CornellEngineering

Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

Topic: Brackish Water Desalination

Instructor: YuJung Chang

YuJung.Chang@aecom.com

Class #19 11/05/2018 2:55 – 4:10pm

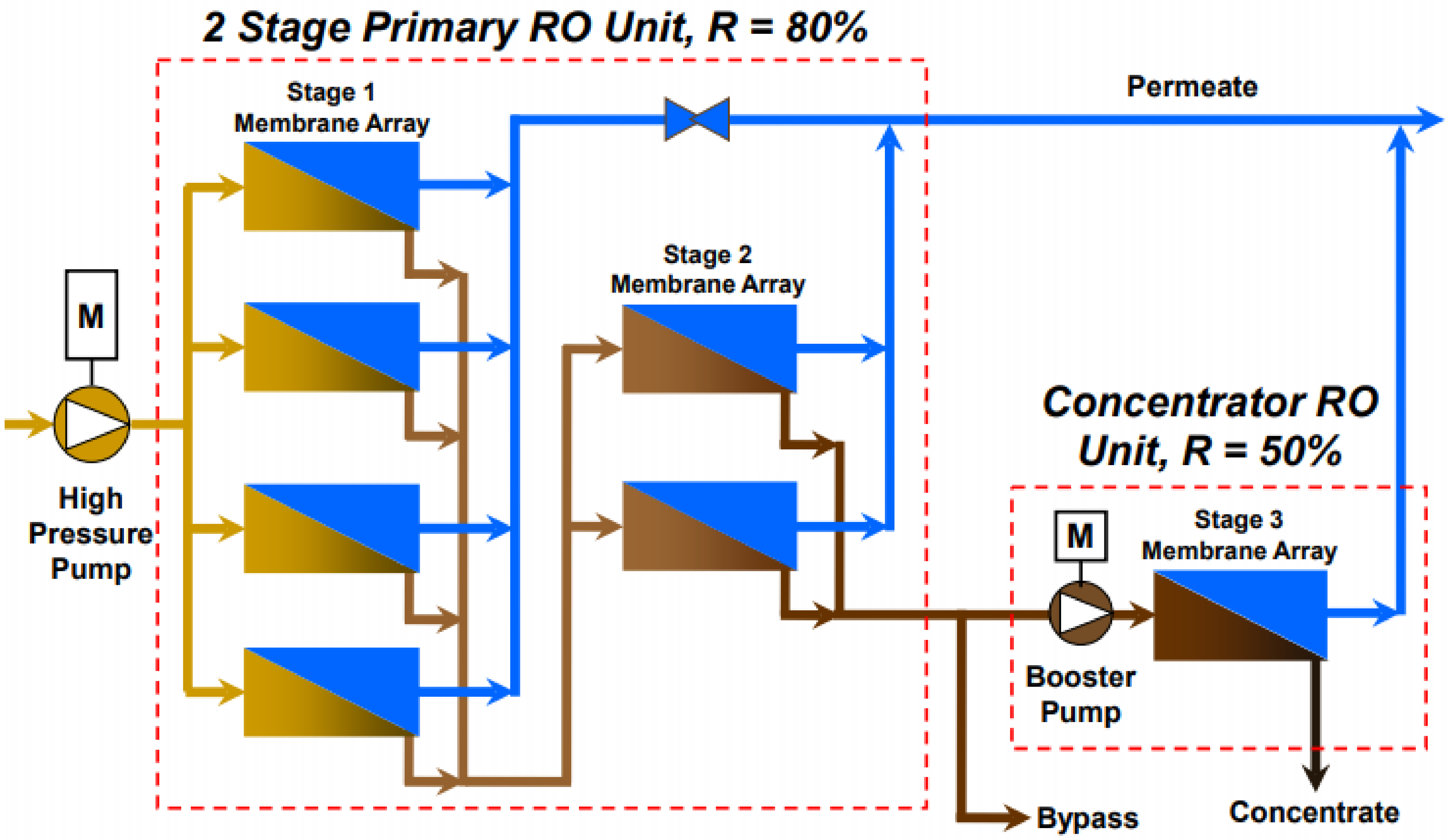
Brackish Water Reverse Osmosis (BWRO) Desalination

- BWRO is primarily used for removing salts from brackish groundwater, such as CaCO3, CaCO4, SiO2, etc.
- These Salts could also form scales and foul the membranes
- Typical BWRO treatment consists of:
  - Pretreatment
  - Salt removal (with BWRO)
  - Post treatment (re-mineralize treated water) to reduce corrosion in the distribution system
- The single biggest challenge to BWRO is how to get rid of the final brine solution (concentrate disposal)

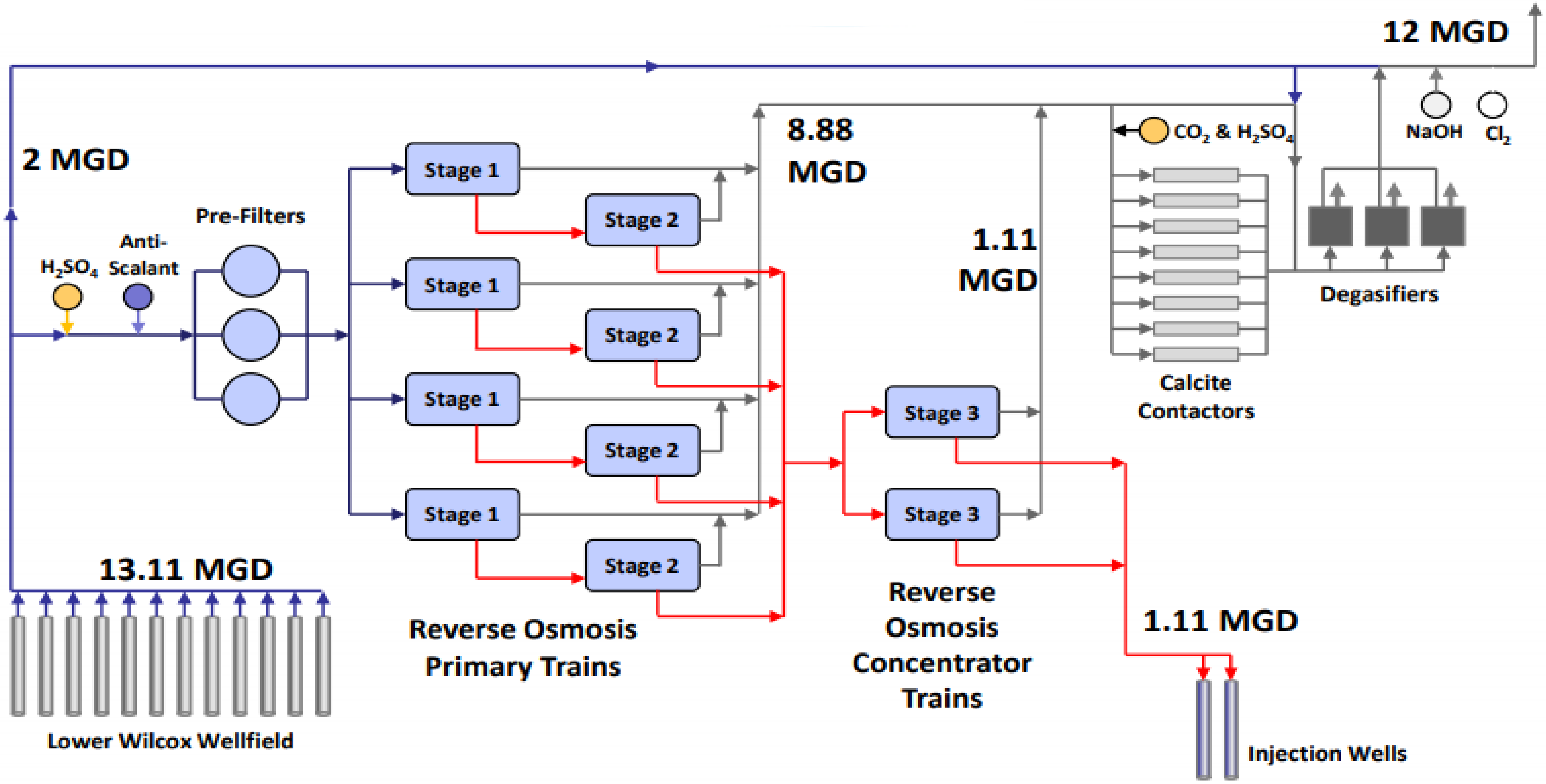
Multi-Stage BWRO Configuration to Maximize RO Recovery

- The only way to minimize brine is to increase recovery by "squeezing" more water out of the BWRO brine
- The only way to achieve higher recovery is to use another set of RO membranes to treat the reject brine, again, therefore the use of "multi-stage BWRO system
- 2 or 3 stage RO is most common
  - # of stages depend on feed water quality
- Brine from 1st Stage is fed to the 2nd Stage
- Brine from 2nd Stage is fed to the 3rd Stage

Conventional 3-Stage BWRO System



Typical PFD for 3-Stage Brackish Desalination



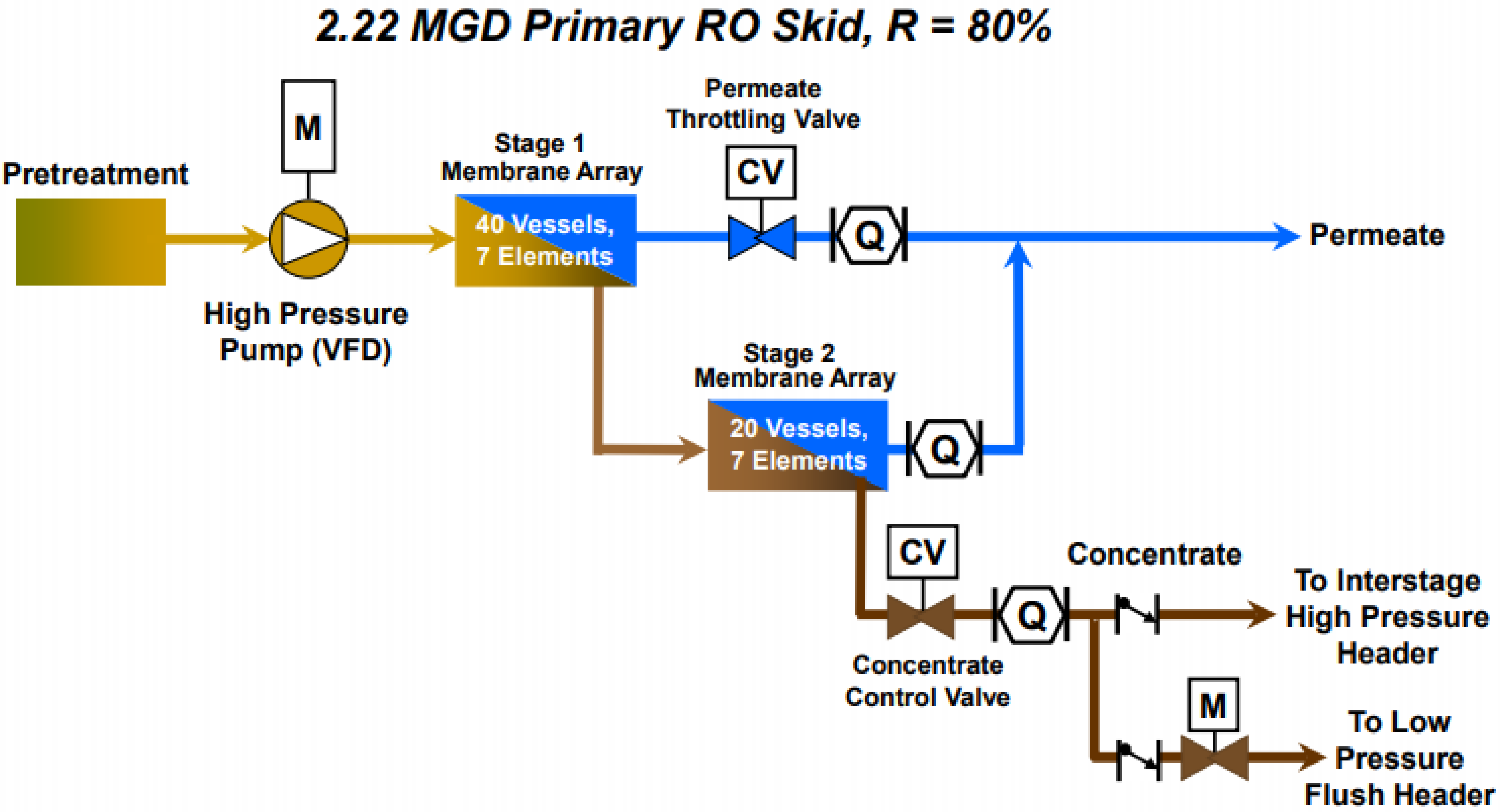
Pretreatment

- Scale Inhibitor/Anti-scalant
- pH Adjustment - 6.5 using sulfuric acid
- Cartridge Filters
  - 3 x 7.0 MGD units
  - 14.0 MGD with one unit offline
  - 5-Micron nominal polypropylene, string-wound, SOE, 40-inch

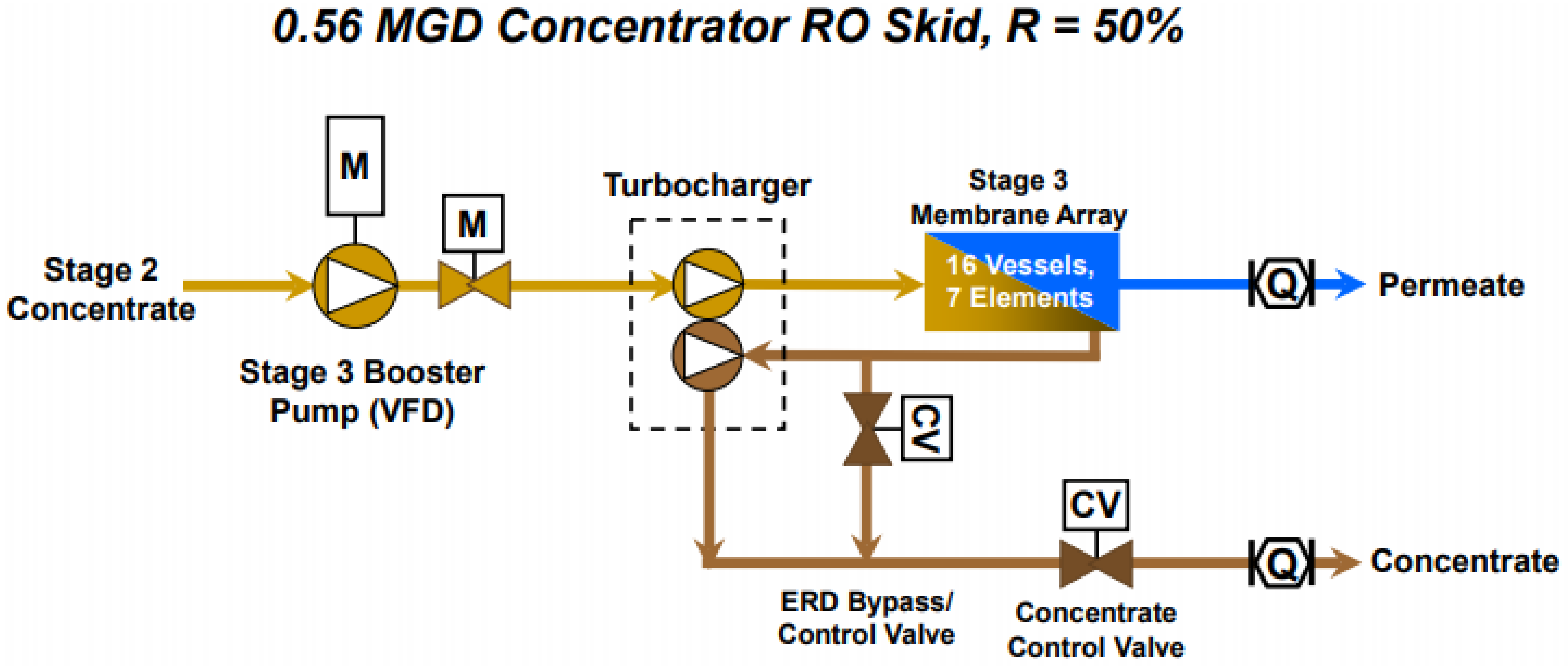
Cartridge Filters

- **DOE –** The most common filter cartridges found are DOE, or Double Open Ended. These cartridges have no built in seals on either end, thus the name. Instead the filter cartridge housing is relied upon to seal one side and stop contaminants from bypassing the cartridge.
- **SOE –** As the name indicates, Single Open Ended cartridges have one end sealed. This seal is usually accomplished by using a polyporpylene cap. By using a cap on one end, filter bypass is impossible, so systems that require higher purity filtration typically implement this type of cartridge filter. The higher cost associated with the end cap prevents this type from being used in general applications.

Primary RO Skid Configuration



3rd Stage Concentrator RO Skid Configuration



Post Treatment

- Calcite Contactors – Calcium and alkalinity addition
- Raw Water Blending – Supplemental alkalinity & hardness
- Degasifiers –Excess CO_2 removal
- Sodium Hydroxide – Final pH stabilization
- Chlorine – Disinfection

Raw Water Blend (Bypass) Control Valve

Injection Well for Concentrate Disposal

- 2 Injection Wells
- Injection Well Details:
  - Well Depth: Approx. 5,100 ft
  - Avg. Flow: 500 gpm (30 day avg)
  - Instantaneous Flow: 1,000 gpm
  - IW Pressures: 775 psi max, 150-250 psi at 385 gpm
  - Injection Zone TDS: 90,000 mg/L
- First Class 1 UIC General Discharge Permit issued by TCEQ for RO Concentrate Disposal

Question #1: What's the color?

Design Considerations for Production Wells

Silica and Iron

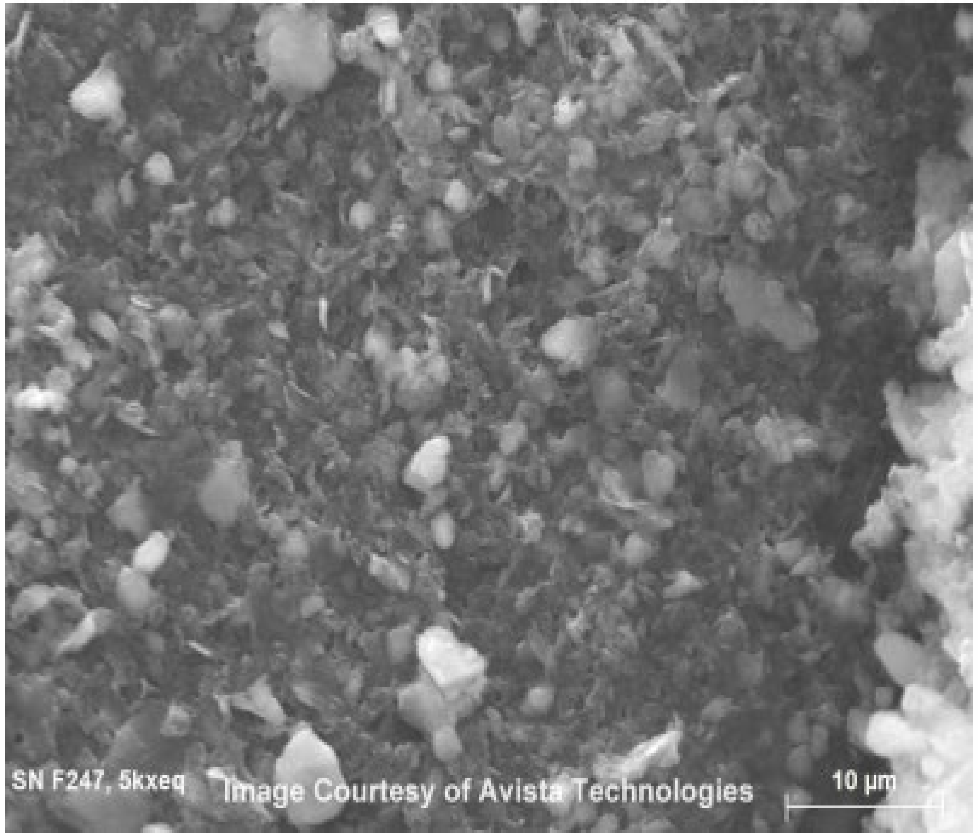
- Due to higher design recovery, both Iron and Silica were concerns from initial well data
- More than 50% of iron is maintained in dissolved form
- Cause of partial iron oxidation (measured at well) is uncertain
  - Low amounts of DO are present in raw water at the wellhead
  - ORP is consistently negative (-150 to -200 mV)
  - No clear correlation between oxidized iron, DO, and ORP
- Well operational pre-flushing is necessary
- Well pump speed control philosophy has proved to provide stable and reliable control
- Raw water entering the plant maintains a negative ORP

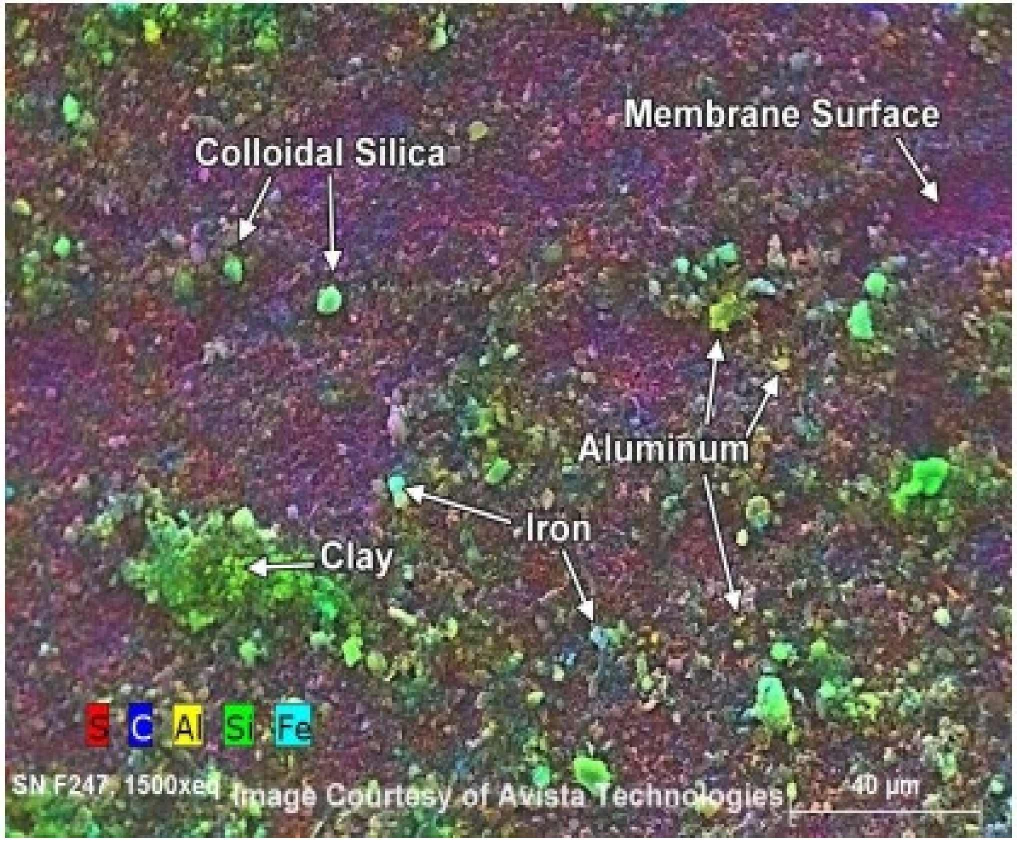
Supply Well Water Quality Monitoring

- SDI (Silt Density Index)
- Overall raw water quality (SDI & turbidity) appears to be improving over time
- However, some wells still produce higher turbidity and SDI despite of flushing
- WQ monitoring needs to continue for a substantial period of time

SEM & CEI Images of Fouling Materials

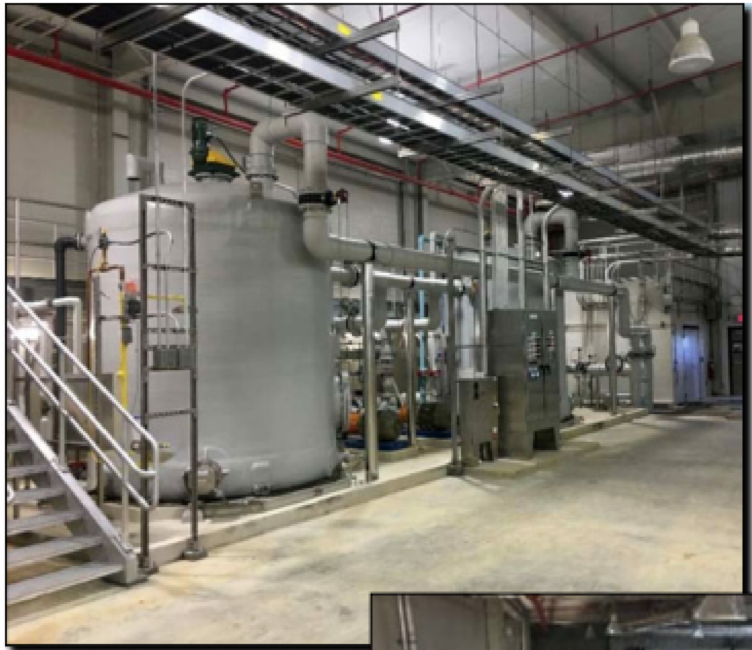
- Fe, Al, Colloidal Silica and Clay are the primary fouling material





Clean In Place (CIP) System

- Two 900 GPM Cleaning Pumps, VFD Controlled
- Two 5,000 Gallon Mixing Tanks
- Cleaning Capacity: Entire 1st stage (40 vessels)
  - Upsized piping and tanks
  - Hard-piped to RO skids
- Accessibility: Catwalk tank access for chemical loading from mezzanine storage area
- System Flexibility:
  - Immersion heaters and mechanical mixers on both tanks
  - Cleaning pumps can recirculate tanks for mixing or transfer solutions



Post Treatment with Calcite Re-Mineralization System

- 30% Side Stream of 10 MGD of RO Permeate =
  - 3.0 MGD for Phase I (12 MGD finished water)
  - 7.5 MGD (3.75 MGD x 2) at Buildout (30 MGD finished water)
- TomCO Pressurized Solution Feed System (PSF)$_{TM}$ used for efficient CO2 feed to the influent water stream
- Sulfuric acid feed for supplemental pH adjustment and backup to CO2

Calcite Contactor System Design

Design Parameter	Design Criteria
Number of Units	8 (7 + 1 Standby)
Contactor	Pressurized, Up-Flow
Contactor Diameter	12-feet
Calcite Bed Depth	9-feet
Design EBCT	17 minutes (at 4 gpm/ft^2)
Maximum Loading Rate	6.5 gpm/ft^2
Influent pH	5.0 SU
Design Flow Rate	372 gpm (0.53 MGD)
Forward Flush Design Flow	1,700 gpm
Air Scour	600 CFM

Re-Mineralization Efficiency Depends on Calcite Media

- Limited suppliers of NSF 60 Calcite in US. None are currently in Texas, so must be sourced from out of state suppliers.
- Should consider freight costs and lead time. Bulk delivery sizes are not always the same.
- Media is naturally sourced, with wide variety of particle size, distribution, and calcite purity
- Design and operation of system is significantly affected by the media that will be used:
  – Finer (smaller) media size will dissolve faster but can more easily be carried out of column at high loading rates, leading to increased turbidity
  – Courser (larger) media size will fluidize much differently than finer media, will require a deeper media bed.

3,000 lb. Calcite Super Sacks

Finished Water Quality

Parameter	Overall Finished Water Quality Goal	BGD Finished Water Parameters
pH, Std Units	7 – 8.5	7.9 – 8.2
TDS, mg/L	< 400	< 320
Alkalinity, mg/L as $CaCO_3$	100 – 300	120- 160
Calcium, mg/L as Ca (mg/L as $CaCO_3$)	40 – 100 (100 – 250)	38 – 46 (95 – 115)
LSI	0.1 – 0.4	> 0.1 (at 25 °C)
CCPP, mg/L as $CaCO_3$	4 – 10	7 – 12 (at 25 °C)

Understanding Langelier Saturation Index (LSI)

- An Index that predicts whether calcium-based solids will tend to precipitate, or dissolve in a specific water chemistry

LSI = (pH) + (Temperature) + (Calcium Hardness) + [(Total Alkalinity) – (CYA Correction Factor @ current pH)] – (TDS Factor)

- If LSI > 0, solid tend to precipitate
- If LSI < 0, solid tend to dissolve
- We like finished water having LSI slightly positive to avoid corrosion

Equivalent Factors for Langelier Saturation Index (LSI)

Equivalent Factors - Langelier Saturation Index (LSI)

Temperature (°F)	Temperature Factor	Calcium Hardness (PPM)	Calcium Hardness Factor	Alkalinity (PPM)	Alkalinity Factor	Cyanuric Acid (if present)	Cyanurate Correction Factor	Total Dissolved Solids	TDS Factor
32	0.0	5	0.3	5	0.7	**pH**	**Factor**	< 1000 ppm	12.10
37	0.1	25	1.0	25	1.4	7.0	0.23	1000 ppm	12.19
46	0.2	50	1.3	50	1.7	7.2	0.27	2000 ppm	12.29
53	0.3	75	1.5	75	1.9	7.4	0.31	3000 ppm	12.35
60	0.4	100	1.6	100	2.0	7.6	0.33	4000 ppm	12.41
66	0.5	150	1.8	150	2.2	7.8	0.35		
76	0.6	200	1.9	200	2.3	8.0	0.36		
84	0.7	300	2.1	300	2.5	Note: Only use if CYA is used in your pool. Only applies to >7.0pH. If so, select correction factor based on pool pH.		Note: most calculators assume **12.1** for under 1000ppm, or **12.2** for anything over 1000.	
94	0.8	400	2.2	500	2.6				
105	0.9	800	2.5	800	2.9				

Q2: What's the number?

Example of LSI Calculations

- Water pH = 7.4
- Water Temp = 84F (0.7)
- Calcium Hardness: 300 (2.1)
- Alkalinity: 100 (2.0)
- TDS: < 1,000 (12.1)

Calculation:

- LSI = [7.4 + 0.7 + 2.1 + (2.0 – 0.31) – 12.1]

  = 10.2 + 1.69 – 12.1

  = - 0.21
- This water is slightly corrosive. Adjusting pH to 7.8 will make LSI to be 0.19, which is slightly possitive

Final BWRO Brine Disposal

- Evaporation Pond is cost-prohibitive for BWRO Brine Disposal due to very high construction costs; particular with the underlined barrier and monitoring for leakage & repair