



Algaecide Selection and Reservoir Treatment

Elizabeth Crafton, Teresa Cutright, Don Ott, and Jessica Glowczewski

Workshop Outline

Key Points

- Products
 - Types and mechanism of inactivation
- How to select a product
 - Bench-scale testing
- How to determine a dose
- When and where to treatment
- Examples of management plans
- Closing remarks
- Questions

Algaecide Products

Commonly Used and Referenced Products

- Two categories of products
 - Copper and non-copper
- Copper based-product
 - Chelated and non-chelated
- Hydrogen peroxide-based products
- Liquid and granular
- Different formulations

Algaecide Products

Commonly Used and Referenced Products

- Copper based-products
- Different formulations
- Liquid and granular
 - Copper sulfate crystals
- Common active ingredients
 - Copper sulfate pentahydrate
 - Copper ethanolamine complex
 - Chelates of copper gluconate and copper citrate
 - Copper triethanolamine

- Cutrine Ultra
- EarthTec
- SeClear



Algaecide Products

Commonly Used and Referenced Products

- Non-copper
- Hydrogen peroxide-based products
- Liquid and granular
- Common active ingredients
 - Sodium carbonate peroxyhydrate
 - hydrogen peroxide & peroxyacetic acid
- PAK27
- GreenClean granular
- GreenClean Liquid5.0



Hydrogen Peroxide-Based Products

Selective Treatment

- Oxidative Stress
- Selective treatment
 - Dose dependent
- Prokaryotic vs. eukaryotic
- Side reaction of photosynthesis
- Mehler reaction
- Different antioxidant systems
- Reduce photosynthetic viability
- Down regulates *mcyD*
- Biological residence
- Can achieve prolonged suppression
- Requires a refined application approach

Copper-Based Products

Treatment

- Toxicity
- Non-selective treatments
- Historical usage
- Cost less per application than hydrogen-peroxide products
 - Requires more frequent of application
- Adverse impacts from long-term use at higher concentration
- Copper-mediated gene expression
- Copper homeostasis mechanisms
- Mutation leading to copper resistant

How to Select a Product

Reservoir and Site-Specific Product Selection

- Target group of organisms
 - Sheath (*Lyngbya*)
- Location of target population
 - Planktonic vs. benthic
- Physical habitat characteristics
 - Boat access
- Flow pattern
- Treatment intent
 - Reactive or preventative

How to Test a Product

Bench-Scale Testing

- Investigate multiple products and doses
- Investigate different products for each group of organisms of interest
- Determine performance of a product based on reservoir specific population and water characteristics
 - Iron, OM loading
- Quantify the impact to account for any changes needed in the treatment plant

Bench-Scale Testing

Procedure

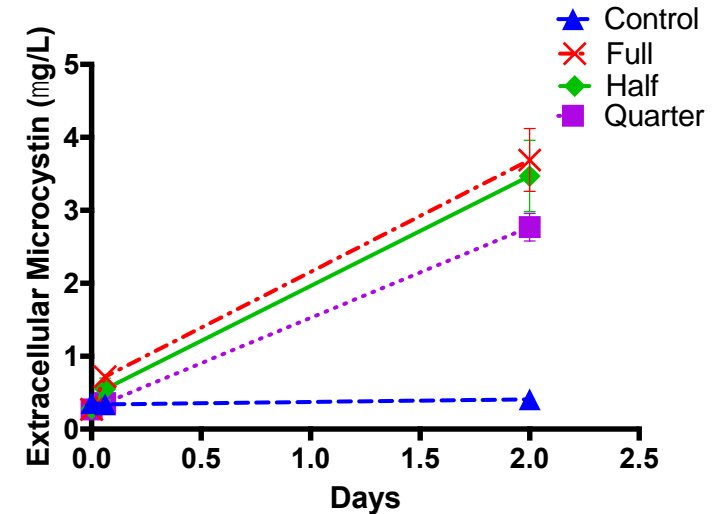
- 35 μm phytoplankton net
 - Concentrate phytoplankton population
- Treated and control reactors
 - 1.6 L per reactor
- Baseline, 2, 7, and 14 days after treatment
- Sonde
 - Temperature, DO, TSS, pH, ORP, Chl-a, phycocyanin
- Extracellular and total microcystin
- qPCR



Impacts of Treatment

Product Impact on WQ Parameters

- Relationship to IOM release
- Extracellular cyanotoxins
 - Microcystins release
 - Numerous publication
 - Copper sulfate > chelated copper > PAK27
- Geosmin/MIB
 - Release of internal dissolved fraction in cytoplasmic matrix
 - Latent 'release' of protein bound fraction
- DO



How to Determine Location and Timing

Preventative and Reactive Management

- Intent of the treatment
 - Preventative and reactive
- Historical monitoring data
 - Understand *in-situ* activity
 - Windows in time for activity
 - Accounting for seasonal variation
- Additional sampling to locate ideal areas
- Account for transport in data analysis and sampling
- Outline ‘hot spots’
 - Ideal habitat characteristics
- Accumulation locations

Field Application

Targeted Application Approach & Spot Treatments

- ‘hot spot’ areas in the system
 - Impact downstream accumulation
 - Hydrogen peroxide-based treatment
- Outline accumulation areas
 - Copper-based treatments
- Spot treatments respective to treatment intent and monitoring
- Targeted application
 - Sediment-water interface
 - Surface broadcast
 - Injection at different depths

Dynamic Management Plan

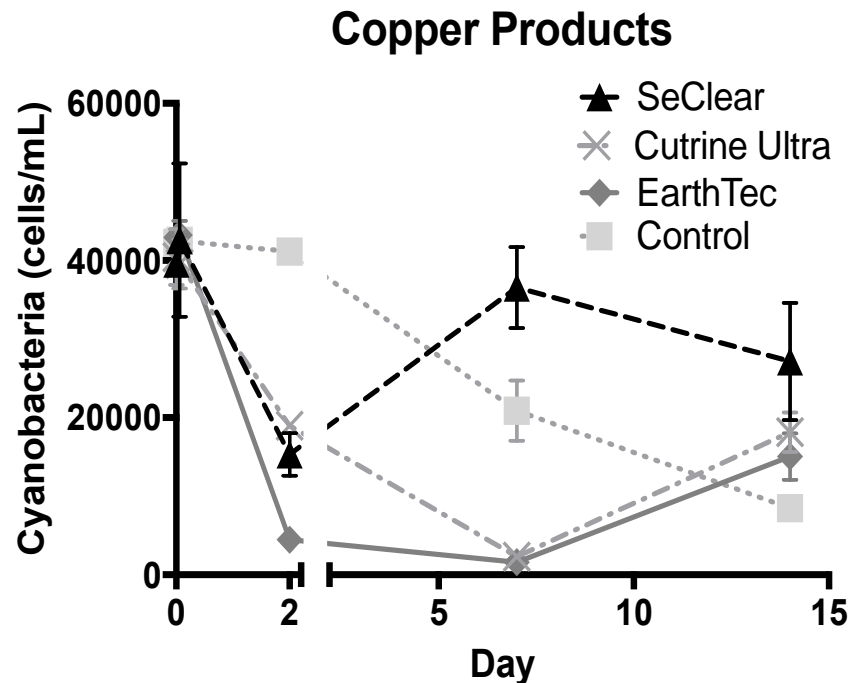
Key Aspects

- Outline accumulation areas and ‘hot spots’
 - Product for both types of outlined areas
- High and low dose based for each type of treatment
 - Reactive vs. preventative
 - Population density
- Timing of application
- Historical activity (‘window’) and current weather patterns

Dynamic Source Water Management Plan

Example #1

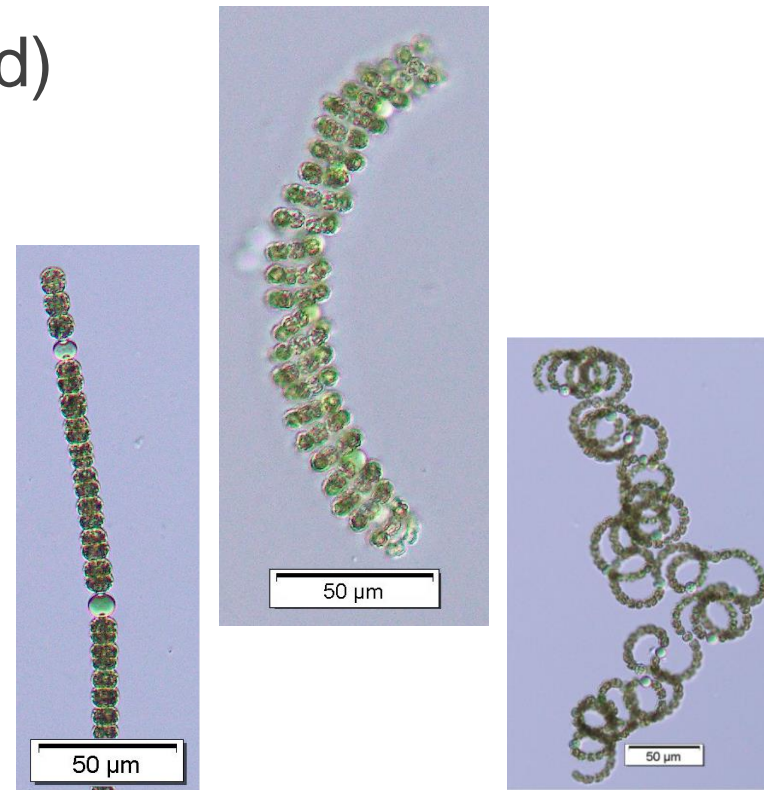
- Bench-scale testing
 - EarthTec, Cutrine Ultra, SeClear, and PAK27
 - Three doses
- Multi-product management plan
- copper product for accumulation areas
- PAK27 dose for 'hot spots'



Dynamic Source Water Management Plan

Example #1

- Bench-scale testing provided both product and doses for each location
- Accumulation area (if needed)
 - Cutrine Ultra (0.125 mg/L Cu)
- 'Hot spot' area
 - PAK27 Dose (2 mg/L H₂O₂)
- Field tests
 - Application approach
 - Timing



Dynamic Source Water Management Plan

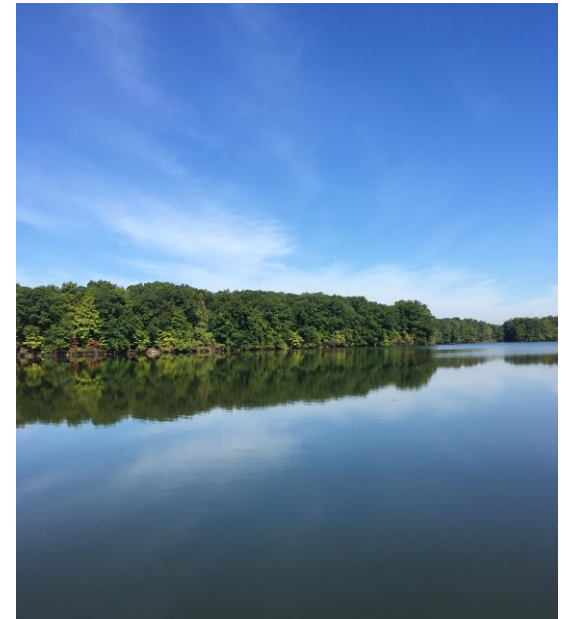
Example #1

- Bench-scale
 - Provided products and doses for field test for each type of area
- Field test
 - Provided insight to refine application approach and timing of treatments
- All necessary 'tools' are available
 - 'hot spots' – PAK27 (2 mg/L H₂O₂)
 - Continuous monitoring in area (Chl-a, phycocyanin)
 - Accumulation areas – Cutrine Ultra (0.125 mg/L Cu)
 - Routine monitoring with Sonde and visual IDs and enumeration

Dynamic Management Plan

Data Driven Application of Management Plan

- Sondes (chlorophyll-a and phycocyanin)
 - All monitoring or potential treatment areas
 - profiles
 - Continuous monitoring at 'hot spots'
 - PAK27
 - Timing of treatment
 - Dominance shift
 - Frequency
- Visual ID and enumeration
 - All locations
- qPCR



Dynamic Management Plan

Example #2

- Overall algaecide prescription
 - Includes all tools
- Planktonic and benthic
 - Benthic suspected but not proven
 - Proven and isolated with investigative sampling
- FlowCam
 - Calibration
- Limited historical data
 - Outline index and action thresholds based on available

*Overall
Prescription*



Target Pest(s)	Index Level			Action Threshold
	Level #1	Level #2	Level #3	
Lake Bowen				
Chlorophyll-a (mg/m ³)	40	85	130	175
Algae Count (FlowCam) (#/mL)	200	670	1130	1600
Anabaena (#/mL)	50	130	220	300
Cyclotella (#/mL)	5	13	21	30
Cylindrospermum (#/mL)	-	-	-	-
Dinobryon (#/mL)	5	15	25	35
Peridinium (#/mL)	10	30	50	70
Synedra (#/mL)	100	300	500	700
Synura (#/mL)	5	15	25	35
Reservoir 1				
Chlorophyll-a (mg/m ³)	40	70	95	120
Algae Count (FlowCam) (#/mL)	200	470	735	1000
Anabaena (#/mL)	20	70	115	160
Cyclotella (#/mL)	2	7	12	16
Cylindrospermum (#/mL)	5	12	19	25
Dinobryon (#/mL)	5	12	19	25
Peridinium (#/mL)	10	30	50	70
Synedra (#/mL)	50	120	185	250
Synura (#/mL)	2	6	10	14

Index Level	Response
Level 1	<ul style="list-style-type: none"> The active growth season has started. Make note of when Level 1 is surpassed and when the population density remains above Level 1 for a minimum of 7 days
Level 2	<ul style="list-style-type: none"> Transitional period between the start of active growth and elevated growth. Make note of when Level 2 is surpassed and when the population density is maintained for a minimum of 7 days
Level 3	<ul style="list-style-type: none"> Growth has surpassed the normal range based on historical data. The observed elevated growth may be reflective of peak season. If not, the observed growth may be the initial phases of an algal bloom. Data should be compiled and review closely, taking note of when Level 1 and Level 2 were surpassed. Elevated monitoring is recommended to closely watch the population to determine if it is growth correlates to peak season conditions of if it is the early phase of a bloom.
Action Threshold	<ul style="list-style-type: none"> Increased monitoring to daily Panel review of data and trends to determine if algaecide treatment is necessary. Panel review findings are logged.

Table 1: Full Water Column Application Summary

Reservoir: Lake William Bowen

Location: LWB-5

Purpose: LWB-5 has been outlined as an ideal growth area and greatly contributes to downstream conditions. Treatment of LWB-5 is intended to prevent growth and promote prolonged suppression. The timing of first treatment each year is very important as shifting dominance away from cyanobacteria is required to achieve prevention. This location will be treated routinely to maintain dominance shift that was achieved by the initial treatment. Controlling growth at LWB-5 will greatly reduce the impact downstream (preventative).



Evidence: LWB-5 has conditions that more readily promote algae/cyanobacteria growth and has been shown to be especially problematic. The bottom portion of the water column at LWB-5 had the highest chlorophyll-*a* concentration (2017) in the historical monitoring data, as well as the 9th (2018) and 11th (2018) highest. Whereas, the surface portion of the water column at LWB-5 had the 4th (2016), 14th (2018), and 18th (2017) highest algae counts in the historical data. Geosmin concentration at LWB-5 favor the early portion of the growth season (March, April, and May). Data from LWB-5 suggest chlorophyll-*a* containing algae favor the lower portion of the water column. While the algae count data suggest that algae/cyanobacteria growth is relatively consistent throughout the water column.

Prescription:

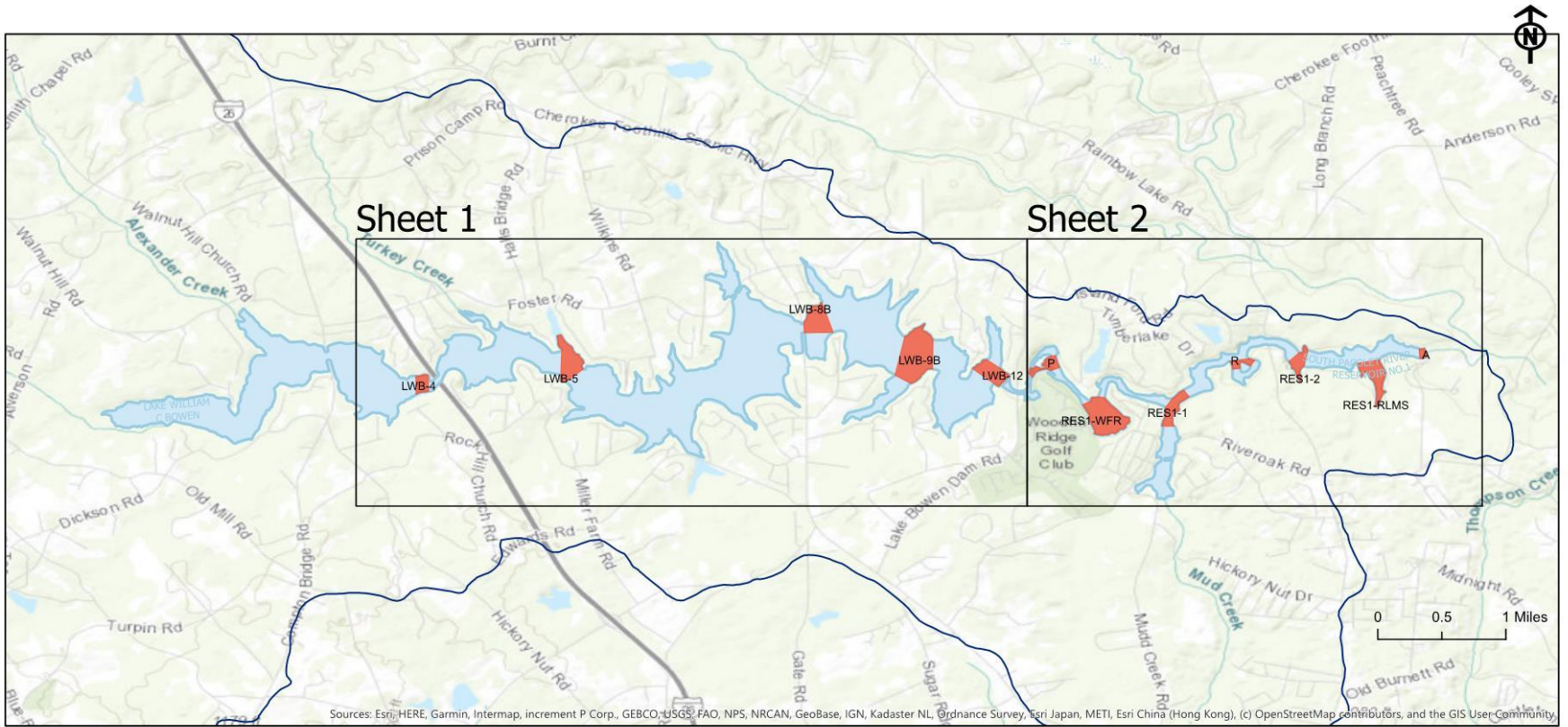
Dose		Frequency of Application
Planktonic Cyanobacteria	Diatoms/Benthic Cyanobacteria	
2.0 mg/L H ₂ O ₂	3.1 mg/L H ₂ O ₂	<ul style="list-style-type: none"> Application should be focused on this site during late April, May, late September, and October. It should be best to closely watch the population density and treat at Index 3 during said months. When Action Threshold is passed for Algae Counts and/or chlorophyll-<i>a</i>: <ul style="list-style-type: none"> Total Algae Count or respective group of organisms (e.g. diatom, cyanobacteria).

Water Column	Area (acres)	Depth (ft)	Volume (acre-ft)	PAK27 (lbs)	
				Planktonic Cyanobacteria	Diatoms/Benthic Cyanobacteria
Full	21.3	18	383.4	7,554.3	11,709.1
Half	21.3	9	191.7	3,777.1	5,854.6

Location	Application Type
RES1-WFR	Surface broadcast
LWB5	1/2 Surface broadcast and 1/2 injected as slurry at 10 ft.
LWB4	1/2 at surface and 1/2 at 9 ft.
LWB8B	1/2 at 5 ft and 1/2 at 15 ft.
LWB9B	1/2 at 10 ft and 1/2 at 25 ft.
LWB12	1/3 at 5 ft, 1/3 at 20 ft, and 1/3 at 32 ft.
RES1-1	1/2 surface broadcast and 1/2 injected as slurry at 5 ft.
RES1-2	1/2 surface broadcast and 1/2 injected as slurry at 12 ft.
RES-P	Surface broadcast
RES-R	1/2 surface broadcast and 1/2 injected as slurry at 5.3 ft
RES-A	1/3 at surface, 1/3 at 10 ft, and 1/3 at 18 ft.
RES-RLMS	1/2 surface broadcast and 1/2 injected as a slurry at 10 ft.

Table 1: Upper Half of Water Column Application Notes

Location	Application Type
RES1-WFR	Surface broadcast
LWB5	Surface broadcast
LWB4	Surface spray
LWB8B	Surface spray
LWB9B	Surface spray
LWB12	Surface spray
RES1-1	Surface broadcast
RES1-2	Surface broadcast
RES-P	Surface broadcast
RES-R	Surface broadcast
RES-A	Surface spray
RES-RLMS	Surface broadcast

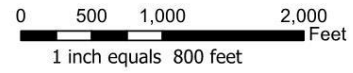
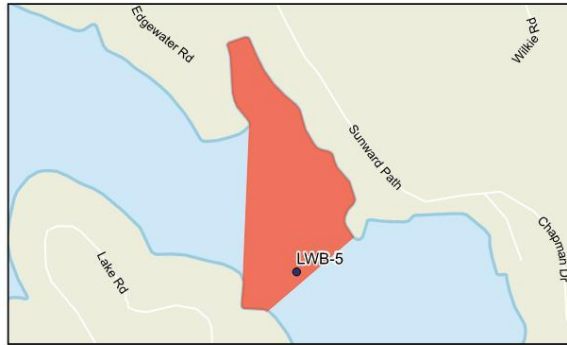
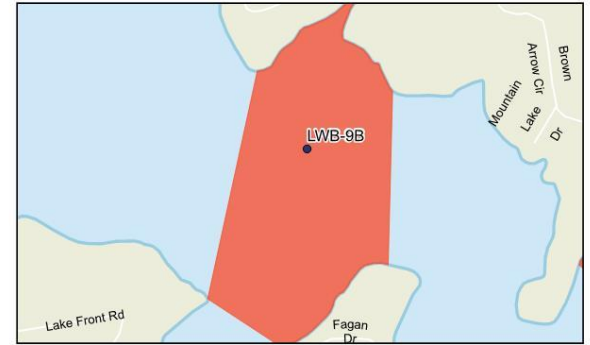
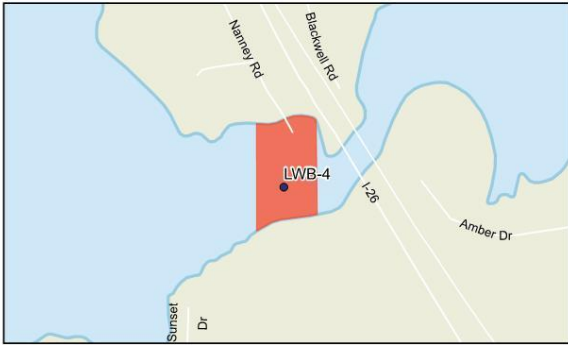


Proposed Treatment Areas

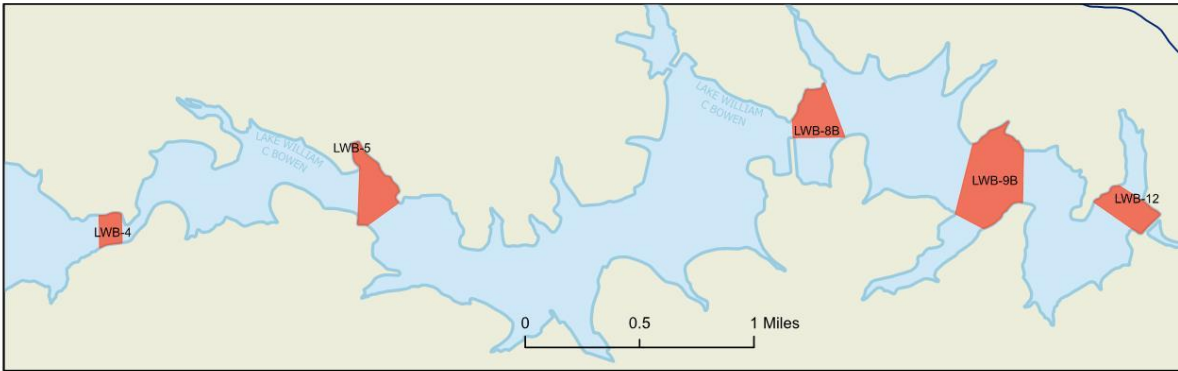
Index Sheet

- South Pacolet River Watershed
- Treatment Area
- Water

Station	AreaAC	Station	AreaAC
A	1.9	P	7.6
LWB-12	15.7	R	4.3
LWB-4	6.9	RES1-1	12.5
LWB-5	21.3	RES1-2	9
LWB-8B	18.9	RES1-RLMS	17.9
LWB-9B	47.9	RES1-WFR	35.1



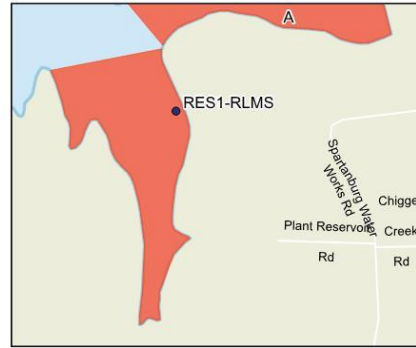
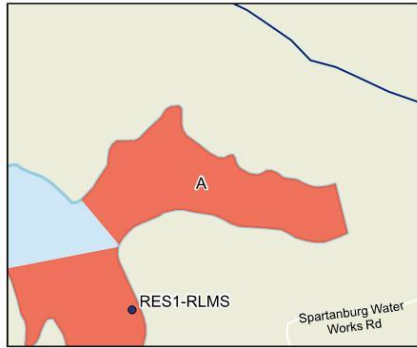
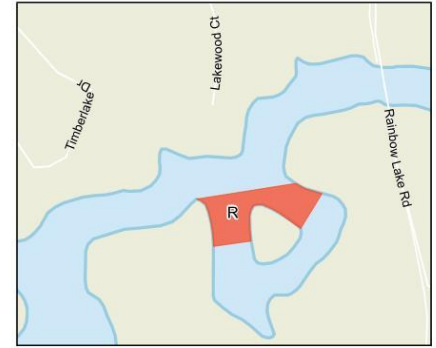
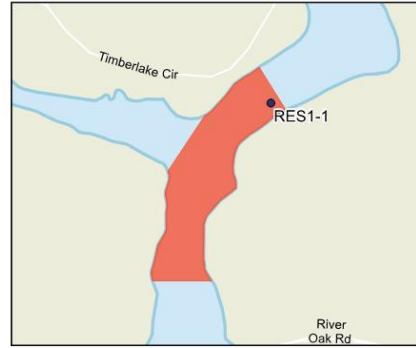
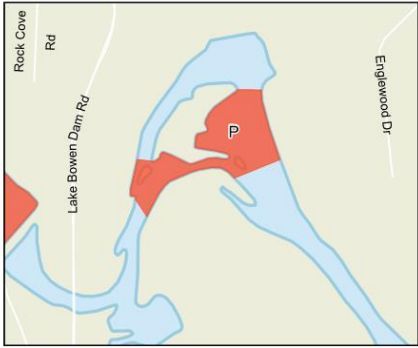
- SW Sampling Sites
- Road
- South Pacolet River Watershed
- Treatment Area
- Water



Station Area^{AC}

LWB-12	15.7
LWB-4	6.9
LWB-5	21.3
LWB-8B	18.9
LWB-9B	47.9

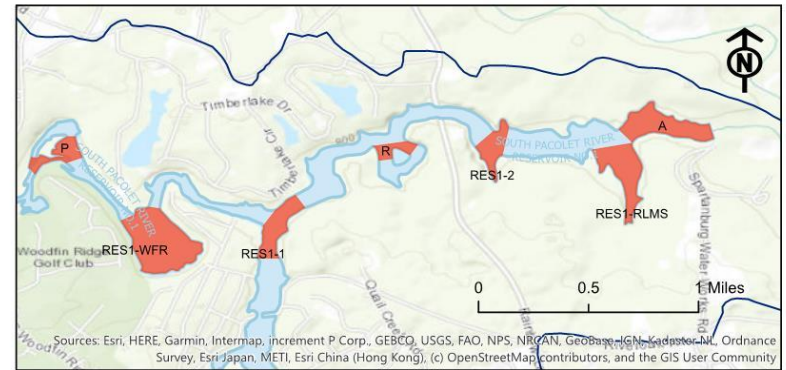
Proposed Treatment Areas Lake William Bowen



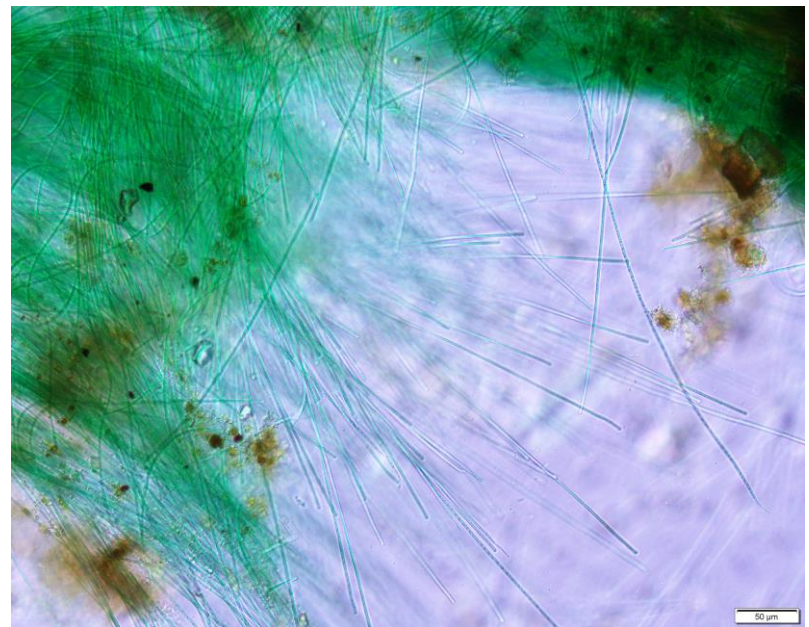
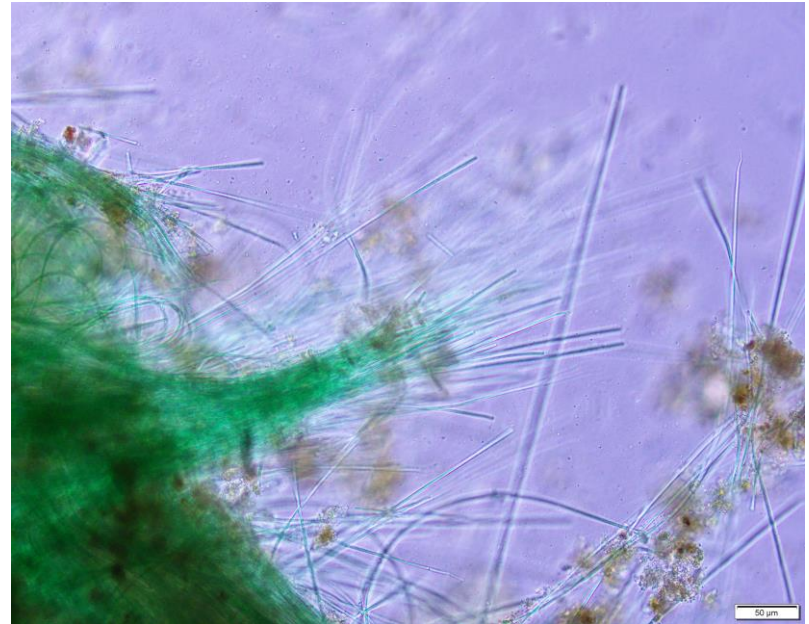
1 inch equals 800 feet

Station	Area AC
A	19.4
P	7.6
R	4.3
RES1-1	12.5
RES1-2	9
RES1-RLMS	17.9
RES1-WFR	35.1

Proposed Treatment Areas Municipal Reservoir #1



Treatment
June 3-5, 2019



First Treatment

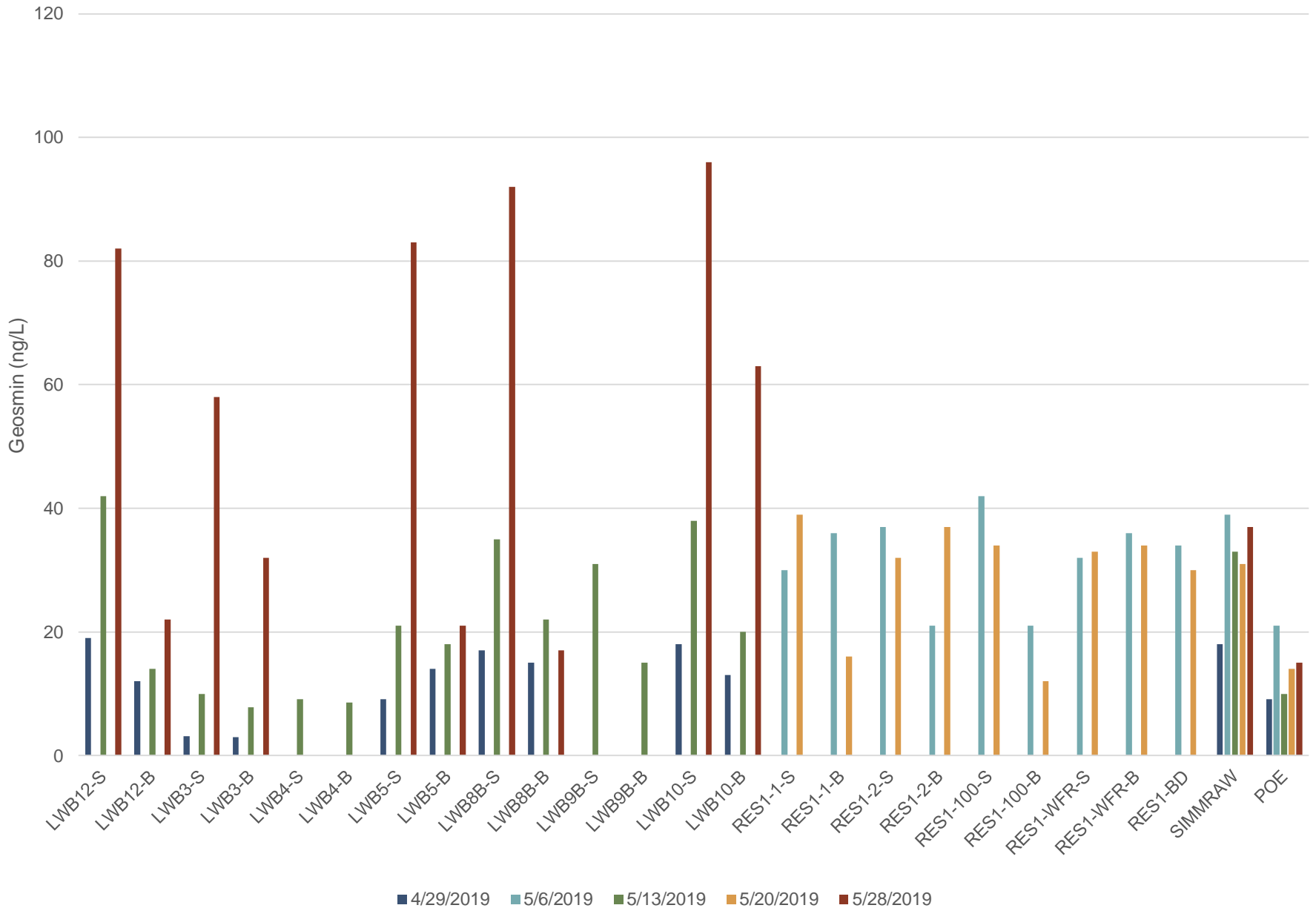


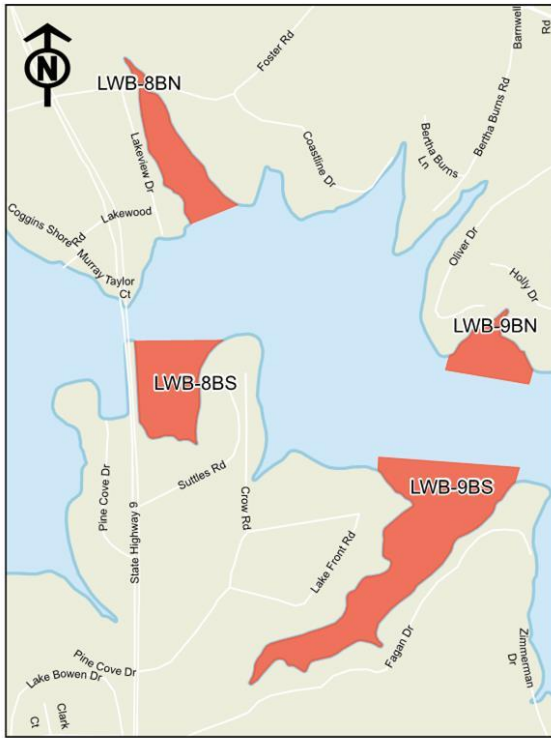
Table 1: Algaecide Prescription for Each Treatment Location.

Location	Target	Area (acre)	Average Depth (ft)	Target Depth (ft)	Volume (acre-ft)	Product	Dose	Application
RES1-WFR	Full Water Column	35.1	5.50	4.0	140.4	PAK27	5,809.3 lbs.	Injected 2 ft. from SWI*
LWB8BN	Benthic	13.2	9.00	4.0	52.8	PAK27	2,184.7 lbs.	Injected 2 ft. from SWI*
LWB8BS	Benthic	16.7	11.00	4.0	66.8	PAK27	2,764.0 lbs.	Injected 2 ft. from SWI*
LWB9BN	Benthic	9.0	11.00	4.0	36.00	PAK27	1,489.6 lbs.	Injected 2 ft. from SWI*
LWB9BS	Benthic	43.4	14.00	4.0	173.6	PAK27	7,183.0 lbs.	Injected 2 ft. from SWI*
LWB12	Benthic	45.8	16.00	4.0	183.2	PAK27	7,580.3 lbs.	Injected 2 ft. from SWI*
RES1-2	Benthic	9	16.27	4.0	36.0	PAK27	1,489.6 lbs.	Injected 2 ft. from SWI*
RES-A	Upper Water Column	19.4	22.00	14	271.6	GreenClean Liquid 5.0	1,455.8 gallons	Inject 2 ft. from surface and at 10 ft.

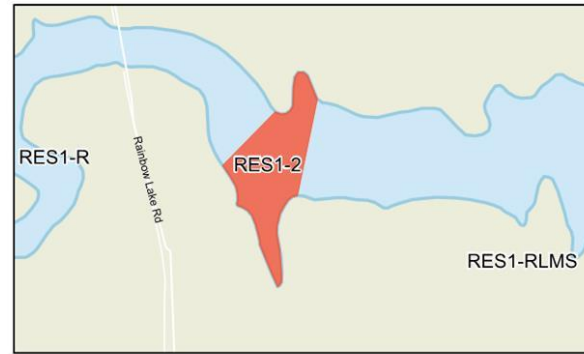
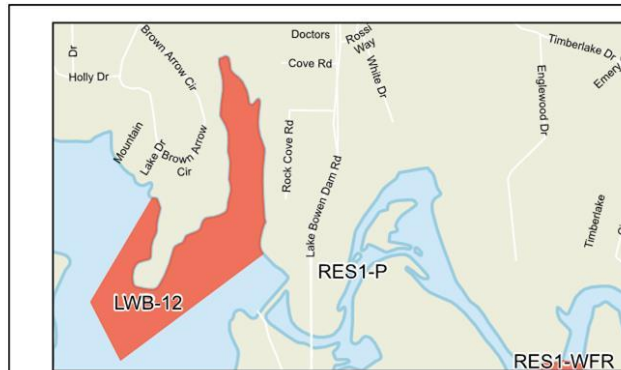
**Sediment water interface*

Table 2: Total Amount of Product Needed to Complete Treatments.

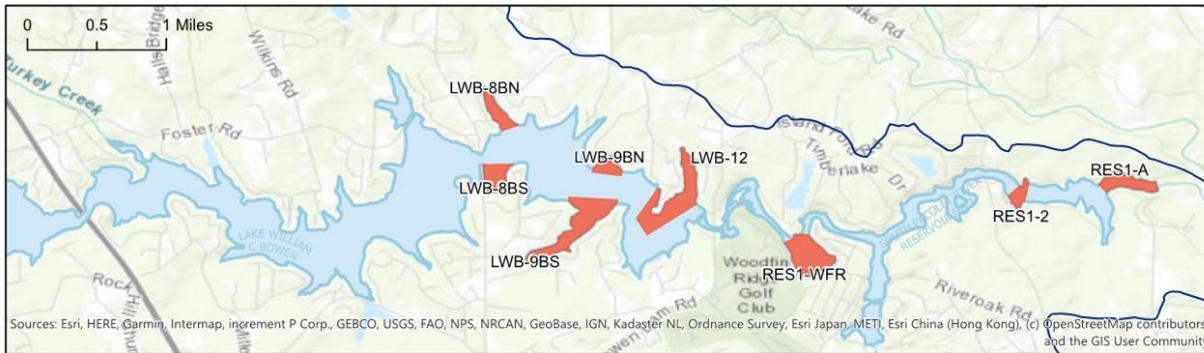
Product	Total Amount Required
PAK27	28,500.5 lbs.
GreenClean Liquid 5.0	1,455.8 gallons



0 0.1 0.2 0.4 Miles

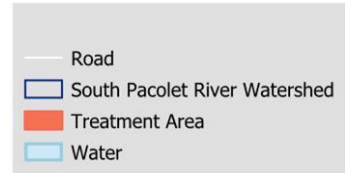


0 0.1 0.2 0.4 Miles



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Station	Area (acres)
LWB-8BN	13.2
LWB-8BS	16.7
LWB-9BN	9.0
LWB-9BS	43.4
LWB-12	45.8
RES1-A	19.4
RES1-WFR	35.1
RES1-2	9.0



Immediate Treatment Areas Lake William Bowen and Municipal Reservoir #1

Revised: 5/23/2019

Closing Remarks

Key Components

- Dynamic management plan
 - Active participation
- Short-term management with algaecide is temporary
 - Provides cost reduction to fund long-term management efforts
- Long-term efforts need to transcend nutrient management and mitigation
 - Biotic component of internal geochemical cycle
 - Cyanobacteria dominance-induced bacteria changes
 - OM/DBP formation potential, Fe, Mn