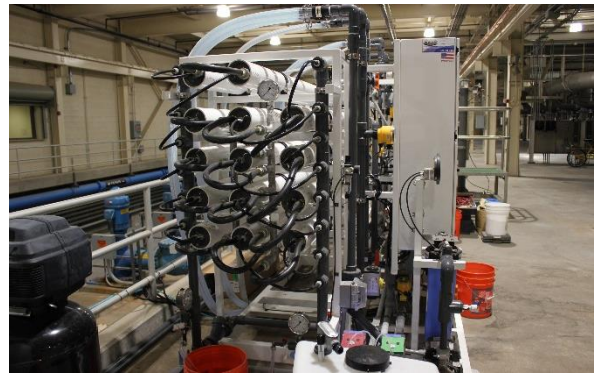
Brown AND Caldwell

2018 Multi-States Salinity Summit

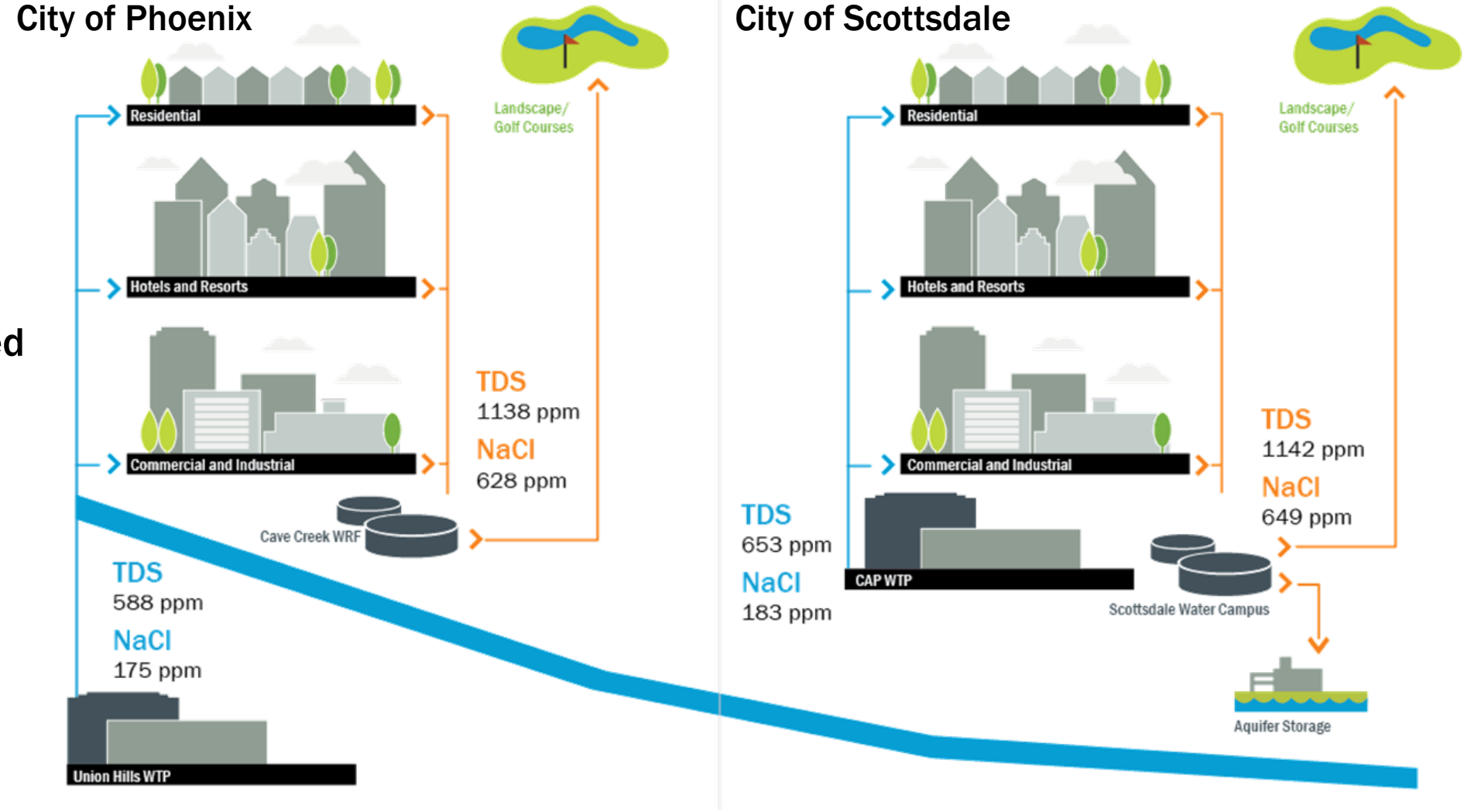
A Novel Approach for Concentrate Minimization: Phase II

February 8, 2018

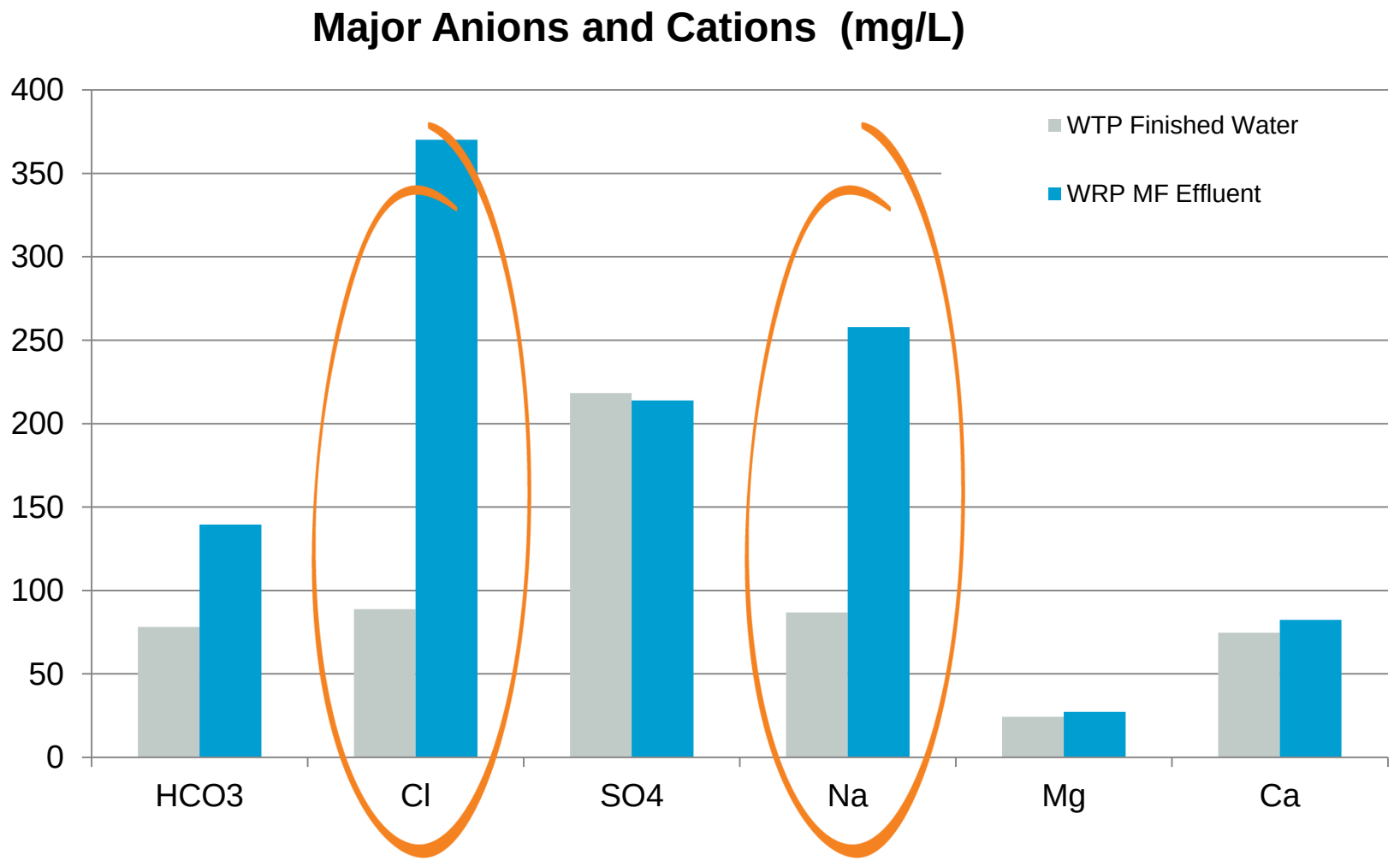


With Hard Waters, More Water Softeners, More Water Quality Impacts

Many utilities' ability to reclaim or discharge treated wastewater is being adversely impacted by elevated sodium and chloride levels.



Comparison of Potable and Reclaimed Water



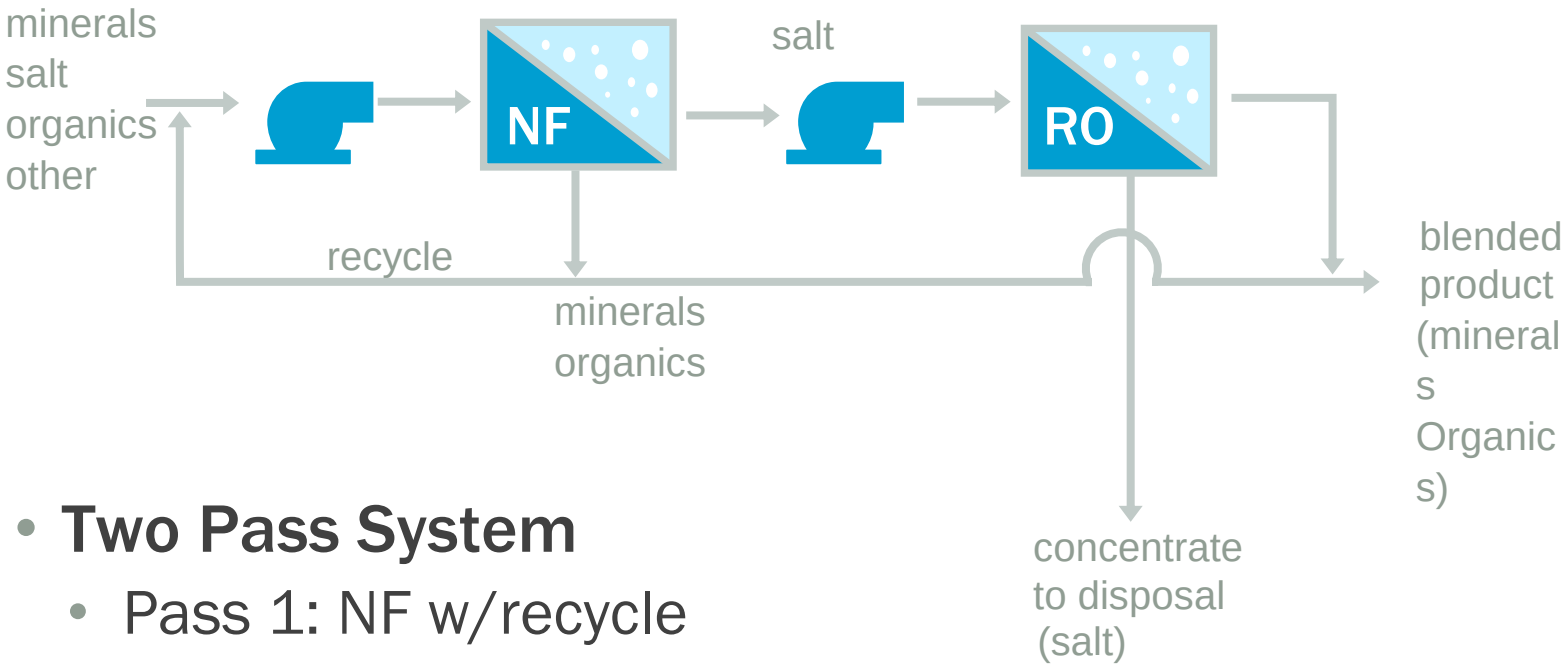
NF Membrane Selection

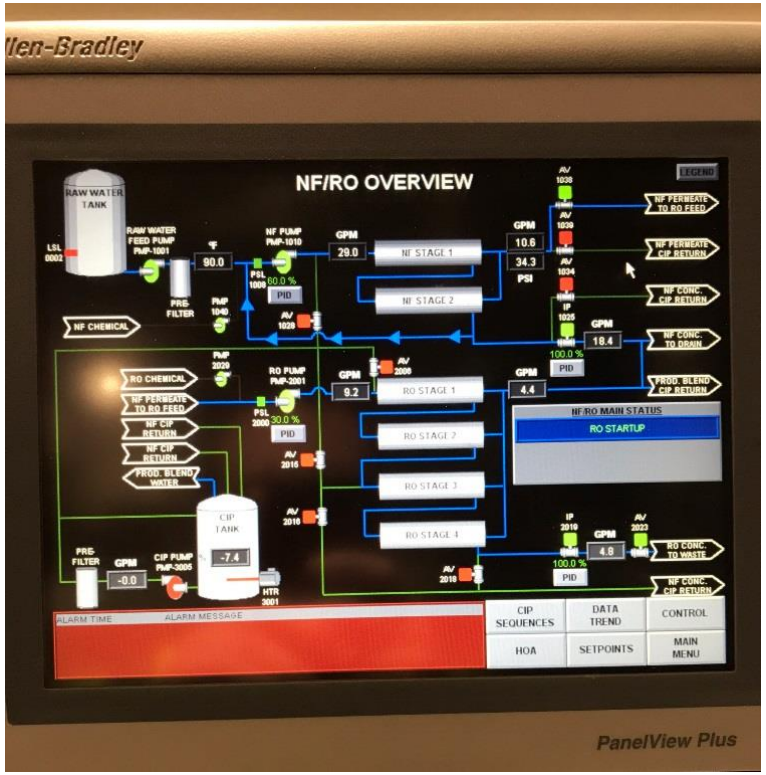
Short duration test of 4 NF products to select one for pilot test

	DOW	CSM	Hydranautics	KMS
Cation Passage Sodium Calcium	 88.5% 64%	 90.9% 54%	 87.0% 60.3%	 82.1% 26.2%
% Reduction of TDS	45%	41%	46%	38%
RO concentrate % NaCl	79.2%	81.5%	79.1%	83.2%
Predicted max recovery	92.7%	93.0%	93.3%	93.7%

NF Membrane Test

Pilot Study Schematic





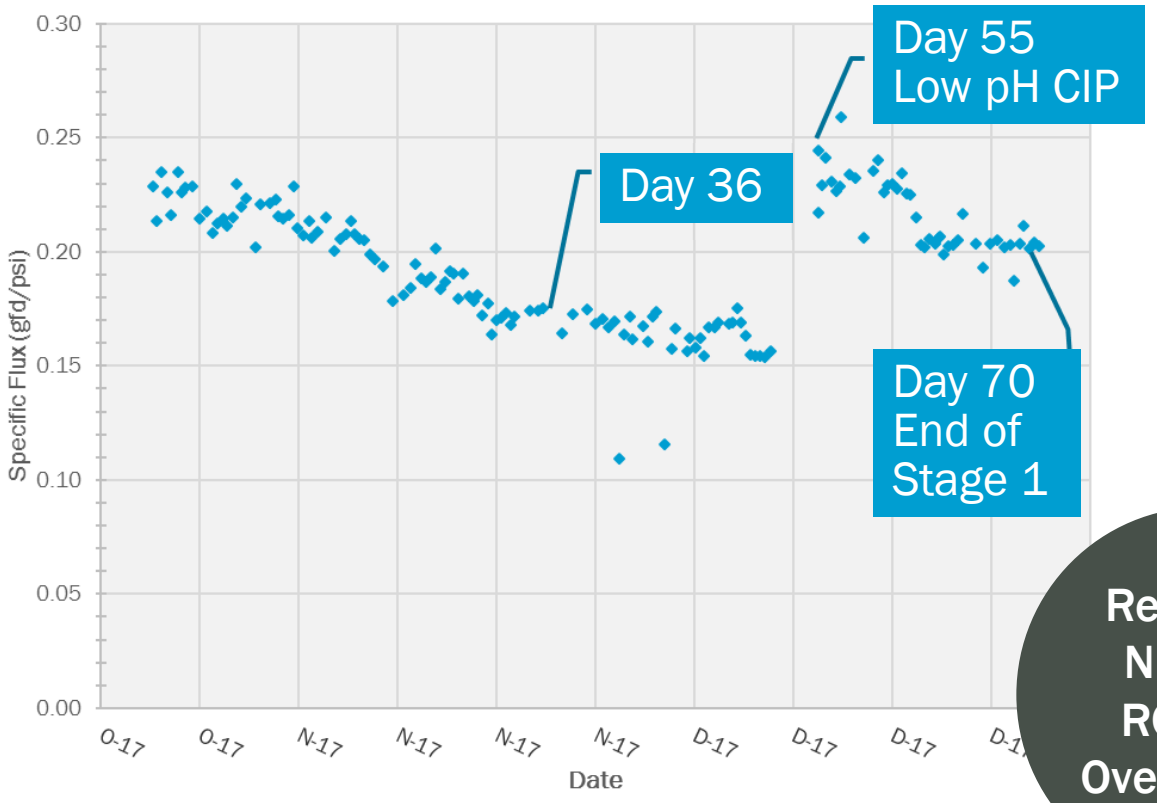
- **Two Pass System**
  - Pass 1: NF w/recycle
  - Pass 2: RO
- **Scalable system: 30 gpm**

Match RO Recovery, Minimize Chemical Addition

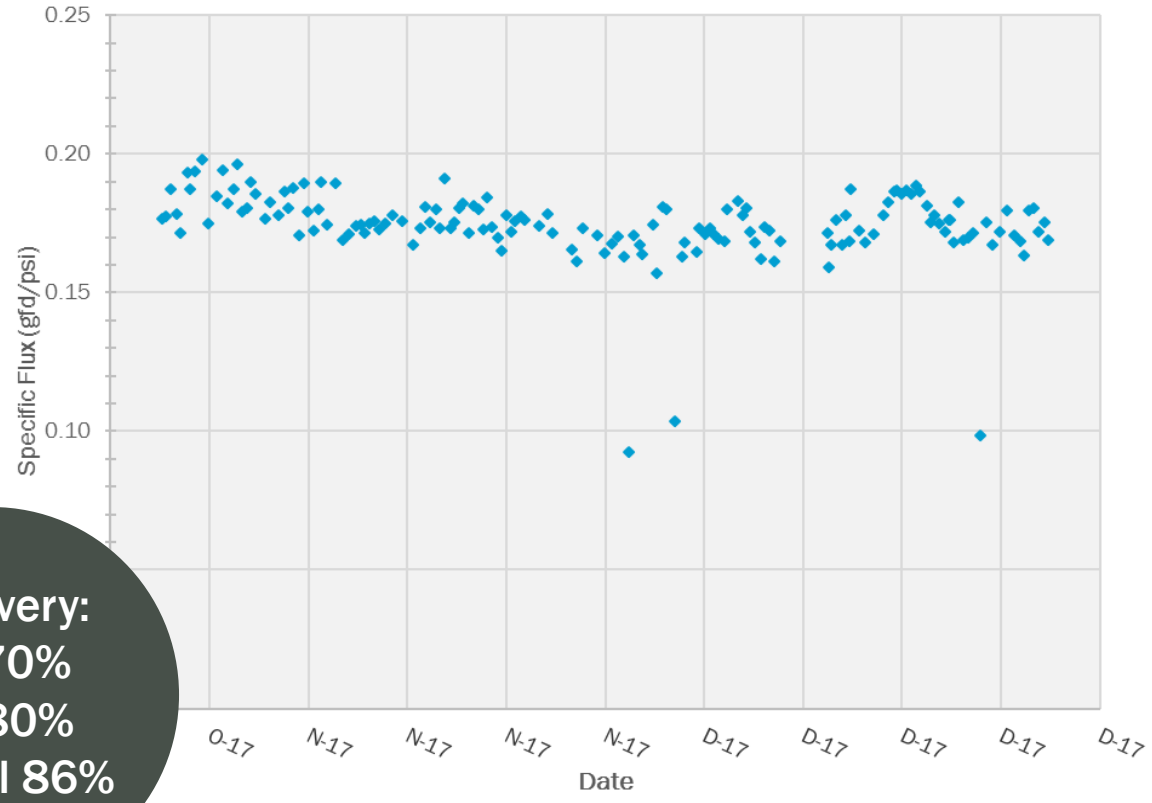
Stage 1 Test

Stage 1 Specific Flux

Nanofiltration

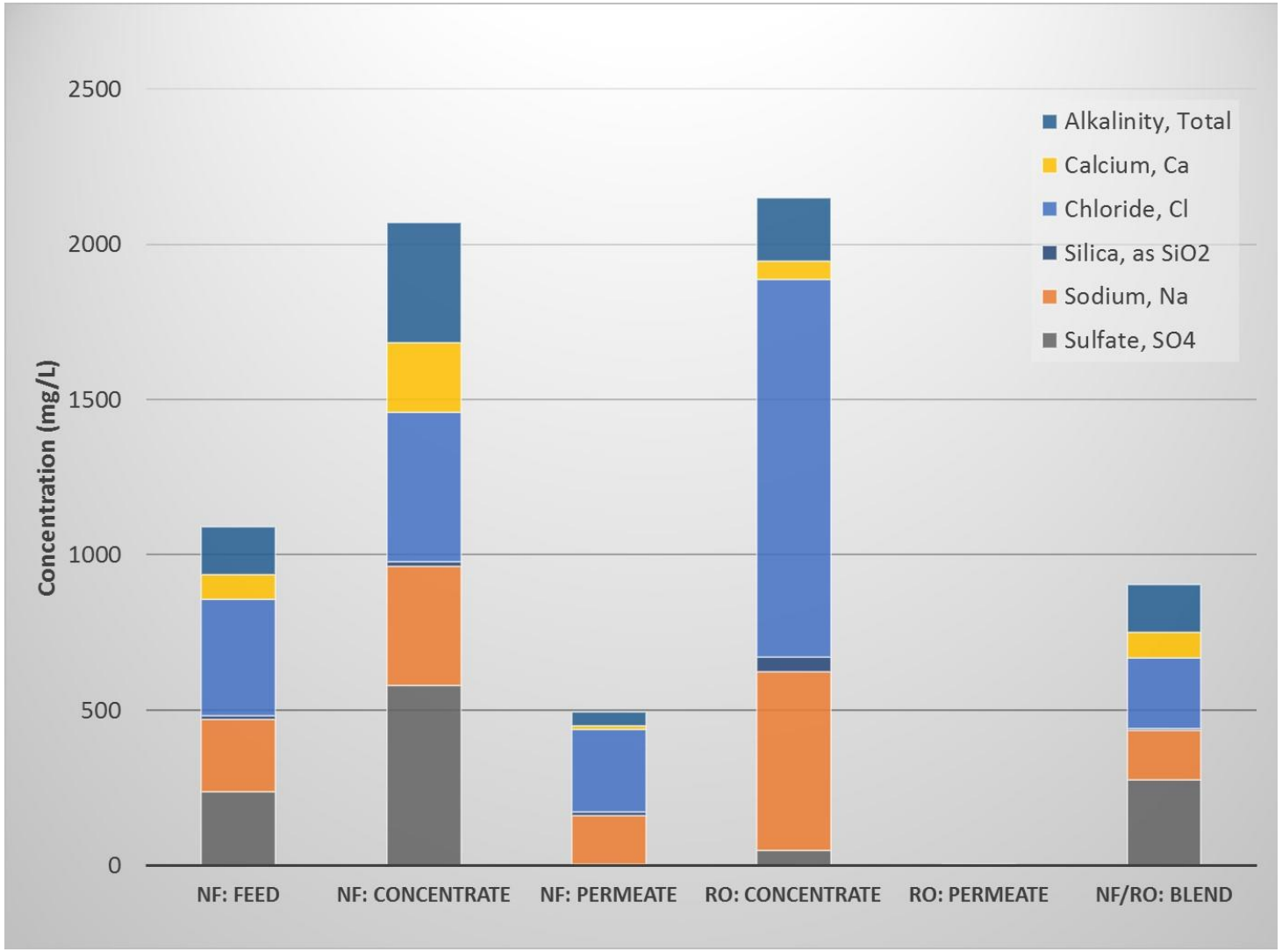


Reverse Osmosis



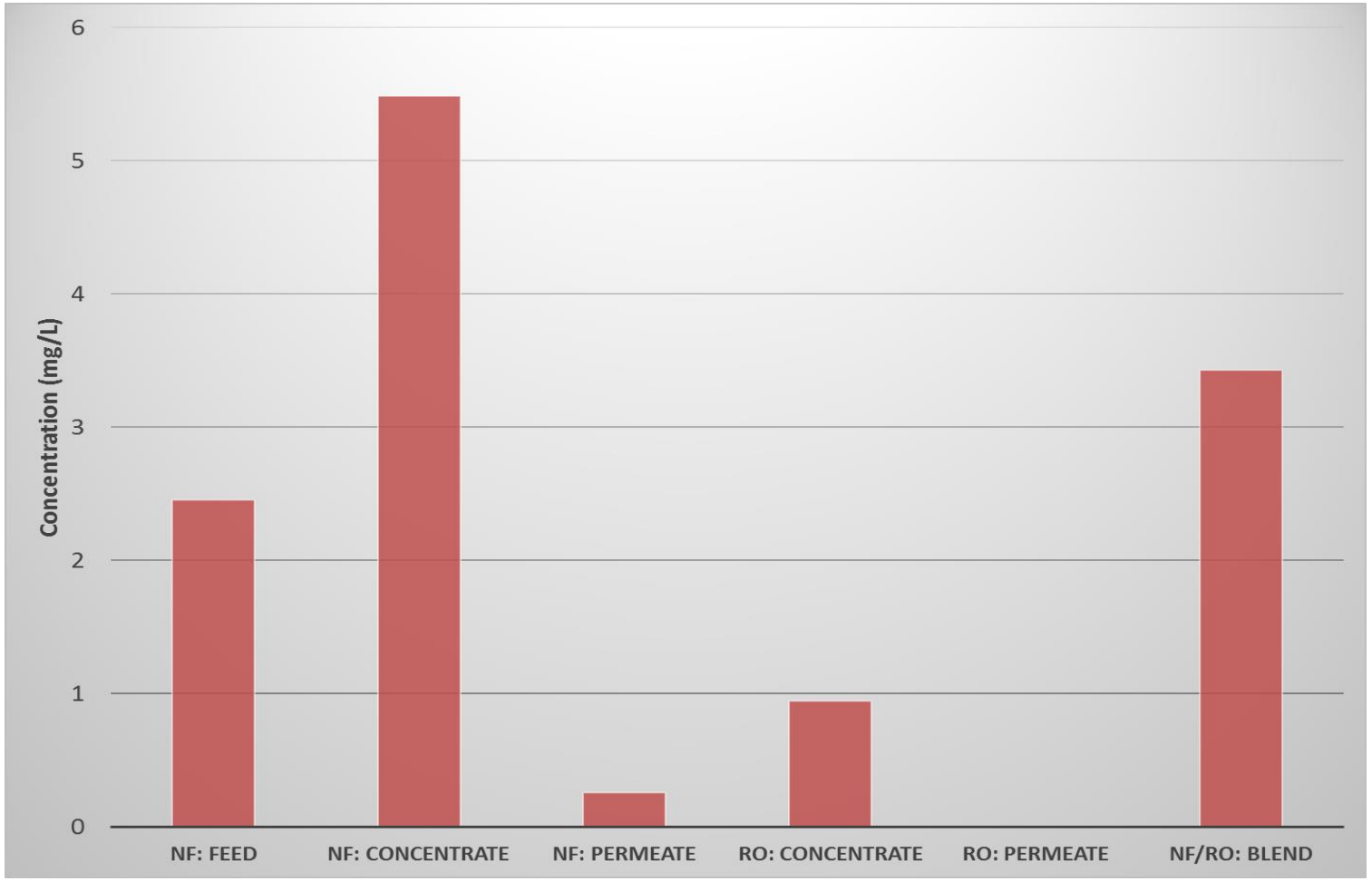
Recovery:
NF 70%
RO 80%
Overall 86%

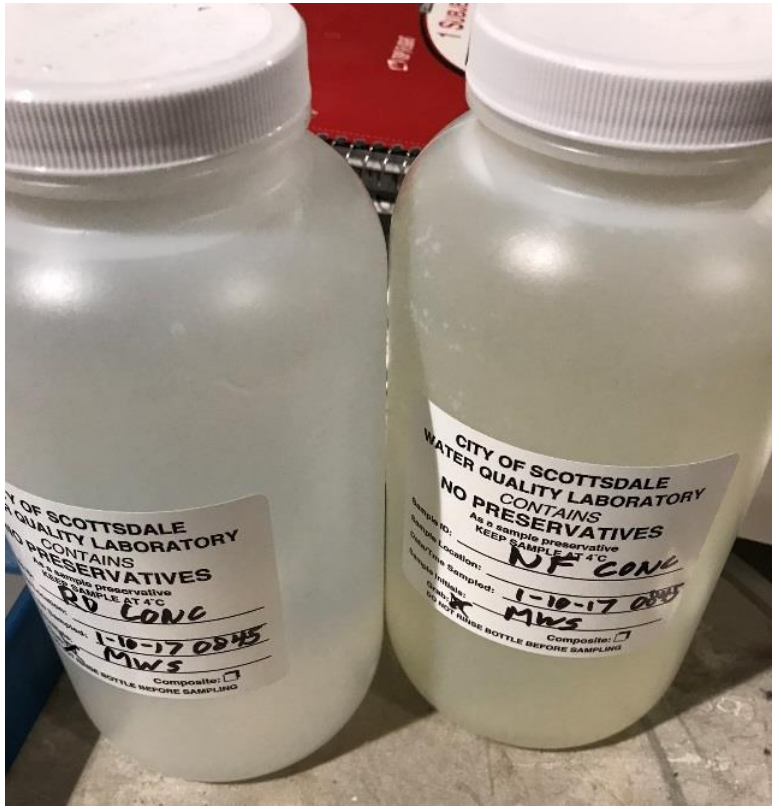
Stage 1 Water Quality



- **Average TDS reduction 20%**
- **Good recovery of**
  - Calcium 90%,
  - Sulfate >99%
  - Alkalinity 84%
- **Salt reduction**
  - Chloride 48%
  - Sodium 41%

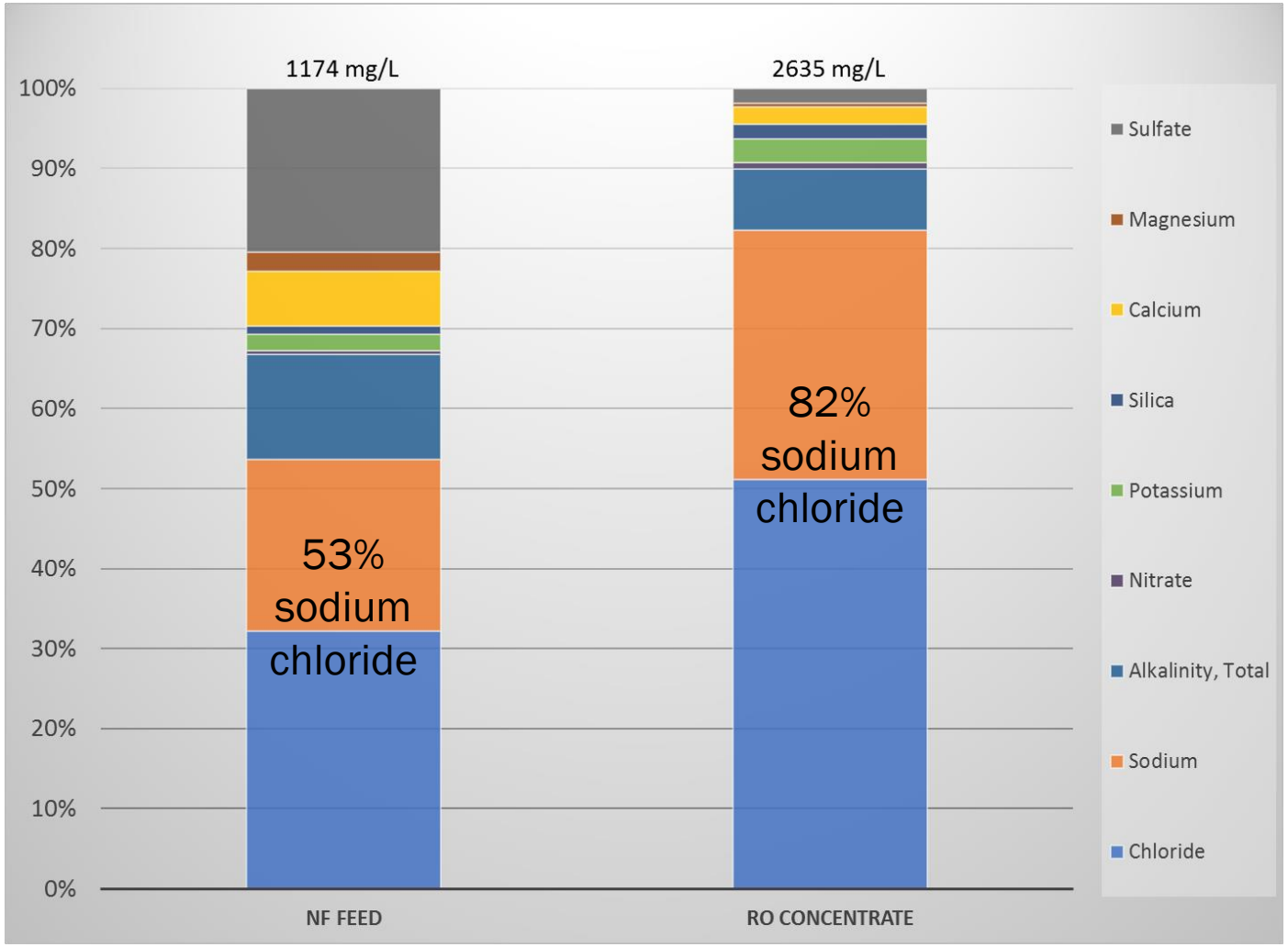
Stage 1 Water Quality (TOC)





NF concentrate clearly has higher color than RO concentrate

Stage 1



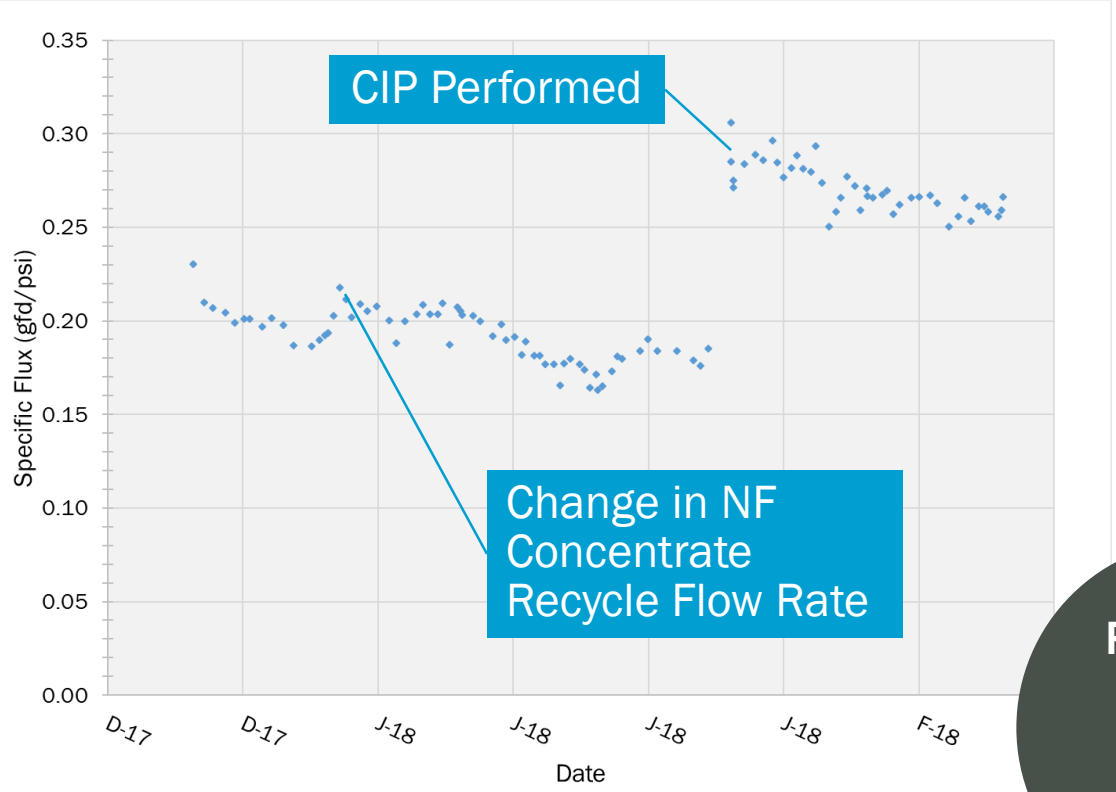
- Increase of sodium chloride percentage of TDS demonstrates selective removal
- Sulfate, calcium, magnesium make up <5% of RO concentrate vs. 30% of Feed

High Recovery

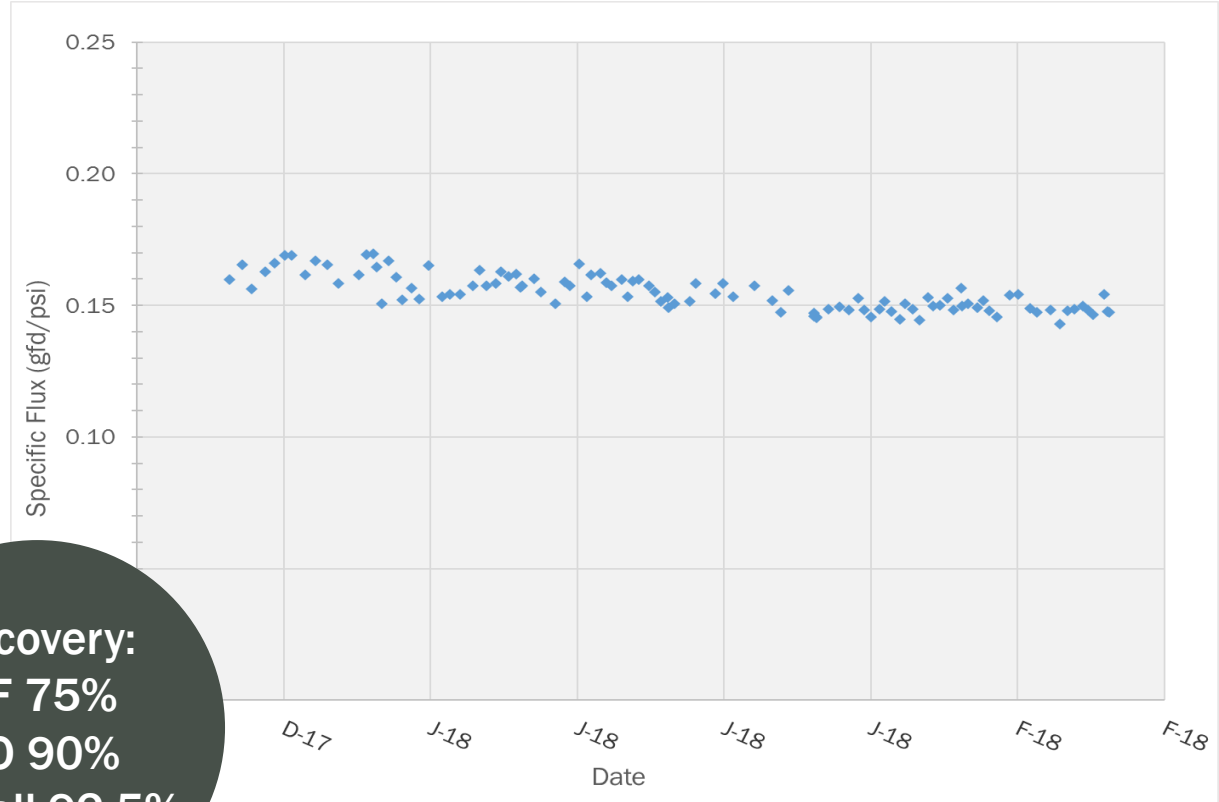
Stage 2 Test

Stage 2 Specific Flux

Nanofiltration



Reverse Osmosis

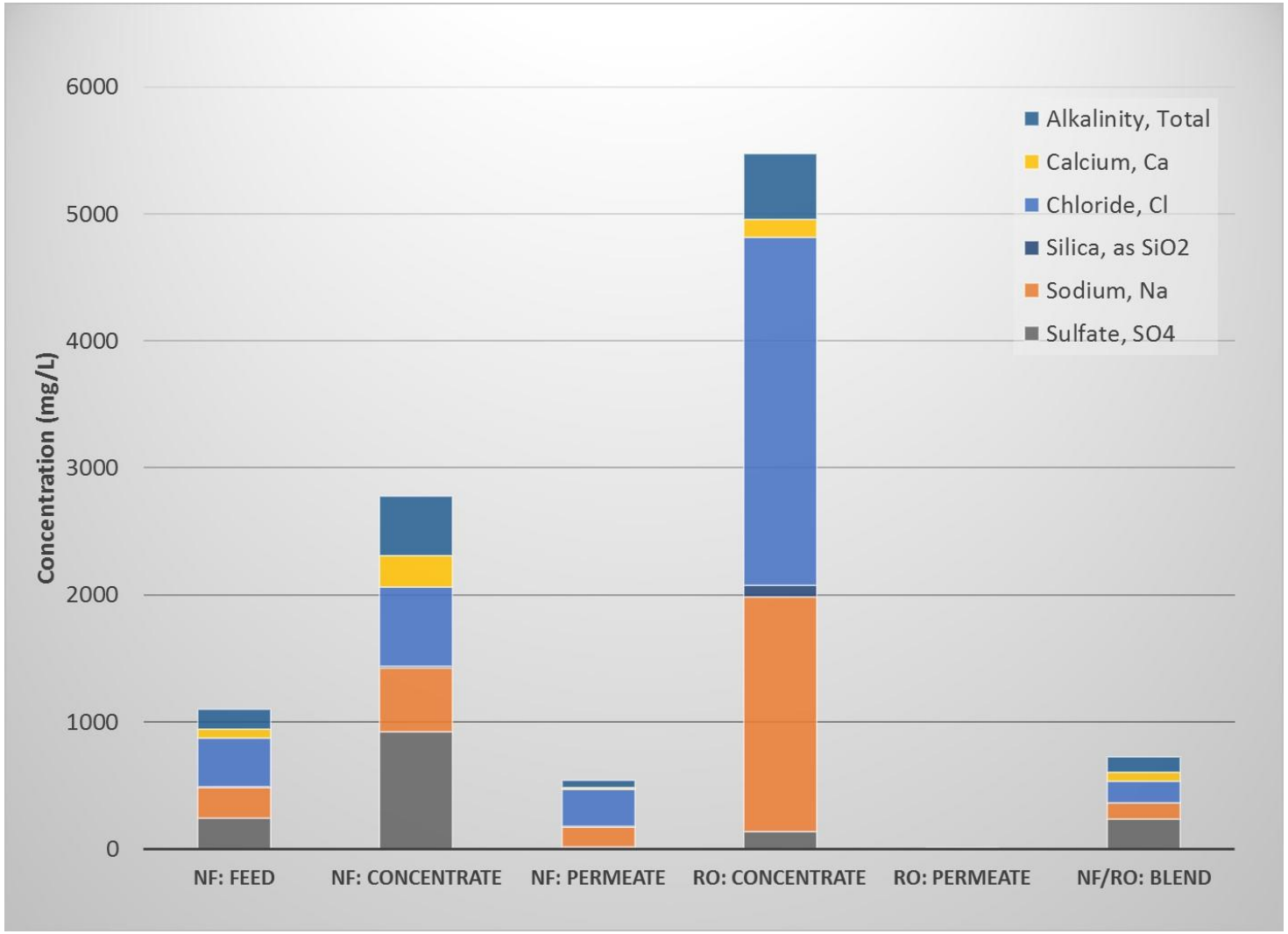


Recovery:
NF 75%
RO 90%
Overall 92.5%

Stage 2

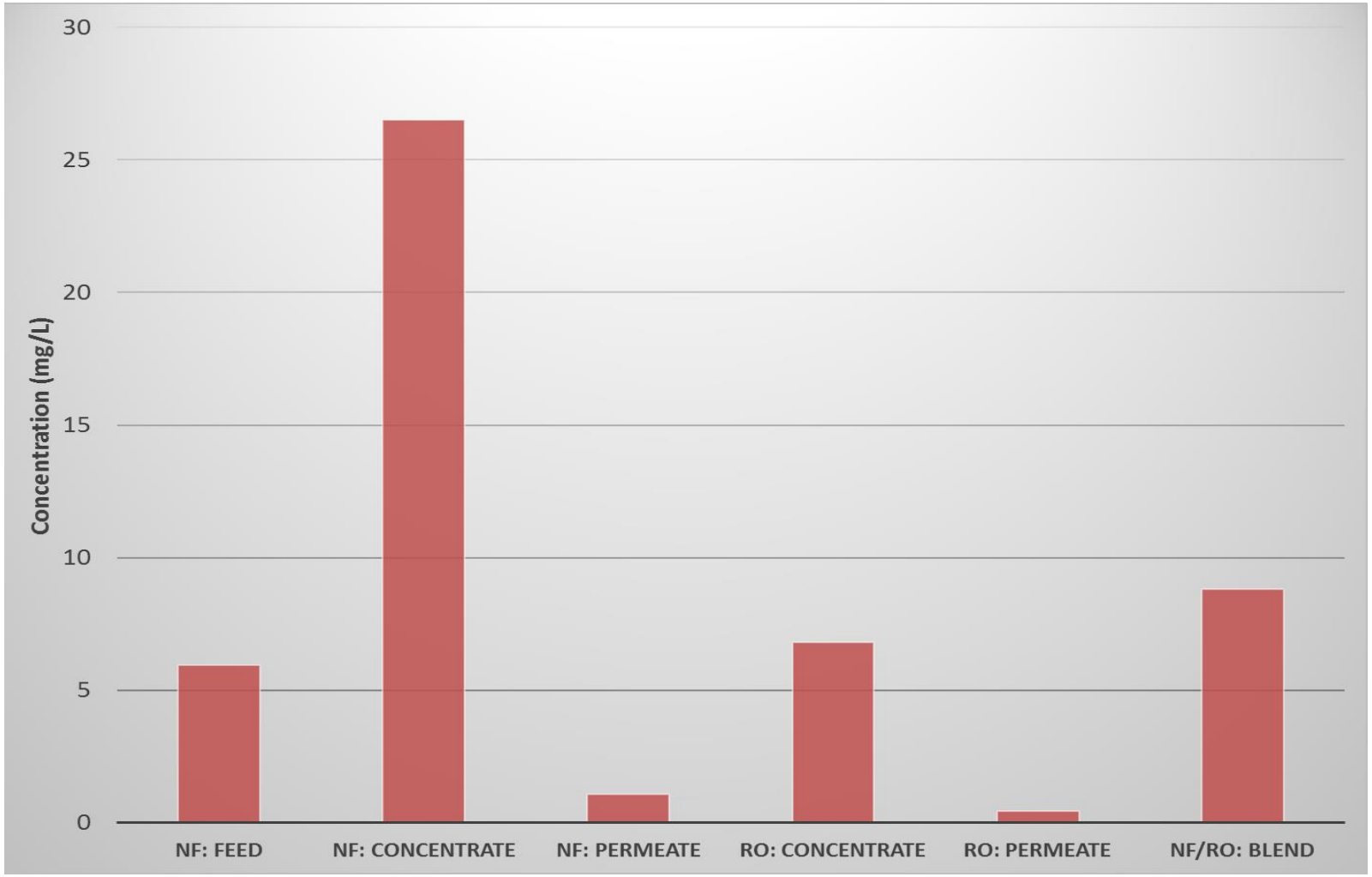
- Stage 2 NF fouling appeared to be mostly particulate fouling
- Began with 5 micron cartridge filter
- Approximately one month of operation
- Switched to 1 micron filter

Stage 2 Water Quality



- **Average TDS reduction 35%; inline with projection from NF membrane selection**
- **Good recovery of**
  - Calcium 94%,
  - Sulfate 99%
  - Alkalinity 76%
- **Salt reduction**
  - Chloride 56%
  - Sodium 49%

Stage 2 Water Quality (TOC)



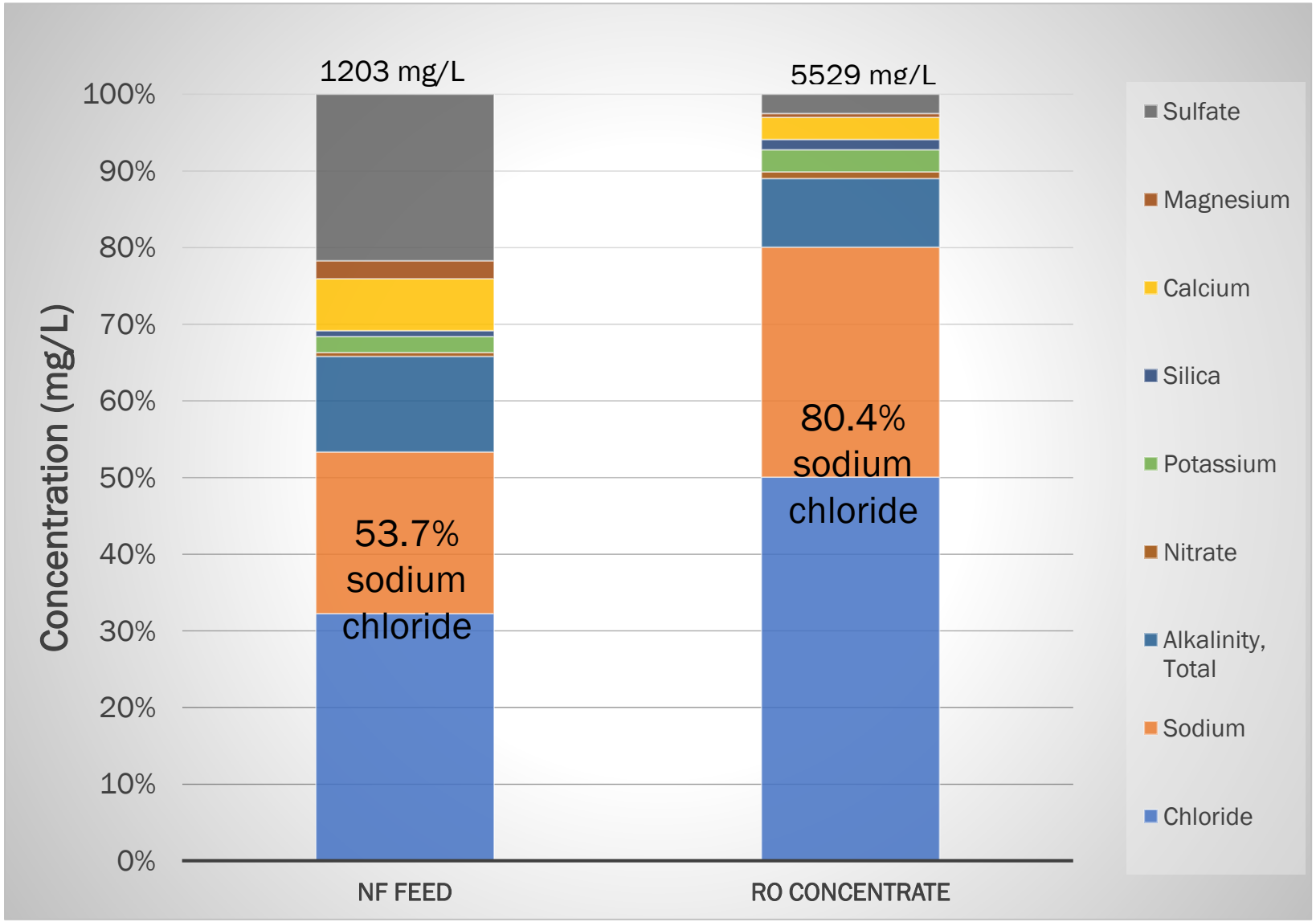
Data from a single sample.
Feed TOC about 2x Stage 1
Detected some passage of TOC through NF membrane.

Stage 2

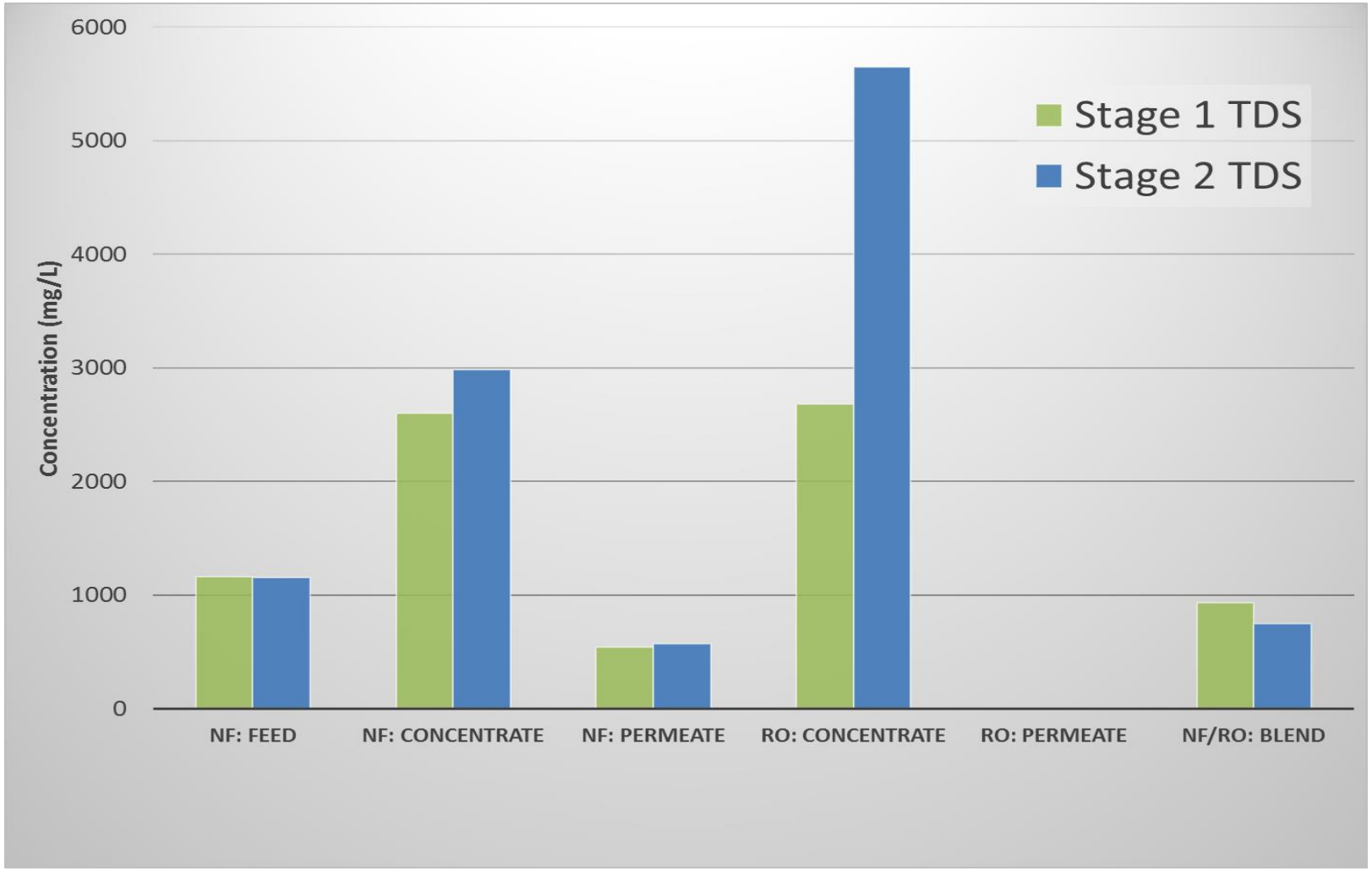
UV Adsorbance, cm^{-1}	
Feed	0.148
NF Concentrate	0.527
NF Permeate	0.020
RO Concentrate	0.125
RO Permeate	Not Detected
Blended Product	0.150

Stage 2

- Lower fraction of hardness, sulfate and alkalinity will benefit high recovery or ZLD processes
- Sulfate, calcium, magnesium make up 5% of RO concentrate vs. 30% of Feed



Water Quality Comparison (TDS)



Higher RO recovery on Stage 2 improves blended product water quality

Energy and Chemical Consumption

- Water Campus RO operating 10-20% under design during test period (25-40% less energy required)
- Pilot energy use includes recovery of NF recycle hydraulic energy
- Pilot uses no acid; RO uses approximately 42.5 lb/mg

	Units	Water Campus RO	Stage 1	Stage 2
System Recovery		85%	86%	92.5%
Average Energy Usage	Kwh/kgal	0.76 – 1.16	1.26-1.38	1.44
Average Anti-scalant usage	Lb/kgal	6.9	3.5	8.6
Acid usage	Lb/mg	42.5	0	0

This Approach Benefits Different Concentrate Management Strategies

	Reduced Salt Load	Reduced Volume	Reduced Chemical Consumption	Reduced Energy	Reduced Maintenance
Disposal to sewer or interceptor	✓	✓			
Evaporation ponds		✓			
Thermal/Mechanical Evaporation		✓	✓	✓	✓
High Recovery Processes (HERO, CCD, etc)		✓	✓	✓	✓
Zero Liquid Discharge		✓	✓	✓	✓
Salt recovery		✓	✓	✓	✓

Summary

- Selective removal of sodium chloride is possible; addresses problems with water softener discharges
- Significant reduction in concentrate volume possible with little increase in capital and operating cost
  - <10% more membrane area
  - Slightly higher energy consumption
  - Lower chemical consumption


Questions?