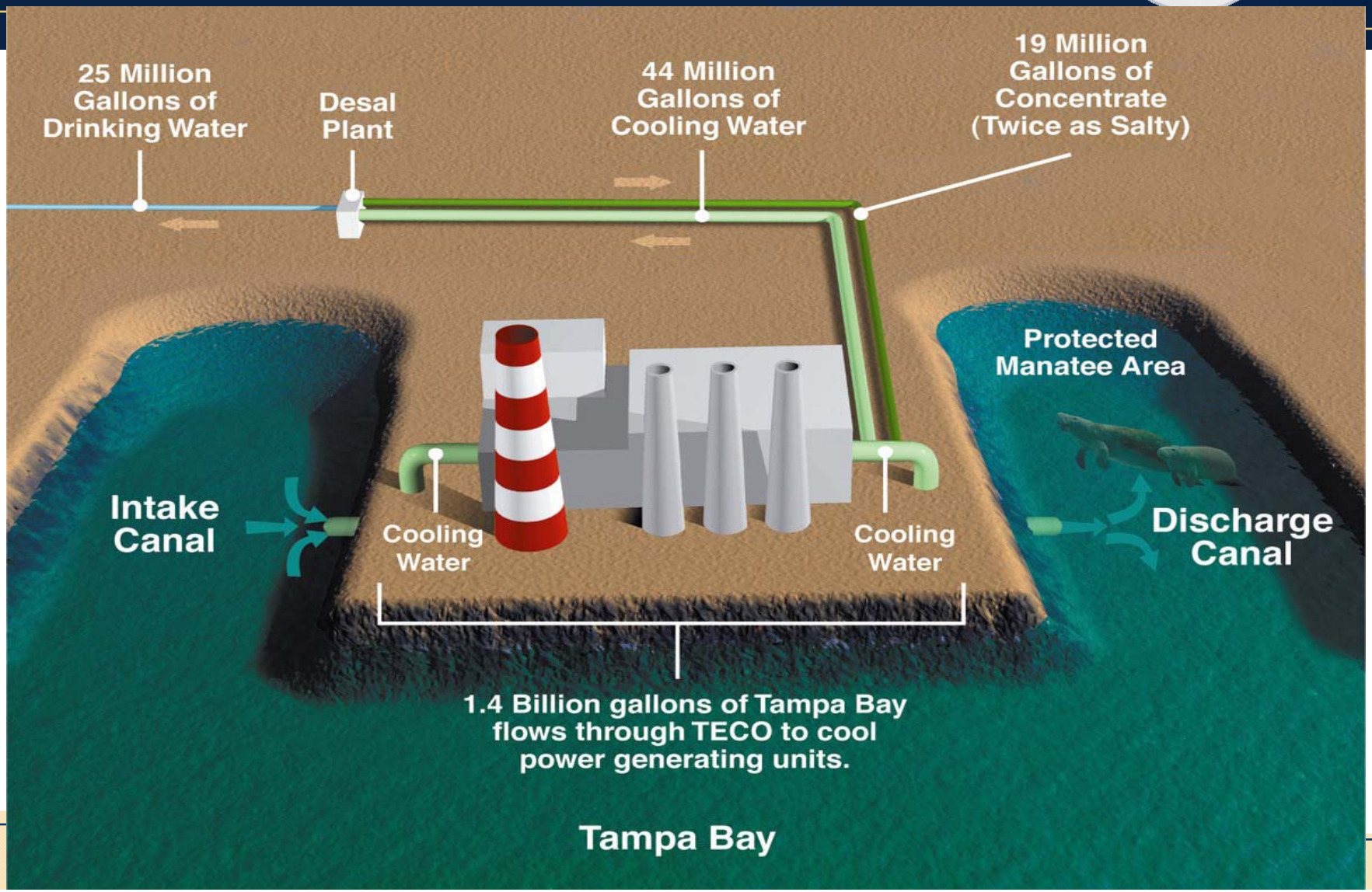
Collocation in Tampa, Florida

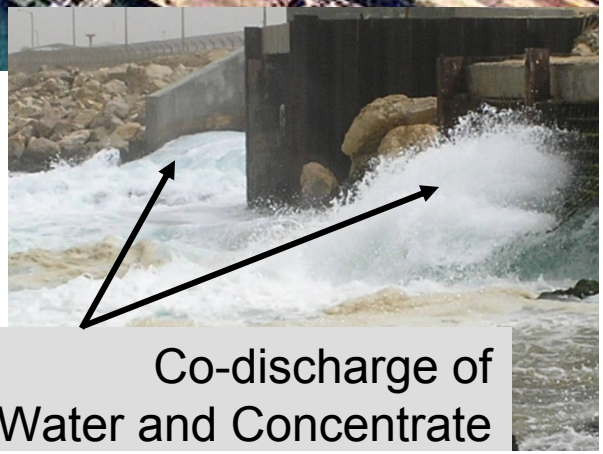


Collocation Concepts in Ashkelon

Power Plant

Desalination Plant

Ashkelon Power Generation Plant - Waste Heat Used to Warm Intake Seawater



Co-discharge of Cooling Water and Concentrate

Main Areas Expected to Yield Cost Savings in the Next 5 Years

- **Improvements in Membrane Element Productivity:**
  - **Nano-composite SWRO Membranes;**
  - **Larger Membrane RO Elements (16” Diameter or Higher).**
- **Increased Membrane Useful Life and Reduced Fouling:**
  - **Increased Membrane Material Longevity;**
  - **Use of Systems for Continuous RO Membrane Cleaning;**
  - **UF/MF Membrane Pretreatment.**
- **Wider Use of Pressure Exchanger Type Energy Recovery Systems;**
- **Co-Location With Power Plants;**
- **Larger RO Trains and Equipment;**
- **Full Automation of All Treatment Processes.**

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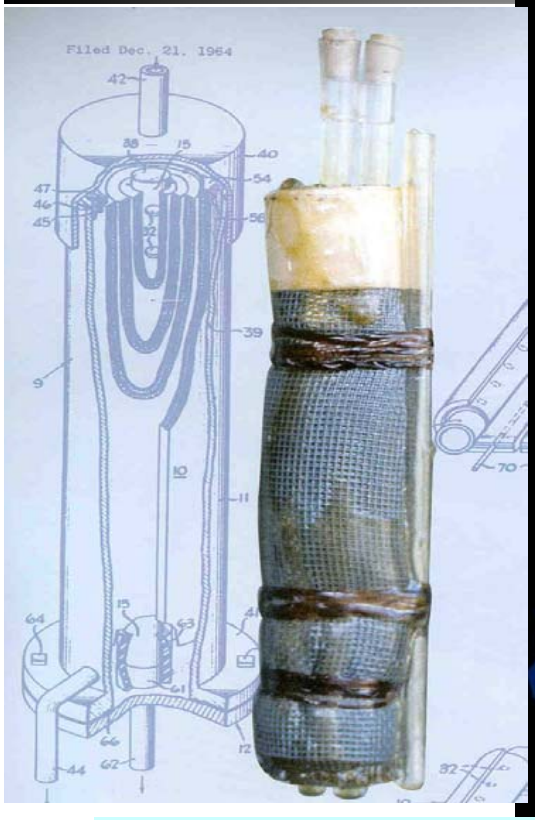
SWRO Performance Optimization - Future Improvements Will Come From Better Membranes and Lower Cost Materials!



Questions ?