OTCO Reservoir Management: Proactive Algae Treatment

Emma van Dommelen and Diane Roher, PE
Hazen and Sawyer
July 12, 2022

Agenda

Background Overview

Case Studies

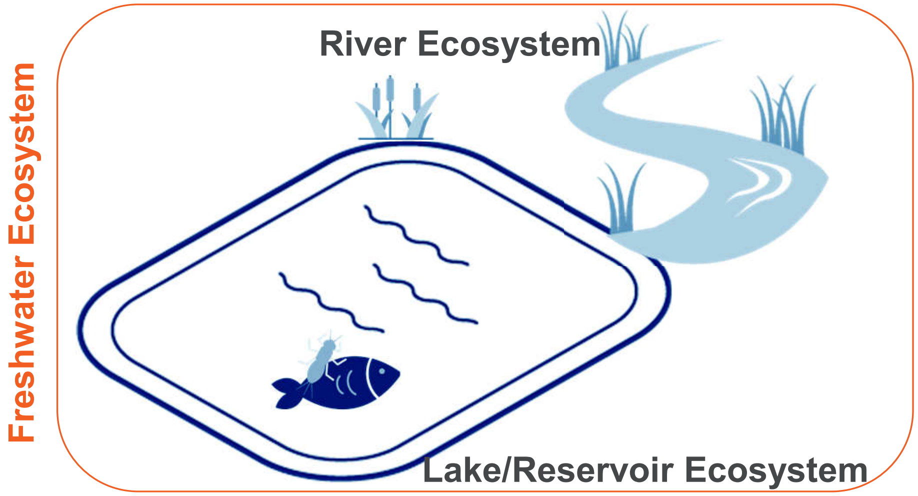
Key Takeaways

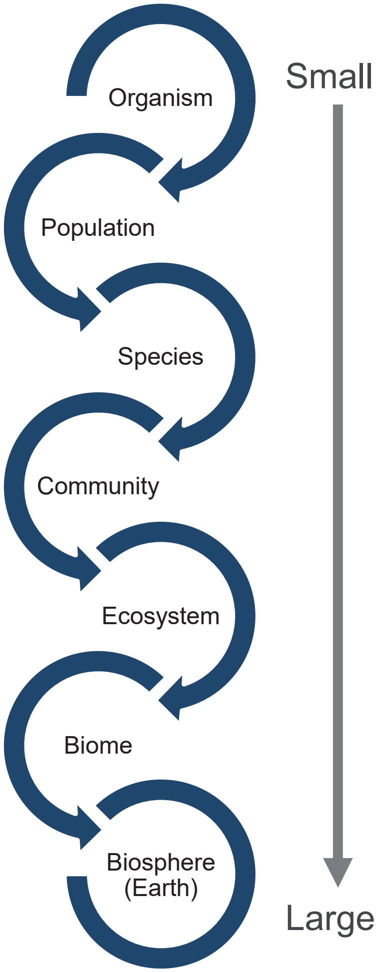
Background Overview

Biological Organization

Ecosystems

- Ecosystems are part of a larger puzzle
- Ecosystem Definition
  - **Defined: Abiotic and biotic components interact to form a biological community**





Reservoirs are constantly balancing both *biotic* and *abiotic* processes

Biotic

Living components:
Phytoplankton and plants

Abiotic

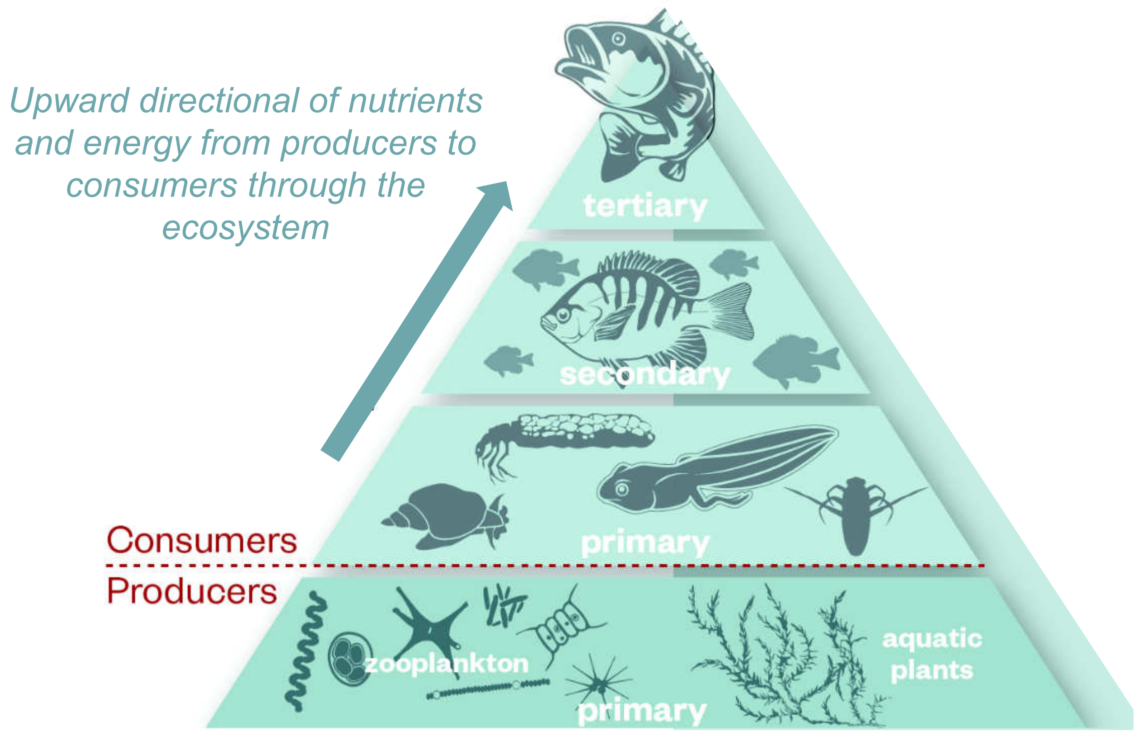
Chemical and physical factors:
Temperature, dissolved oxygen (DO), pH

Trophic Classes and Hierarchy

Understanding the Complexities of the Foodweb

Key Highlights

- Primary producers are foundation
- Food source
- Short circuit
- Cyclic overproduction



Phytoplankton

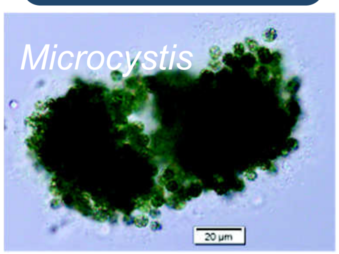
Example Biotic Component

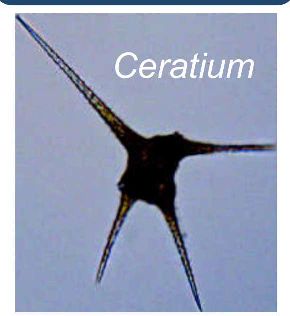
- Primary producers, foundation to aquatic ecosystems
  - **Utilize abiotic sources to produce energy**

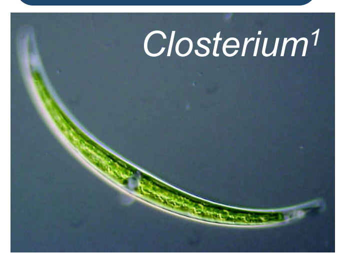
Phytoplankton

- Cyanobacteria
- Diatoms
- Dinoflagellates
- Green Algae
- Golden Algae

*Formerly "blue-green algae" but Cyanobacteria are **not** algae*







[1] https://en.wikipedia.org/wiki/Closterium#/media/File:Closterium_sp.jpg

[2] https://www.nikonsmallworld.com/galleries/2018-photomicrography-competition/dinobryon-golden-algae-a-colonial-freshwater-algae

Water Treatment Challenges

How does an ecosystem imbalance impact treatment?

Symptoms

- Overproduction of biomass
- Increased T&O events
- Risk of HABs
- Cyanotoxins
- Increased anoxia
- Phosphorus, Mn, and Fe flux from anoxic sediment
- Aquatic nuisance species

Diagnosis

- Underlying ecosystem imbalance created and worsened by external influences
- Climate changes, eutrophication, etc.
- Breakdown of ecosystem feedback and function

Challenges

- Filter run times
- Increased residuals
- T&O compound removal
- Cyanotoxin removal
- Elevated Mn/Fe
- Low DO water
- DBP-FP

Management Plan

Management Goal

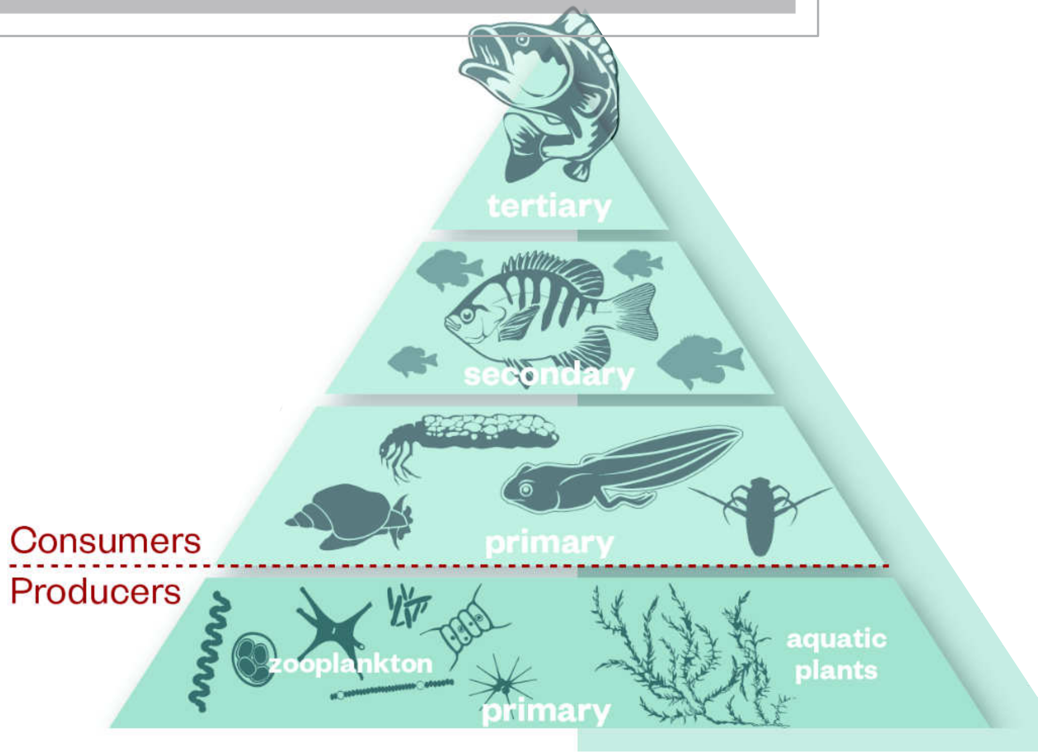
Improve water quality by stabilizing the ecosystem and increasing resiliency

Why stabilize the ecosystem?

- Reestablish upward flow of nutrients and energy
- Nutrients get ‘stuck’ at primary producers
- An imbalanced ecosystem will continue to degrade
- Rate of degradation is influenced by external factors
- Drives cyclic overproduction of phytoplankton
- Increases challenges for water treatment

Why increase ecosystem resiliency?

- Absorbs the impact of external forces while maintaining balanced, high-service ecosystem
- Normal function and feedback in ecosystems
- High quality water comes from balanced systems that are resilient



Monitoring Plan

- Characterize the system
- Drive and design short and long-term management program

Management Plan

Short-Term

- Immediate action to maintain WQ
- Proactively manage growth of phytoplankton
- Prevent symptoms of overgrowth

Long-Term

- Address the driving forces to prevent the problem
- Increase ecosystem resiliency
- Correct the ecosystem imbalance

Source Water Management

Responsive Management Actions to Curb HAB Onset

Copper Products

- Historically common
- Non-target toxicity
- Copper accumulation

Algaecide

Hydrogen Peroxide Products

- Proactive approach
- Selectively targets cyanobacteria
- No residual or accumulation

Approach to treatment timing and areas are different based on type of product

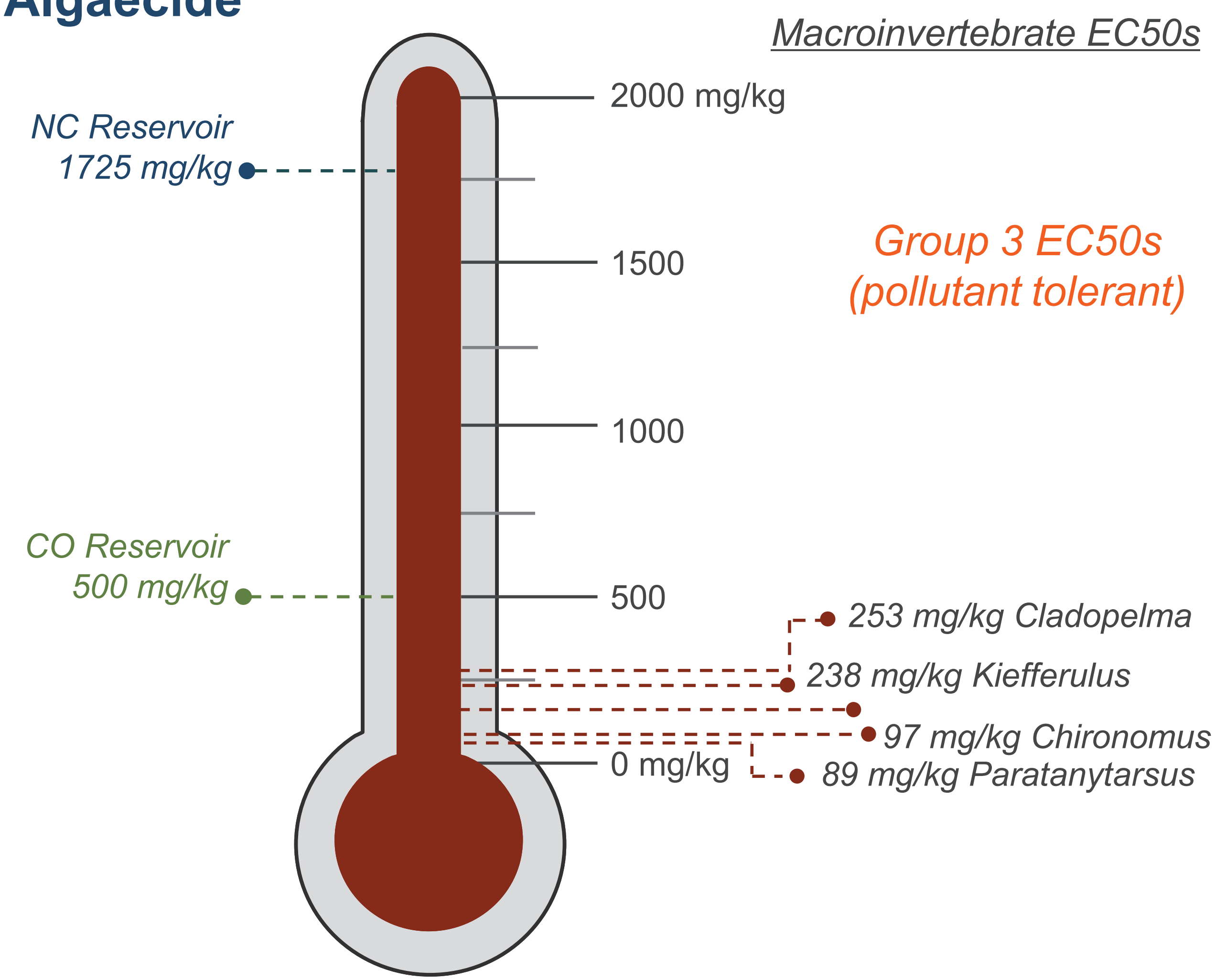
Long-Term Use of Copper Algaecide

Limitations on Responsive Management

Significant copper accumulation in sediments

Limits top-down control

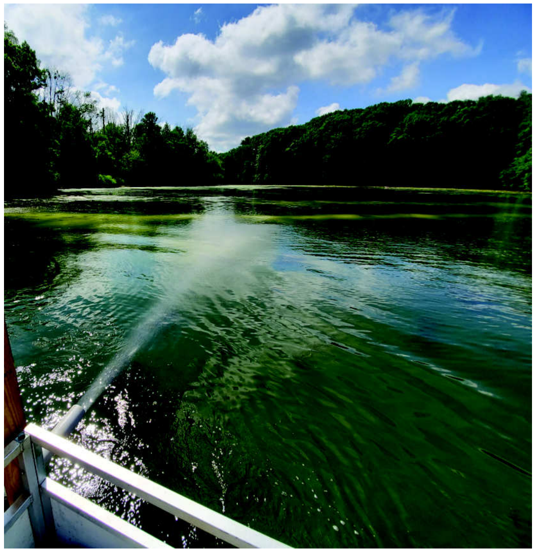
Harsh environment for microbes to breakdown organic matter



Hydrogen Peroxide Treatments

Leveraging an alternative algaecide to mitigate cyanotoxins

- Alternative algaecide
  - **No copper**
  - **Not comparable to copper**
- Selectively targets cyanobacteria
  - **Cyanotoxin-producing species are more susceptible**
- Exploits fundamental difference between true algae (eukaryotes) and cyanobacteria (prokaryotes)
- Imposes oxidative stress on cells
- Not intended to kill cells
  - **'Injure not kill'**
  - **Proactive application**
- Disrupt cellular function
  - **Reproduction, secondary metabolites, nitrogen fixation**
  - **6-8 weeks per treatment**



Case Study #1

Franklin, TN

Project Overview

City of Franklin

City of Franklin is approximately 25 miles south of Nashville

City of Franklin's WTP and Reservoir

Franklin WTP

Harpeth River as source water

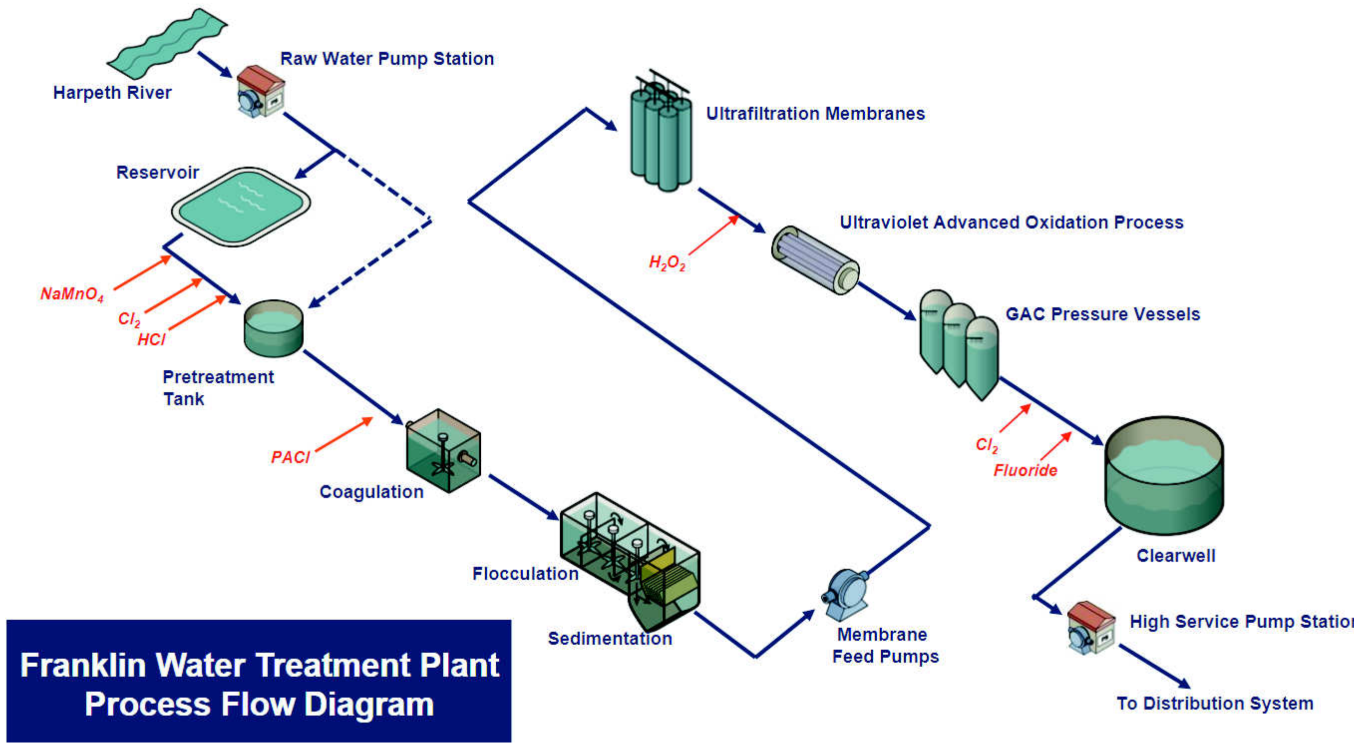
- Permitted withdrawal of 20% instantaneous flow up to a maximum pumping rate of 7,800 gpm
- Restricted withdrawal at river flows below 10 cfs or when dissolved oxygen is at or below 5.0 mg/L

Storage reservoir

- Supplies the plant during low flows in the river
- Option for blending river water and reservoir water during optimal conditions

Water Treatment

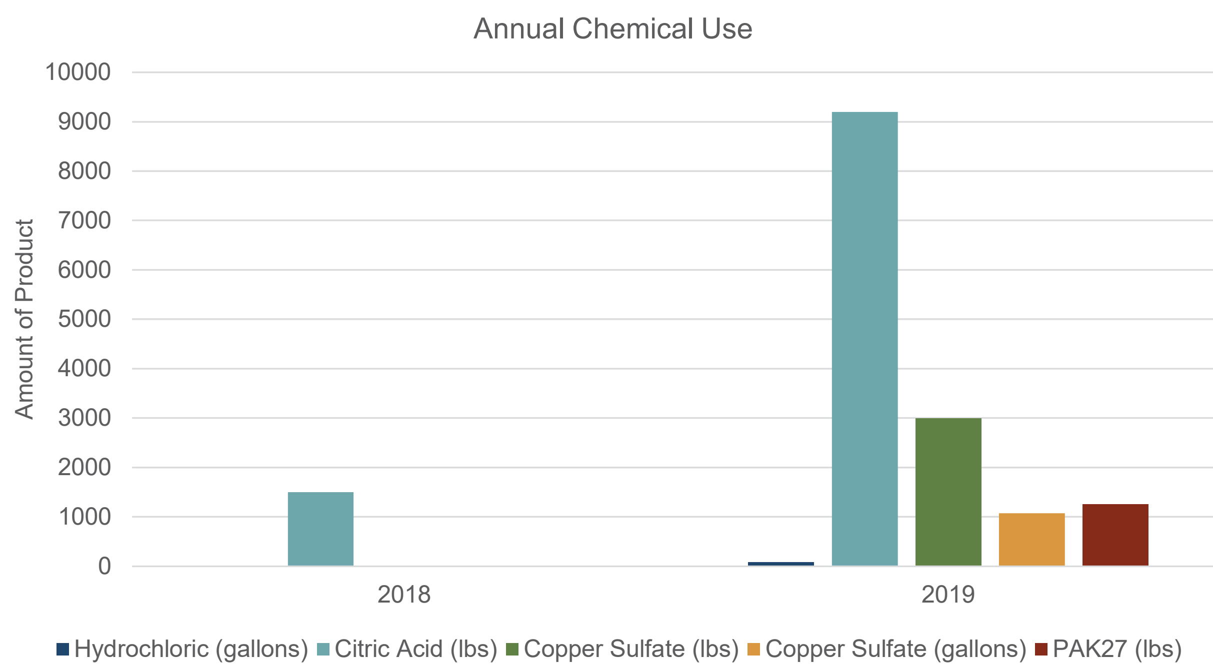
- Treats approximately 2.6 MGD
- Purchases additional water from neighboring utility



Historical Reservoir Management

Various chemicals and combinations of chemicals used for algae treatment

- Algal growth in the reservoir treated with various algaecides over time
- Citric acid additions
  - **pH control – phytoplankton growth**
  - **Citric acid with diazotrophic (N_2-fixing) can actually *enhance* growth**
- Citric acid & copper sulfate
  - **Co-fed to increase copper solubility**
- More treatments in 2019 as compared to 2018



2018: 9 treatments
2019: 30 treatments

Reservoir Timeline

2010

Reservoir Construction

2016

- SolarBees Installed
- Sonic Solutions systems added

2019

Algal Blooms continued

Reservoir Sampling

2020

YSI Sonde installed

New Algaecide Management Plan

2022

Effective Monitoring and Management Plan in Place

**Replaced Sonic Solution system in Fall 2020*

Developing a Management and Monitoring Plan

State of the Reservoir (2019)

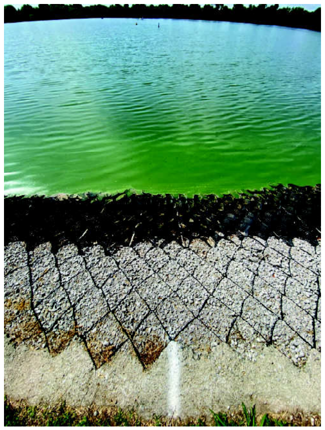
- August 15, 2019, Reservoir Sampling Event
  - **Predominantly identified *Dolichospermum* in reservoir (diazotrophic filamentous cyanobacteria)**
  - **No cyanobacteria noted in river on day of sampling**
- Solar Bees and Ultrasound likely not reducing growth
- Phytoplankton growth causes instability in source water quality
- Development of short-term action plan
  - **Sonde for continuous data collection in reservoir**
  - **Start algaecide management plan in March 2020 (PAK27)**
- Development of long-term action plan
  - **Minimize algaecide**
  - **Achieve WQ goals**
  - **Consideration of supplemental or alternative treatment strategies**

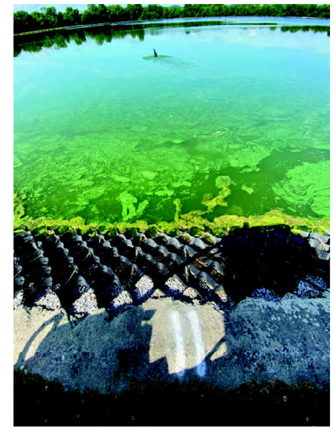
Installation of Water Quality Buoy

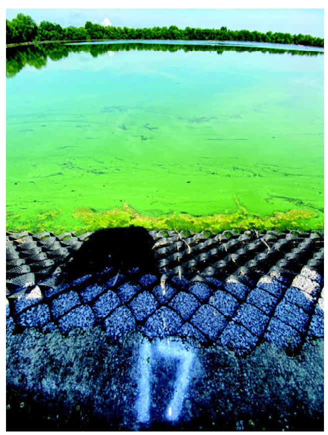
- Water Quality Sonde Installed in Spring 2020
  - Data uploads to cloud storage
- Buoy is located here in reservoir
- Measures the following at a fixed depth (~3 ft) in the photic zone in 15-minute intervals
  - pH, Conductivity, Temperature, Dissolved Oxygen, Chlorophyll-a , Phycocyanin
- Operators marked stations
  - Total of 37 stations around perimeter
- Photos regularly taken at each station for documentation and comparison
  - Photos are utilized for visual changes noted in the reservoir over time

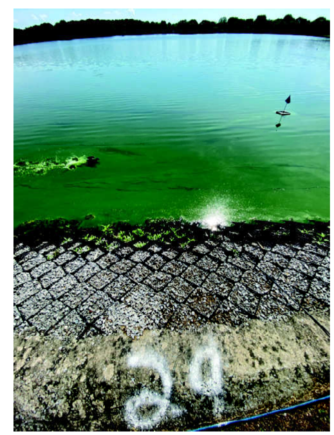
Monitoring Location Photos

May 2021 Growth Season



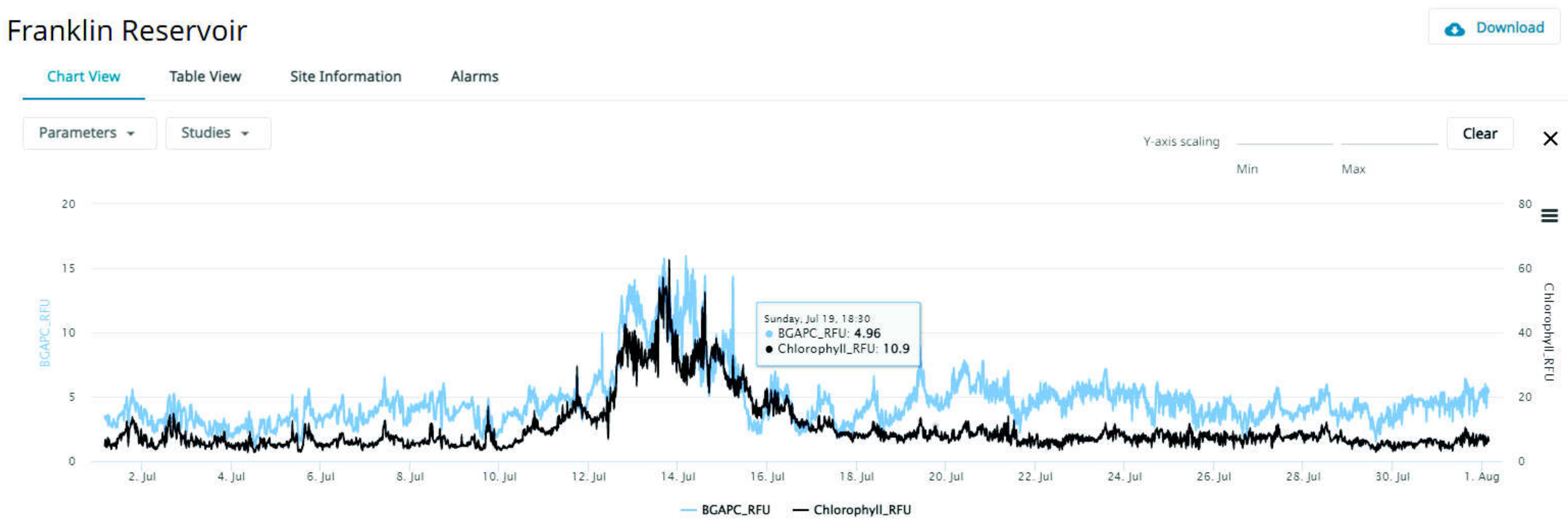






Hydrosphere Data Platform

Temperature, DO, pH, conductivity, chlorophyll-*a*, phycocyanin

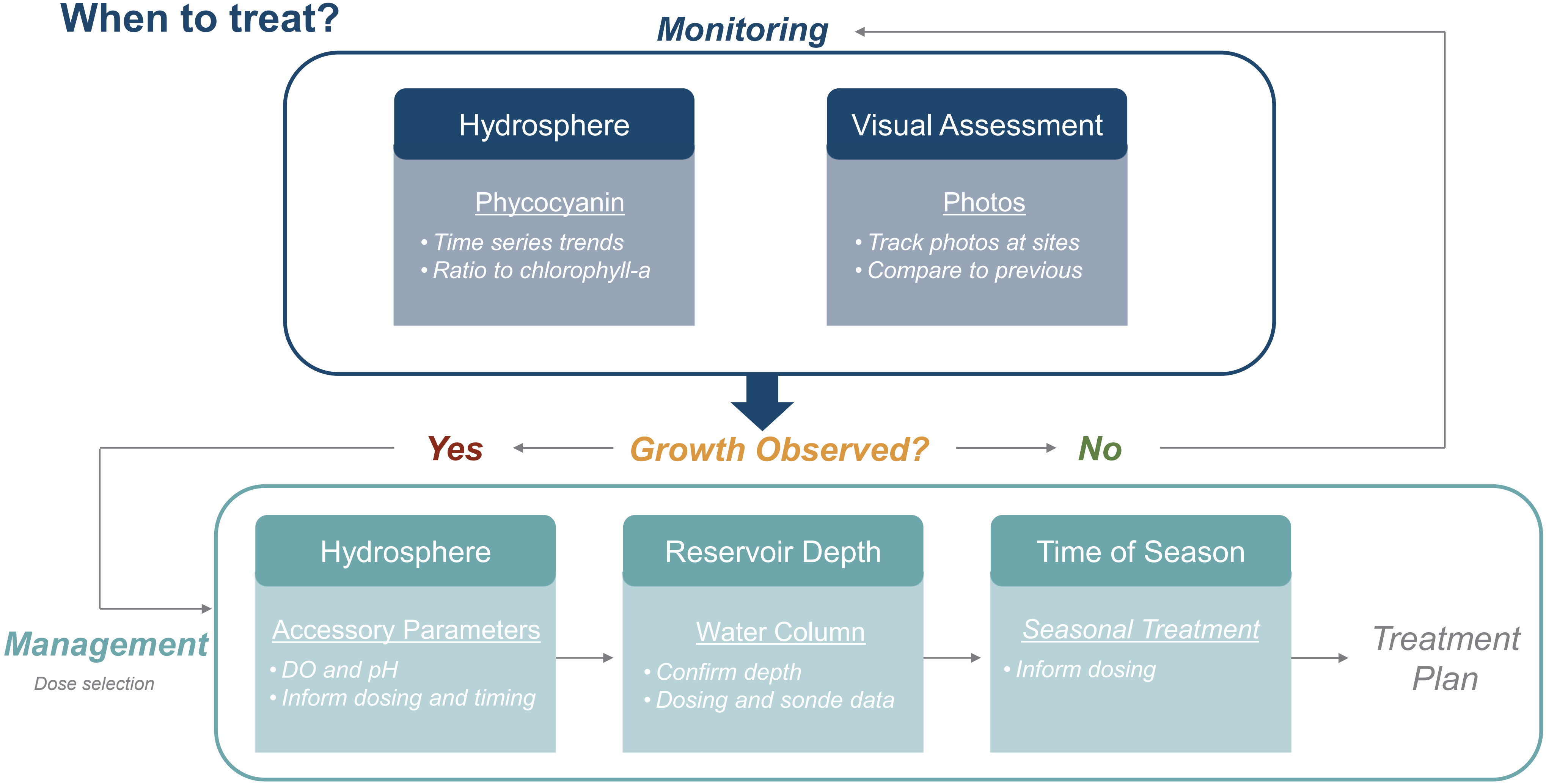


Algaecide – PAK27©

Hydrogen Peroxide Product

- Granular hydrogen peroxide product
- NSF60 certified
- Upper photic zone
- Target dose of 2 mg/L = 1,655 lbs of product
- Target dose of 3 mg/L = 2,485 lbs of product
- pH mean of 10.5
- Applied by hand on bank or boat

When to treat?



How to treat?

Baseline Operations for the City of Franklin

OFF SEASON
November - February

- Phycocyanin Threshold (4 RFU)
- Estimate 12 weeks between treatments
- 750 lbs target dose

EARLY GROWTH SEASON
March - June

- Phycocyanin Threshold (3 - 4 RFU)
- Estimate 4-6 weeks between treatments
- Target doses dependent on need and build
  - 750 lbs
  - 1,200 lbs
  - 1,600 lbs
  - 1,600 or 2,280 lbs

PEAK GROWTH SEASON
July - October

- Phycocyanin Threshold (6 RFU)
- Estimate 7-8 weeks between treatments
- 1,600 lbs each target dose

State of the Reservoir (2020 - present)

- Reservoir is monitored on regular basis
- PAK27 is applied according to treatment plan or as needed
  - Spot treated as necessary
  - Larger or more frequent doses as necessary
  - Based on reservoir visual inspection and hydrosphere
- Planned off season treatment to mitigate early growth season
- More holistic approach for reservoir and impacts on downstream treatment
  - Impacts to cost efficiencies such as pretreatment

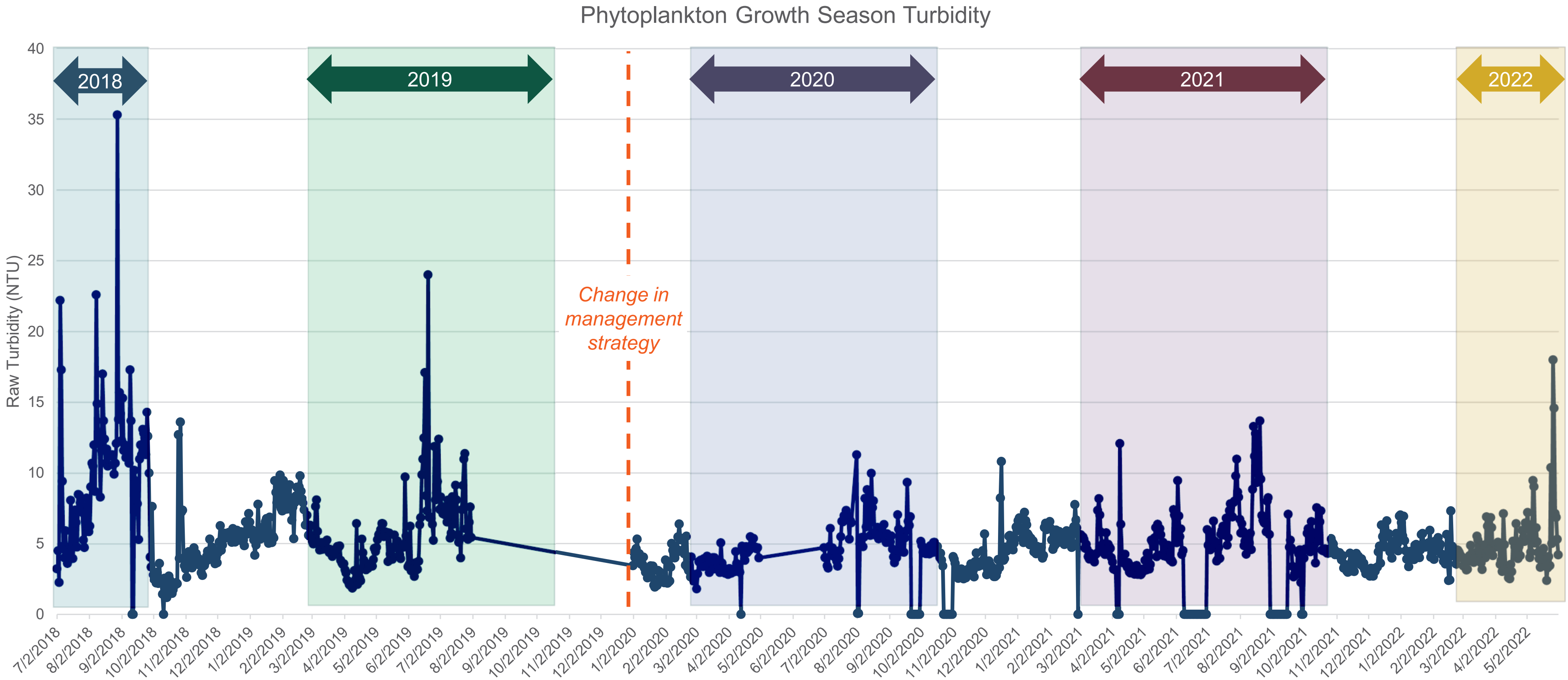
Lessons Learned

- Utilizing 2020 lessons for changes in 2021 through present
- Late fall treatment to aid off-season growth and following early growth season
- Treatment scale in early growth season
  - **Phytoplankton growth in this system is too aggressive for slow build approach**
  - **Early growth season for proactive treatment**
- Weather
  - **Integrated treatment plan with rain events in 2020 to guide treatment plan**
- River pumping schedule
  - **Reservoir depth decreases when no pumping**
  - **Increase monitoring of DO at low levels (restrictions on treatment)**
- Wind and accumulation per site from photos
  - **Consider wind direction during treatment**
  - **Site accumulation driven by wind direction**

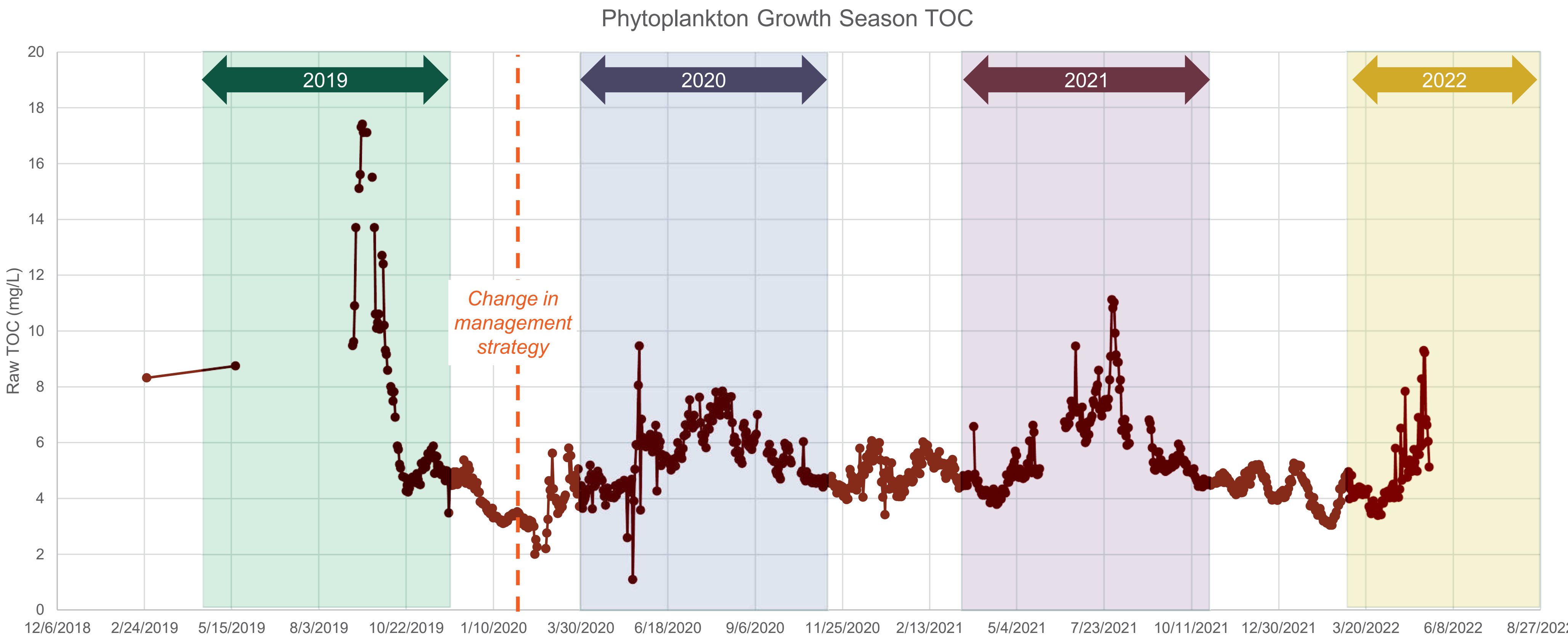
Raw Water Quality

Raw Water Quality

Phytoplankton is not only contributor and not all phytoplankton are captured with turbidity measurement



Raw Water Quality



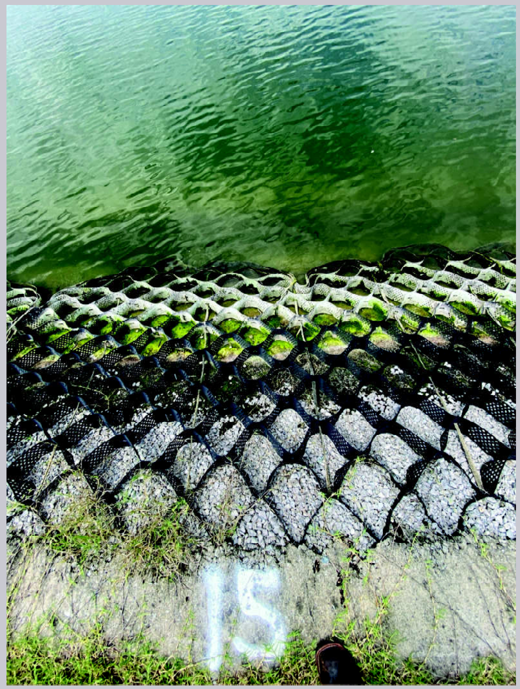
Outcomes

Reservoir Photos: Three-Year Round Up

August 2019

8/16/19

August 2020



8/18/20

August 2021

8/16/21

Reservoir Photos: Three-Year Round Up

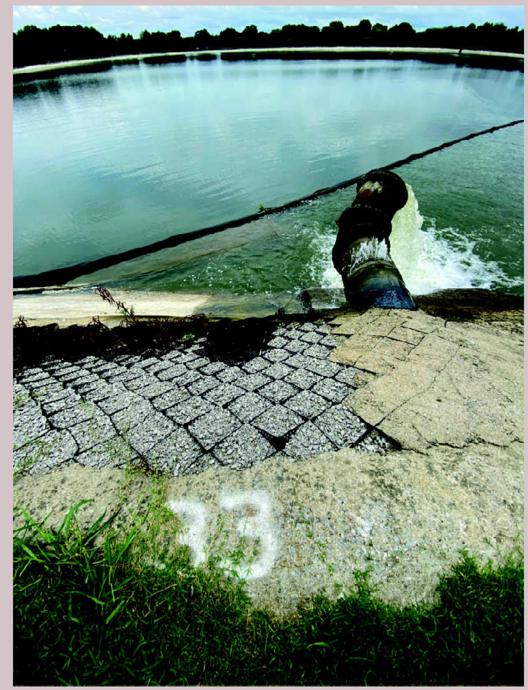
August 2019

8/16/19

August 2020

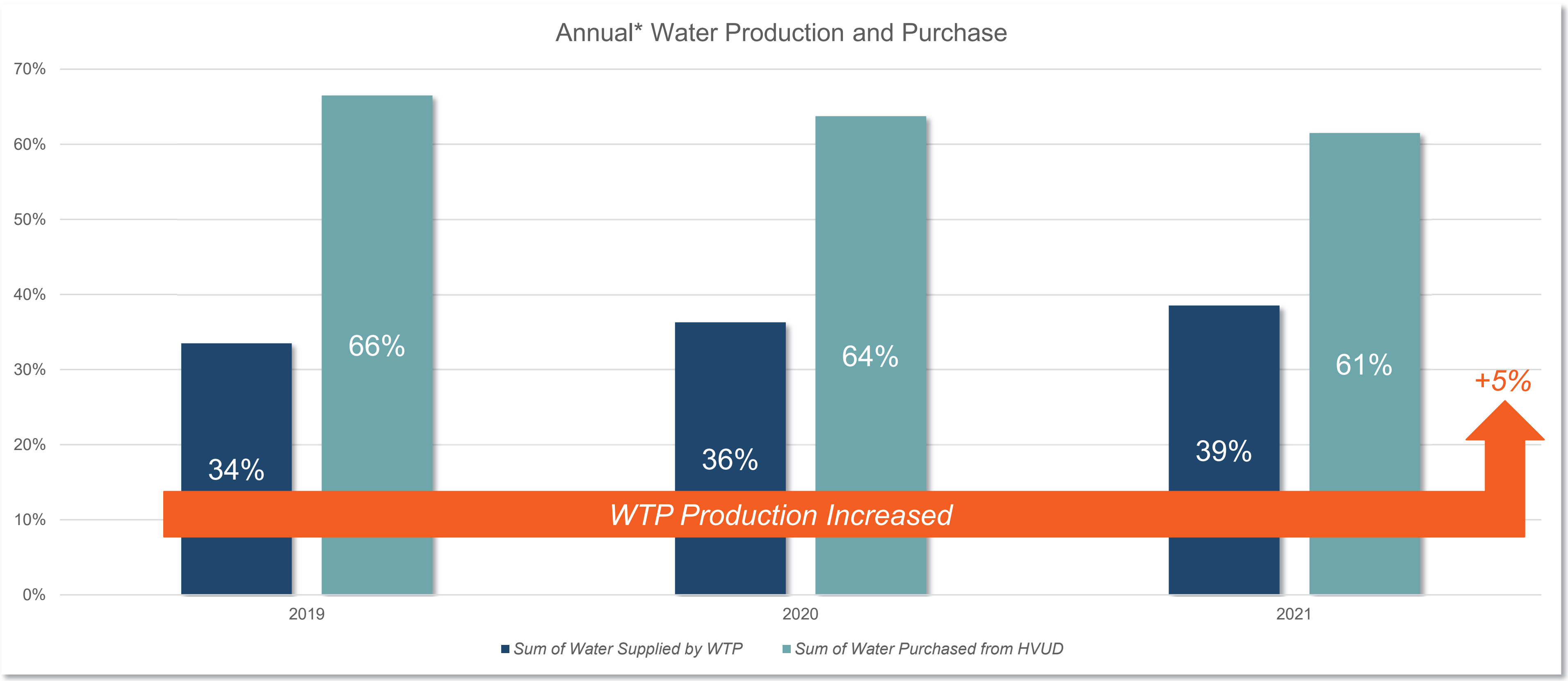
8/18/20

August 2021



8/16/21

Reservoir Value: Annual Water Production and Purchase

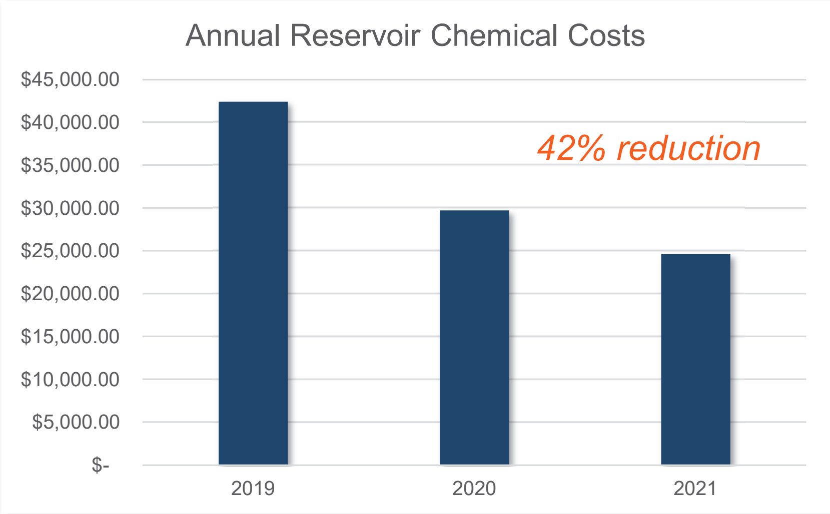


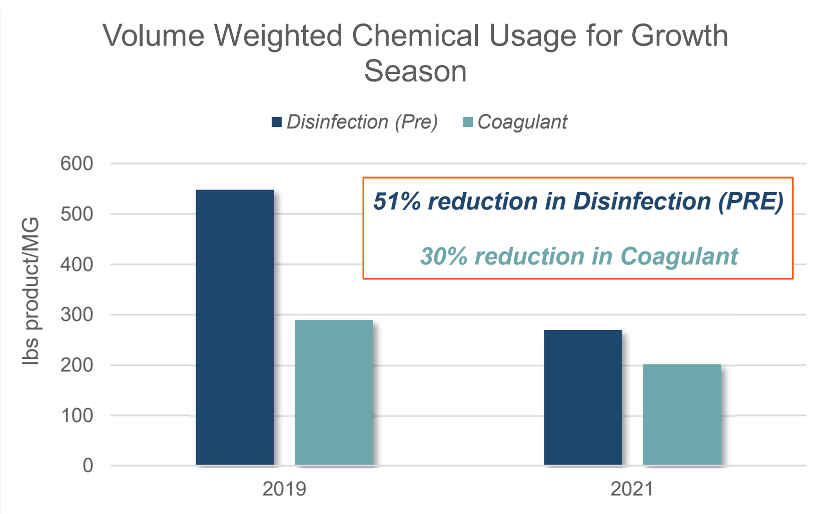
Available coinciding data was used for comparison (February – November)

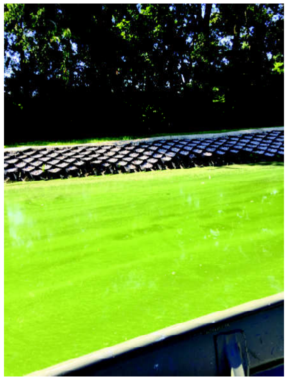
Hydrogen Peroxide Case Study

Observed success of hydrogen peroxide treatment program

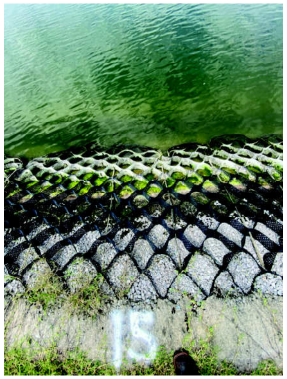
- Stabilized raw water quality
  - **Decreased pH, TOC, growth**
- Average days between treatments was 40 days
- $55K invested → $826K saved (1,401% ROI, two years)
  - *$531K in purchased water*
  - *$66K in coagulant*
  - *$31K in algaecide*
  - *$200K in pre-disinfection*







8/16/19



8/18/20

8/16/21

Hazen

Future Work

- Continue proactive management of algal growth in reservoir
- Evaluate options for liquid algaecide
- Considerations for full reservoir aeration
- Mitigate growth during non-pumping timeframes
- Continue updating treatment plan on annual basis

Case Study #2

Colorado Reservoir

Triggered Based Approach to Source Water Management

Colorado Reservoir

Short-Term

Initial effort
(e.g. peroxide and alum treatment)

Mid-Term

Source control next 1 to 3 yrs
(e.g. aeration, BMPs)

Long-Term

Capital-intensive alternatives (3 yrs+)
(e.g. WPF upgrades, ASR, forebay)

Roadmap:
A Trigger Based Approach

Short-Term Plan

Key Elements and Triggers

Hydrogen Peroxide

- Leverage while implementing preventative measures
- Proactive approach to prevent dense phytoplankton populations
- Shift dominance away from cyanobacteria
- Treatments ***triggered*** by monitoring data

Alum Application

- Initial treatment completed in October 2020
- 43 years until residual external load 'replaces' inactivated available phosphorus
  - **Nutrient budget and dosing strategy**
- Follow up treatment ***triggered*** by monitoring data

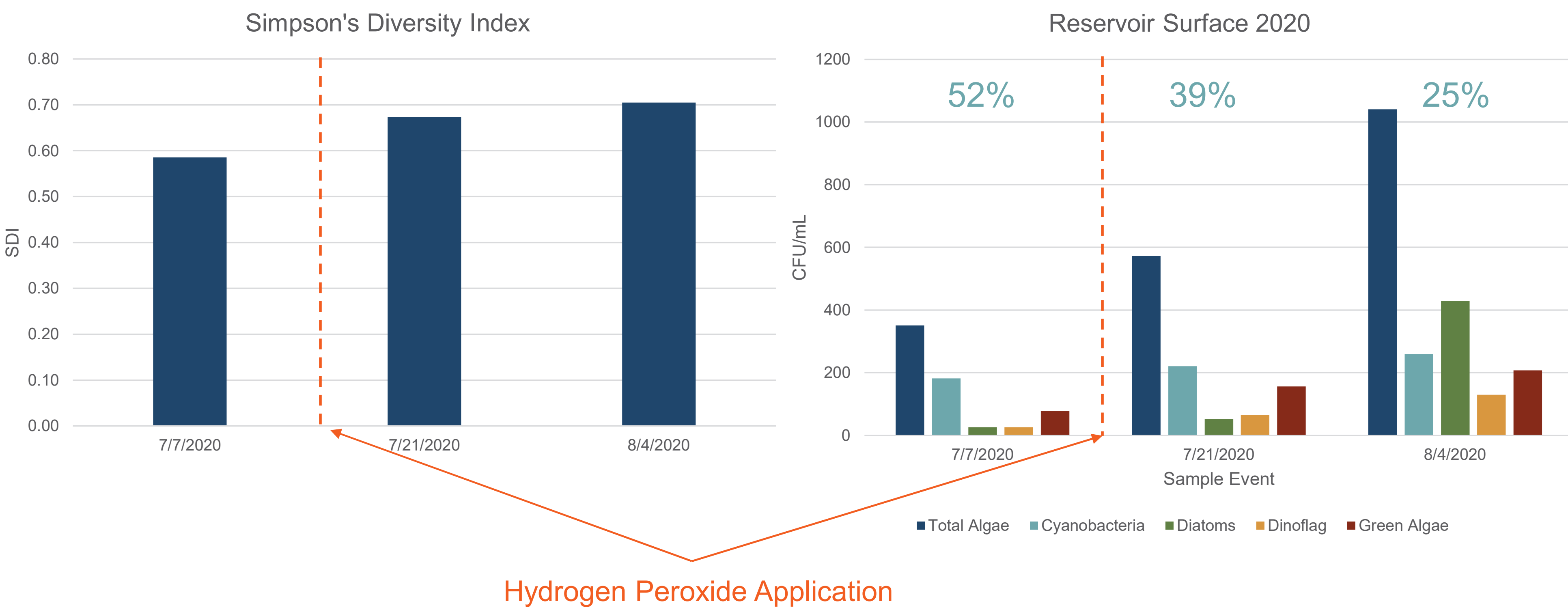
Hydrogen Peroxide Triggers

Parameter	Trigger	Duration	Notes
Enumeration	Late Spring Increase	Annual	Used with cyanobacteria dominance and SDI; Timing of initial treatment
Simpson's Diversity Index (SDI)	< 0.6	2 weeks	Calculation; used with cyanobacteria dominance
Cyanobacteria Dominance	40%	2 weeks	Calculation (enumeration based); used with SDI
Microcystin	7.5 ppb	2 weeks	Helpful to track but enumerations, dominance, and pigments are more proactive
Cylindrospermopsin	5.0 ppb	2 weeks	
Phycocyanin	TBD	2 weeks	To be developed after data has been collected
Chlorophyll-*a*	8.8 – 12.7 ppb	4 weeks*	Proactive treatments to ensure Reg 31 compliance
	12.7 – 16.5 ppb	2 weeks	Responsive treatment trigger

**two consecutive observations*

Hydrogen Peroxide Treatments

Triggers in Action



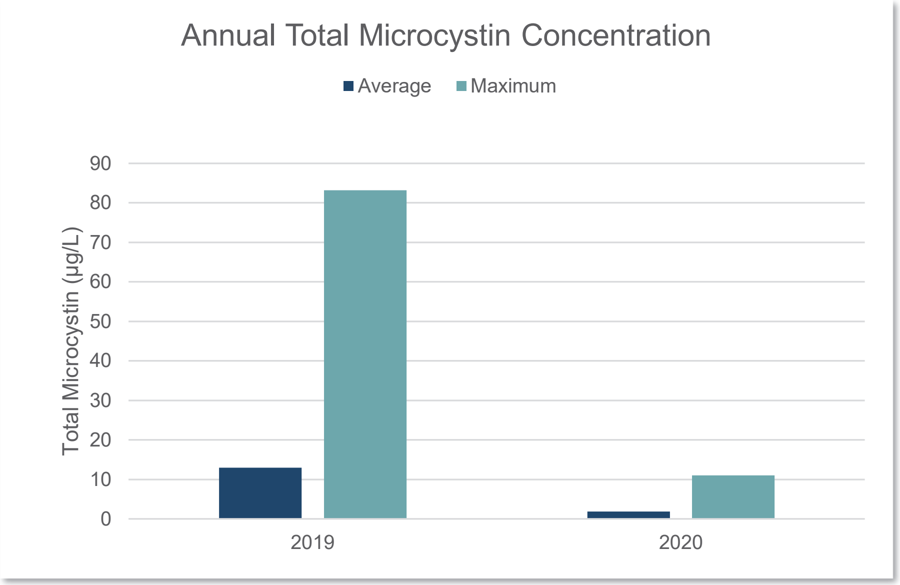
Hydrogen Peroxide Triggers

Gauging success

- Reduced HABs
- HAB issues at other local reservoirs this past summer
- If the City hadn't acted, this could have happened again and may have been worse

Before

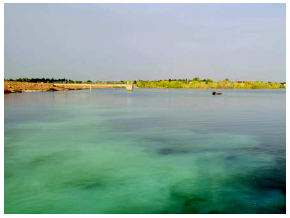
After

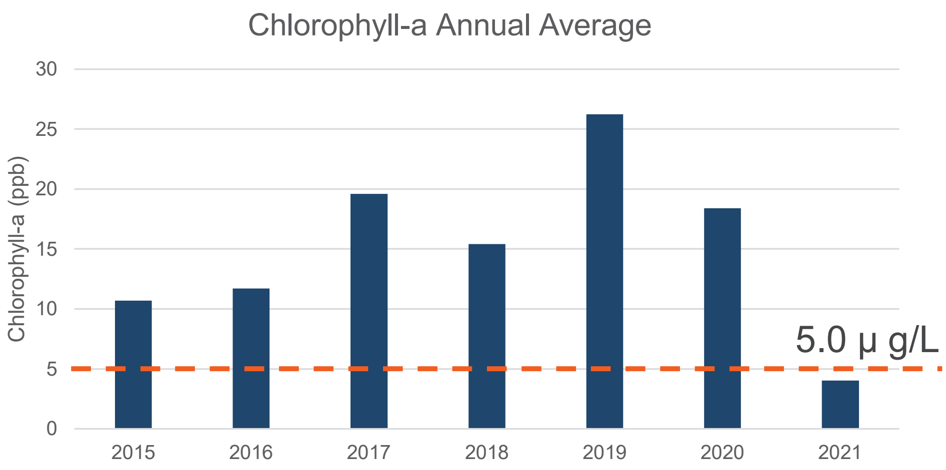


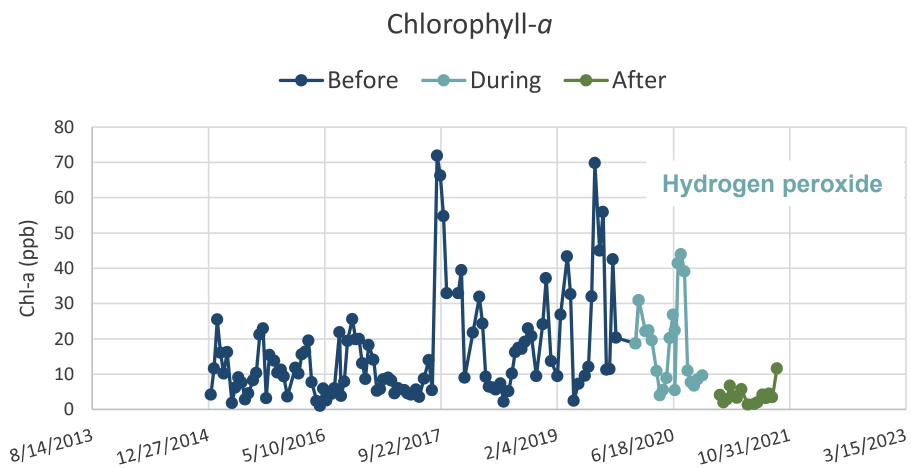
Success of Preventative Management

Early success of preventative management program

- Reservoir in Colorado
  - **Frequent recreational closures**
  - **Regulation for chl-*a* (5 ppb)**
- Hydrogen peroxide treatment used for 1 year
  - **No Closures**
  - **87% reduction in microcystin (annual mean and max)**
- Phase 1 of preventative management implemented end of 2020 (Oct)
  - **Phase 2 and 3 forthcoming (2022 and 2023)**
- Cost savings of $62.3M
  - **Prevented $62M pre-treatment facility**







Hazen

Case Studies: Lessons Learned

Every source water is unique	• Leverage data trends • Ecosystem imbalances may present differently
No one-solution to fit all	• Individually tailored plans • One strategy or technology will not solve the multidimensional problem
Coupled monitoring and management leads to greater success	• Monitoring can be used to drive management and track recovery after disruption

Take Away Message

Source water management is linked to drinking water treatment and delivery

Coupled monitoring and management can lead to greater success

Leverage source water management to support data-driven decision making

Thank you!

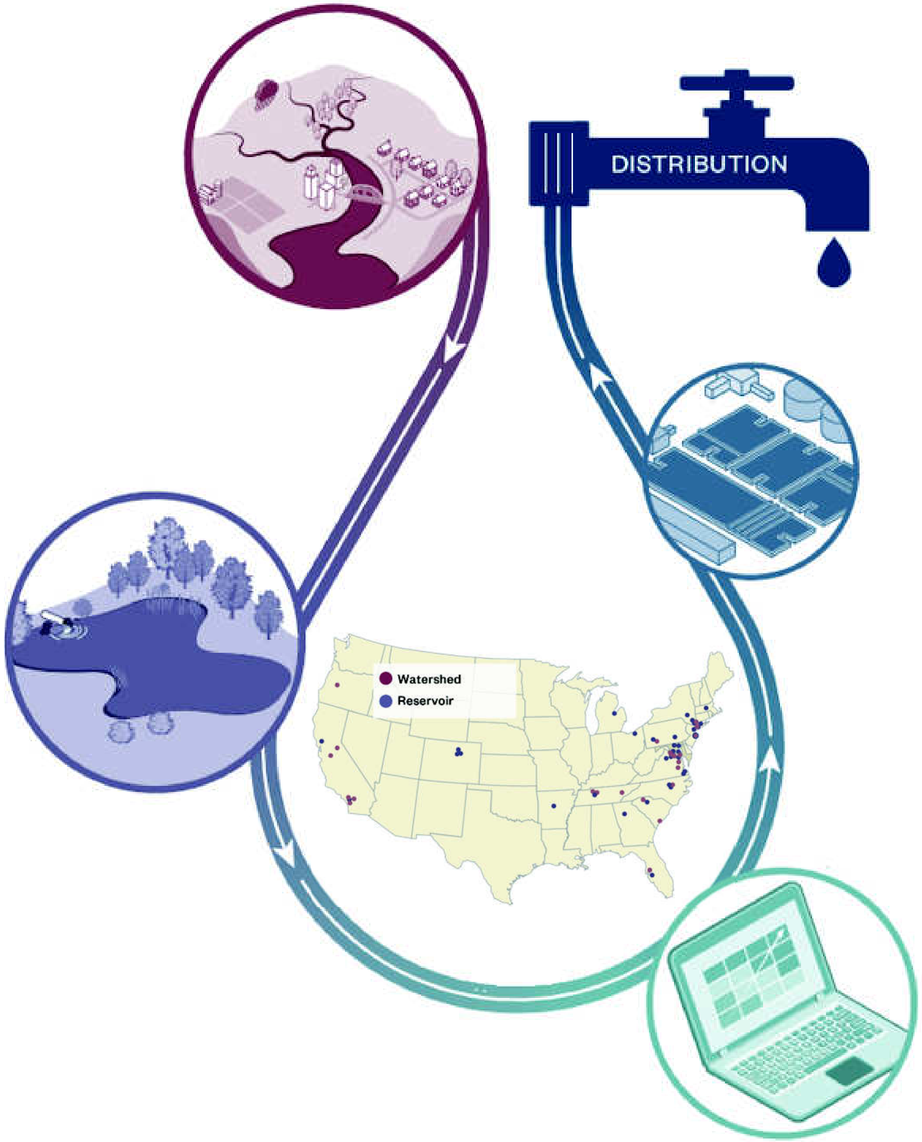
Please reach out with any questions:

Emma van Dommelen
Assistant Engineer II

evandommelen@hazenandsawyer.com

Diane Roher, PE
Principal Engineer

droher@hazenandsawyer.com



Hazen