# Membrane Clean In Place Recipe Optimization

## Surface Water Treatment Workshop

**May 2, 2018**

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# Outline

- ✓ Introduction
- ✓ UF/RO Background
- ✓ Pretreatment Optimization
- ✓ UF/RO CIP Optimization
- ✓ Case Studies
- ✓ Summary

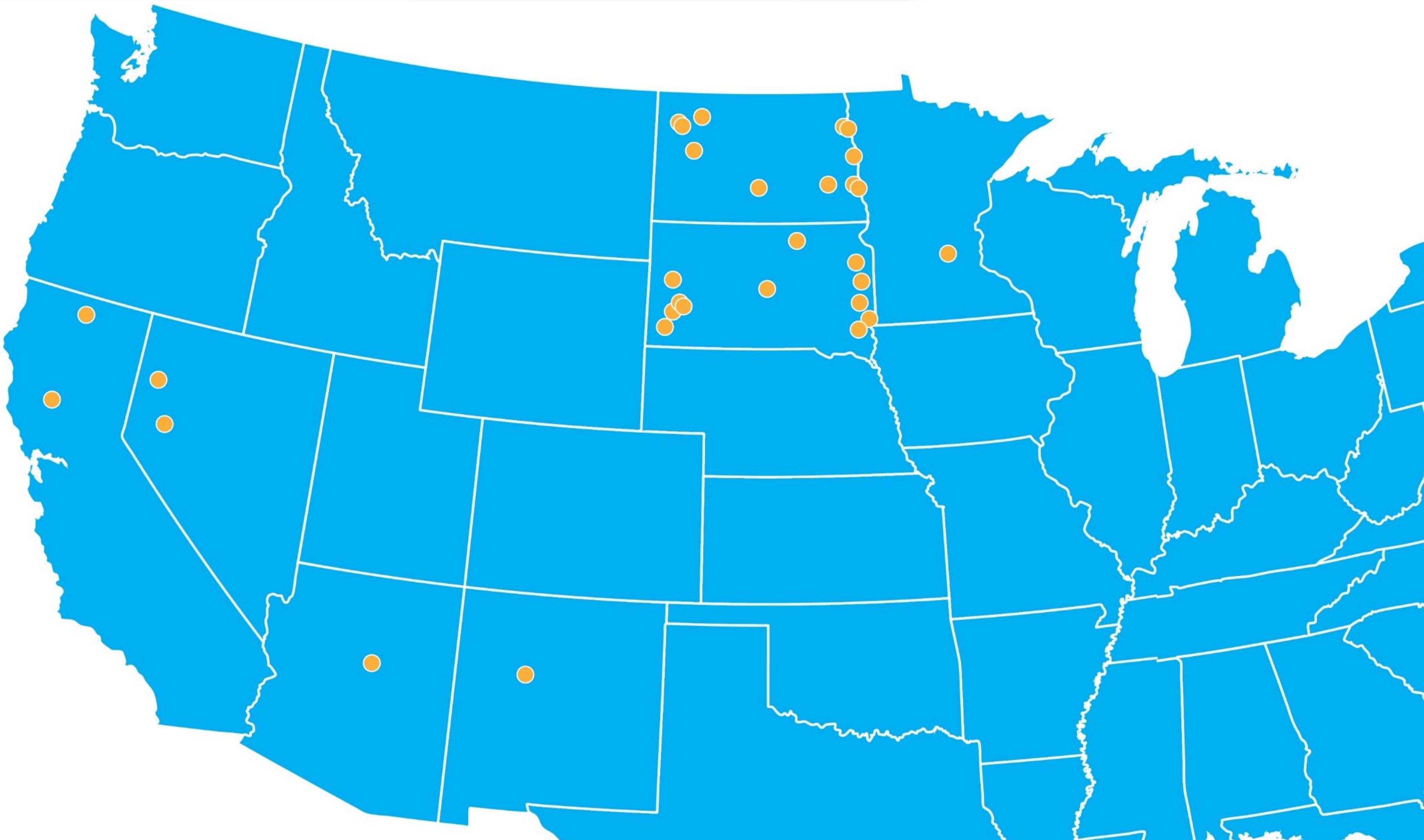
# Membrane Technology

## Overview

- Significant growth and increase in applications in last 10-20 years
- Growing Professional Knowledge and Industry Acceptance
- Improved Technologies
- Competitive Costs
- Growing Regulations

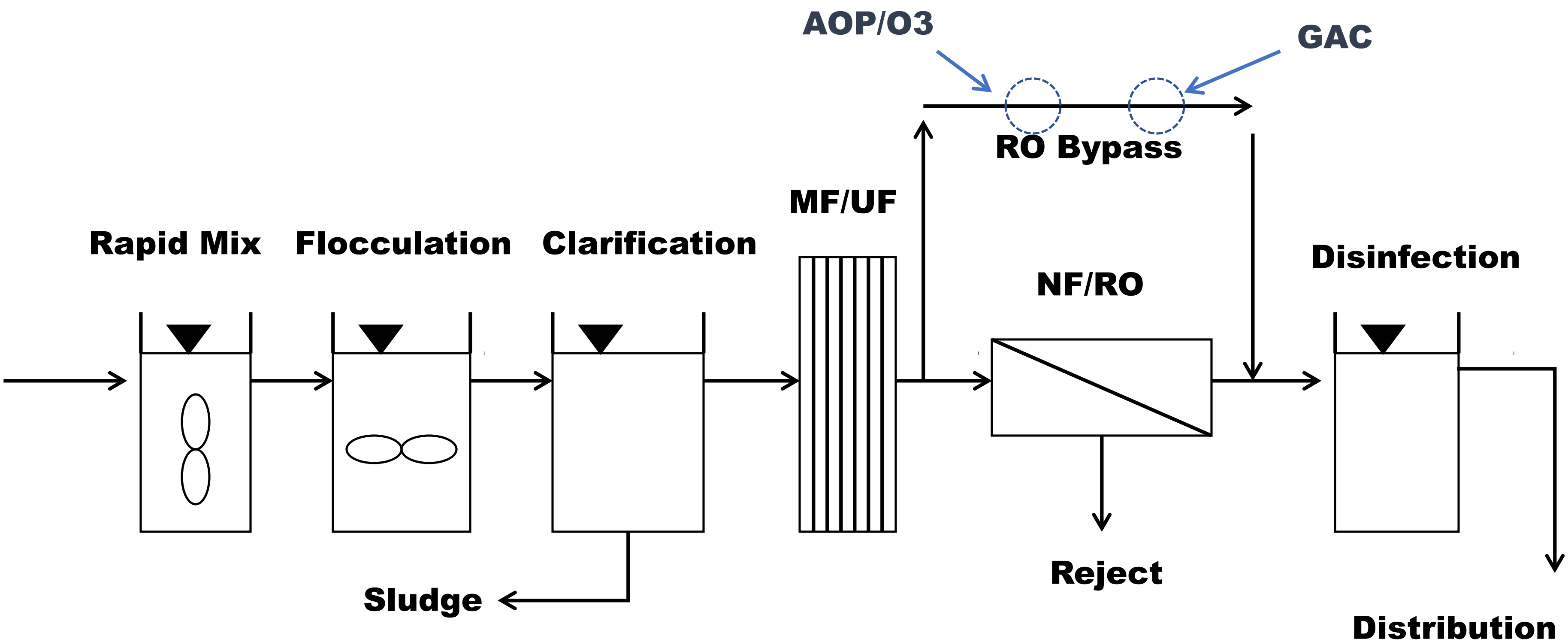
# AE2S Membrane Resume/Experience

## Where Have We Done Work?



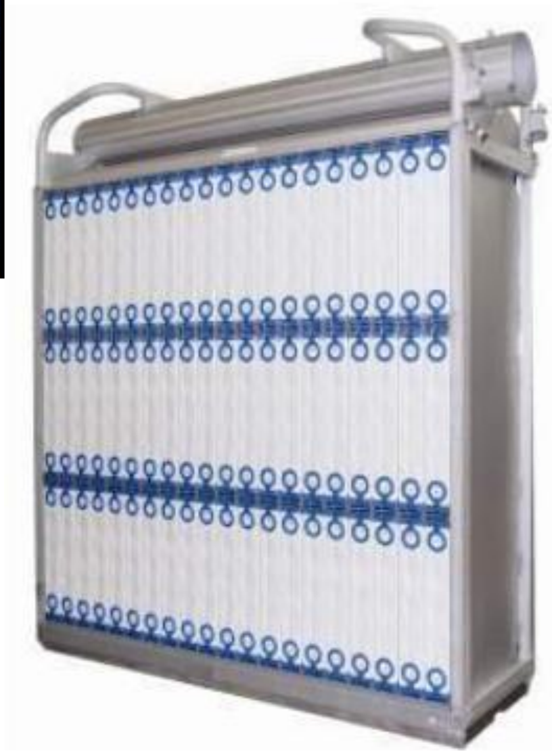
# Typical Membrane Treatment

## What Are We Talking About?




**Membrane Treatment**

# WHAT IS MICROFILTRATION / ULTRAFILTRATION?

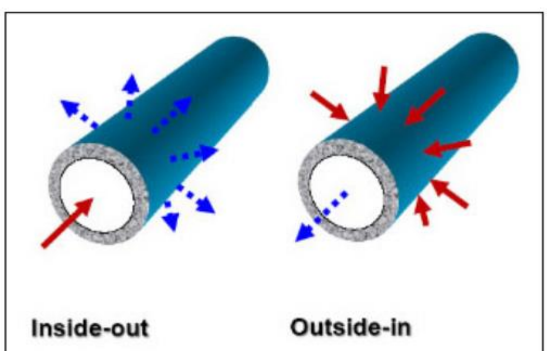



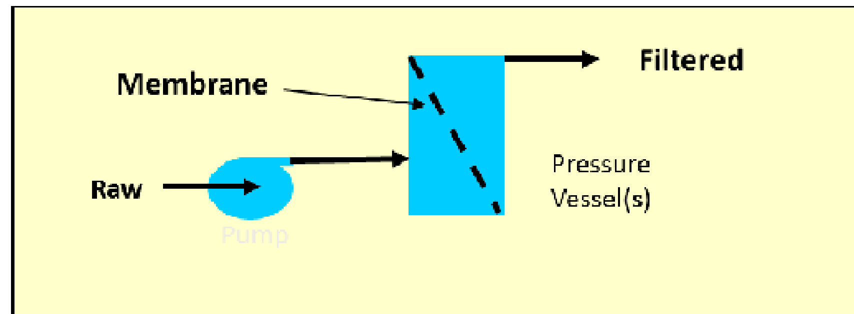
Images Courtesy of GE

# Microfiltration/Ultrafiltration

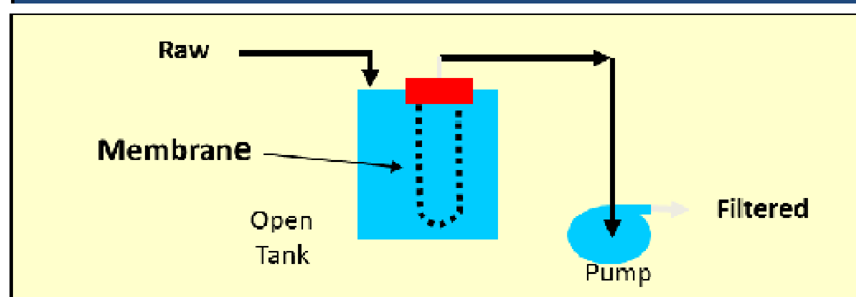
## MF/UF Membrane Concepts

- Pressure-driven physical separation process
  - MF – 0.1-10 microns
  - UF – 0.005-0.1 microns
- Hollow Fiber
  - Inside-Out/Outside-In
- Pressure (Encased)
- Vacuum (Immersed/Submerged)
- Polymeric / Ceramic




Pump supplies positive pressure to DRIVE water through membrane media.




Pump suction PULLS water through membrane media.

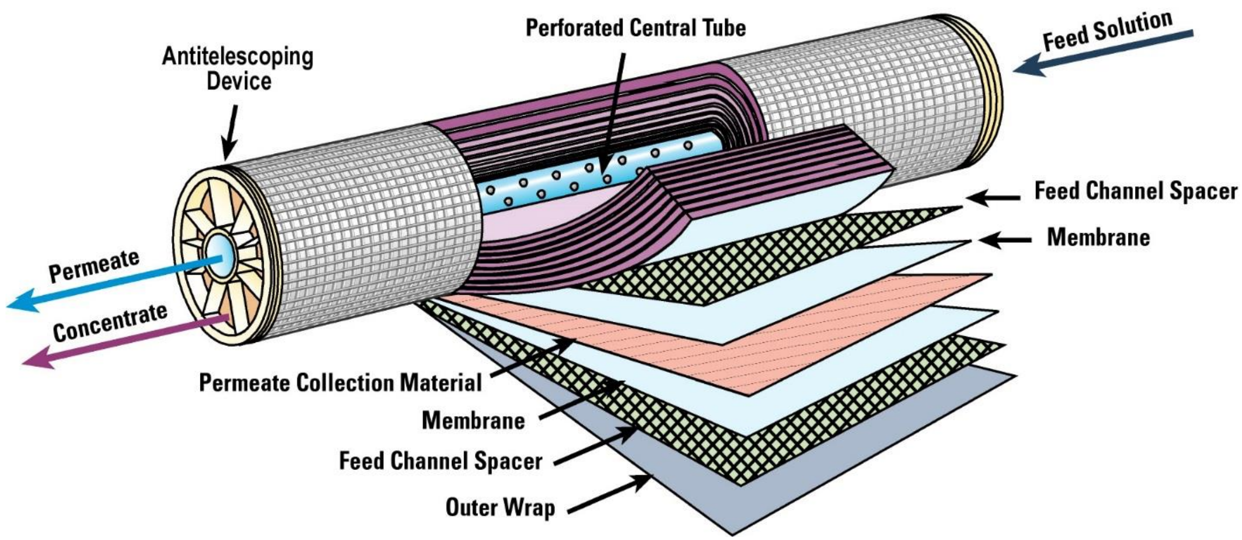
# Nanofiltration/Revere Osmosis

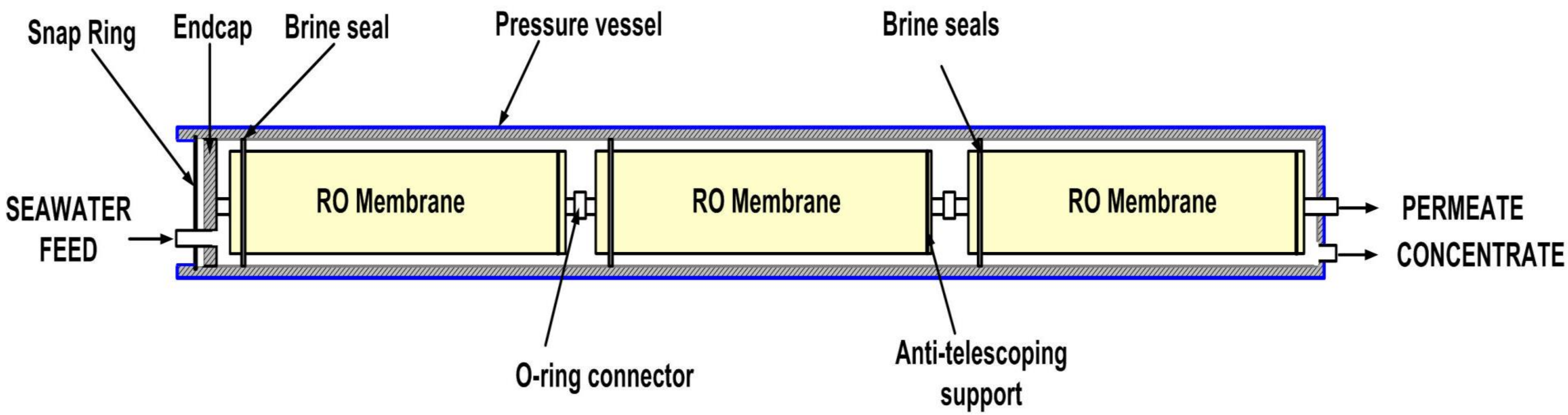
## NF/RO Membrane Concepts

### WHAT IS NANOFILTRATION/REVERSE OSMOSIS?

# Nanofiltration/Reverse Osmosis

## NF/RO Membrane Components

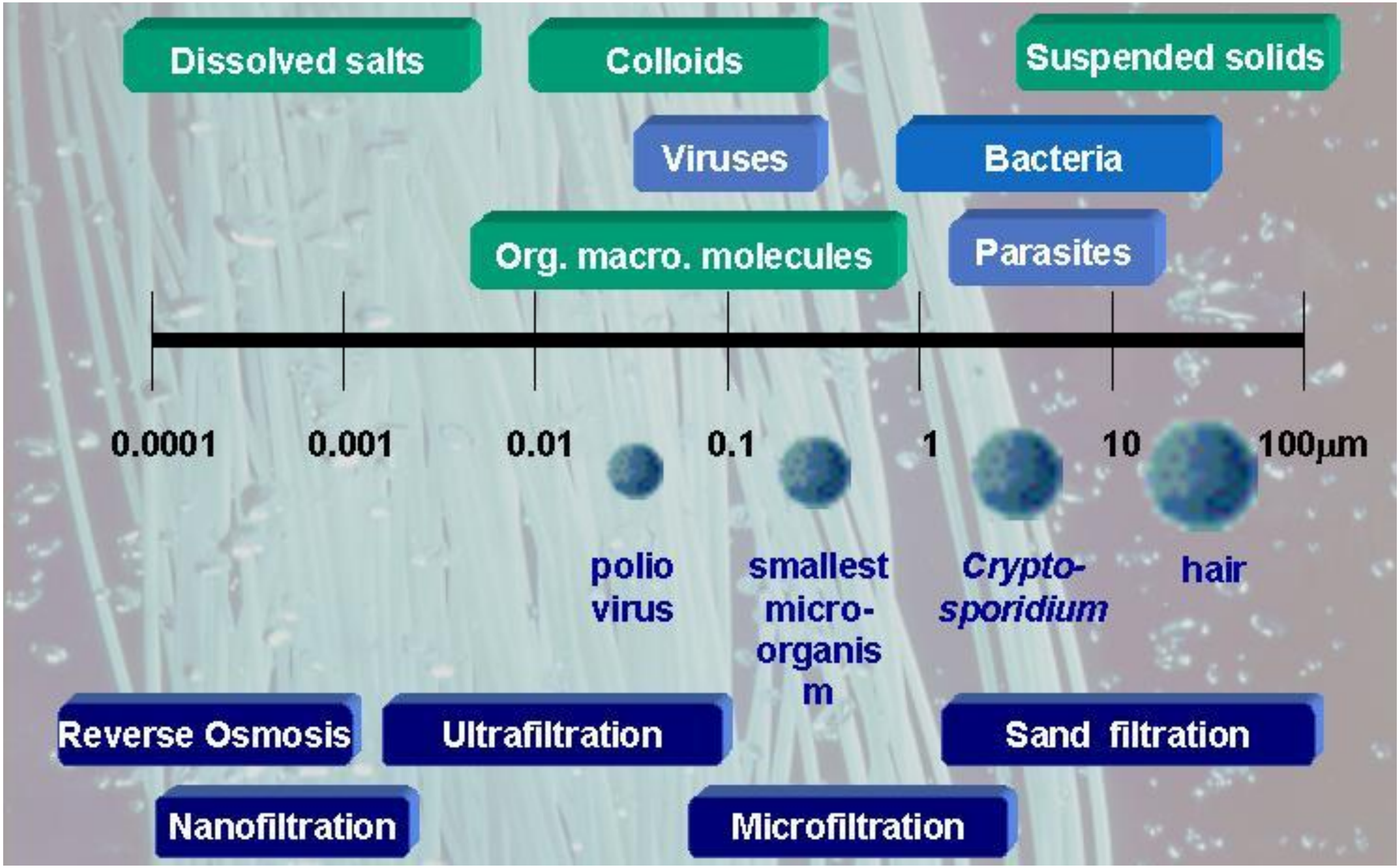



Images Courtesy of GE

# Membrane Filtration Summary

## Why Use Membranes?



# Water Chemistry

- ✓ Scaling/Fouling
- ✓ Uniqueness of Each Surface Water
- ✓ Seasonal Variations
- ✓ Projection Software
- ✓ Importance of Pilot Testing

# Water Chemistry

## Scaling/Fouling

| | |
|---|---|
| Scaling | Precipitation and Deposition of Soluble Salts (Calcium Carbonate, Barium Sulfate, etc.) |
| Fouling | Entrapment of Particulates (silt, clay, SS, algae, silica, etc.) |
| Physical/Chemical Damage | Large Particles / Oxidants (Chlorine, Sodium Permanganate, etc.) |

# Water Chemistry

## Scaling/Fouling Impacts

- Membranes can be highly susceptible to fouling and scaling issues
- Leads to operational problems
  - High operating pressures
  - Frequent cleaning
  - Irreversible fouling
  - Low membrane life and loss of performance
  - Increased O&M costs

# Membrane Operations Overview

## Pretreatment

- Remove Foulants, Optimize Recovery, Extend Membrane Life, Chemical Conditioning

## MF/UF

- Backwash
- Maintenance Clean / Chemically Enhanced Backwash
- CIP / Recovery Clean
  - Citric Acid (inorganics)
  - Caustic (organics)
  - Chlorine or Hydrogen Peroxide (biofilms)
- Integrity Testing

## NF/RO

- Antiscalants
- CIP

# Pretreatment Optimization

## Improved Membrane Performance/Life through Optimized Pretreatment Operations

- Coagulation Dose / Type
- Turbidity Removal
- TOC Removal

- Acid Feed
- Antiscalants
- Bisulfites

**Table 3: Potential RO/NF Chemical Pretreatment Options**

| Technique | Purpose |
|---|---|
| Coagulants / polymers | Added as a part of coagulation / flocculation process to improve solid removal |
| Scale Inhibitors | Allow new compounds to be formed which have a better solubility properties and some absorb to the surface of the micro-crystals thereby reducing further crystal formation |
| Antifoulants | Help keep some compounds such as Iron in suspension |
| Acids | To lower pH and therefore reduce scaling potential of some compounds such as Carbonates |
| Bisulfites | Dechlorination |

https://www.amtaorg.com/wp-content/uploads/12_Pretreatment.pdf

# Membrane Optimization

## Scaling/Fouling

| | | |
|---|---|---|
| Scaling | Precipitation and Deposition of Soluble Salts (Calcium Carbonate, Barium Sulfate, etc.) | Antiscalants, Pre-Oxidation, pH Adjustment |
| Fouling | Entrapment of Particulates (silt, clay, SS, algae, silica, etc.) | Minimize Downtime, Flushing Systems, Pretreatment Optimization |
| Physical/Chemical Damage | Large Particles / Oxidants (Chlorine, Sodium Permanganate, etc.) | Pre-Screening/Cartridge Filters, Sodium Bisulfite |

# Microfiltration/Ultrafiltration

## MF/UF Membrane Concepts

### 1. Pretreatment

### 2. Membrane Integrity Test

### 3. Backwash/Feed Flush

- Hourly
  - Frequency: Runtime, TMP, Flux Decline, Volume Throughput
- No Chemical
- Aeration

### 5. Maintenance Clean/CEB

- Daily-Weekly
  - Frequency: Hours of Service, Number of Backwashes, TMP
- Temperature
- Chemicals
  - NaOCl, NaOH
  - Citric Acid, HCl, H2SO4

### 6. Clean-In-Place (CIP)

- Monthly
- Chemical
  - NaOCl, NaOH
  - Citric Acid, HCl, H2SO4
- Temperature

# Nanofiltration/Reverse Osmosis

## NF/RO Membrane Concepts

- Pretreatment
- Feed Water Temperature
- Fouling Indices - SDI Testing
- Antiscalants
- Feed water pH
- Permeate Flush
- CIP
    - Temperature
    - pH Range
    - Frequency
    - Duration/Procedure
    - Chemicals

# NF/RO Optimization Parameters

## Chemical Selection

- Antiscalant Selection
  - % Saturation Projections
- CIP Chemical Selection
  - NaOH / HCl
  - Proprietary Chemicals
  - pH Range
    - Acid: 2.0 / 3.0
    - Base: 11.0 / 12.0
  - Specialty Chemicals
  - Order of Chemicals
- Temperature
- Pilot Testing
- Membrane Autopsies

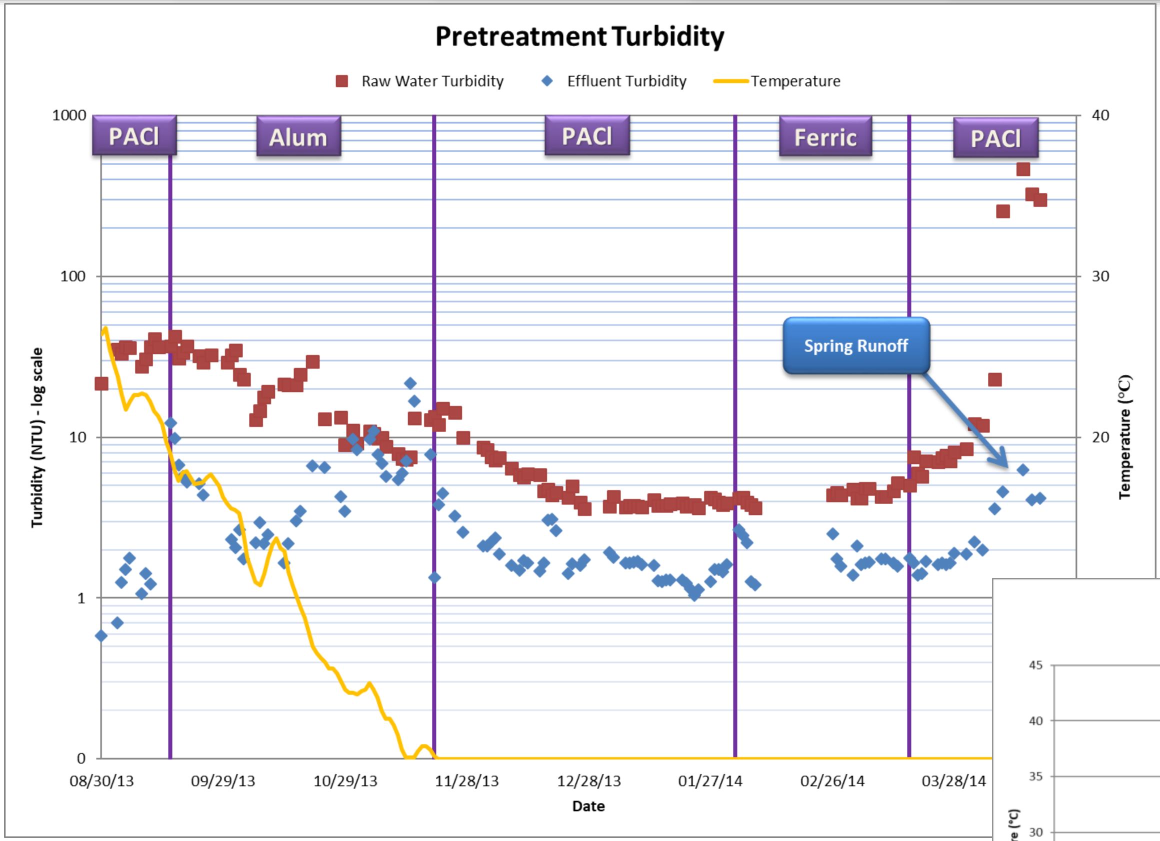
# Case Studies

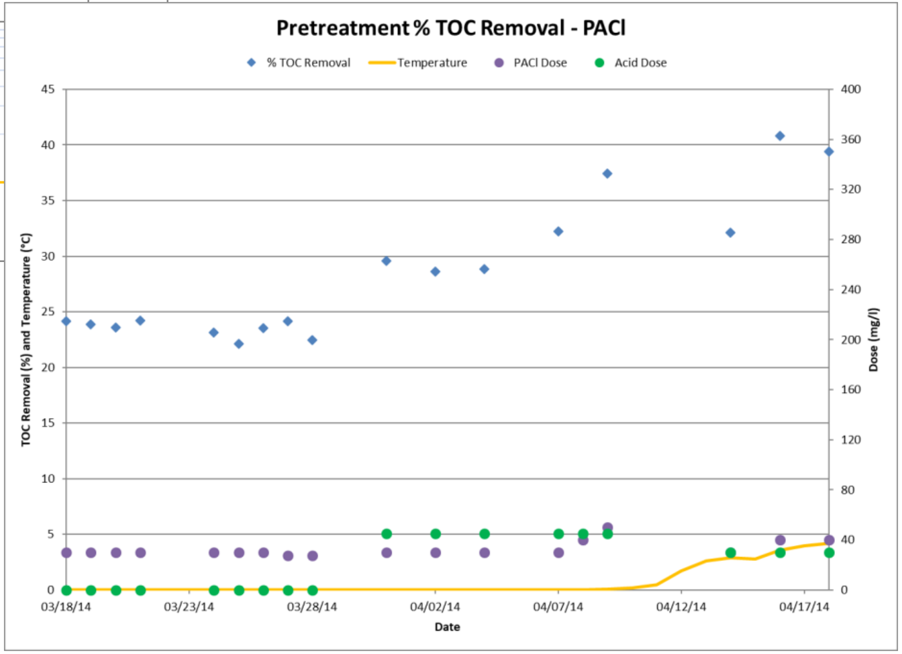
Grand Forks WTP Piloting

Fargo WTP Piloting

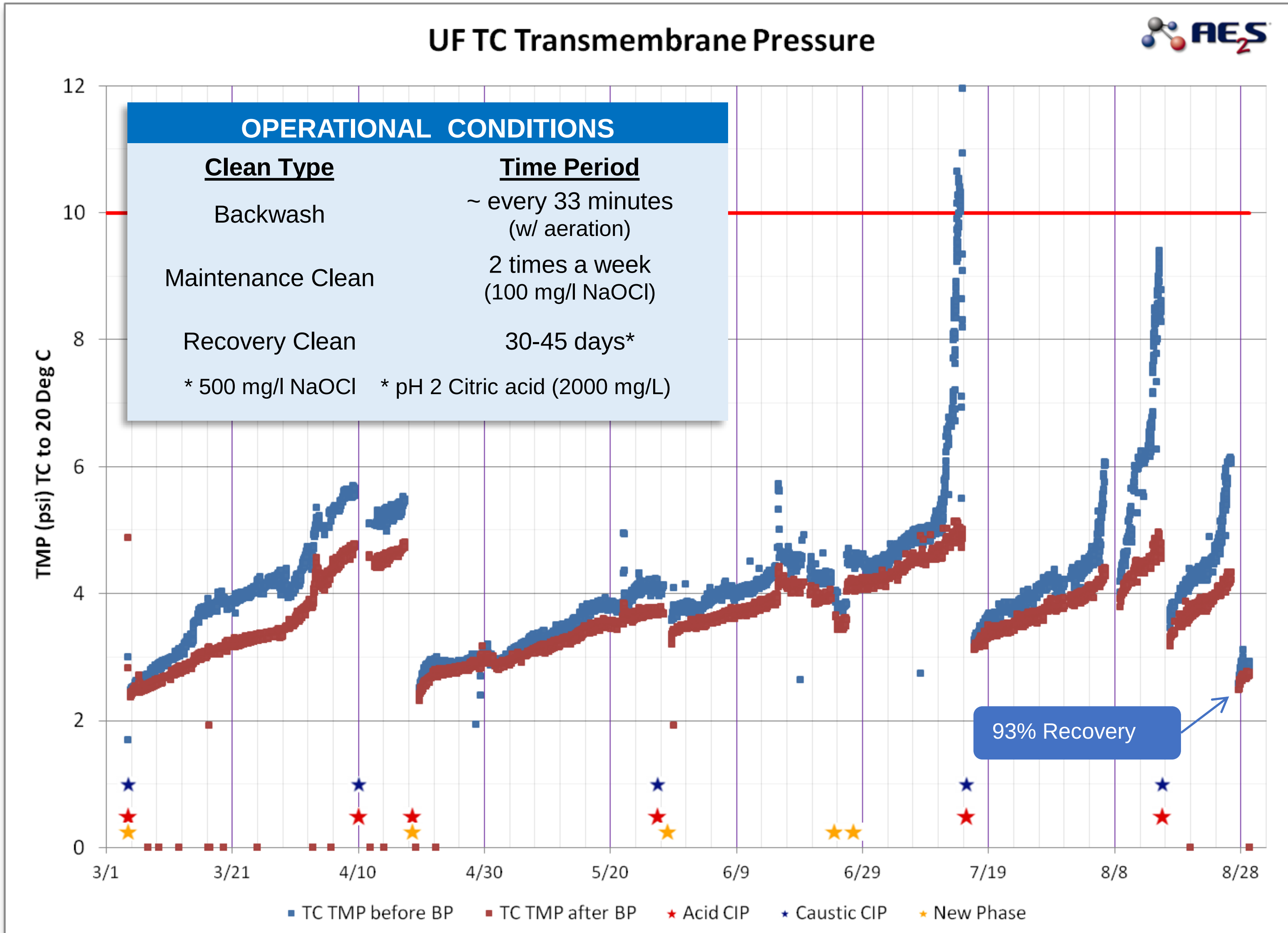
Valley City WTP

# GFWTP - Pretreatment Pilot Study Results



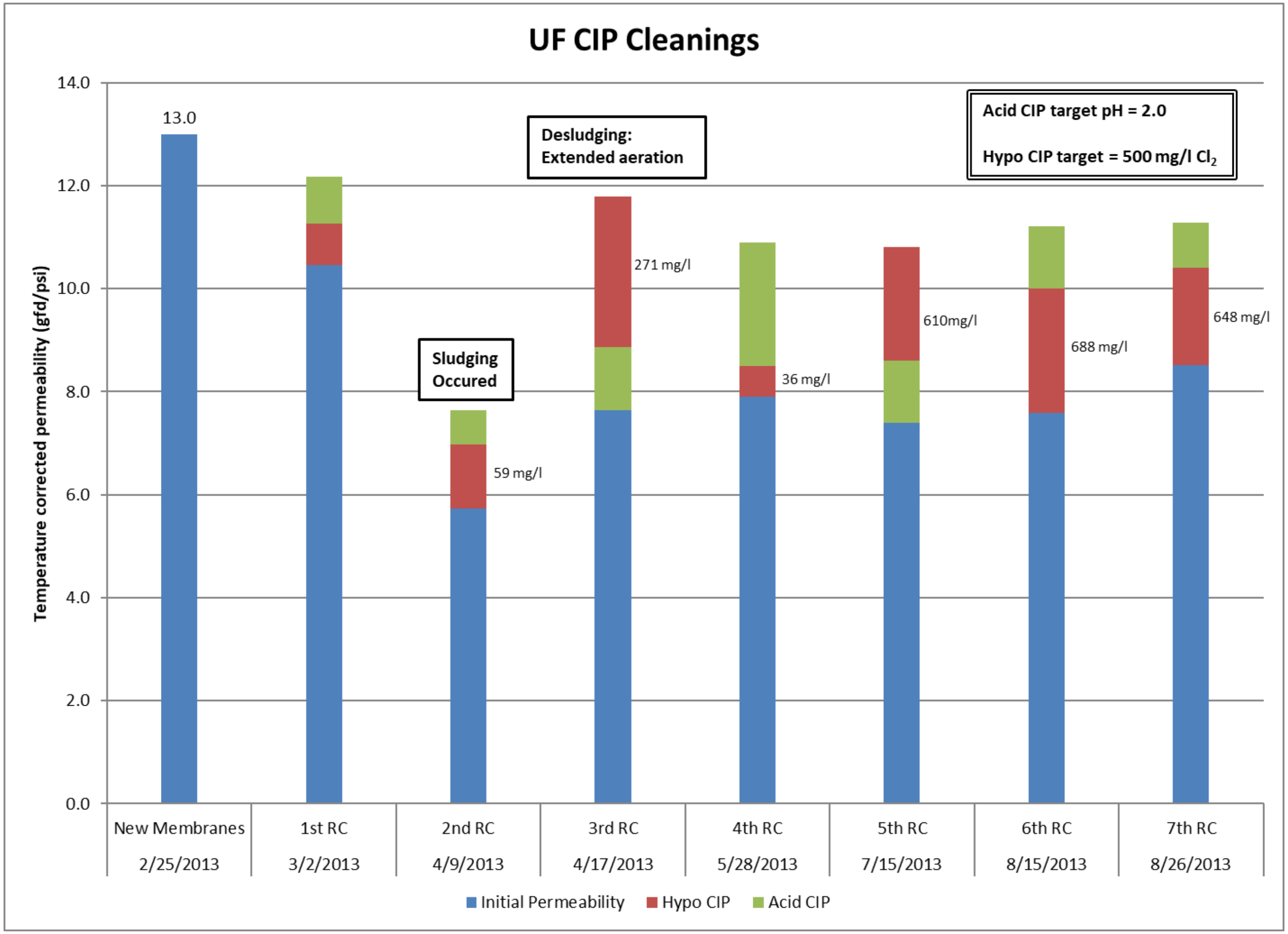



# GFWTP - UF Pilot Study Results



# GFWTP – UF CIP Results

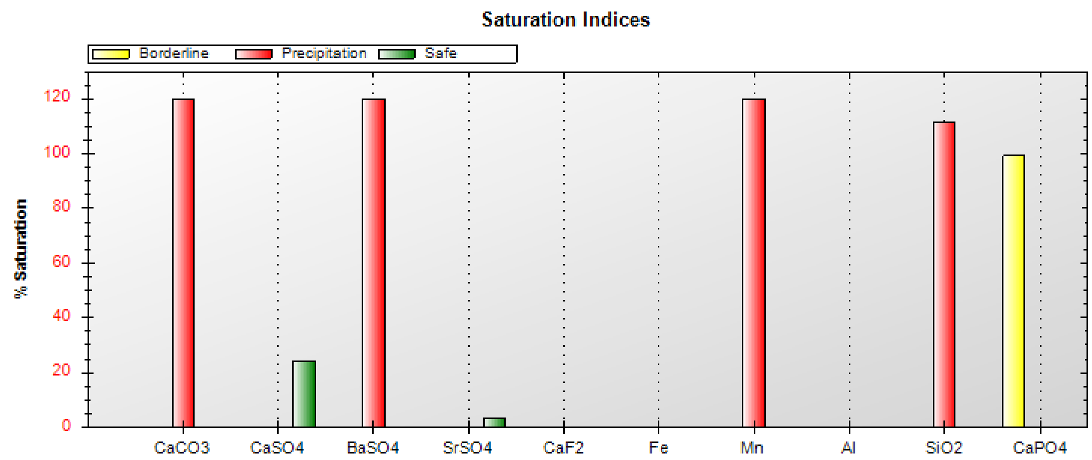
## CIP Summary

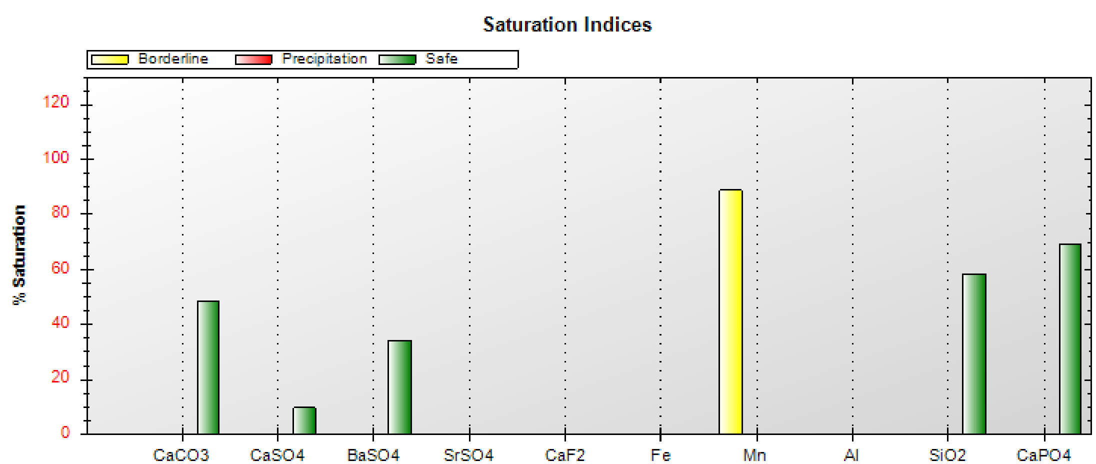


# NF/RO Optimization Techniques

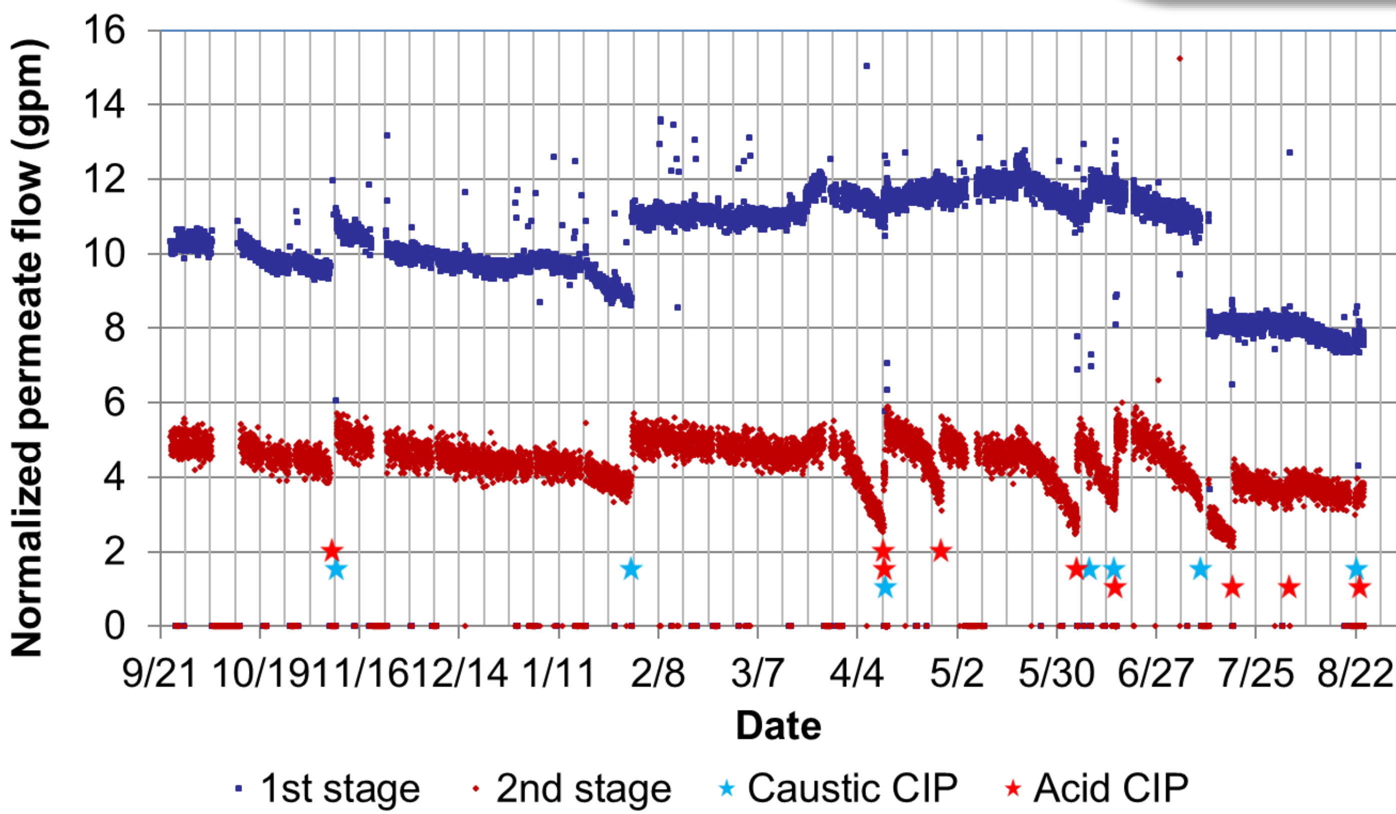
## Antiscalant Selection

### % Saturation



# RO Membrane Performance



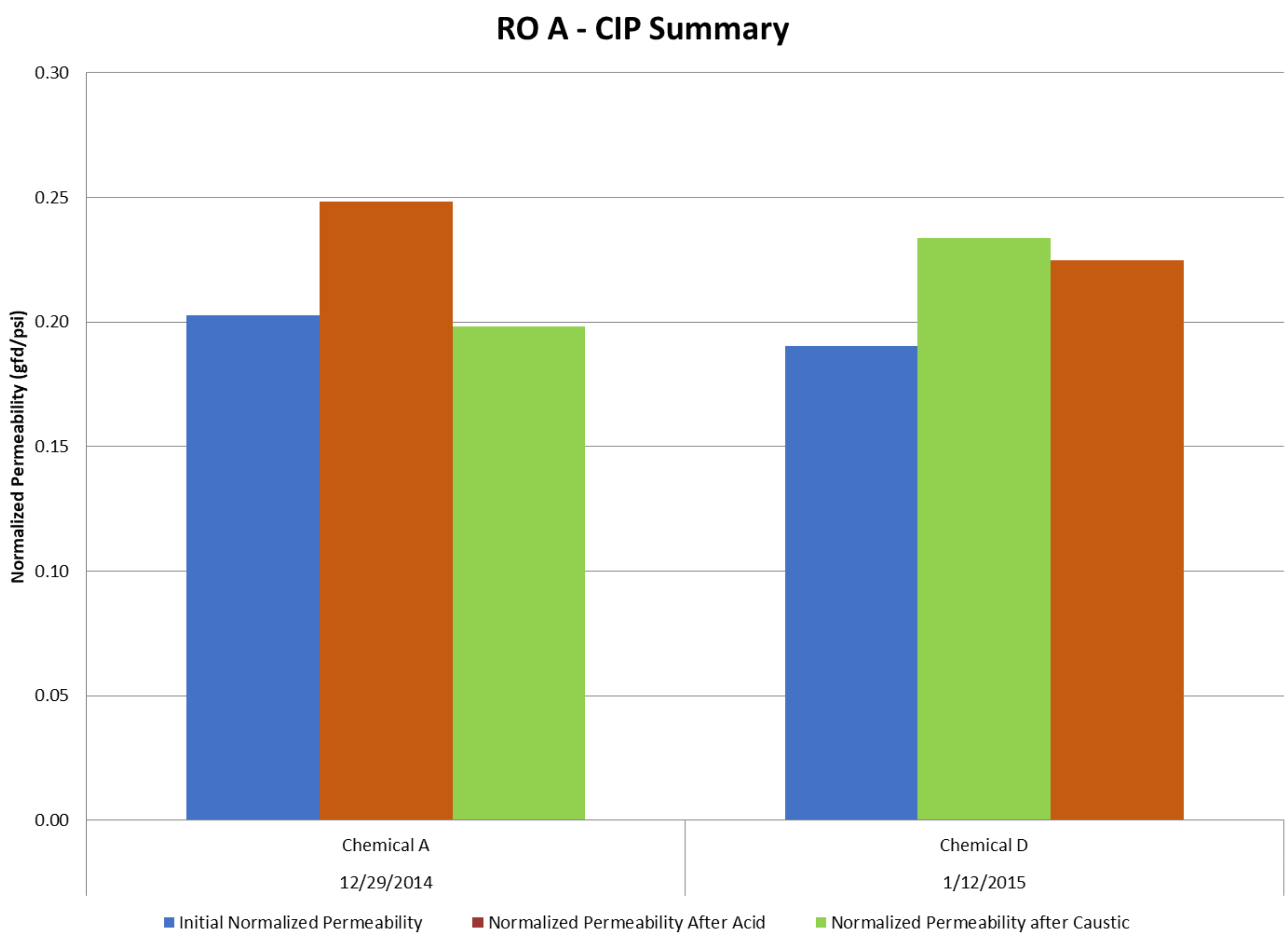

| FEED WATER | |
|---|---|
| Avg SDI | ~ 2.8 |
| Avg pH | ~ 7.0 |
| **OPERATIONAL CONDITIONS** | |
| **Clean Type** | **Time** |
| Recovery Clean | 30-45 days |
| * low pH | * high pH |

**RO membrane autopsy found that 1st stage majority organic fouling and 2nd stage majority inorganic fouling (scaling)**

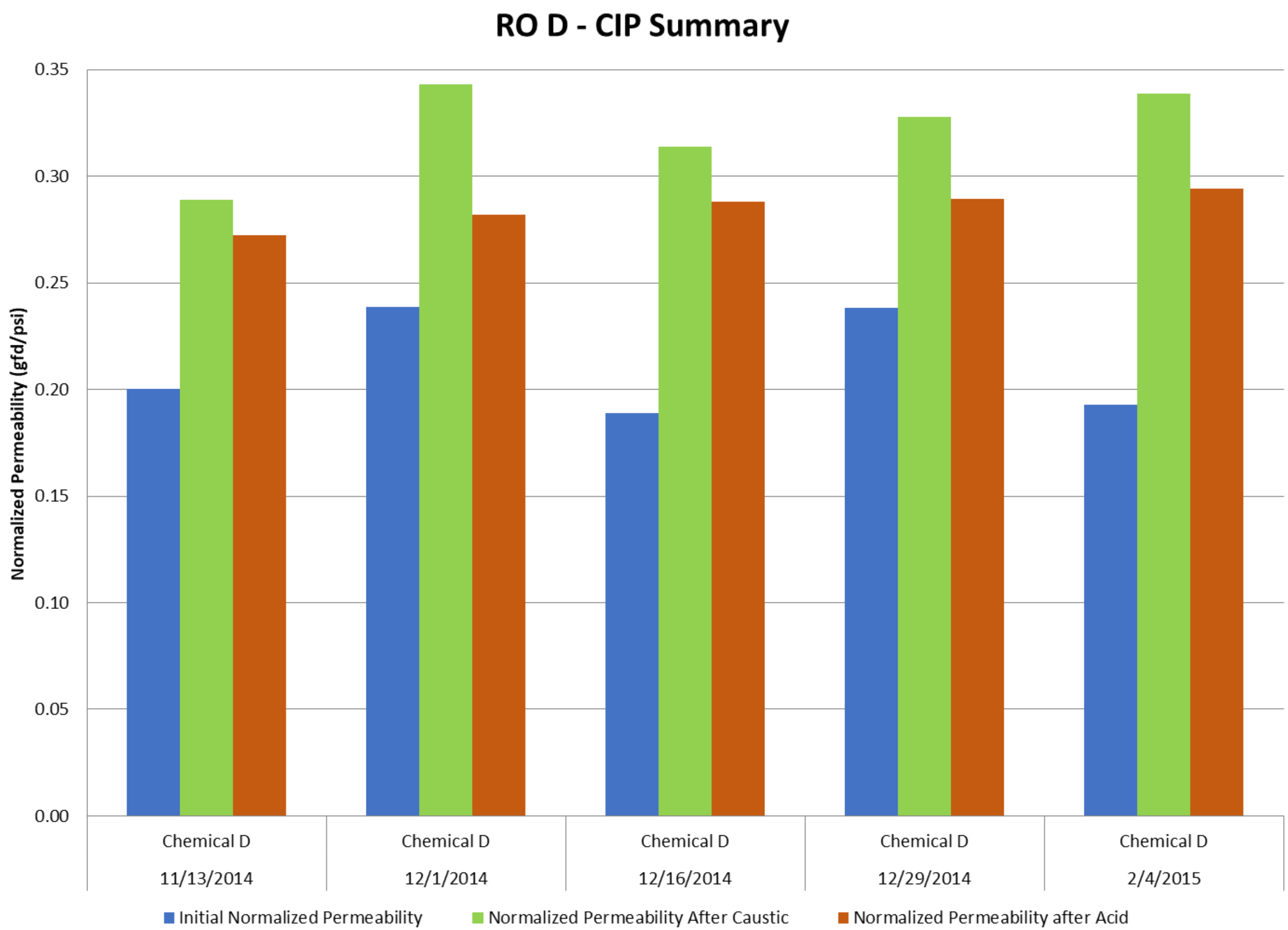
## RO CIP Recommended Operations

| Product A and B | Product C | Product D |
|---|---|---|
| • Low pH (3.0) - 60 min flush<br>• High pH (11.7) – 60 min flush and 12 hour soak | • High pH (10.5) – 60 min flush, 12 hour soak, 60 minute flush<br>• Low pH (2.0) – 60 min flush, 60 min soak, 60 min flush | • High pH (12.5) – 180 minutes: 30 min flush, 30 min soak, etc<br>• Low pH (2.4) – 120 minutes: 30 min flush, 30 min soak, etc |

# GFWTP – RO CIP Summary



# GFWTP – RO CIP Summary



# GFWTP - Optimization Results

| MEMBRANE OPTIMIZATION RESULTS | |
|---|---|
| ANTISCALANT | • Chemical C – avg. 9% loss of permeability in 30 days<br>• Chemical B – avg. 23% loss of permeability in 30 days<br>• Chemical A – avg. 26% loss of permeability in 30 days |
| CIP CHEMICALS | • Chemical B and C performed similarly – recovered ~ 98% of Normalized Permeate Flow<br>• Chemical A had irreversible fouling |

# Fargo WTP – MF/UF Pilot Performance Evaluation

| Module Model Number | Membrane 1 | Membrane 2 | Membrane 3 |
|---|---|---|---|
| Type of Membrane | Submerged | Encased | |
| Material of membrane fiber | PVDF | | |
| Surface area per each membrane module, $ft^2$ ($m^2$) | 550 (51) | 538 (50) | 375 (35) |
| Nominal pore size, (µm) | 0.02 | 0.1 | 0.04 |

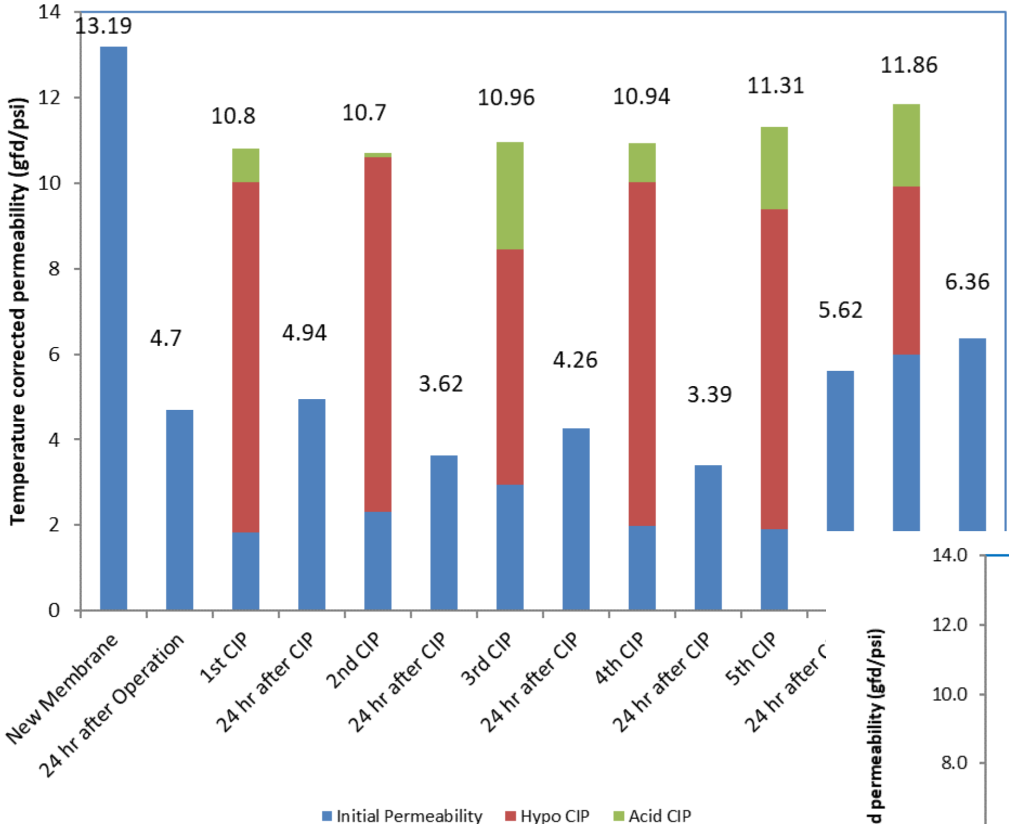
| | SHEYENNE RIVER RAW WATER | SETTLED WATER |
|---|---|---|
| pH | 7.8-8.5 | 7.2-7.8 |
| Temperature (°C) | 1.0-28 | 1.0-28 |
| TOC (mg/L) | 7.3-16 | 5.5-9.4 |
| Turbidity (NTU) | 10-700 | Typical: <3<br>Maximum: <9 |

# Fargo WTP – MF/UF Pilot Performance Evaluation

| Maintenance Cleans | Membrane 1 | Membrane 2 | Membrane 3 |
|---|---|---|---|
| Hypo Concentration (mg/L) | 100 | 600 | 200 |
| $H_2SO_4$ (mg/L) | 0 | 0 | pH 2 |
| Water Temperature (°F) | ambient | 90 | ambient |
| Frequency (hours) | 72 | 72 | 72 |

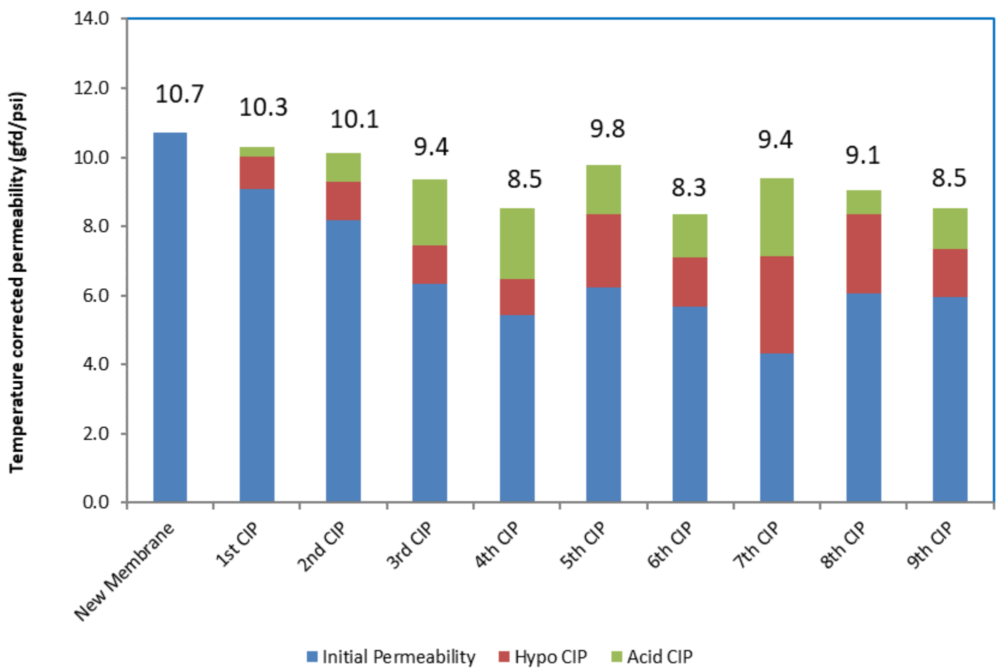
| | Membrane 1 | Membrane 2 | Membrane 3 |
|---|---|---|---|
| ACID CIP | | | |
| Citirc Acid (mg/L) | 2,000 | 20,000 | 10,000 |
| $H_2SO_4$ (mg/L) | Add HCl - pH to 2 | 0 | Add HCl - pH to 2 |
| Water Temperature (°F) | 95 | 90 | 90 |
| Interval (weeks) | > 5 | 6 | 6 |
| Hypo CIP | | | |
| Hypo Concentration (mg/L) | 500 | 2,000 | 600 |
| NaOH concentration (mg/L) | 0 | 10,000 | 0 |
| Water Temperature (°F) | ~70 | 90 | 68 |
| Interval (weeks) | > 5 | 6 | 6 |

# Fargo WTP – MF/UF Pilot Performance Evaluation



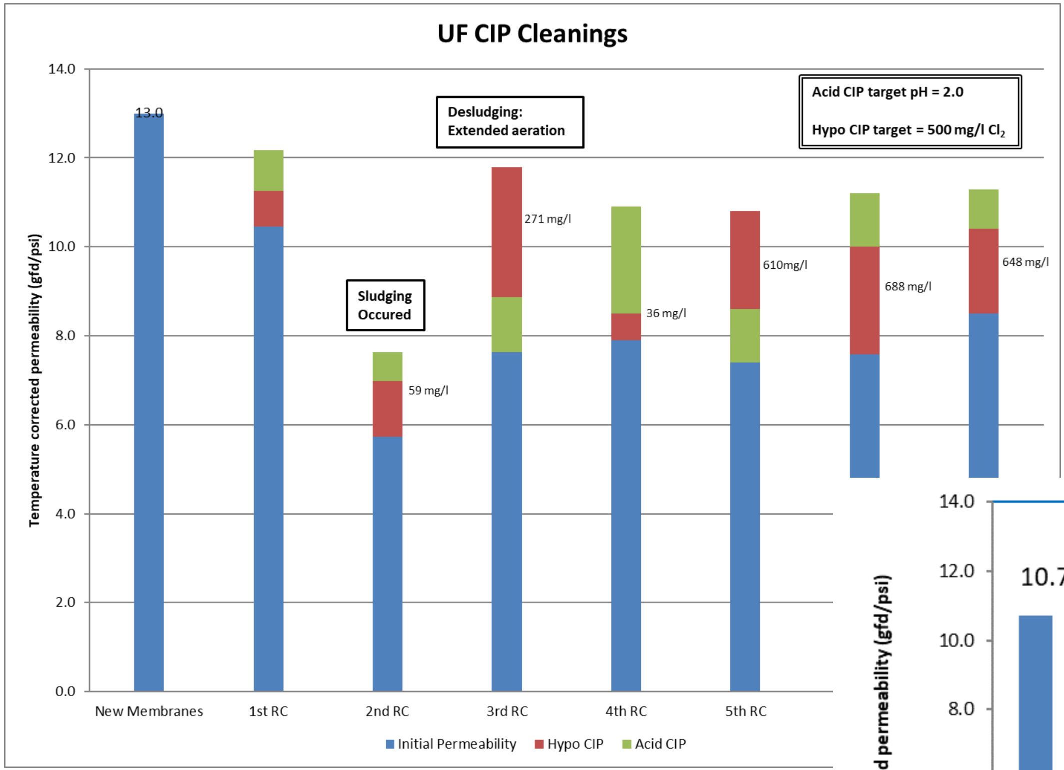

Membrane #2

Membrane #1

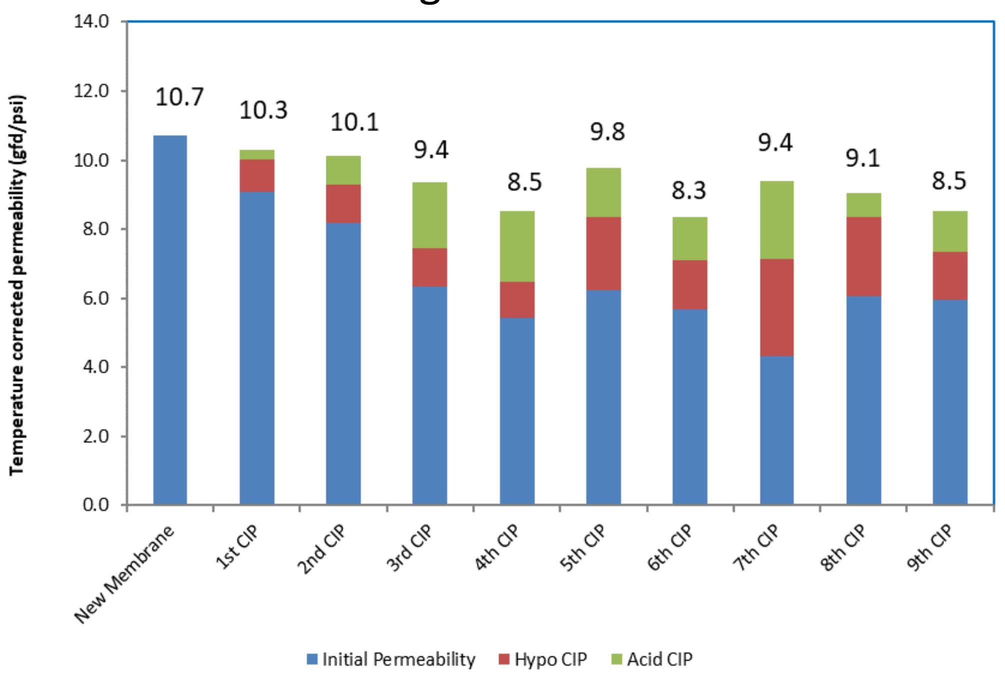


# GF / Fargo Comparison

Grand Forks




Fargo - Membrane #1



# Valley City Membrane Types

## UF BASIS OF DESIGN

- Zenon ZeeWeed 1000
- 4 Trains x 3 Cassettes each
- 4.66 MGD Firm


## RO BASIS OF DESIGN

- GE MUNI 1.0 Skids
- 2.0 MGD Firm Capacity

# Valley City - Online Chemical Feeds

## Pre-UF Membranes

- Sodium Permanganate - Oxidation of Manganese
- Sulfuric Acid – pH Adjustment
- PACL

## Pre-RO Membranes

- Sodium Bisulfite - Oxidant Neutralizer
- Antiscalant

## Post RO/UF Mixing

- Sodium Hydroxide - pH Adjustment

# Valley City - Offline Chemical Feeds (CIP)

## Ultrafiltration Membranes

- Citric Acid
- Sodium Hydroxide
- Sodium Hypochlorite
- Sodium Bisulfite
- Add GE Chemical

## Reverse Osmosis Membranes

- Sodium Hydroxide
- Citric Acid

# Summary

- ✓ Importance of Water Chemistry
- ✓ Importance of Pretreatment
- ✓ Importance of Pilot Testing
- ✓ Improving Membrane Operations/Life/Reducing Costs through Optimized Operations
- ✓ Many Resources/Manufacturer Products Available

# QUESTIONS?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