

Memorandum

To: Lower Mississippi River Watershed Management Organization
From: Greg Wilson, Barr Engineering Co. (Barr)
Subject: Lake Augusta Water Quality Monitoring and Alum Treatment Effectiveness
Date: December 4, 2019
Project: 23190078.00 2019 004

This memorandum is intended to provide the results of the 2019 lake water quality monitoring, compare the 2019 lake water quality monitoring to the results from past sampling, provide an estimate of the actual total phosphorus load reduction achieved on Lake Augusta from the alum treatment (per the Minnesota Board of Water and Soil Resources [BWSR] information request) and recommendations for next steps.

Results of 2019 Lake Water Quality Monitoring

Barr staff completed four separate lake water quality monitoring events during the summer of 2019, which occurred on a monthly basis between June and September. Samples were collected from the Lake Augusta sample station that represents the deepest location. During each sample event: (1) A 0-2 meter composite water sample was collected for laboratory analysis for total phosphorus (TP) and chlorophyll *a* (2) water samples were collected from the 4, 6, 8 and 10-meter depths, and 0.5 meters above the bottom and analyzed for total phosphorus, and (3) water samples were collected from 0-2 meters and from 0.5 meters above the bottom and analyzed for chloride. Dissolved oxygen (DO), temperature, specific conductance, pH, and turbidity were measured at 1-meter intervals from surface to bottom and the Secchi disc transparency was also measured during each visit. The 2019 monitoring results were combined in a spreadsheet with the recent history of water quality sampling results. All of the raw data have been tabulated and attached to this memorandum.

The results of the 2019 lake water quality sampling events indicated the following:

- Lake Augusta was strongly stratified, with DO/temperature data indicating that top two to three meters were mixing—this limits the assimilation capacity of new inflows of phosphorus to the lake, especially since there is no wind mixing and water flushing (through an outlet); which, combined with high water levels, is keeping the lake from mixing each spring and fall
- Secchi disc transparency was very poor throughout the summer
- Bottom-water anoxia contributed to some elevated phosphorus

- TP was generally elevated at the water surface, but was lower throughout most of the rest of the water column, except for the lake bottom depth
- High chlorophyll *a*—still points to the blue-green algae as the primary source of color in the lake (i.e., sediment/erosion is not a significant contributor to the appearance)
- Chloride is higher in the bottom waters, which confirms the lack of lake mixing, but all of the concentrations are lower than the 230 mg/L standard.

Comparison of 2019 to Recent Lake Water Quality Monitoring Results

A comparison of the 2019 lake water quality monitoring results to the Lake Augusta water quality monitoring from the recent past revealed the following (see Figure 1):

- Surface water phosphorus concentrations are slightly higher than the post-alum treatment monitoring (single events) from 2017 and 2018, but significantly lower than the pre-alum treatment monitoring
- Chlorophyll *a* levels were high in 2019, though not as high as last year and significantly lower than the pre-alum treatment monitoring
- Secchi disc transparency was low in 2019, though not as low as last year and comparable to the pre-alum treatment monitoring

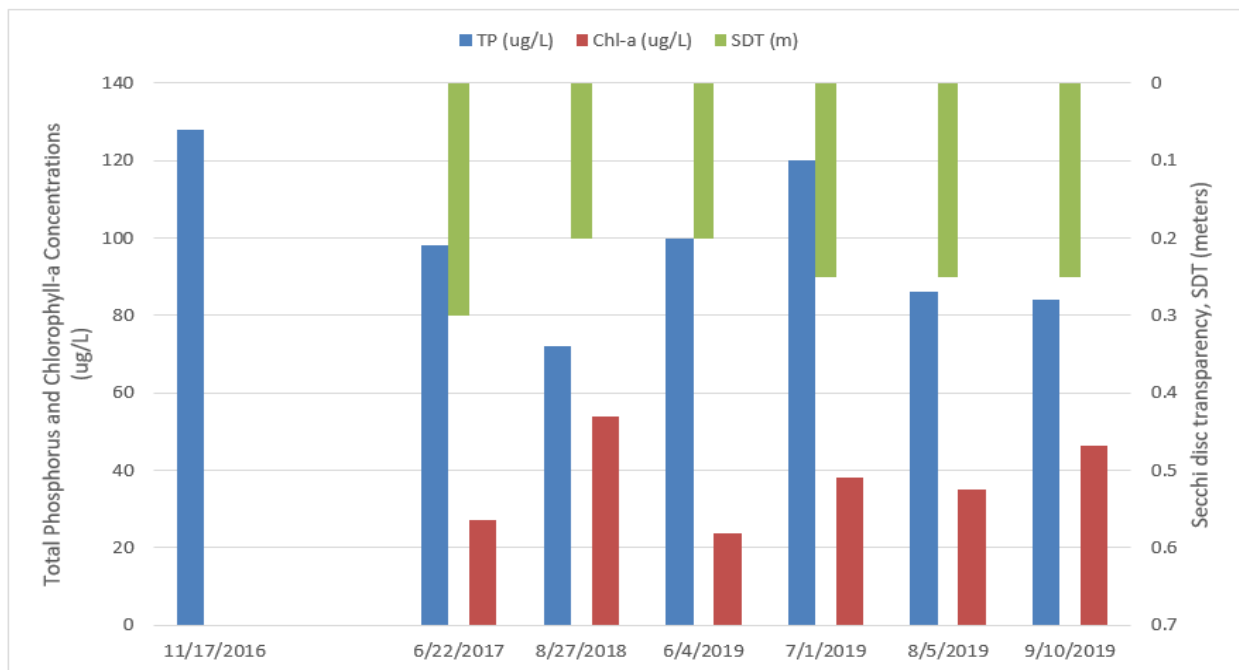


Figure 1 Recent Surface Water Quality Sample Results for Lake Augusta

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Phosphorus levels in the bottom water of the lake are also 80 to 90% reduced from the concentrations that were observed before the alum treatment (i.e., the alum treatment is still controlling the internal load).

The MSP airport had almost 32 inches of precipitation in 2019 by the time Barr collected the last lake sample on September 10th. Between 6 and 7 inches of rain fell in each of the months of May, July and August of 2019.

The recent wet weather patterns indicate a strong likelihood that high lake levels are exacerbating the lake water quality concerns for Lake Augusta. The following table shows how the Lake Augusta lake level measurements or estimates have steadily increased over the recent past. Given the high amount of precipitation in 2019, it is expected that the current lake level is higher than it was when it was surveyed in August, 2018. The following table also shows that the recent 5-foot increase in lake level corresponds with a 34% increase in lake volume, which greatly increases the mass of TP that can be retained within the landlocked lake. These lake and watershed conditions represent a significant departure from the modeling developed for the 2014 WRAPs/TMDL report.

Source	Lake level (MSL)	Estimated lake volume (acre-ft.)
DNR's lakefinder OHW	832.5'	~450
DNR's lakefinder water level (10/24/85)	834.92'	530
Dakota County 1-meter LiDAR DEM (circa 2011-2012)	840.22'	743
8/27/18 survey	845.33'	996

Estimate of Total Phosphorus Load Reduction from Alum Treatment

The BWSR grant work plan had previously provided an estimated TP internal load reduction of 252 pounds per year for the Lake Augusta alum application, which was based on the existing in-lake model loading estimate from the WRAPs/TMDL report combined with an 80% treatment efficiency (referenced from literature). Per BWSR's request, Barr used the 2019 lake water quality monitoring data to develop an estimate of the actual total phosphorus load reduction achieved on Lake Augusta from the alum treatment. The actual load reduction estimate was determined by comparing the 2019 lake sediment to the sediment phosphorus release rate that had previously been determined from our sediment core phosphorus analyses in 2013. The potential sediment phosphorus release rate determined in 2013 was 2.16 mg/m²/day, while our evaluation of the change in summer phosphorus levels in the hypolimnion of Lake Augusta during 2019 corresponded with a sediment phosphorus release rate of 0.45 mg/m²/day. The

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difference in these phosphorus release rates represents a 79% reduction, which is directly comparable with the assumption contained in BWSR grant work plan.

Recommendations

Given the recent wet weather patterns and high lake levels, there are significant data gaps that remain (since the alum treatment). As a result, it is recommended that a feasibility study to determine future implementation activities will need to account for the following aspects of TP loading to improve the water quality of Lake Augusta:

- Excess phosphorus contributions from flooded shoreline soils, erosion and decaying vegetation at varying lake levels
- Assess the rough fish population and account for potential impact on internal phosphorus load in shallow areas of the lake
- Stormwater runoff changes associated with watershed development/redevelopment, including an assessment of the performance of how well the existing stormwater BMPs are working
- Calibrate lake and watershed modeling, where possible, and account for lake mixing changes in evaluation of possible lake outlet controls
- Complete cost-benefit analysis and priority practice ranking of potential improvement options, including BMP combinations necessary to meet lake water quality standards.

Lake Augusta 2019 Lab Data:

Date	Depth (m)	Chl-a (ug/L)	TP (ug/L)	Chloride (mg/L)
6/4/2019	0-2	23.6	100	115
6/4/2019	4		44	
6/4/2019	6		38	
6/4/2019	8		45	
6/4/2019	10		65	
6/4/2019	12.5		120	151
7/1/2019	0-2	38.1	120	118
7/1/2019	4		37	
7/1/2019	6		63	
7/1/2019	8		32	
7/1/2019	10		100	
7/1/2019	12		140	144
8/5/2019	0-2	35	86	116
8/5/2019	4		96	
8/5/2019	6		92	
8/5/2019	8		100	
8/5/2019	10		160	
8/5/2019	12.8		240	145
9/10/2019	0-2	46.5	84	113
9/10/2019	4		74	
9/10/2019	6		63	
9/10/2019	8		69	
9/10/2019	10		110	
9/10/2019	12		220	143

Chlorophyll-a values are not pheophytin corrected.

2019 Field Data:

Date	Depth (m)	DO (mg/L)	Temp (deg C)	Spec Cond (uS/cm)	pH	Turbidity (NTU)	SDT (m)
6/4/2019	0	13.5	21.1	598	9.2	49.4	0.2
	1	13.8	20.2	598	9.2		
	2	6.9	15.6	611	8.1		
	3	4.2	13.7	625	7.7		
	4	3.6	12.4	637	7.5		
	5	2.8	9.4	653	7.3		
	6	2.5	7.4	651	7.2		
	7	1.7	5.6	657	7.1		
	8	0.3	5.0	672	7.1		
	9	0.2	4.4	720	7.2		
	10	0.2	4.2	774	7.2		
	11	0.2	4.0	814	7.1		
	12	0.3	4.0	831	7.1		
	12.5	0.2	4.0	838	7.1		
	12.8	Bottom					

algal bloom present

Date	Depth (m)	DO (mg/L)	Temp (deg C)	Spec Cond (uS/cm)	pH	Turbidity (NTU)	SDT (m)
7/1/2019	0	9.5	23.7	589	9.0	45.4	0.25
	1	9.3	23.7	589	9.0		
	2	0.3	21.3	616	7.8		
	3	0.4	15.3	638	7.6		
	4	0.3	12.1	646	7.5		
	5	0.2	9.5	653	7.3		
	6	0.1	7.2	661	7.2		
	7	0.1	6.0	680	7.2		
	8	0.1	5.3	704	7.2		
	9	0.2	4.5	729	7.2		
	10	0.2	4.5	764	7.1		
	11	0.2	4.4	780	7.1		
	12	0.2	4.3	800	7.1		
	12.3	Bottom					

algal bloom present

Date	Depth (m)	DO (mg/L)	Temp (deg C)	Spec Cond (uS/cm)	pH	Turbidity (NTU)	SDT (m)
8/5/2019	0	15.2	27.1	578	9.5	30.0	0.25
	1	15.3	26.8	578	9.5		
	2	0.4	24.1	598	7.9		
	3	0.3	19.8	670	7.5		
	4	0.4	13.7	668	7.4		
	5	0.5	10.3	672	7.3		
	6	0.4	7.9	680	7.3		
	7	0.4	6.6	694	7.2		
	8	0.3	5.5	716	7.1		
	9	0.2	5.0	755	7.1		
	10	0.2	4.6	795	7.0		
	11	0.2	4.5	822	7.0		
	12	0.1	4.5	835	7.0		
	12.8	0.1	4.5	840	7.0		
	13.3	Bottom					

algal bloom present

Date	Depth (m)	DO (mg/L)	Temp (deg C)	Spec Cond (uS/cm)	pH	Turbidity (NTU)	SDT (m)
9/11/2019	0	9.8	19.9	577	8.9	32.2	0.25
	1	7.9	19.2	580	8.7		
	2	7.8	19.1	580	8.7		
	3	7.8	19.1	580	8.7		
	4	0.4	18.1	630	7.8		
	5	0.4	11.9	671	7.5		
	6	0.5	8.8	675	7.3		
	7	0.5	7.0	688	7.2		
	8	0.4	6.0	706	7.2		
	9	0.2	5.2	746	7.1		
	10	0.2	5.0	781	7.0		
	11	0.2	4.7	820	6.9		
	12	0.2	4.7	826	6.9		
	12.5	Bottom					

algal bloom present

Augusta

8/27/2018

Depth (m)	Chl-a (ug/L)	TSS (mg/L)	VSS (mg/L)	TDP (ug/L)	TP (ug/L)
0-2	54.1	24.5	22	3.9	72
4					40
6					29
8					31
10					43
12.5					85

Chlorophyll-a values are not pheophytin corrected.

Depth (m)	DO (mg/L)	Temp (deg C)	Spec Cond (uS/cm)	pH	Turbidity (NTU)	SDT (m)
0	8.4	22.7	561	8.9	44.3	0.2
1	7.9	22.6	561	8.8		
2	7	22.5	562	8.7		
3	0.5	20.8	586	7.9		
4	0.5	13.4	686	7.4		
5	0.5	10.2	687	7.2		
6	0.2	6.5	696	7.1		
7	0.1	5.3	703	7.0		
8	0.1	4.7	720	7.0		
9	0.1	4.6	752	6.9		
10	0.2	4.4	795	6.9		
11	0.2	4.4	830	6.8		
12	0.2	4.3	845	6.8		
12.5	0.2	4.3	850	6.8		
13	Bottom					

Augusta

6/22/2017

Depth (m)	Chl-a (ug/L)	TP (ug/L)
0-2	27.1	98
3		93
6		28
9		50
10		59

Chlorophyll-a values are not pheophytin corrected.

Depth (m)	DO (mg/L)	Temp (deg C)	Spec Cond (uS/cm)	pH	ORP (mV)	SDT (m)
1	12.4	23.4	613	8.86	250	0.3
2	11.4	23.2	617	8.79	249	
3	2.2	19.7	631	7.66	258	
4	0	12.8	643	7.26	241	
5	0	10.2	646	7.25	240	
6	0	9.1	646	7.23	213	
7	0	7.4	646	7.20	-48	
8	0	6.8	650	7.19	-69	
9	0	6.2	660	7.17	-79	
10	0	5.9	685	7.14	-91	

Pre-alum treatment, 2016-11-17

Depth (m)	TP (ug/L)
0-2	128
4	139
7	134
10	580
13	1220