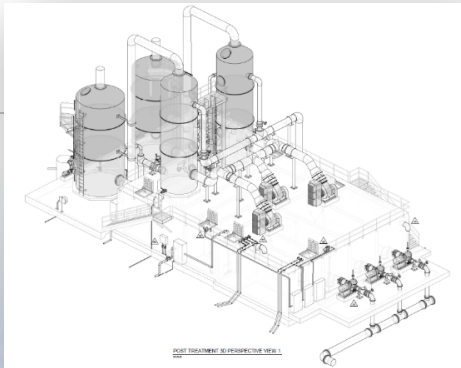
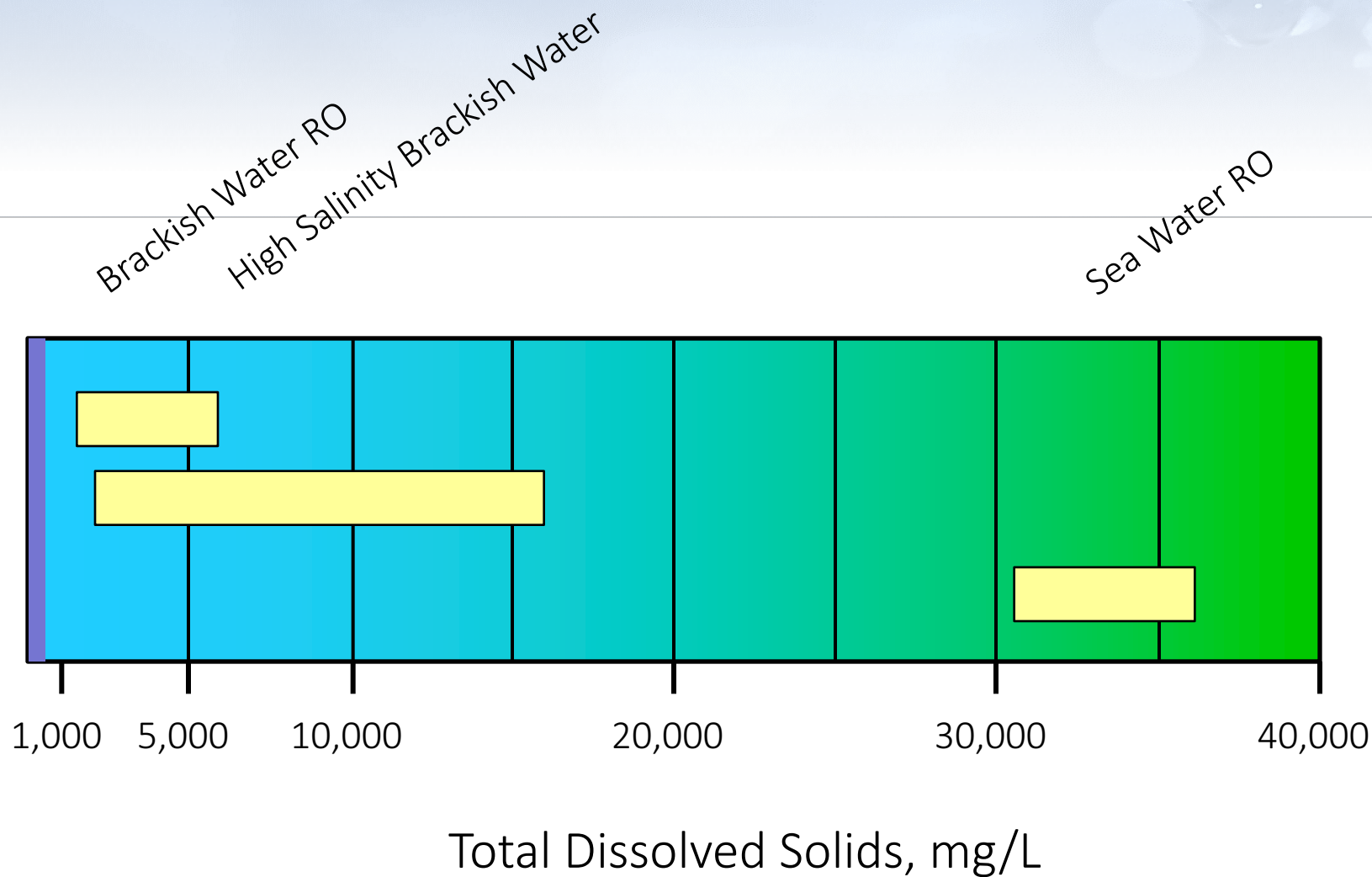


Desalination Process Innovations to Address Extreme Variations in Feed Water Salinity

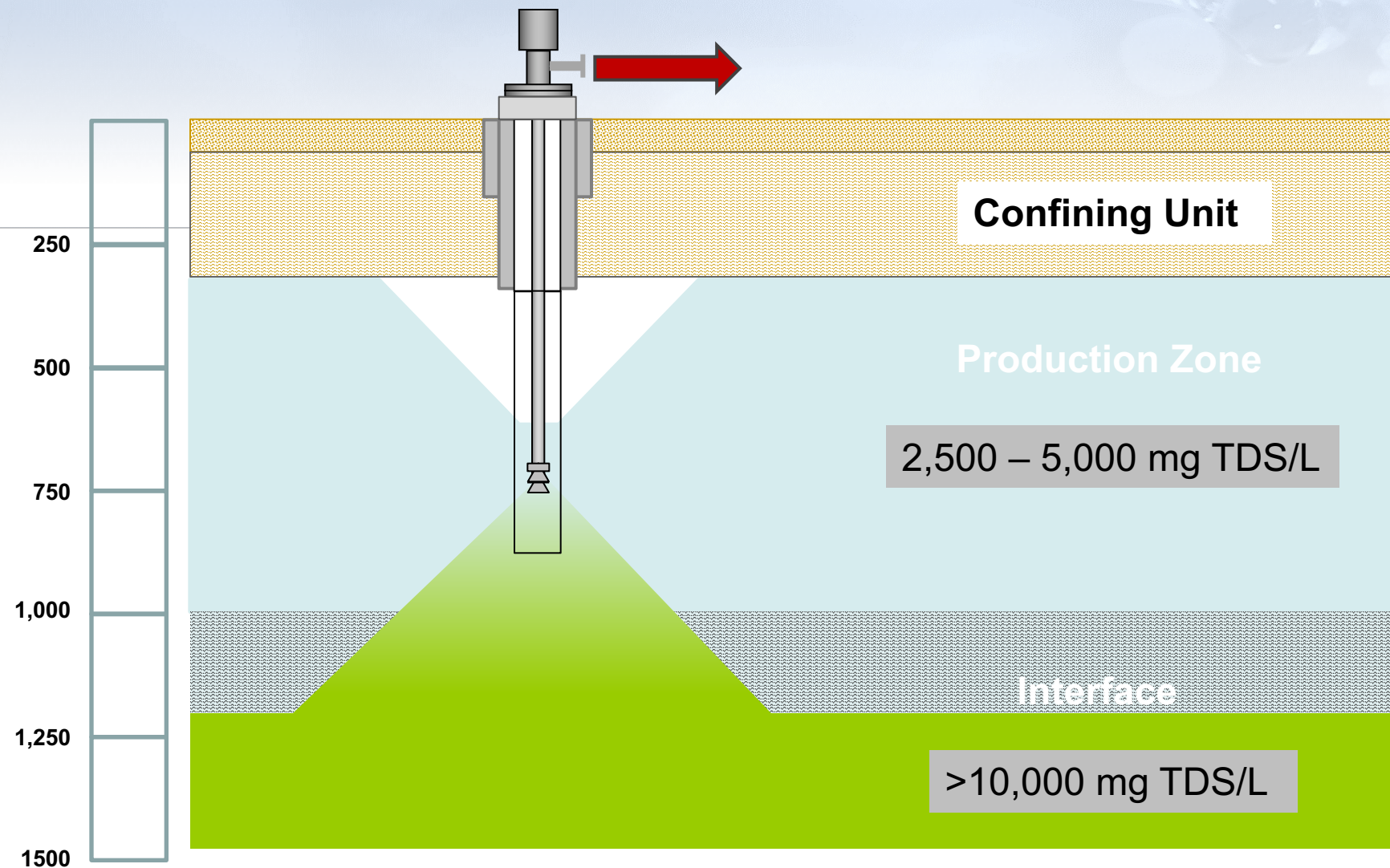
James E Christopher, PE, BCEE | September 21, 2017



Raw Water Salinity Spectrum



Well Field Design



Raw Water Quality

Parameter	Initial (Year 0)	Well Composite	Degraded (Year 10)
Temperature	23-28 °C	21.8 °C	23-28 °C
TDS, mg/L	1,950	2,602	16,564
pH	7.39 SU	6.2	7.69 SU
Alkalinity, mg/L as CaCO ₃	197	163.3	197
Ca Hardness, mg/L as CaCO ₃	248	340	998
Mg Hardness, mg/L as CaCO ₃	247	436	1,040
Iron, mg/L	0.24	1.13	1.07
Sodium, mg/L	519	708	5,002
Chloride, mg/L	953	1,309	9,067
Sulfate, mg/L	97	183	1,271

Concentrate Disposal

■ Surface Water Discharge Permit

- Outfall into Ancloste Power Plant Cooling Water Discharge Canal
- Copper Limit, 0.0098 mg/L
- Iron Limit, 1.72 mg/L
- Recovery Limited to 65%

■ Deep Injection Well

- Recovery and Quality Not Limited

Design Criteria

- Designed for Operation at Initial AND Future Degraded Water Quality
- RO Process Design Criteria
 - Minimum Recovery: 65%
 - Finished Water Capacity: 6.4 MGD
 - Number of RO Trains: Three (3)
 - Membrane Elements: 400 SF/element
 - Average Permeate Flux: ≤ 12 gfd
 - RO Feed Pump Motor: ≤ 800 HP

Finished Water Quality Goals

Parameter	Water Quality Requirements
pH	≤ 9.0 SU
Calcium Hardness	≥ 40 mg/L as CaCO_3
Alkalinity	≥ 40 mg/L as CaCO_3
Iron	0.3 mg/L
Chloride	250 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Langelier Saturation Index (LSI)	0.1-0.5
Calcium Carbonate Precipitation Potential (CCPP)	4-10 mg/L
Free Chlorine Residual	0.0-4.0 mg/L as Cl_2

RO System Operational Plan

- **High rejection seawater RO membranes**
 - RO membrane flux limits
 - High salinity of future degraded raw water
- **Designed for variable recovery**
 - 75-80% for initial water quality/deep well
 - 65-70% as raw water quality degrades
 - 65% for surface water discharge
- **Designed for Variable Permeate Flow Rate**

Multiple Membrane Projections

Reverse Osmosis System Analysis for FILMTEC™ Membranes

ROSA 8.0.3 ConfigDB U412142_201

Project: Tarpon Bay Bid-Initial

Multiple Cases

Case: 1

James Christopher, Tetra Tech

11/14/2012

Project Information:

Case-specific:

Acid

Age

65-80%

23-28°C

Flux Balance

System Details

Feed Flow to Stage 1 2116.70 gpm
Raw Water Flow to System 2116.70 gpm
Feed Pressure 273.27 psig
Flow Factor 0.75
Chem. Dose None
Total Active Area 181440.00 ft²
Water Classification: Well Water SDI < 3

Pass 1 Permeate Flow 1481.61 gpm
Pass 1 Recovery 70.00 %
Feed Temperature 23.0 C
Feed TDS 2009.42 mg/l
Number of Elements 441
Average Pass 1 Flux 11.76 gfd

Osmotic Pressure:
Feed 19.90 psig
Concentrate 63.79 psig
Average 41.85 psig
Average NDP 202.71 psig
Power 314.57 kW
Specific Energy 3.54 kWh/kgal

Boost

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	SW30XLE-440i	42	3	2116.70	268.27	0.00	1668.66	253.70	448.04	11.64	42.00	0.00	8.10
2	SW30ULE-400i	42	4	1668.66	248.70	0.00	1075.23	235.10	593.43	12.72	42.00	0.00	17.61
3	SW30ULE-400i	21	7	1075.23	230.10	0.00	635.09	197.97	440.14	10.78	17.00	0.00	31.48

3 Feed Qualities

Name	Feed	Adjusted Feed	Concentrate			Permeate			
			Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Total
NH4+ + NH3	0.03	0.03	0.04	0.06	0.10	0.00	0.00	0.00	0.00
K	16.00	16.00	20.28	31.38	52.93	0.07	0.16	0.29	0.17
Na	519.00	519.00	657.86	1018.53	1718.80	1.84	4.36	8.09	4.71
Mg	60.00	60.00	76.09	118.01	199.60	0.06	0.15	0.27	0.16
Ca	99.00	99.00	125.55	194.72	329.35	0.10	0.24	0.44	0.26

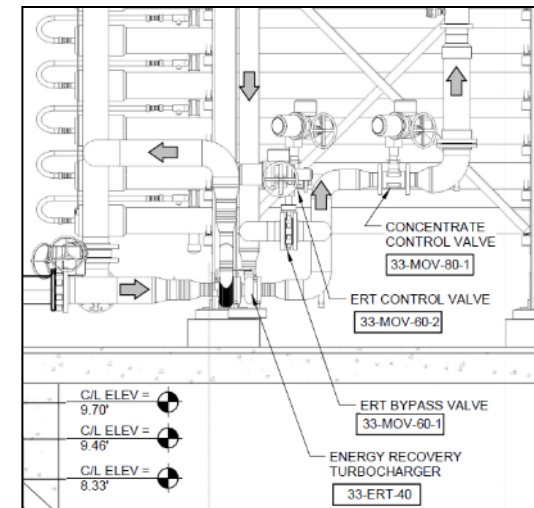
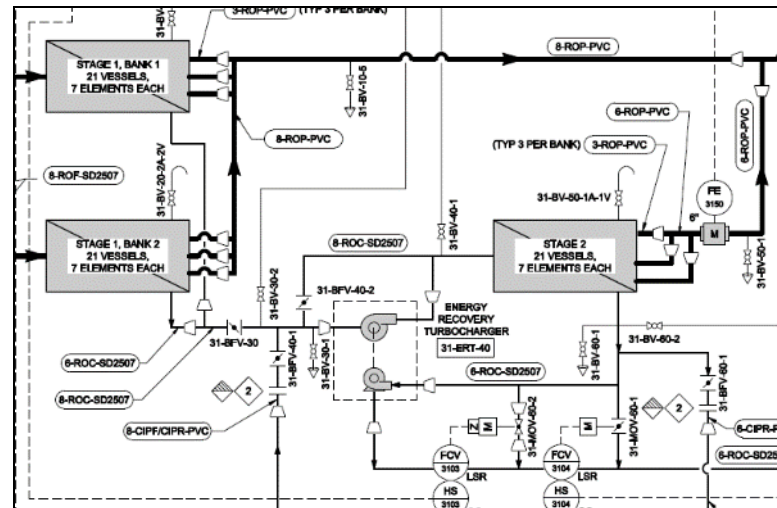
Permeate Back Pressure

RO Membrane Selection

- 2-Stage, 7-element, 42:21 Array
- 1st Stage hybrid element load, 440 SF and 400 SF elements, to meet 12 gfd flux
- Dow Filmtec SW Membranes
 - 1st Stage Elements 1-3: SW30XLE-440i
(99.8% salt rej., 9,900 gpd)
 - 1st Stage Elements 4-7: SW30ULE-400i
(99.6% salt rej., 8,400 gpd)
 - 2nd Stage Elements: SW30ULE-400i
(99.6% salt rej., 8,400 gpd)

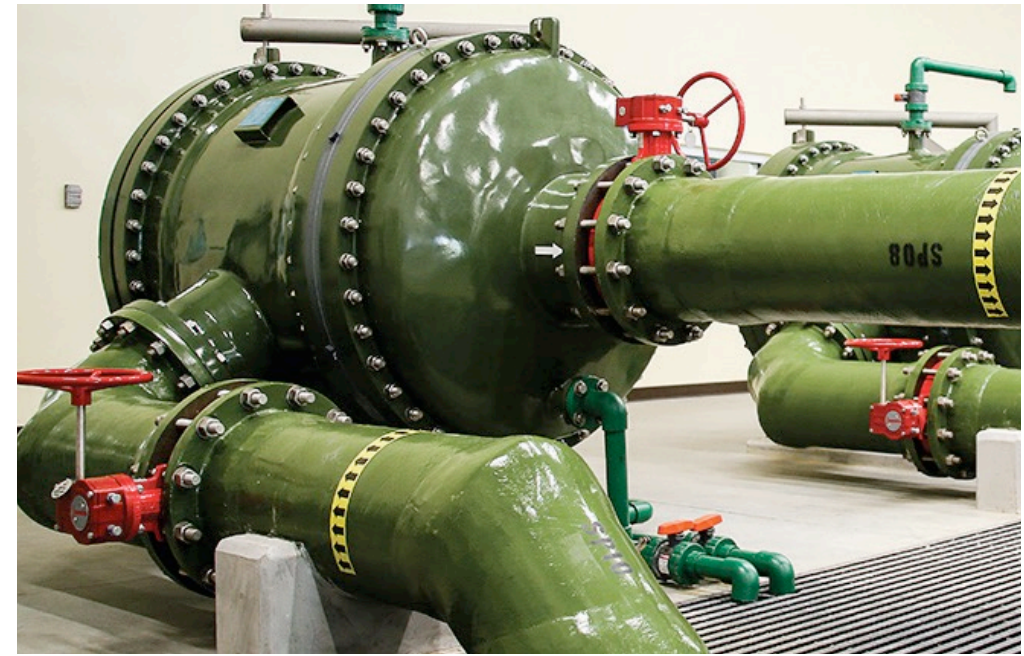
Additional RO Train Features

- Hydraulic Turbocharger for Interstage Boost
 - Greatest boost at degraded raw WQ and 65% system recovery
- Pressure Vessels:
 - Stage 1: 600 psi Rated (max working pressure is 503 psi)
 - Stage 2: 1000 psi Rated (max working pressure is 657 psi)



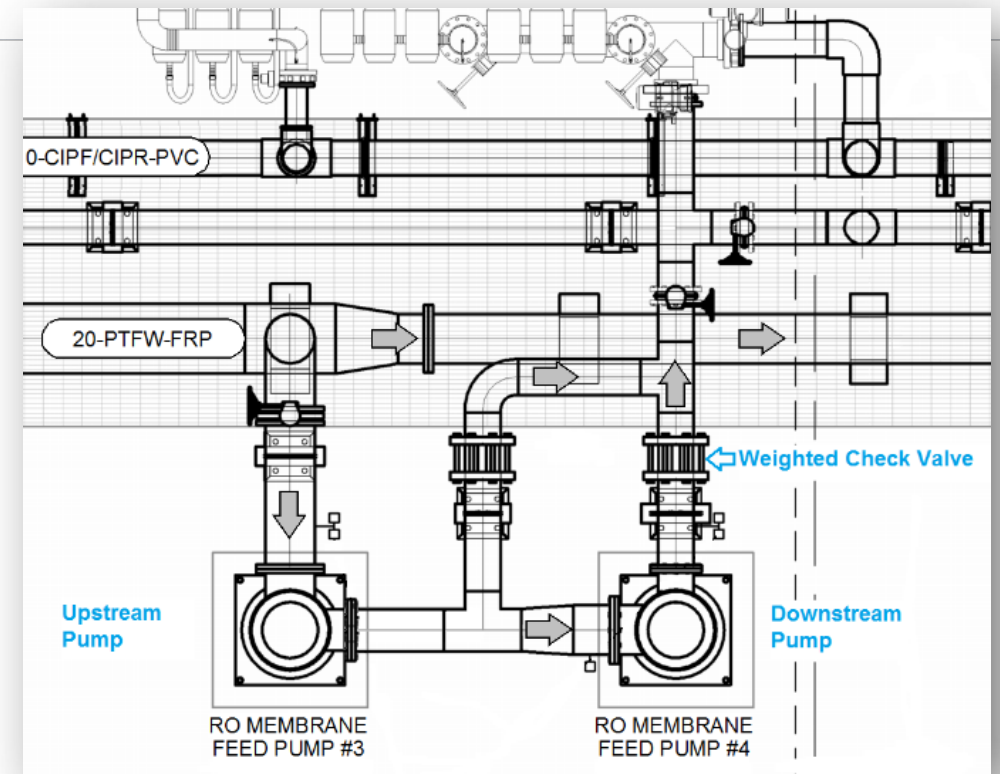
Materials of Construction

- **Raw Water Piping/Pumps**
 - Above Grade-Super Duplex SS 2507
 - Below Grade-HDPE, DR 11
- **RO Trench Piping/Feed Filters**
 - FRP
- **RO Feed Pumps/Piping**
 - Super Duplex SS 2507, 300/600 lb flanges
- **Interstage/Concentrate Piping**
 - Super Duplex SS 2507, 600 lb flanges

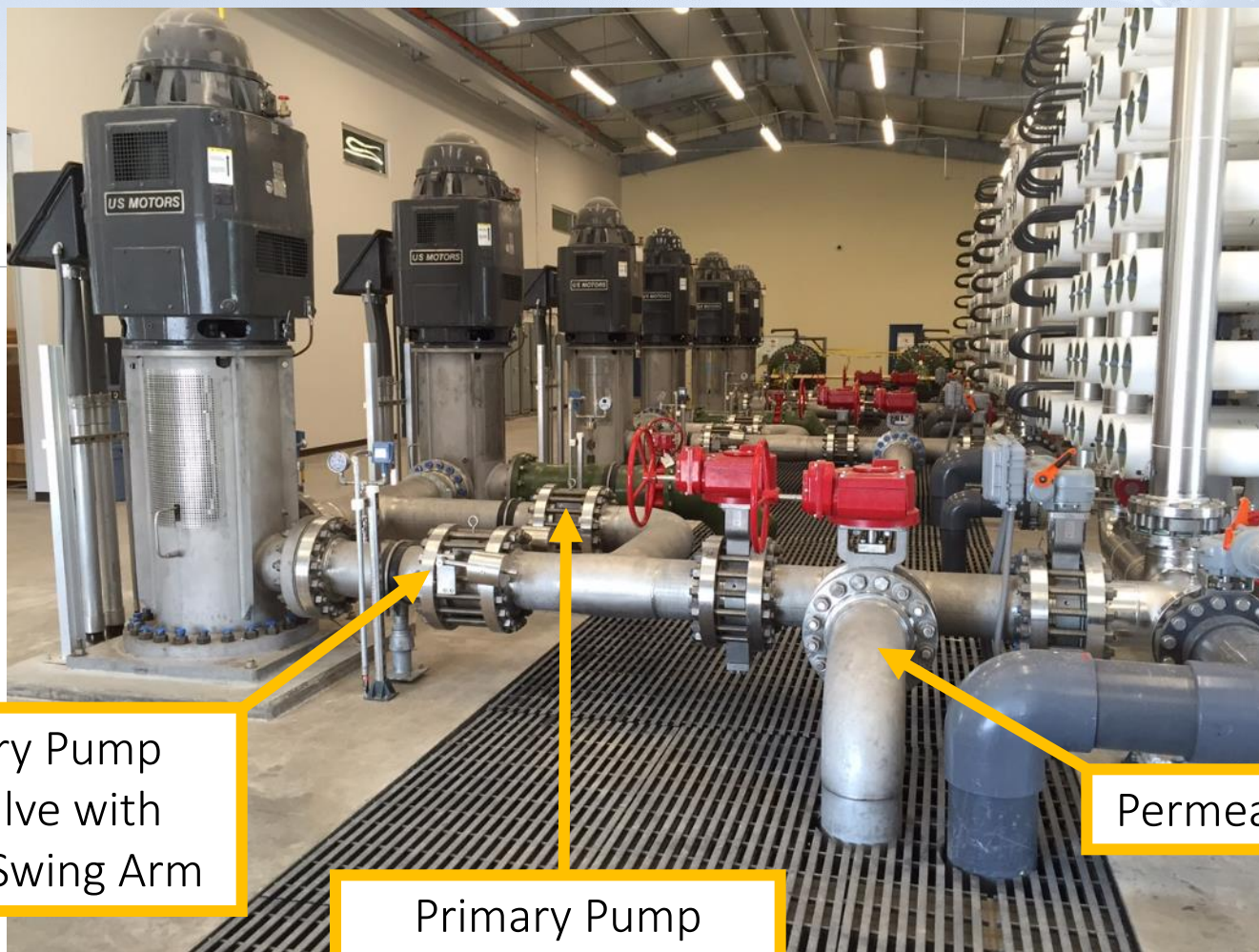


RO Feed Pump Design

- Two feed pumps to satisfy 800 HP limit
- Pumps in series to provide turndown of feed pressure
- One feed pump operates at startup, flow will bypass 2nd pump
- Controls allow operator to select low or high salinity operating mode
- Either pump can be lead



R0 Feed Pumps

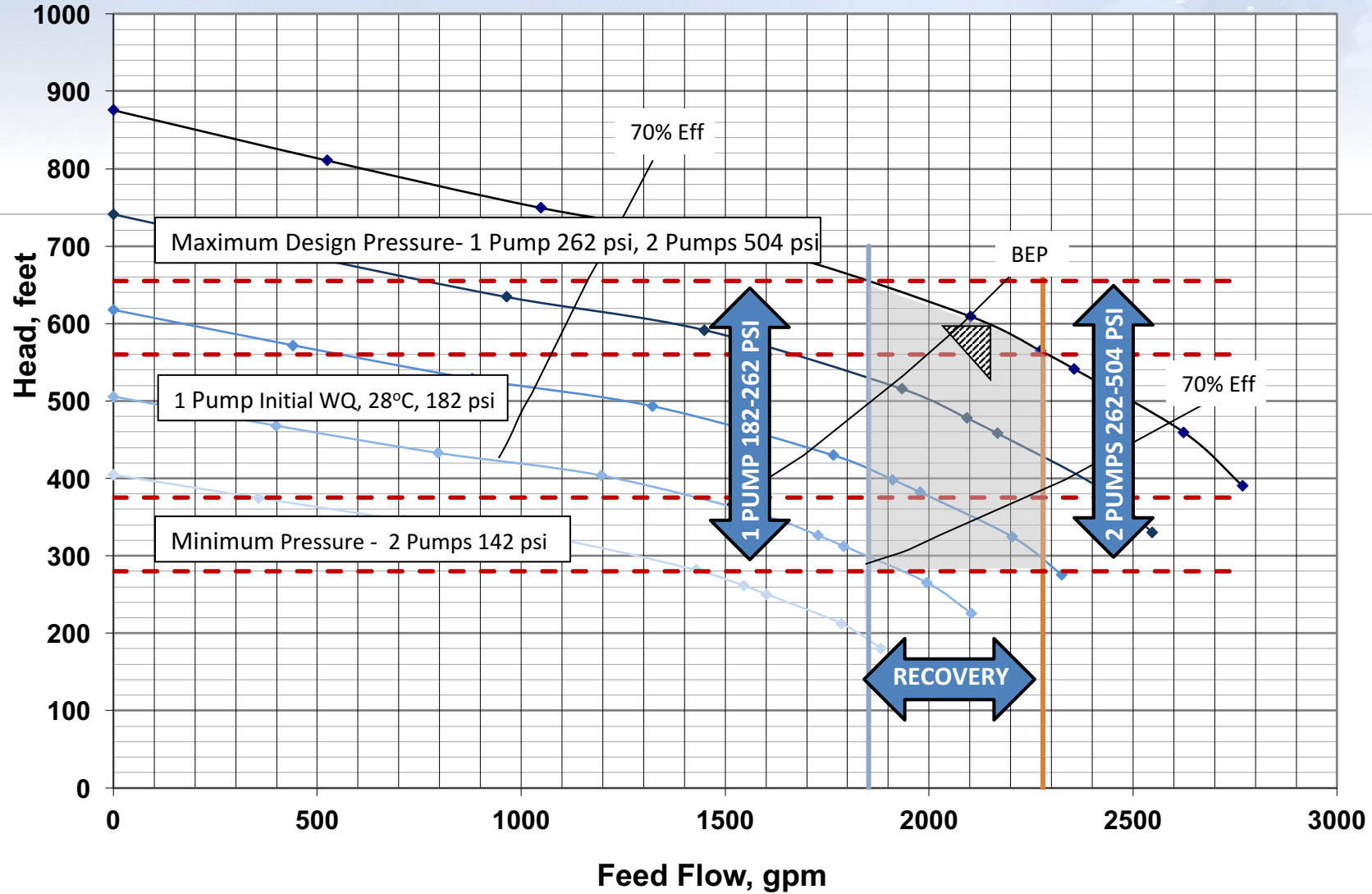


Secondary Pump
Check Valve with
Weighted Swing Arm

Primary Pump
Bypass Piping

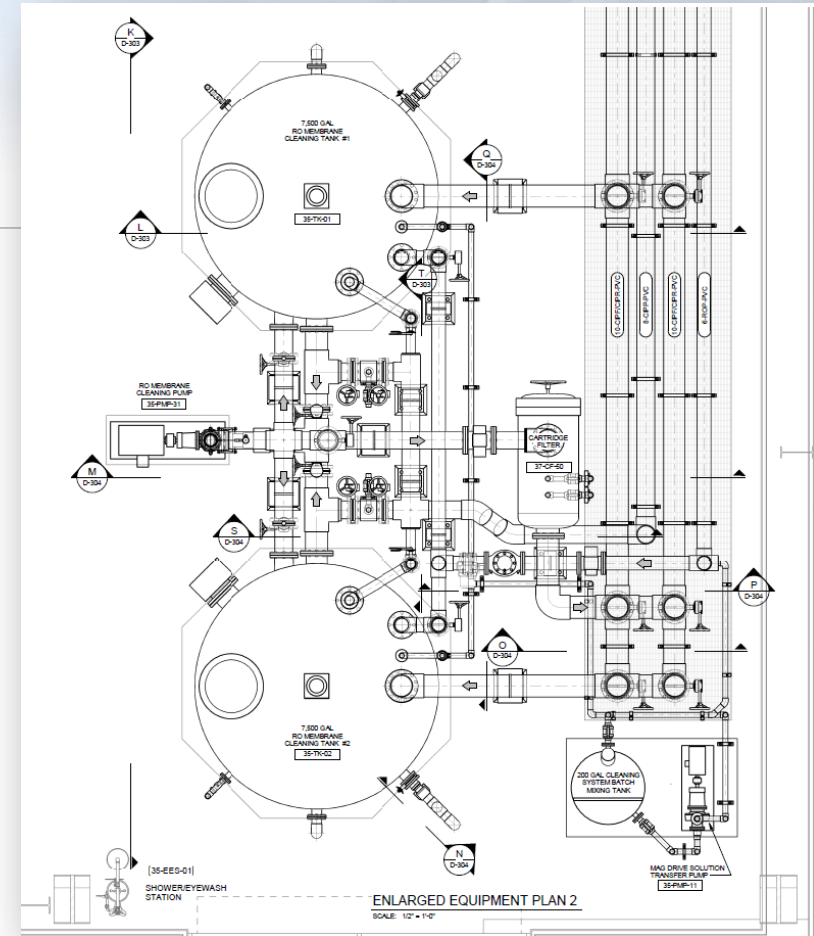
Permeate Flush

Feed Pump Operating Envelope



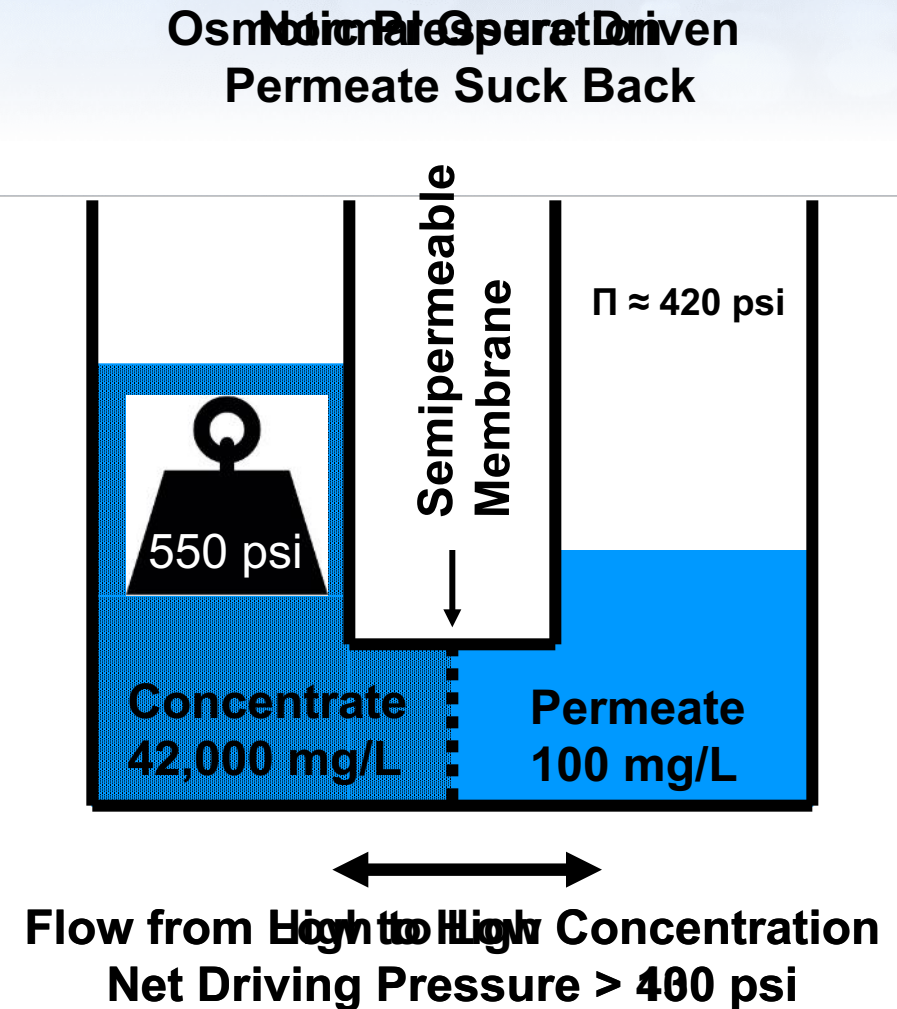
RO Process – Permeate Flush System

- Automated Permeate Flush after Shutdown:
 - Upsized CIP tanks to 7,500 gal/each and recirculation pump to 1,000 gpm for dual purposes (CIP/Flush System)
 - Added motorized valve to RO skid's feed pipe
 - Added controls and valves for filling CIP/Flush tanks



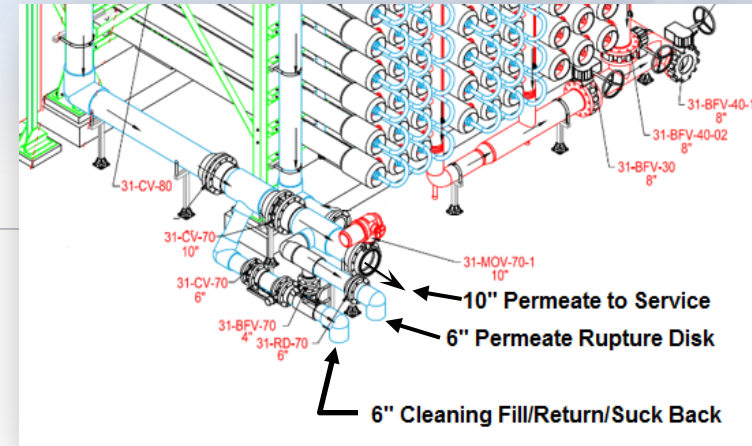
RO Process – Permeate Suck Back

- A sudden loss of feed pressure during operation (Power loss or emergency alarm condition) will lead to a pressure imbalance in the system (RO feed pressure is less than the osmotic pressure)
- As a result, forward osmosis will occur within the membrane elements in a phenomenon known as “permeate suck back”



RO Process – Permeate Suck Back

- Passive “Permeate Suck Back”
Provisions: Sized for power loss with 1-2 RO trains in operation
 - Conventional permeate suck back tank not feasible due to static head for degasifiers
 - Permeate stored in the CIP tanks is used the source
 - Cleaning permeate piping to/from RO trains was upsized
 - Additional check and isolation valves installed on RO trains



Post Treatment

- **Permeate Quality:**

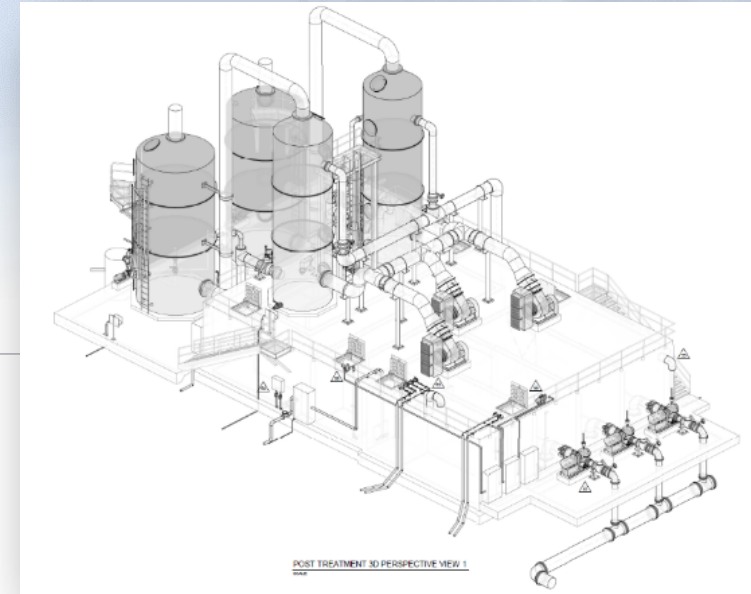
- pH: 5.7
- Alkalinity: < 2 mg/L as CaCO_3
- Calcium: < 1 mg/L

- **Raw Water Blending**

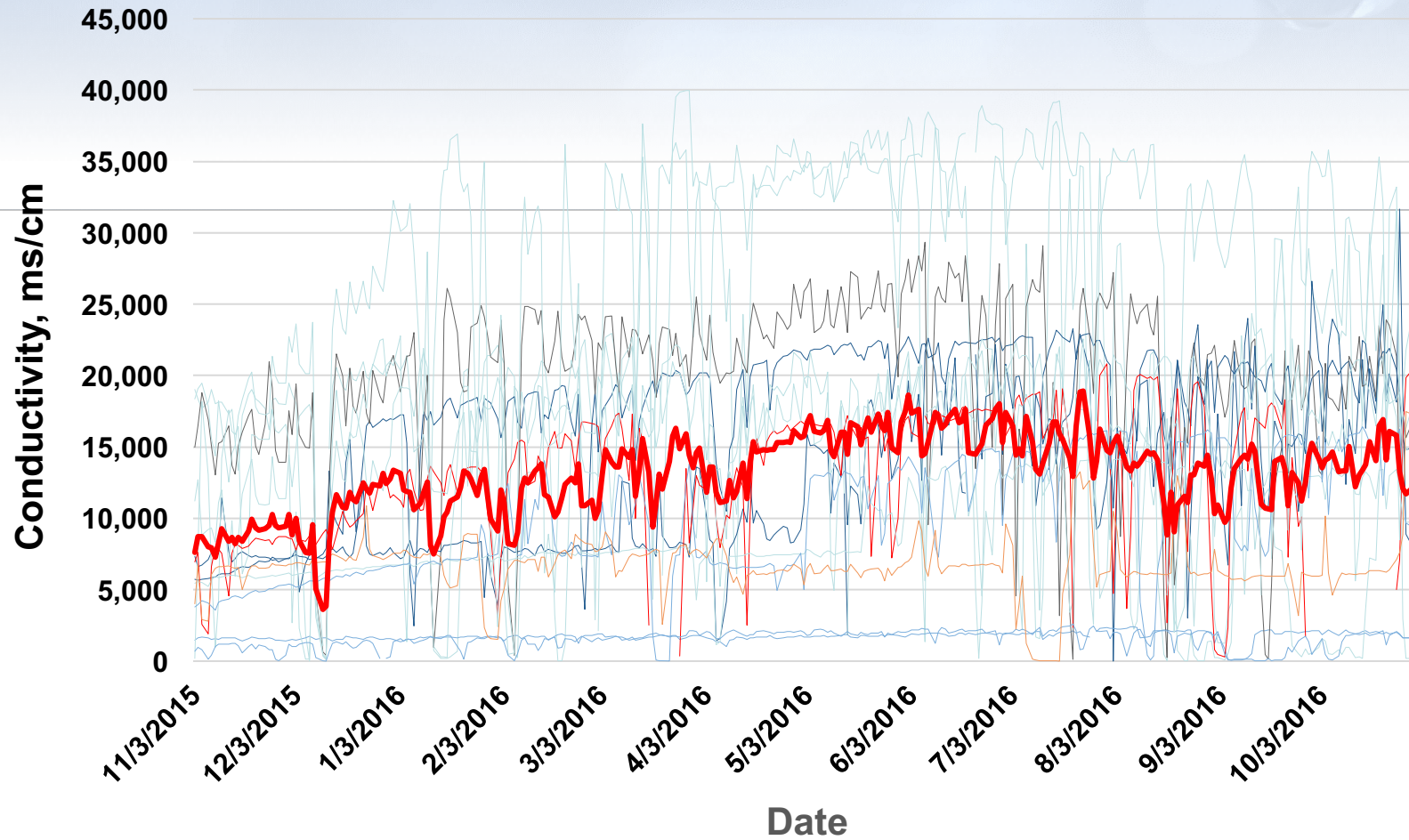
- **pH/Ca Adjustment - Carbon Dioxide**

- **Ca/Alkalinity Adjustment, Calcium Hydroxide (Lime) Slurry**

- **Final pH Adjustment—Sodium Hydroxide**

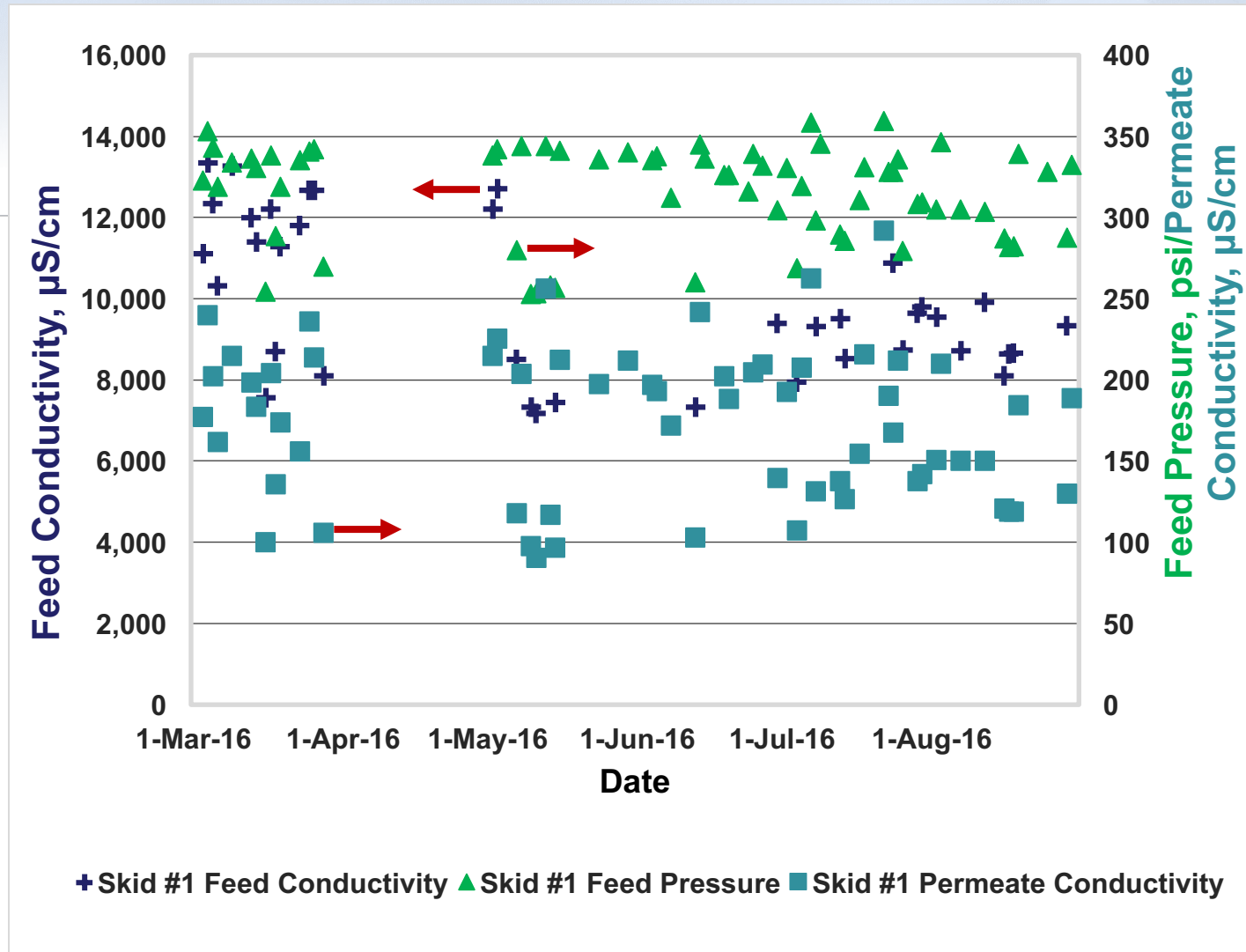


Supply Well Quality



Well No. 16 Well No. 9 Well No. 12 Well No. 15 Well No. 17 Well No. 18 Well No. 22
Well No. 23 Well No. 24 Well No. 26 Well No. 27 Well No. 29 Well No. 30 Average

First Year Operating Data



Questions?

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