

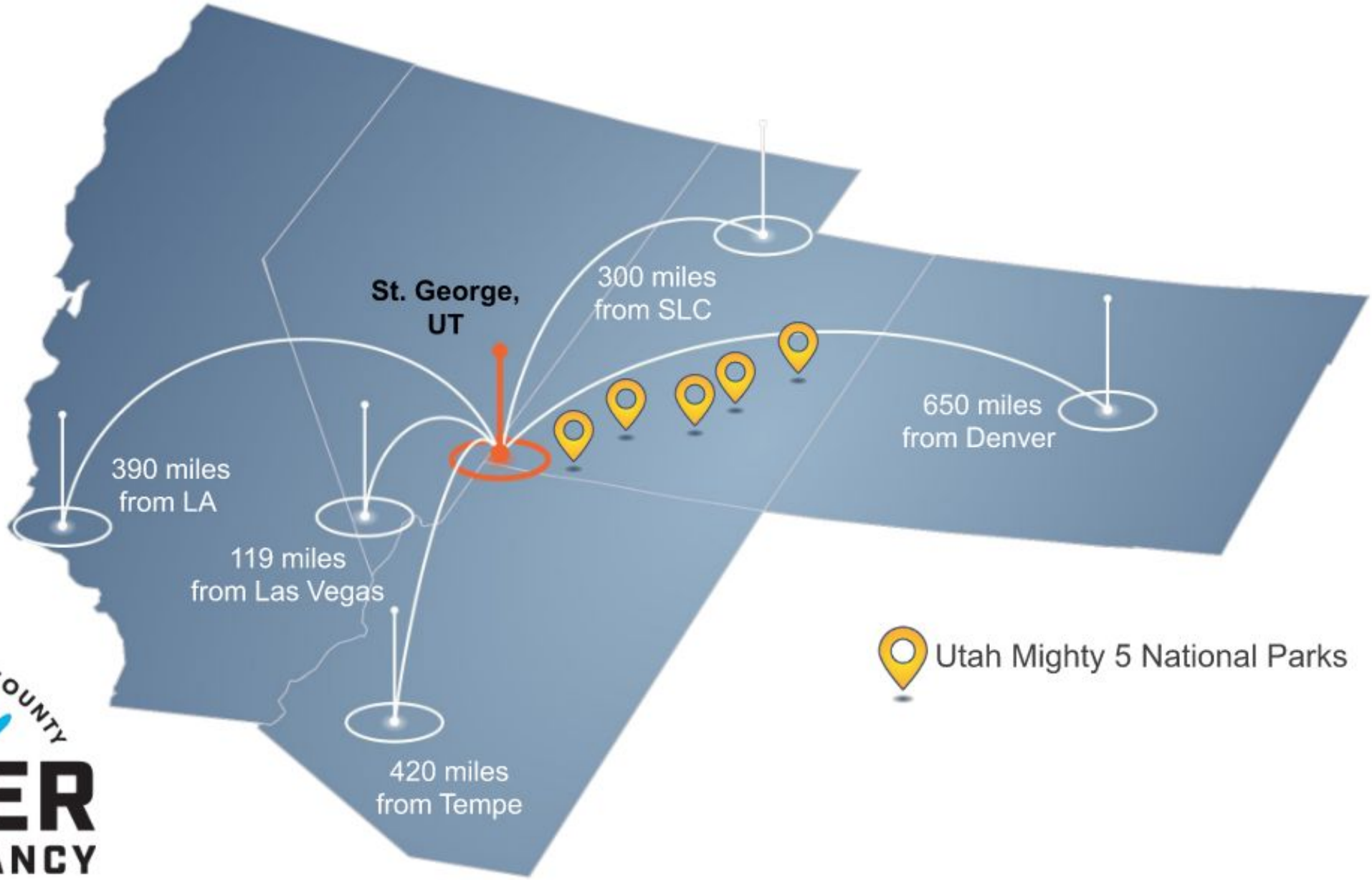
Quail Creek WTP Expansion: Targeted Approach for Water Quality, Construction, and Cost Control

Tyler Bird (Hazen and Sawyer)

Agenda

- Project Background
- Water Quality and Treatment
- Planned Project Phasing
- Cost Management
- Summary and Conclusions

Project Background



WASHINGTON COUNTY
WATER
CONSERVANCY
DISTRICT

WASHINGTON COUNTY
WATER
CONSERVANCY
DISTRICT

HARRISBURG

La Verkin

QCWTP

Hurricane

HARRISBURG JUNCTION

Limited Water Resources

Washington

MIDDLETON

St. George

St. George

Top 50 fastest growing counties in the nation



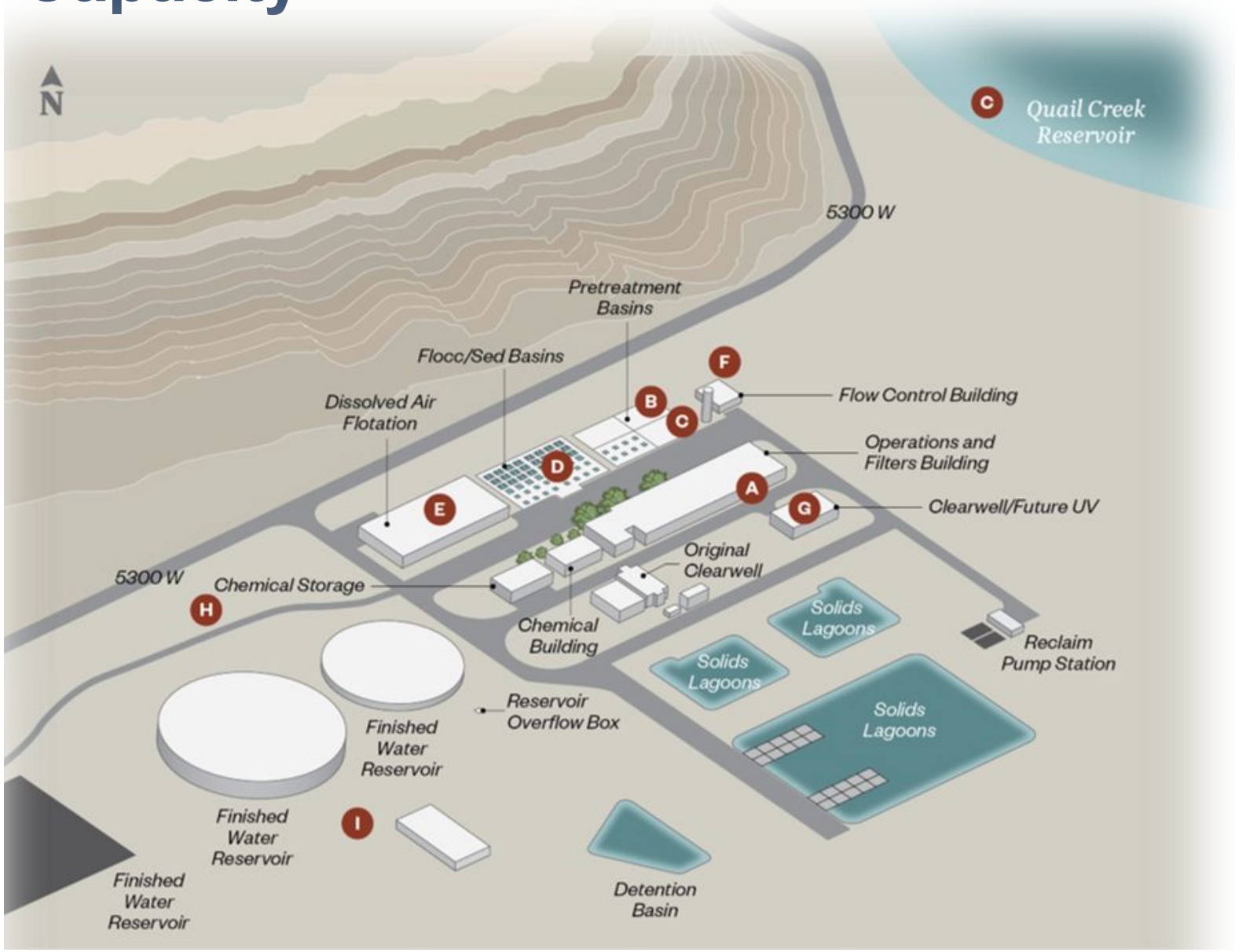
Seasonal Algae and T&O Challenges

BLOOMINGTON HILLS

BLOOMINGTON

Existing Process and Capacity

- $KMnO_4$ and PAC Pretreatment
- Floc/Sed and DAF
- High-Rate Media Filtration
- Chlorine Disinfection
- 60 mgd Capacity



Project Improvements

New Facilities:

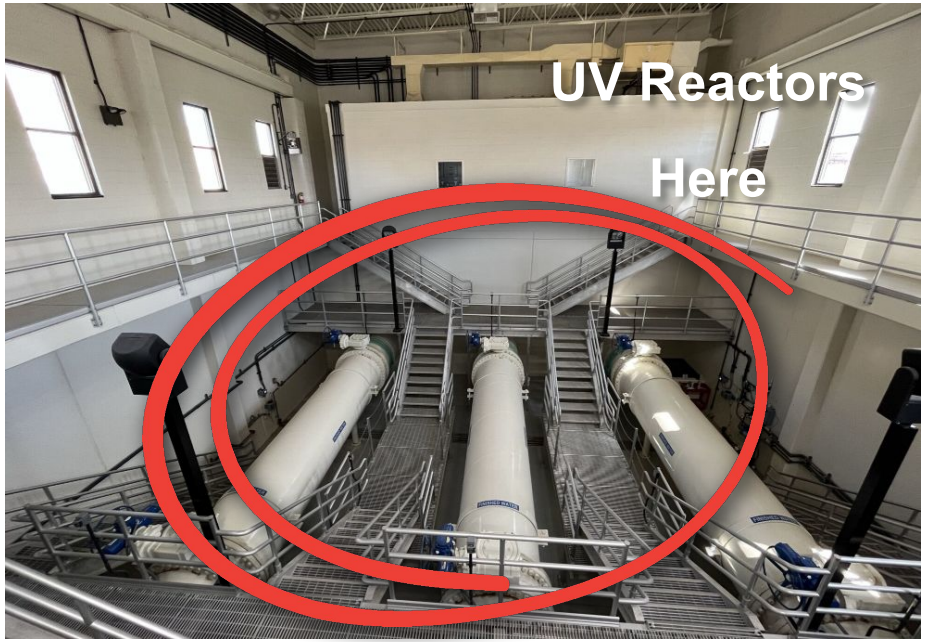
- 90-mgd Pre-ozone
- 35-mgd Dissolved Air Flotation over Filters
- Onsite Hypo Generation
- Backwash Pump Station
- Large Diameter Yard Piping



Project Improvements Cont.

<u>Modified Existing Facilities:</u>

- Rerate Existing DAF to 60 mgd
- New UV System
- Remove and Replace 2-Acres of Failing Drying Beds
- Filter Valve Replacement
- Chemical System Upgrades





Major Project Challenges

- Water Quality
  - **Seasonal manganese, algae, cyanotoxins, MIB/geosmin**
  - **Bromide**
- Construction Sequencing and Maintenance of Plant Operations
- Project Cost Management

Water Quality Considerations

Algae Challenges in the System

Algae Challenges in the System

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

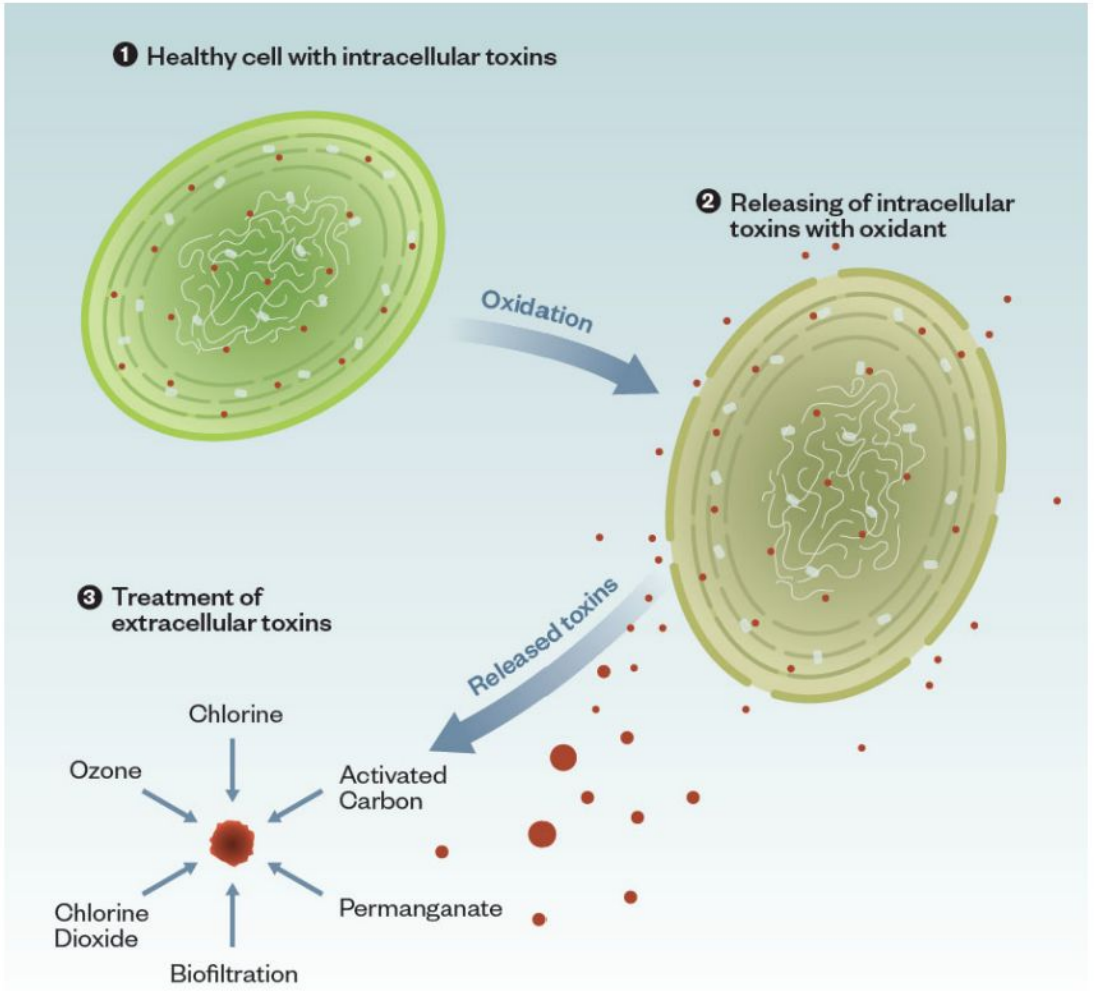
Potential Additional Challenges

- Potential for future Planned IPR



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 ratio 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).

Bromide-Bromate Formation Pathway

- 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)

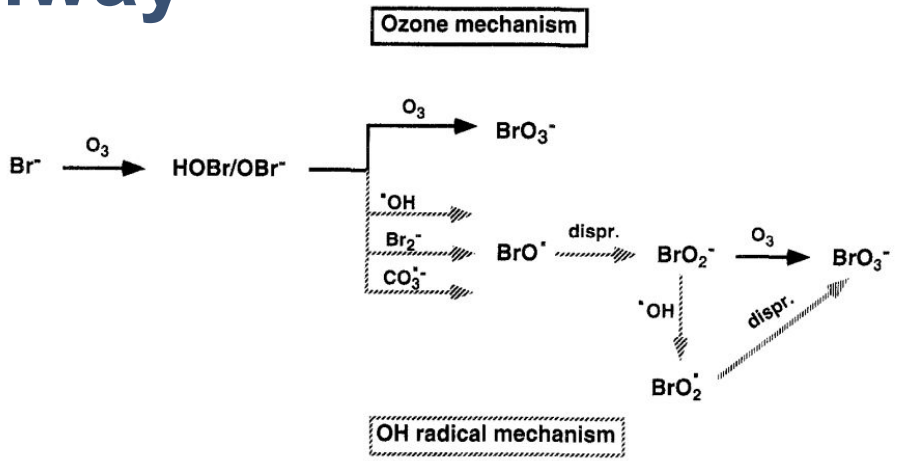


Figure 4. Comparison of the molecular ozone mechanism and the OH radical mechanism. The OH radical mechanism includes reactions of secondary oxidants as $CO_3^{\bullet-}$ and $Br_2^{\bullet-}$. A list of all of the reactions is given in Tables 1 and 2.

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

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			
1			
2			
3			
> 4			
3 + 1mg/L H_2O_2 (single O_3 application)			

** Raw water bromide in pilot: ~60 µg/L, bench testing 80 µg/L*

2022 Bench Testing

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	Pre	Intermediate	2008 Pilot* (O_3 dose)
0	ND	ND	--
0.5	ND	1.2 – 1.9	ND (0.5)
1			
2			
3			
> 4			
3 + 1mg/L H_2O_2 (single O_3 application)			

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	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			
> 4			
3 + 1mg/L H_2O_2 (single O_3 application)			

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	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			
3 + 1mg/L H_2O_2 (single O_3 application)			

** Raw water bromide in pilot: ~60 µg/L, bench testing 80 µg/L*

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.
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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)			

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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.
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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		

** Raw water bromide in pilot: ~60 µg/L, bench testing 80 µg/L*

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"
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	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 1 mg/L O_3 applications)	10		

** Raw water bromide in pilot: ~60 µg/L, bench testing 80 µg/L*

2022 Bench Testing at CU Boulder

Bromate Formation/Mitigation Testing

- Raw water bromide at QCWTP = 52 µg/L
  - **Spiked to 80 µg/L during testing**
- Maximum bromate formation observed in settled water (intermediate ozonation):
  - **[BrO_3^-] = 59 µg/L *([O_3] = 3 mg/L, no H_2O_2)***
  - **74% 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 without AOP**

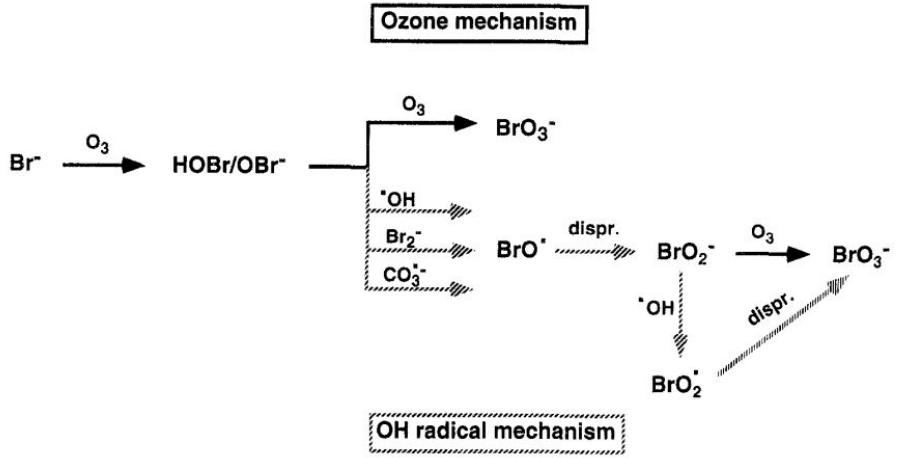
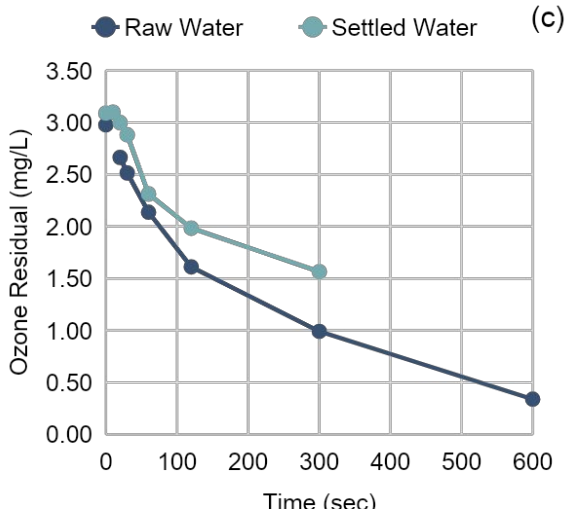


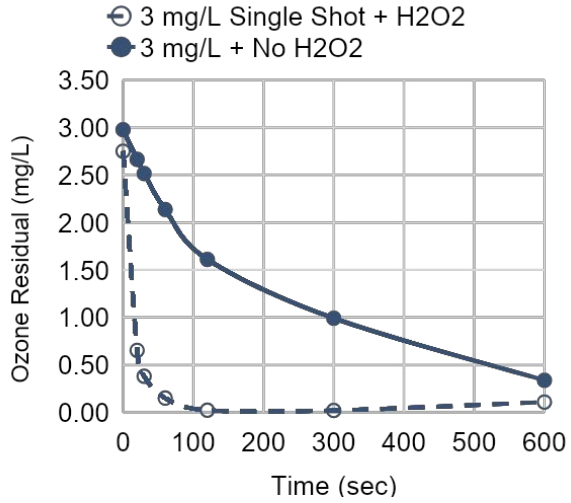
Figure 4. Comparison of the molecular ozone mechanism and the OH radical mechanism. The OH radical mechanism includes reactions of secondary oxidants as CO_3^- and Br_2^-. A list of all of the reactions is given in Tables 1 and 2.

Bench Testing at CU Boulder, 2022/2024

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
- 2022 Peroxone: 3 mg/L ozone + 1 mg/L H_2O_2
- 2024 Peroxone: 3 mg/L H_2O_2 + 1 mg/L ozone (3x)



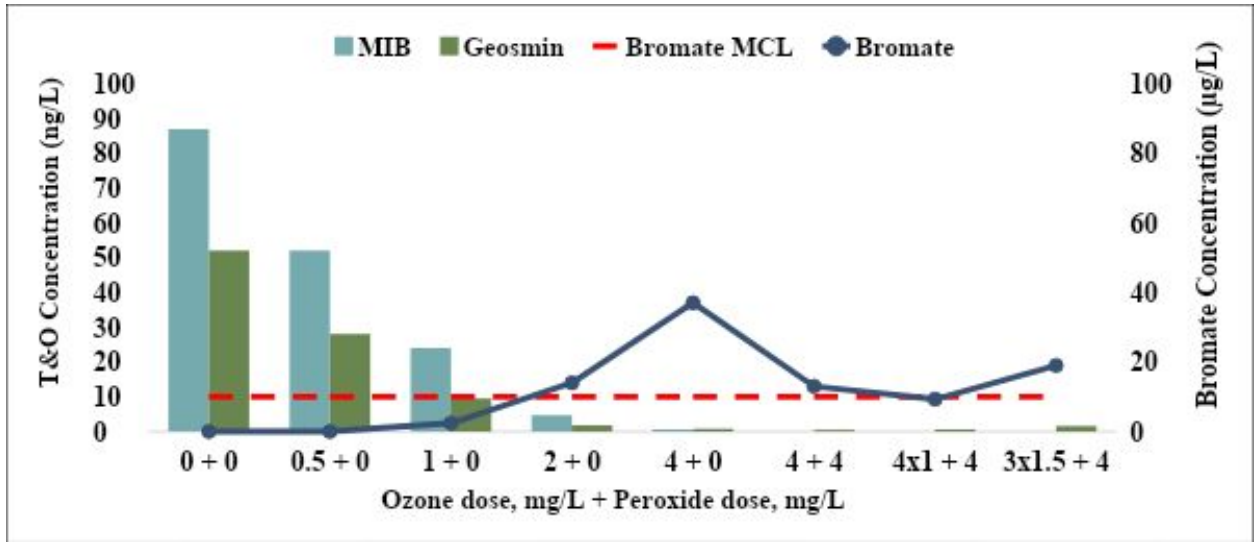


2024 Bench Testing at CU Boulder

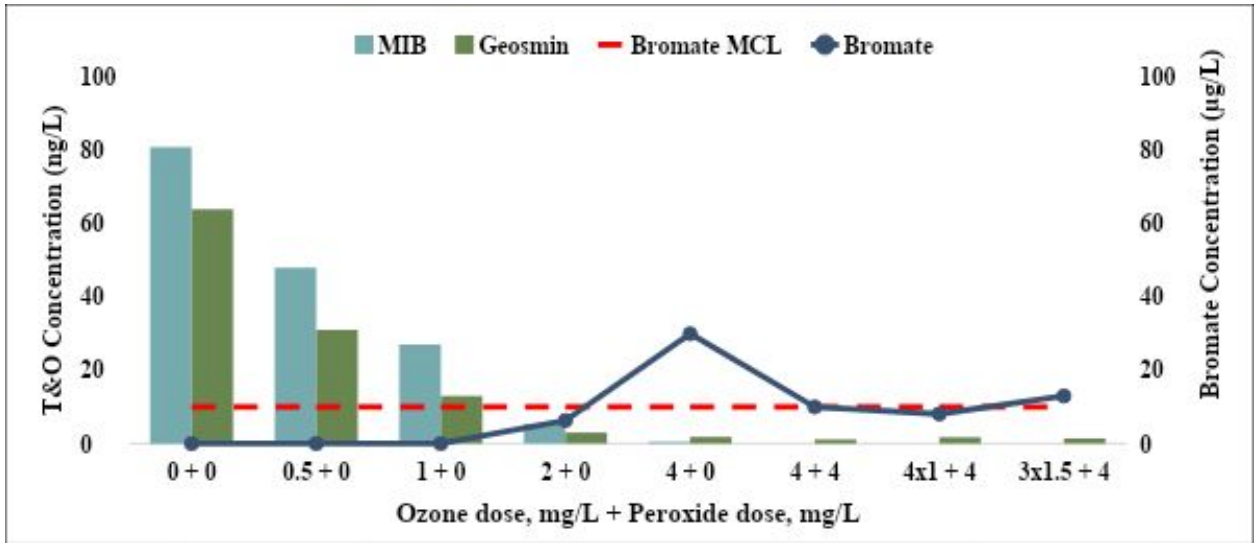
Bromate Formation/Mitigation Testing

Parameter	Quail Creek Reservoir	Sand Hollow Reservoir
pH	8.26	8.28
Bromide, µg/L	45	42

Quail Creek Reservoir



Sand Hollow Reservoir



Ozone – Design Considerations

Ozone Generation and Injection – Hybrid Over/Under-Serpentine Contactors

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



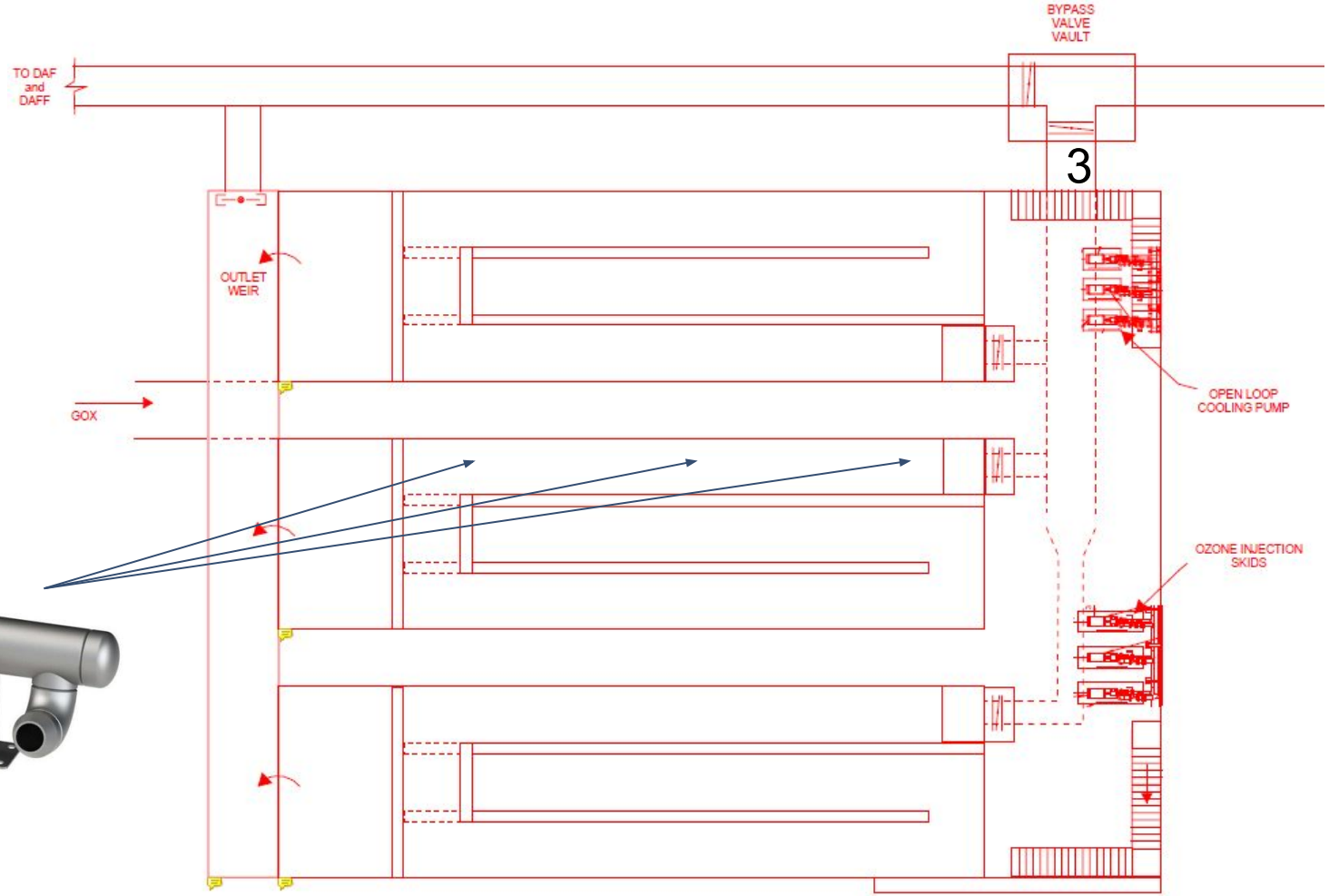
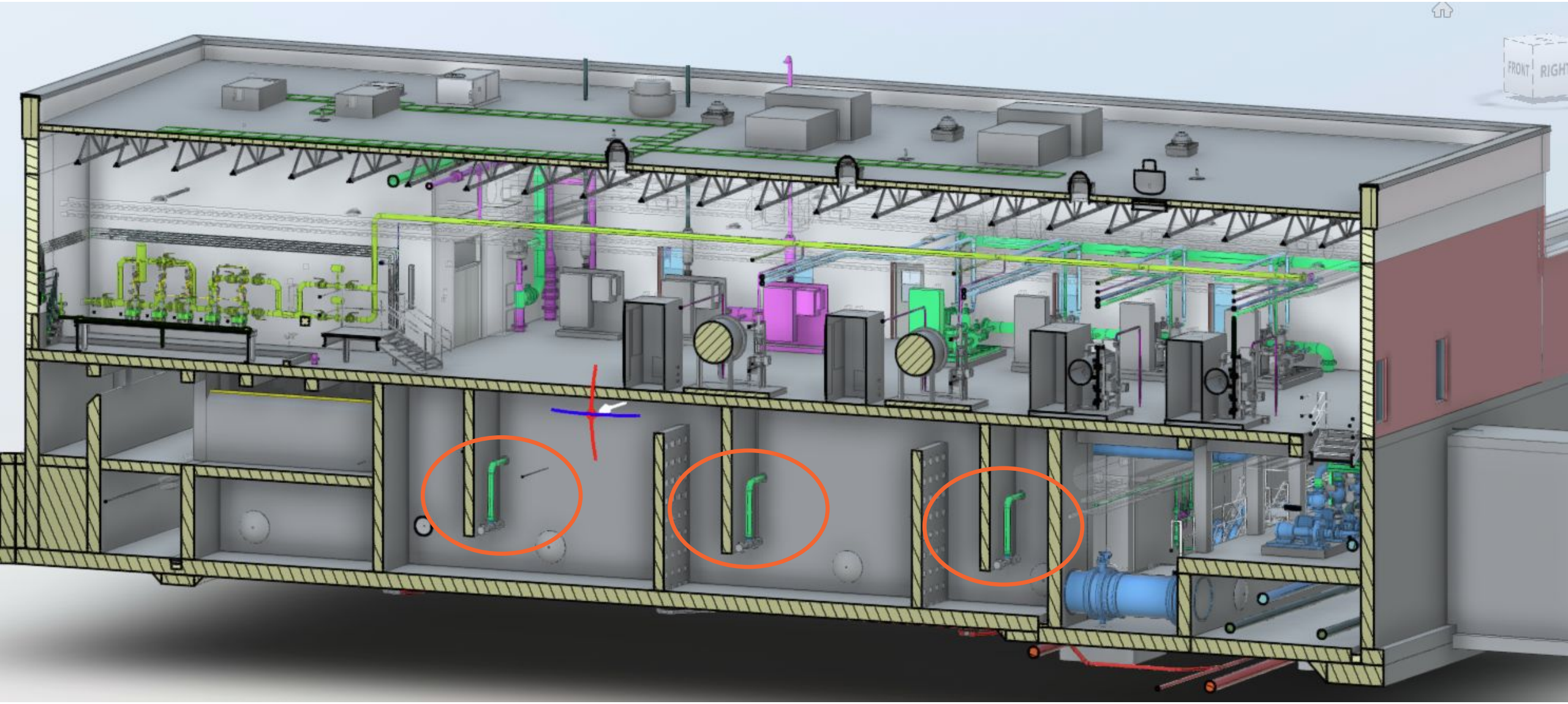


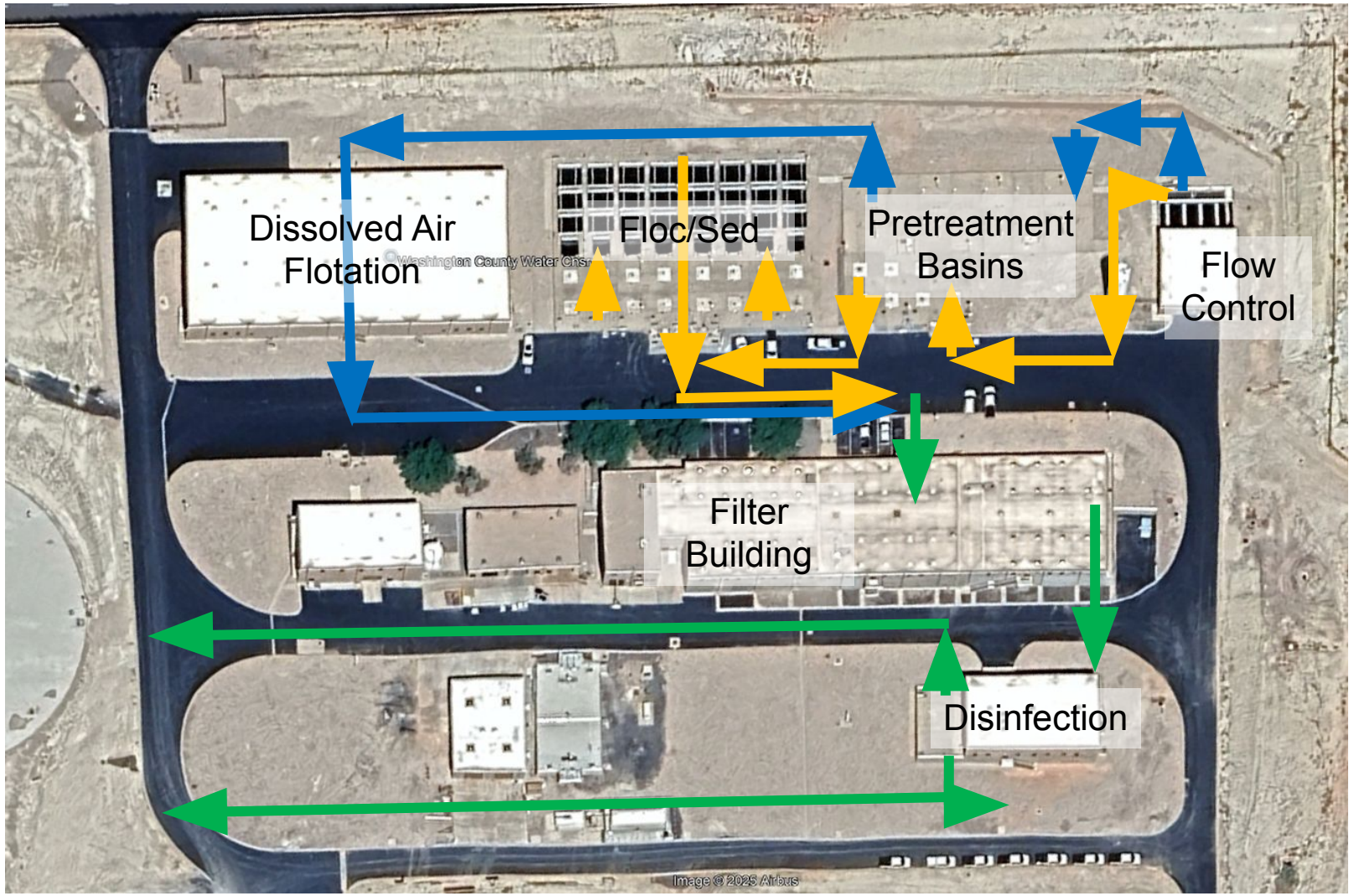
Photo courtesy of Mazzei Injector Company, LLC


FRONT
RIGHT

Construction Sequencing and Maintenance of Plant Operations

Bifurcated Plant (Two Trains)

40 mgd
+ 20 mgd
= 60 mgd
(gross)



Need for Project Phasing

60 mgd (gross)

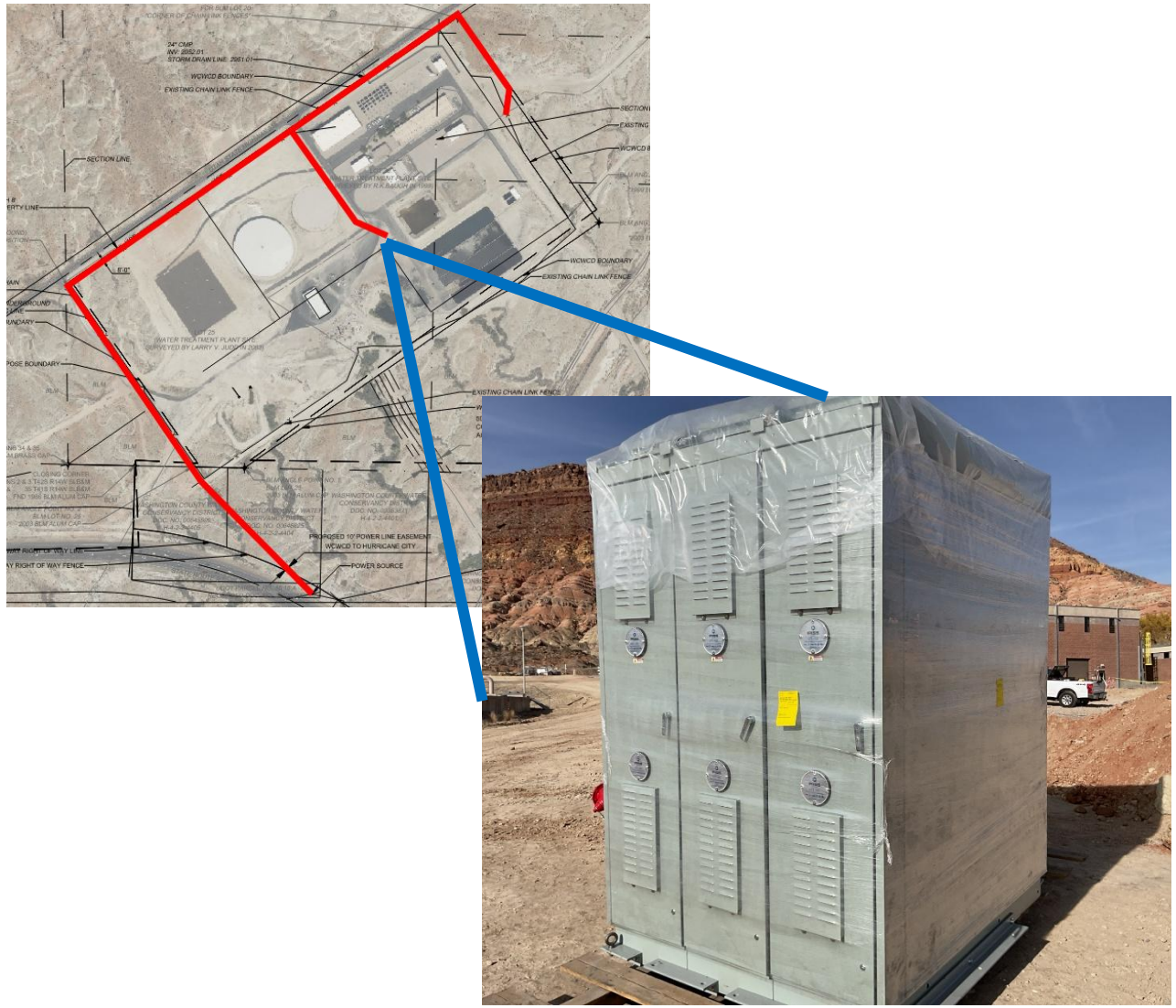
- Pre-procure Long Lead Equipment Items
- Rerate Existing DAF to 60 Mgd
- Flow Control and Filter Improvements
- Create Space for Ozone and DAFF
- Contractor Specialty Construction Packages
  - **Mechanical**
  - **Demo, earthwork, piping**



Phase 0 – (Preliminary Electrical)

Includes:

- New medium voltage service
  - **Including long lead items like switchgear and transformers**
  - **~ 5,000 ft of medium voltage ductbanks**
- AHJ and DOT Coordination
- Owner prepurchased equipment in summer 2024
- Contractor to install electrical ductbanks and equipment in summer 2026

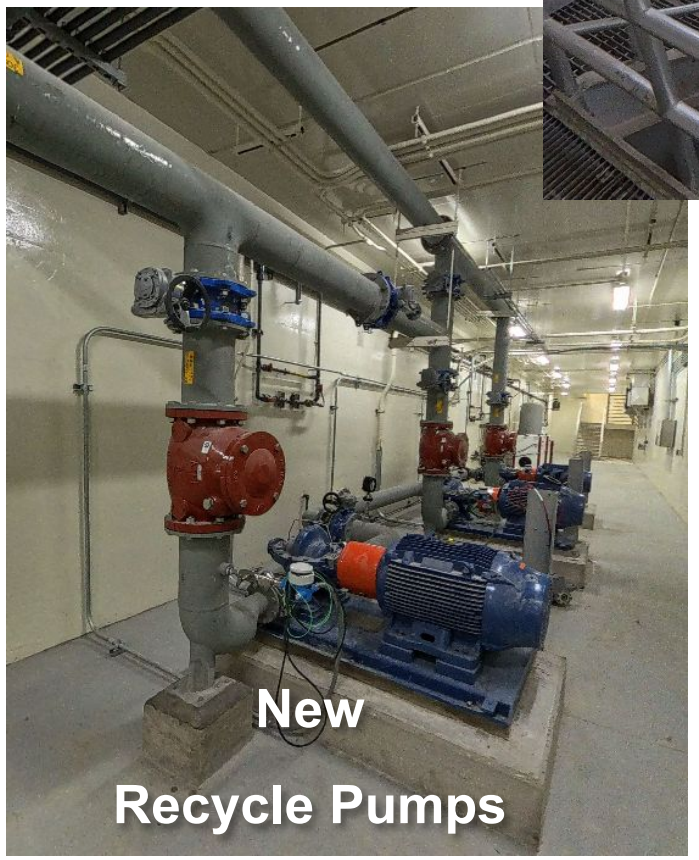


Phase 1 – (Preliminary Mechanical)

Includes:

- Rerate Existing DAF
  - **Recycle Pumps and Injectors**
  - **Air Compressors**
  - **Electrical Improvements**
- Flow Control and Filter Improvements
  - **Valves and Actuators**
- Owner purchased valves and actuators in summer 2024.
- Contractor installed in winter 2025

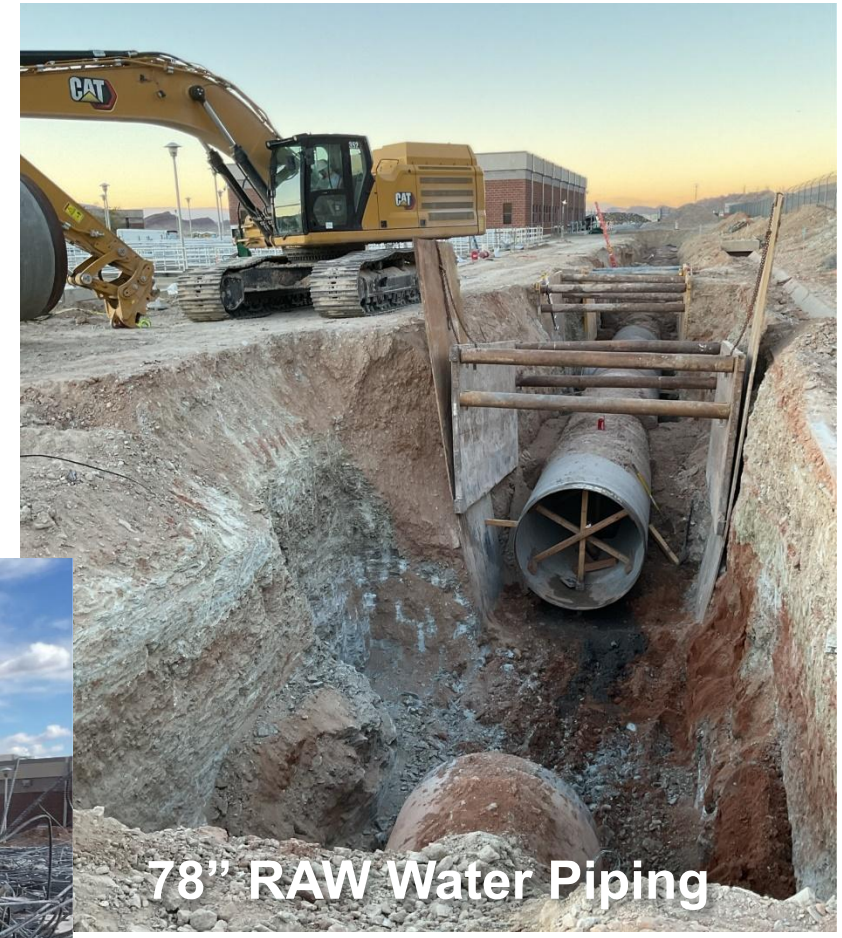




Phase 2 – (Heavy Civil)

Includes:

- Large Diameter Welded Steel Yard Piping
- Demolition of Pretreatment and Floc/Sed



78” RAW Water Piping



Floc/Sed Demolition

Phase 2 – (Heavy Civil)

Includes:

- Excavation for Ozone and DAFF
- Drying Beds
- Misc. Yard Piping and Site Improvements



Ozone and DAFF Excavation

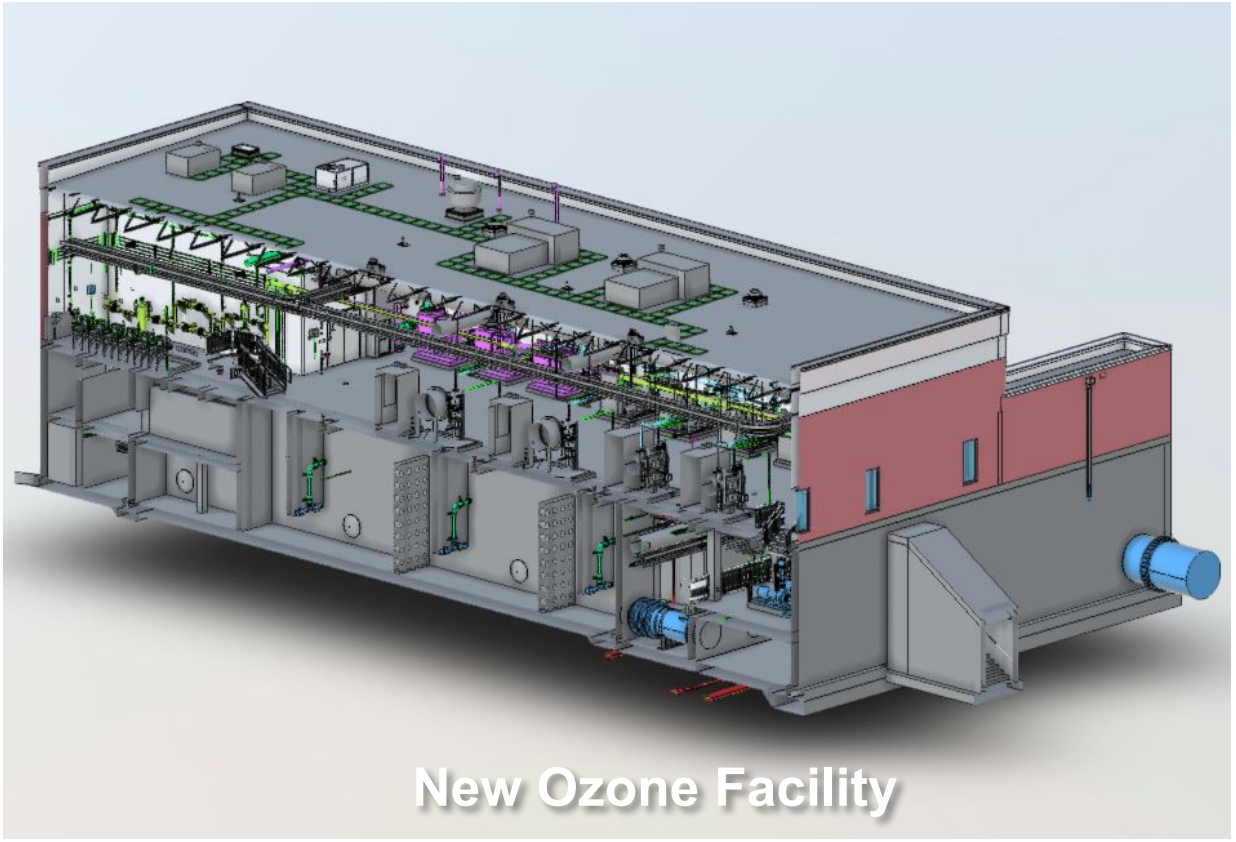


New Drying Beds

Phase 3 – (Everything Else)

Includes:

- Ozone
- DAFF
- UV
- Onsite Hypo Expansion
- Backwash Pump Station
- Chem Storage and Feed Improvements
- Operations Building Remodel



New Ozone Facility

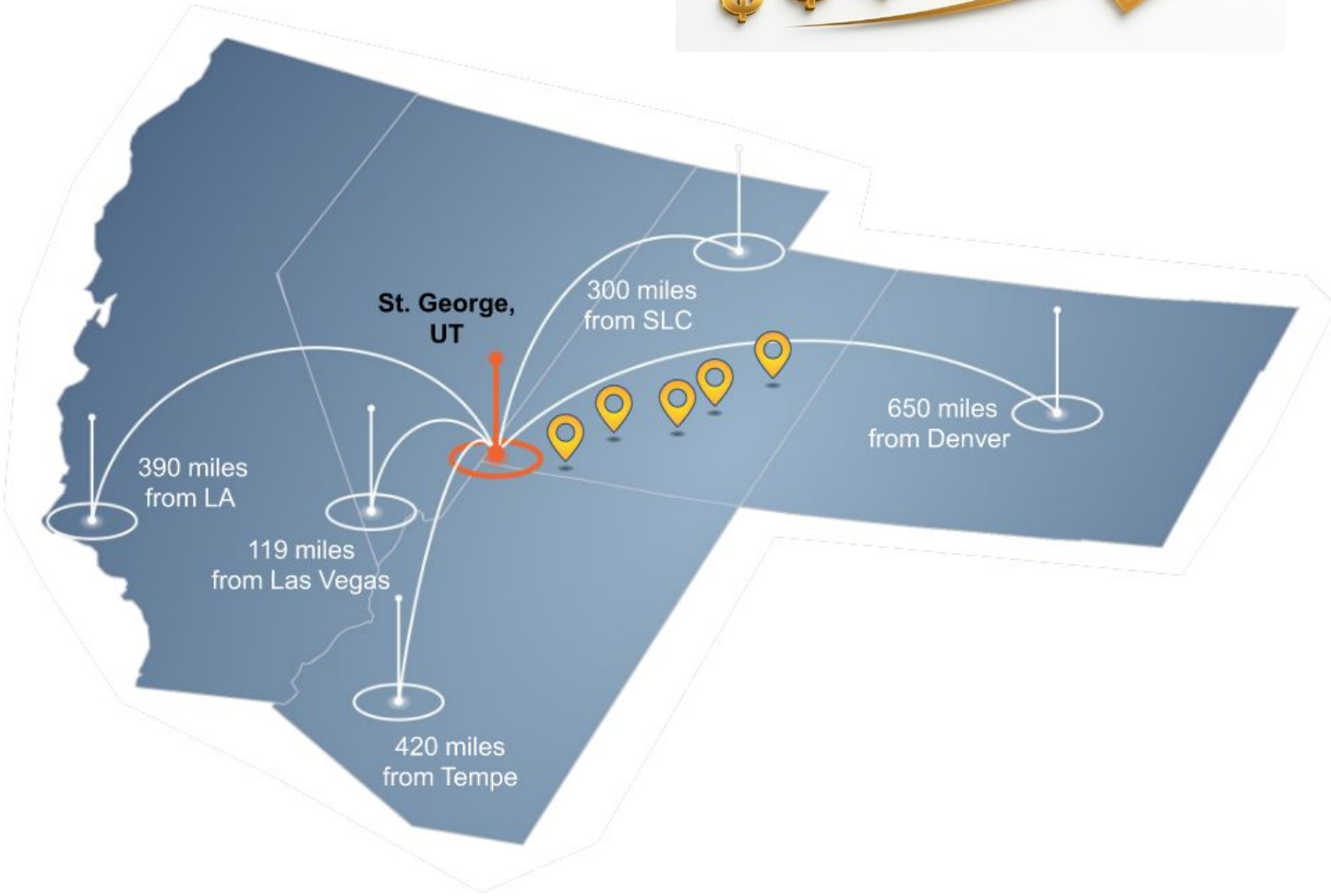
Currently Bidding
Construction Summer 2026 through December 2028

Project Cost Management

Project Cost Challenges and Risks

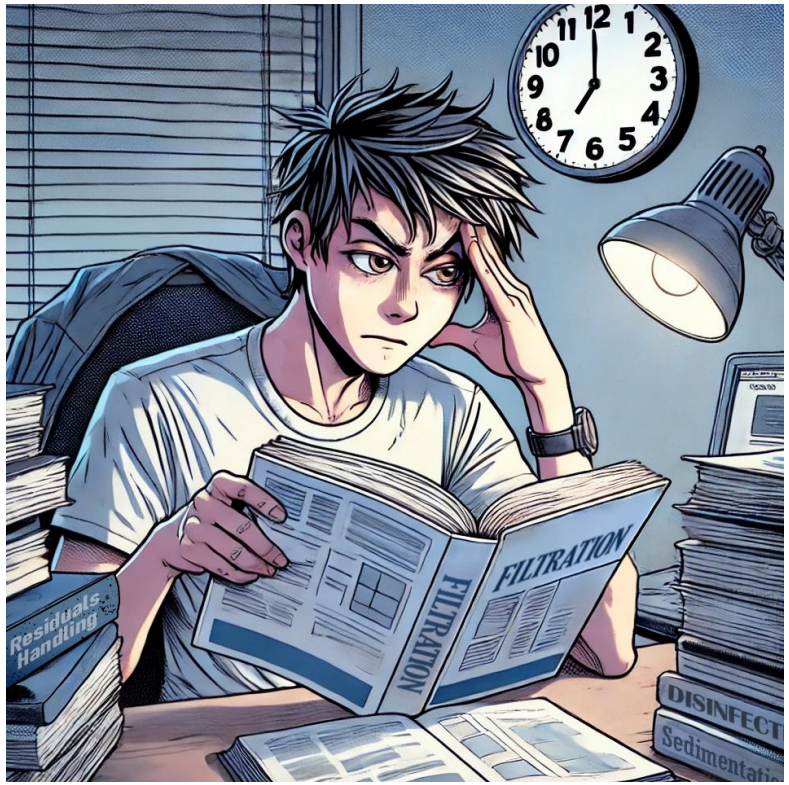


- Fixed Project Budget
- Remote Location
- Regional Record Growth
  - **Qualified Contractor Shortage**
  - **Skilled Labor Shortage**
- Supply Chain Backlog
- Tariff Uncertainty
- Increasing Global Tensions



Value Based Project Definition Development

Technical Memoranda



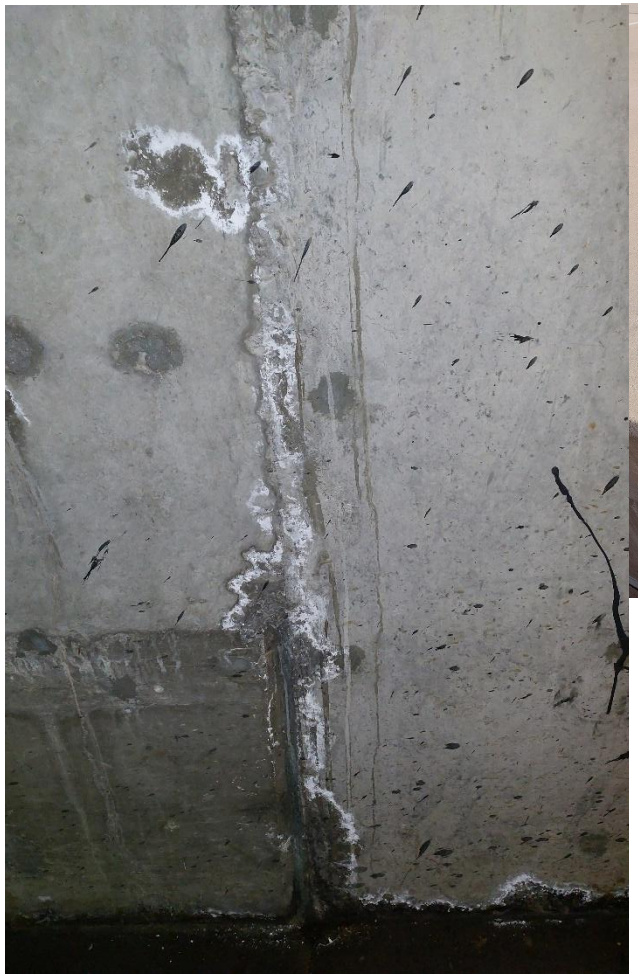
Collaborative Workshops + BODR



- ✔ Project Goals and Objectives
- ✔ Design Criteria/ Operational Goals
- ✔ Condition Assessment Findings
- ✔ *À La Carte* Alternative Identification
- ✔ Real Time VE and Alternative Selection
- ✔ Summarized in BODR

QCWTP Ozone Workshop Example

Ozone Retrofit or Rebuild





Condition: Region 2

- **Roof deck map cracking**
- **Leaking cracks**
- **30+ years of remaining useful life**

Corrective Action Recommendations

Condition Ranking	Performance Ranking 1	2	3	4	5
1	Region 1			Region 4	
2					
3	Region 2				
4	Region 3				Region 5
5					

Region 1 - No Immediate Action Required

Region 2 - More Detailed Inspection Recommended

Region 3 - Schedule Corrective Action Work Order Near Term

Region 4 - Immediate Corrective Action Required

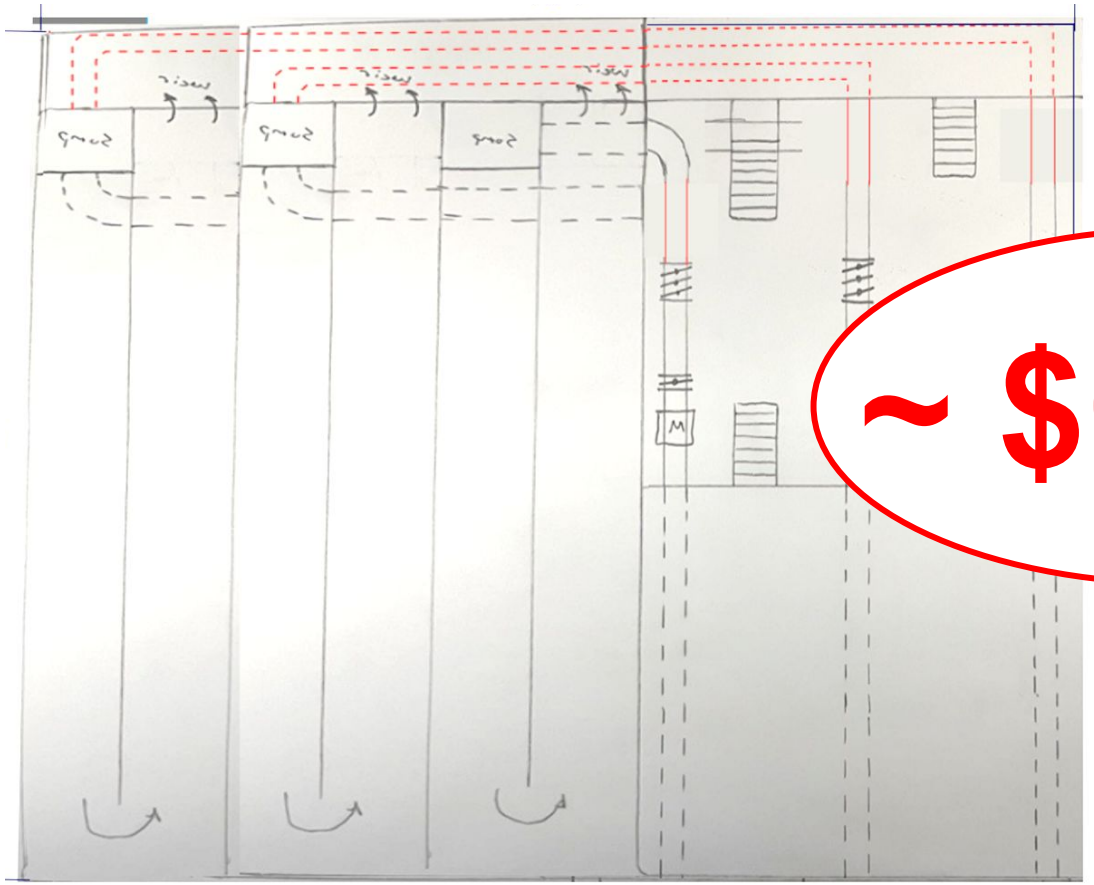
Region 5 - Replace/Refurbish

Decision: Rebuild

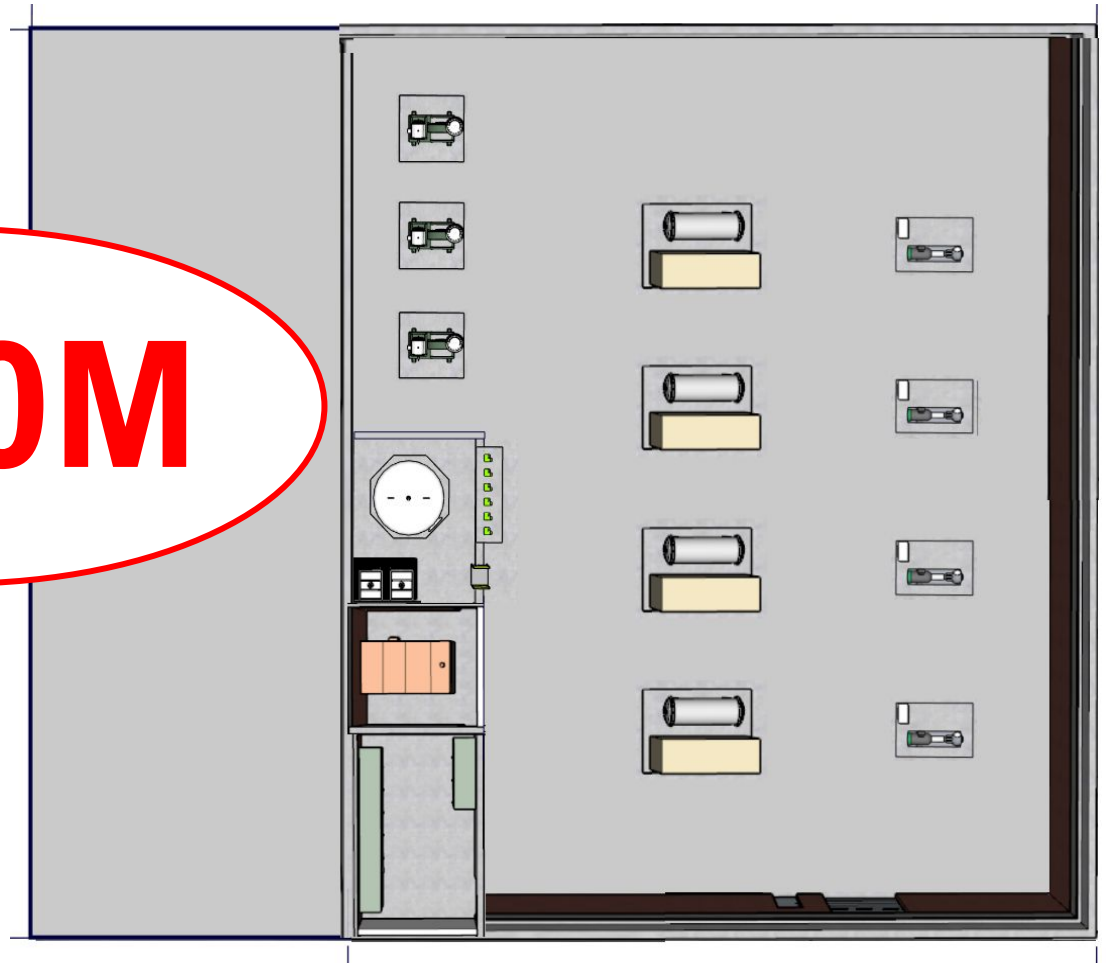
Based on 60-Year Life Cycle Cost Analysis

QCWTP Ozone Workshop Example Cont…

Ozone Rebuild “Cookie Cutter” Option



~ $60M

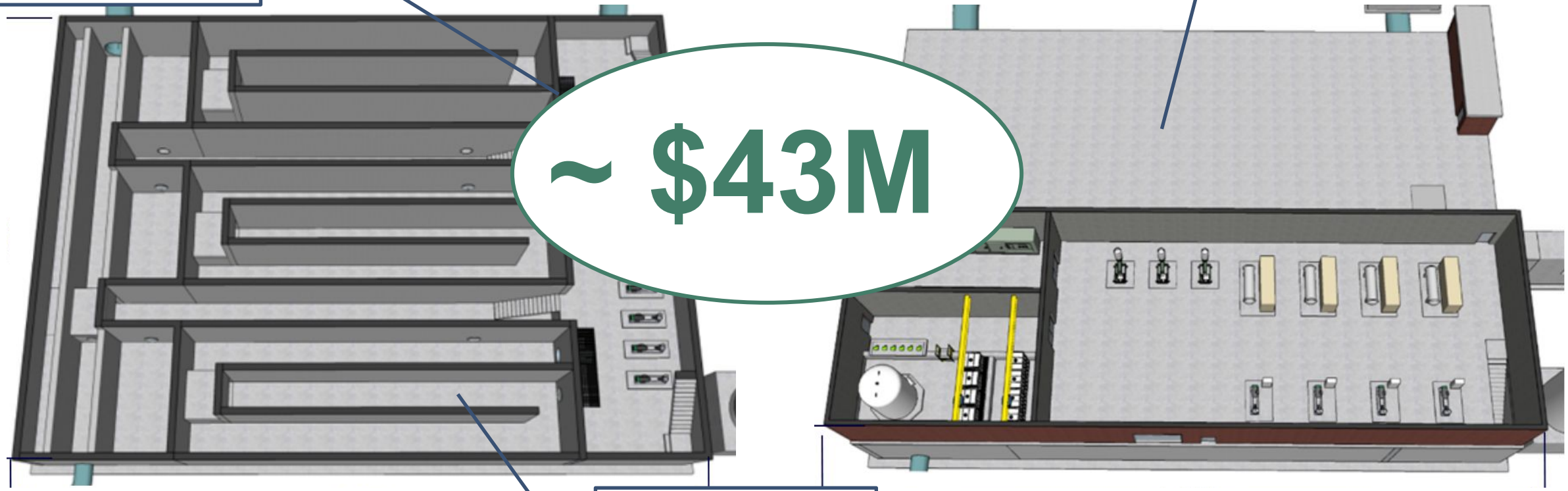


QCWTP Ozone Workshop Example Cont…

Ozone Rebuild “Custom” Option

Simplified Inlet Piping, Optimized Hydraulics

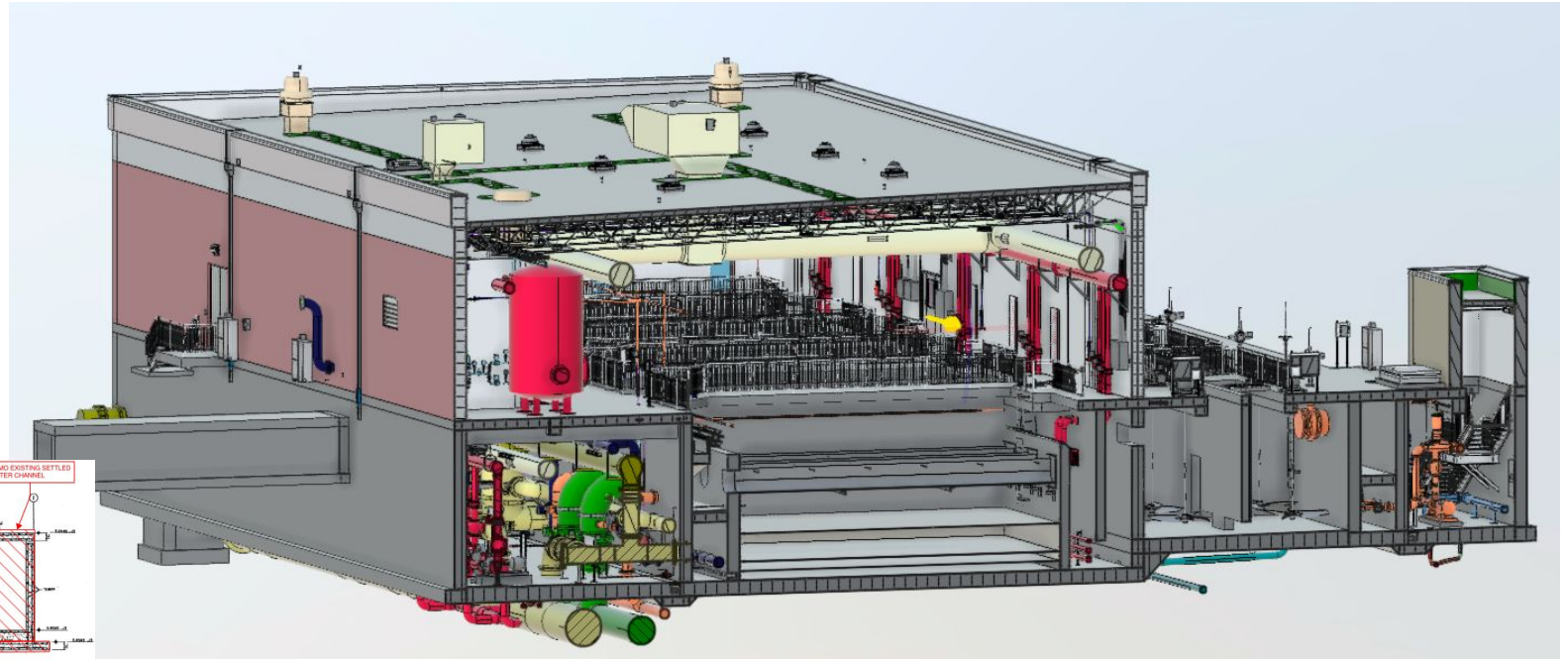
~ 30% Smaller Ozone Facility



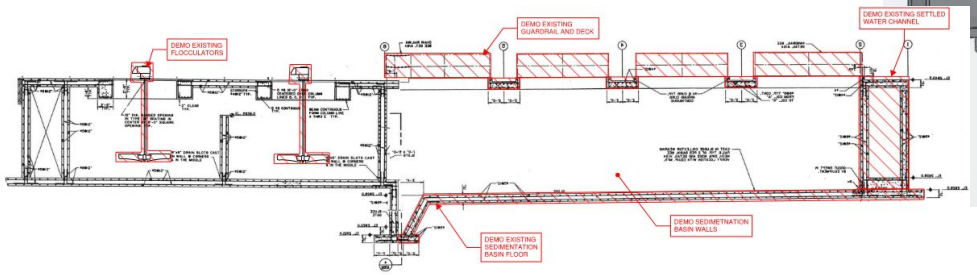
~ $43M

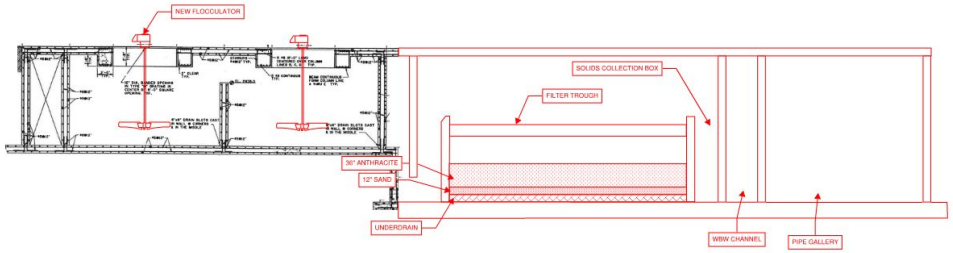
Optimized O3 Contact Time

Similar Approach Used for DAFF



Rebuild





Retrofit

REBUILD selected over Retrofit due to reduced structural risk and similar life cycle cost

Establish Project Phasing

- Simplify Construction Sequencing — **Reduces Risk**
- Accommodate Specialty Contractors — **Expands Contractor Options**

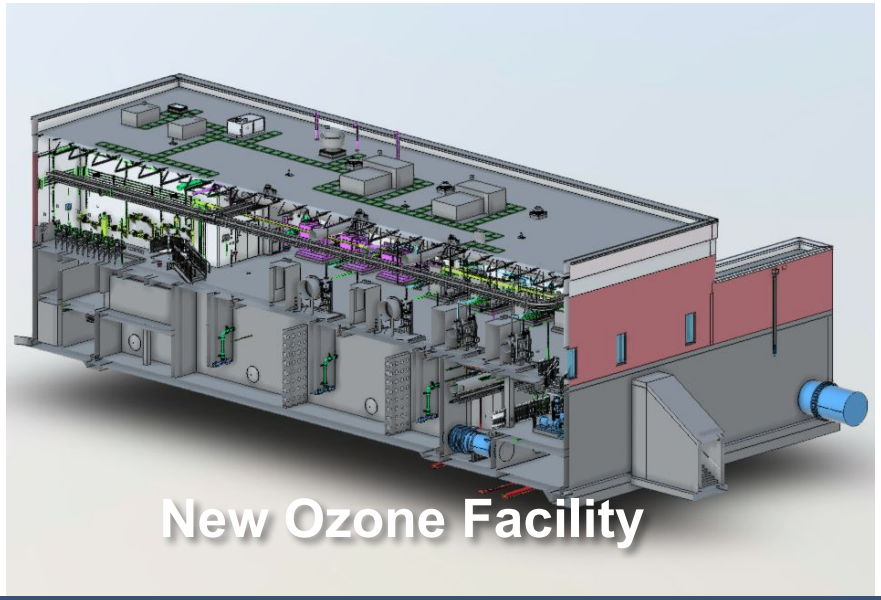
Ozone Facility Example

Phase 1/2





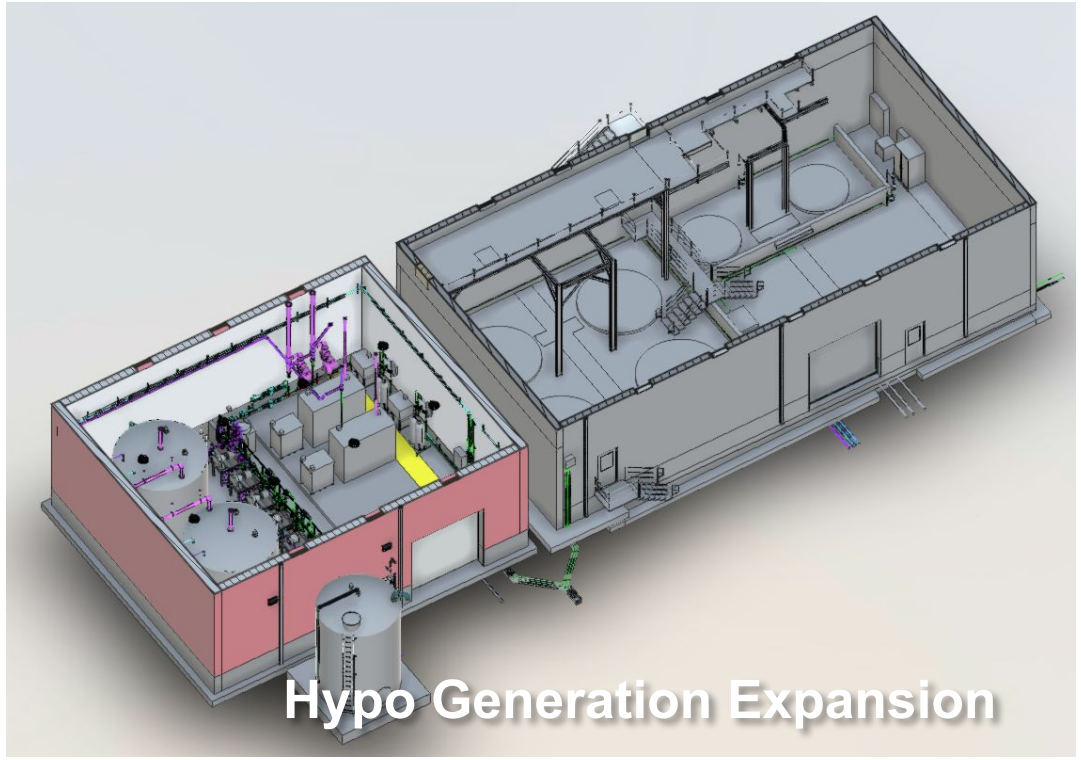
Phase 3

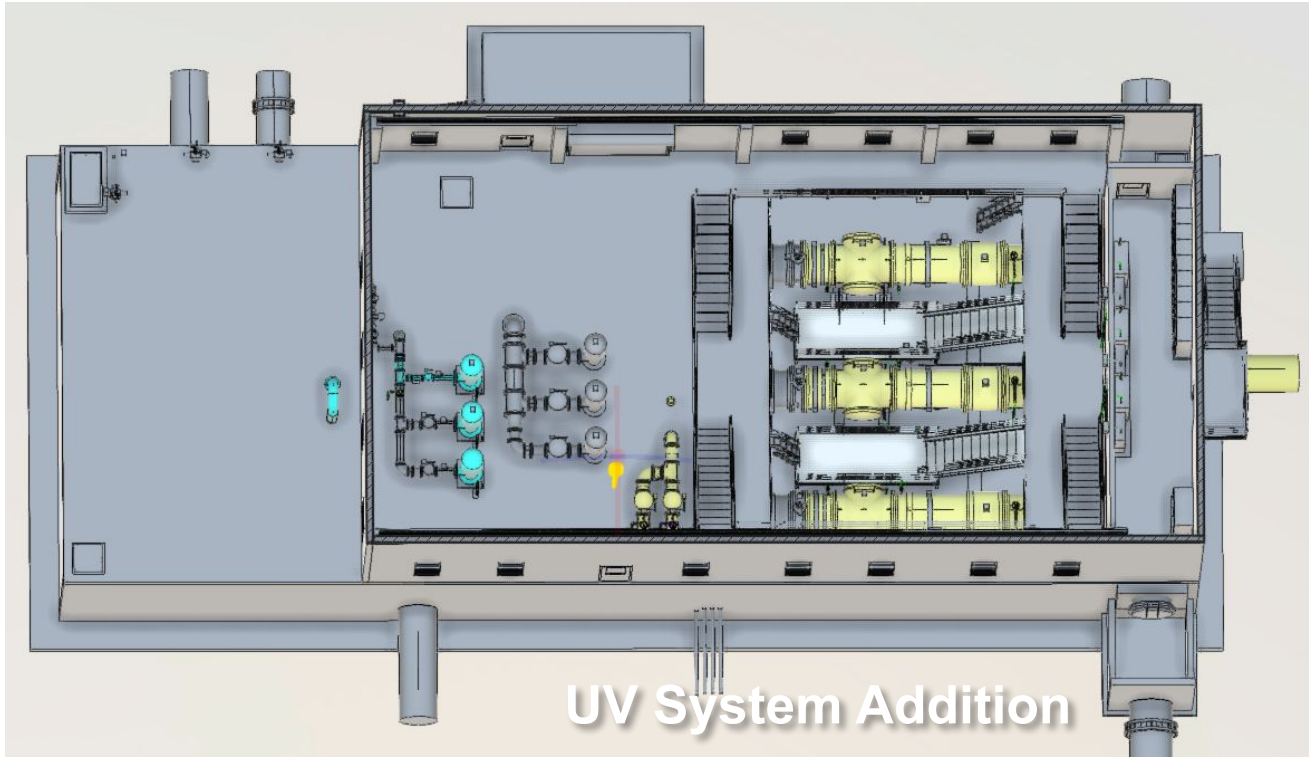


Bid Alternates for Cost Flexibility

- Chemical System Improvements
- UV System vs Maintain Status Quo
- Onsite Hypo Generation Expansion vs Rehab

✓ Planned VE and Alternative Selection





Summary and Conclusions

Summary

- Recent studies show the algae “lyse and treat” approach as an effective option for pre-ozone facilities.
- Multi-stage ozone injection with hydrogen peroxide addition (peroxone) effectively minimizes bromate formation.
- Project phasing simplified construction sequencing reducing contractor risk and cost and enlarged contractor pool for specialty work.
- Creative thinking to implement pre-ozone instead of intermediate ozone saved the client ~$10M in CapEx and additional $Ms in OpEx over the life of the facility.
- Custom right sized ozone facility saved the client ~$17M in CapEx.
- Unique DAFF facility vs DAF with additional Filters saved the client ~$4M in CapEx and fit within the footprint available.
- Established bid alternates provide flexibility to meet project budget without costly redesign

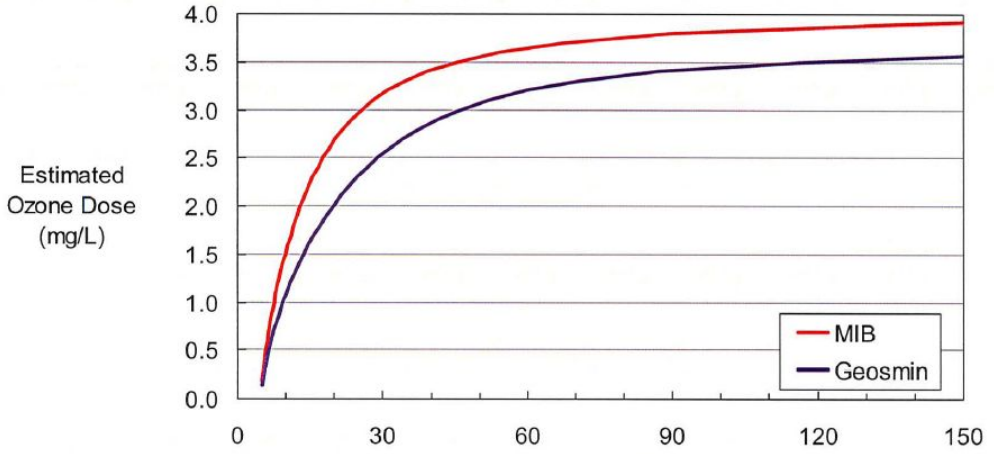
Questions

Tyler Bird: tbird@hazenandsawyer.com

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
- 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
  - No significant difference in ozone demand between pre- and intermediate ozone
  - Mostly silent on the difference in bromate formation



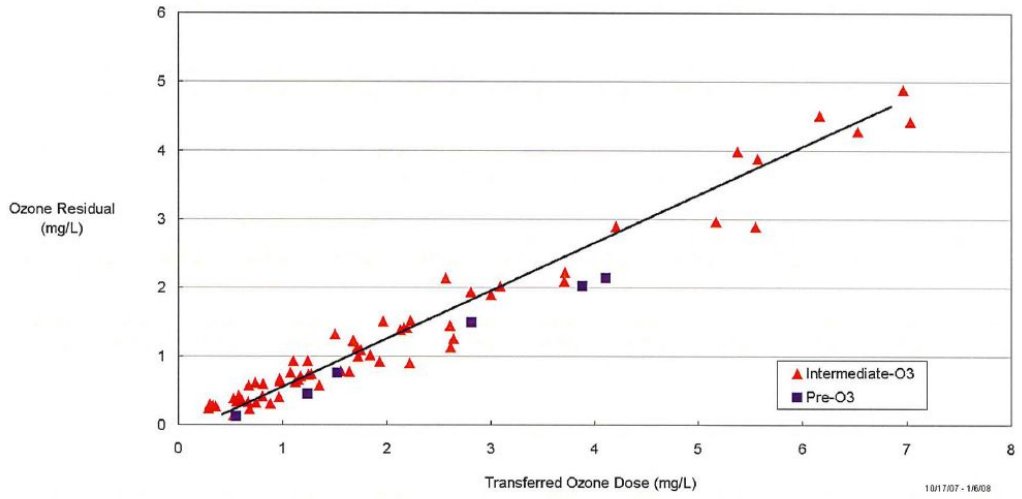


Figure 3.8
NO SIGNIFICANT DIFFERENCE BETWEEN THE PRE- AND INTERMEDIATE-OZONE DEMAND
QUAIL CREEK WATER TREATMENT PLANT
CITY OF ST. GEORGE

Key Question – Is pre-ozone's interaction with algae/cyanobacteria a fatal flaw?

Prepared by:

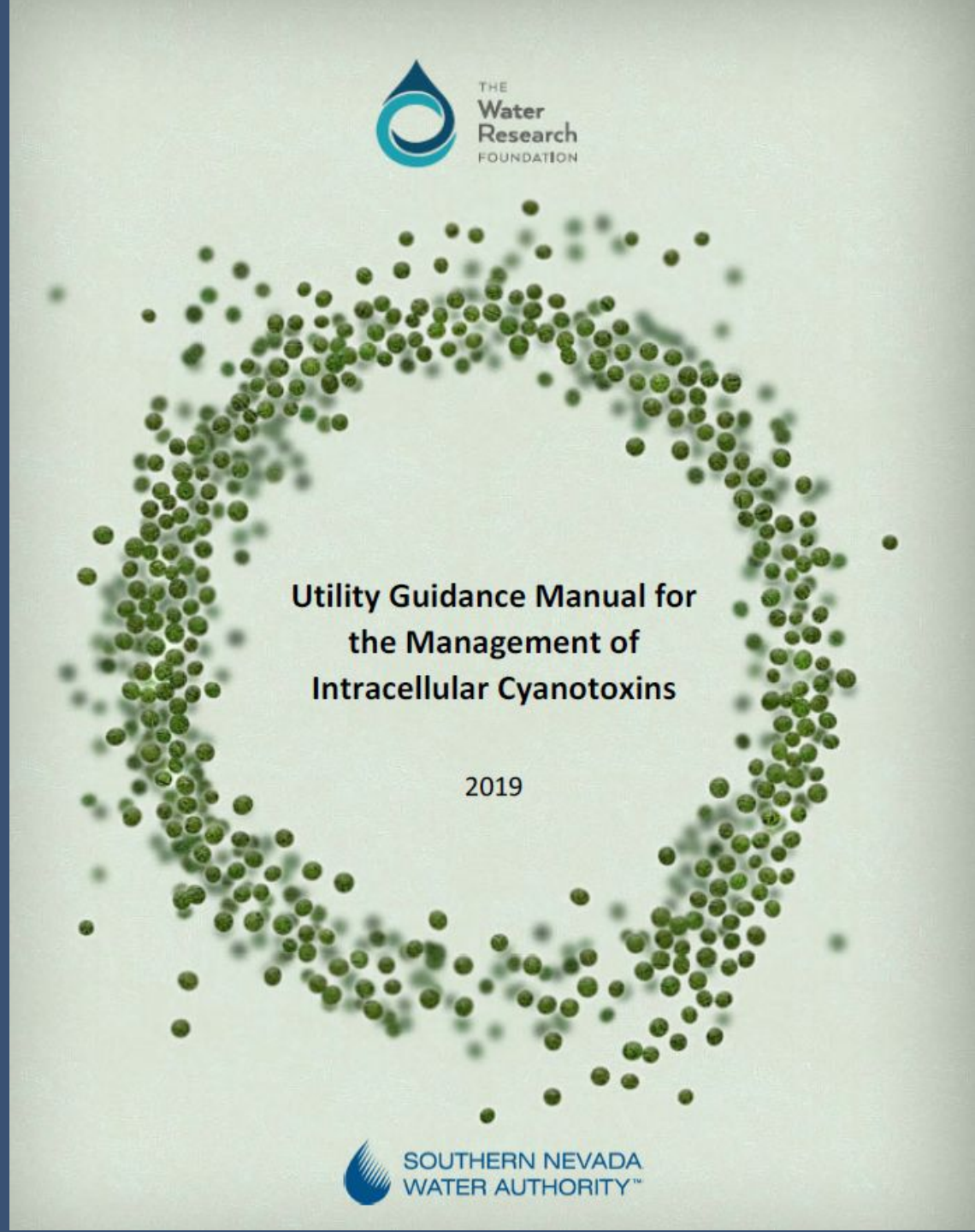
Eric Wert, PhD, PE
Southern Nevada Water Authority

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Craig Adams, PhD, PE
Saint Louis University

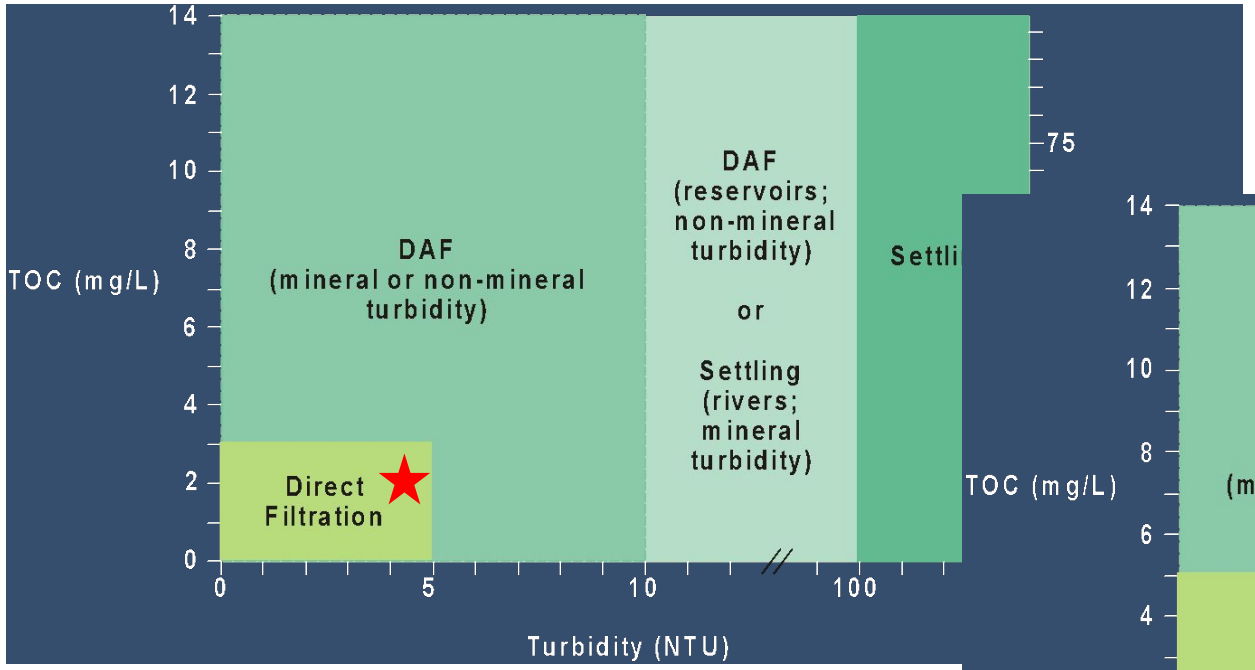
Erik Rosenfeldt, PhD, PE
Hazen and Sawyer

Katherine Greenstein, PhD, PE
Southern Nevada Water Authority
Des Moines Water Works

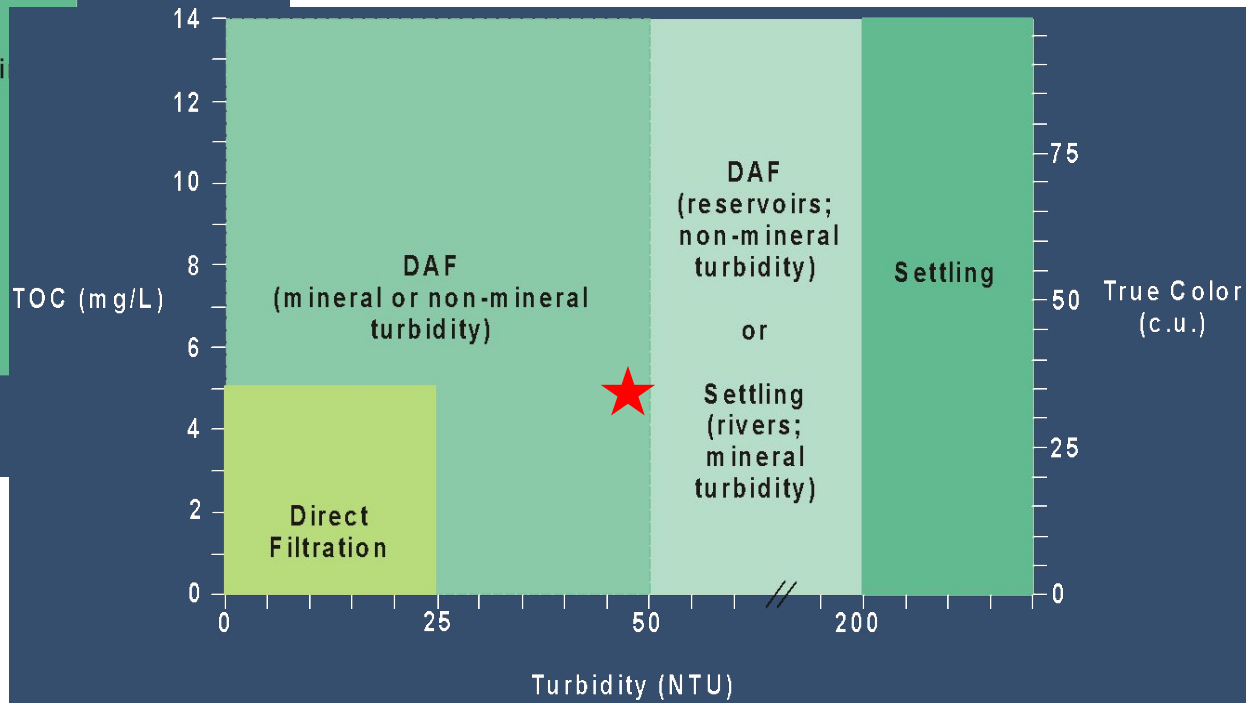


It’s a DAF Plant with a Low-Turbidity Source

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