Placement is Everything: Addressing Water Quality and Design Flexibility by Implementing Pre-Ozone at a Surface Water Treatment Plant in Utah

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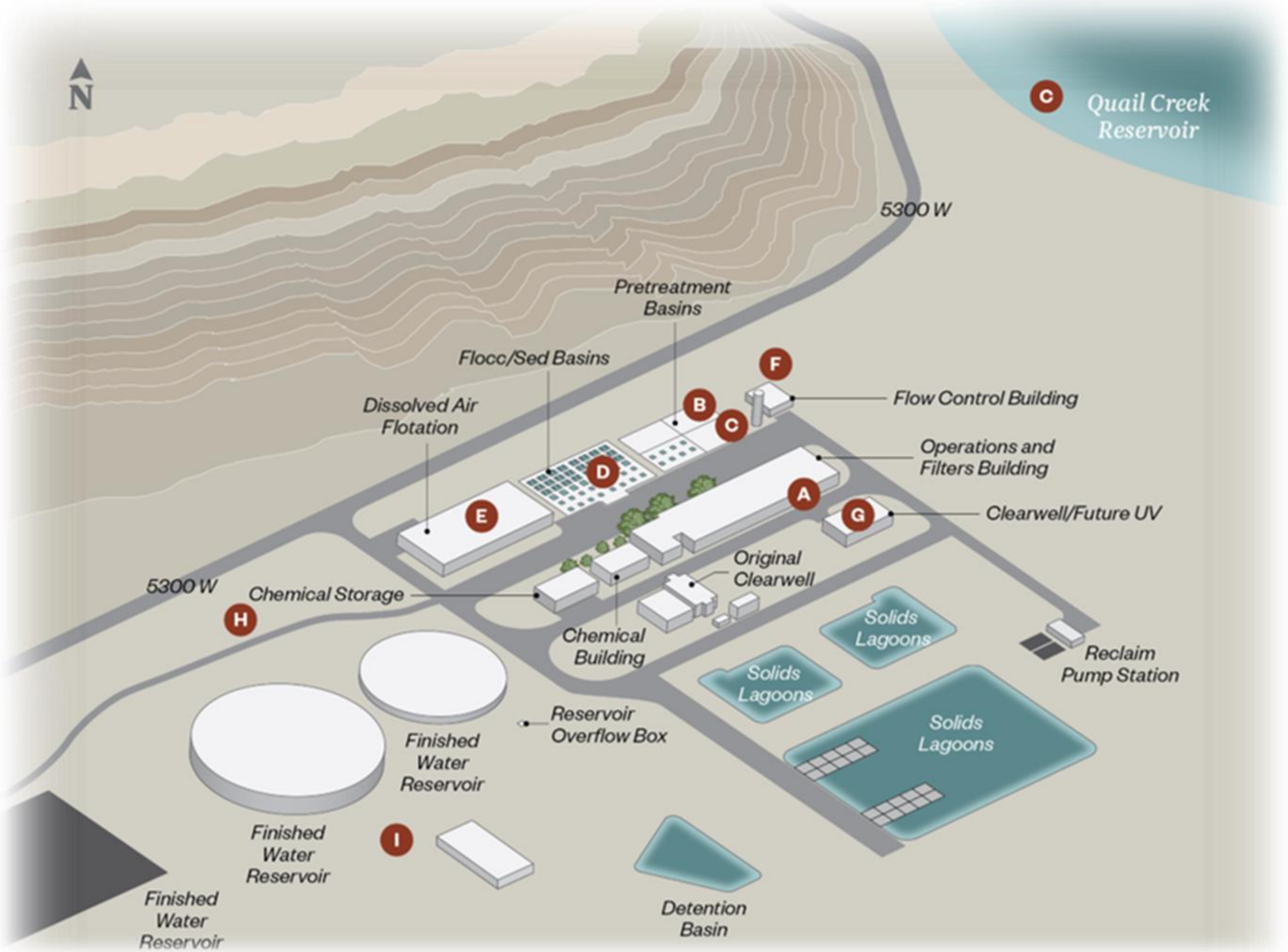
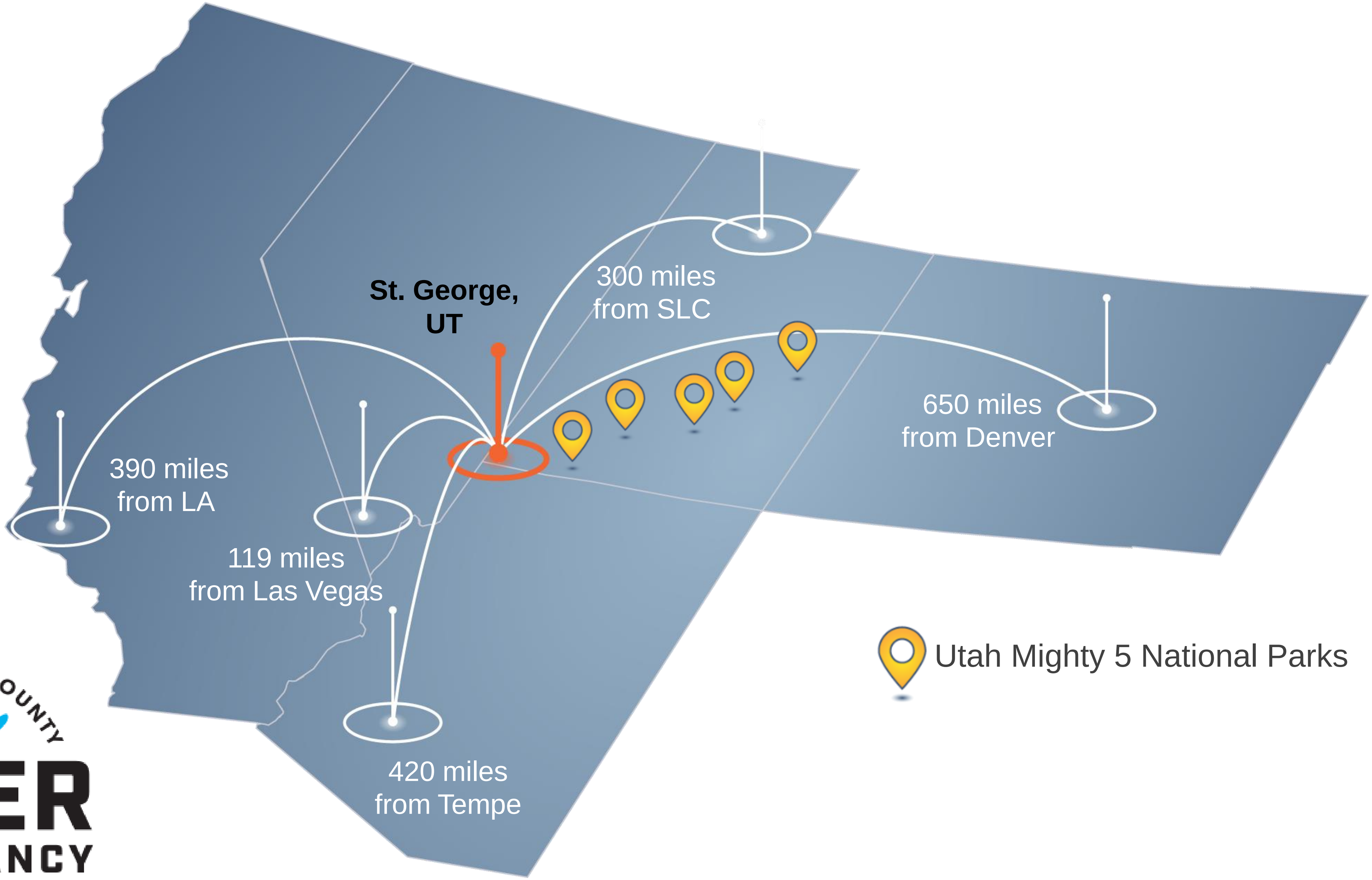
Agenda

- Project Background
- Proposed Quail Creek WTP Treatment Scheme
  - **DAF/DAFF**
  - **Ozone**
  - **Key Questions**
  - **Ozone Design Considerations**
- Summary and Conclusions



Project Background



WASHINGTON COUNTY WATER CONSERVANCY DISTRICT


HARRISBURG
La Verkin
Hurricane
HARRISBURG JUNCTION
QCWTP
Limited
Water
Resources
Washington
MIDDLETON
St. George
St. George
BLOOMINGTON HILLS
BLOOMINGTON
Fifth fastest
growing
county in the
nation
Algae
Challenges

Project Description

- **EXPAND** the Quail Creek WTP from 60-mgd to 90-mgd
- Top influences on facility layout, ease of operations, and cost (CapEx and OpEx):
  - **Ozone:**
    - *Pre – close, consolidated*
    - *Intermediate – spread campus*
  - **Stacked DAF (DAFF)**
    - *Eliminates an entire facility*

Algae Challenges in the System

Algae Challenges in the System

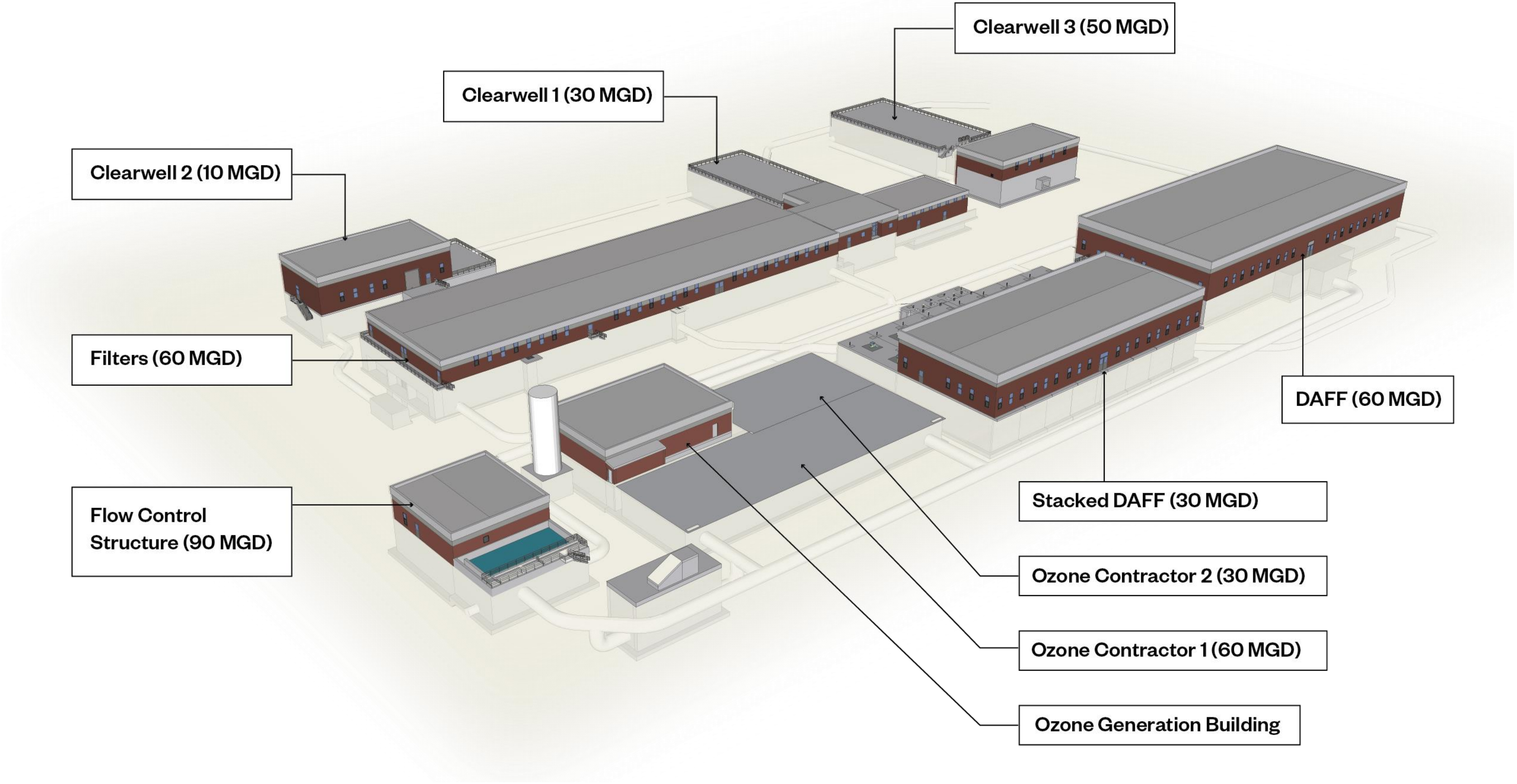
- Observed Rapid Blooms
- History of T&O Challenges
- Concern around Cyanotoxins

Potential Additional Challenges

- Potential for future Planned IPR
- Manganese
- Disinfection Byproducts (THMs, HAAs, Bromate)

Proposed QCWTP Treatment Scheme

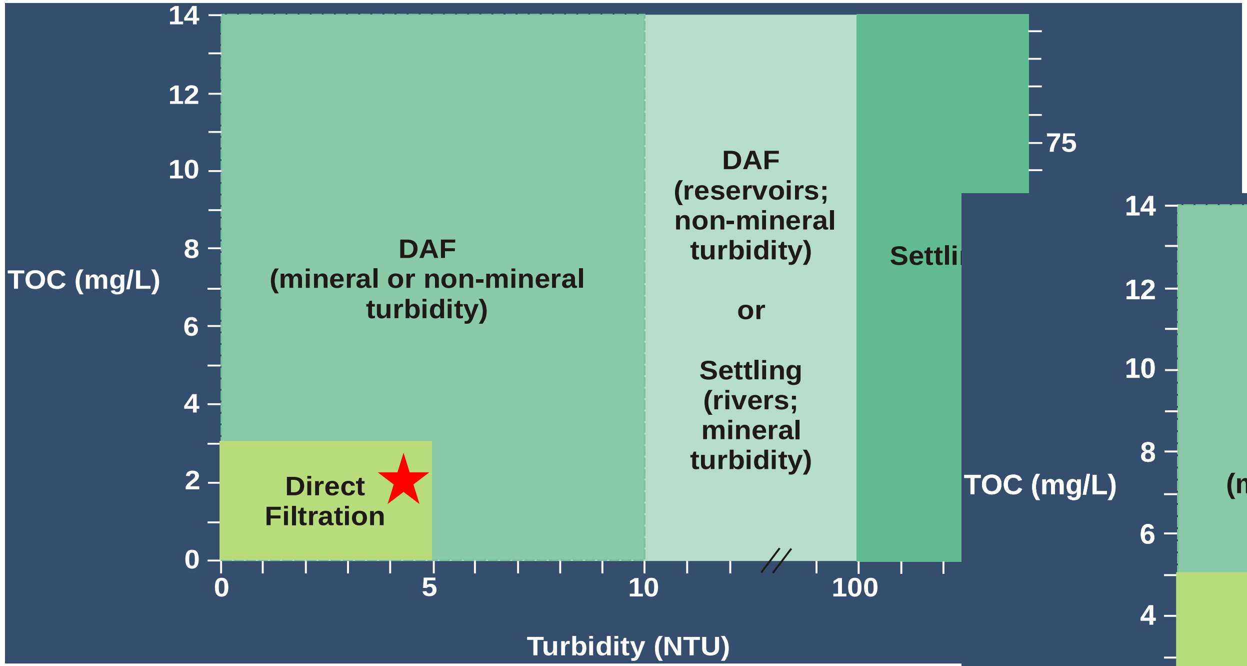
Proposed Treatment Relies on Ozone and DAFF



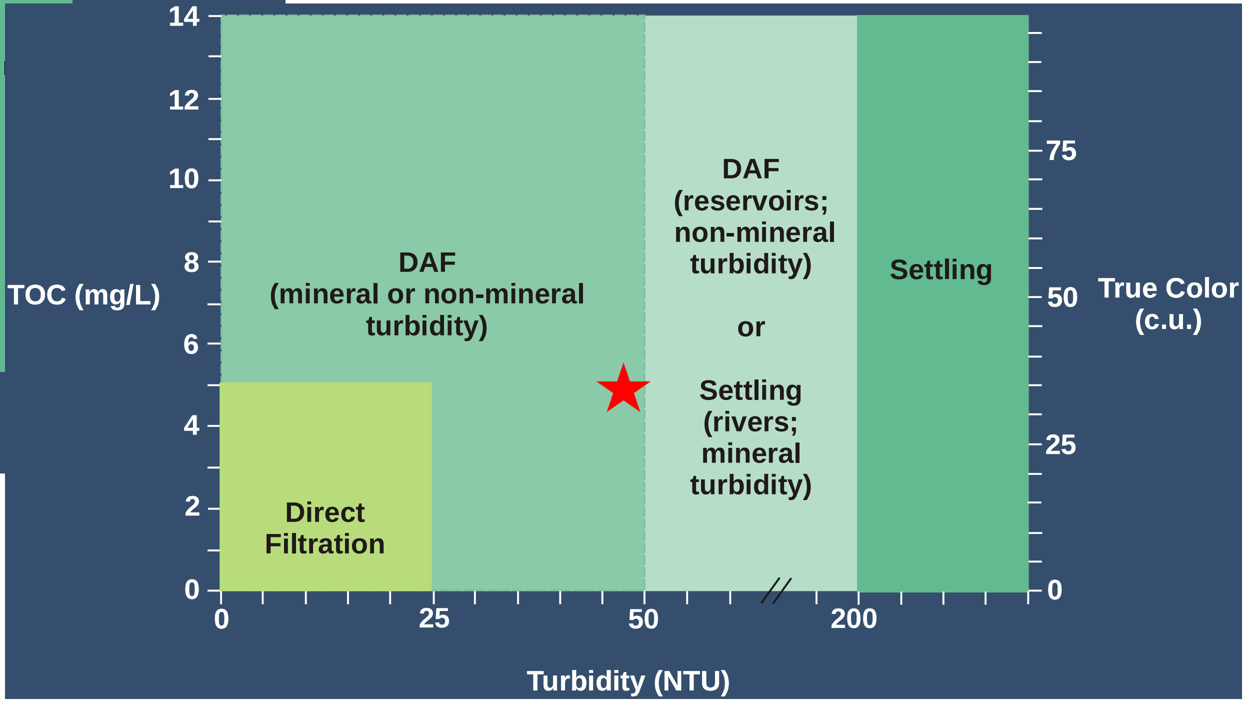
All in on DAF?

To DAF or not to DAF (one of the questions)

Average Water Quality



Maximum Water Quality



Treatment selection guidelines for particle and NOM removal

M. T. Valade, W. C. Becker and J. K. Edzwald, AQUA – Journal of Water Supply, 2009

Ozone – Pre or Intermediate?

Previous Studies: Ozone Pilot Testing Report (2008)

Study Objectives

- Determine ozone doses to control T&O and ozone application point
- Steps to control bromate formation
- Impacts of ozone on downstream processes
- Operation of filters
- Manganese control with ozone

Pilot Design

- Included coagulation, flocculation and sedimentation followed by granular media filtration (three filters tested – conditioned existing media, new existing media and enhanced biological support)
- Ozone tested at two locations: pre- and intermediate-ozonation
- Raw water spikes: MIB/geosmin, bromide, manganese and ammonia

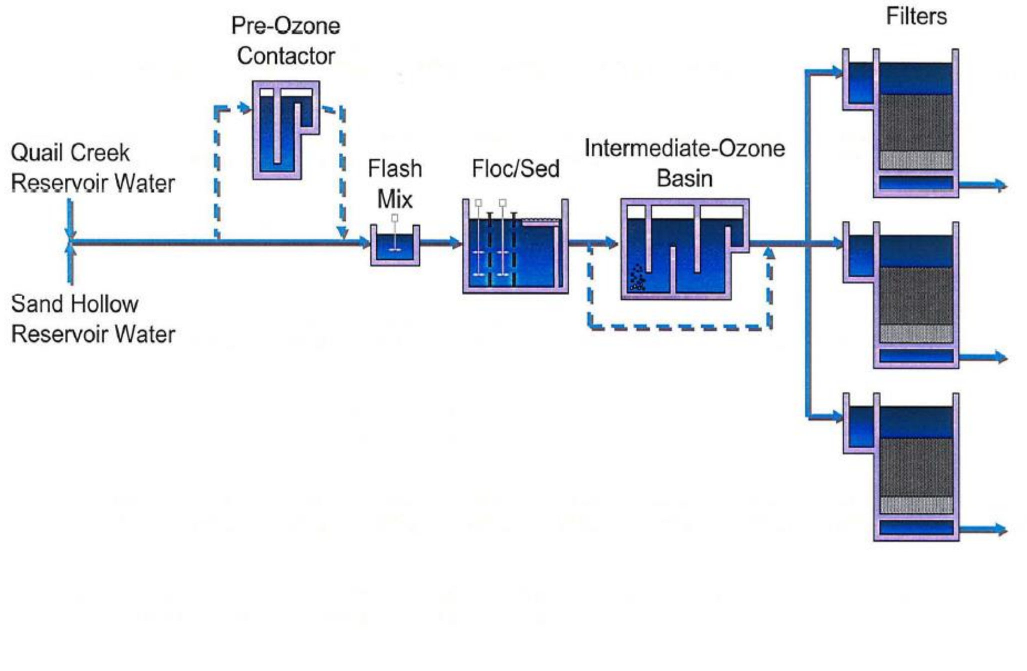
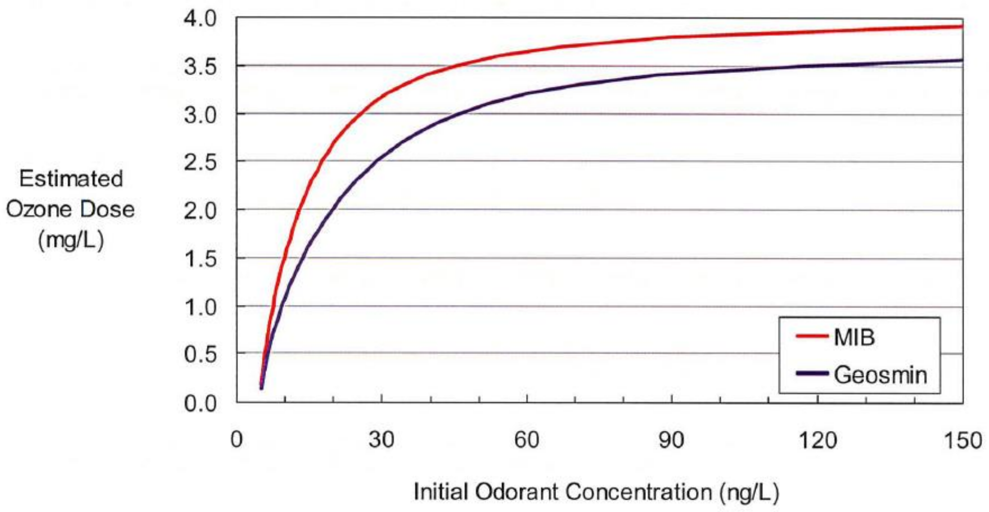


Figure 2.1
SCHEMATIC OF THE PILOT PLANT PROCESS
QUAIL CREEK WATER TREATMENT PLANT
CITY OF ST. GEORGE

Previous Studies: Ozone Pilot Testing Report (2008)

Key Observations

- Ozone was capable of T&O (MIB/geosmin) oxidation
  - **For disinfection: < 1 mg/L; for T&O: 3-4 mg/L**
  - **Peroxide could be introduced beginning/end of the contactor achieve higher MIB and geosmin removal and to quench ozone**
- Intermediate ozonation recommended with fine-bubble diffusers; reasons:
  - **No space on site or in the hydraulic profile for new pre-ozone contactor**
  - **Concerns about releasing intracellular algal metabolites in pre-ozone**
  - **Report indicates no significant difference in ozone demand between pre- and intermediate ozone**



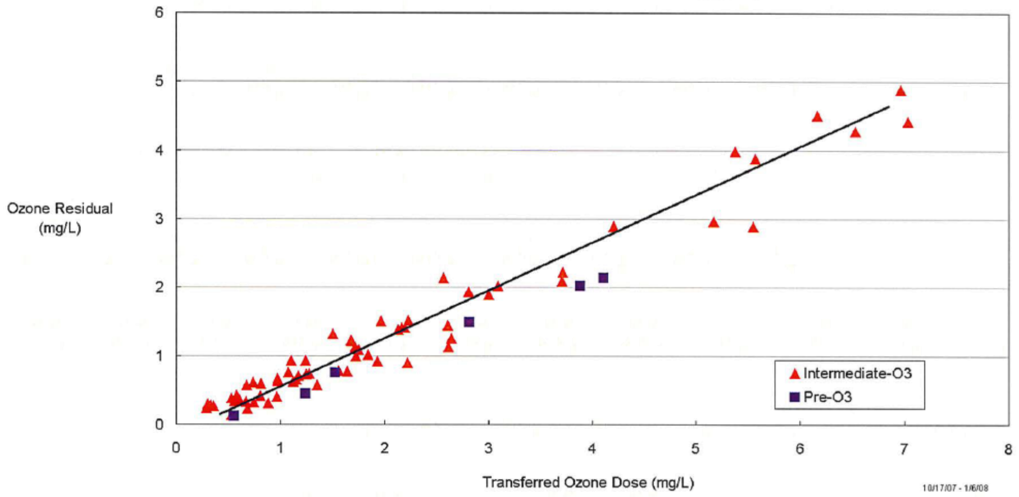


Figure 3.8
NO SIGNIFICANT DIFFERENCE BETWEEN THE PRE- AND INTERMEDIATE-OZONE DEMAND
QUAIL CREEK WATER TREATMENT PLANT
CITY OF ST. GEORGE

Previous Studies: Ozone Pilot Testing Report (2008)

Challenges

- Higher ozone concentrations (3-4 mg/L) expected to produce bromate above 10 µg/L
- Concern about overoxidation of manganese (observed under one set of conditions: 0.5 mg/L raw water Mn, 1.14 mg/L of added potassium permanganate, high ozone dose for T&O oxidation)
- **Concern that pre-ozone could potentially lyse cells and release T&O and cyanotoxins**

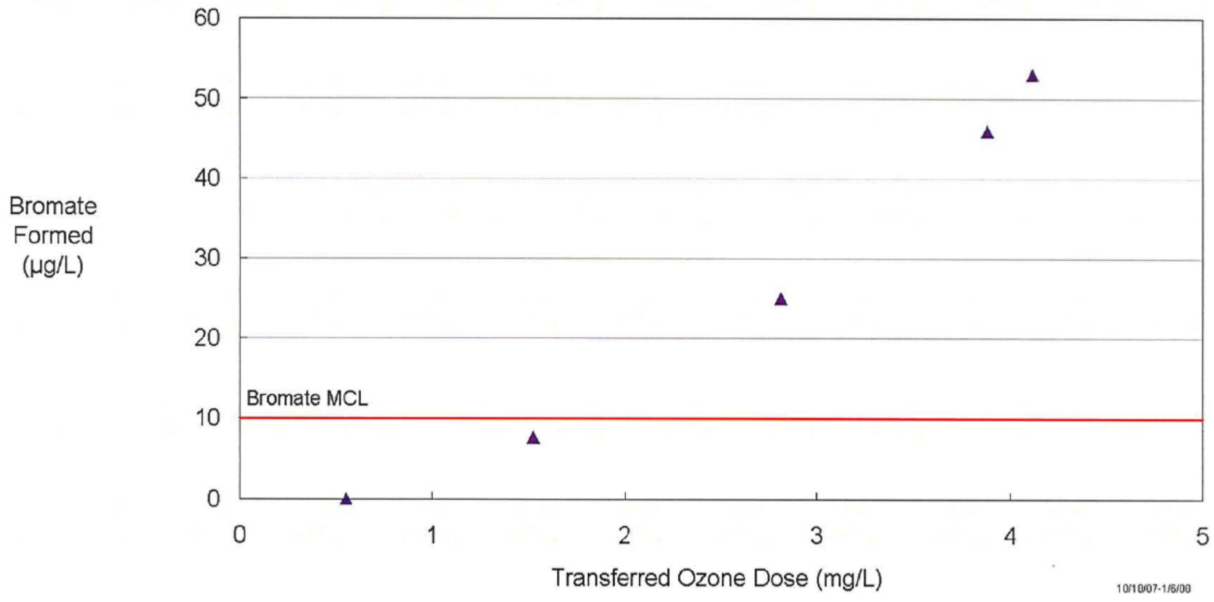
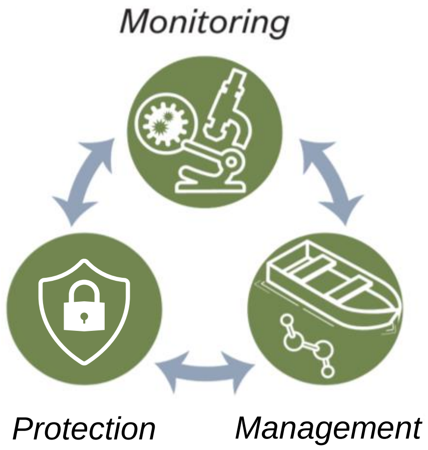


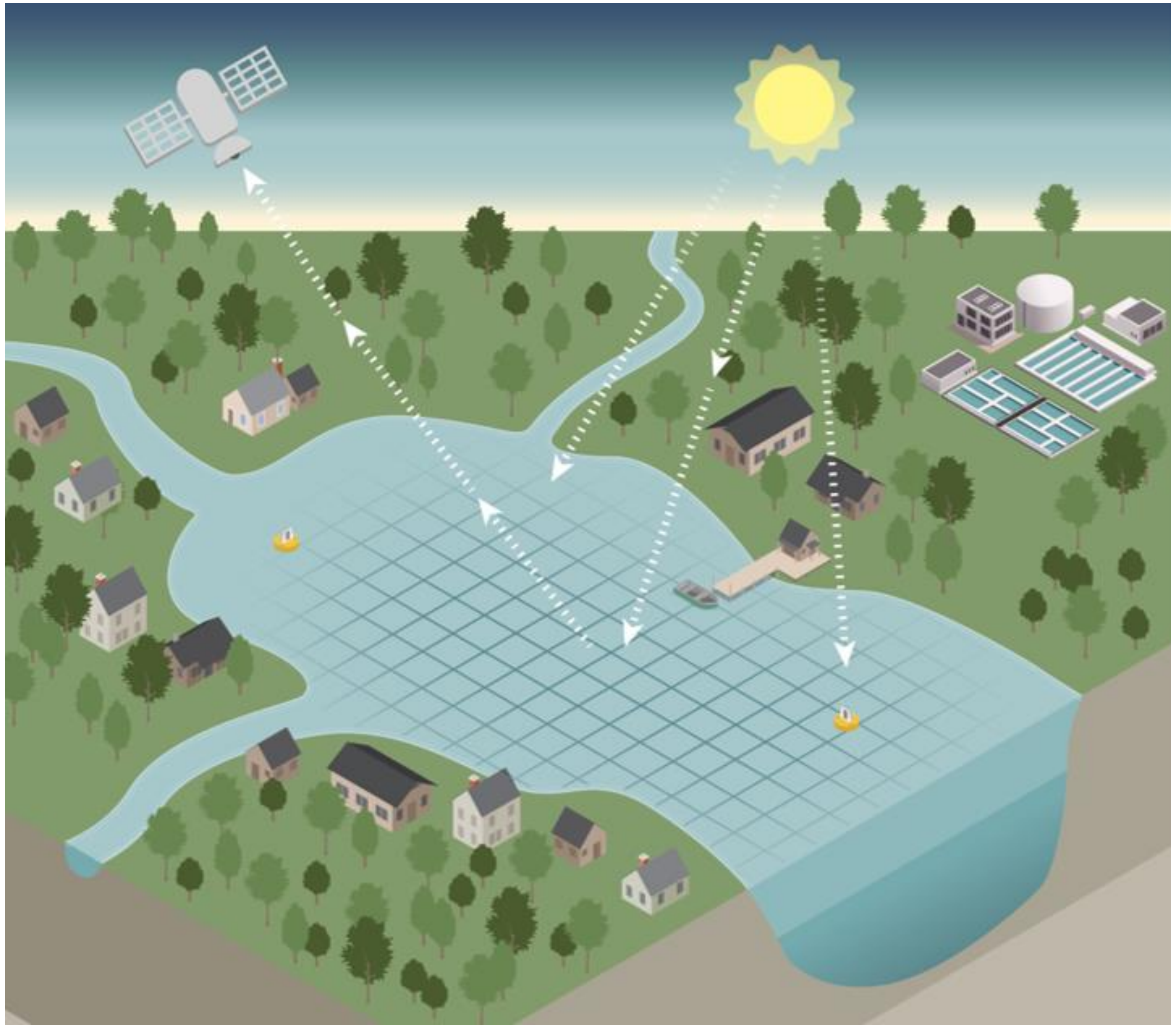
Figure 3.13
BROMATE FORMATION UNDER AMBIENT CONDITIONS (INTERMEDIATE-OZONE, 60 µG/L BR⁻)
QUAIL CREEK WATER TREATMENT PLANT
CITY OF ST. GEORGE

Key Question – Pre-ozone interaction with algae, cyanobacteria?

The Foundation: Enhanced Monitoring and Management

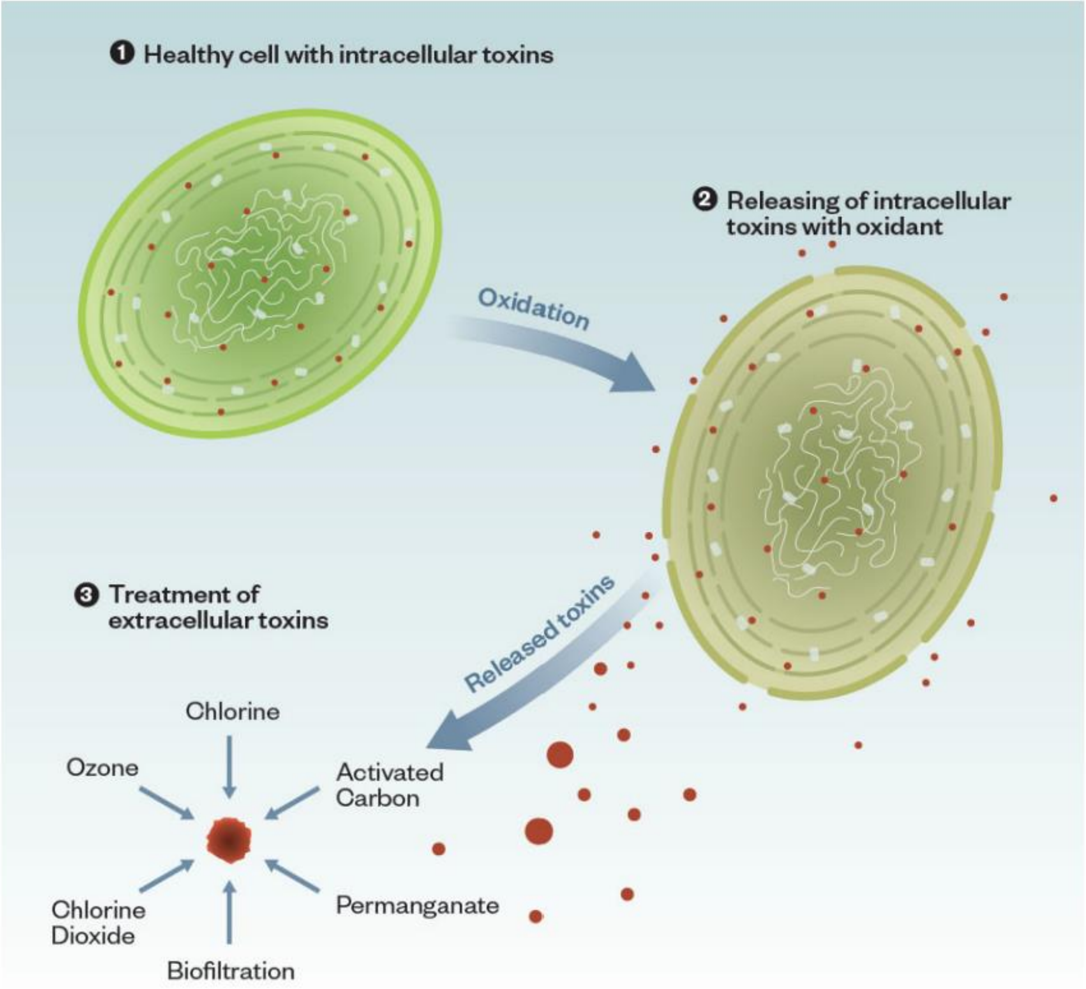
- Success of source water management and protection is based on monitoring
- Quality and quantity of monitoring data
- Balancing cost and time investment
- Streamlining decision in a time effective manner
- Leverage new technology like remote sensing





Pre-ozone impact on cell lysis and treatment

- **WRF 4692**: Utility Guidance for the Management of Intracellular Cyanotoxins investigated the **"lyse and treat"** approach
- Oxidants disrupt cyanobacterial cell during pre-oxidation and release the intracellular toxins into the water ("Lyse")
- Released toxins are oxidized concurrently in the pre-oxidation step and/or in downstream processes
- Key things to consider:
  - **Amount of oxidant exposure to ensure complete lysis**
  - **Morphology of cyanobacteria that can impact lysis**



Mechanism of "Lyse and Treat" scenario (adopted from WRF 4692)

Extending WRF 4692: Lyse and Treat at QCWTP

- The WRF 4692 report indicates that a delivered ozone dose of 0.75 O3:DOC ratio for a CT of 4 mg*min/L should be adequate for complete lysing
- At QCWTP, where raw and settled DOC are approximately 2 mg/L, this would indicate an ozone dose of **1.5 mg/L**, applied for **3-4 minutes** would be adequate for complete lysing and release of intracellular toxins and/or T&O

Summary of oxidant:DOC ratios needed for complete lysis of cyanobacterial cells and release of intracellular toxins

Method	Free Chlorine	Ozone	Permanganate
Oxidant:DOC Ratio (t<20 min)	0.5 Cl_2:DOC	0.75 O_3:DOC	4.0 MnO_4:DOC
CT_{lab} (mg-min/L)	11	0.72	185
CT_{USA}(mg-min/L)	15	3.0	741
Method	Free Chlorine	Ozone	Permanganate
CT_{CA} (mg-min/L)	21	4.1	589
Notes: CT = Oxidant exposure calculated using the integration method; CT_{lab}=Oxidant exposure required when using lab cultured Microcystis (pH=8; Temp=20°C); CT_{USA}=Oxidant exposure required when treating naturally occurring cells from blooms in the United States (pH=8; Temp=20°C); CT_{CA}=Oxidant exposure required when treating naturally occurring cells from blooms in Canada (pH=8; Temp=20°C).			

Extending WRF 4692: Ozone fits in multiple barrier approach

- Once cyanotoxins and/or T&O compounds are released, it is important to understand the effectiveness of different oxidants to remove these compounds

Common Oxidation Efficacy for Treatment of Extracellular Metabolites (Adopted from WRF 4962)

Oxidant	Microcystins	Cylindrospermopsin	Anatoxin	Saxitoxins	MIB and geosmin
Free chlorine	pH	pH	Slow/No oxidation		
Monochloramine	Slow/No oxidation				
Chlorine dioxide	Slow/No oxidation				
Permanganate					
Ozone		pH	pH		
Hydroxyl radicals				Unknown	

Key Question – Bromate formation and mitigation?

2022 Bench Testing at CU Boulder

Bromate Formation/Mitigation Testing

- Raw water bromide at QCWTP = 52 µg/L
- Studies have shown 30-80% conversion in bromide-laden natural waters treated with ozone (von Gunten and Hoigne, 1994)

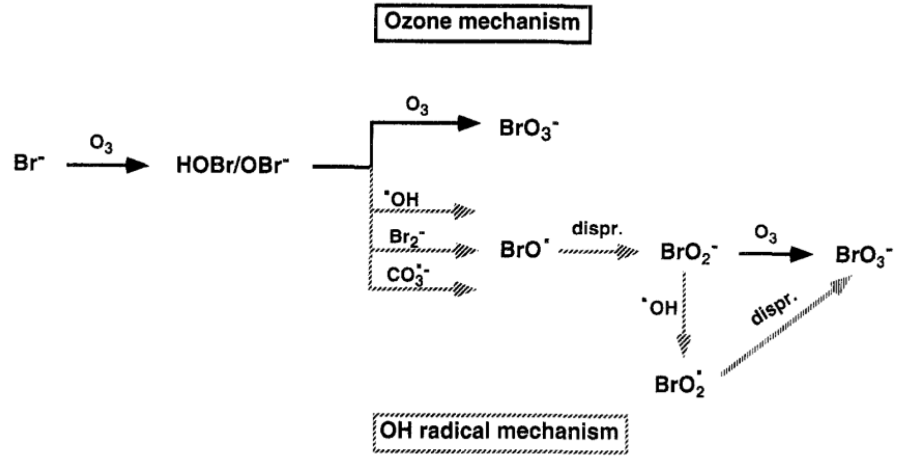


Figure 4. Comparison of the molecular ozone mechanism and the OH radical mechanism. The OH radical mechanism includes reactions of secondary oxidants as CO_3^- and Br_2^-. A list of all of the reactions is given in Tables 1 and 2.

Table 3. Bromate Formation in Pilot Plant (pH = 8, *T* = 20 °C) (*25*): Experimental and Calculated Data

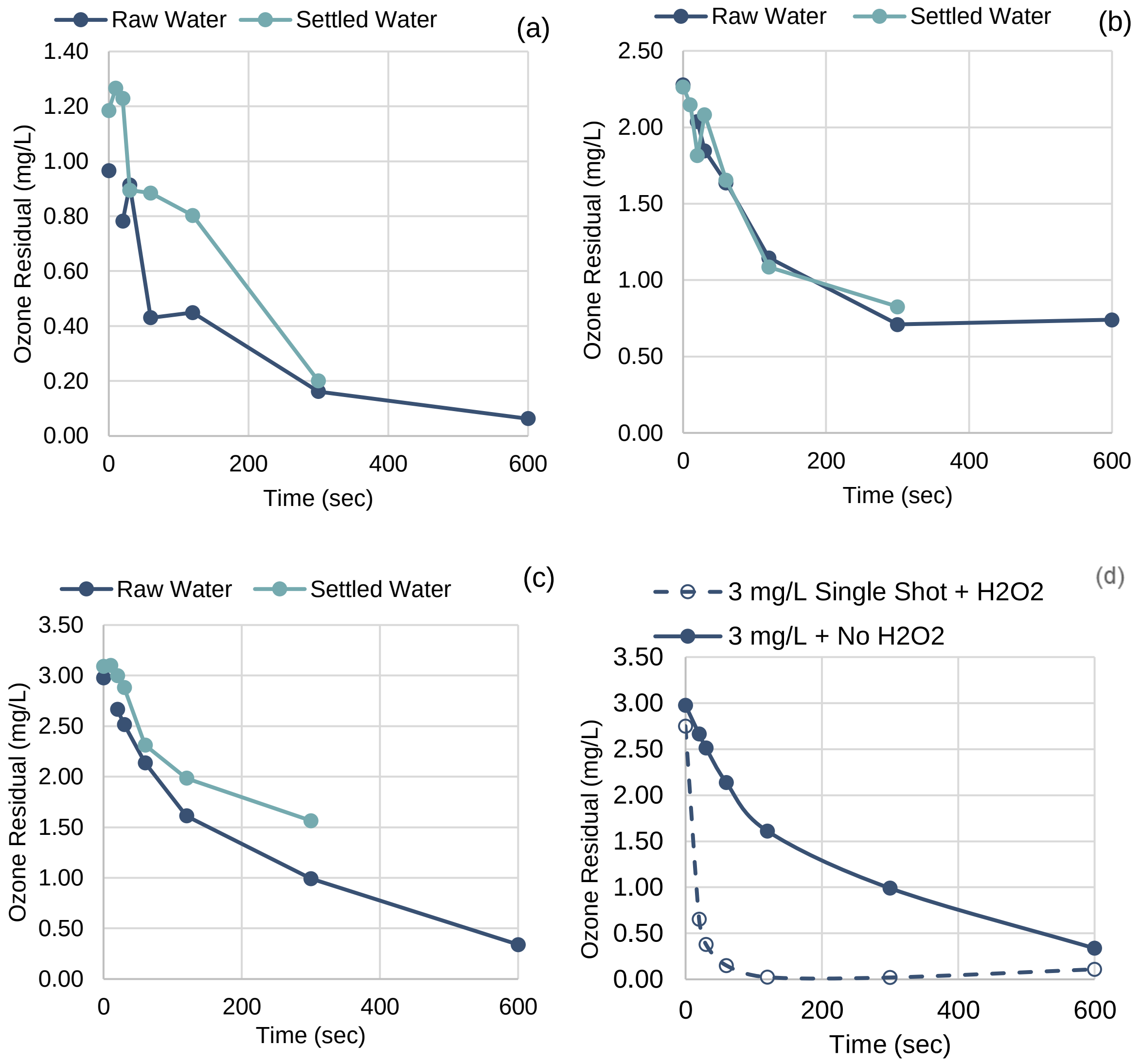
initial Br^- (mg/L)	O_3 dose (mg/L)	O_3 exposure[a] (mg/L·min)	BrO_3^- (µg/L) measd[c]	BrO_3^- (µg/L) calcd[d]	measd/calcd	BrO_3^- [b] (µg/L)
0.22	2	2.28	5	7	0.7	2
1.79	2	2.98	56	55	1.0	35
2.03	3.5	5.85	141	110	1.3	78
3.33	3.5	5.45	120	149	0.8	118

[a] Estimated from experimental data given by Krasner et al. (*25*). [b] Calculated bromate by ozone mechanism (reactions 1–9). [c] Measured by Krasner et al. (*25*). [d] Calculated considering reactions 1–27.

2022 Bench Testing at CU Boulder

Demand/Decay Testing

- Samples collected
- Bench testing studies conducted
- Demand/decay tests performed to simulate pre- and intermediate ozone
- Ozone doses: 0.5, 1.0, 2.0 and 3.0 mg/L
- Peroxone: 3 mg/L ozone + 1 mg/L H_2O_2



2022 Bench Testing

Bromate Formation/Mitigation Testing

- Raw and settled waters tested with:
  - 3 mg/L O_3 + 1mg/L H_2O_2 - in one ozone addition.
  - 3 mg/L O_3 + 1mg/L H_2O_2 - added in 3 x 1 mg/L O_3 "doses"
- Settled water showed higher bromate formation compared to raw water at 3 mg/L O_3 dose (no peroxide)
- Multiple applications of ozone in raw water showed lower bromate formation compared to single application

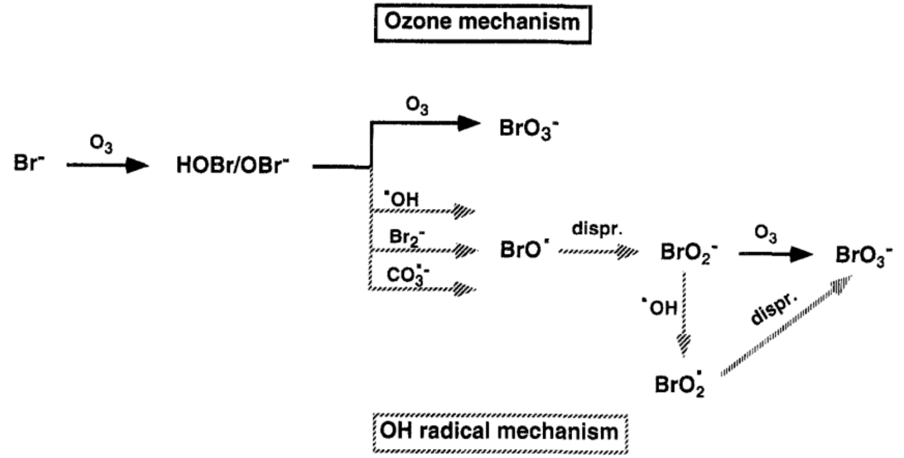
Ozone Dose (mg/L)	Bromate Formed (µg/L)		
	Pre	Intermediate	2008 Pilot* (O_3 dose)
0	ND	ND	--
0.5	ND	1.2 – 1.9	ND (0.5)
1	2	4.7	8 (1.5)
2	13	28	
3	23	59	25 - 52 (2.8)
> 4			46 – 77
3 + 1mg/L H_2O_2 (single O_3 application)	13		
3 + 1 mg/L H_2O_2 (3 x 1mg/L O_3 applications)	10		

** Raw water bromide in pilot: ~60 µg/L, bench testing 52 µg/L*

2022 Bench Testing at CU Boulder

Bromate Formation/Mitigation Testing

- Raw water bromide at QCWTP = 52 µg/L
- Maximum bromate formation observed in settled water (intermediate ozonation):
  - $[BrO_3^-]$ = 59 µg/L *($[O_3]$ = 3 mg/L, no H_2O_2)*
  - **71 % conversion**
- Maximum bromate formation observed in raw water (pre-ozonation):
  - $[BrO_3^-]$ = 23 µg/L *($[O_3]$ = 3 mg/L, no H_2O_2)*
  - **28 % conversion**



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Pre- vs Intermediate Ozone Summary

Reason	Recommendation
Water Quality	• Results indicate both pre- and intermediate ozone provide same WQ benefits (T&O, CECs, algal toxins, Fe/Mn control) • Bromate challenges may be exacerbated with intermediate ozone
Ozone Performance	
Infrastructure and Layout	
Cost	

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Ozone Performance	• Minimal difference in ozone demand and decay between pre- and intermediate • Increase in decay in raw water not expected to negatively impact ozone performance and may help reduce quenching requirements
Infrastructure and Layout	
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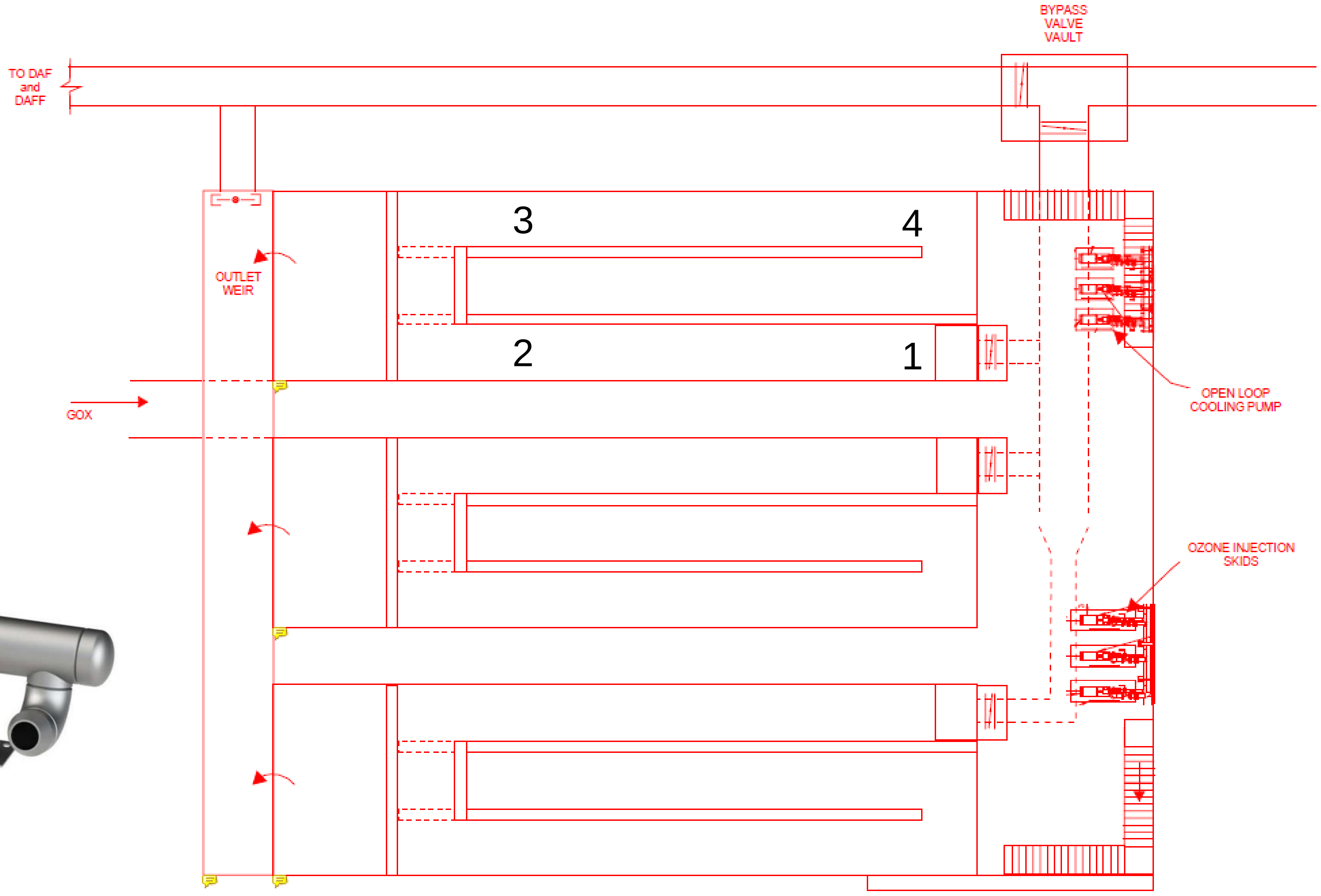
Ozone Performance	• Minimal difference in ozone demand and decay between pre- and intermediate • Increase in decay in raw water not expected to negatively impact ozone performance and may help reduce quenching requirements
Infrastructure and Layout	• Pre-ozone can be achieved by repurposing existing pretreatment basins or building new ozone contactors • Location in hydraulic profile will eliminate the need for pumping in pre-ozone configuration
Cost	• Pre-ozone provides significant cost and annual O&M savings at QCWTP by eliminating intermediate pumping

Ozone – Design Considerations

Ozone Generation and Injection

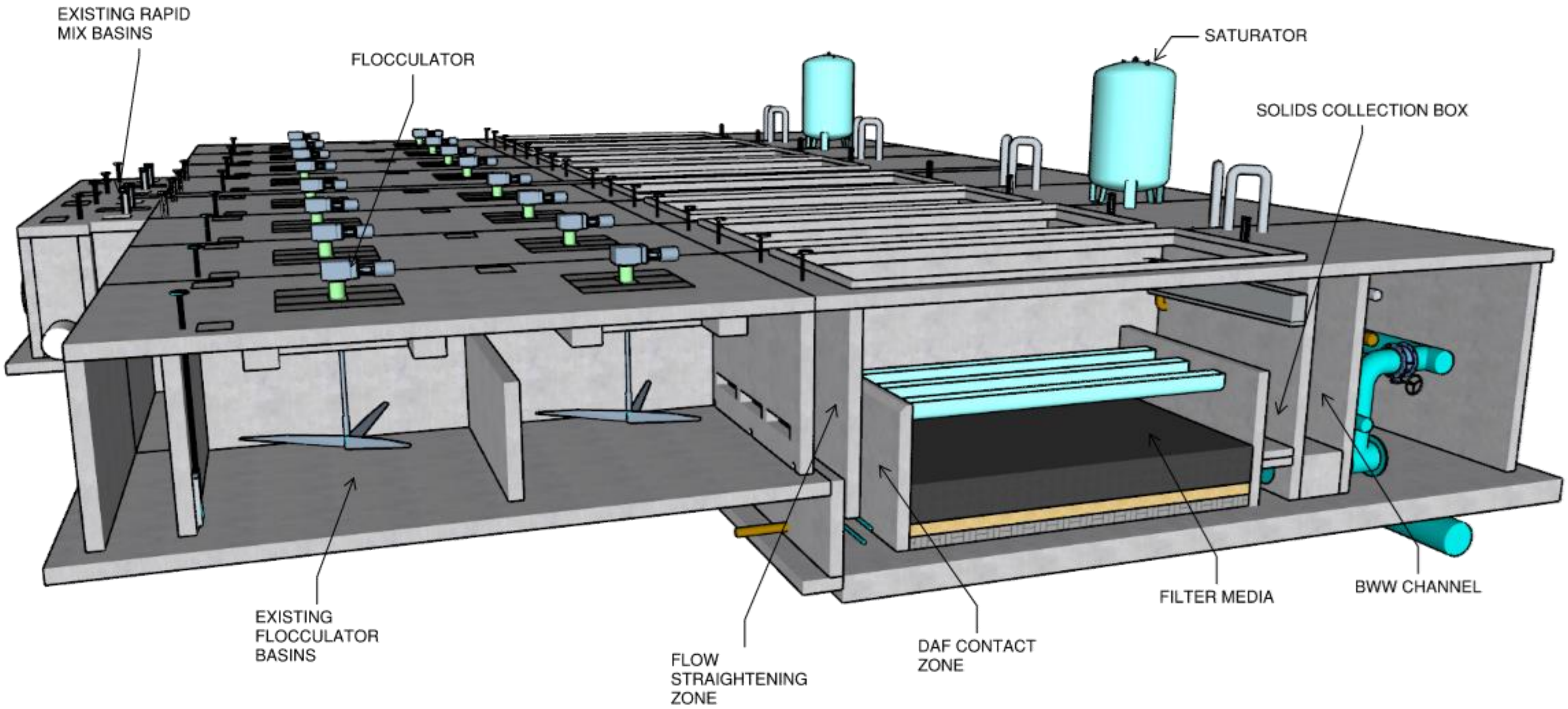
- Generated ozone gas to be introduced using **sidestream injection** with basin diffusers
- Additional injection points within the contactor facilitate strategy for bromate mitigation

Photo courtesy of Mazzei Injector Company, LLC

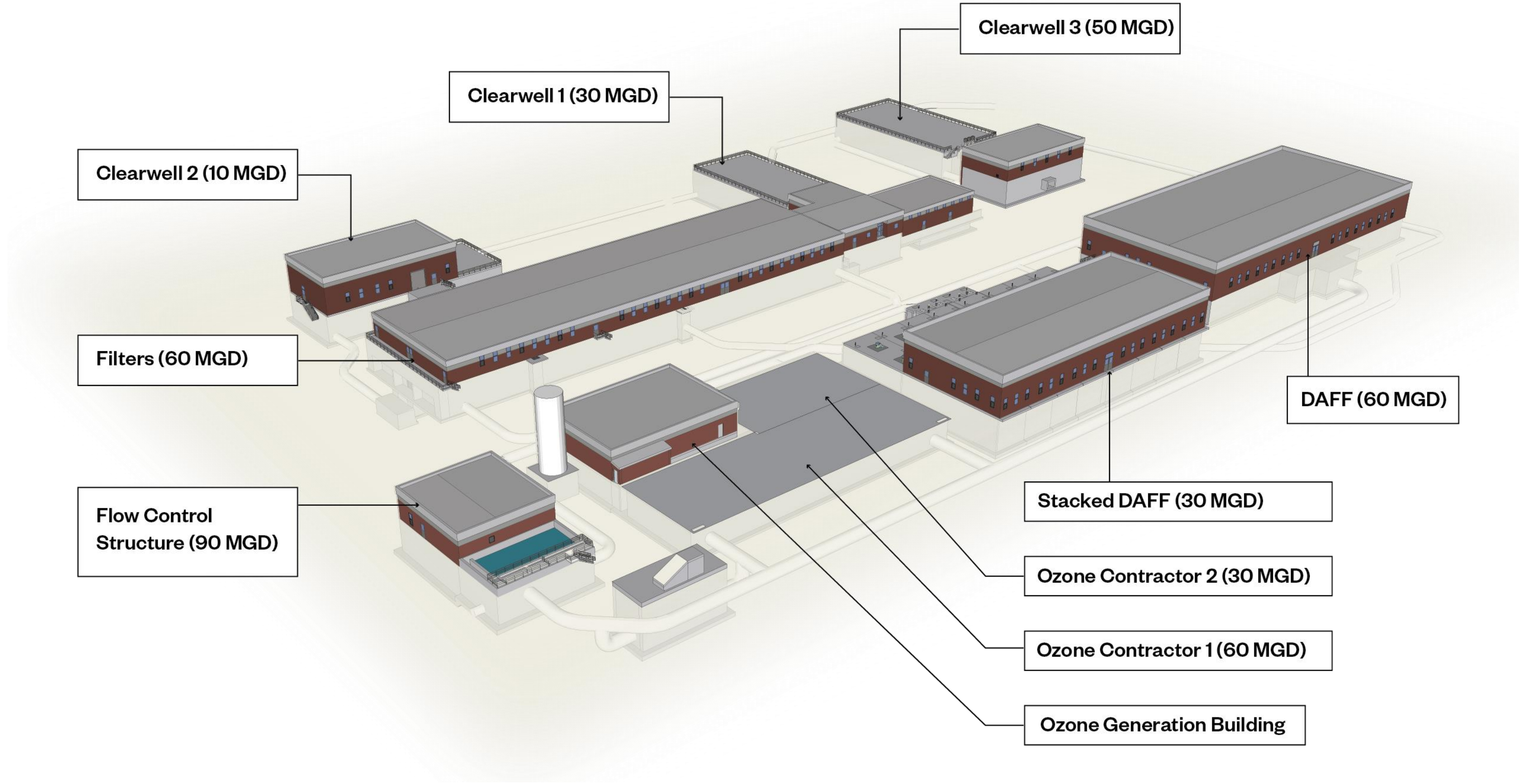


Travelling Full Circle

Pre-Ozone Opens the Door for a stacked DAFF Alternative



QCWTP in a Compact Campus Layout



Questions

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