OREGON WATER TREATMENT PLANT OZONE IMPROVEMENTS

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Project Manager

TMACOG

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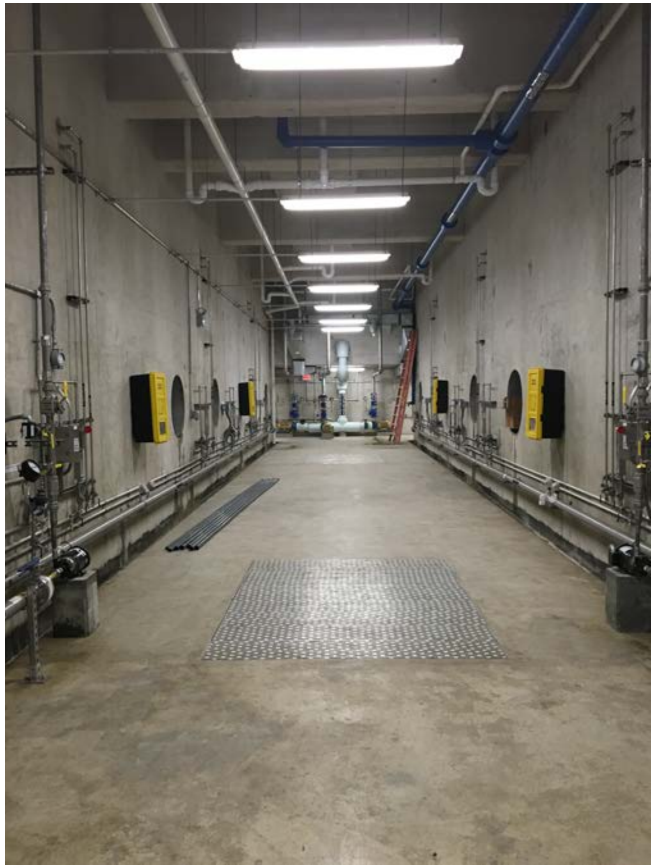
Health and Safety Tips

- Follow safety warnings and alarms
- Ozone Generators operate under high voltage (5,000 Volts) and high frequency (7,000 to 10,000 Hz)
- Respirator kits located in Contactor Gallery
- Ambient ozone monitors sniff for ozone
- Ambient oxygen monitors sniff for oxygen
- Alarms trigger ventilation to start and ozone generator shutdown. Ventilation failure triggers ozone shutdown.
- If you smell ozone, leave the area immediately

Ozone Generator Room per mfg. O&M manual



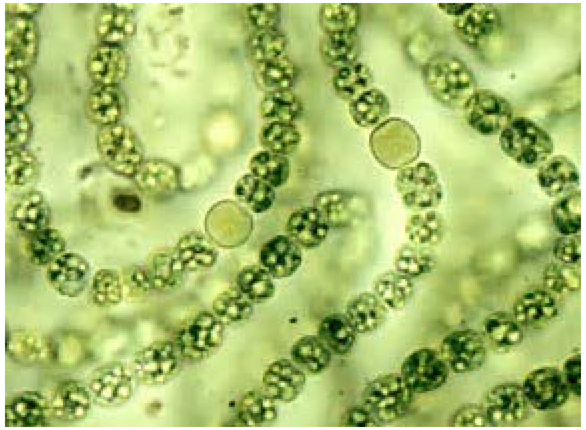
Cyanobacteria bloom in Lake Erie, Summer 2014

Credit: Joshua Lott/Reuters

Credit: Haraz N. Ghanbari/Associated Press

Cyanotoxins detected in treated water creating concern of drinking water safety

Cyanobacteria: Cause and Concerns



Cyanobacteria

Cause

- Excess nutrient in water bodies
- Warm temperature

Concerns

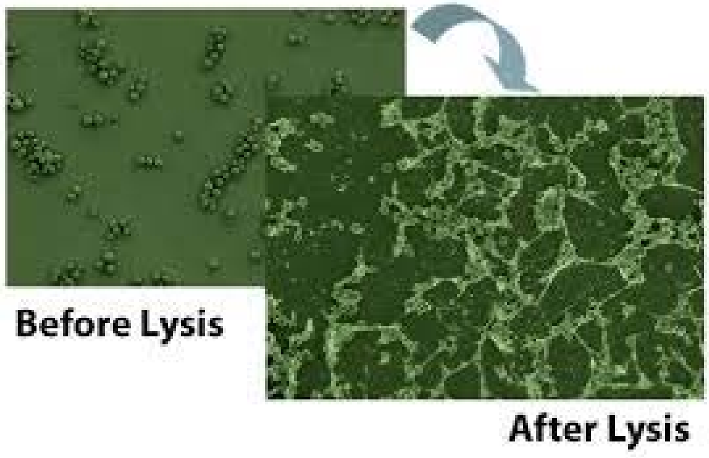
- Taste & odor issue
- Increased turbidity and DBPs formation
- Cyanotoxin
  - acute exposure to high doses: vomiting/diarrhea, organ damage, and death
  - chronic effects: liver damage and cancer

Intracellular vs. Extracellular Cyanotoxins

Intracellular (intact cells)

- Intact cells contain cyanotoxins
- Physical removal of intact cells also removes cyanotoxins

Extracellular (lysed cells)



- Lysed cells release cyanotoxins
- Requires both physical and chemical processes to remove both the cyanobacteria and the cyanotoxin

Lake Erie 2014 Cyanotoxins

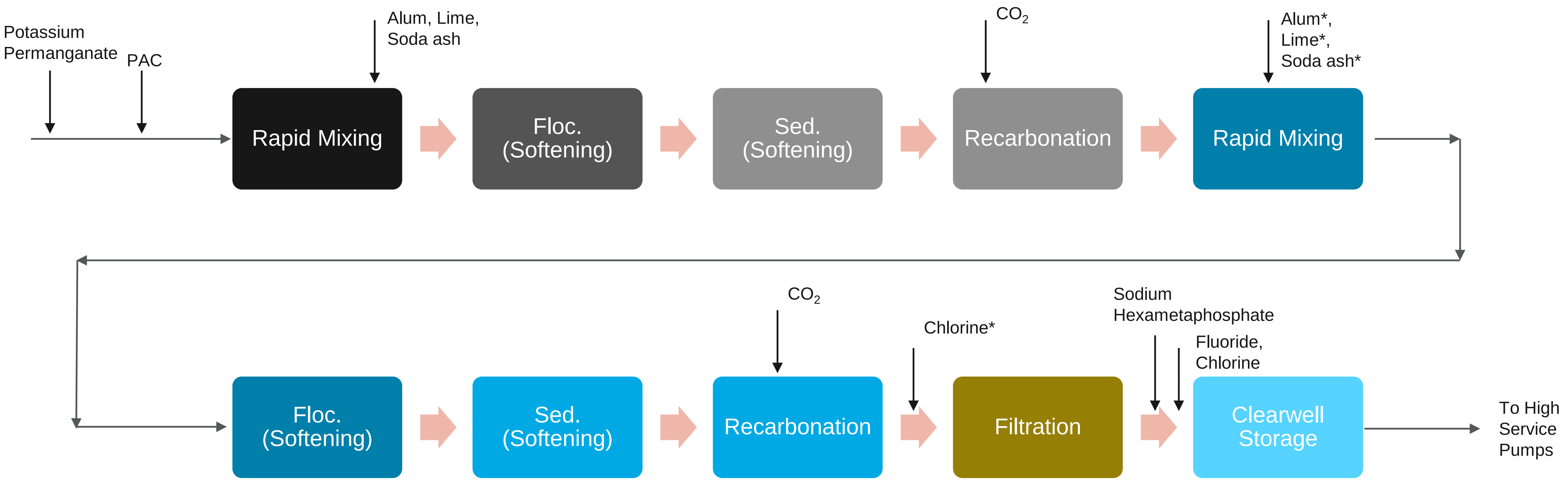
Lake Erie Cyanotoxins

Algae in Lake Erie at Maumee Bay State Park in Oregon in August of 2014 (Henry, T. 2014b)

(Haraz N. Ghanbari/Associated Press)

- August 2, 2014 – City of Toledo issued a Do Not Drink order because of detections of the cyanotoxin microcystin in finished water
- Nearly 500,000 residents impacted
- August 4, 2014 – Ban was lifted

Oregon, OH Water Treatment Plant - 2014

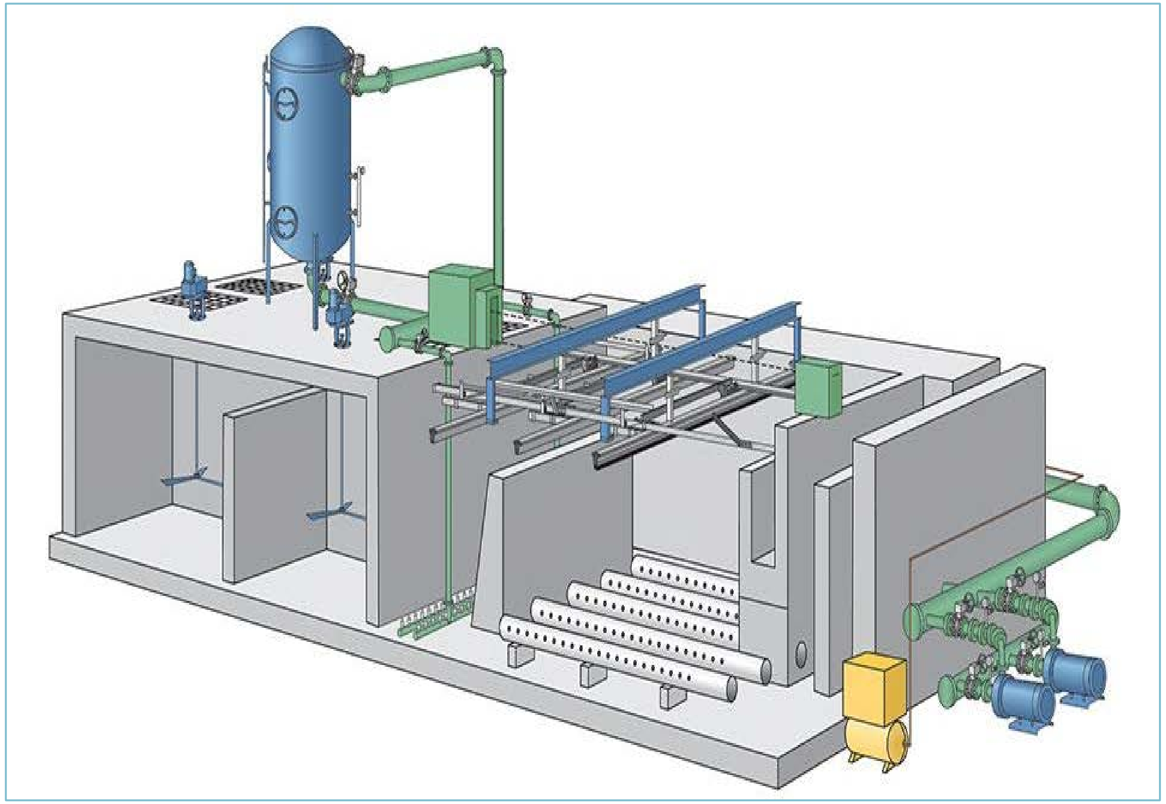


* Not typically used

Approach to Evaluate Algal Toxin Mitigation Strategies

Mitigation Strategy	Test Scale	Testing Approach
Dissolved air flotation	Pilot (Leopold Clari-DAF pilot unit)	• Approx. 3 weeks • Raw water • Evaluated alum and ACH coagulants • Measured algae counts, microcystin, turbidity, and TOC removal
Ozone	Bench	• Raw and settled water • Spiked with microcystin • Assessed ozone demand and decay • Measured bromate and microcystin concentrations

DISSOLVED AIR FLOTATION



Xylem/Leopold Clari-DAF System - Figure used with permission

Alternative to conventional sedimentation/flocculation

Coagulant added in two stage flocculation process

Flocculated particles attach to micro-bubbles and float to surface rather than settling by gravity

Air saturator creates microbubbles that float particles to surface creating a sludge blanket or float layer

Float layer removed by hydraulic or mechanical system

Clarified water withdrawn from bottom of DAF basin

Dissolved Air Flotation Pilot

Shortly after “Do Not Drink Advisory”, Xylem contacted City offering 2 - 3 week DAF complimentary pilot

August 8 – 28, 2014 pilot unit

Primary objective to assess ability of DAF to remove algae and cyanobacteria. Secondary goals related to turbidity and TOC removal

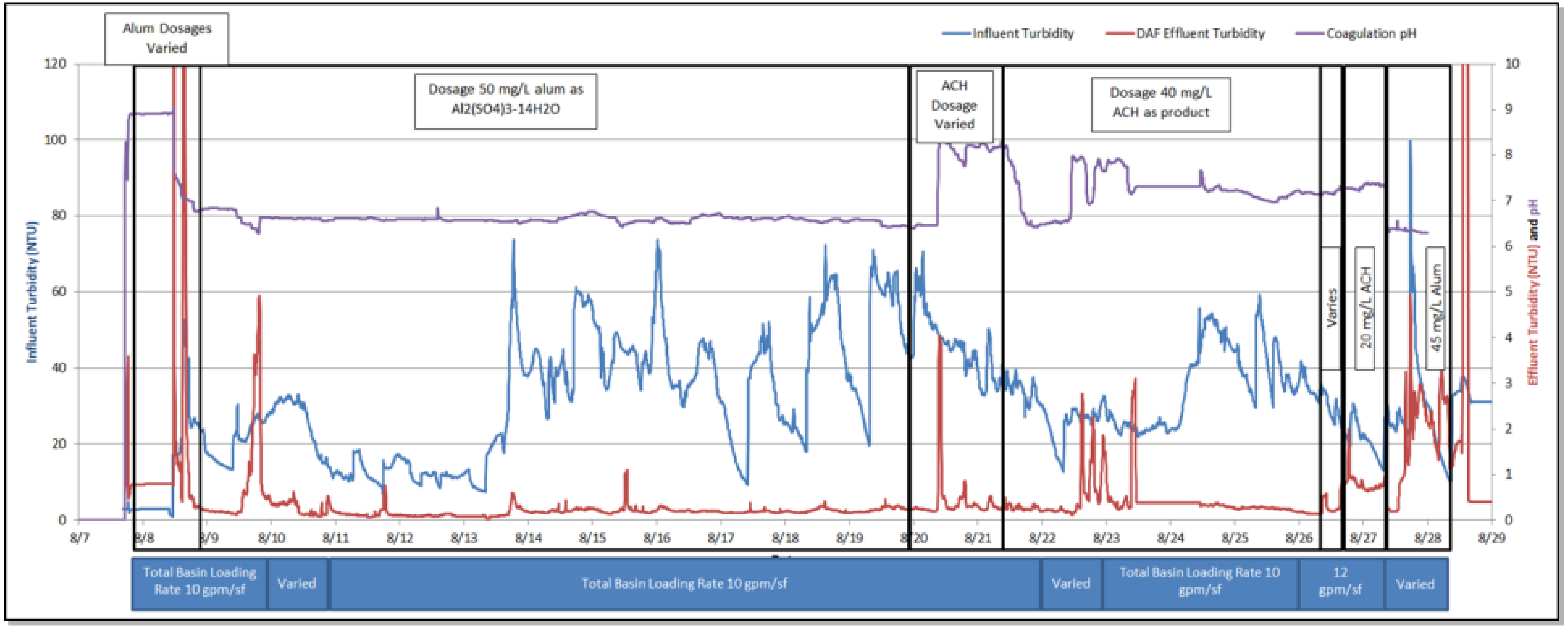
Performance goals were set at levels reasonable for pretreating raw water

Pilot unit included DAF and Filtration System

Two coagulants were tested

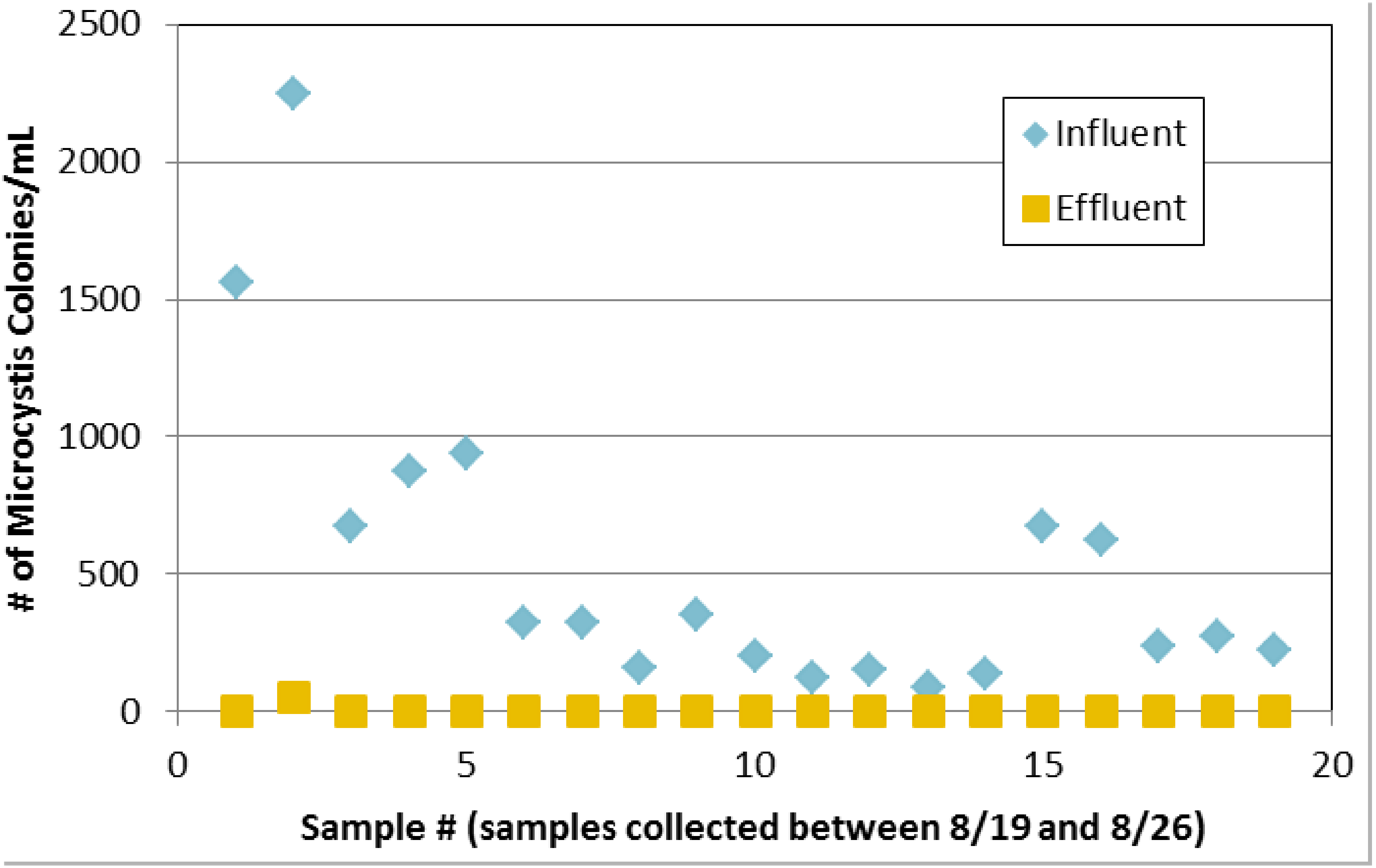
DAF Pilot – August 2014

DAF Performance – Turbidity and TOC Removal



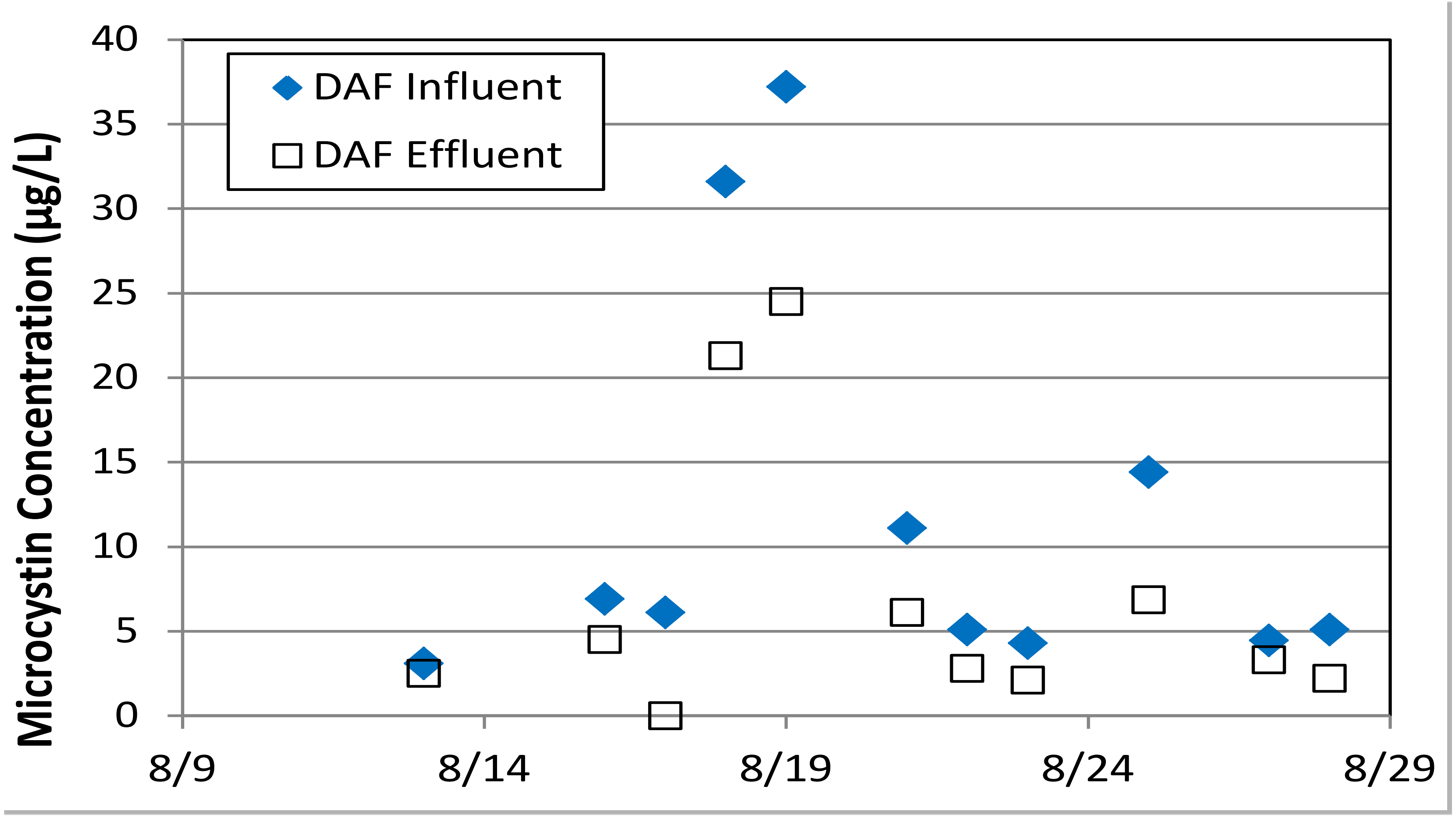
- Effluent turbidity averaging 0.2 to 0.3 NTU during stable operation
- 37.3% TOC removal (n=25) and 49.4% UV_{254} Removal (n=42)

DAF Performance – *Microcystis* Removal (Intracellular)



93% total algae removal in 19 samples and Consistent removal of *Microcystis*

DAF Performance – Microcystin Removal (Extracellular)



Some extracellular microcystin removal observed

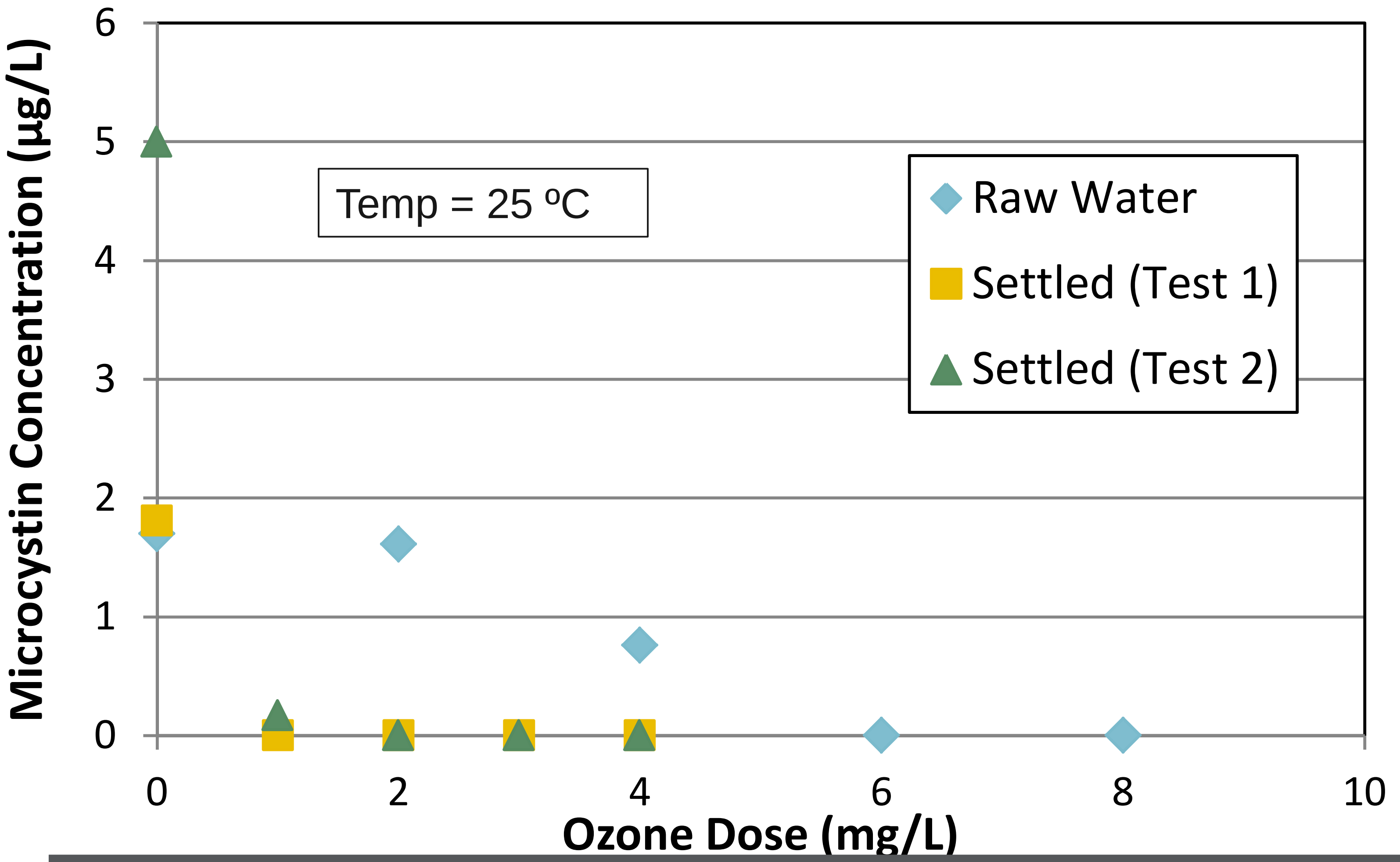
Ozone and Microcystin in Literature

- Ozone is very effective for elimination of microcystin - reactions are dependent on ozone dose

- Ozone is more effective than chlorine, hydrogen peroxide, and potassium permanganate in destroying microcystin. Peptide hepatotoxin microcystin-LR were used in this study

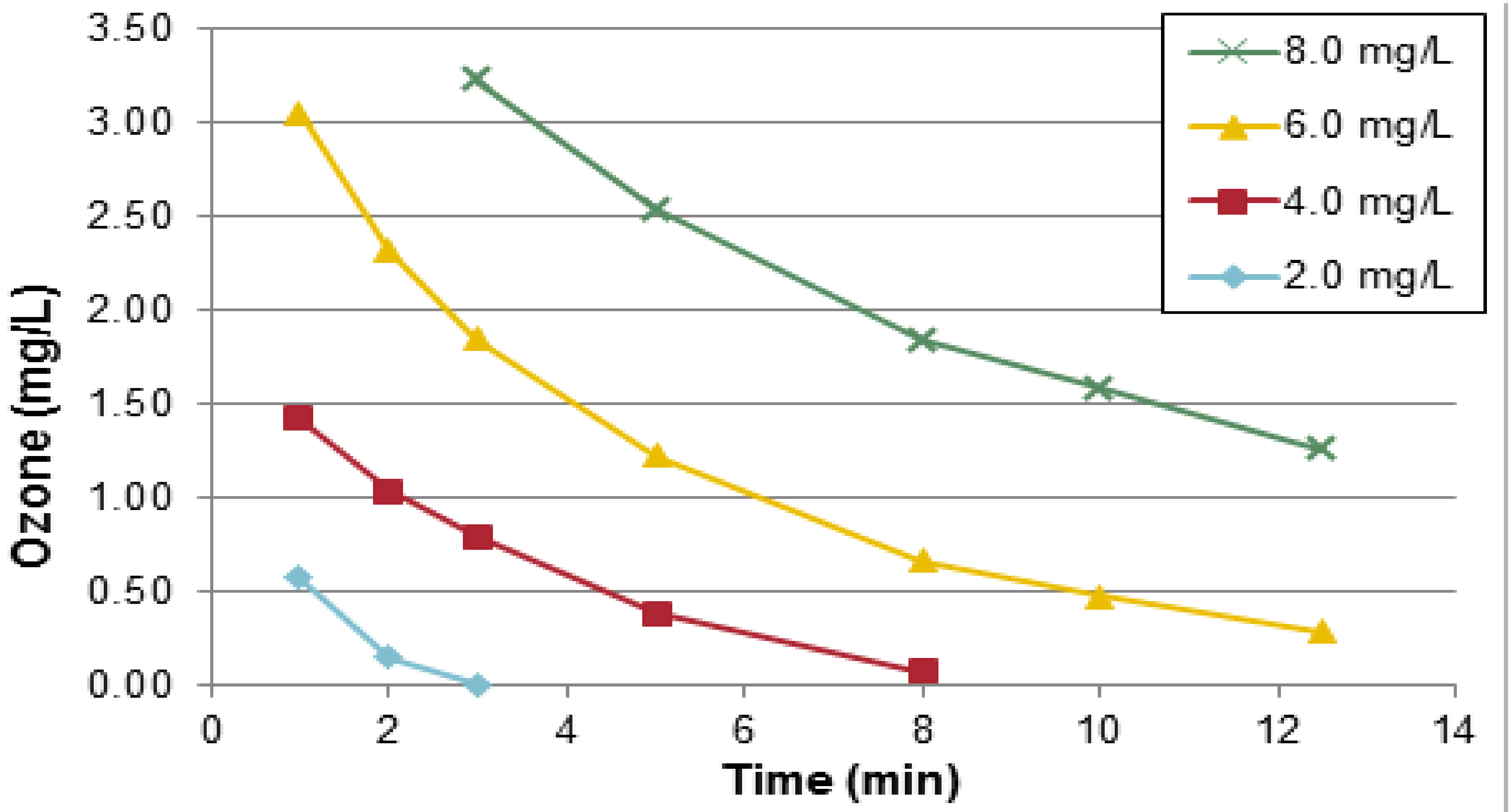
- Different algal toxins are more resistant to oxidation

Microcystin Removal with Ozone



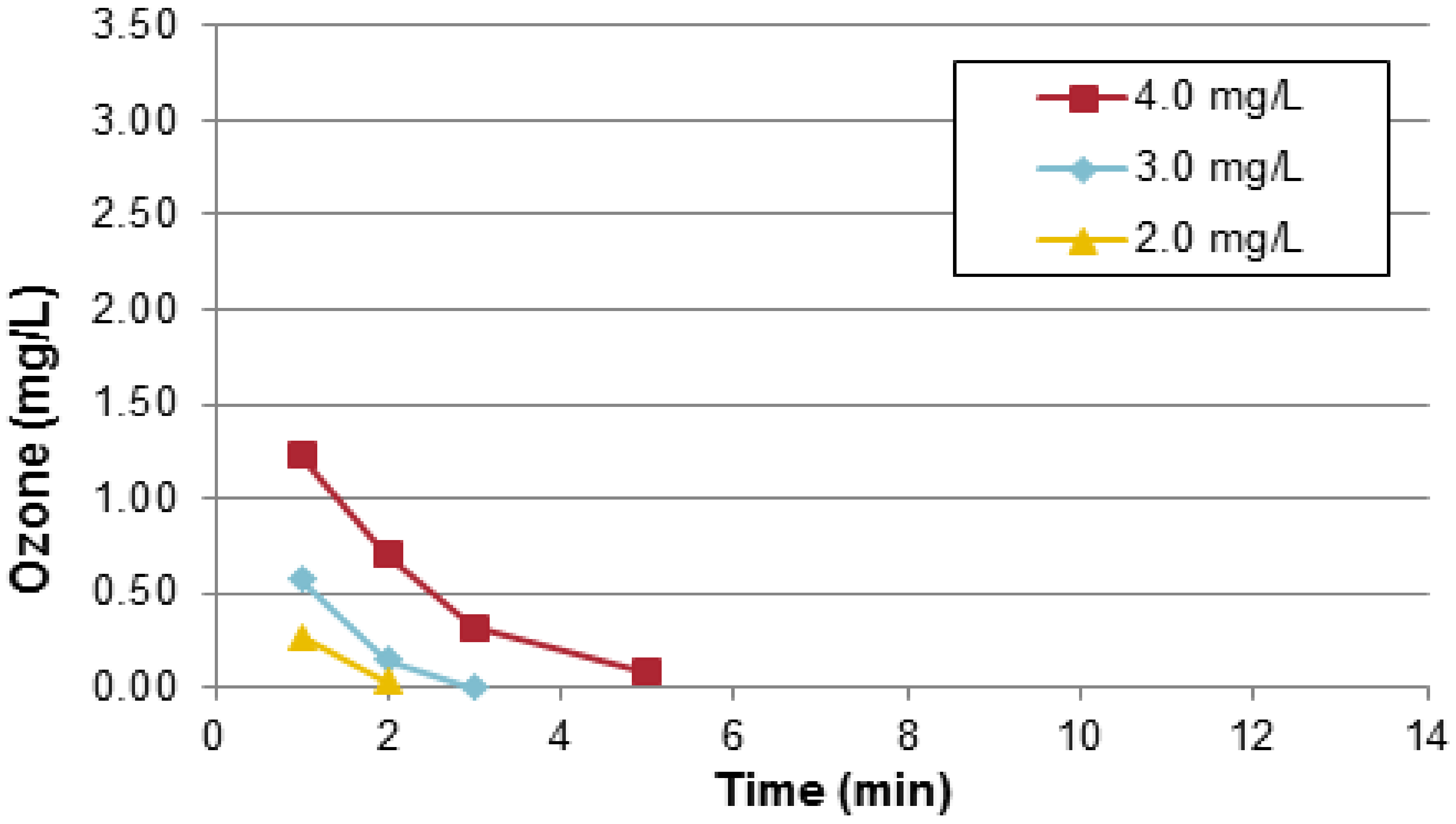
2 mg/L ozone dose for settled water reduced microcystin to below the 0.03 µg/L detection limit

Ozone Demand and Decay – Raw Water, 25 °C



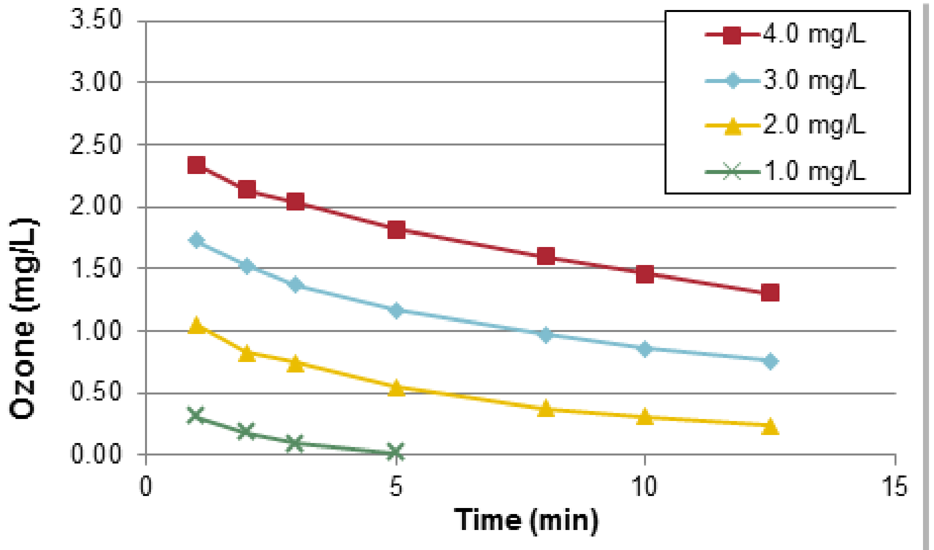
Raw water. T = 25 deg. C, pH = 7.9, TOC = 5.34 mg/L.

Ozone Demand and Decay – Settled Water, 25 °C

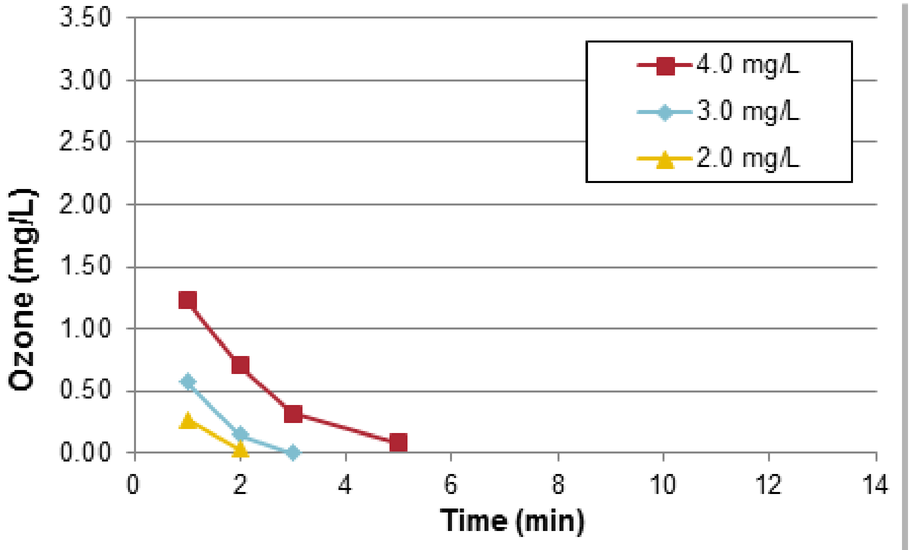


Settled water. T = 25 deg. C, pH = 9.5, TOC = 2.85 mg/L.

Ozone Demand and Decay – Settled Water, Impact of Temperature



Settled water. T = 1 deg. C, pH = 9.5, TOC = 2.85 mg/L.

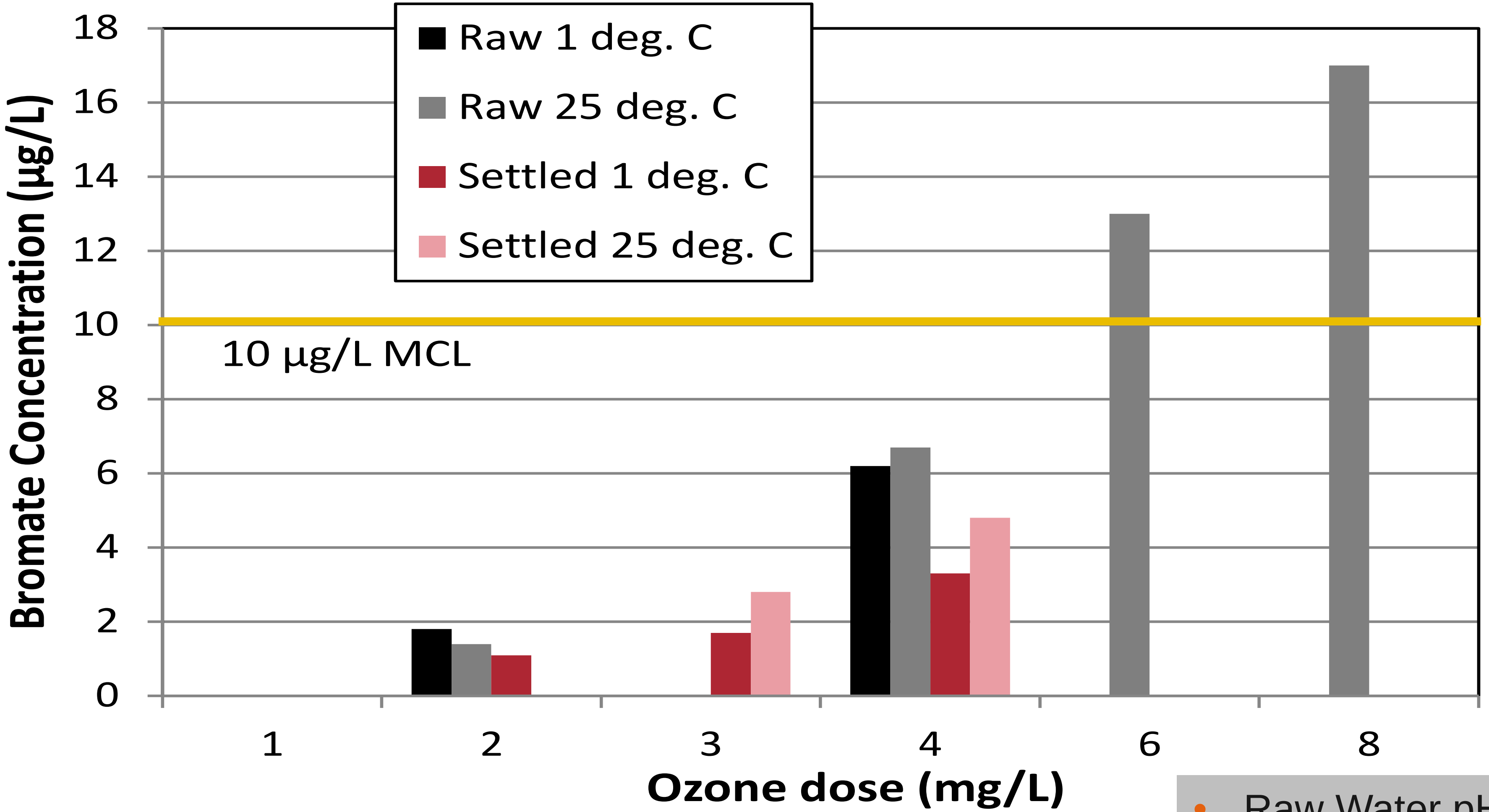


Settled water. T = 25 deg. C, pH = 9.5, TOC = 2.85 mg/L.

Preliminary design:

- 2 mg/L ozone dose
- 8 minute contact time
- Quenching capabilities

Bromate Formation with Ozone



- Raw Water pH = 8.0
- Settled Water pH = 9.6

Impact of Settled Water Ozone on Microcystin Removal and Bromate Formation

Ozone Dose (mg/L)	Microcystin (µg/L)[1]	Microcystin Removed (%)	Bromate (µg/L)
0	>5.0	0.0%	BDL
1	0.17	>96.6%	BDL
2	<0.03	>99.4%	BDL
3	<0.03	>99.4%	2.8
4	<0.03	>99.4%	4.8

Note: Samples were spiked with 12 µg/L Microcystin; bromate concentrations for experiments conducted at 25 °C

Ozone Process Benefits & Effectiveness

Primary Benefit: Oxidation

- Elimination of cyanotoxins

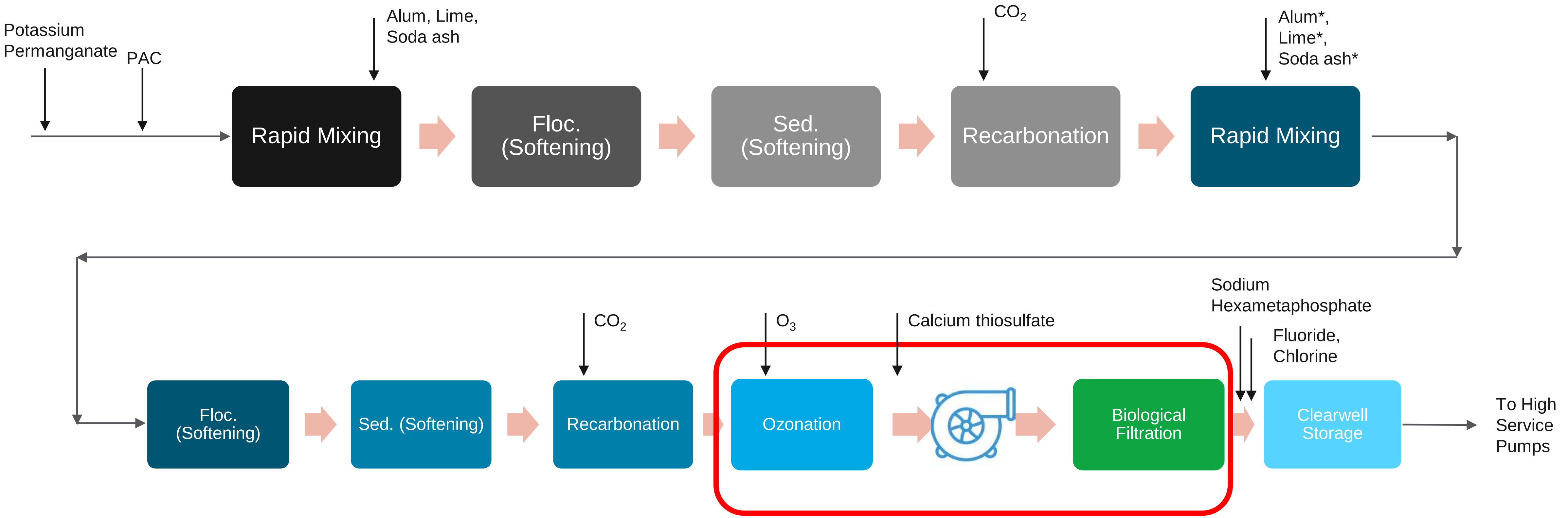
- **Secondary Oxidation Removal Benefits:**
  - Color
  - Iron
  - Manganese
  - Taste and Odor compounds

Other Benefits: Disinfection

- Excellent for *Giardia* and virus; good for *Cryptosporidium*

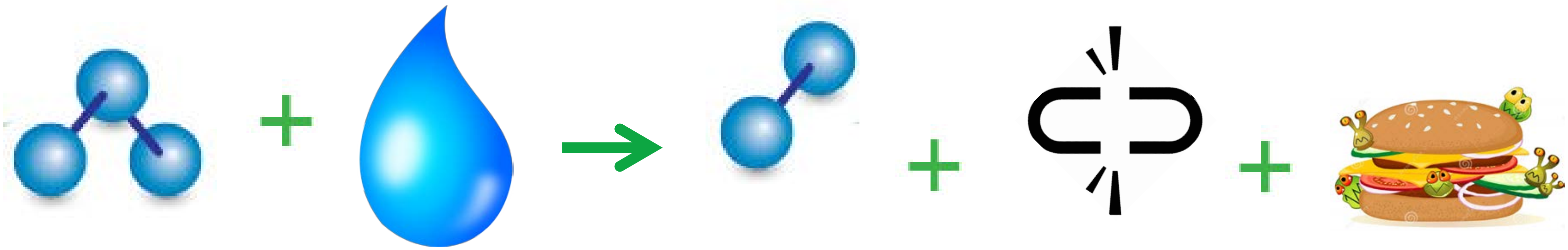
Other Benefits: Disinfectant By-Product Reduction

Oregon, OH Water Treatment Plant



* Not typically used

Ozone Overview



O_3
Ozone
(produced onsite from oxygen)

Lake Erie Water

O_2
Oxygen Molecule

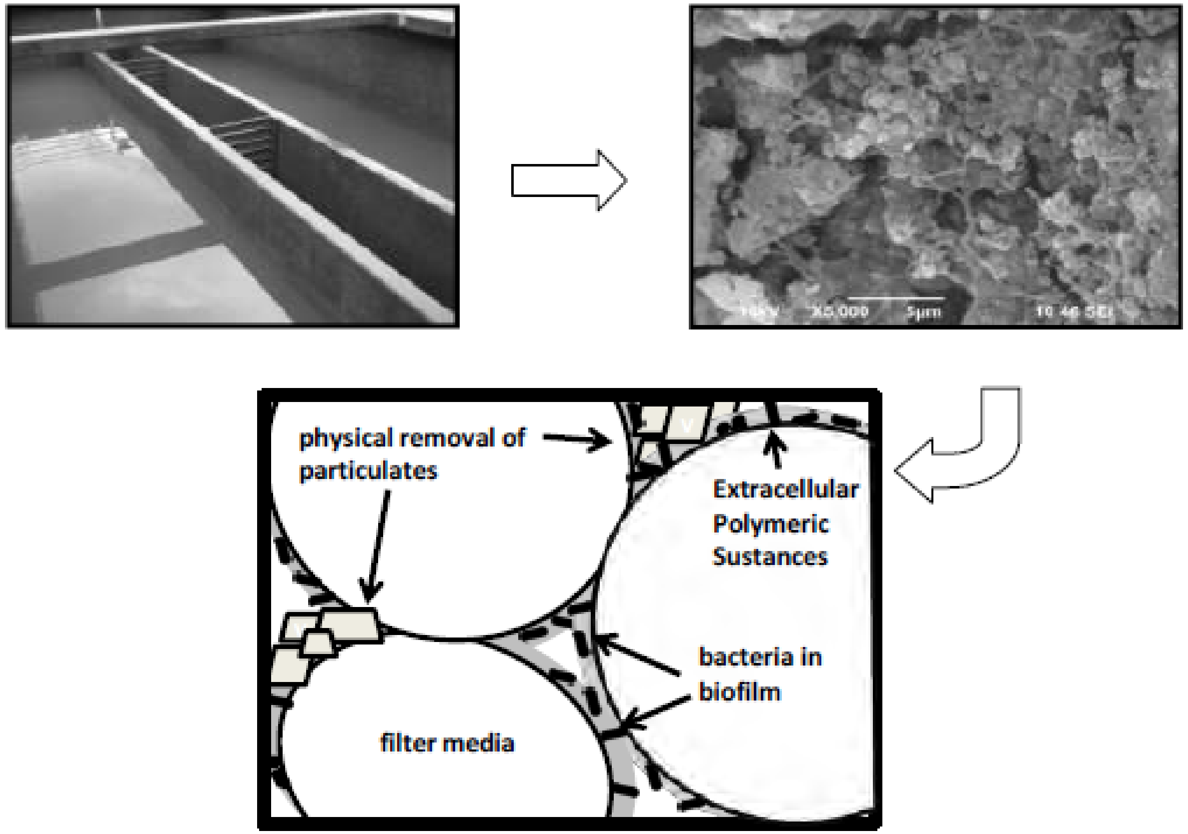
Destroyed:
Cyanotoxins
T&O compounds
Other contaminants

Biodegradable Organics

Biological Filtration (BAF) Overview

Biofiltration (bi′ō fil trā′shən), *n.*

biological treatment within a filter at a drinking water treatment facility, is an operational practice of managing, maintaining, and promoting *biological activity on granular media* in the filter to enhance the removal of organic and inorganic constituents before treated water is introduced into the distribution system.



WaterRF Biological Filtration Monitoring and Control Toolbox: Guidance Manual, 2013

Ozone and Biofiltration Work Synergistically

Ozone = Biofiltration

Biofiltration = Ozone

Biofiltration removes biodegradable organics produced by **ozone**, thereby improving distribution system stability.

Ozone breaks down organics, providing more “food” to encourage biological growth, thereby, optimizing **biofilter** performance.

Biofiltration and ozone work synergistically to produce high quality water.

Reason for Including Biofiltration

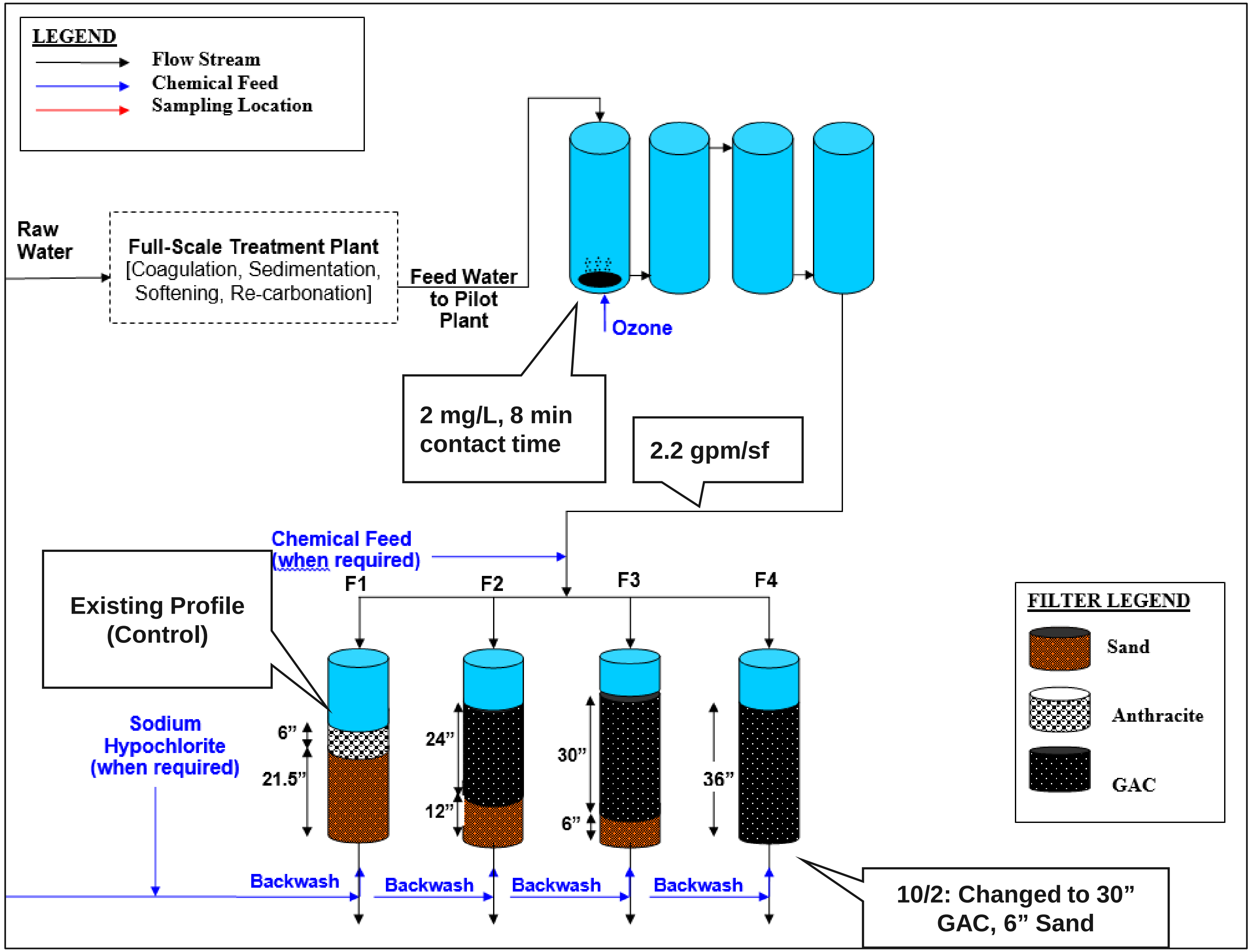
Ozone	
Destroys *microcystin*	Creates biodegradable organics (risk of regrowth)

↓

Biofiltration	
Removes biodegradable organics	Reduces risk of distribution system regrowth

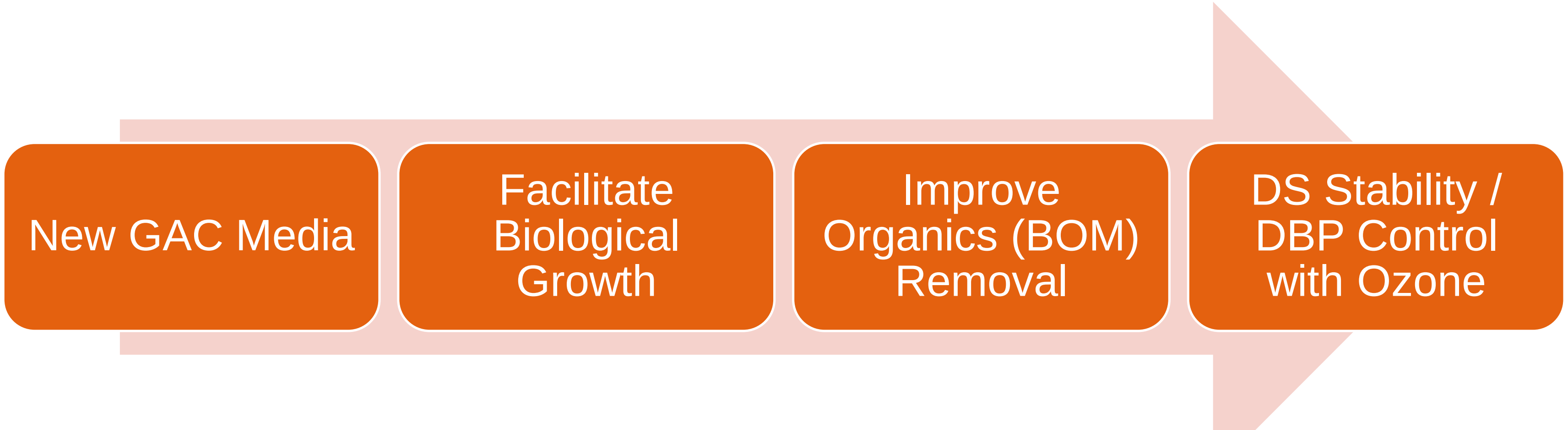
Ozone and Filtration Pilot

BAF Pilot Schematic



Media Type	Media Effective Size
Sand (Existing)	0.35-0.45
Anthracite (Existing)	0.85-0.95
GAC (Celina, OH)	0.80-1.00
GAC (Denton, TX)	1.00-1.20

Objectives

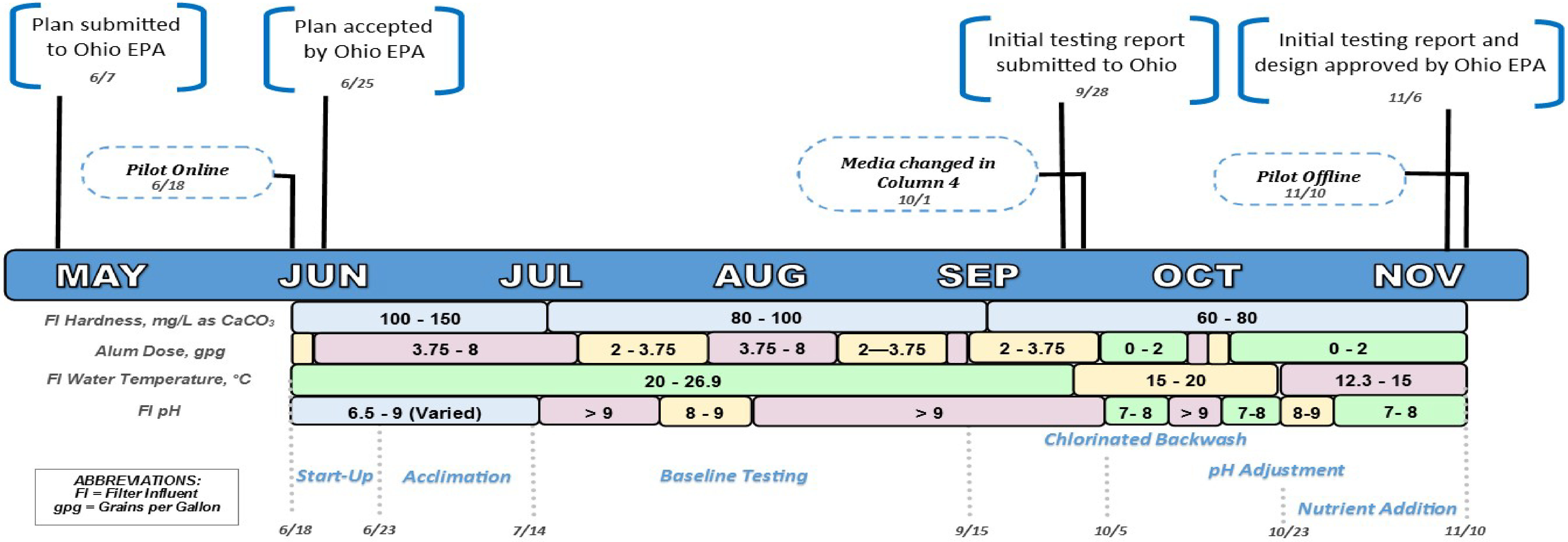


- Optimize filter design and operation to maximize organics removal
  - Effectiveness for reducing TOC, AOC and DBPs
  - Impact of chlorinated backwash
  - Optimal pH range
  - Impact of nutrient addition

Demonstrate that proposed media profiles consistently meet regulatory requirements (July 13th - September 3rd)

- Filtered NTU < 0.3, 95%
- Filtered NTU < 1.0, 100%
- TOC removal ratio ≥ 1.0
- $\geq$ 90% production efficiency
- $\geq$ 5,000 gal/sf UFRV

Pilot Testing Phases



Key Findings

- All filters met turbidity criteria
- All filters met headloss goals
- All filters met UFRV and Production Efficiency Criteria
- GAC filters performed significantly better (demonstrated 20% greater TOC removal) than control filter with use of chlorinated backwash

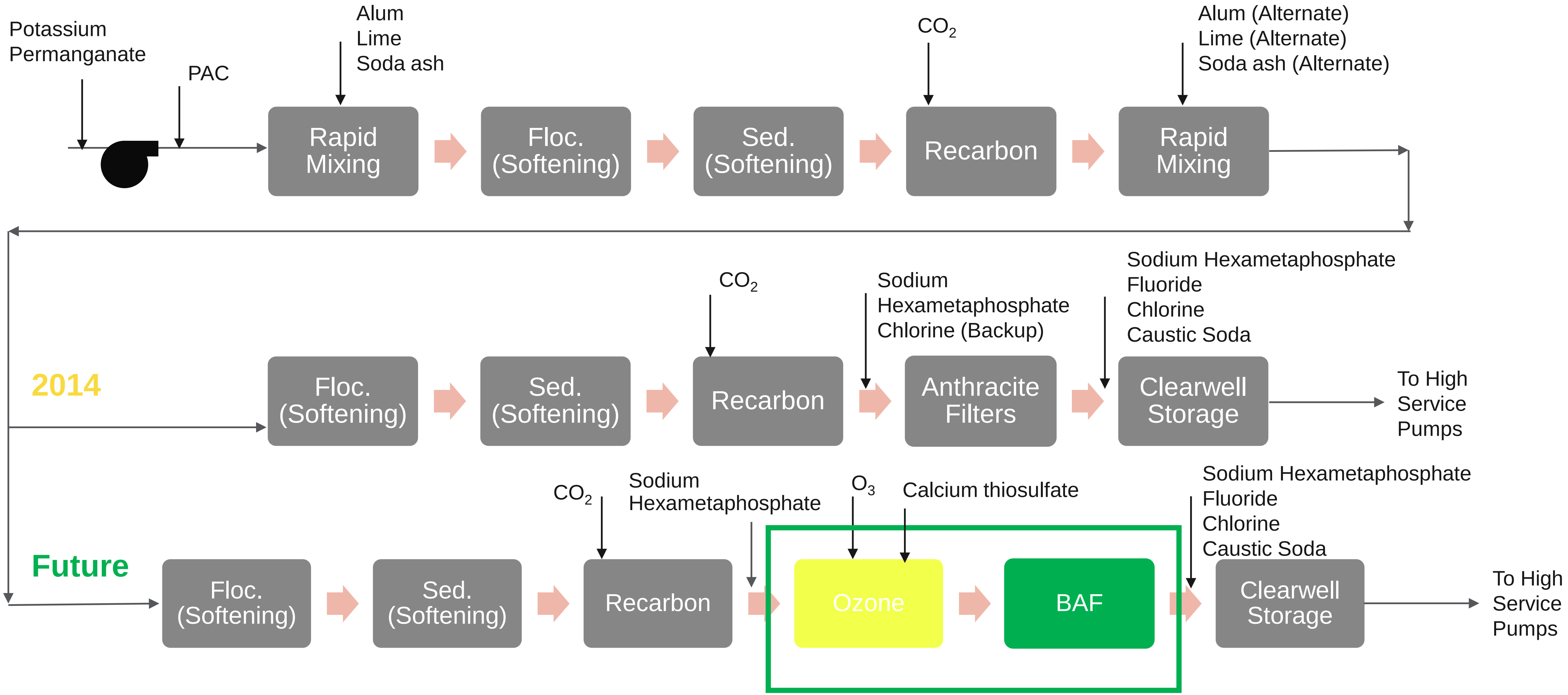
Recommendations

- Design filter loading rate 2.2 gpm/sf (with one offline)
- Profile: 6” sand and 33” GAC
- New gravel-less underdrains with air scour capability and air/water backwash

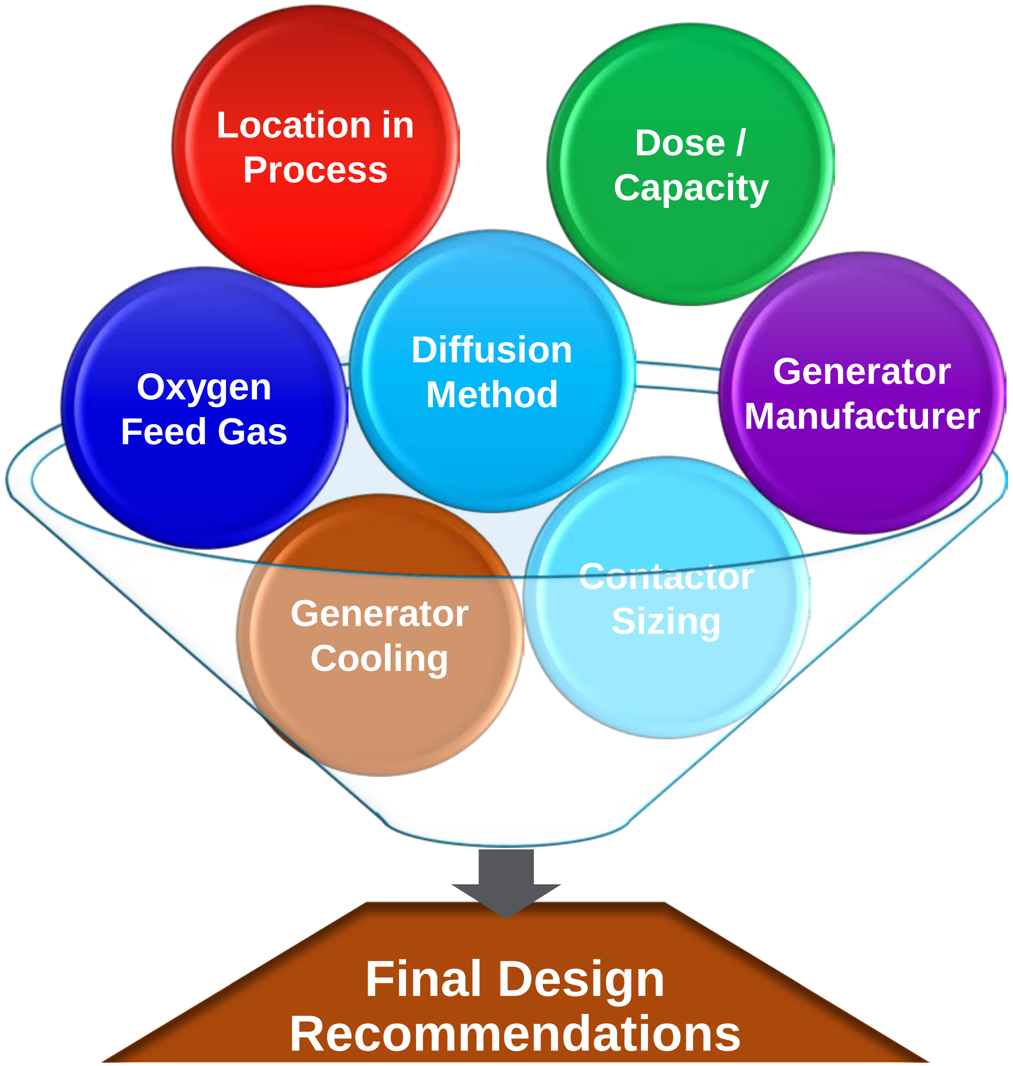
Design Criteria – Oregon WTP Ozone System

Condition	Flow (MGD)
OWTP Permitted Maximum Flow	16
Ozone System Design Capacity	16
Individual Contactor Maximum Flow	12
Total Contactor Flow Capacity	24
Average Plant Flow	9
Minimum Plant Flow	6

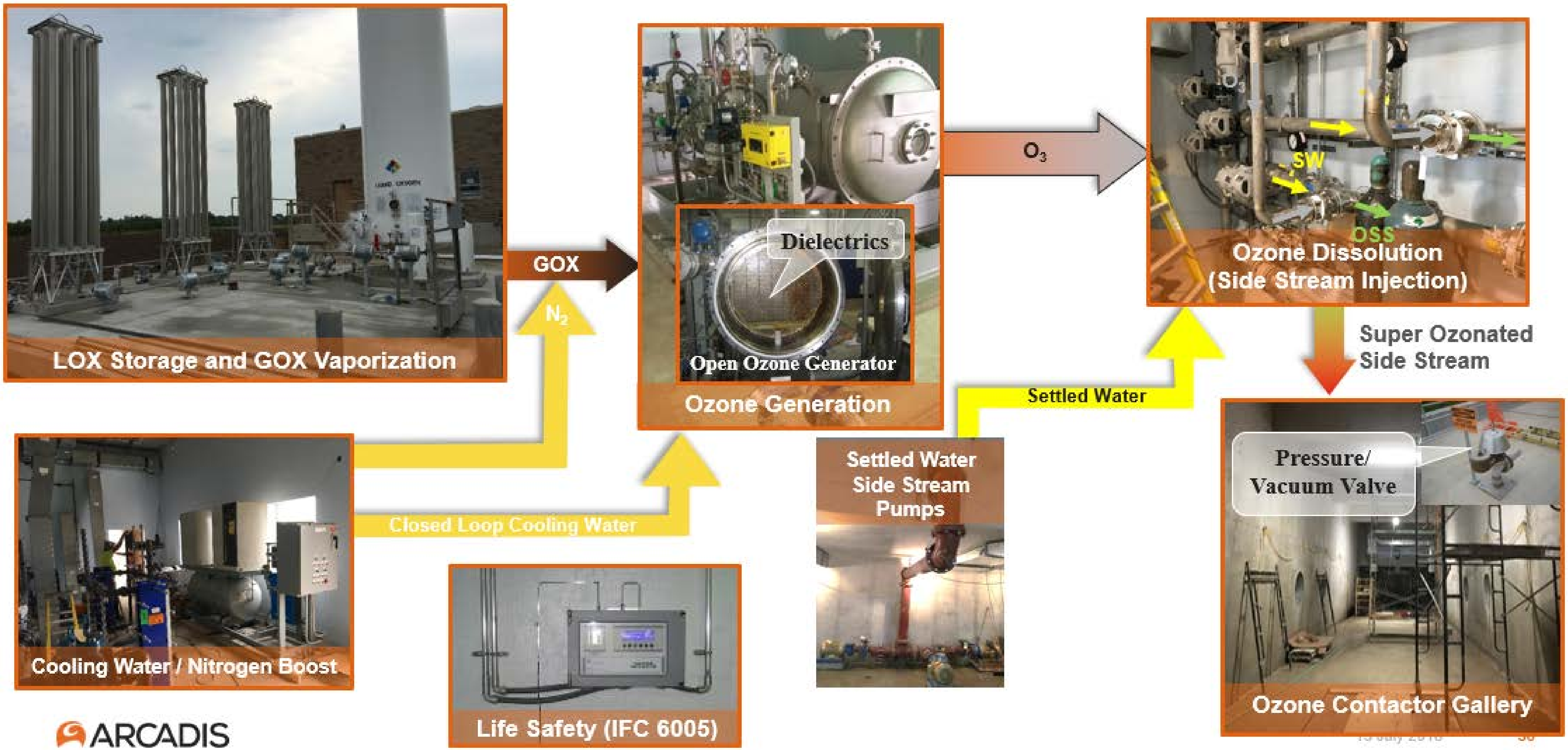
Process Flow Diagram



Design Decisions



Ozone System Photo Schematic



LOX & Vaporizers

LOX Tank Level & Tank Pressure

- Capacity = 6,000 gal (87,830 lbs)
- Pressure Building Regulator
- Over Pressurization will trigger blow off valve
- Typical set at 60-70 PSIG

Cycling of Vaporizers (8 hrs)

- Converts LOX to GOX
- Frost build up is normal (efficiency drops)
- 1 Duty / 2 Thaw cycle

Supplemental Air (Nitrogen) System

- Air is added for its nitrogen
- Small quantity of nitrogen improves ozone generation efficiency

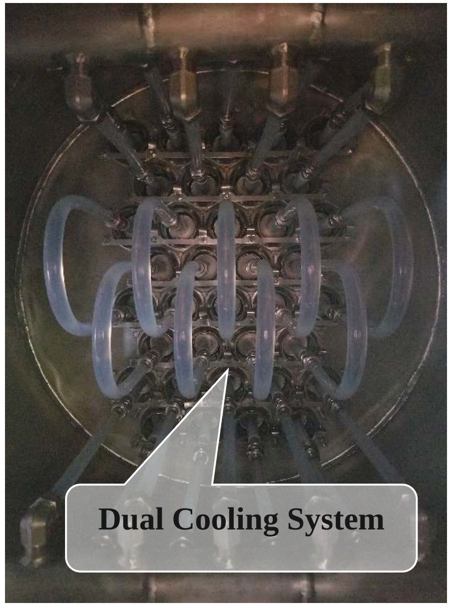
Dew Point Monitoring

Dew Point Monitoring

- GOX and air must be dry (maximum dewpoint of less than -76° F)
- Moisture forms nitric acid in generator shell and can cause damage to dielectrics
- Monitor is located in Ozone Building Mechanical Room
- System should be purged for an extended period following extended shutdowns.

Ozone Cooling System Components

- Closed Loop Cooling Water Pumps
- Closed Loop Heat Exchangers
  - Open Loop Cooling Water taken from Plant Potable Water
- DI Water Ion Exchanger & Water Conditioner
- Supplies cooling water for Ozone Generators and PSU's
- Dual Cooling System



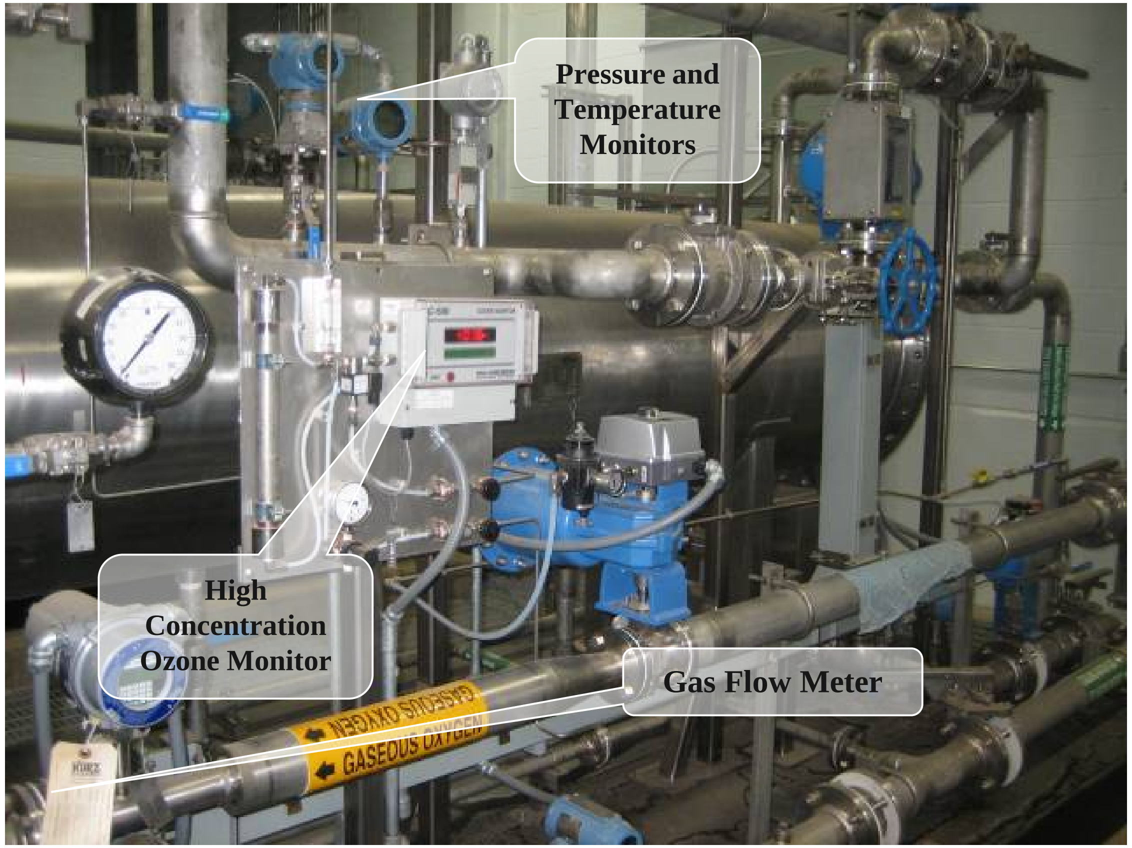
Ozone System Components Instruments

Ozone Generators

- Low flow and High Flow orifice plates
- Duty/Standby generators located in the Generator Room
- Instruments mounted on generators
- Power Supply Units (PSUs) are adjacent to each generator
- Power Supply Unit contains Local Control Panel

GOX flow rate into the generator is measured by calculating mass flow from differential pressure across installed orifice plate(s).

Max gas flow rate is 52 scfm @ 500 ppd, 8 wt% ozone



Side Stream Injection

Side Stream Pumps

- Located in Contactor Gallery

Venturi Mixer

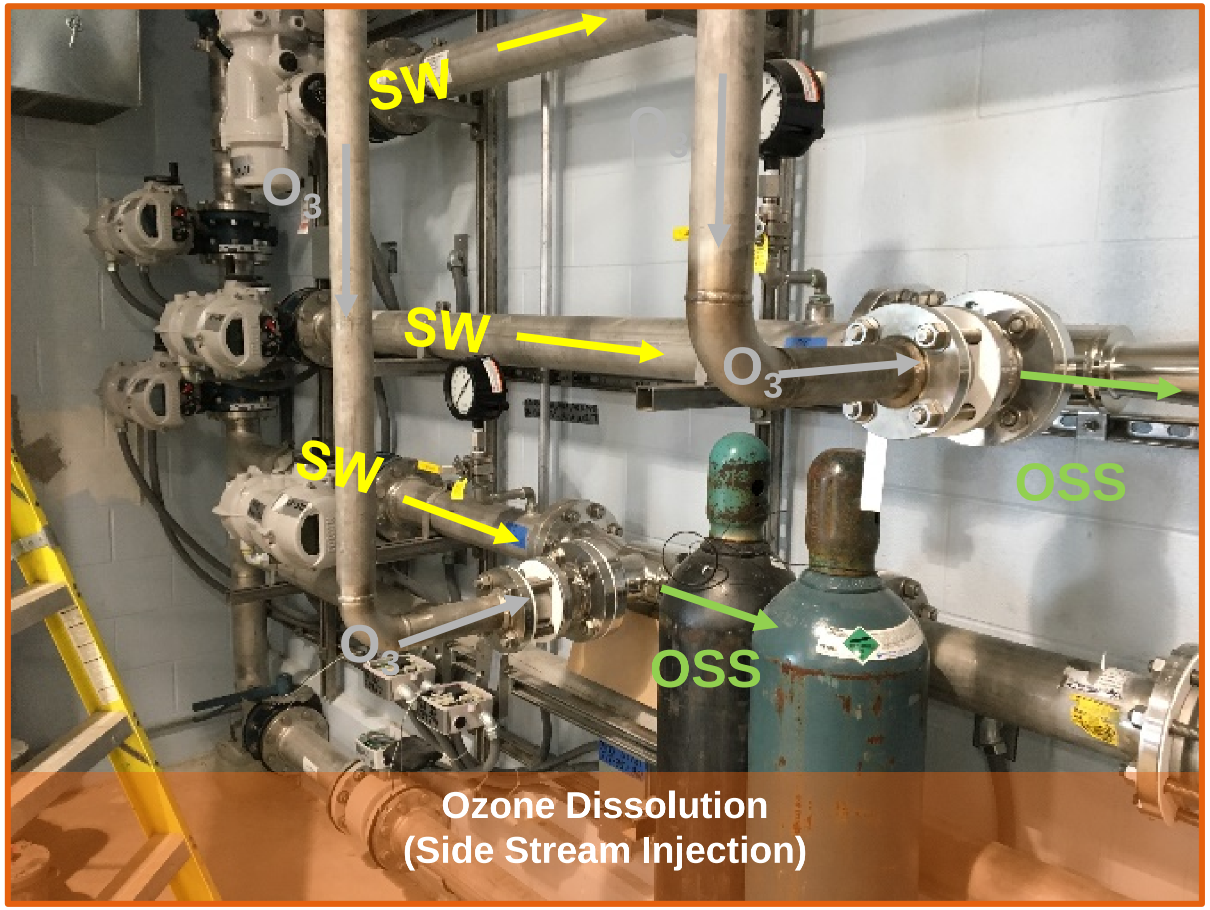
- Located in Generator Room
- Mixes ozone gas and settled water to form ozonated side stream

Nozzle Injector Manifold

- Located within each Contact Basin

Thermal Mass Flow Meter

Settled Water Side Stream Pumps

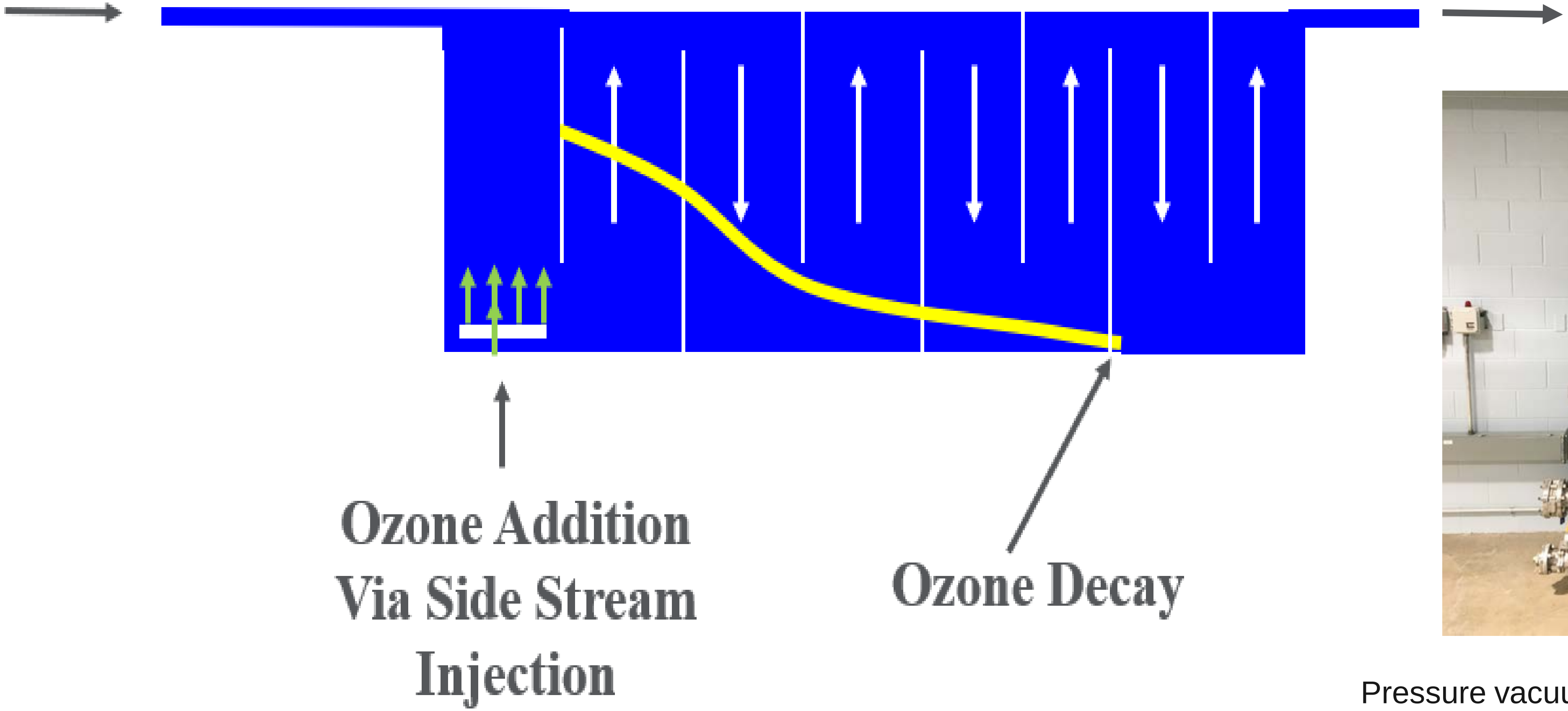


Ozone Dissolution (Side Stream Injection)

Venturi Mixer

Nozzle Injector Manifold

Ozone Contactors

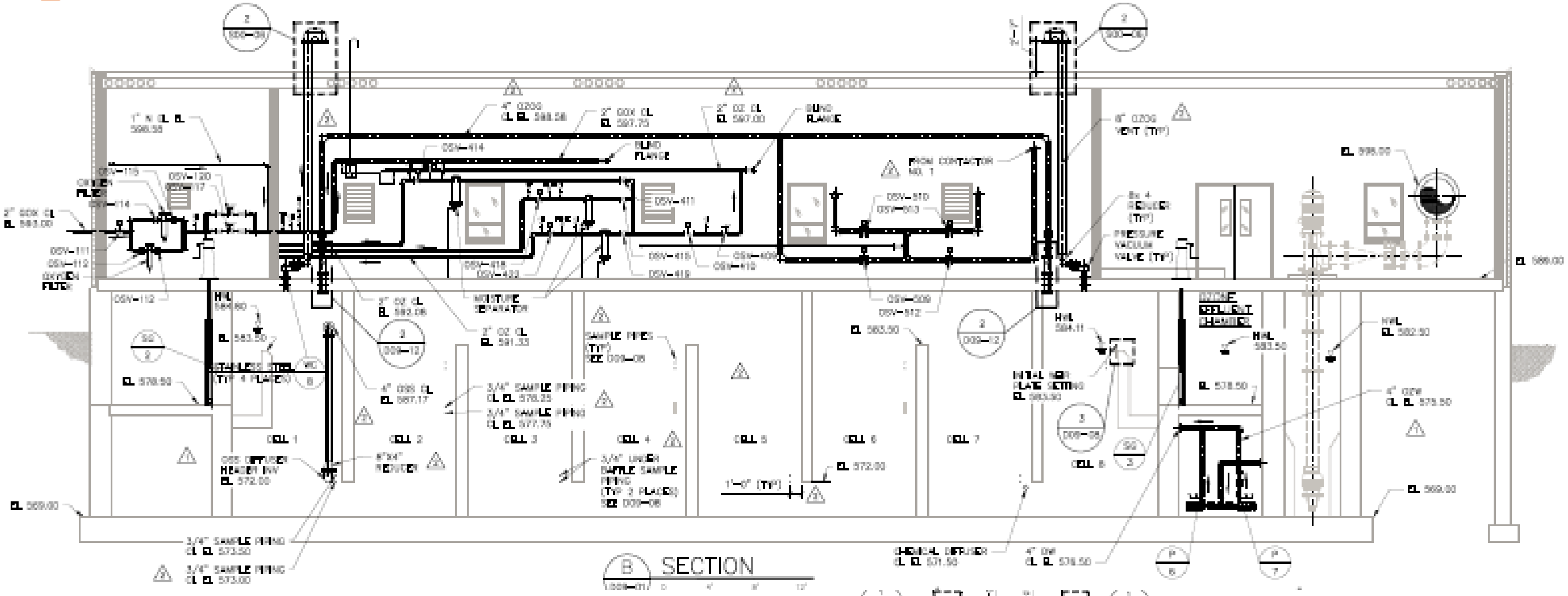


Pressure vacuum relief valve (right)
Contactor exit port to destruct (left)

Ozone Building – Section Cuts

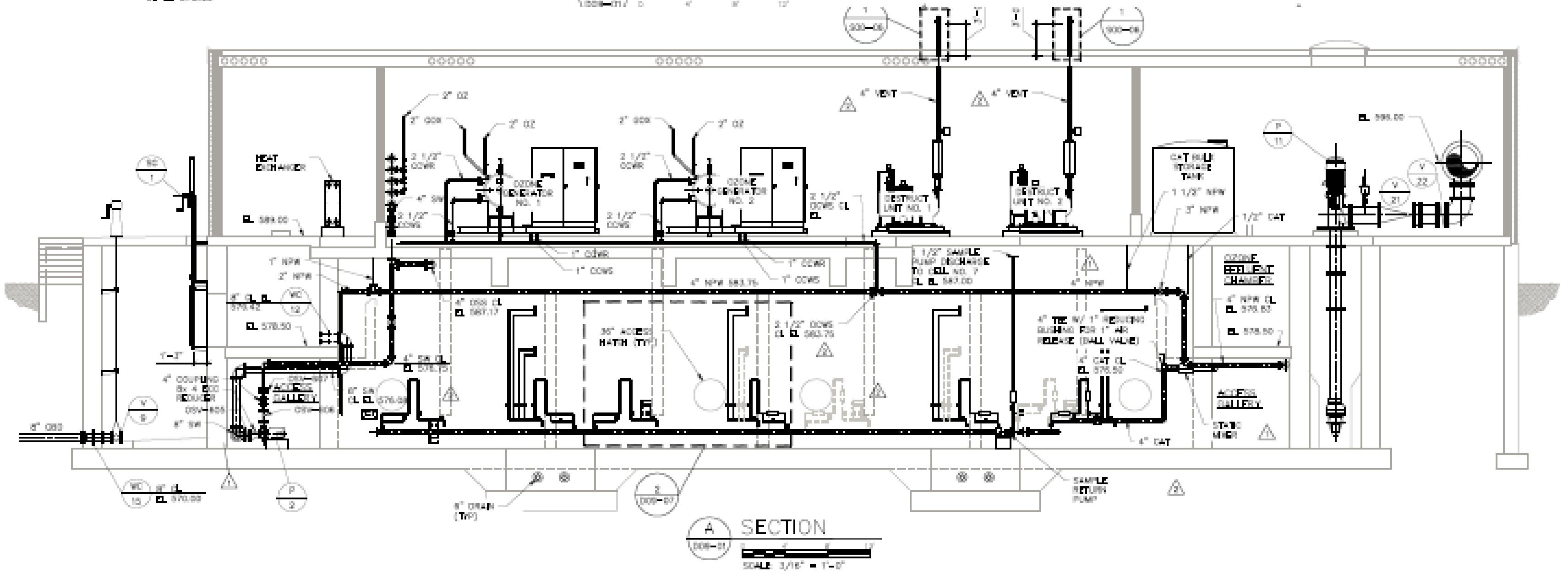
Contactor Cells

- Oxygen Gas Piping
- Ozone Gas Piping
- Low Lift Pumps
- Contactor Baffles



Contactor Gallery

- Heat Exchangers
- Ozone Generators
- Ozone Destruct Units
- CAT System
- Sampling Locations



Ozone Contactors Monitoring

Ozone Monitoring Requirements

Dissolved Ozone Monitors
(Located in Contactor Gallery)

Hach Ampules and Analyzer for Calibration
(or Indigo Method)

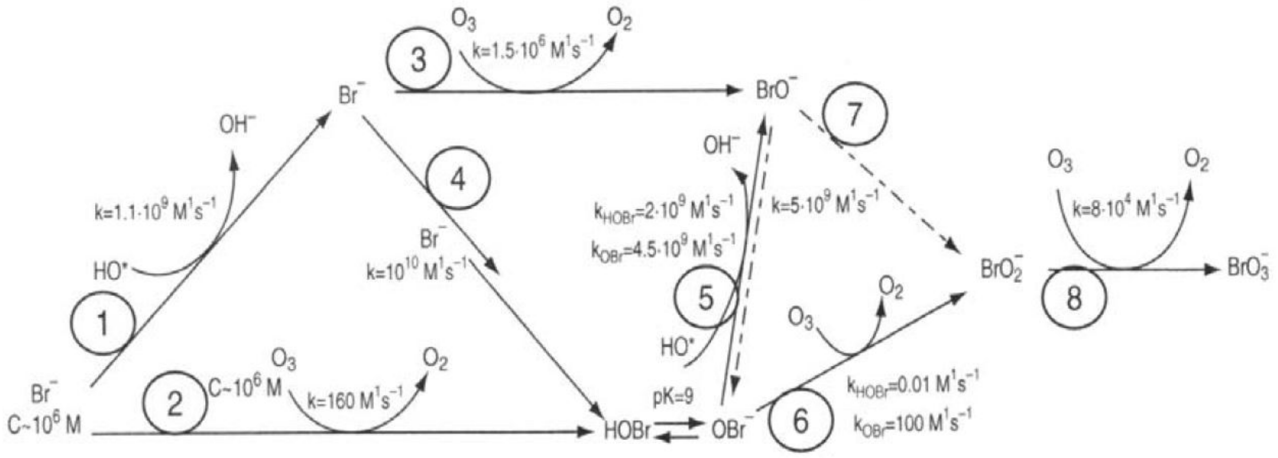
Ozone Contactors Monitoring

Ozone addition can result in bromate formation

- Bromate MCL: 10 µg/L

Bromate formation factors

- Source Water
- Ozone Dose
- Contact Time



Source: von Gunten, U., *et. al.*, 1996, Bromate Formation in Advanced oxidation Processes. *JAWWA*, 88 (6), 53-65

Ozone Quenching System

Calcium Thiosulfate (CAT) Dosing System

- Located in Low Lift Pump Room
- Provides operational flexibility by allowing to dose ozone at higher concentrations

CAT System Components

- Bulk Storage Tank (2500 gal)
- Day Tank (150 gal)
- Transfer Pump (10 gpm)
- Dosing Pumps (5 gph)

Ozone Destruct System

Ozone Destruct Units

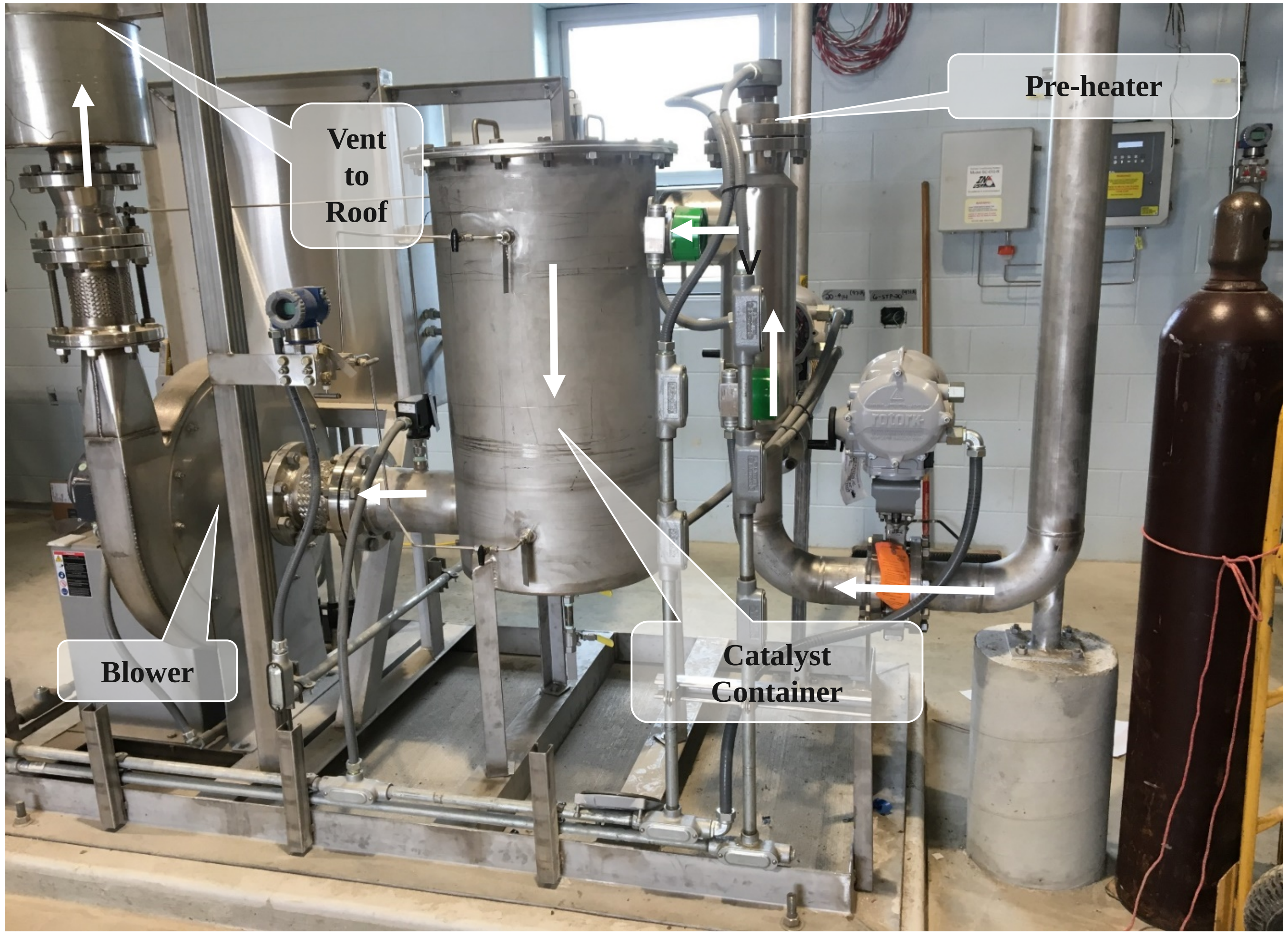
- Duty/Standby units located in Generator Room
- Creates vacuum within contactor head space
- Removes off gassed ozone
- Each unit is piped to both contactors

Destruct Unit Components

- Pre-heater
- Destruct Catalyst
  - Chlorine inactivates catalyst
  - Requires periodic replacement
- Blower

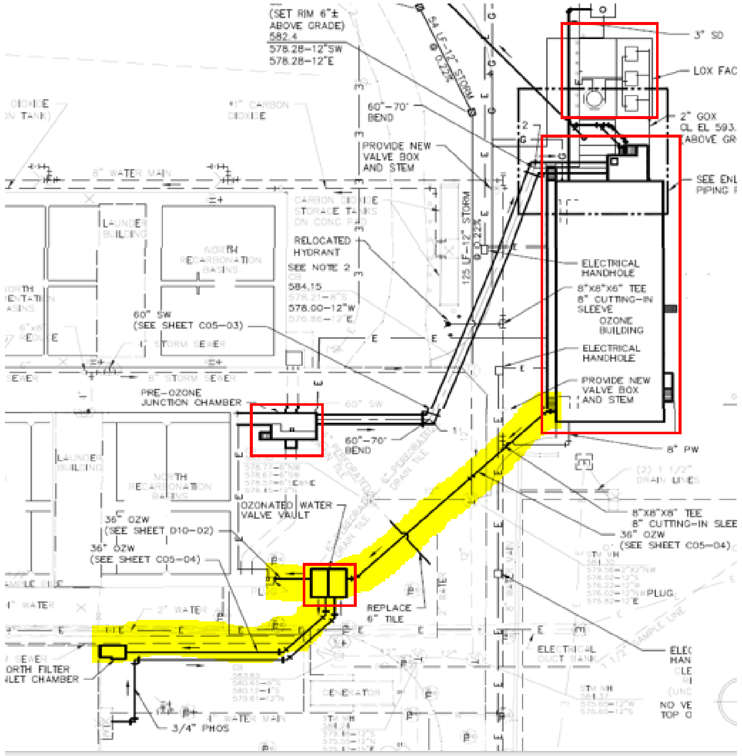
Pressure/Vacuum Relief Valves

- Allows air into contactors
- Vent to roof in case of blower failure



Low Lift Pumps to Filters

Three 8 MGD pumps
40 hp variable speed motors
Level controlled
Future pump provision included
Two discharge options to existing filters



Filter Modifications

Remove surface wash

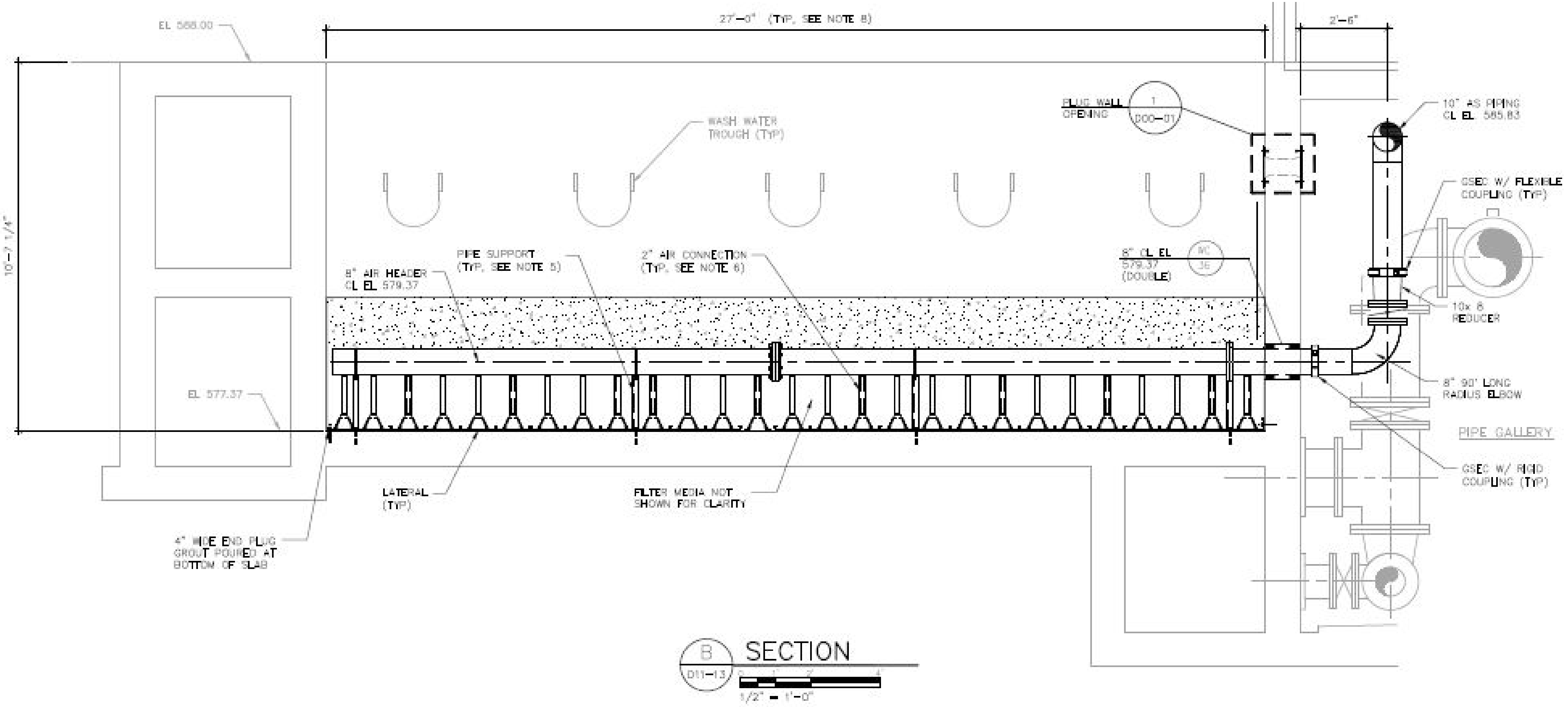
Remove anthracite & sand media

Remove clay and PVC block underdrains

Filter Modifications

- New Underdrains with air scour capability and air/water backwash
- 33" GAC
- 6" sand
- Maintain chlorinated backwash
- Filter console modifications

Design Modifications: Section View



Air Scour System

Oregon WTP HAB Infrastructure Improvements			
Construction Contract	Original Bid	Final Contract	Change Order
General & Mechanical	11,379,360.00	11,354,846.13	(0.22)%
Electrical & Instrumentation	1,218,000.00	1,275,829.05	4.75%
Total	$ 12,597,360.00	$ 12,630,675.18	0.26%

Project Financed Using: Ohio EPA Water Supply Revolving Loan Account HAB
Ohio Public Works Commission

Construction Schedule	
Advertise	November 9, 2015
Bid Opening	December 18, 2016
Notice to Proceed	March 14, 2016
Substantial Completion	March 23, 2018

Design & Consultancy for natural and built assets

Questions?

Thank you!

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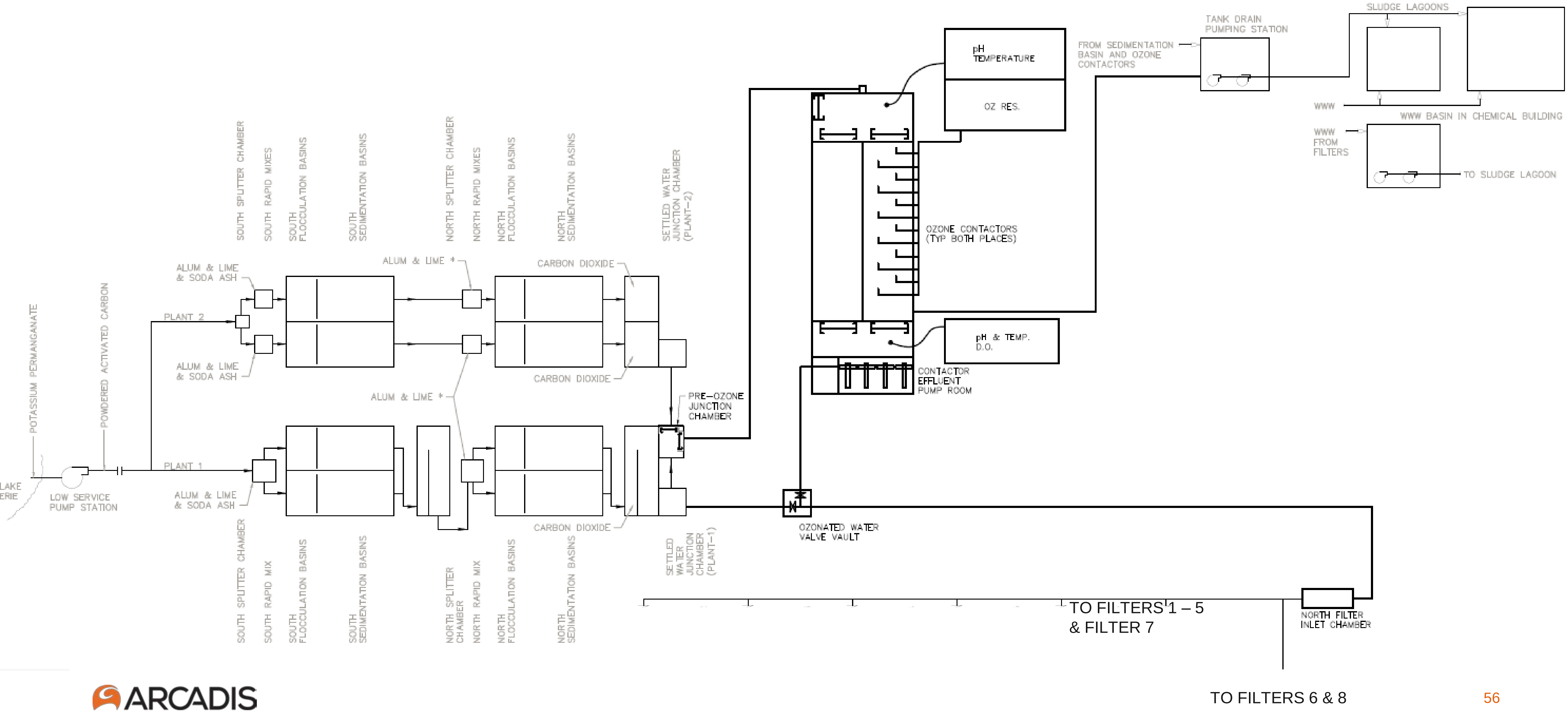
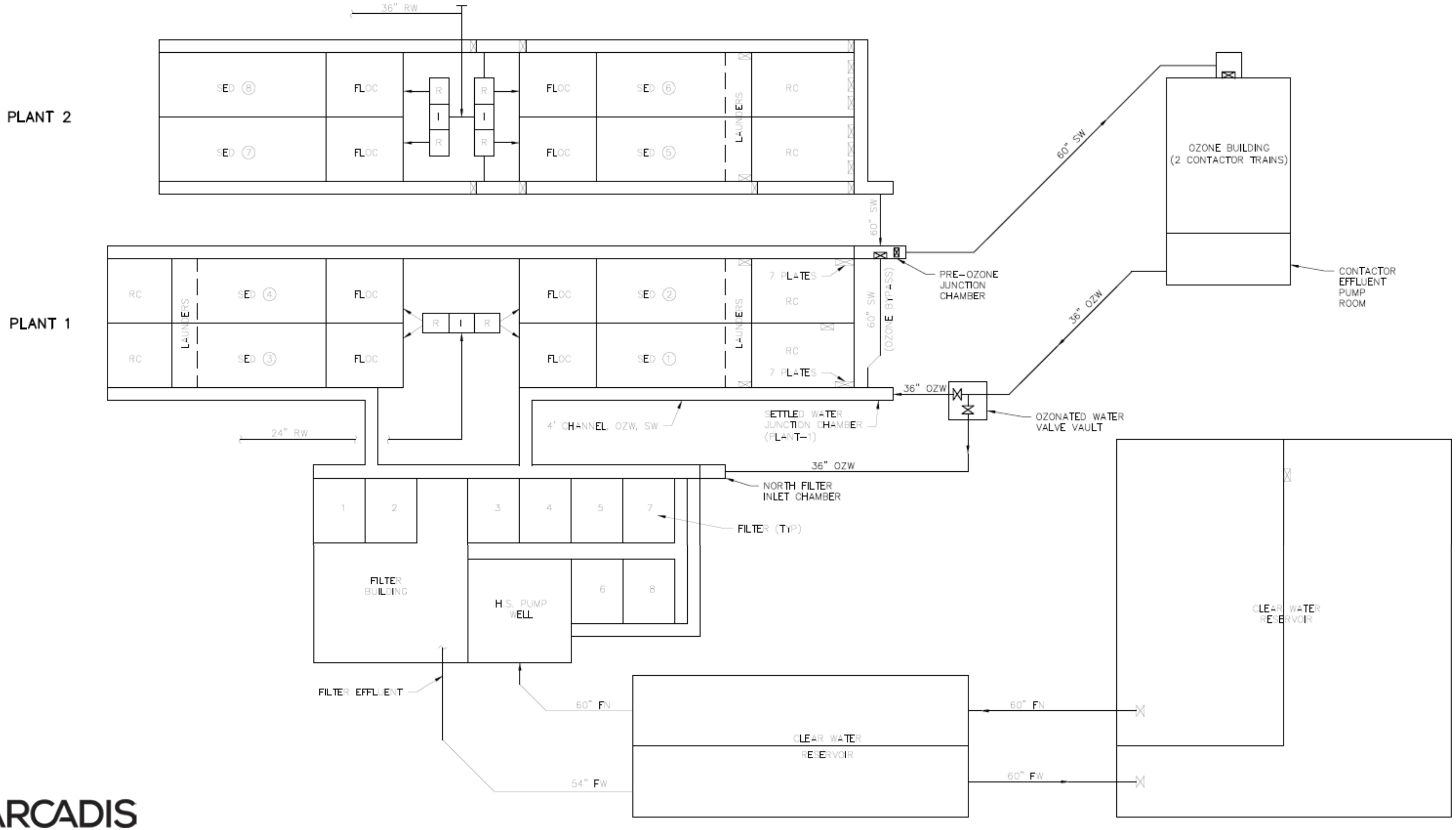
Professional Engineer - Ohio and Michigan

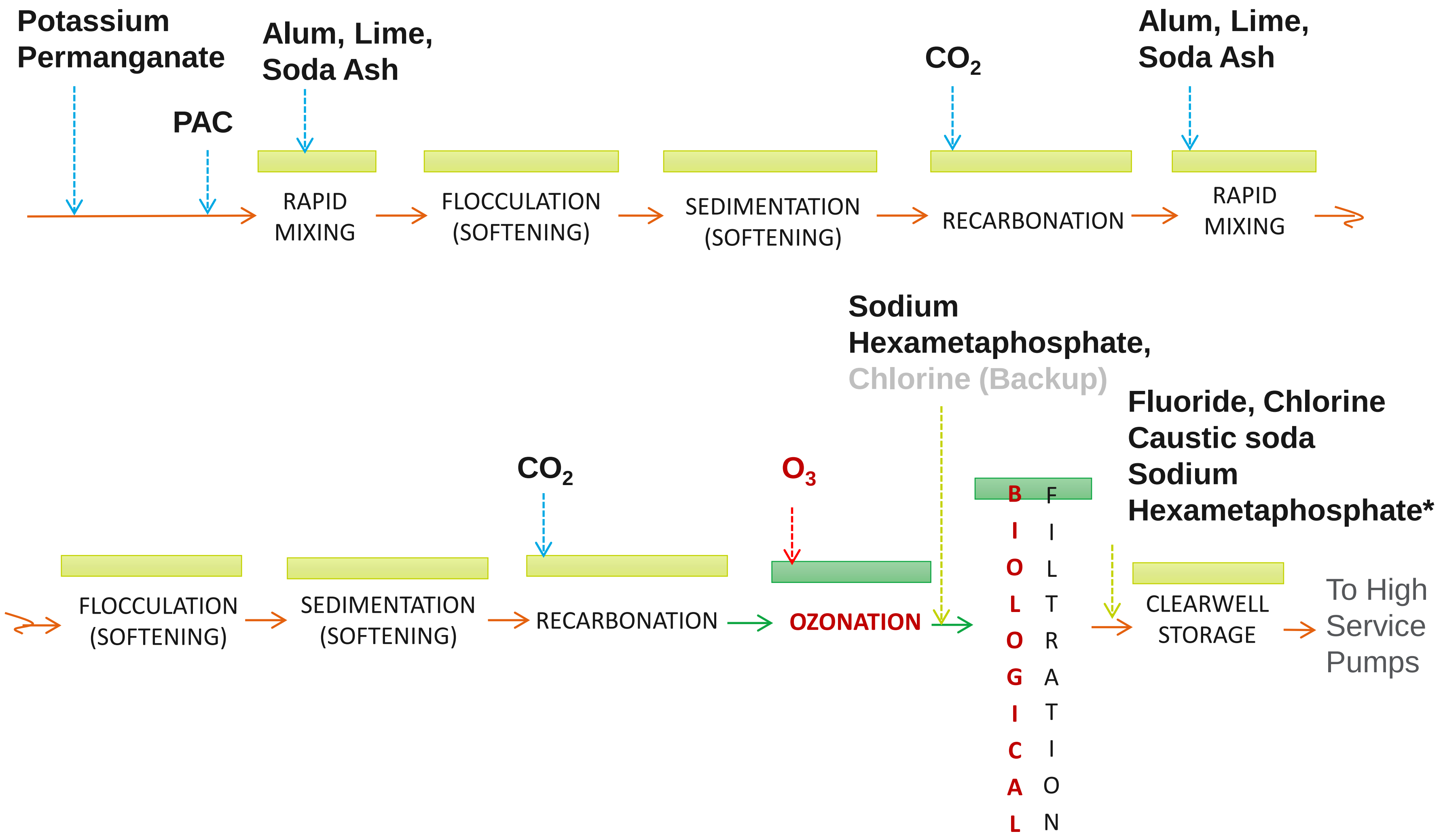
Plant Flow Diagram



Plant Hydraulic Flow Diagram



Oregon, Ohio Water Treatment Plant - Proposed



Plant Yard Piping Plan

Pre-Ozone Junction Chamber

LOX Facility

Ozone Building

Ozonated Water Valve Vault