Addition of 1,4-dioxane removal system to municipal water treatment plant: pilot to operation

Ali Ling, PhD, PE

Acknowledgements:

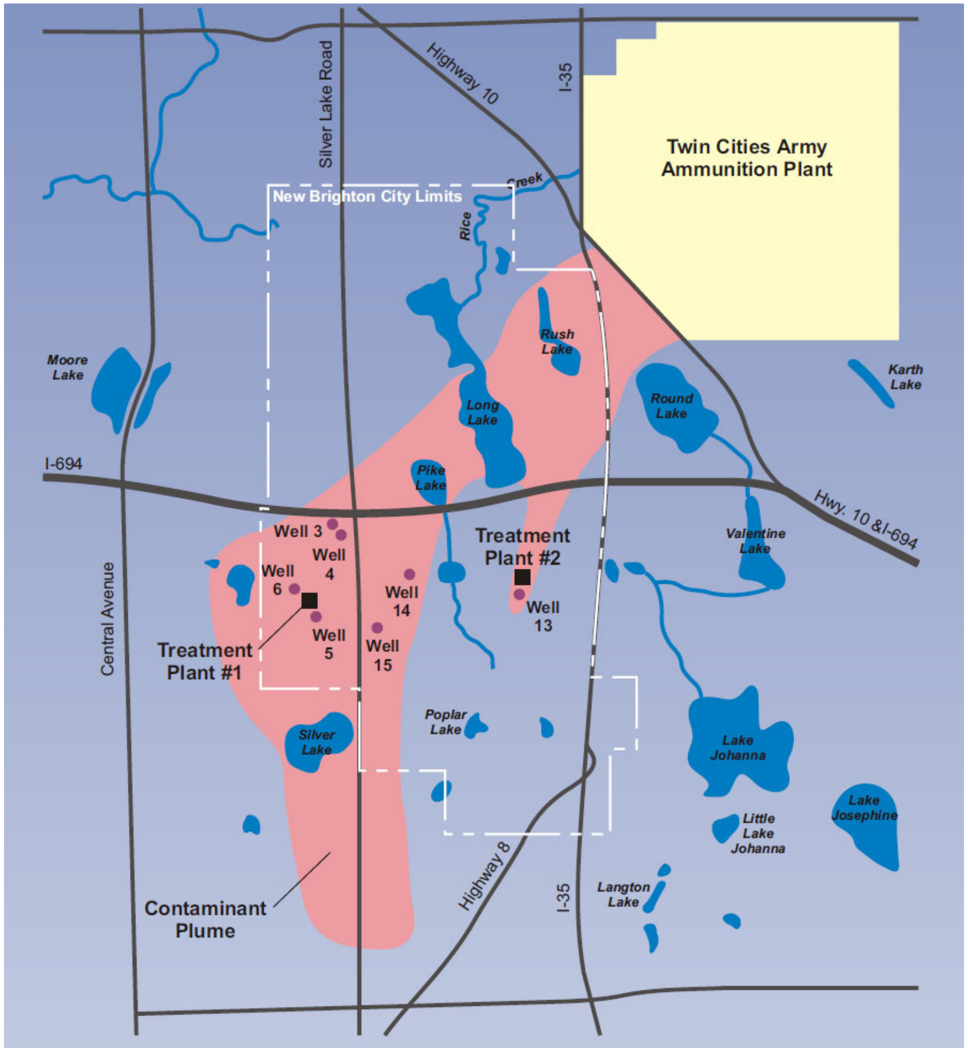
Katie Wolohan, PE

Julie Macejkovic, PE

Abby Morrisette, PE

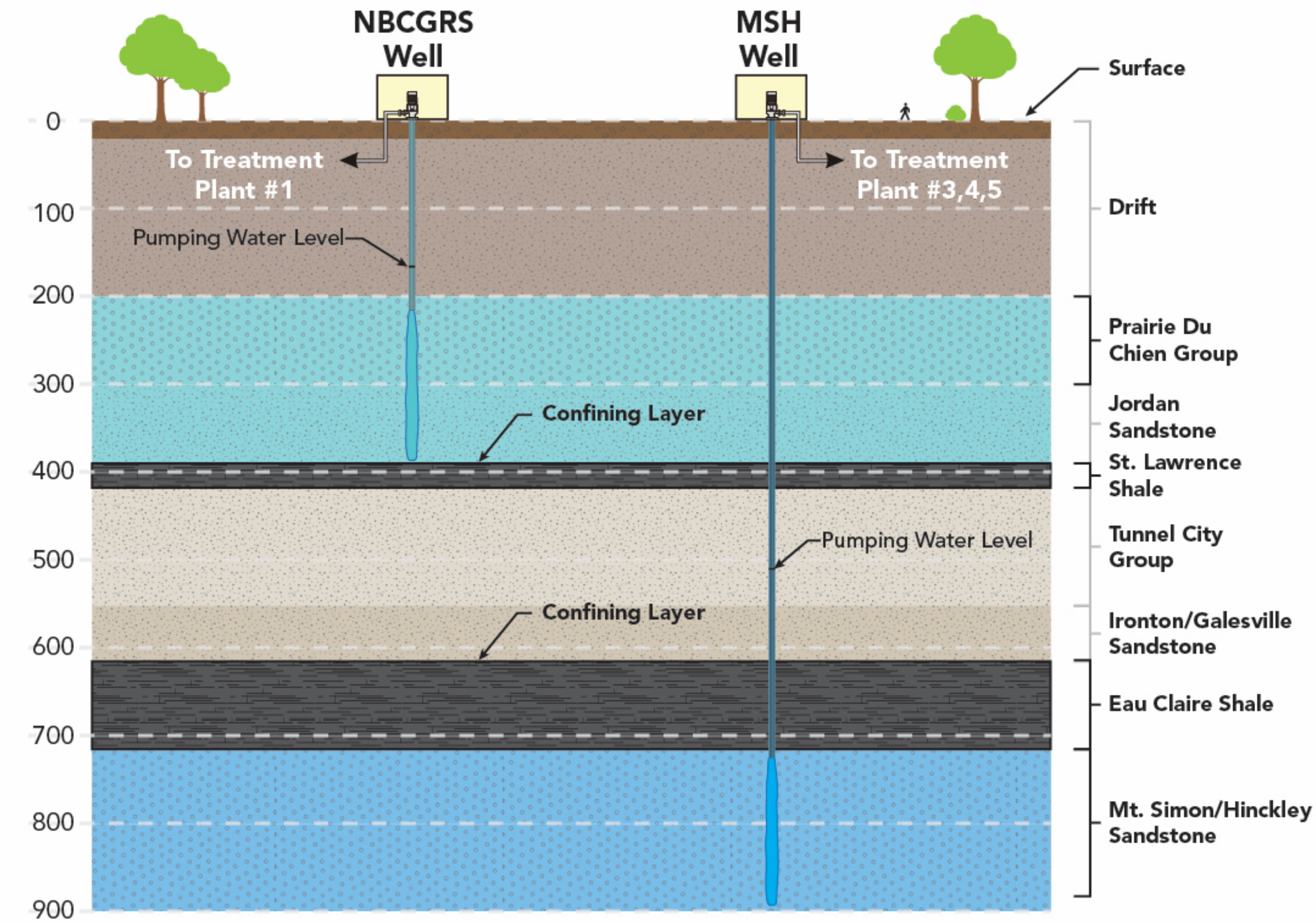
Andy McCabe, PhD

City of New Brighton, Minnesota groundwater contamination



A single treatment system that solves two problems associated with TCAAP groundwater contamination.

New Brighton groundwater sources



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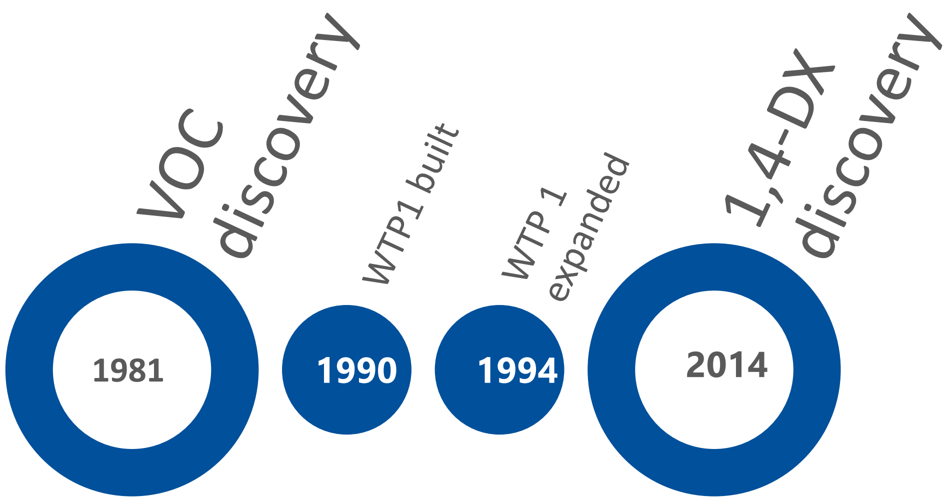
Contaminated groundwater treatment history



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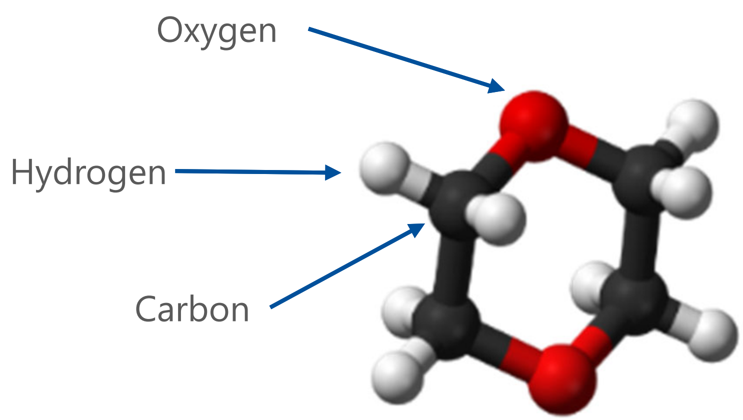
1,4-Dioxane



1,4-dioxane molecule

	1,4-Dioxane Concentration
Federal SDWA	No limit
Michigan Drinking Water Criterion	7.2 µg/L
Minnesota Health Risk Limit (since 2013)	1.0 µg/L
New Brighton WTP1 wells	1.0-6.8 µg/L

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Pilot planning:1,4-Dioxane treatment technology evaluation

Research potential technologies

Select technology for pilot test

2 advanced oxidation processes (AOPs)
- Demonstrated application at scale
- Removal of 1,4-DX to target levels
- Scalable pilot potential

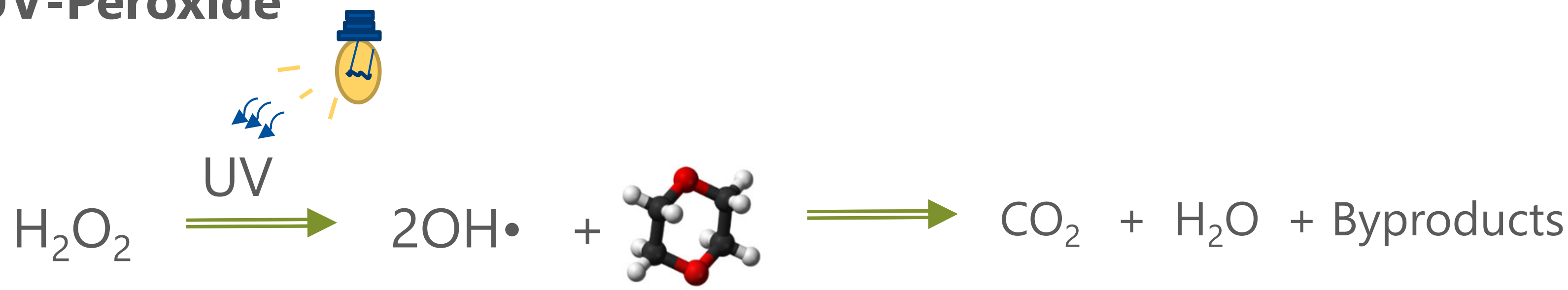
Pilot planning: test equipment

APT HiPOx Pilot System

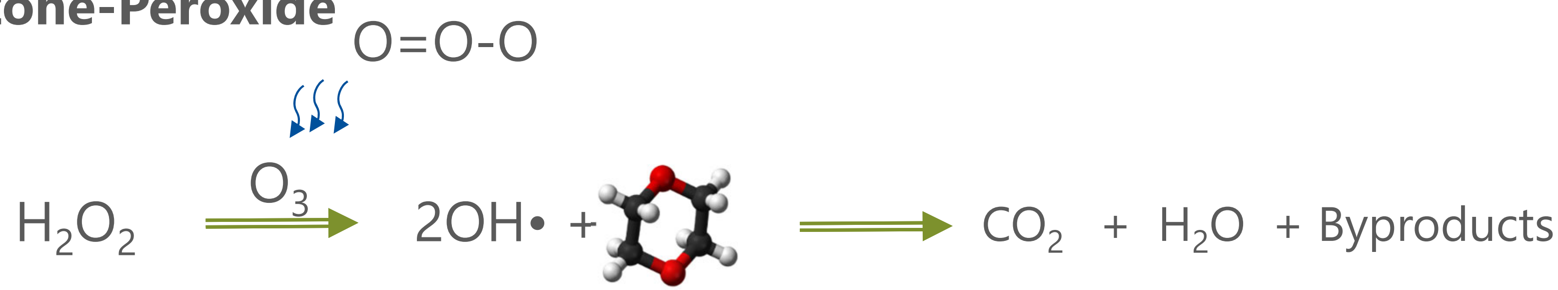
Trojan UVPhox Pilot System
(low pressure UV lamps)

Pilot planning: chemical treatment of 1,4-Dioxane by advanced oxidation

UV-Peroxide



Ozone-Peroxide



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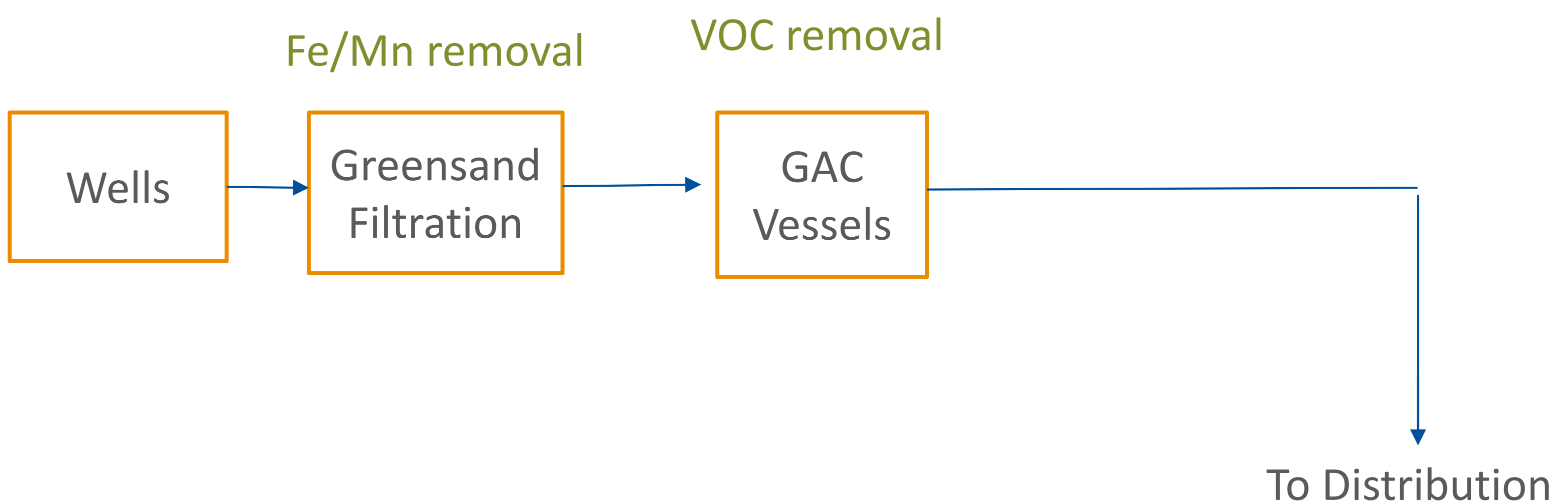
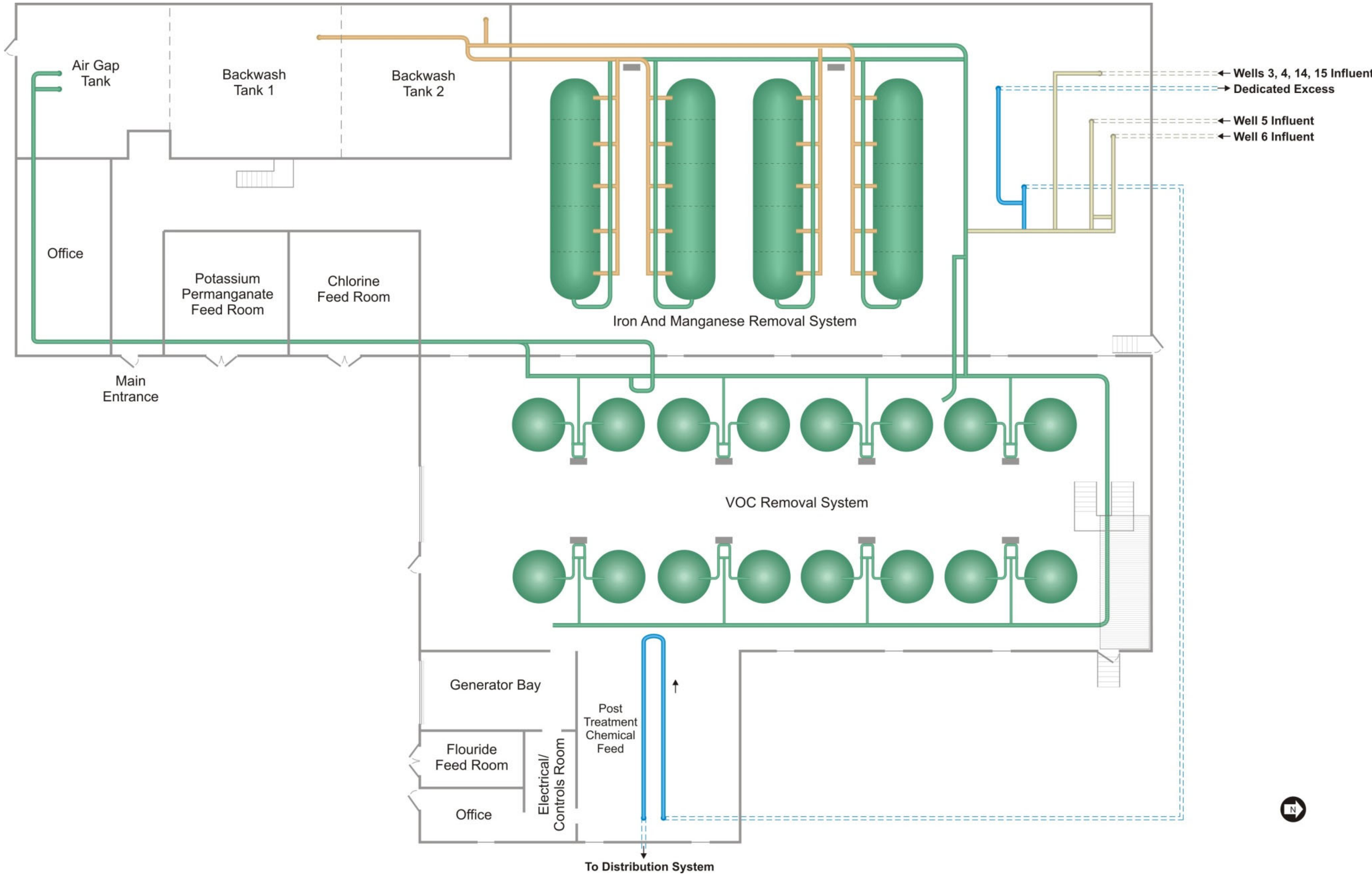
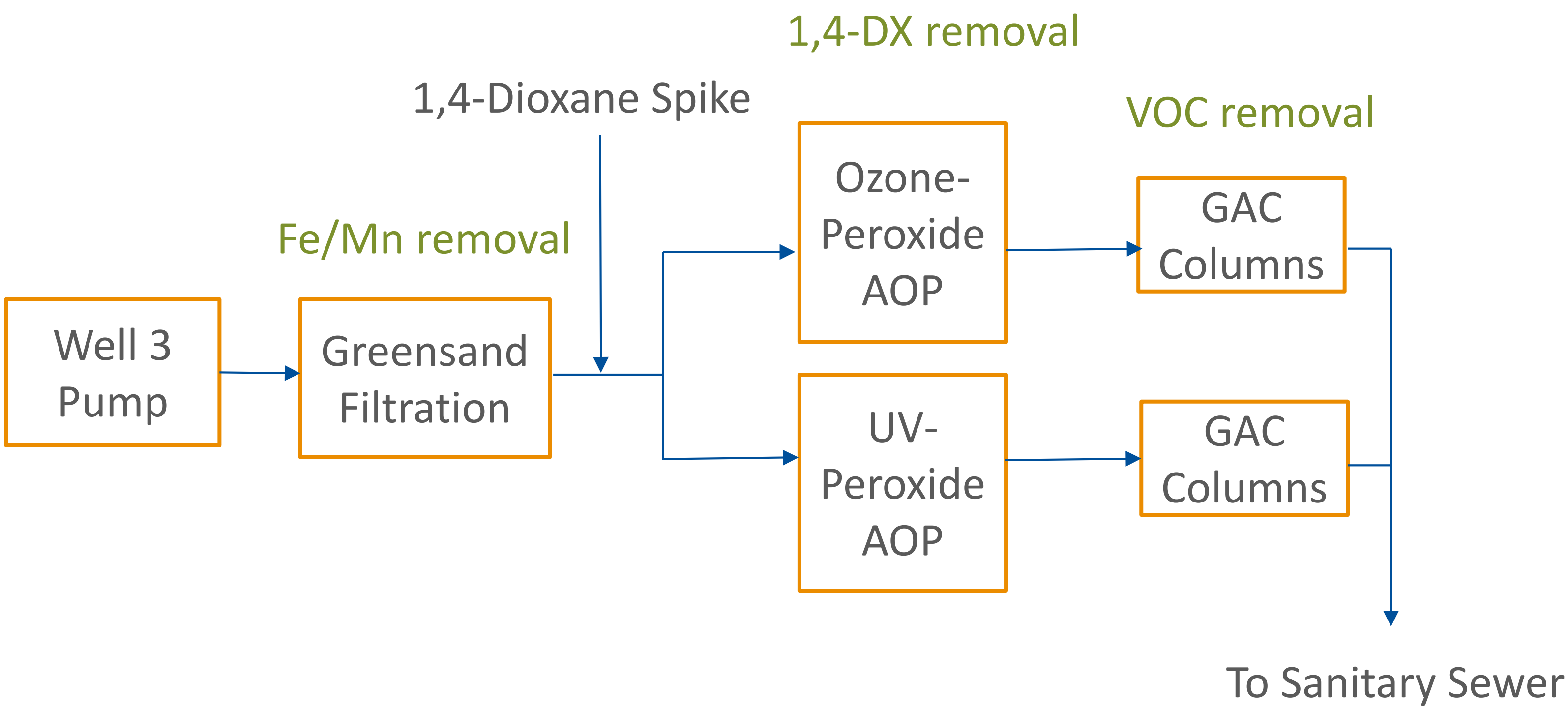
Pilot planning: existing WTP1 processes




Air Gap Tank
Backwash Tank 1
Backwash Tank 2
Wells 3, 4, 14, 15 Influent
Dedicated Excess
Well 5 Influent
Well 6 Influent
Office
Potassium Permanganate Feed Room
Chlorine Feed Room
Iron And Manganese Removal System
Main Entrance
VOC Removal System
Generator Bay
Post Treatment Chemical Feed
Flouride Feed Room
Electrical/ Controls Room
Office
To Distribution System
N

Pilot planning: WTP1 process with AOP addition

Designed 50 gpm pilot to simulate existing WTP1 treatment processes with AOP.



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Pilot Planning: 1,4-Dioxane treatment technology evaluation

Research potential technologies

Develop screening criteria

Select technologies for pilot test

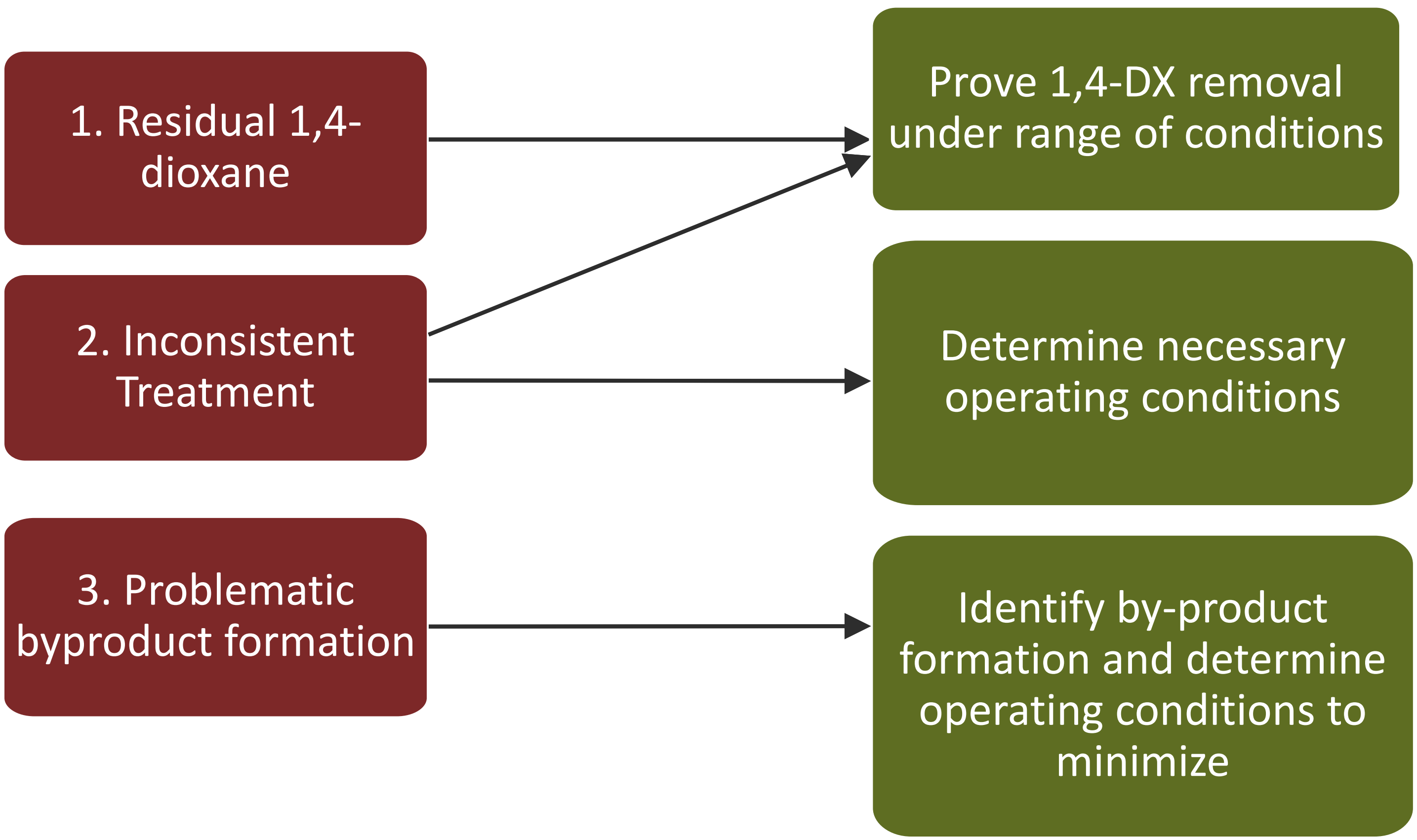
Perform treatability testing

Two advanced oxidation processes (AOPs)

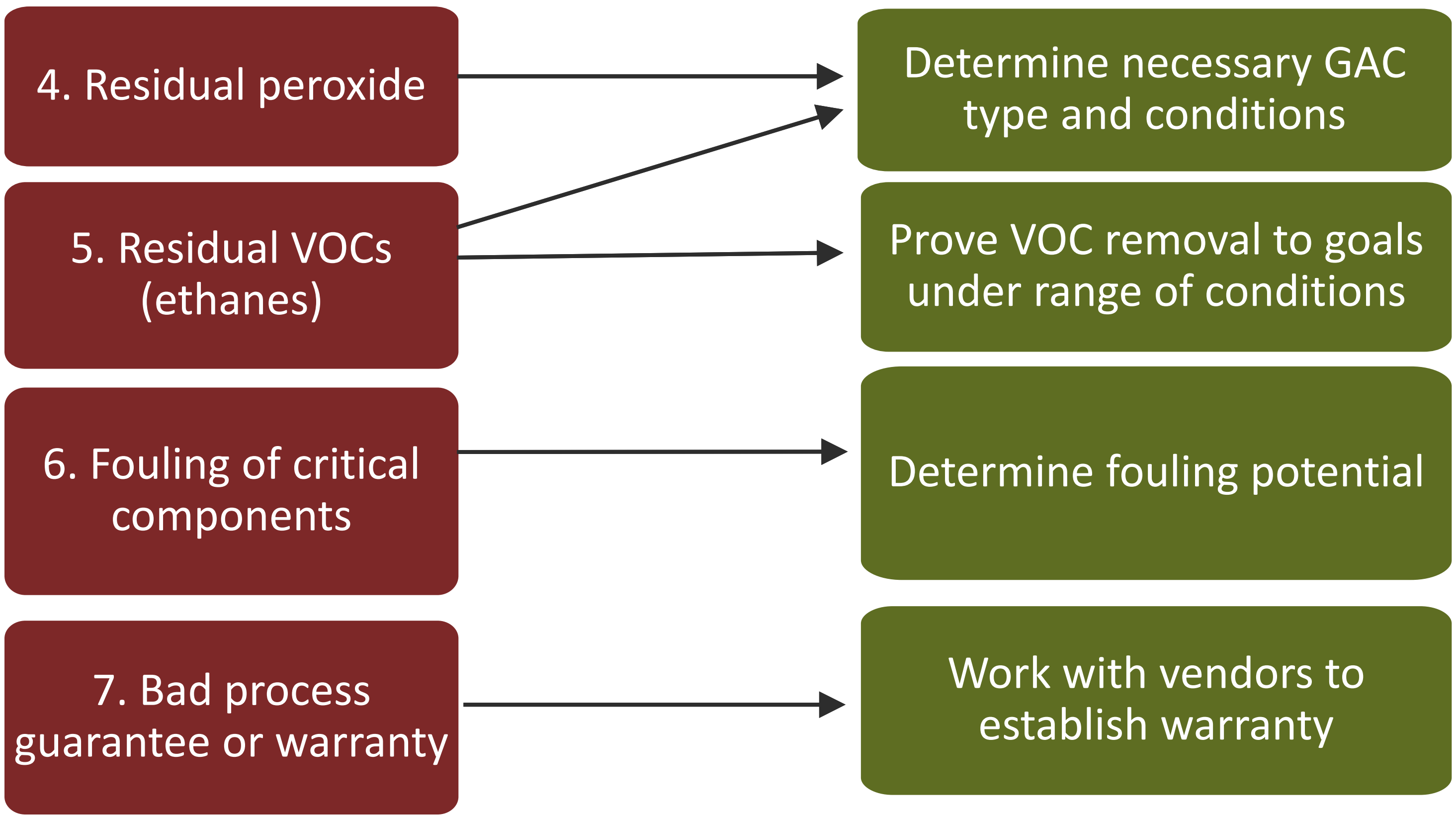
- Demonstrated application at scale
- Removal of 1,4-DX to target levels
- Scalable pilot potential

Pilot planning: risk assessment

Pilot planning: risks and objectives



Pilot planning: risks and objectives



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Pilot planning: testing phases and runs

Phase	Description	Duration (6 months total)
0	Pilot Start-Up and Training	1 month
1	AOP Optimization	3 months
2	Continuous Run	2 months
3	GAC Optimization	5 months (concurrent *with Phases 1 and 2*)
4	Hydroxyl Scavenger Testing	Short; conducted when convenient

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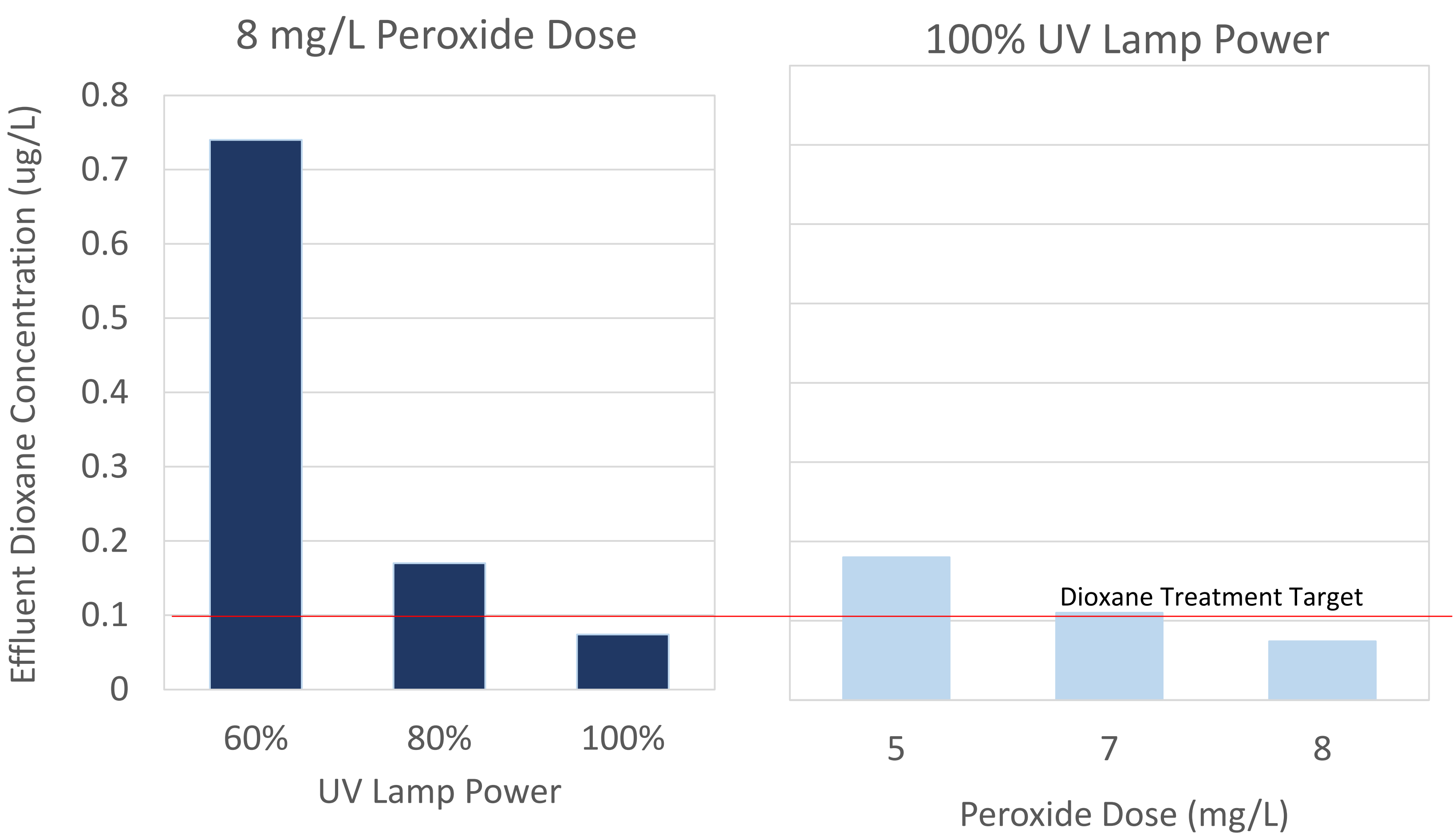
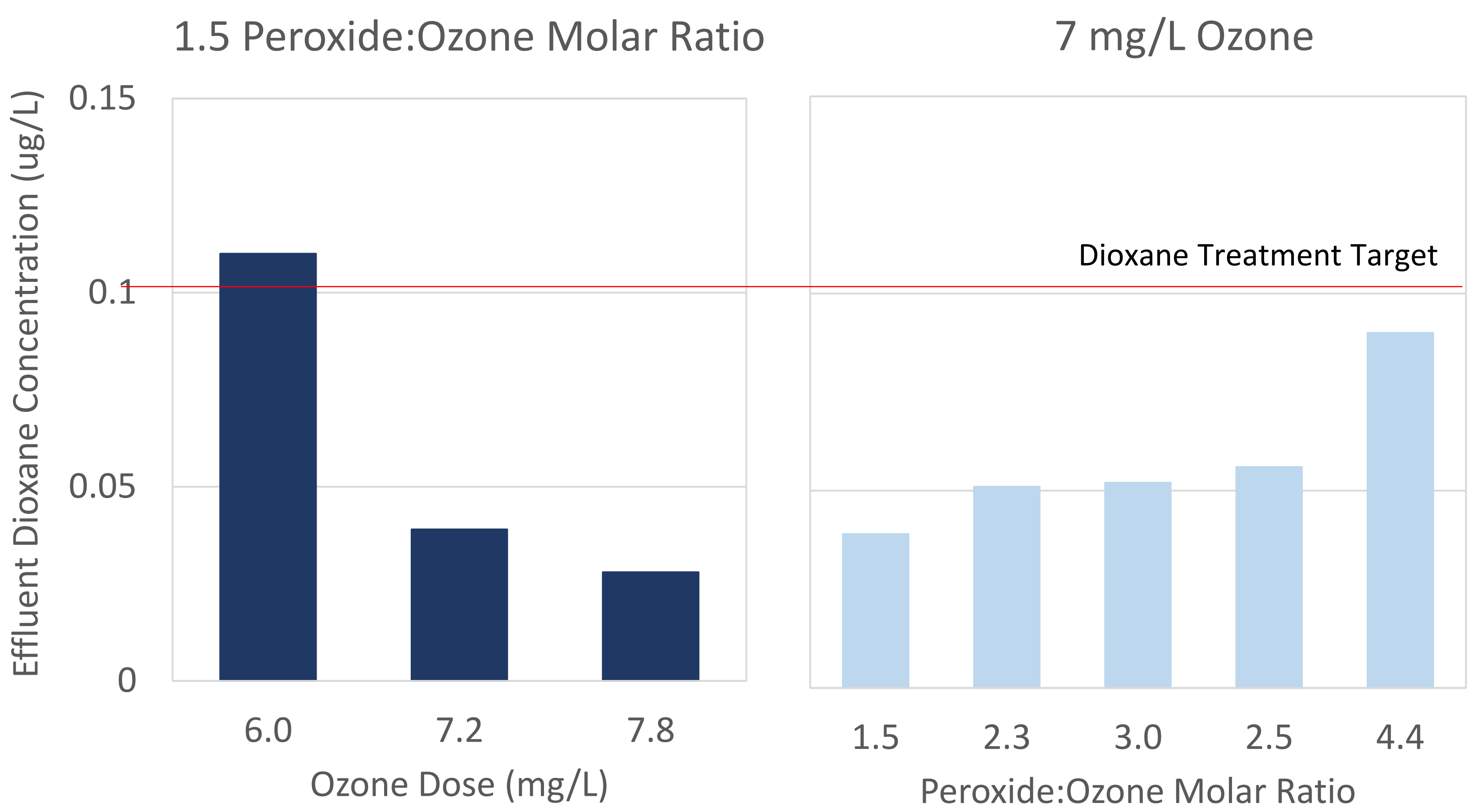
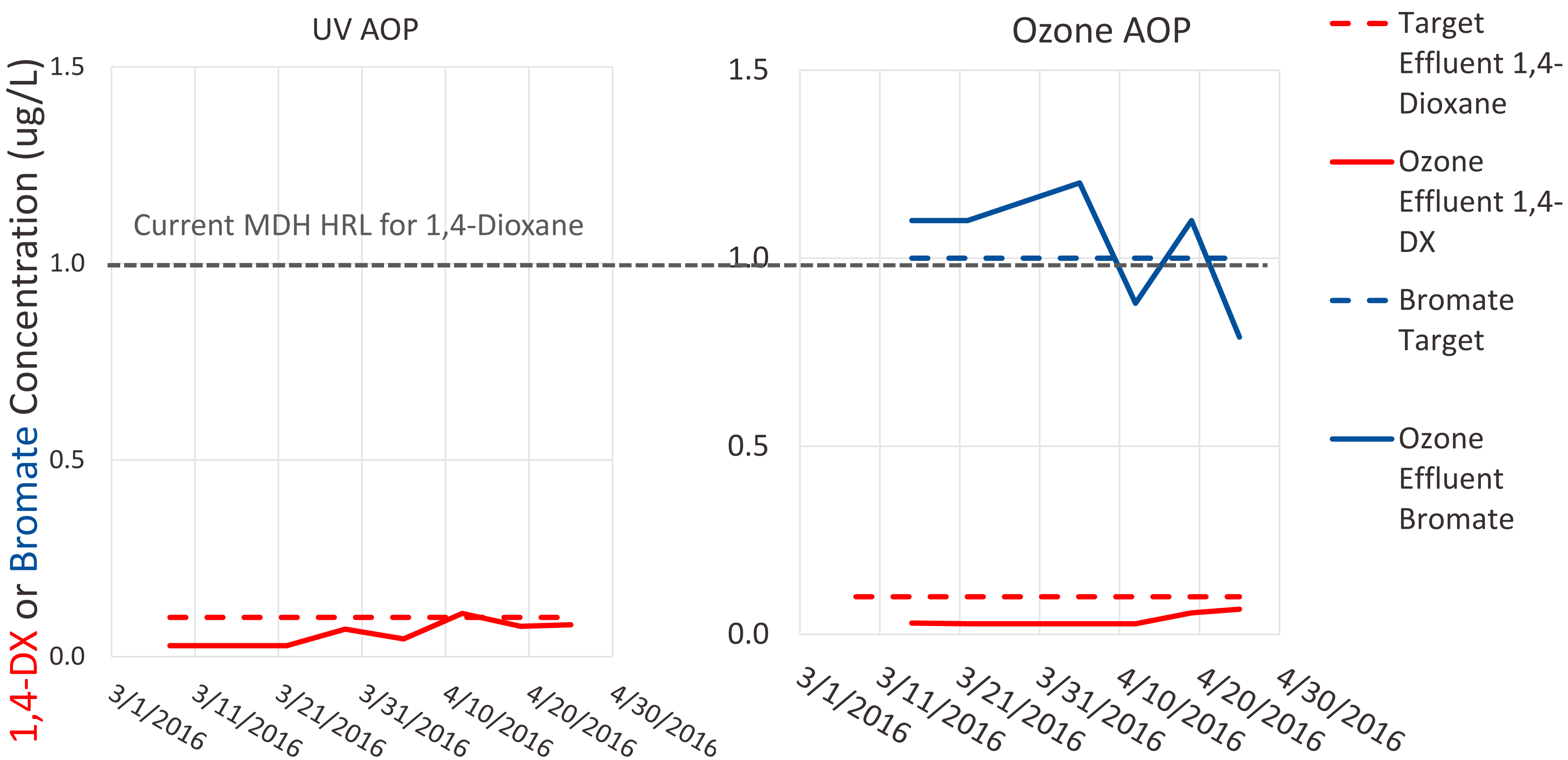
Results: operational settings – UV AOP



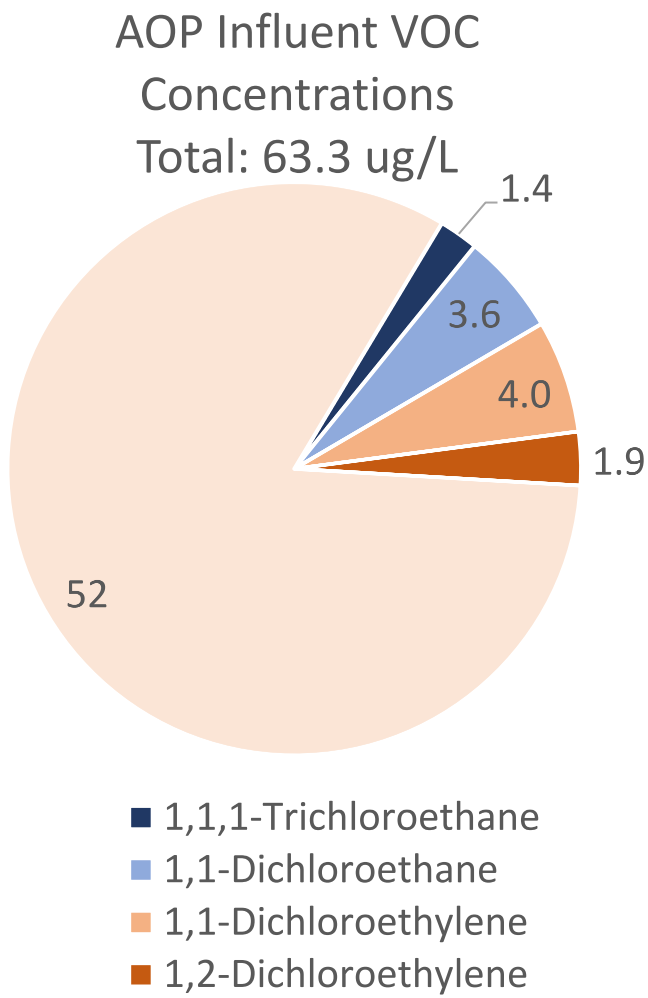
Results: operational settings – Ozone AOP

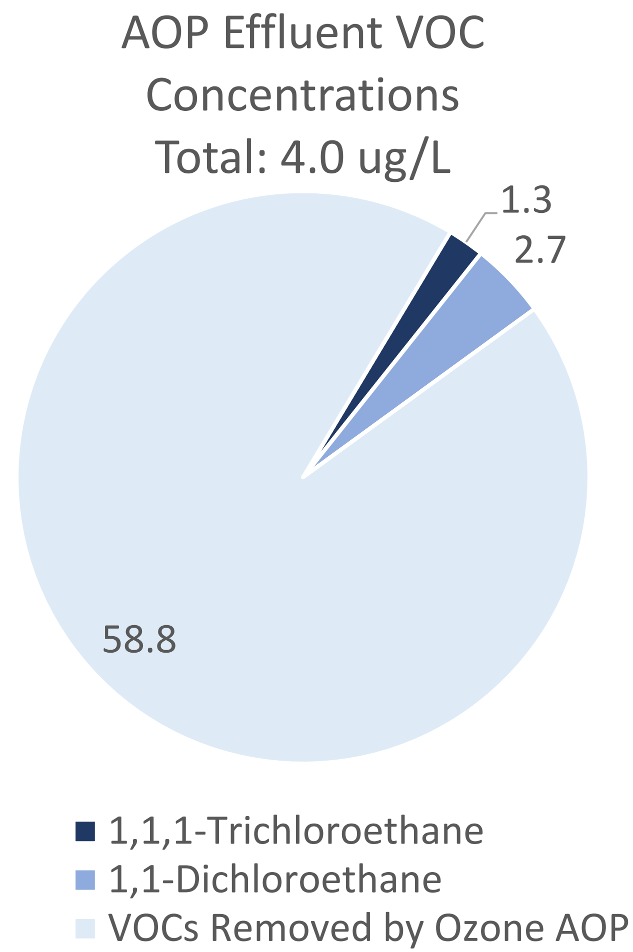


Results: 1,4-DX removal consistency

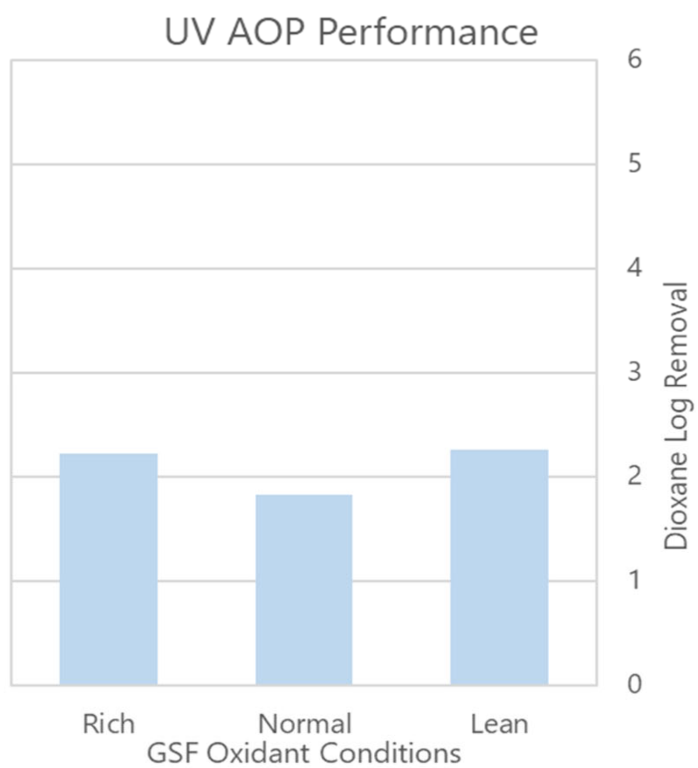


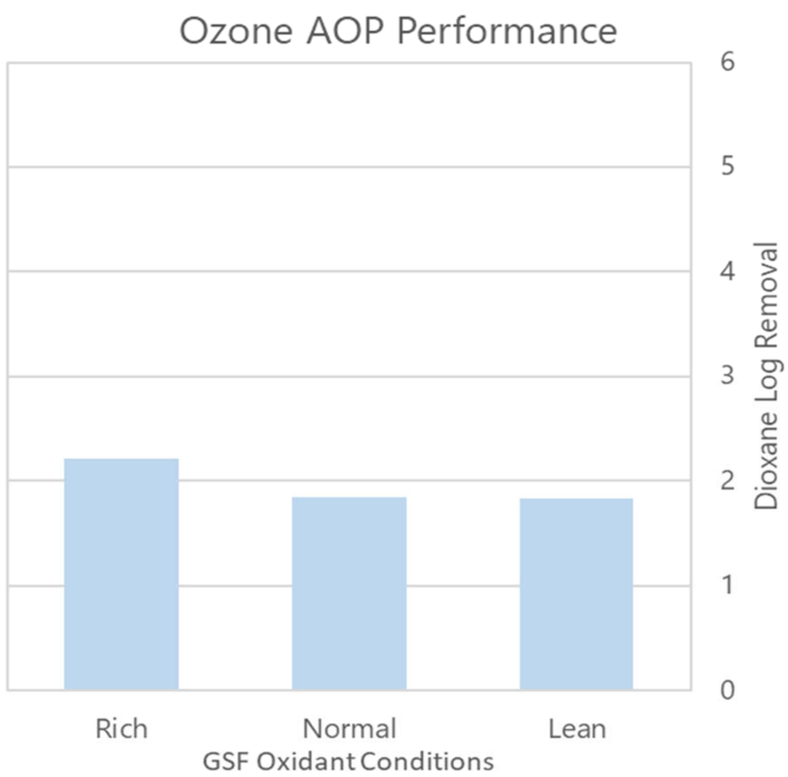
Results: VOC removal by AOPs



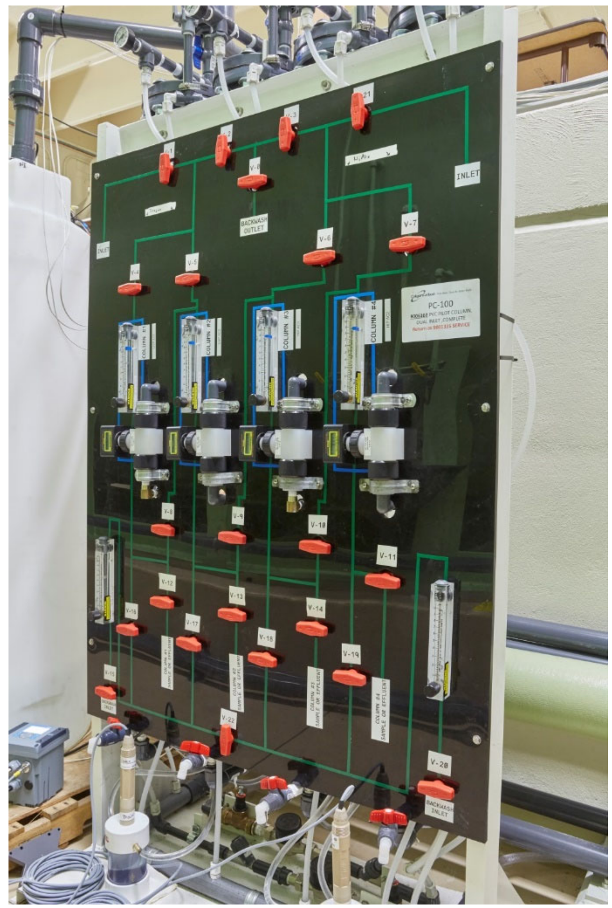


Results: sensitivity to GSF performance





Results: effect of AOP on downstream GAC



Currently-used Calgon F400 GAC effective for quenching peroxide - no special catalytic carbon required

Results: byproducts and distribution system

- VOC and SVOC tentatively identified compounds (TICs) scanned to measure byproducts
- Simulated distribution system bench tests to evaluate effect on disinfection by-product formation
- Assimilable organic carbon (AOC) through treatment steps analyzed to evaluate effect on microbial regrowth

Results: byproducts and distribution system

- VOC and SVOC tentatively identified compounds (TICs) scanned to measure byproducts
- Simulated distribution system bench tests to evaluate effect on disinfection by-product formation
- Assimilable organic carbon (AOC) through treatment steps analyzed to evaluate effect on microbial regrowth

No significant changes anticipated

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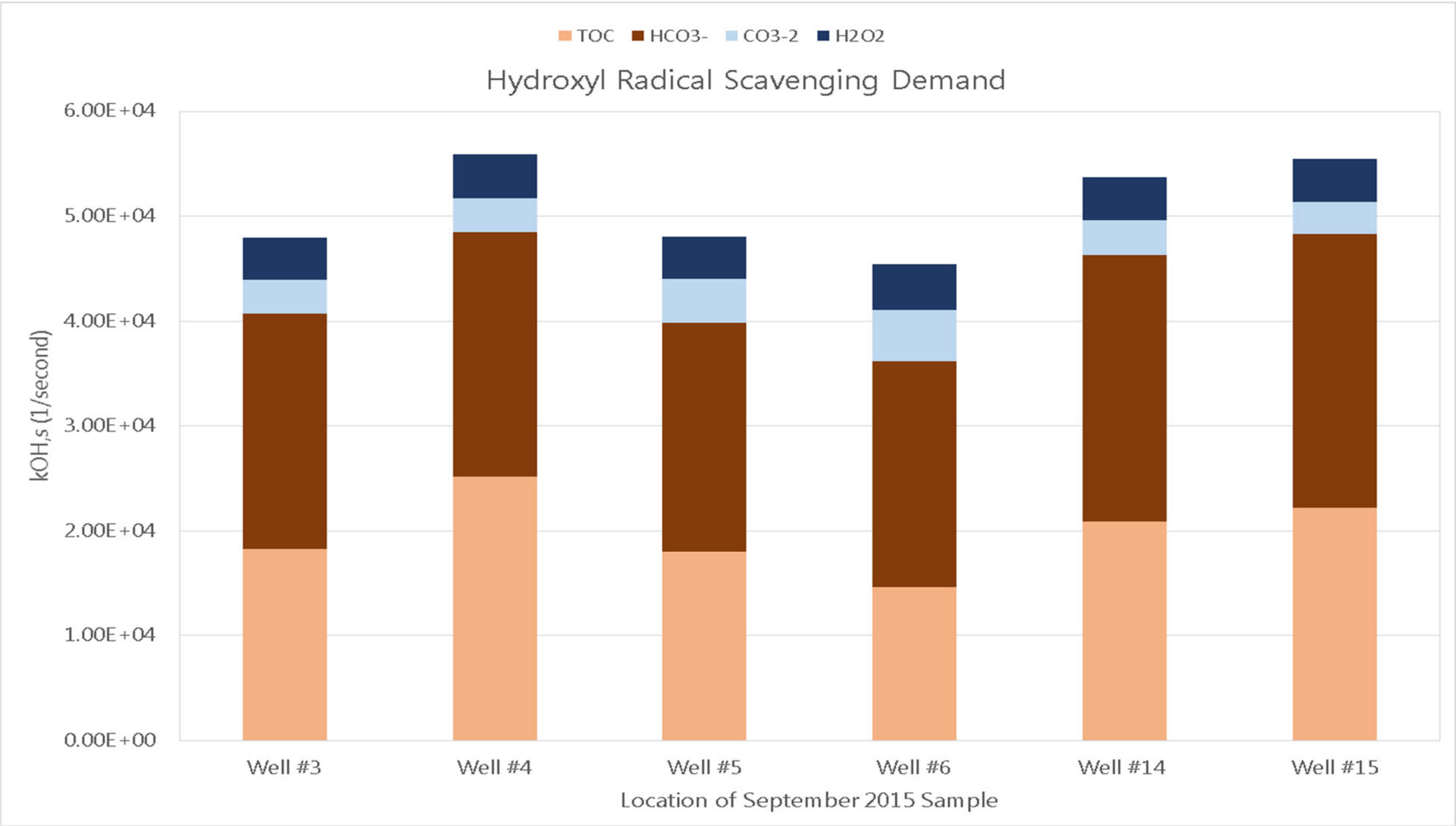
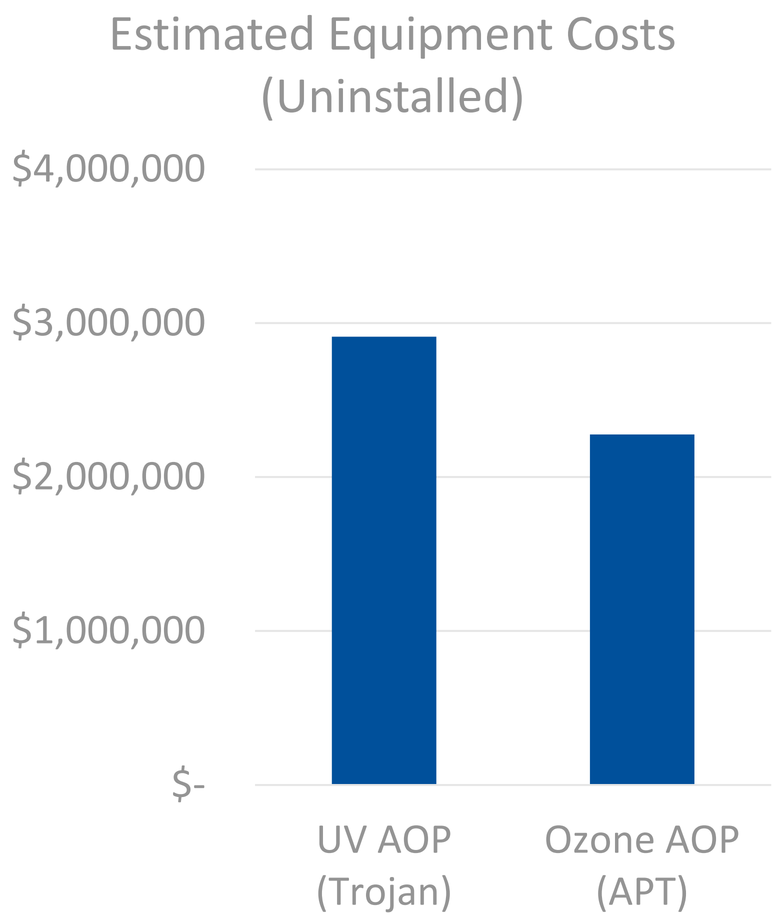
Results: hydroxyl scavenging

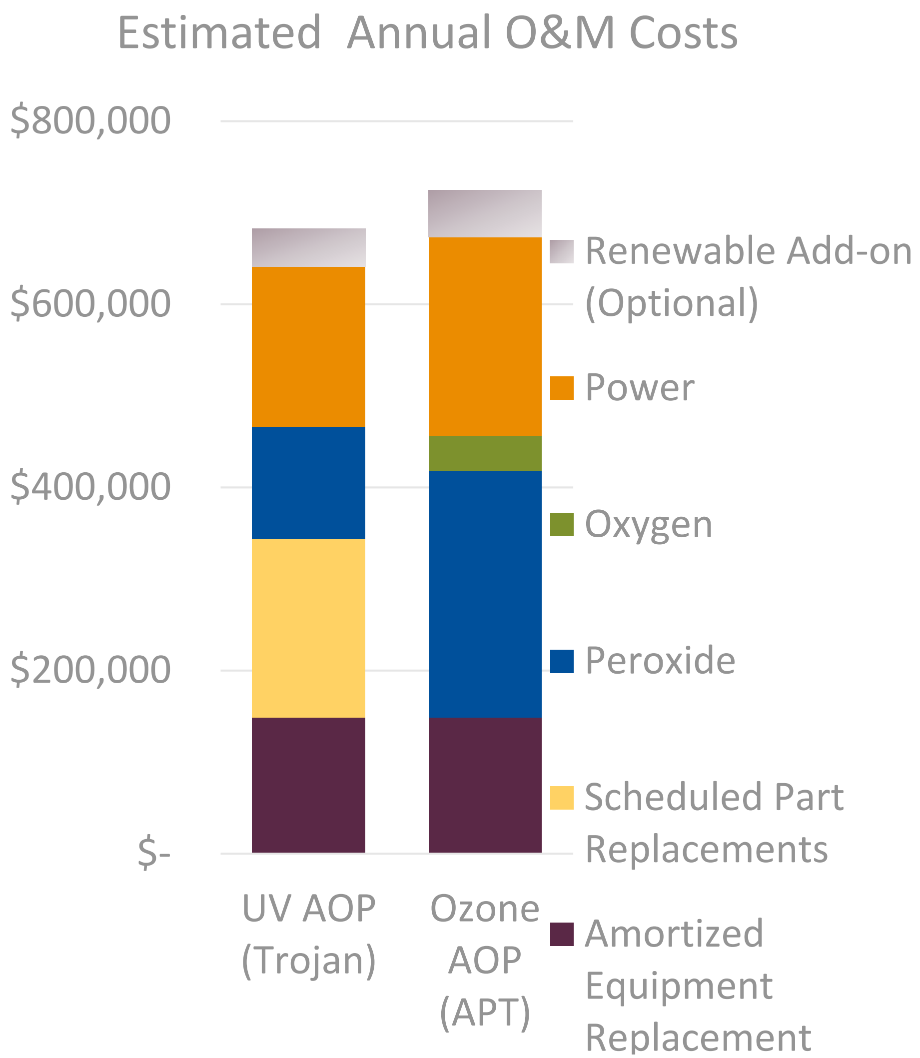


Results: pilot summary

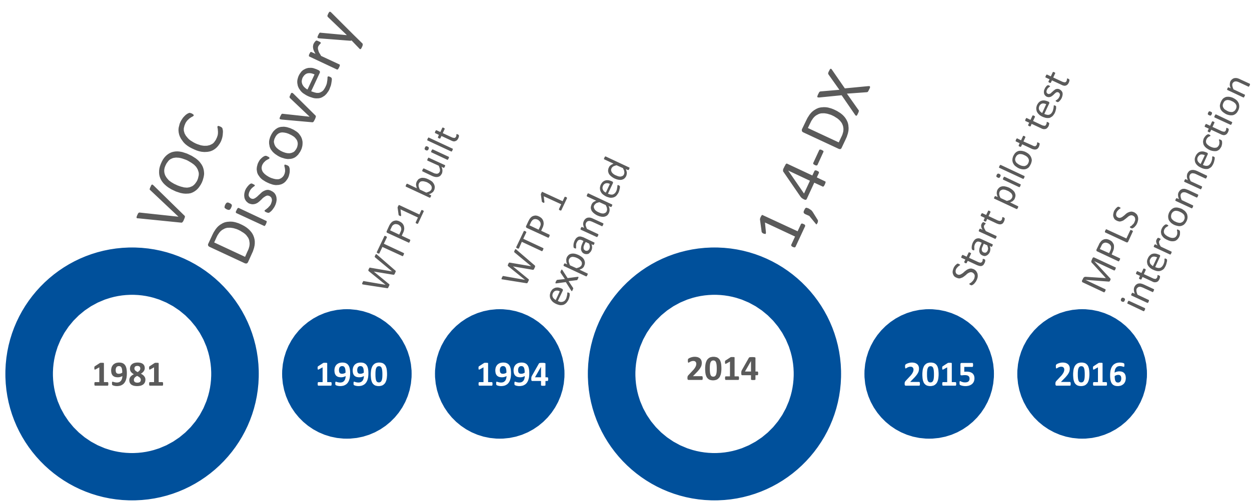
	UV AOP	Ozone AOP
Meets 1,4-Dioxane target (1/10th of current MDH HRL)	Yes	Yes
Removes most VOCs	Yes	Yes
Peroxide dose	8 mg/L	23 mg/L
Peroxide residual	4 mg/L	16 mg/L
Byproducts	None identified	Bromate, with high health risk

Results: AOP cost comparison

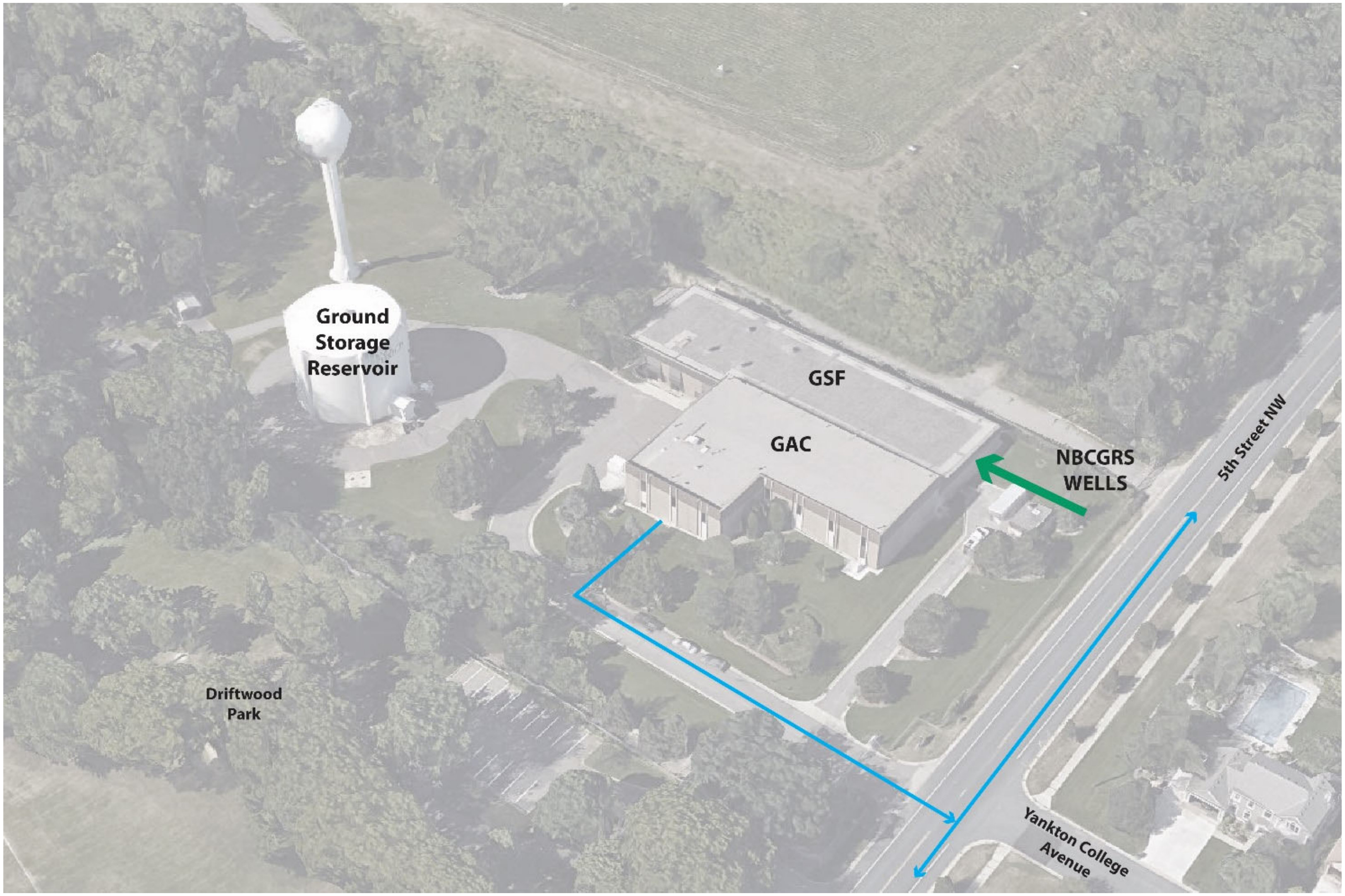




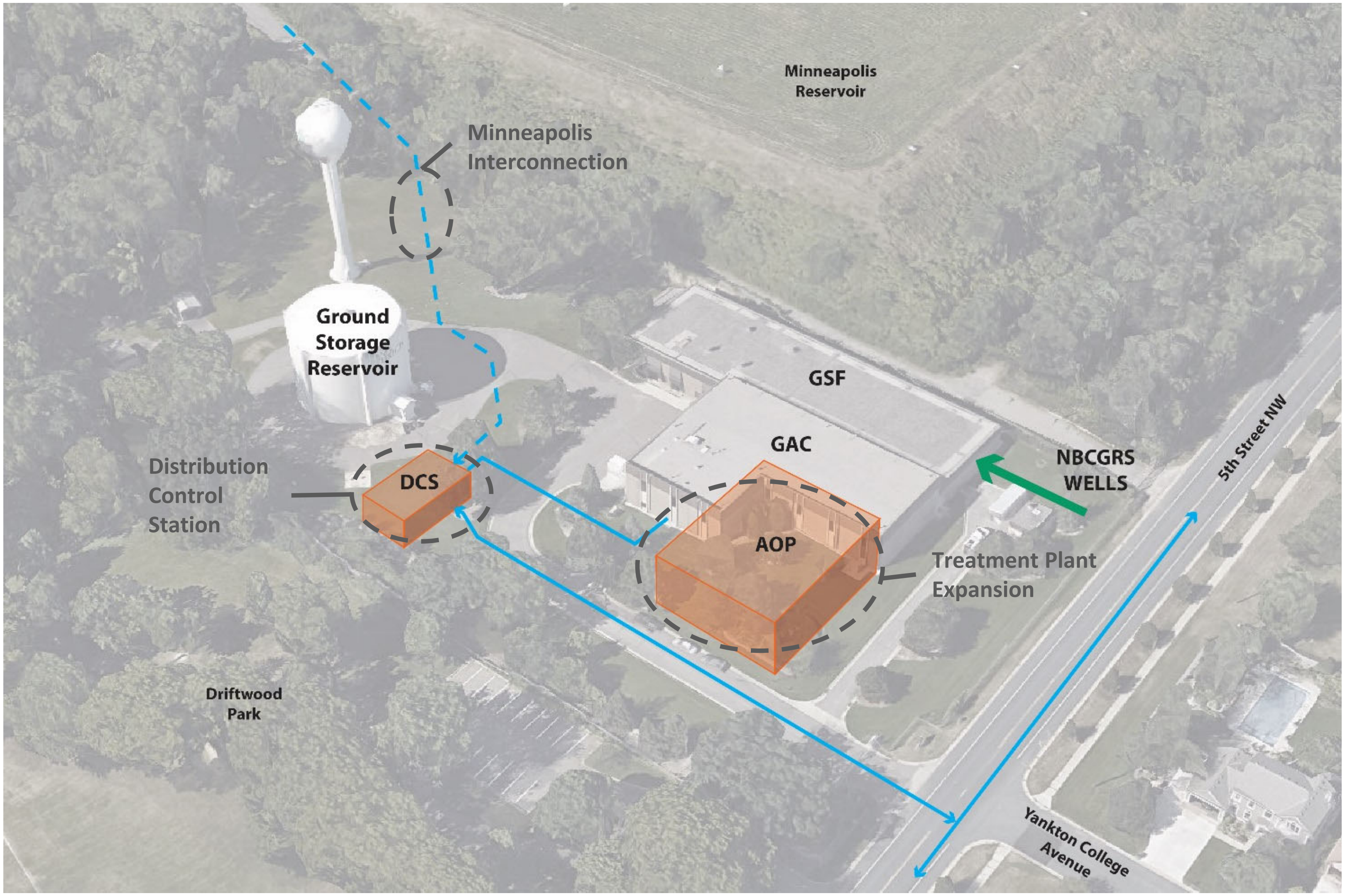
Design: interim water supply measures



Design: WTP1 prior to July 2016



Design: Minneapolis interconnection and WTP1 upgrade



Design: Minneapolis interconnection

- Switch from groundwater to surface water
- Barr supported corrosion control planning and monitoring

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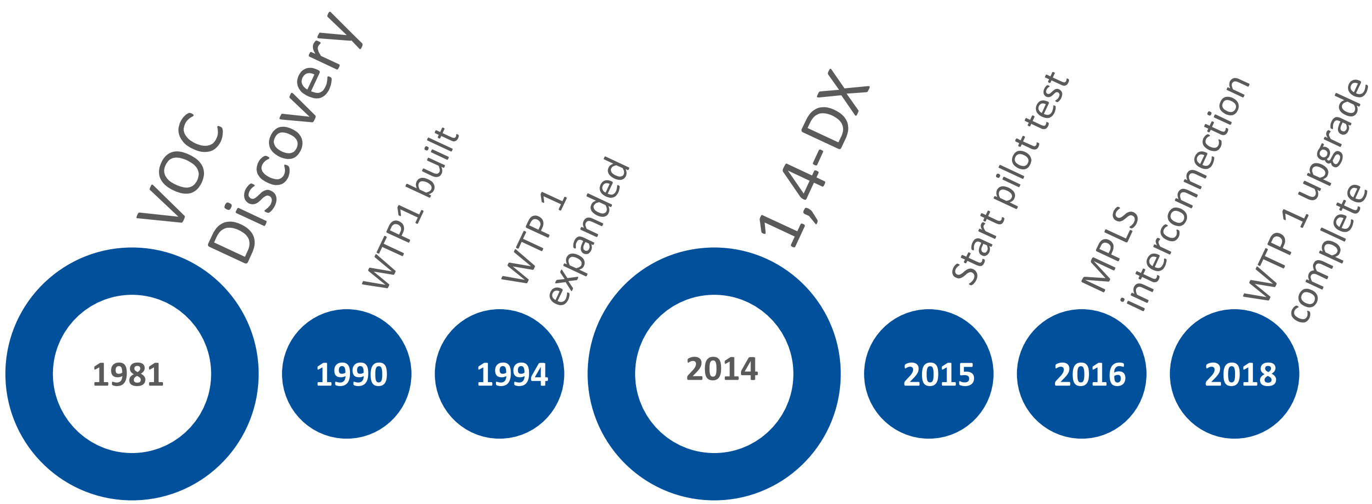
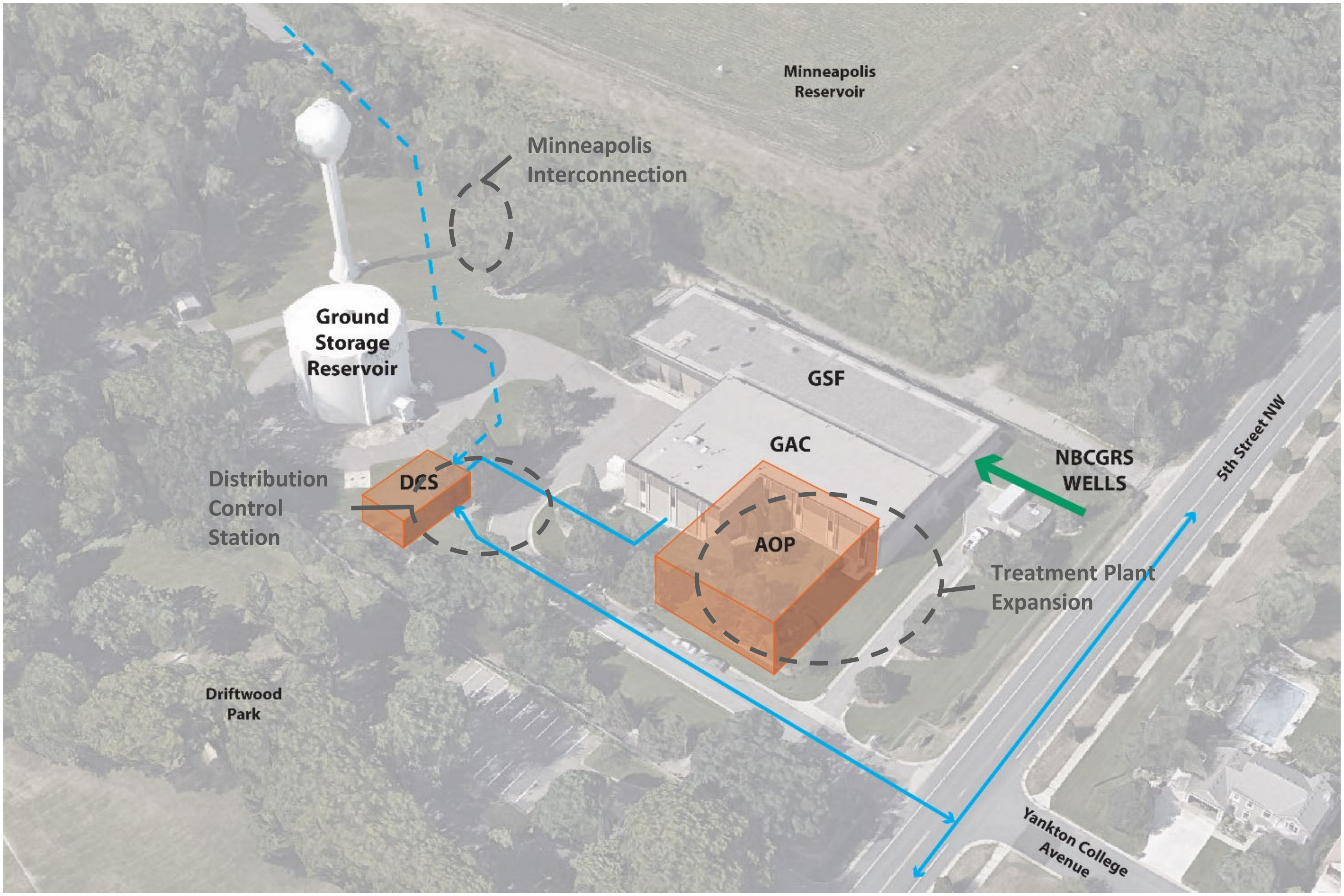
Design: distribution control station

Design: WTP1 upgrade through startup

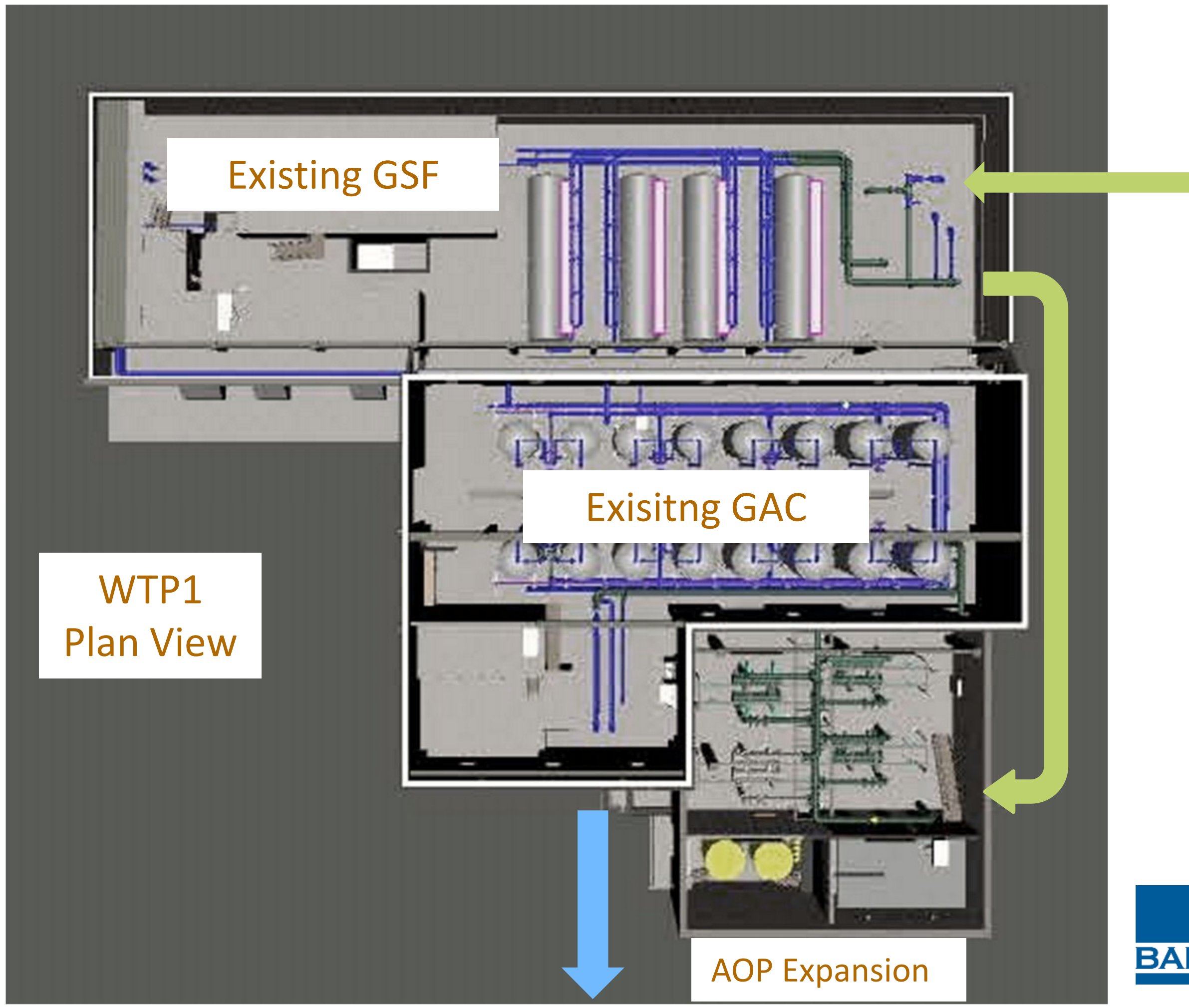


Where we're headed: the long-term solution.



New Layout

Addition of Trojan UVPhox™ equipment will require expansion of existing WTP1.



Design: operating conditions

- **7.3 MGD** (design flow)
- **5.1 MGD** (typical annual peak day)
- **96% UVT** (typical based on pilot study)
- **3 trains** available
- **2.0-log removal** (Trojan guaranteed performance)

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Design: Trojan UV-AOP equipment

Three treatment trains are installed in parallel, each with two treatment units.

Unit 1

2 lamp chambers per unit
(72 lamps each end)

2 lamp chambers per unit
(72 lamps each end)

Unit 2

Trojan UVPhox™

Two D72AL75 units (Trojan's largest) per treatment train

Design: WTP1 expansion additional improvements

Site landscaping has been revised to implement sustainable water use and storm water management practices.

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Additional Improvements

- System-wide upgrade of SCADA and controls
- Expanded electrical equipment and generator capacity
- Piping changes to accommodate flow reconfiguration
- Valve upgrades for existing processes
- HVAC and lighting upgrades
- Refinishing of portions of the existing exterior finishes

Start-up Fall 2018

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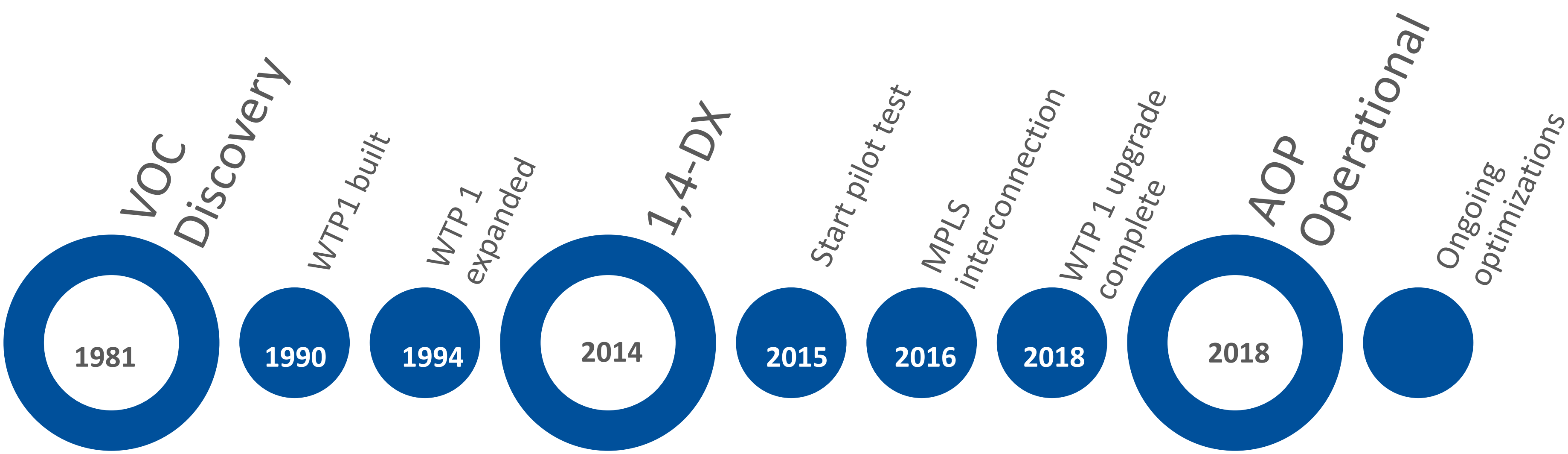
Design: WTP1 upgrade through startup



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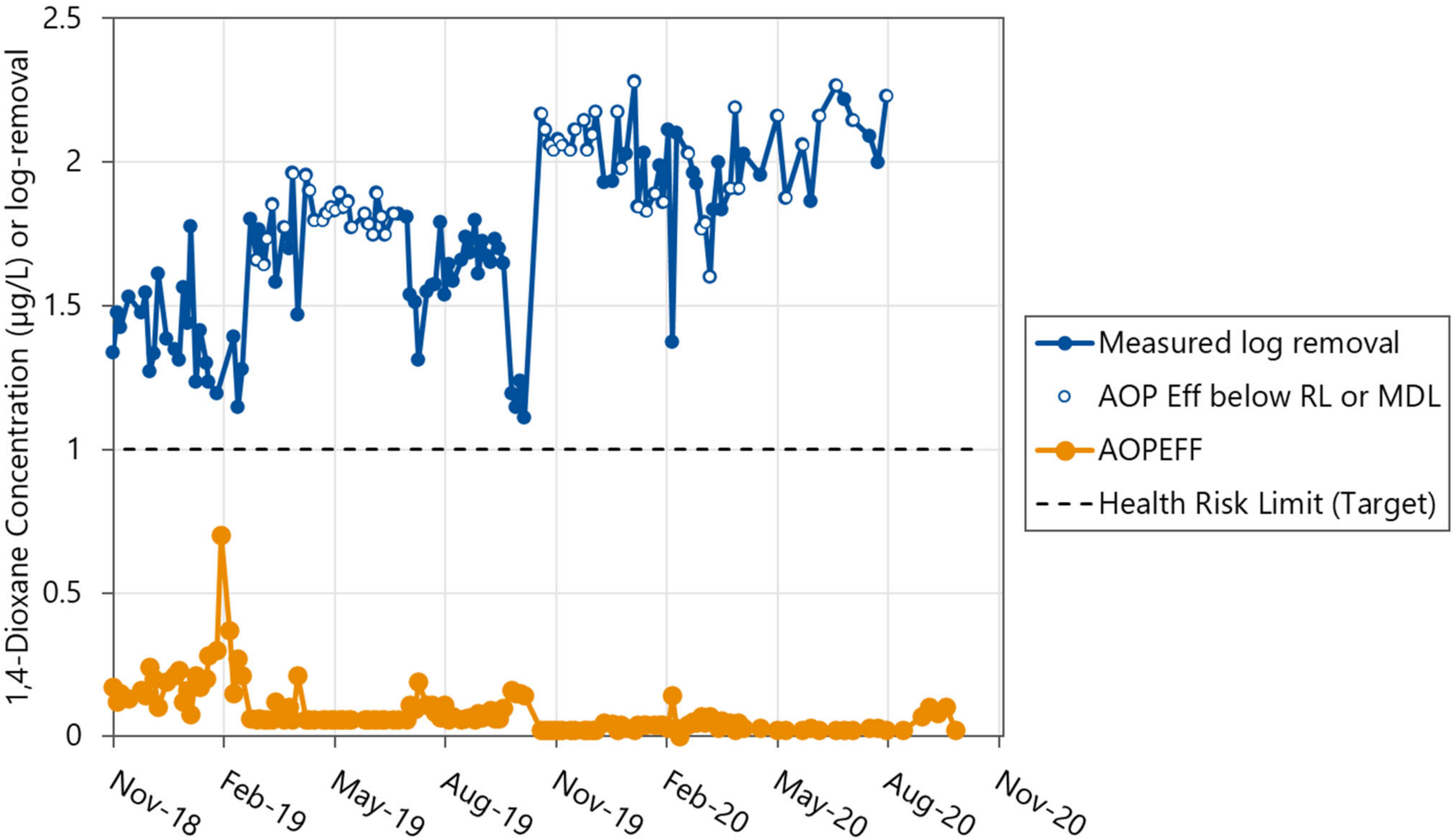
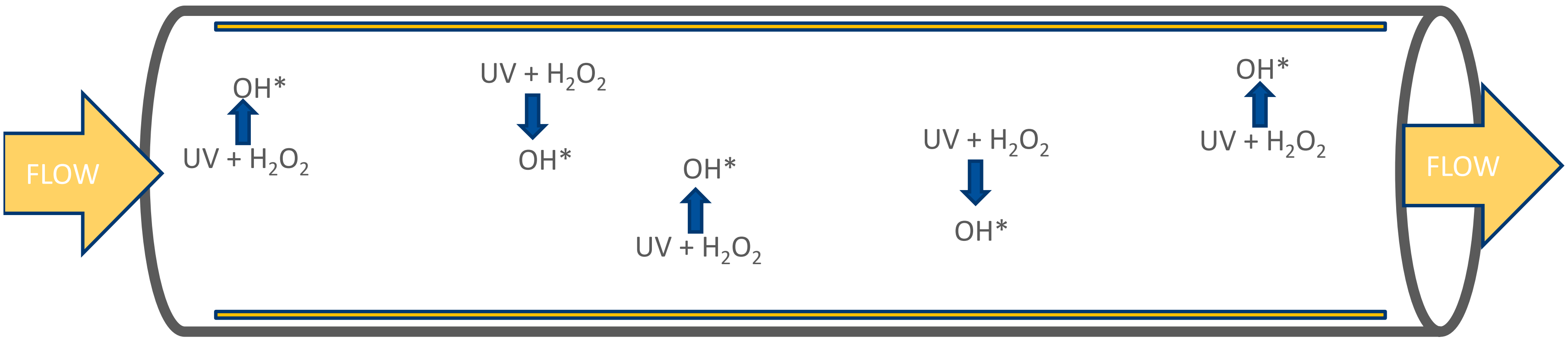
Full-scale Performance



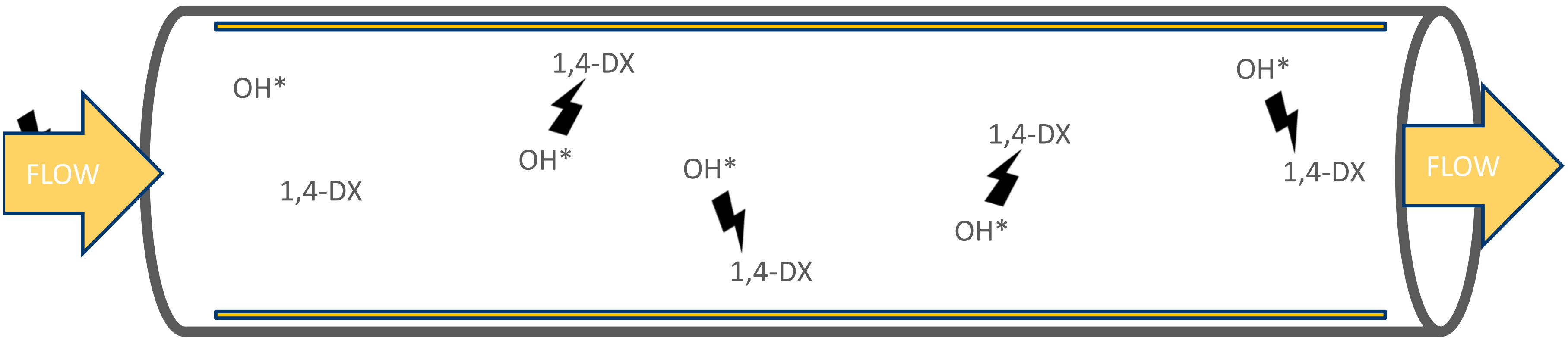
ADVANCED OXIDATION



Hydroxyl radical (OH*) is a short-lived, very strong oxidant

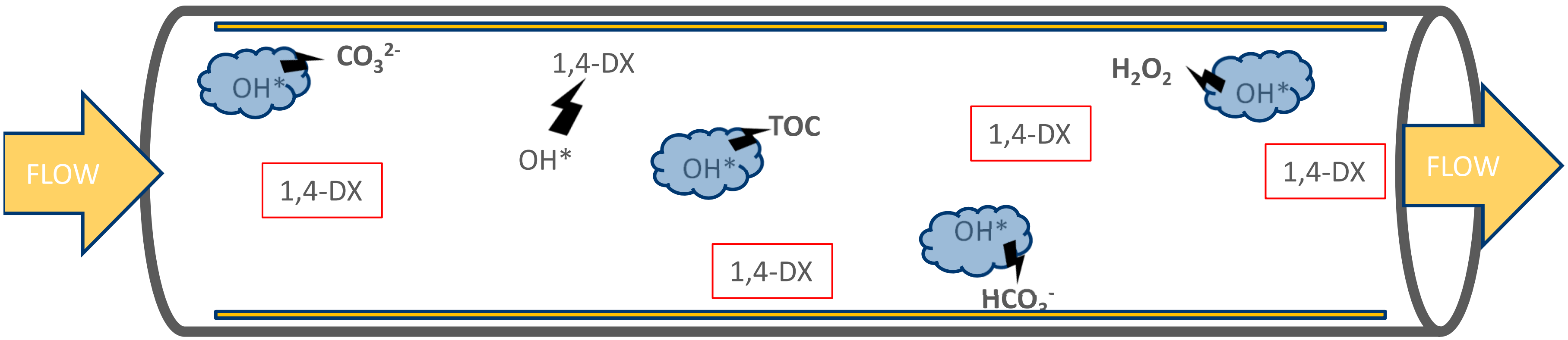
Make it in AOPs using selected chemistry

ADVANCED OXIDATION



Reason for using AOP is to remove 1,4-dioxane (DX)

HYDROXYL RADICAL SCAVENGING



But other things react with (scavenge) hydroxyl radical

AOP PROGRAMMING

ENTER IN
- Log-removal target
- Hydroxyl radical scavenging term

MEASUREMENTS
- Flow
- Inline UVT

DICTATES
- Peroxide pumping rate
- UV lamp power

CONTROLS
- Actual OH* concentration
- 1,4-dioxane log-removal

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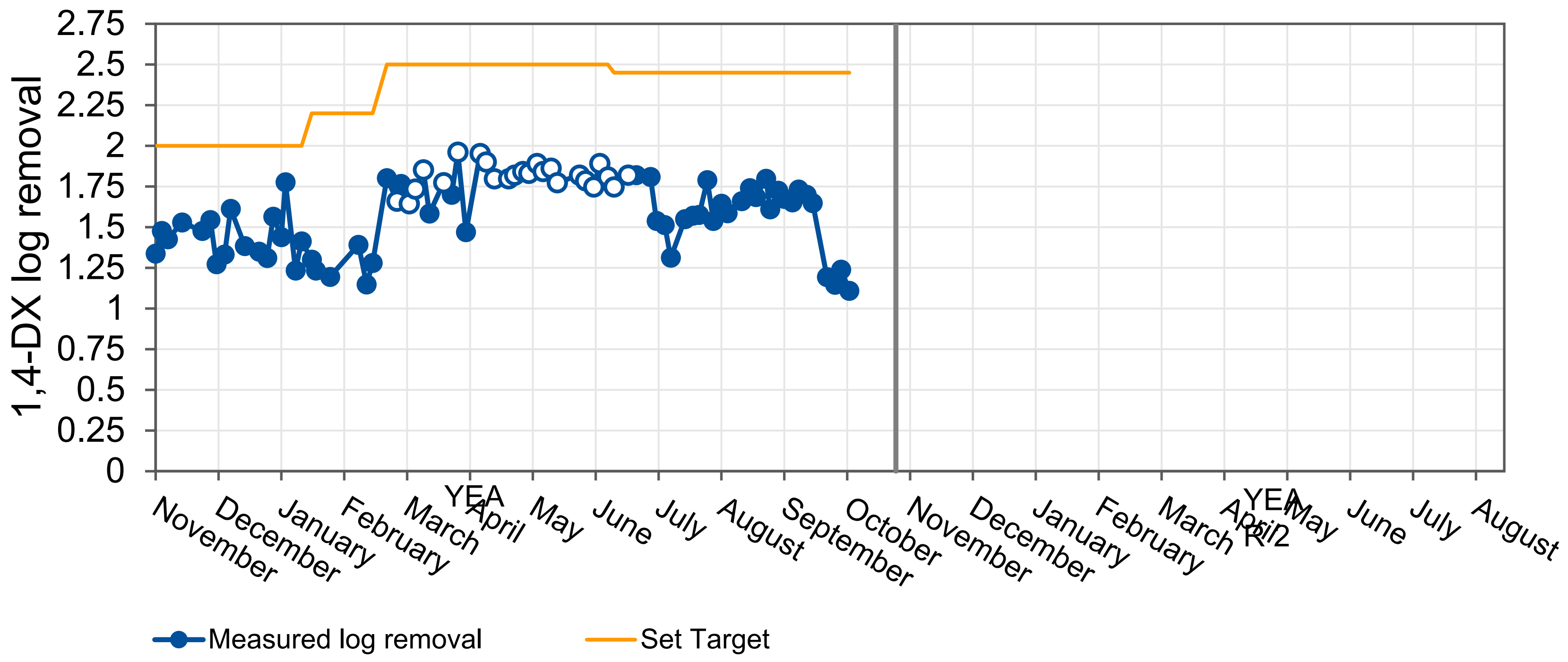
PROBLEM



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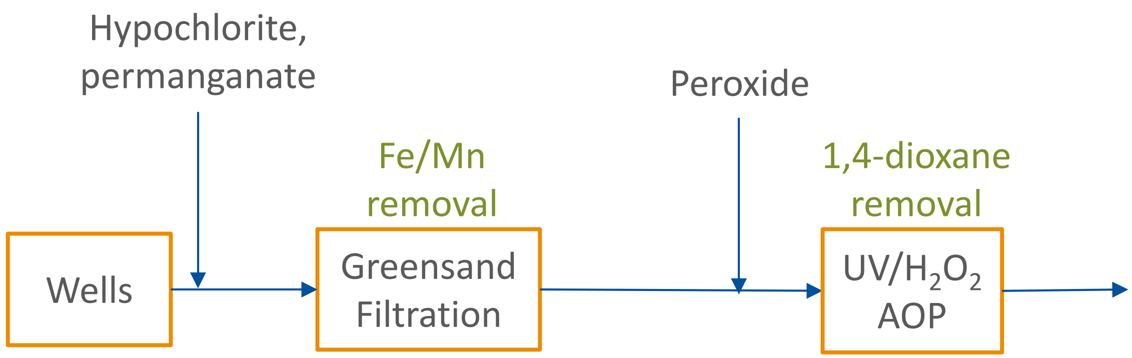
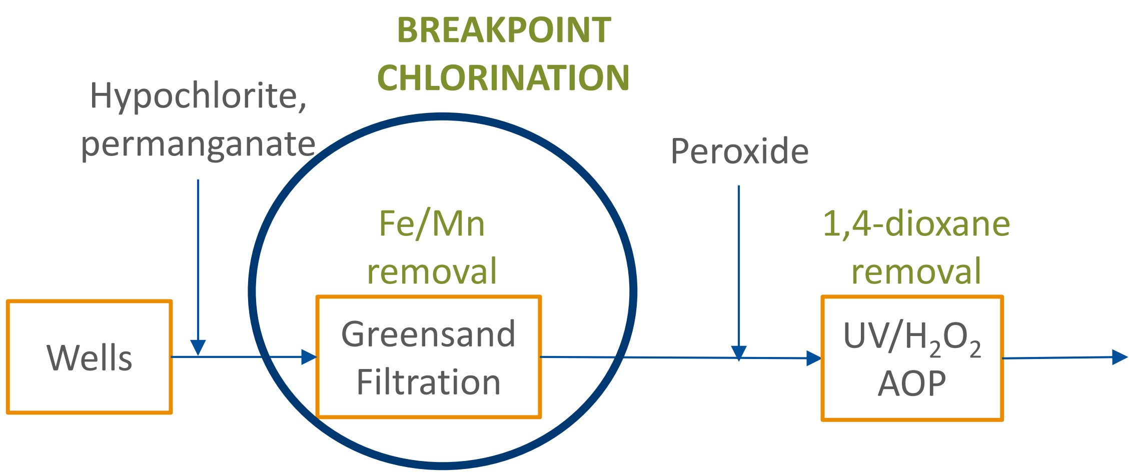
Hydroxyl Radical Scavenging Issue



Hydroxyl Radical Scavenging Issue

$$NH_2Cl \xrightarrow{UV\ light} radical\ intermediates \longrightarrow NO \longrightarrow NO_2$$

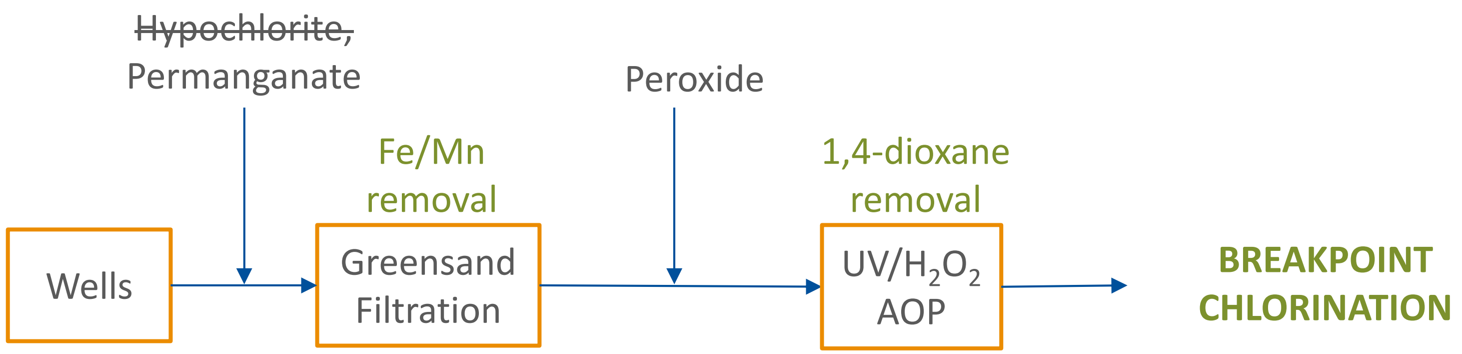
HYDROXYL RADICAL SCAVENGER



Chloramine degrades over the course of 1-2 days during shipment, so this wasn't observed during hydroxyl radical scavenging tests

Hydroxyl Radical Scavenging Issue

- Removing hypochlorite as oxidant = no chloramines
- Need to be aware of breakpoint chlorination downstream



Project Lessons Learned

- Scavenging term that best predicts removal may not match measured value
- Consider effect of process changes on downstream processes (e.g. moving breakpoint chlorination downstream)
- Make sure on-line monitoring equipment used to set treatment level (UVT) is functional

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