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Optimization of Dual-Staged Nanofiltration Membranes for Seawater Desalination

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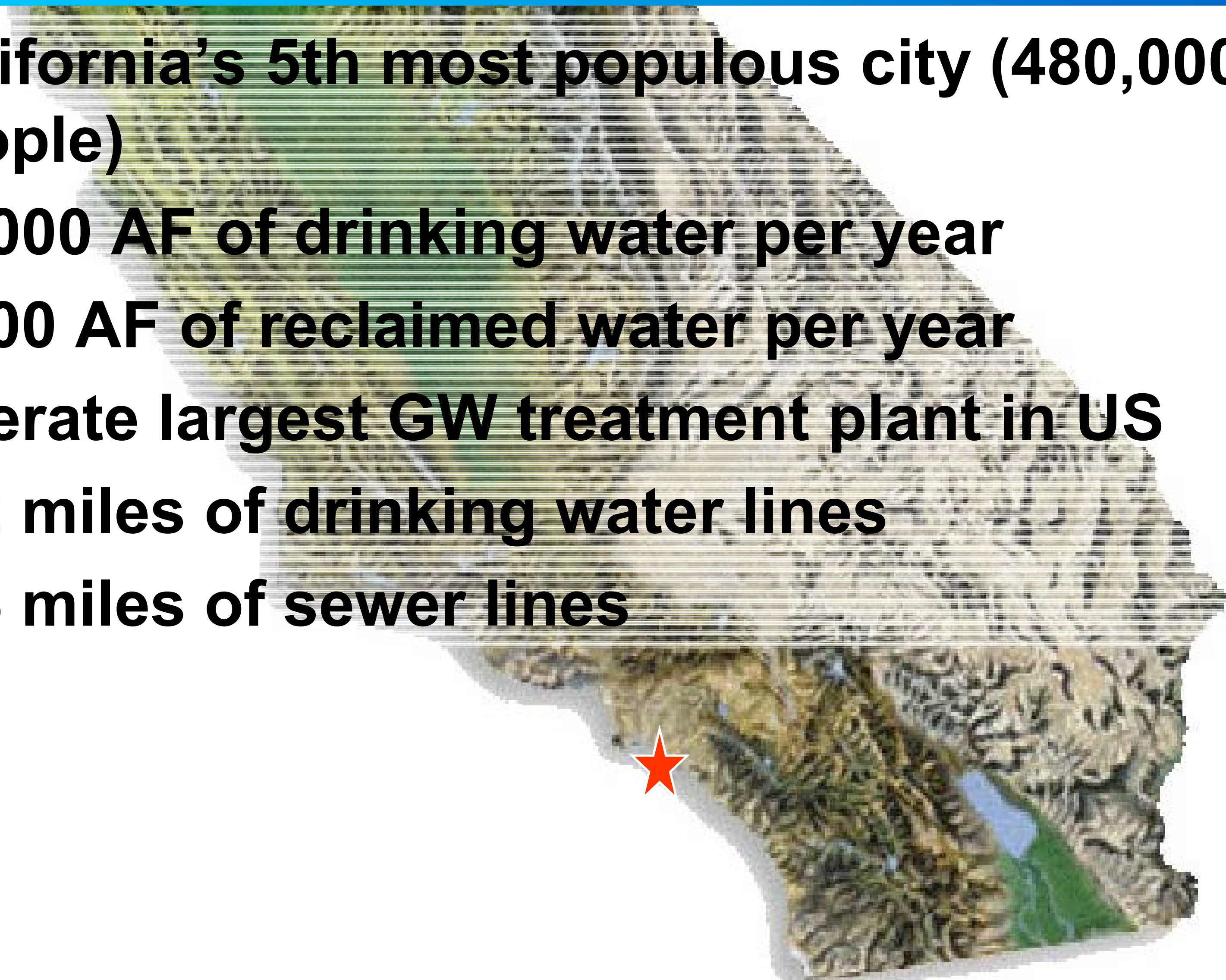
Presentation Outline

- Long Beach Overview
- Dual-Staged NF Process
- Pilot Testing (3 phase)
- Conclusion
- Next Step

Long Beach Water Department

- California's 5th most populous city (480,000 people)
- 70,000 AF of drinking water per year
- 5,500 AF of reclaimed water per year
- Operate largest GW treatment plant in US
- 912 miles of drinking water lines
- 763 miles of sewer lines



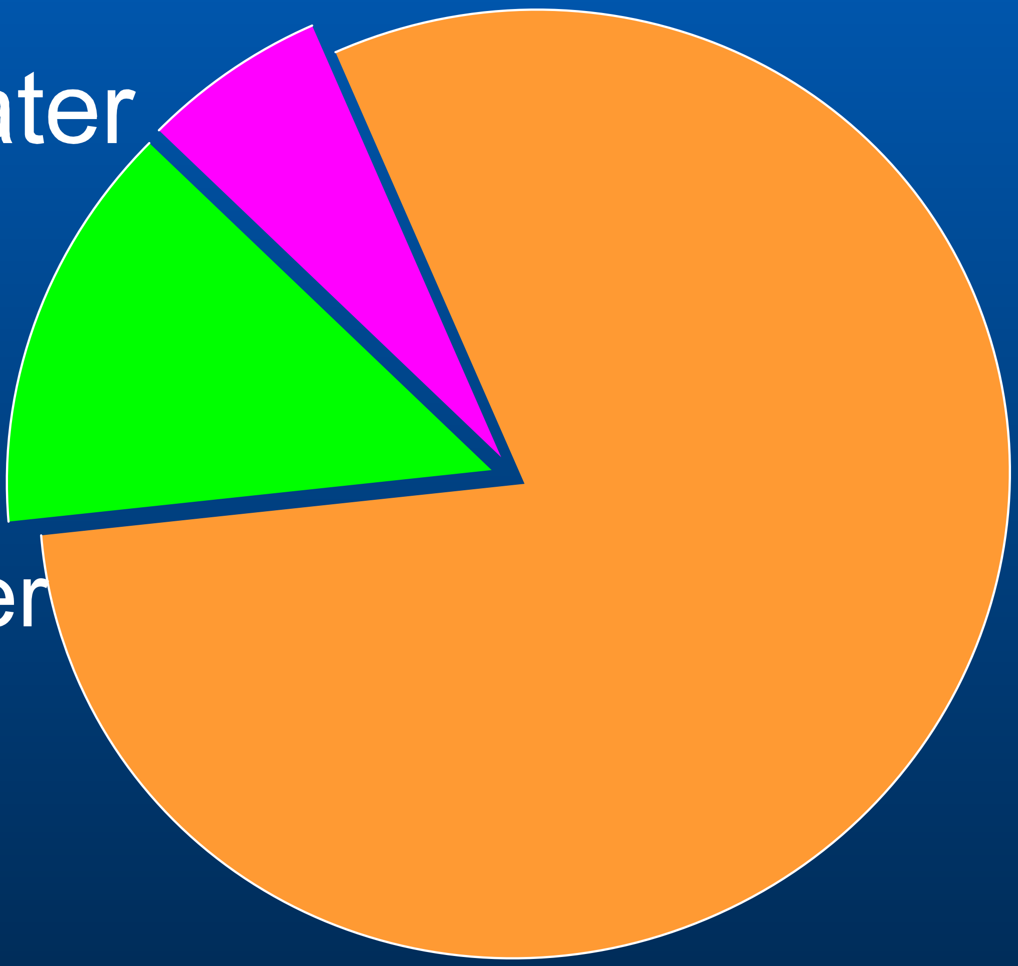
Long Beach Water Department

6%: Recycled Water

14%: Conservation

80%: Drinking Water

-46% LB Groundwater
-54% Imported



Future Reliability

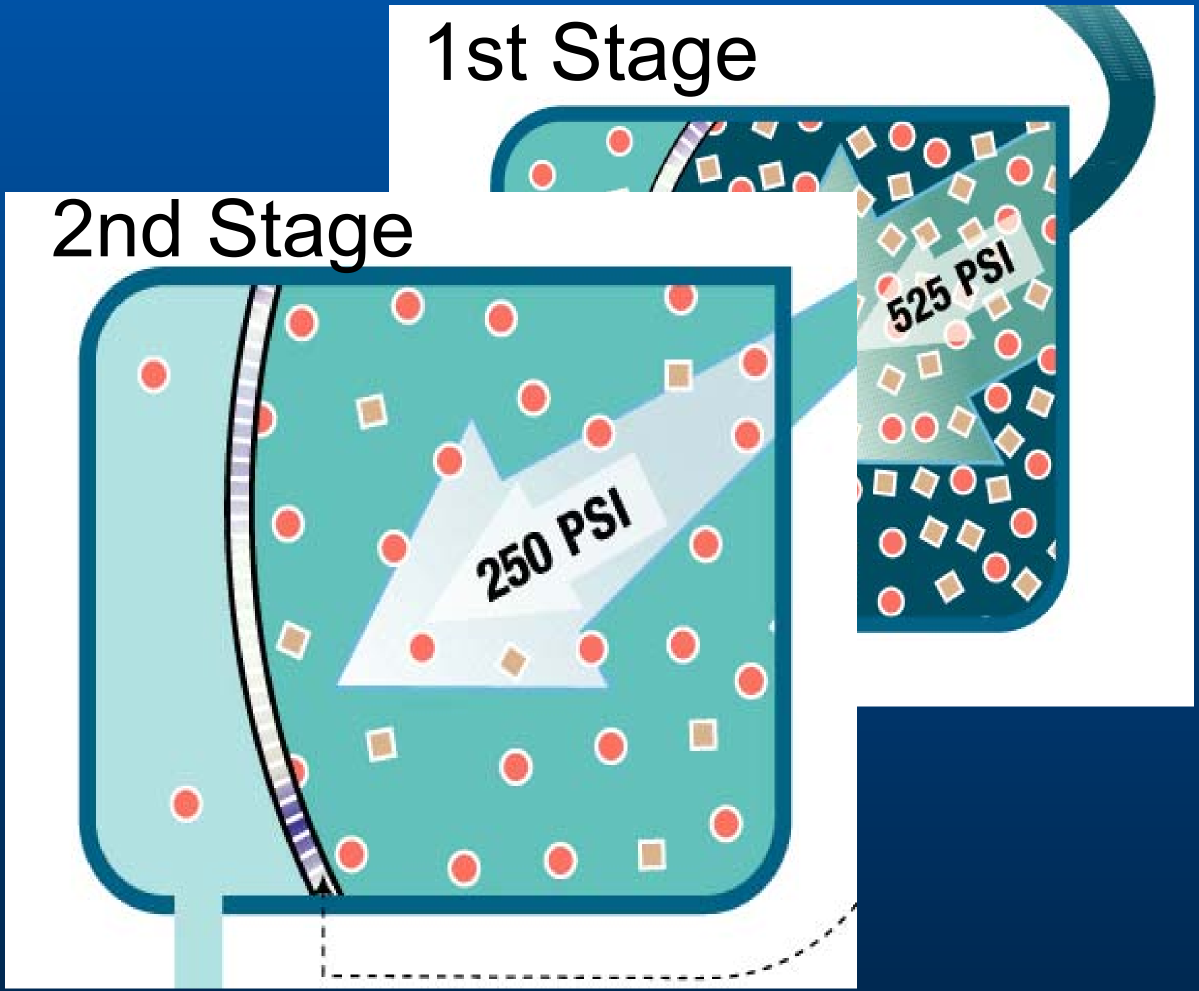
- Very little population growth
- Expansion of recycled water and water conservation
- Seawater desalination necessary ==> supplement City’s imported drinking water supply

“Traditional” RO Process

- Uses pressures in excess of 800 psi
- Energy intensive
- High-pressure materials required $\Rightarrow$ high capital costs
- “Traditional” seawater desalination method cost prohibitive

Nanofiltration Process

- **Patent pending dual-staged process**



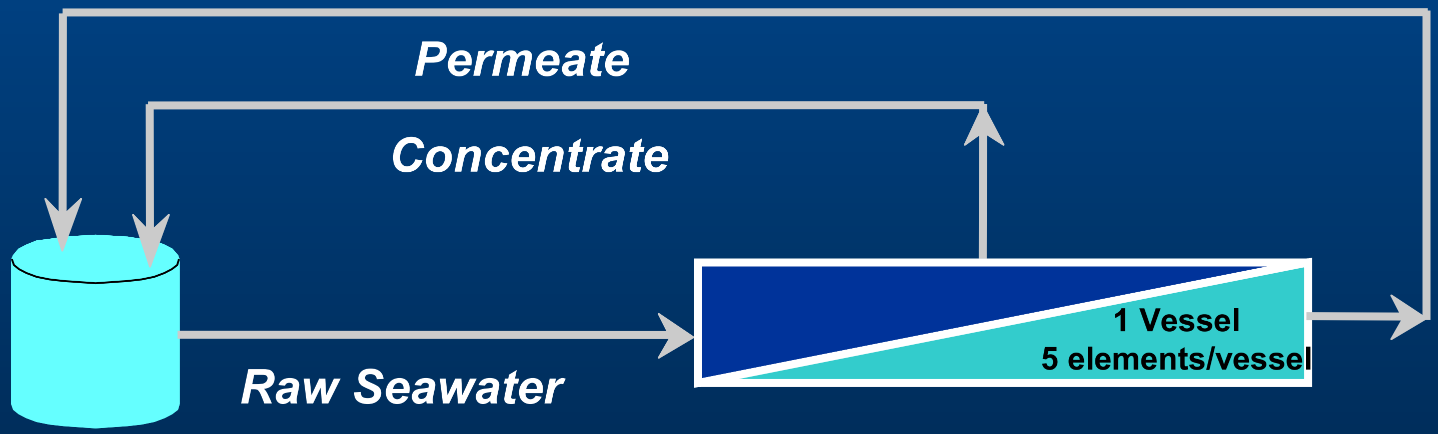
- Energy savings
  - **Lower pressure requirements ==> Lower energy consumption**
- Quality protection
  - **Two physical barriers**

Pilot Plant

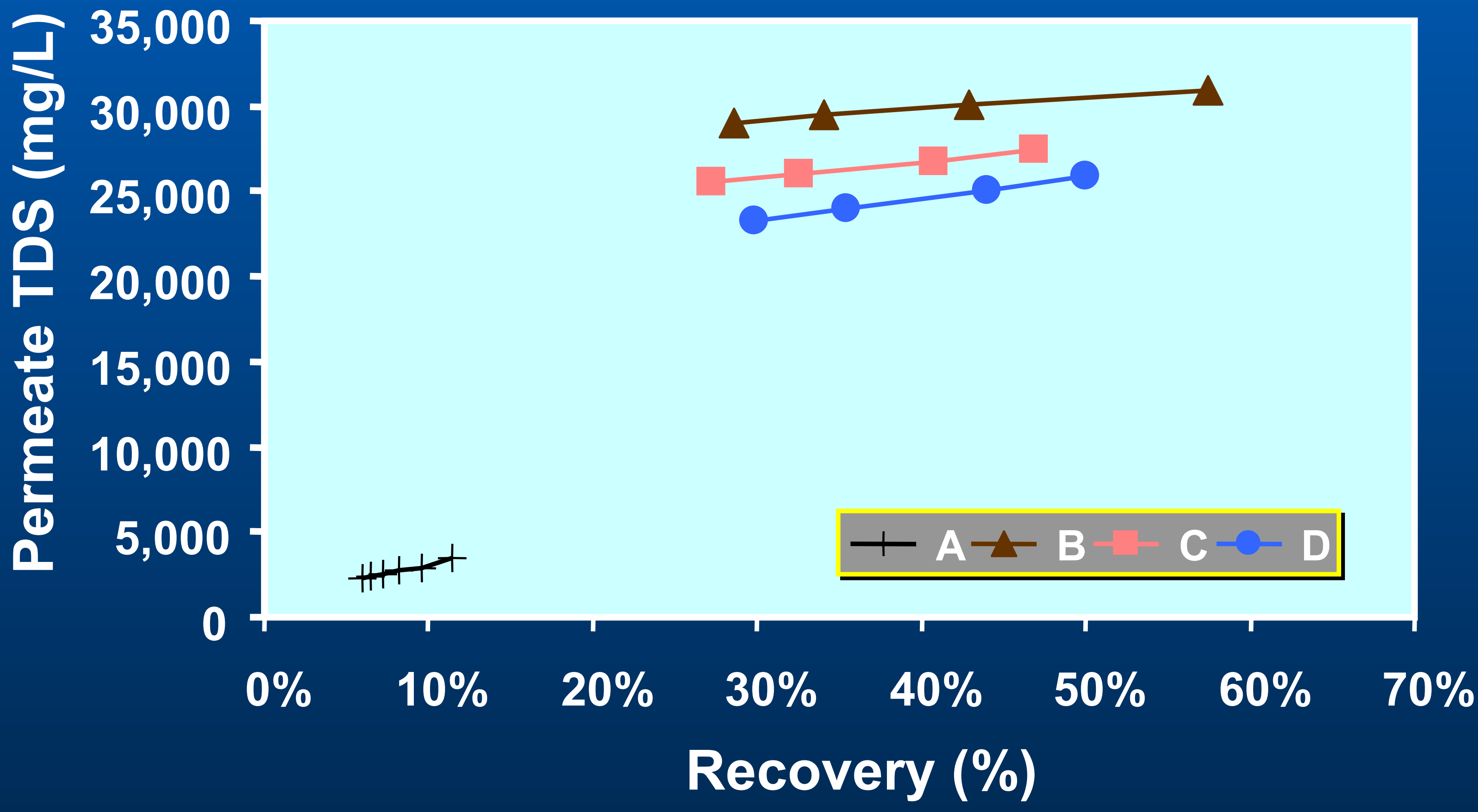
- **Overview**

Phase 1

- 3 manufacturers / 4 nanofiltration membranes evaluated:
  - Dow/FilmTec
  - Koch/Fluid Systems
  - Osmonics
- Process Schematic

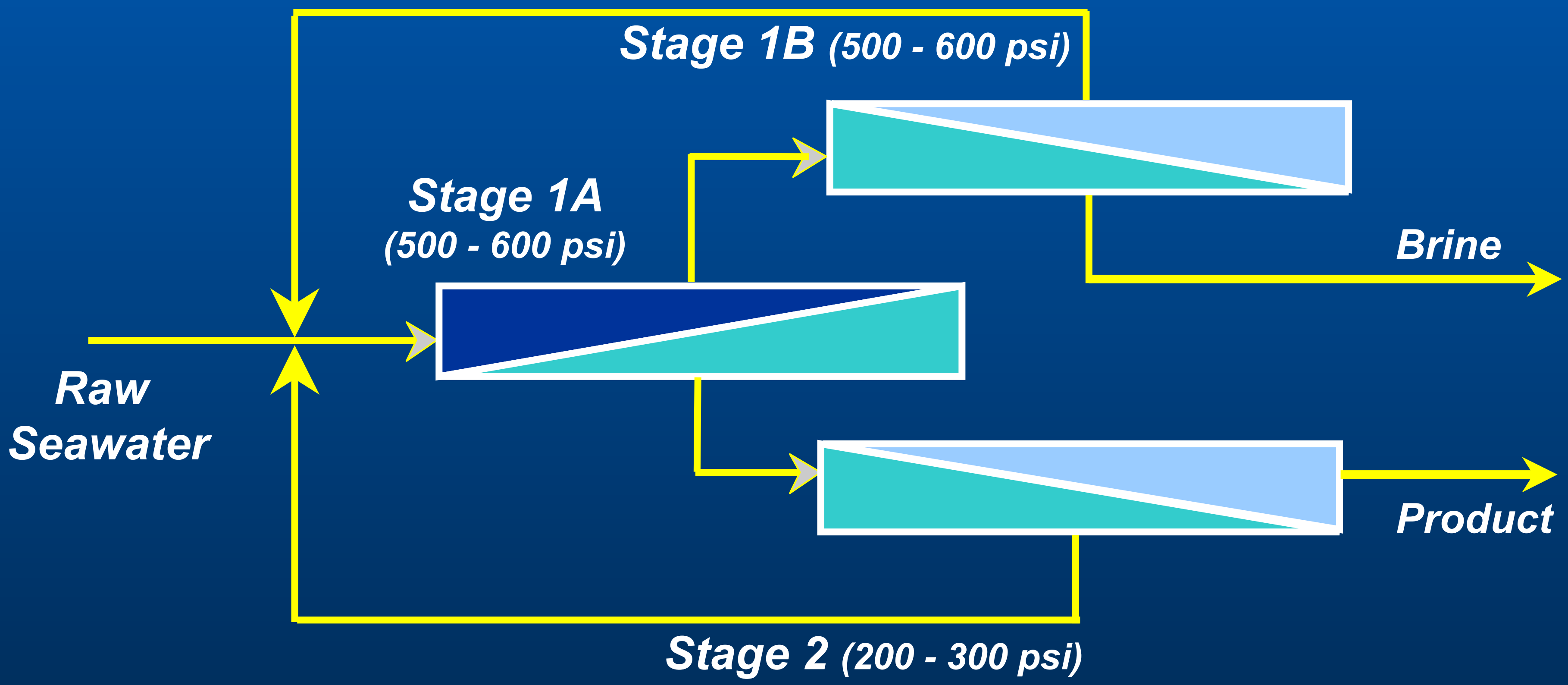


Phase 1 Results



Phase 2

- **Membrane A was selected for phase 2 testing**



Phase 2 Test Condition

- **Operational data**

Parameter	Units	Stage 1	Stage 2
Flux (26°C)	gfd	8.4	18
Flux (20°C)	gfd	7	16
Applied P	psi	560	230
Recovery	%	40	73

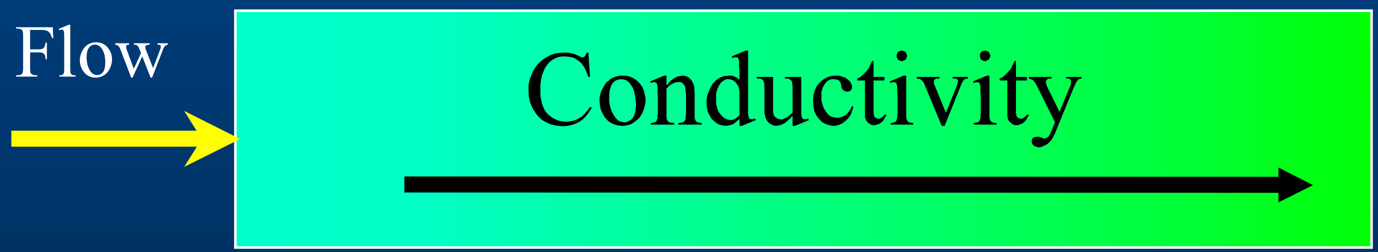
Phase 2 Test Results

- **Water quality**

	Unit	Raw Seawater	Stage 1 Permeate	Stage 2 Permeate	LBWD Tap
Mg^{2+}	mg/L	1532	28	0.2	13
Ca^{2+}	mg/L	546	10.1	0.1	39
SO_4^{2-}	mg/L	2888	33	0.2	100
Na^{+}	mg/L	11912	1280	92	75
Cl^{-}	mg/L	19737	1806	117	59
TDS	mg/L	37480	3247	218	390
Hardness (as $CaCO_3$)	mg/L	7755	140	1.26	151
pH	---	8.01	7.84	7.37	8.16
LSI	---	1.12	-1.93	-4.56	0.34

Phase 3 – NF Optimization

- **Need to come up with a hybrid system**
- **Optimization**
  - **Mix membranes between stages (i.e.. different membranes in stage 1 vs. Stage 2)**
  - **Mix membranes within a vessel to come up with a optimal permeate WQ and flux**



Better

Permeate Quality/ Flux

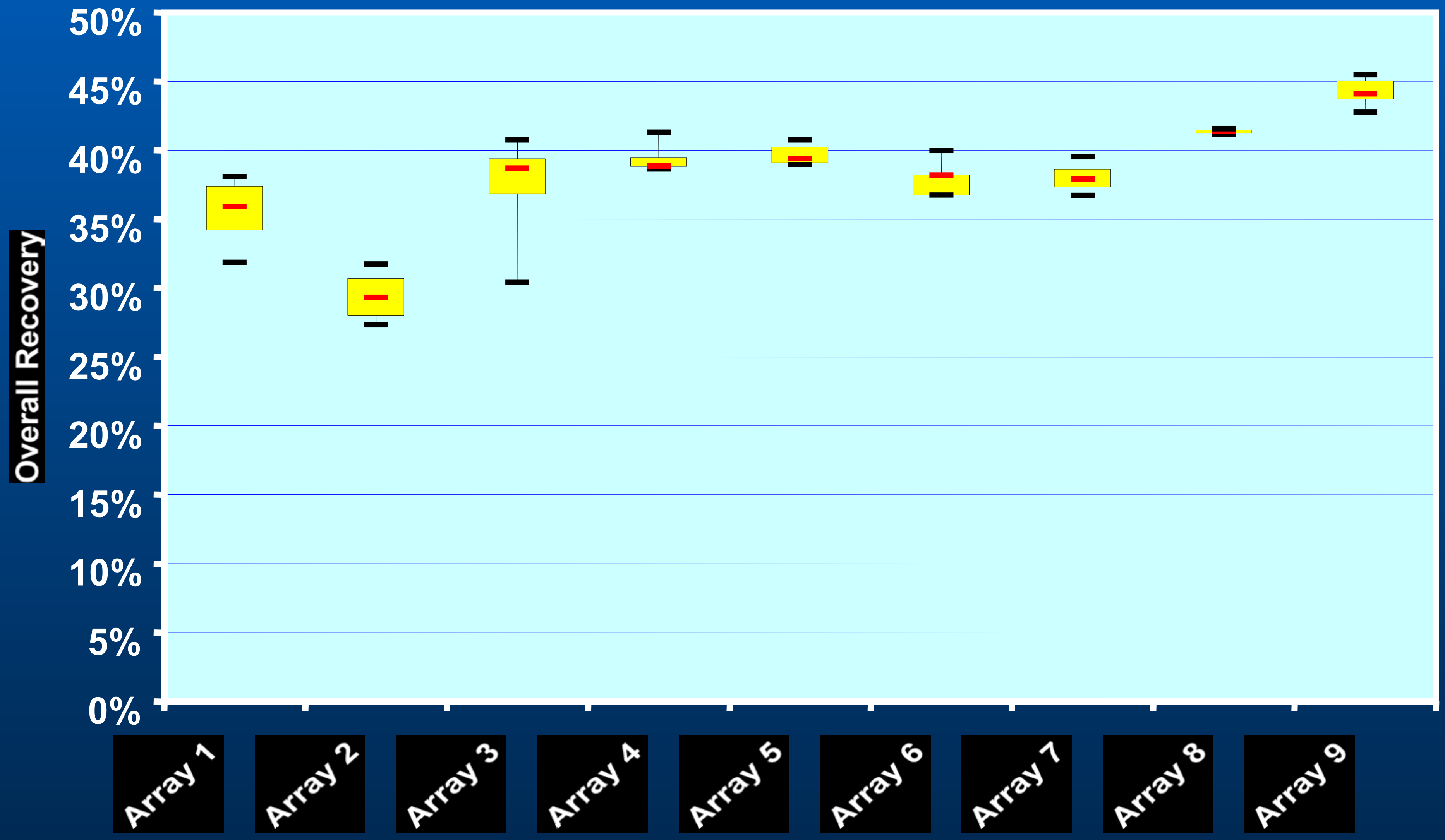
Worse

Phase 3 – NF Optimization

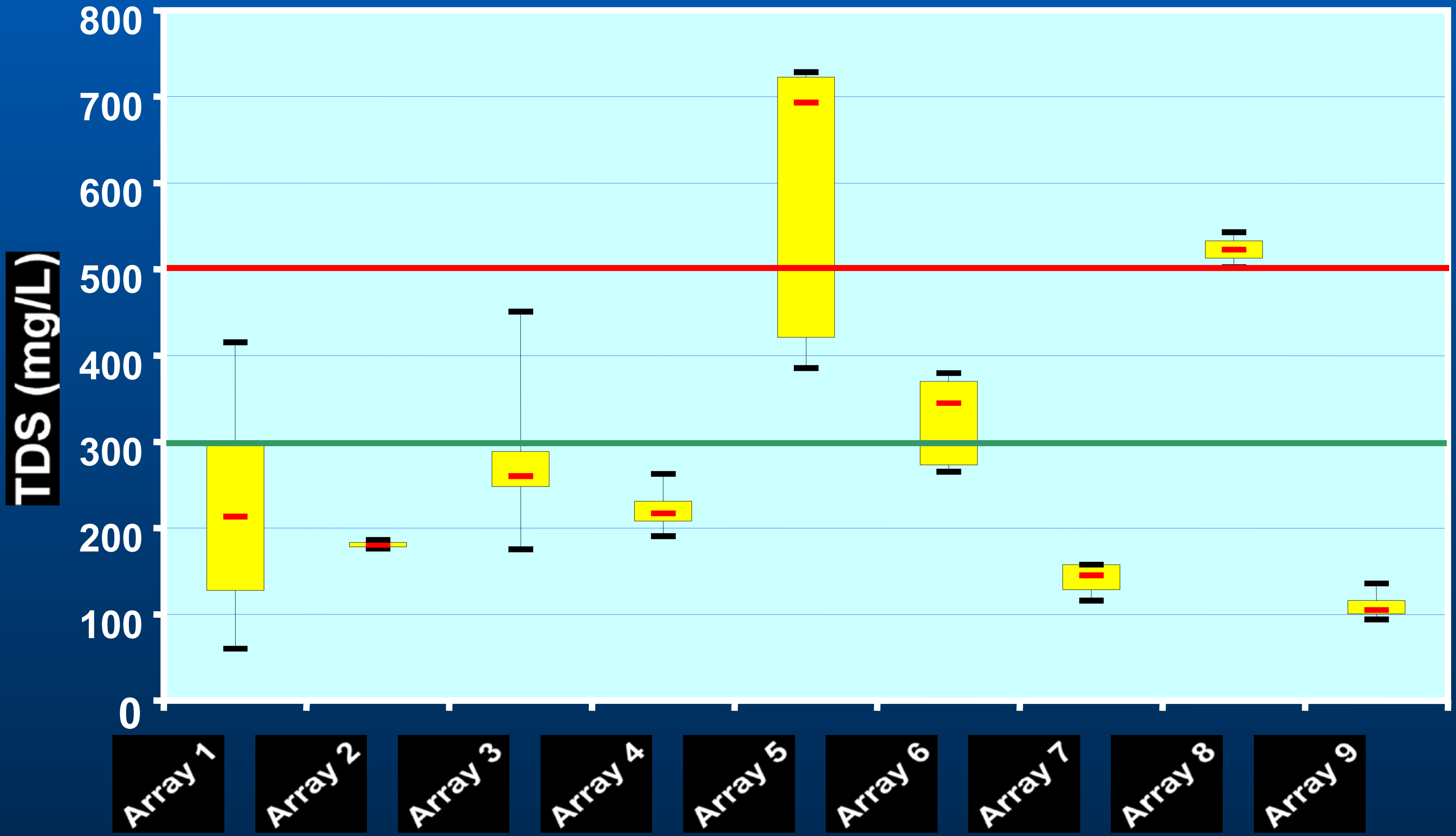
- **Membrane Technical Specification, 25°C**

General Information					Test Conditions				
					$MgSO_4$		NaCl		
Manufacturer	Model	Mat'l	Area (ft^2)	Product Flow (gpd)	mg/L	Min Rej.	mg/L	Min Rej.	P (psi)
FilmTec	NF90	PA	80	1,850	2,000	95%			70
Hydranautics	ESPA1	PA	85	4,000			1,500	99%	225
Hydranautics	ESPA2	PA	85	3,000			1,500	99%	225
Hydranautics	ESPA4	PA	85	2,500			1,500	99%	225
Trisep	ACM4	PA	81	3,200			2,000	98%	100
Trisep	TS80	PA	81	2,000	2,000	97%			100
Trisep	X20	PA	81	2,000			2,000	99%	100

Phase 3 Results – Recovery

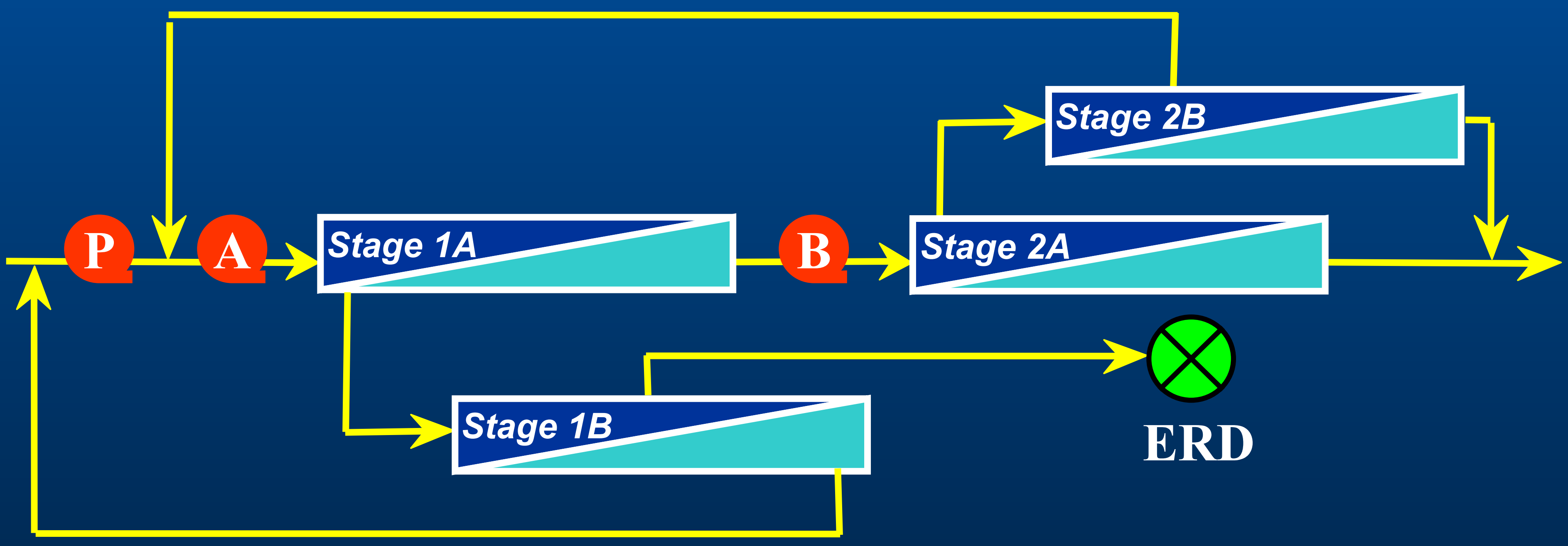


Phase 3 Results – TDS

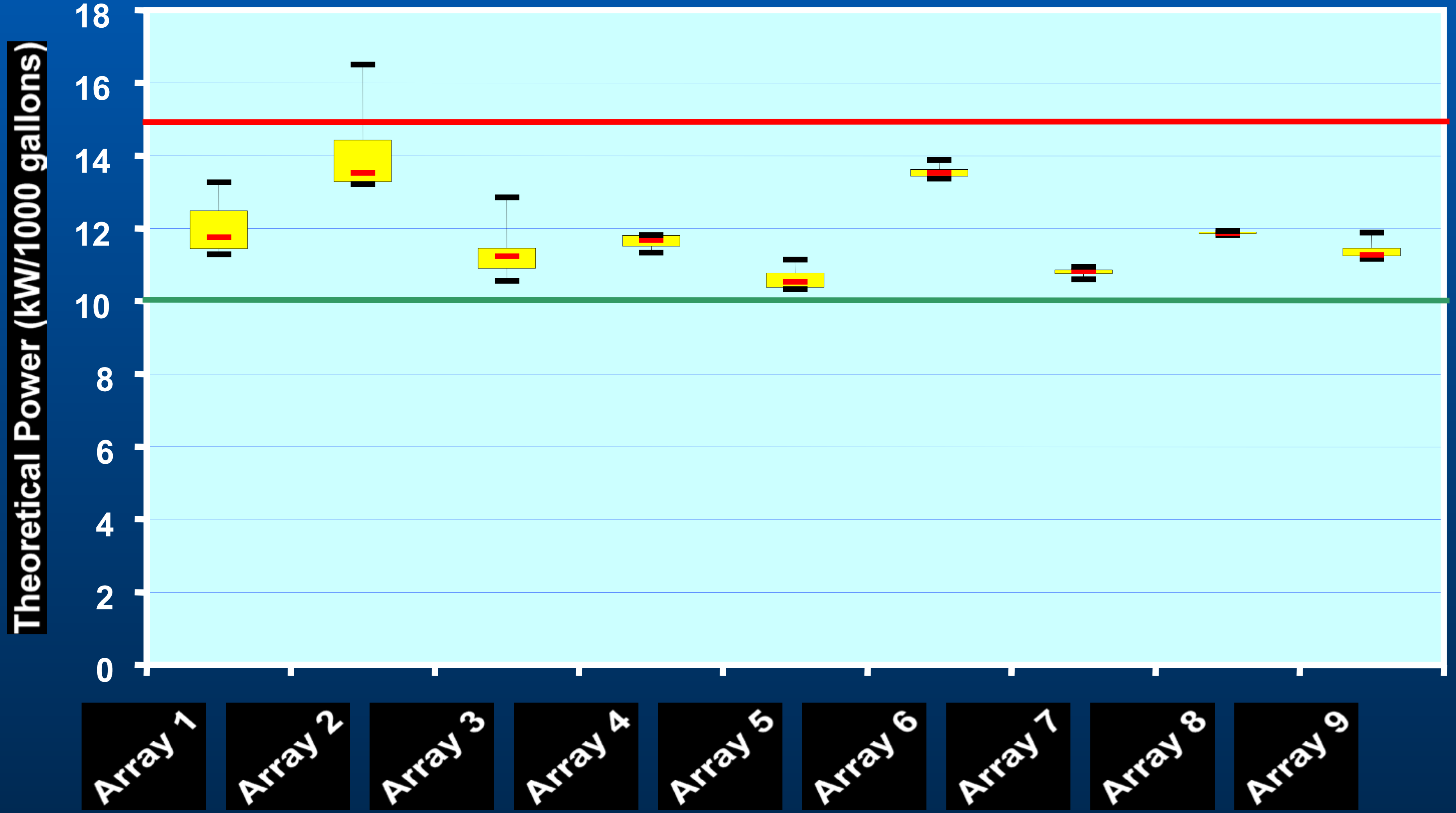


Phase 3 Results – Power

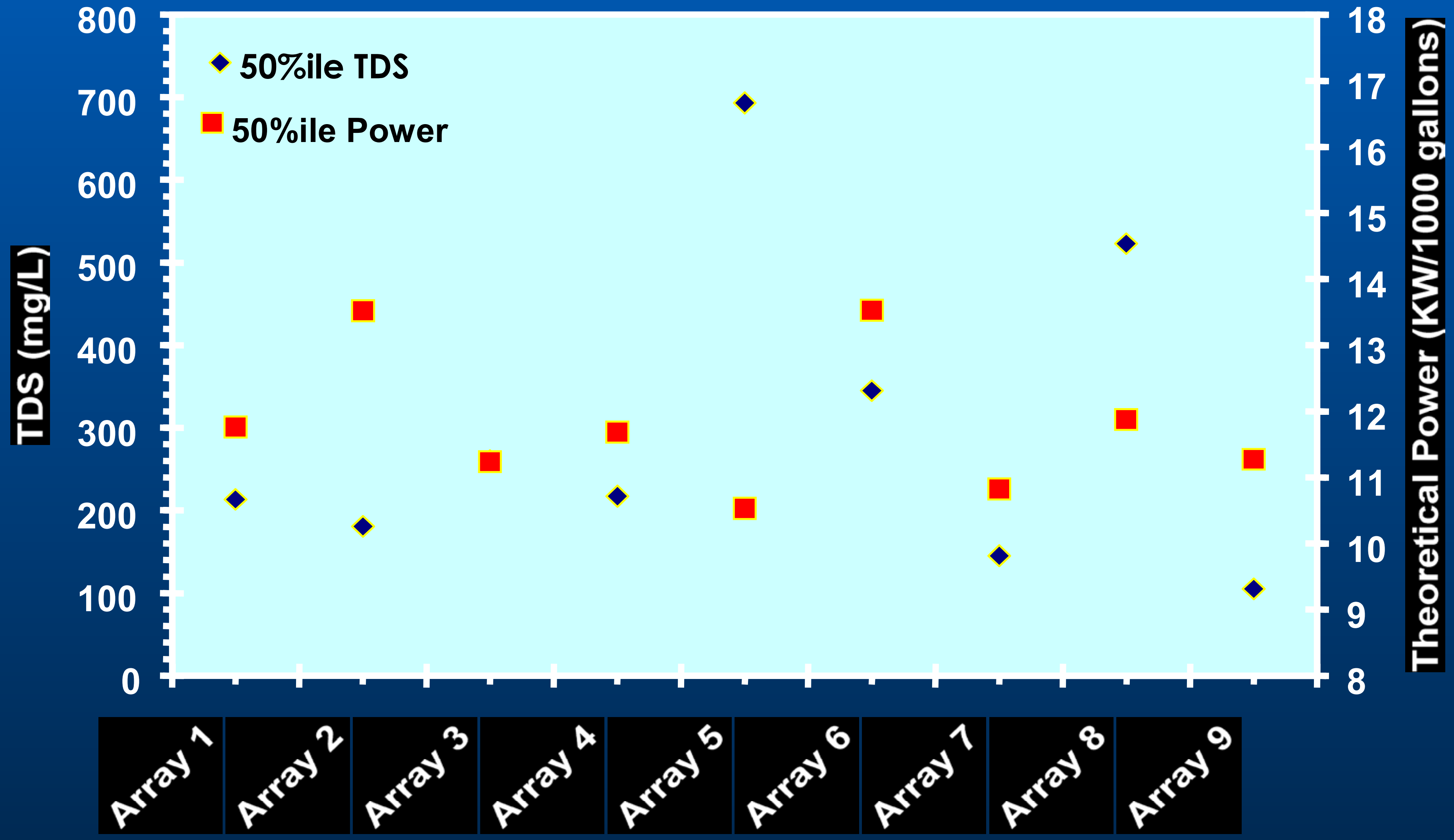
- HP = Q * P * 2.3 / (3960 * e)
  - Standard efficiencies (75% - 82%)
  - included additional energy losses
- kW = 0.746 * HP



Phase 3 Results – Power



Phase 3 Results



Conclusions

- Dual-staged NF process provides flexibility
- Opportunity to use less costly materials
- A wide range of membranes manufacturers
- General permeate WQ consistent with single-pass SWRO
- Theoretical power cost on lower range of "literature values"
- Power cost comparisons are difficult due to varying end product quality

Future Work

- AWWARF TC (challenge testing/ modeling/ corrosion)
- A 300,000 gpd demonstration facility is under design and is expected to be completed by the first part of 2004
- Future research will focus on:
  - Pretreatment
  - Boron removal
  - Post-treatment
  - Brine discharge
  - Long-term membrane performance
  - Physically test energy recovery devices (ERD)
  - Detailed cost information
  - Treatment performance as a whole

Questions

1.1 Gigawatts