

Coomandook Ag Bureau Desalination Night

DESALINATION

Coorong District Council

Coomandook Uniting Church

April 3, 2019

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A row of industrial water meters is shown in a shallow depth of field. The central meter is in sharp focus, revealing its internal mechanical components, including a circular dial and various gears. The meters are mounted on a metal structure. Overlaid on the image is the text "It's not about water. It's about energy!" in a bold, sans-serif font. The first part of the text is blue, and the word "energy!" is red.

**It's not about water.
It's about energy!**



“Energy is eternal delight!”

Energy is liberation.

William Blake, author, poet, visionary, 1757 – 1827

Presentation Overview

- Introduction
- Basics of Reverse Osmosis
- The Sustainability of Seawater Reverse Osmosis (SWRO)
- Some Australian Inland Plants
- The Big Six
- Conclusions

Desalination History

- Aristotle described distillation - 400 BC
- Distillation: Desalination on early ships - 200AD
- Distillation: MED (Norbert Rillieux, 1806 - 1894)
- Coolgardie Water Distillery (WA) - 1895
- Distillation: Desalination MSF - 1956
- Distillation: Desalination MED - 1960
- Distillation: Desalination MVC, METC – 1960
- Membrane: RO (Drs. Sourirajan & Loeb @ UCLA, 1959)
- Membrane: RO (John Cadotte - FilmTec, 1970)
- Membrane: Desalination RO and NF - 1970
- Membrane: Pre-treatment (MF, UF) - 1990
- Membrane: Wastewater (MBR) - 2000

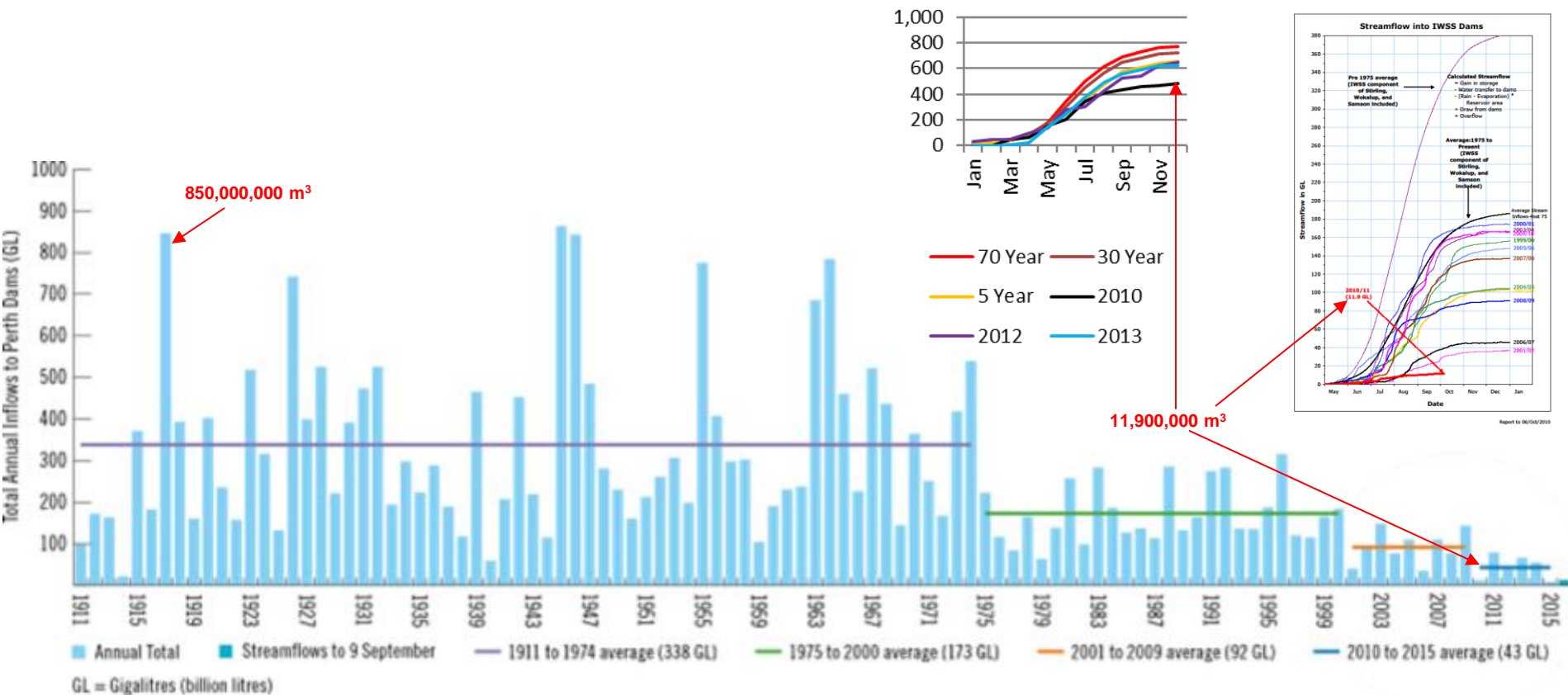


Dr. Sid Loeb
2005 - 2008

Impact of Drying Climate

- Reduced Inflow to Dams (as at 1 Nov 16)

Declining Stream-flows and Below Average Rainfall



Courtesy of the Water Corporation

What processes are used?

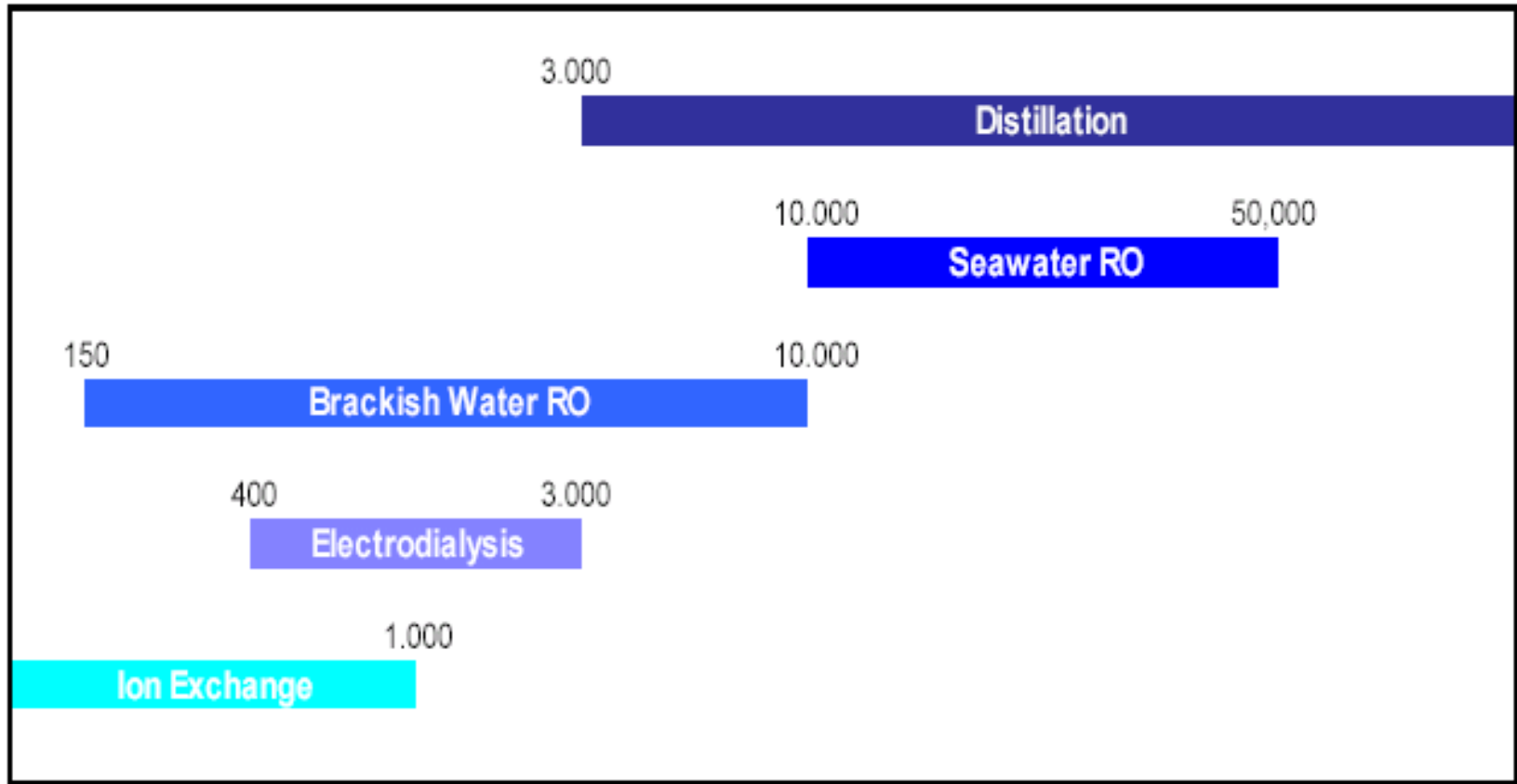
- **Major Processes**

- Thermal (Distillation)
 - Multi-Stage Flash Distillation (MSF) – not applicable to this forum
 - Multiple-Effect Distillation (MED) – ZLD, Water Supply (e.g. Ravensthorpe)
 - Vapour Compression (MED-TC, MVC), Water supply (e.g. Burrup Fertilizers)
- Membrane (Separation)
 - **Reverse Osmosis (RO) – applicable to all mining and oil & gas (upstream and downstream)**
 - Nano Filtration (NF) – Sulphate Reducing Plant (SRP – Oil & Gas)
 - Electrodialysis (ED, EDR, HEED) – applicable to lo salinity waters, industry
 - Capacitive Deionisation (CDI) – applicable to lo salinity waters, industry

- **Minor Processes**

- Freezing
- Membrane Distillation – Possible for industry
- Solar Humidification

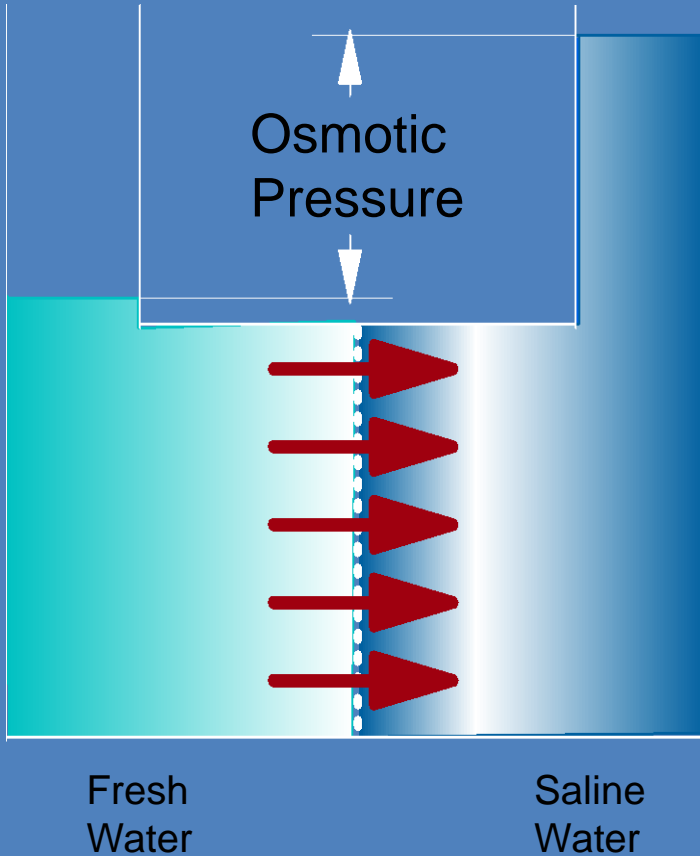
What processes are used?



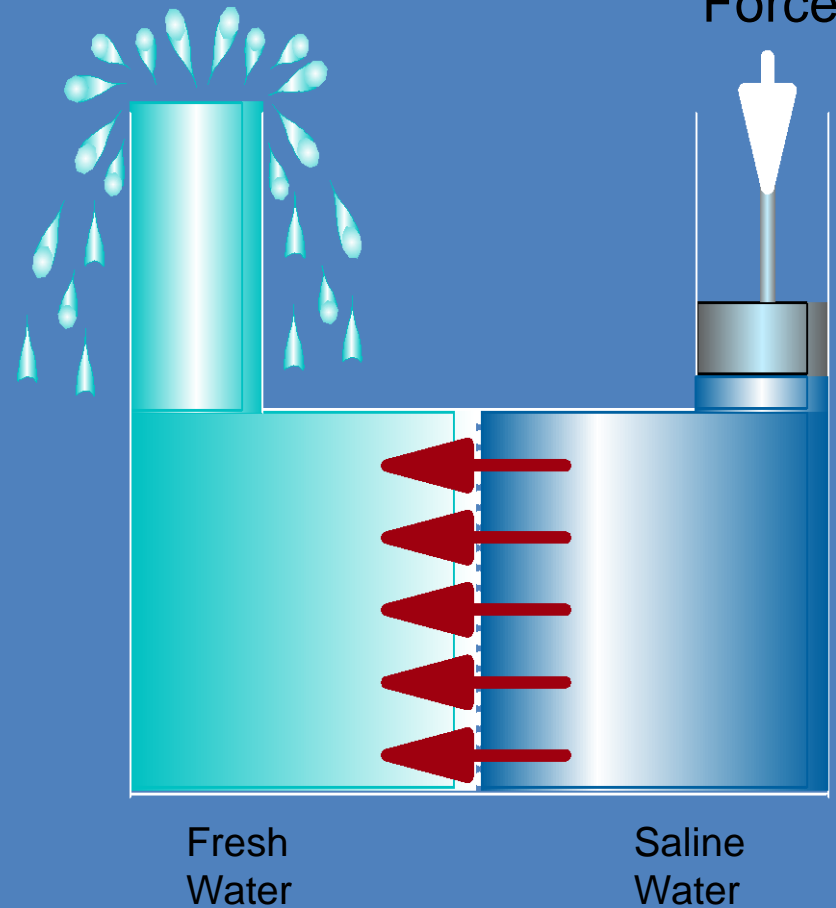
Salinity of Feedwater in mg/l (ppm) TDS

Principal of Reverse Osmosis

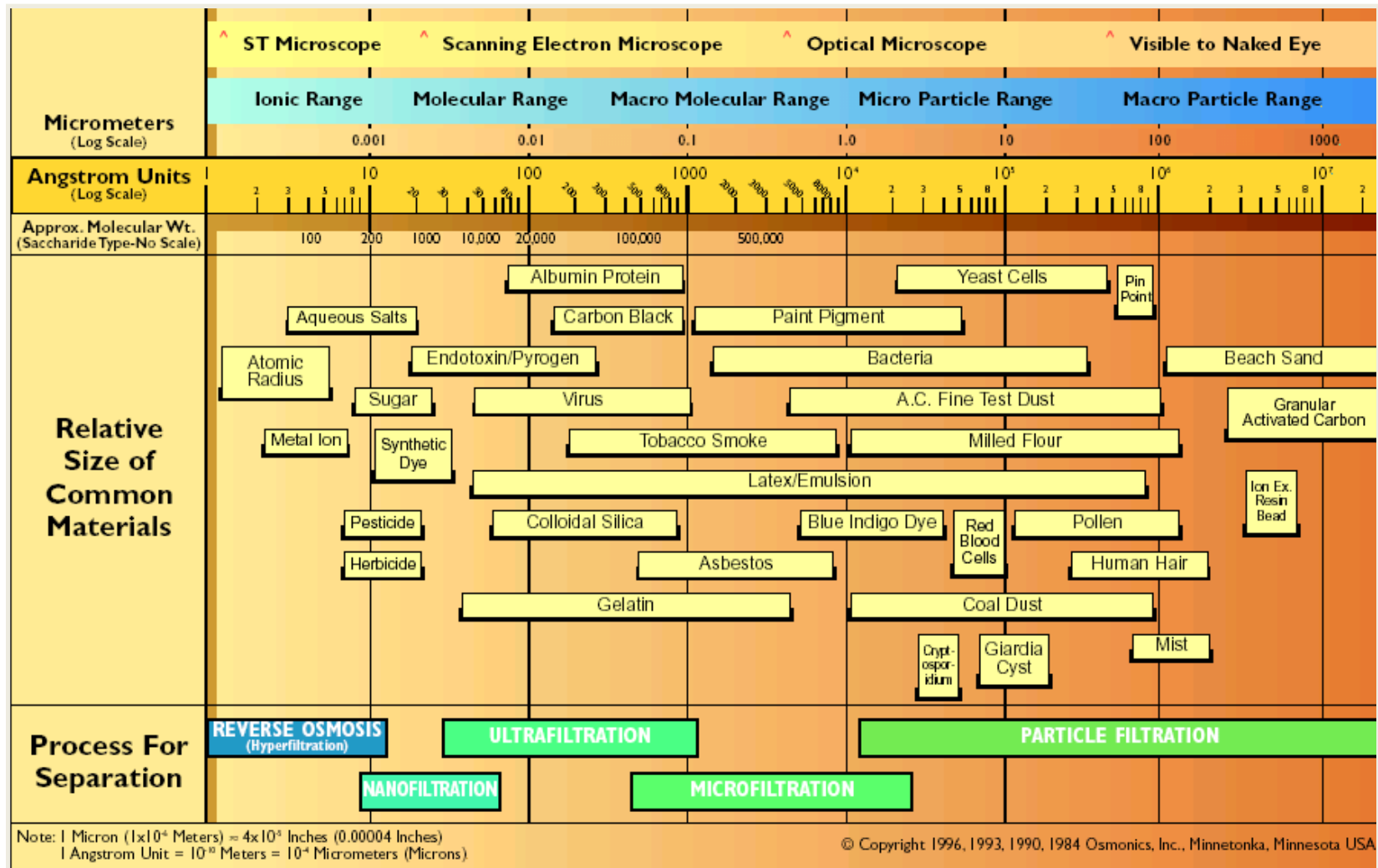
Osmosis



Reverse Osmosis Force



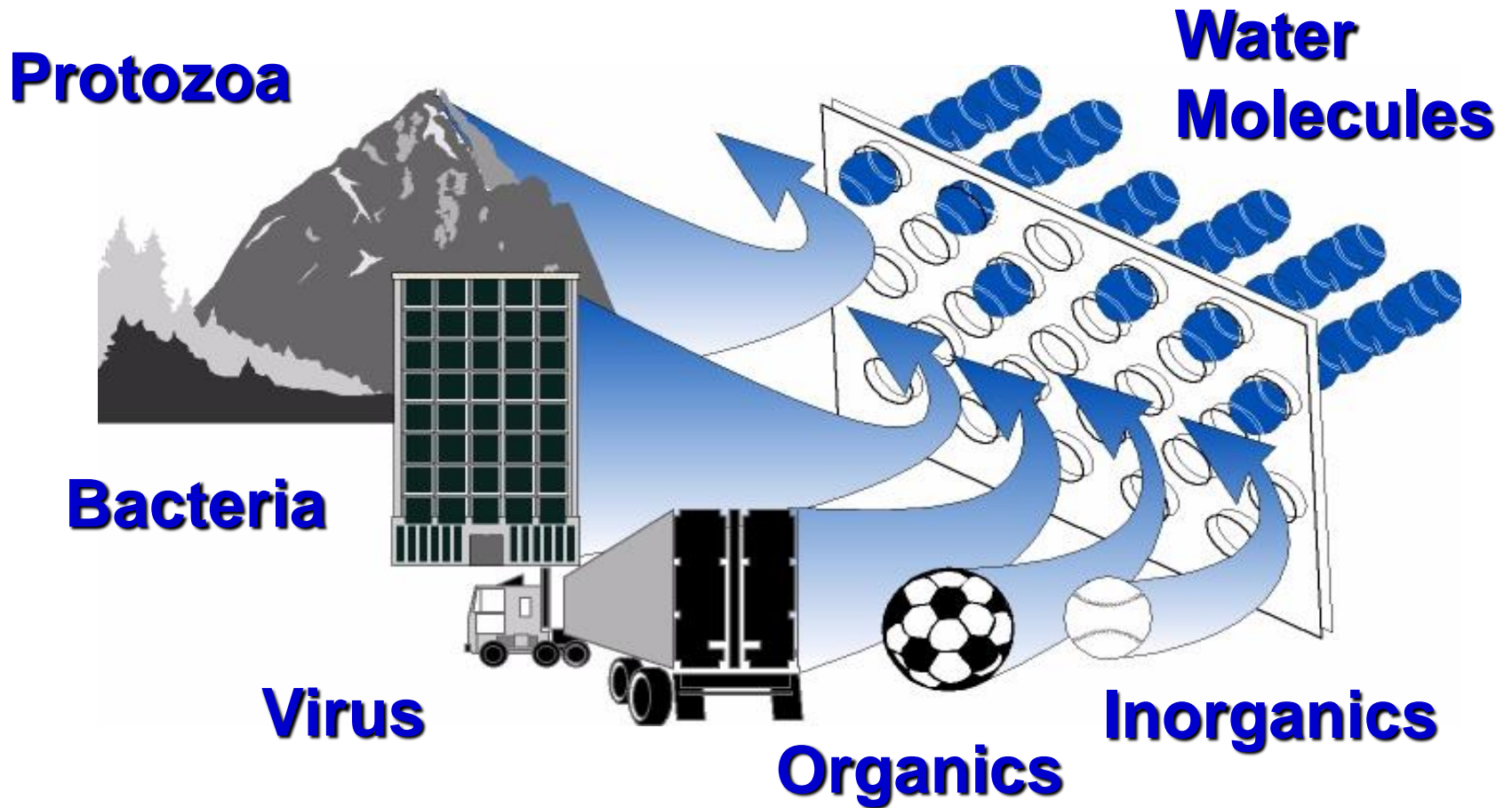
Membrane Separation - Filtration Spectrum



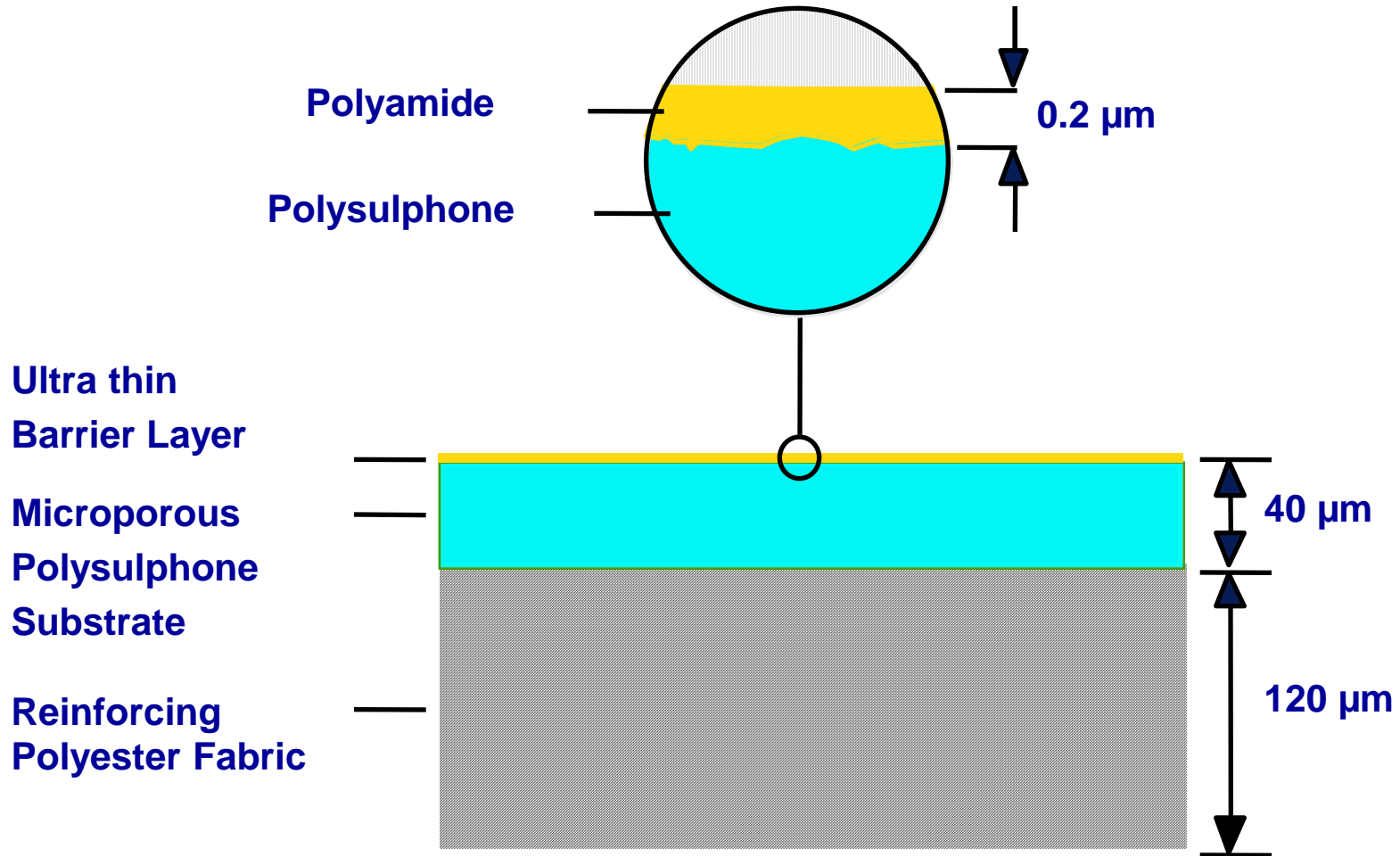
Courtesy of Osmonics

Reverse Osmosis

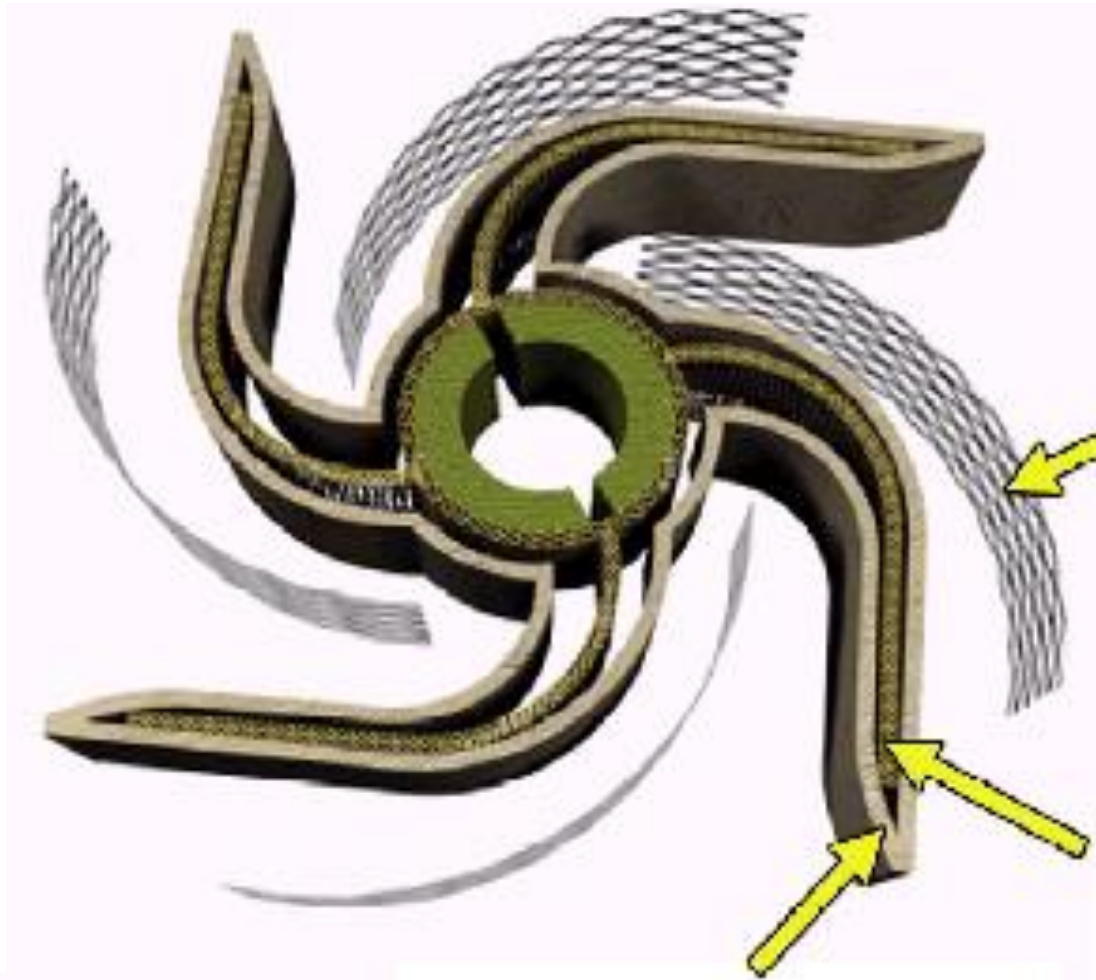
An RO Membrane is like a Microscopic Strainer that allows Water Molecules to pass through



Cross-Section Thin Film Composite (TFC)



Membrane arrangement - Membrane element

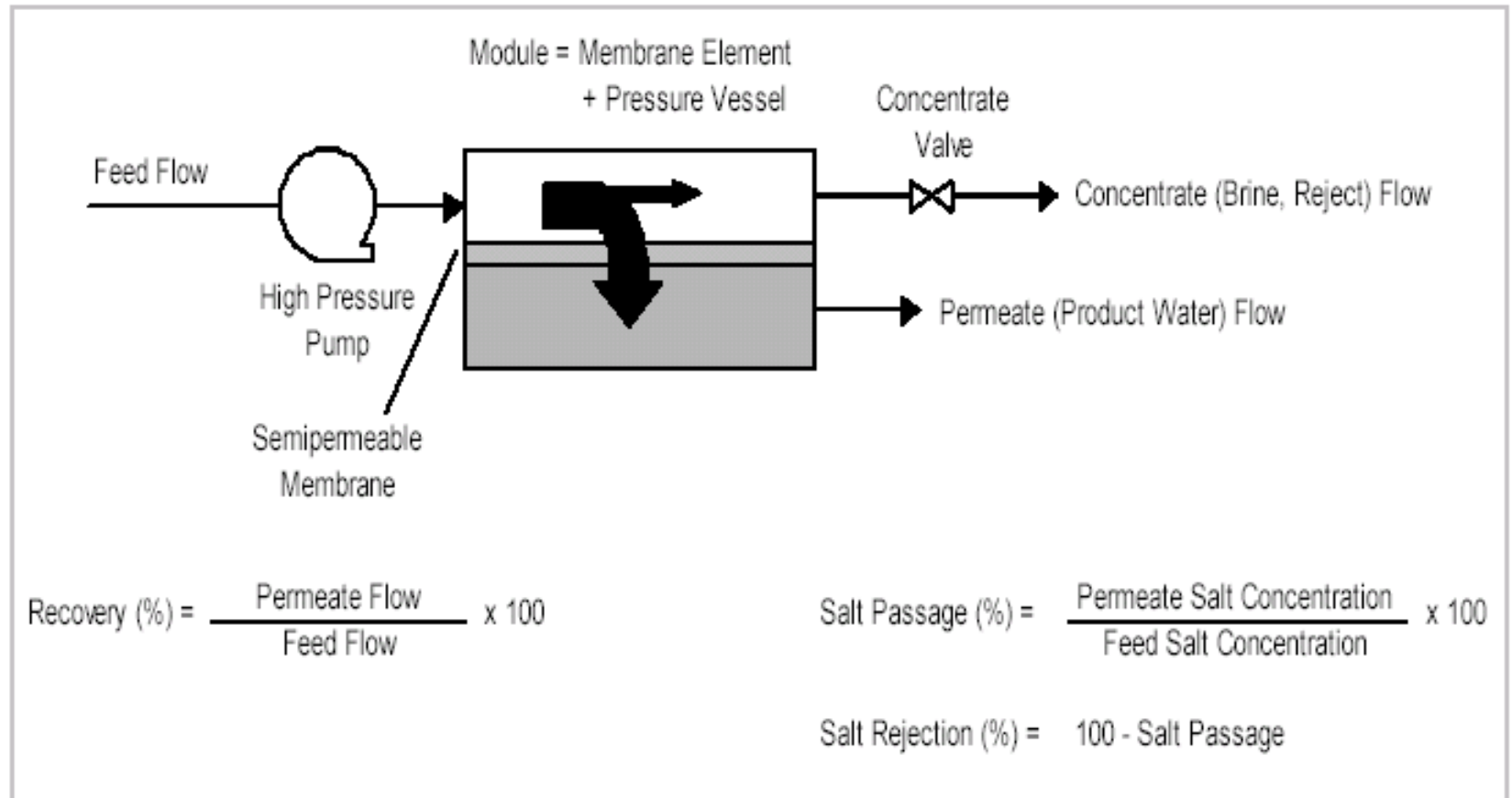


Feed spacer

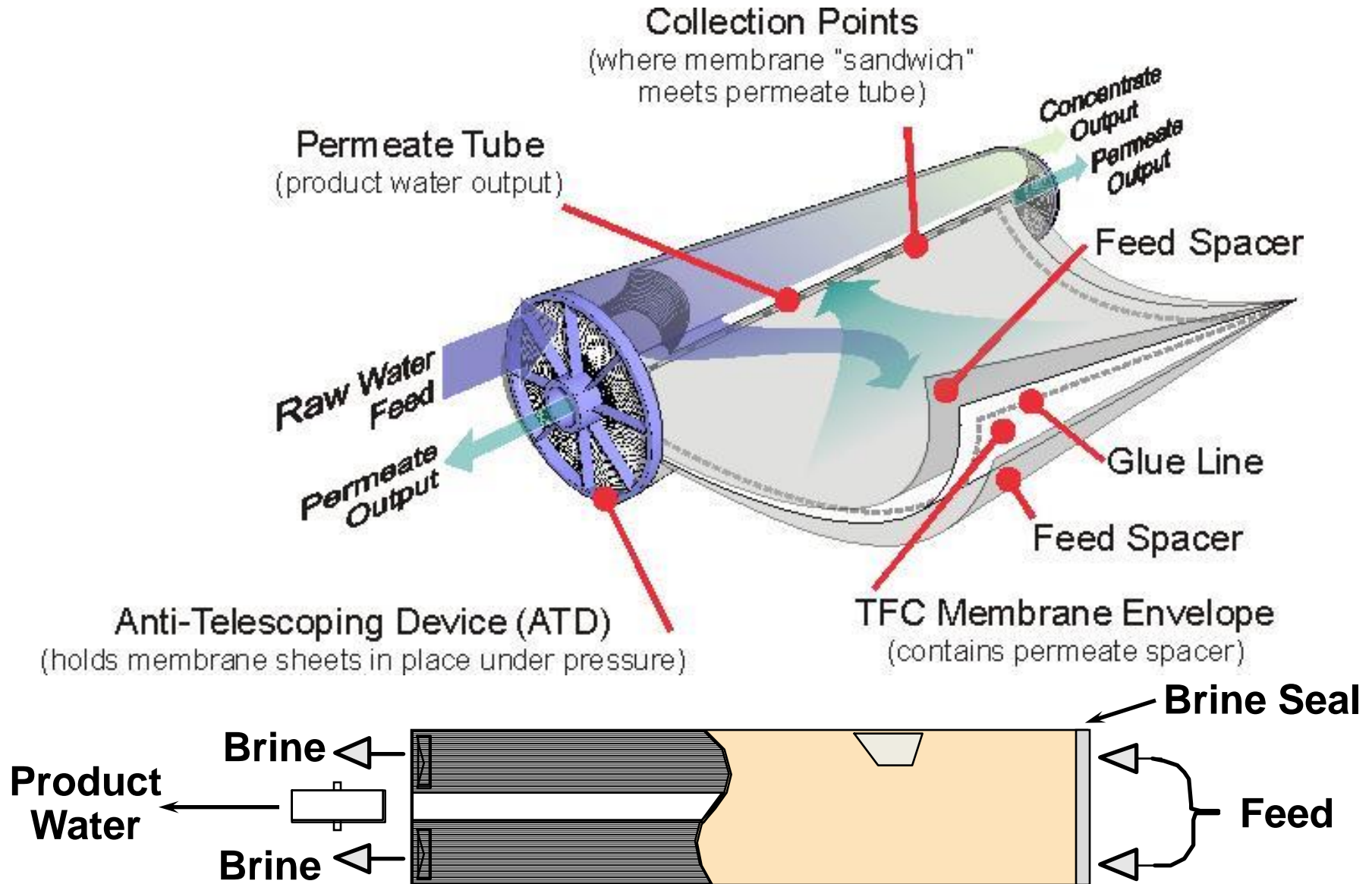
Permeate spacer

Membrane leaf

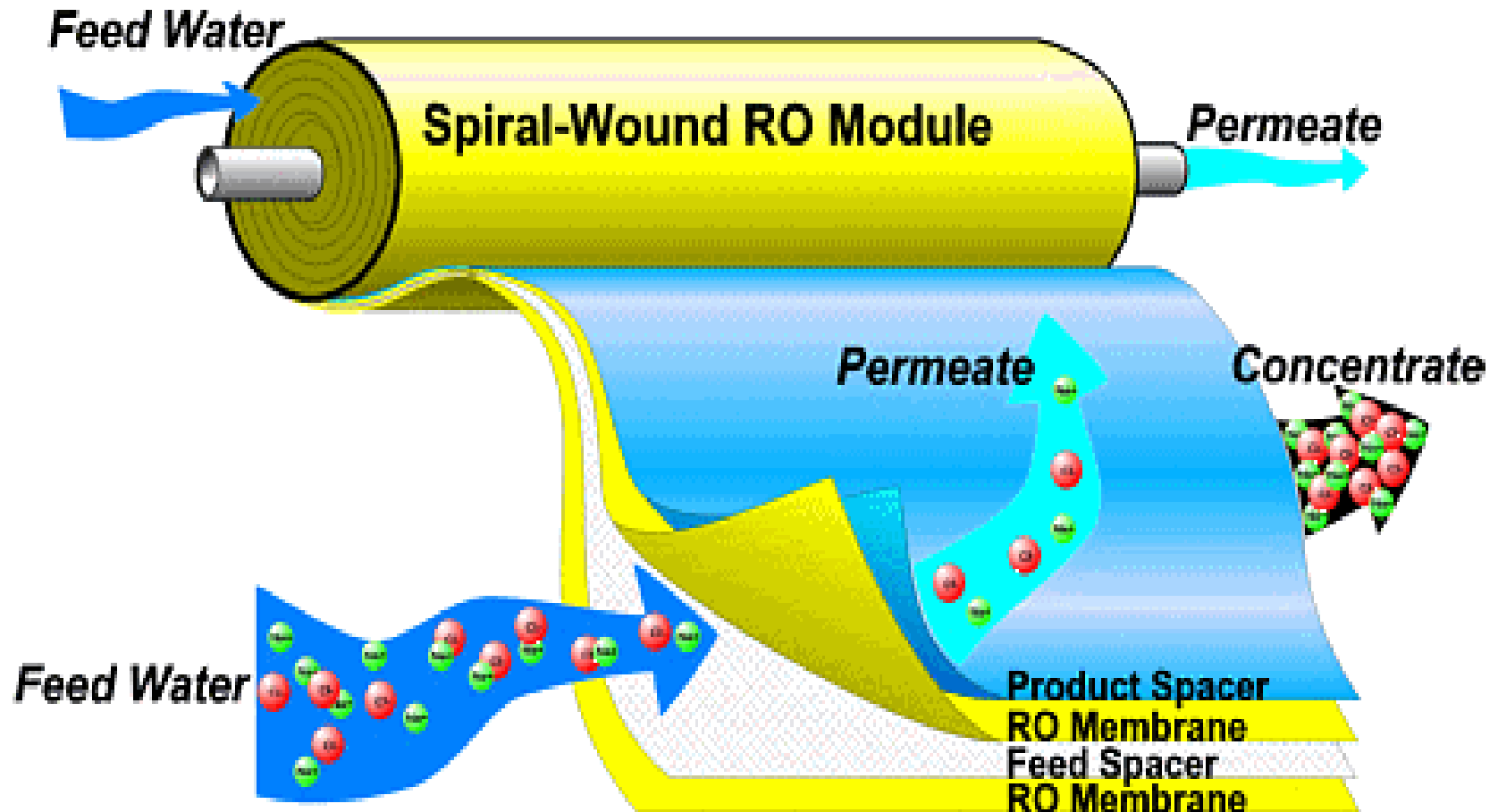
Reverse Osmosis Process (RO)



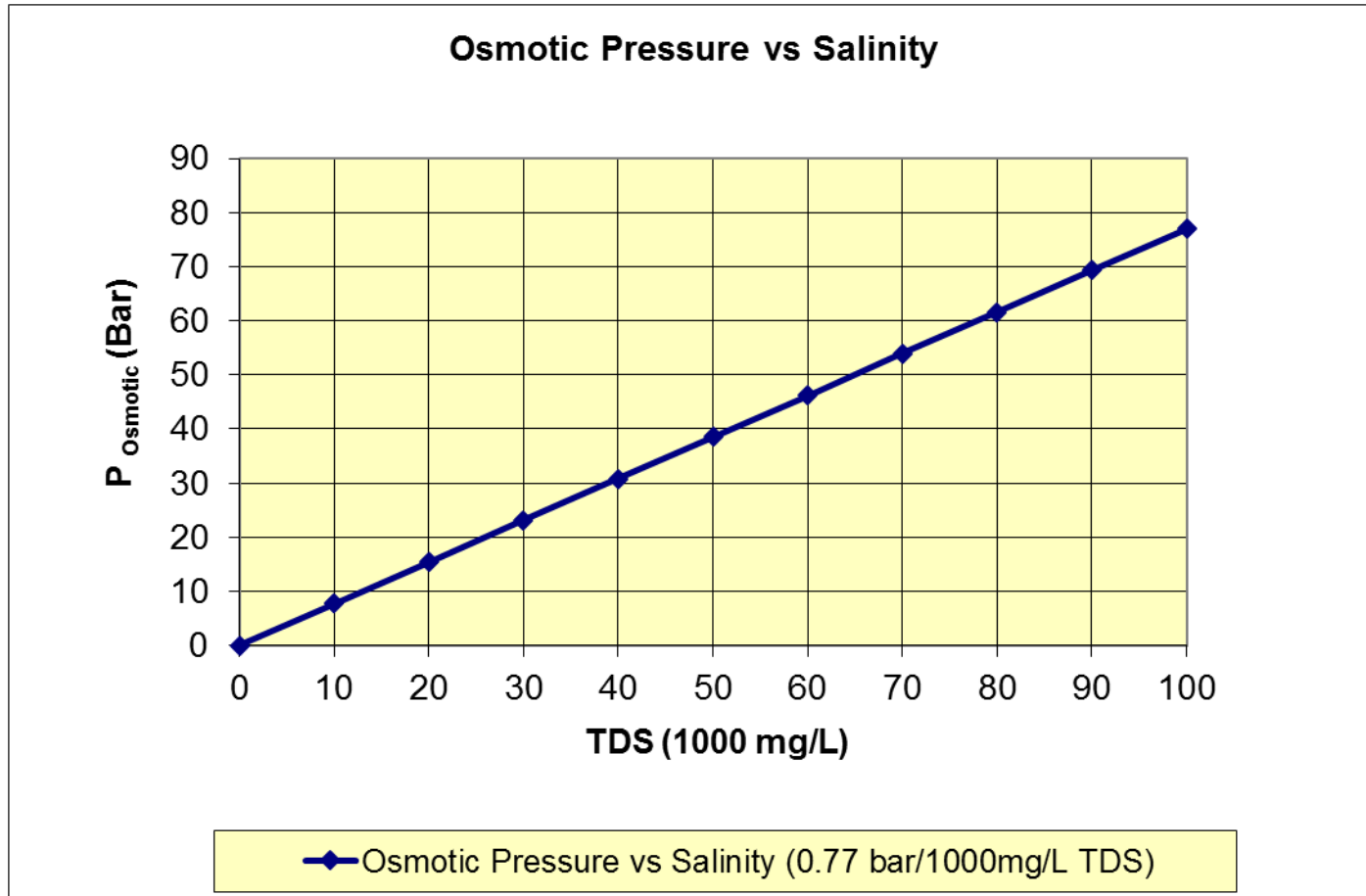
Spiral Wound Reverse Osmosis



Reverse Osmosis Spiral Wound Membrane



Reverse Osmosis: Osmotic Pressure vs. Salinity



The Osmotic Pressure of dilute solution obeys a relationship similar to the ideal gas:

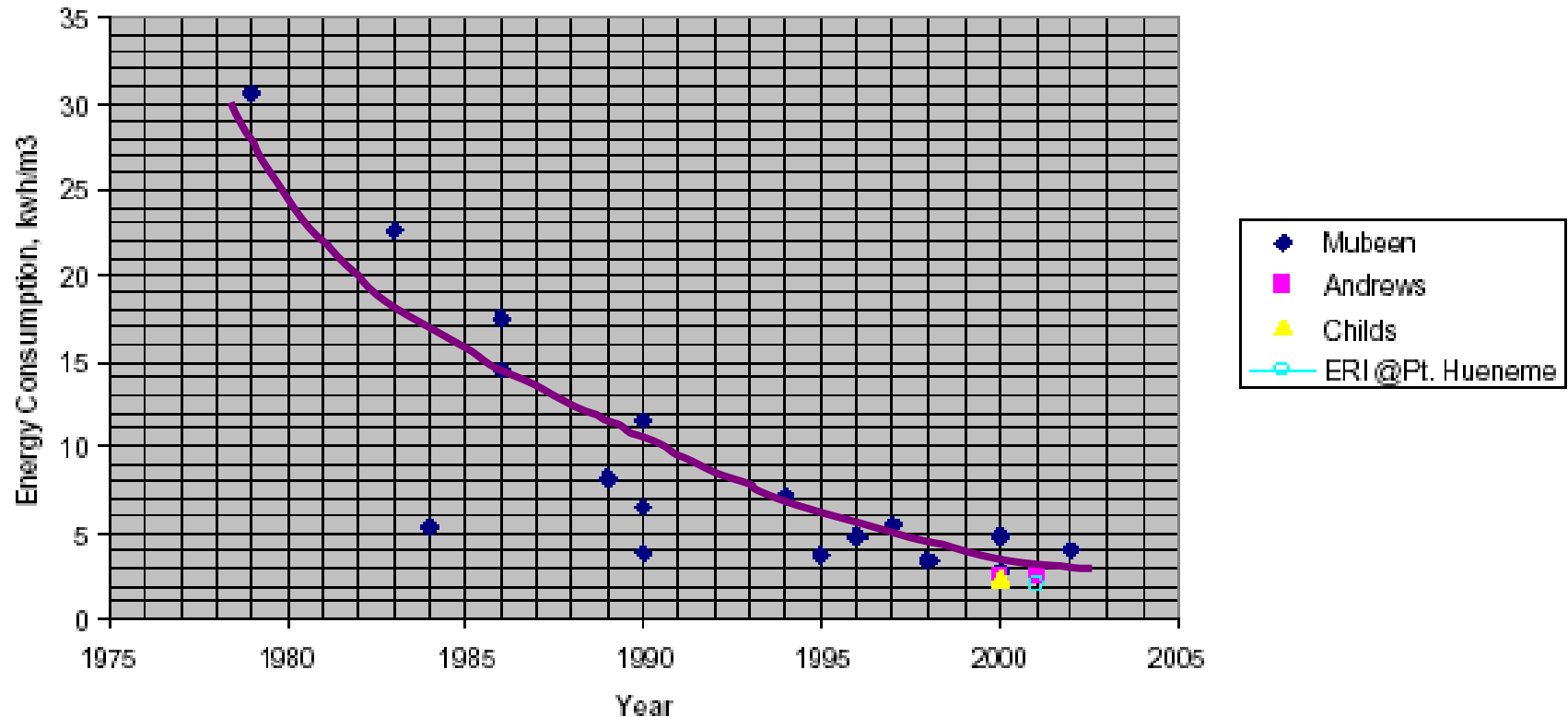
$P_{\text{osm}} = nR_0T/V$, where:

n/V is the molar solute concentration

R is the gas constant

T is the absolute temperature

SWRO Power Consumption (July 1, 2001)



Mubeen: data collected by Mubeen from IDA literature from 1980 to 2002.

Andrews: data point from Andrews describing energy consumption of DWEER pressure exchanger.

Childs: data point from Childs describing combined pump/recovery Vari-RO pumping system.



ERI: data for ERI pressure exchanger collected at Point Hueneme USN.

The Sustainability of SWRO

Mammoth Water Condenser, Coolgardie Water Distillery, 600 m³/d

*The ultimate in un-sustainability
Lasted as long as the trees (fuel) nearby*



 Mammoth Water Condenser. 

Designed by W. H. Gurn, M.E. No. 1

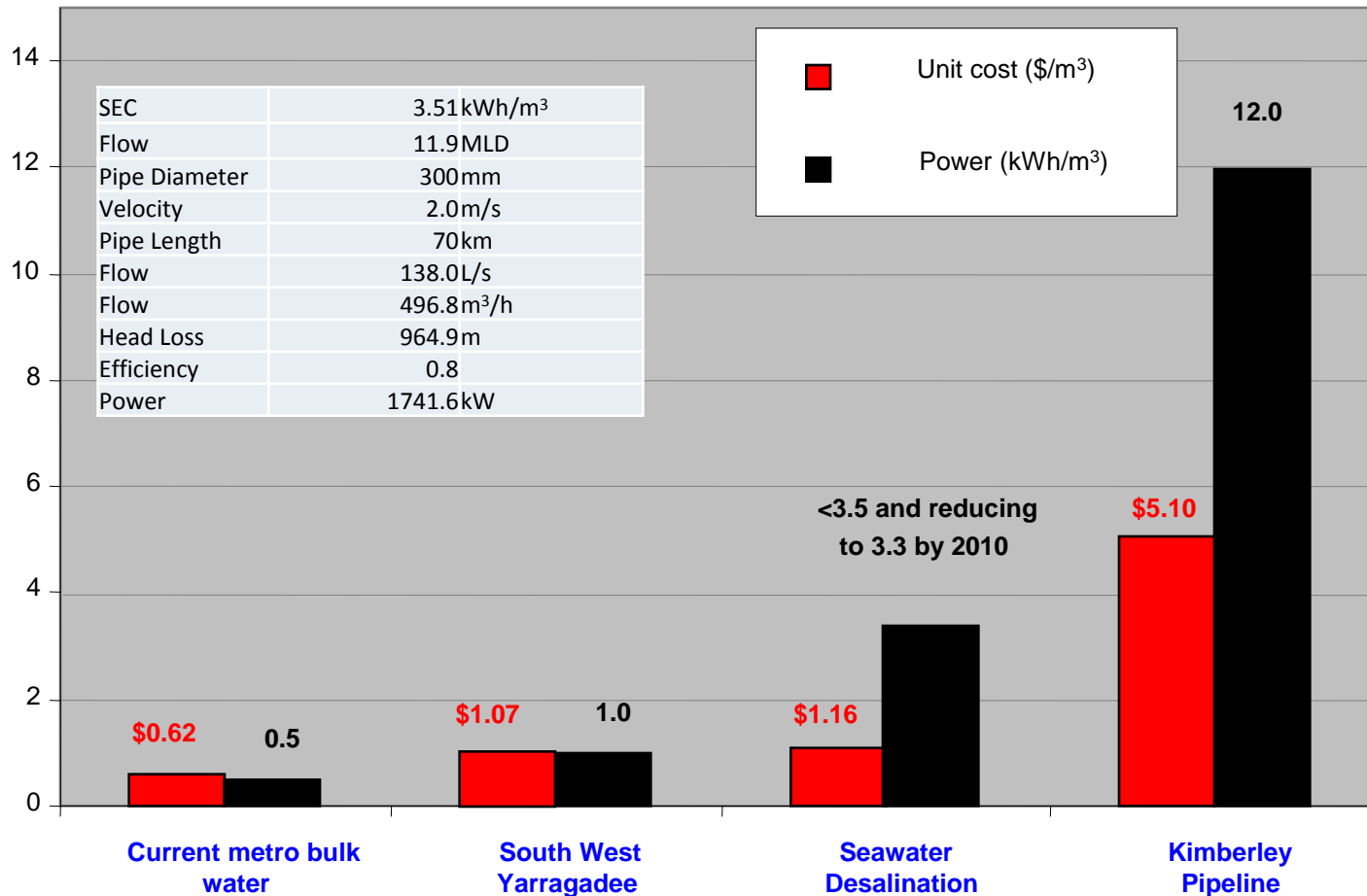
Trusted by the Western Australian Government at Coolgardie.

This Condenser can produce 881,000 gallons of fresh water per day, consuming 120,000 gallons of salt water and 881 tons of wood fuel.

In 1896 the worlds largest desalination plant was built in Western Australia at Coolgardie

The Sustainability of SWRO

Water Source Comparison (including another unsustainable concept)



To convey 1 m³ over 70 km uses 3.51 kWh/m³

The Sustainability of SWRO

Solar-powered SWRO commissioned in South Africa

WATER DESALINATION REPORT – 25 March 2019

South Africa

SOLAR-POWERED SWRO COMMISSIONED

France's Mascara Renewable Water and Turnkey Water Solutions, its South African partner, have commissioned the region's first solar desalination unit in Witsand, for Hessequa municipality in South Africa's Western Cape Province. The company's Osmosun SWRO plant is designed to produce 16 m³/h (4,227 GPH) at 40 percent recovery, or about 100 m³/d (26,420 GPD) when powered exclusively by a photovoltaic solar generator.

According to Mascara's Daniel Villessot, the system can produce approximately 300 m³/d (79,260 GPD) at an average total energy consumption of 3.2 kWh/m³ (12.1 kWh/kgal) when operating on an optional grid connection. The SWRO pretreatment consists of coagulation, sand filtration, an antiscalant and cartridge filtration, while power generation is provided by 400m² (4,305 ft²) of PV panels with a total plant footprint of 800m² (8,610 ft²).

The plant was commissioned in mid-December 2018, and was officially inaugurated in February 2019. It is owned by the municipality of Hessequa and operated by Turnkey Water Solutions.



Mascara's Osmosun SWRO in Witsand

- Likely Power requirement 60kW.
- Likely PV system size 100kW
- Likely daily energy demand = $100 \text{ m}^3 \times 3.2 \text{ kWh/m}^3 = 320 \text{ kWh}$
- Likely daily energy production 400kWh

The Sustainability of SWRO

Plug-in hybrid electric vehicle power train

This means that the vehicle runs only on electric motor for propulsion and when the battery is empty, the system uses internal combustion engine (ICE) powered by diesel or petrol fuel.

Plug-in hybrid electric vehicle's use an electrified powertrain with no linkage between ICE and wheels.

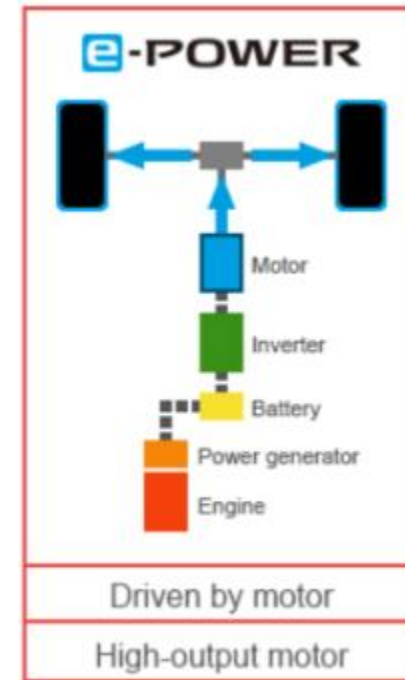
Working with an electric motor, plug-in hybrid electric vehicles can use 60% less petrol than a traditional car.

Plug-in hybrid electric vehicles can be powered both by rechargeable battery and diesel/petrol fuel.

The Nissan e-POWER system is a series hybrid which pairs an electric motor with a small petrol-fuelled 1.2-litre three-cylinder engine three-cylinder 1.2 litre engine that is rated at 58kW, which acts as a generator for the **1.5kWh** battery which is stored underneath the two front seats, which in turn powers the 40kW electric motor driving the front wheels.

Whereas a conventional parallel hybrid uses the engine to drive the wheels, the purpose of the e-POWER's engine is just to charge the battery -- the wheels are always electrically driven.

The engine itself runs at constant rpm at optimum efficiency.



Energy Recovery Devices



The Sustainability of SWRO

Energy Recovery Devices



**IDE – IRIS
PRESSURE EXCHANGER**



**DYPREX
PRESSURE EXCHANGER**



**ROVEX PRESSURE
EXCHANGER**



**FEDCO HYDRAULIC
PRESSURE BOOSTER**



**ERI – TITAN PX
PRESSURE EXCHANGER**

Key Factors Affecting Costs

- **Source Water Quality** - TDS, Temperature, Solids, silica, Silt and Organics Content.
- **Product Water Quality** – TDS, Boron, Bromides, Disinfection Compatibility.
- **Concentrate Disposal Method** – evaporation ponds, Wind Aided Intensified eVaporation (WAIV) Technology, other systems - blowers etc.
- **Power Supply & Unit Power Costs;**
- **Project Risk Profile;**
- **Project Delivery Method & Financing;**
- **Other Factors:**
 - Country (Australia is very expensive)
 - Location (Remote is more expensive)
 - Intake and Discharge System Type;
 - Pretreatment & RO System Design;
 - Plant Capacity Availability Target.

Ravensthorpe TWS RO Plant



Capacity 180 kL/day
Feed TDS 4,000 & 13,000 mg/L
Permeate TDS < 300 mg/L



Swan Brewery RO Plant

- Capacity 1 ML/day
- Feed TDS < 800 mg/L
- Permeate TDS < 100 mg/L



Leonora TWS RO Plant



- Capacity 1 ML/day
- Feed TDS < 2000 mg/L
- Permeate TDS < 200 mg/L



Rottnest Island SWRO Plant



200 kL/day

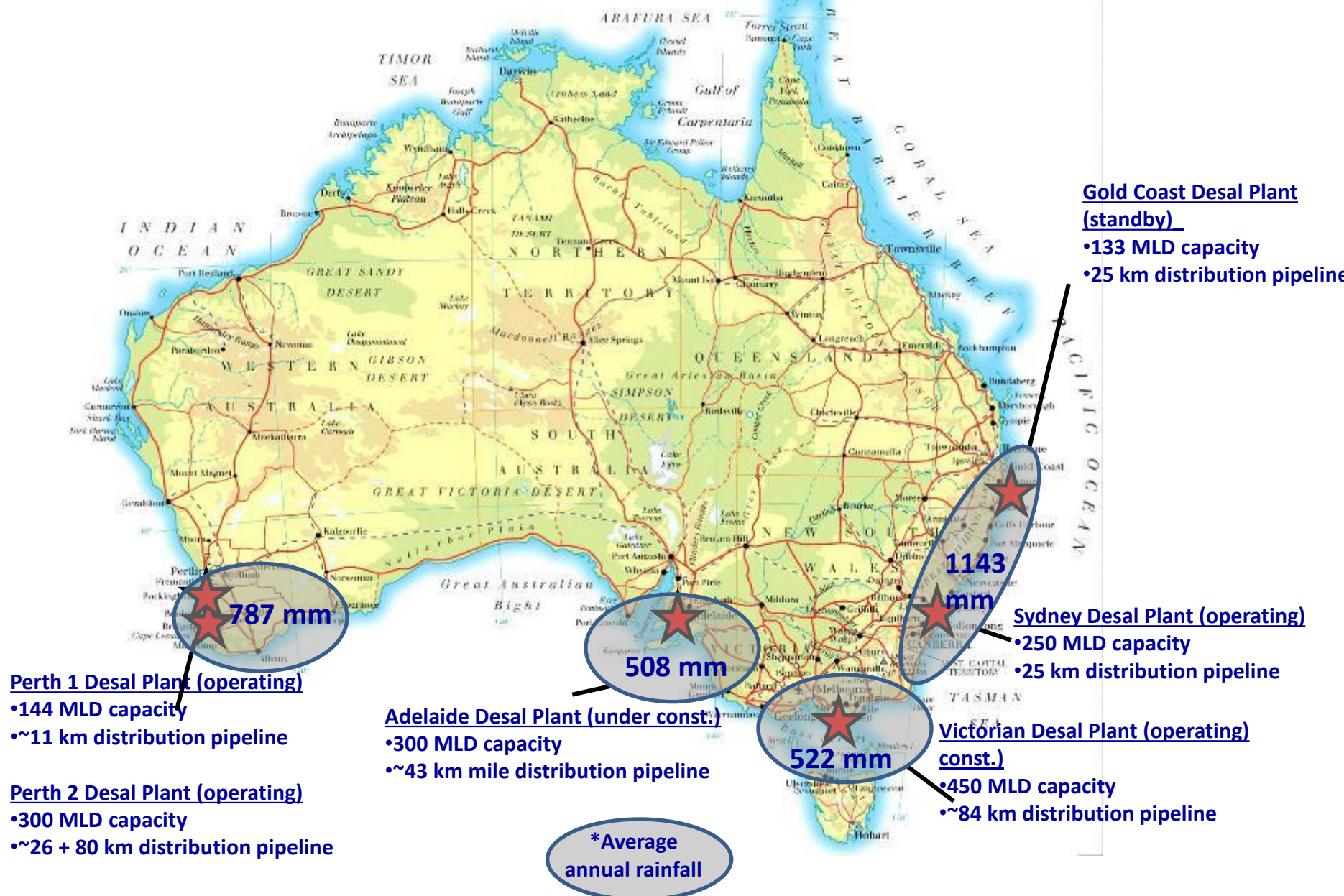
- Pre-treatment: direct supply from beach wells with 5 micron cartridge filters



The Big 6

Australia's six big desalination plants

Australia Rainfall and Seawater Desalination



The Big Six – No. 1

Perth Seawater Desalination Plant (Perth I) – 144 MLD

- Client: Water Corporation
- Capacity: 144 MLD (38 mgd)
- Plant Capital Cost: \$324 million
- Connecting System (IWSS): \$63 million
- Total Capital Cost: \$387 million
- Total Operating Cost: \$19 million/year
- Unit Cost: \$1.16/m³
- Commissioning Completion: 2007
- Configuration: Open Intake, Diffuser Outfall, Travelling Band Screens, Dual Media Pressure Filtration, 5 Micron Cartridge Filtration, 2 Pass SWRO System, Lime and CO₂ Re-mineralisation
- Seawater Feed Quality: 35000 – 38000 mg/L TDS
- Product Water Quality: < 200 mg/L
- Specific Energy Consumption (SEC): < 3.6 kWh/m³ (13.63 kWh/kgal) – Wind Powered
- Technology Contractor: Suez (France/Spain)
- Awards: GWI Membrane Desalination Plant of Year 2007
- ERI Awarded GWI Environmental Contribution of the Year 2007

Perth Seawater Desalination Plant



- Located in Kwinana
- 144 MLD Capacity: 45 million m³/Y
- 24 MW Power Required

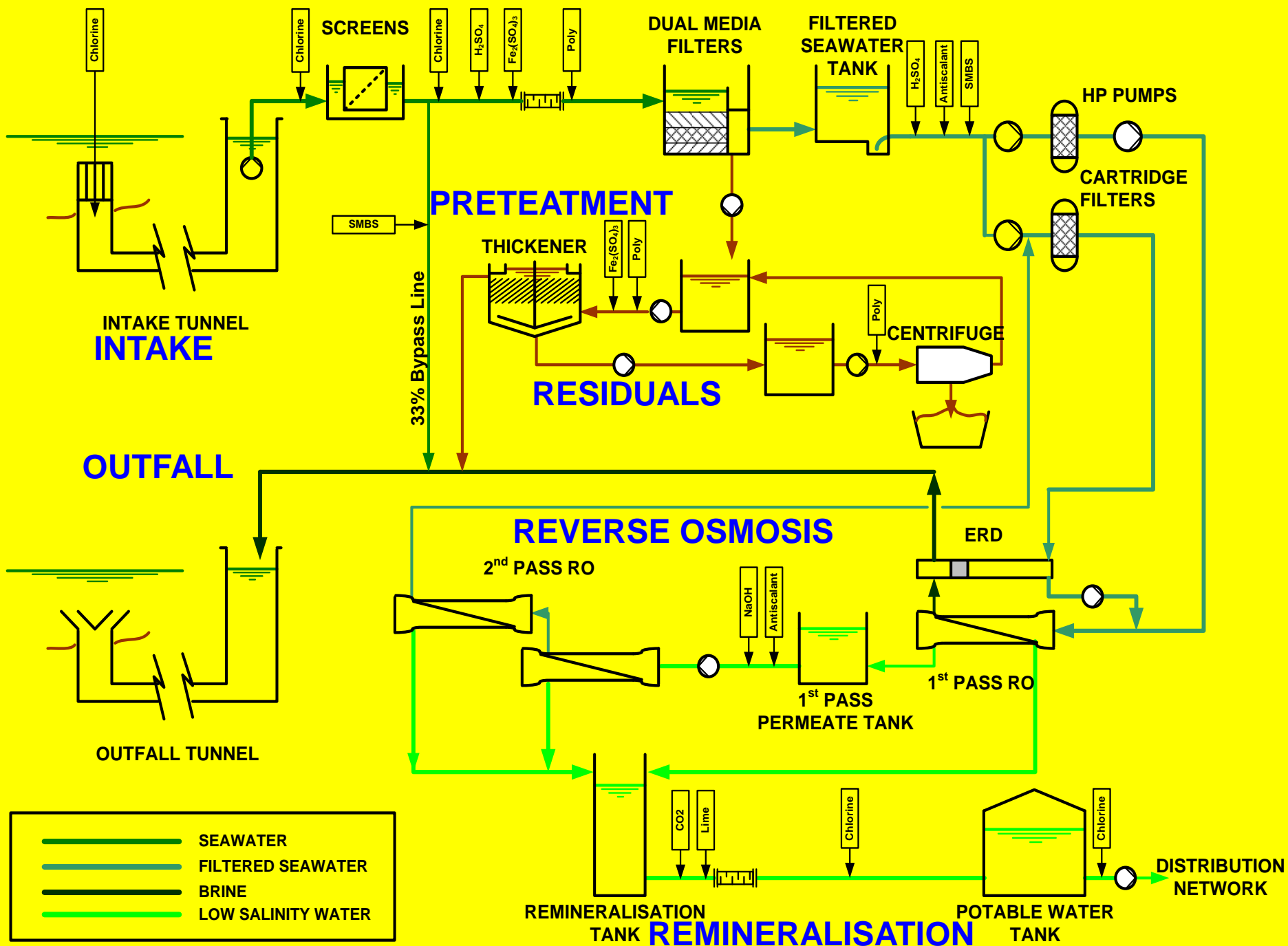
- 140 mg/L Product Water
- Commenced operation in Nov. '06
- Wind Power is used as offset

Courtesy of Water Corporation

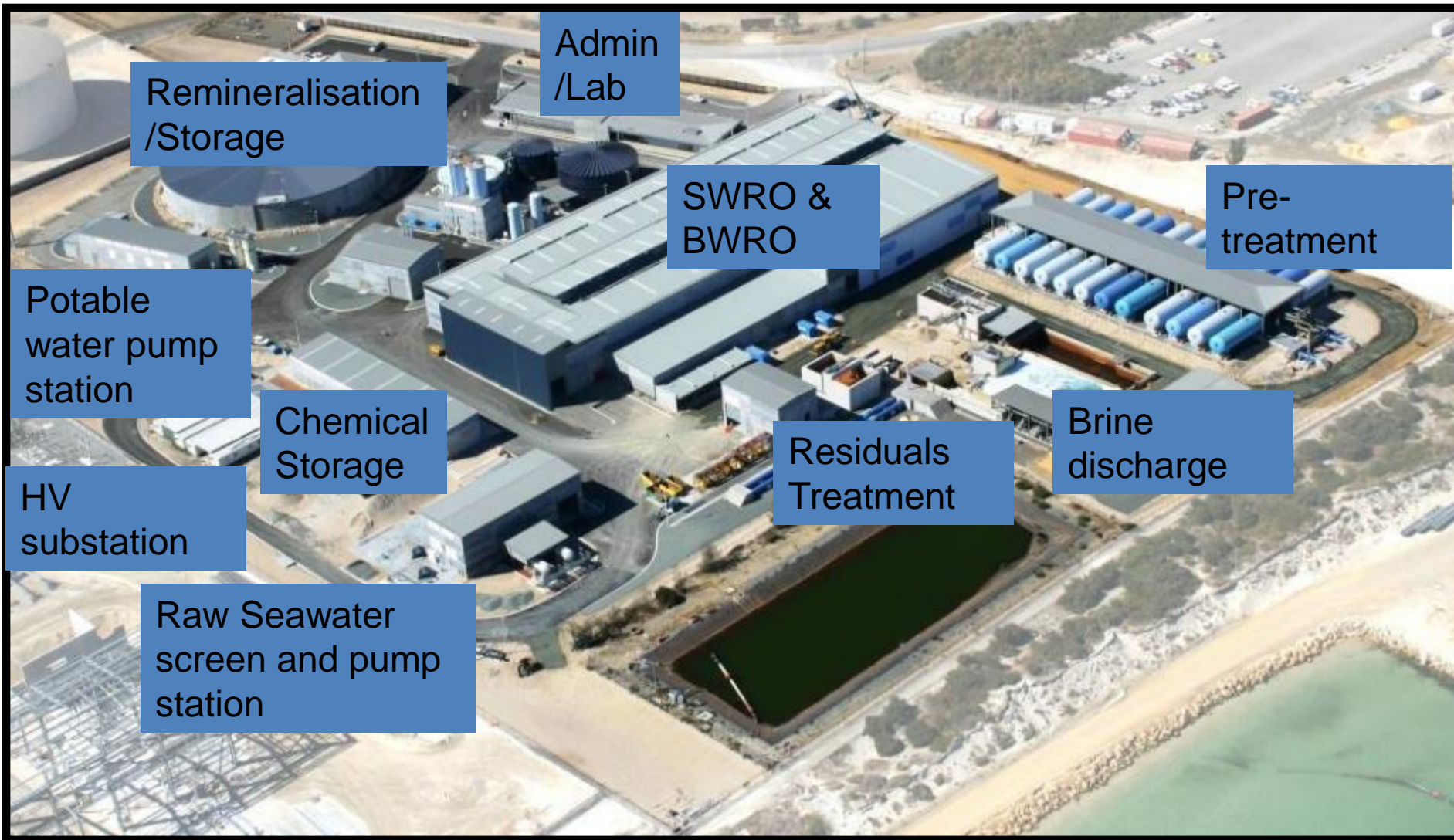
Perth Seawater Desalination Plant



Courtesy of Water Corporation



Aerial View of Desalination Plant



Courtesy of Water Corporation

Perth Seawater Desalination Plant

Seawater Intake System – Inlet Structure



Courtesy of the Water Corporation

Perth Seawater Desalination Plant

Seawater Intake System – Inlet Structure



Courtesy of the Water Corporation

Perth Seawater Desalination Plant

Seawater Intake System – Pipes and Works



Courtesy of the Water Corporation

Courtesy of the Water Corporation

Perth Seawater Desalination Plant

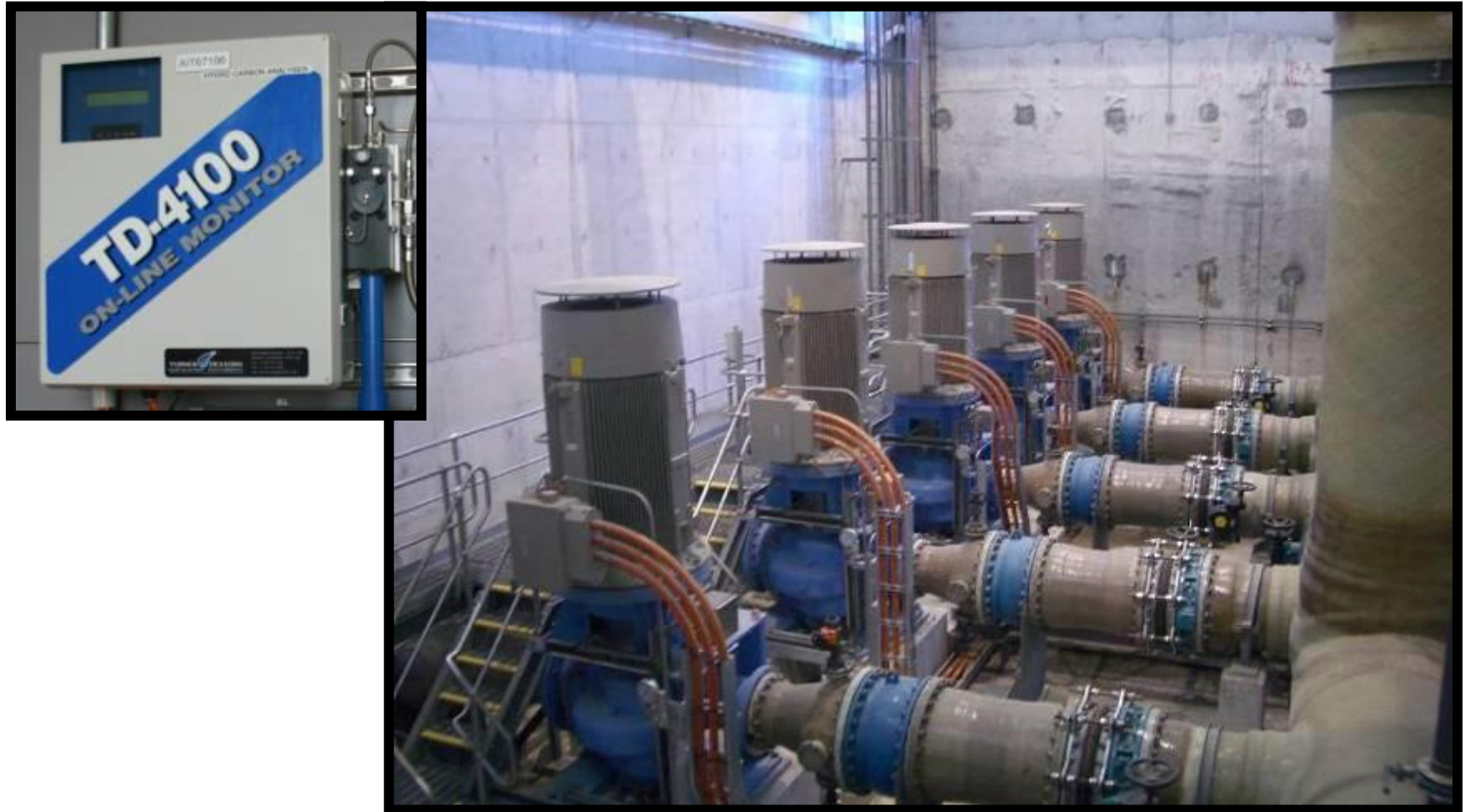
Onshore Active Screening – Band Screen



Courtesy of the Water Corporation

Perth Seawater Desalination Plant

Seawater Intake and Outlet Works



Courtesy of the Water Corporation

Perth Seawater Desalination Plant

Single Stage Dual Media Pressure Filtration and Cartridge Filters



Perth Seawater Desalination Plant

High Pressure Pumps 2.6 MW Each (6 in total)



Each Pump Equivalent to
15 Toyota Lexus GX
Wagon 8st 4dr Man 6sp
4x4 4.0i
0.179 MW @ 5200rpm
each.*

*Red Book (Australia) specifications

Courtesy of the Water Corporation

Perth Seawater Desalination Plant

Circulation Pumps 134 kW each (12 in total)



Each Pump Equivalent
to 1 Toyota RAV 4 5st
4dr Man 4x4 2.0i
0.132 MW @ 5200rpm
each.*

*Red Book (Australia) specifications

Courtesy of the Water Corporation

Perth Seawater Desalination Plant

RO Building Looking South – 2nd Pass RO



Courtesy of the Water Corporation

Perth Seawater Desalination Plant

Pressure Exchanger Rack 1.2 MW each (12 in total)



Each Rack Equivalent
to 8 Ford Escape
Wagon 4dr Auto 4sp
4x4 3.0i
0.152 MW @ 4750rpm
each.*

*Red Book (Australia) specifications

Courtesy of Water Corporation

Perth Seawater Desalination Plant

Potabilization System and Drinking Water Storage Tank



Courtesy of Water Corporation

Perth Seawater Desalination Plant

Drinking Water Transfer Pump Station



Courtesy of Water Corporation

Perth Seawater Desalination Plant

Concentrate Discharge



Courtesy of Water Corporation

Perth Seawater Desalination Plant

Concentrate Discharge



Courtesy of Water Corporation

Perth Seawater Desalination Plant

Sustainable Power - Wind Energy

Zero Greenhouse Gas Emissions

**Stanwell/Griffin Joint Venture - Emu Downs
wind generation facility – at Badgingarra
200 north of Perth**

**Water Corporation is purchasing 66
percent of the energy output**

24 MW (185 GW hrs/annum)

Opened on 12 November 2006



Courtesy of the Water Corporation

Perth Seawater Desalination Project

Specific Energy Consumption of Components and Total

Perth Seawater Desalination Plant - Specific Energy Consumption (SEC) for Components of Plant								
Total Potable Water Production	Intake Pumping	Desal Plant Plus Pre-Treatment Only	Potable Pumping	Total Plant	Intake Pumping Excluding Pre-Treatment	Potable Water Pumping	Desal Plant Only	Total Plant
<i>m³</i>	<i>kWh</i>	<i>kWh</i>	<i>kWh</i>	<i>kWh</i>	<i>kWh/m³</i>	<i>kWh/m³</i>	<i>kWh/m³</i>	<i>kWh/m³</i>
144000	7,228	501,271	7,988*	516,487	0.05	0.06*	3.48	3.59

****approx. 11 km of conveyance to Perth Integrated Water Supply System (IWSS)***

SEC	3.47	kWh/m ³
Flow	144.3	MLD
Pipe Diameter	1040	mm
Velocity	2.0	m/s
Pipe Length	340	km
Flow	1670.0	L/s
Flow	6012.0	m ³ /h
Head Loss	954.2	m
Efficiency	0.8	
Power	20844.1	kW

The Big Six – No. 1 - Education

Teach Your Children - Crosby Stills, Nash & Young



PSDP 2006 – A quick Lesson

The Big Six – No. 2

Gold Coast Desalination Plant - 133 MLD (35 mgd)

• Client:	Water Secure - Queensland
• Capacity:	133 MLD (36 mgd)
• Plant Capital Cost:	\$908 million (tunnels \$260 million)
• Connecting System (IWSS):	\$242 million
• Total Capital Cost:	\$1,150 million
• Total Operating Cost:	\$39 million/year
• Unit Cost:	\$2.90/m ³
• Commissioning Completion:	2009
• Configuration:	Submerged Intake, Diffuser Outfall, Drum Screens, Dual Media Gravity Filtration, 5 Micron Cartridge Filtration, 2 Pass SWRO System, Lime and CO ₂ Re-mineralisation
• Seawater Feed Quality:	35000 – 38000 mg/L TDS
• Product Water Quality:	< 200 mg/L
• Specific Energy Consumption (SEC):	< 3.30 kWh/m ³ (12.38 kWh/kgal) Green Offsets
• Technology Contractor:	Veolia (France)
• Awards:	GWI Membrane Desalination Plant of Year 2009

Gold Coast Desalination Plant



- Located in Tugin
- 133 MLD Capacity: 45 million m³/Y
- 22 MW Power Required

- 140 mg/L Product Water
- Commenced operation in Nov. '08
- Green Energy as offset

The Big Six – No. 3

Sydney Desalination Plant – 250 MLD: Expandable to 500 MLD

- Client: Sydney Water – New South Wales
- Capacity: 250 MLD (expandable to 500 MLD)
- Plant Capital Cost: \$960 million (tunnels \$230 million)
- Connecting System: \$500 million
- Other: \$300 million
- Total Capital Cost: \$1,760 million
- Total Operating Cost: \$45 million/year
- Unit Cost: \$1.93/m³
- Commissioning Completion: 2010
- Configuration: Submerged Intake, Diffuser Outfall, Drum Screens, Dual Media Gravity Filtration, 5 Micron Cartridge Filtration, 2 Pass SWRO System, Lime and CO₂ Re-mineralisation
- Seawater Feed Quality: 32000 – 41000 mg/L TDS
- Product Water Quality: < 140 mg/L TDS
- Specific Energy Consumption (SEC): < 3.9 kWh/m³ (14.76 kWh/kgal) – Wind Powered
- Technology Contractor: Veolia (France)
- Awards: Not Yet Complete

The Big Six – No. 3

Sydney Desalination Plant – 250 MLD: Expandable to 500 MLD



Courtesy of Sydney Water

The Big Six – No. 4

Adelaide Desalination Plants I and II – 150 MLD + 150 MLD

- Client: South Australia Water
- Capacity: 150 MLD + 150 MLD
- Plant Capital Cost: \$1,530 million (Estimated)
- Connecting System (IWSS): \$300 million (Estimated)
- Total Capital Cost: \$1,830 million
- Total Operating Cost: \$81 million/year (300 MLD)
- Unit Cost: \$3.00/m³ Estimated levelised cost
- First Water: December 2012
- Configuration: Submerged Intake, Diffuser Outfall, capacity to 273 MLD 2 Pass SWRO System, initial capacity 204 MLD Lime and CO₂ Re-mineralisation
- Seawater Feed Quality: 35000 – 38000 mg/L TDS
- Product Water Quality: < 200 mg/L
- Specific Energy Consumption (SEC): < 5 kWh/ m³ (18.93 kWh/kgal) – Wind Powered
- Technology Contractor: Acciona (Spain)
- Awards: Not Completed Yet

The Big Six – No. 4

Adelaide Desalination Plants I and II – 150 MLD + 150 MLD



Courtesy of SA Water

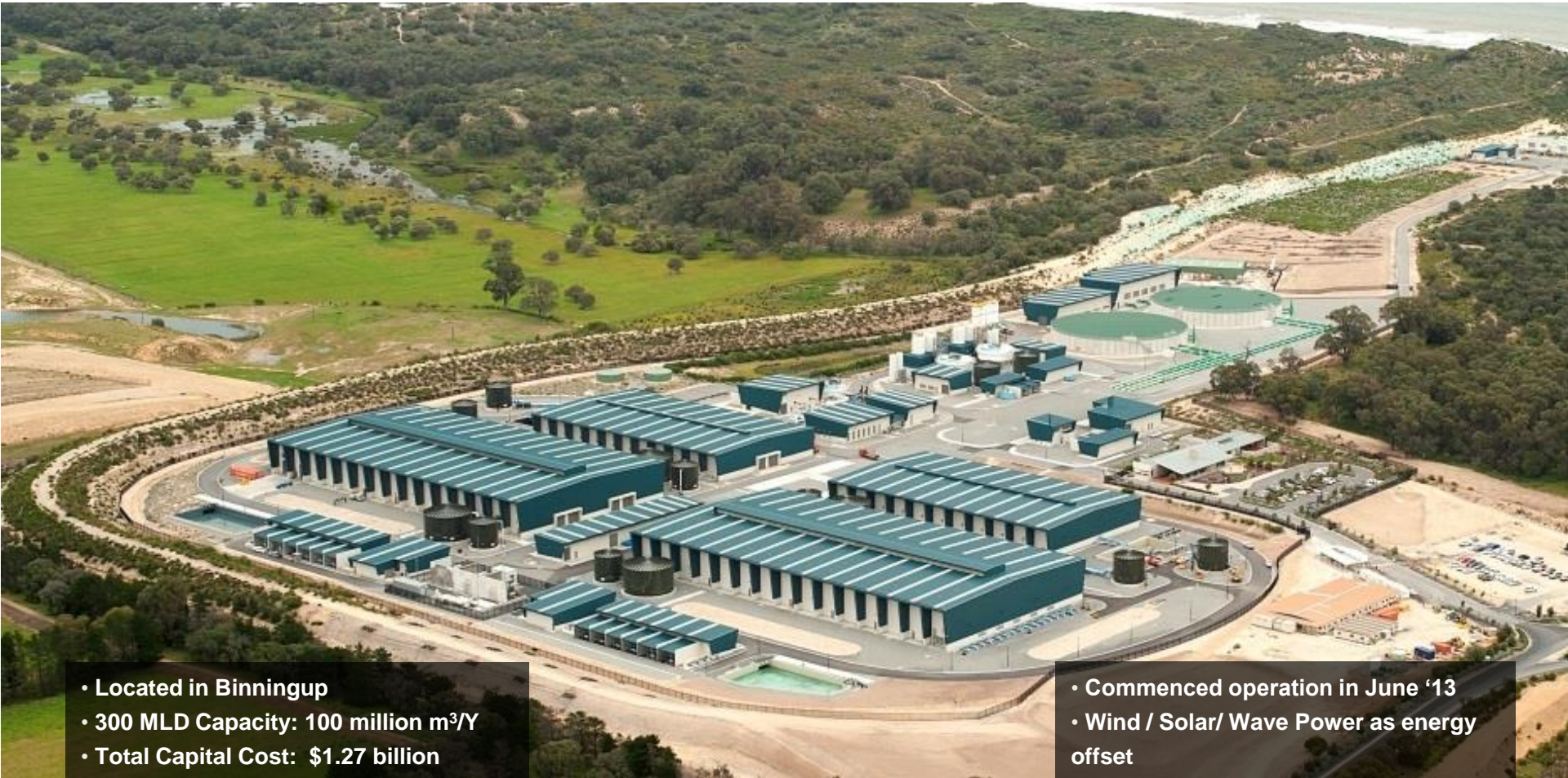
The Big Six – No. 5

Southern Seawater Desalination Plant (Perth II) – 150 MLD to 300 MLD

- Client: Water Corporation of Western Australia
- Capacity: 150 MLD 1st Stage, 300 MLD 2nd Stage
- Plant Capital Cost: \$780 million (Estimated with double intake/outfall)
- Connecting System (IWSS): \$120 million (Estimated)
- Total Capital Cost: \$900 million (Estimated)
- Total Operating Cost: \$35 million/year (Estimated)
- Unit Cost: \$1.90/m³ Estimated
- Commissioning Completion: 2011
- Configuration: Submerged Intake, Diffuser Outfall, Travelling Band Screens, UF PVDF Pressure Filters, 5 Micron Cartridge Filtration, 2 Pass SWRO System, Lime and CO₂ Re-mineralisation
- Seawater Feed Quality: 35000 – 38000 mg/L TDS
- Product Water Quality: < 200 mg/L
- Specific Energy Consumption (SEC): < 3.6 kWh/ m³ (13.63 kWh/kgal) – Green Offsets (undecided)
- Technology Contractor: Tecnicas Reunidas, Valoriza Agua (Spain)
- Awards: GWI Membrane Desalination Plant of Year 2012

The Big Six – No. 5

Southern Seawater Desalination Plant (Perth II) 300 MLD



- Located in Binningup
- 300 MLD Capacity: 100 million m³/Y
- Total Capital Cost: \$1.27 billion
- Purpose: Base load core supply

- Commenced operation in June '13
- Wind / Solar/ Wave Power as energy offset
- Status: Phase 1 & 2: operating

Courtesy of Water Corporation

future?

Future Desalination Developments

SWRO will still become more efficient due to:

- New high rejection membranes
- Chlorine Tolerant Membranes
- New large diameter membranes
- New energy recovery devices
- Membrane pre-treatment advances
- New materials (more plastics and composites)
- Advanced pre-treatment and post treatment
- Even more effective control systems and instrumentation (optical fibre probes and transducers)

Future Desalination Developments

- Ceramic Membranes
- Non-chemical treatments for disinfection pre- and post treatment
- Nano-technology and smart membranes
- Electro Dialysis Reversal (EDR) may become the solution for inland towns where groundwater sources are limited and not too saline in the presence of silica – high SEC.

Conclusions

- A clean unlimited energy supply is the key to most world problems, including water supply.
- Sewater Desalination can have the smallest footprint of any source in Australia
- A substantial component of Australia's water supply needs will be met by water reuse, groundwater and seawater desalination in the medium to long term (18 SWRO and 10 Reuse existing, under construction and proposed).
- Inland desalination main issues:
 - Power
 - Feedwater Quality
 - Brine Disposal
 - Pre-treatment
 - Cost

Perth Seawater Desalination Plant

**Awarded
GWI World Membrane Desalination
Plant of the Year 2007**



Courtesy of Water Corporation



**ERI Awarded GWI
Environmental
Contribution of the
Year 2007**



Courtesy of ERI

Gold Coast Desalination Plant

**Awarded
GWI World Membrane Desalination
Plant of the Year 2009**



Courtesy of WaterSecure



Sydney Desalination Plant

**Awarded
GWI World Membrane Desalination
Plant of the Year 2011**



Courtesy of Sydney Water



Southern Seawater Desalination Plant

**Awarded
GWI World Membrane Desalination
Plant of the Year 2012**



Courtesy of Water Corporation