Austin Lake Baseline Aeration Data 2017 and Year 1 Post-Aeration Data (2018) Kalamazoo County, Michigan
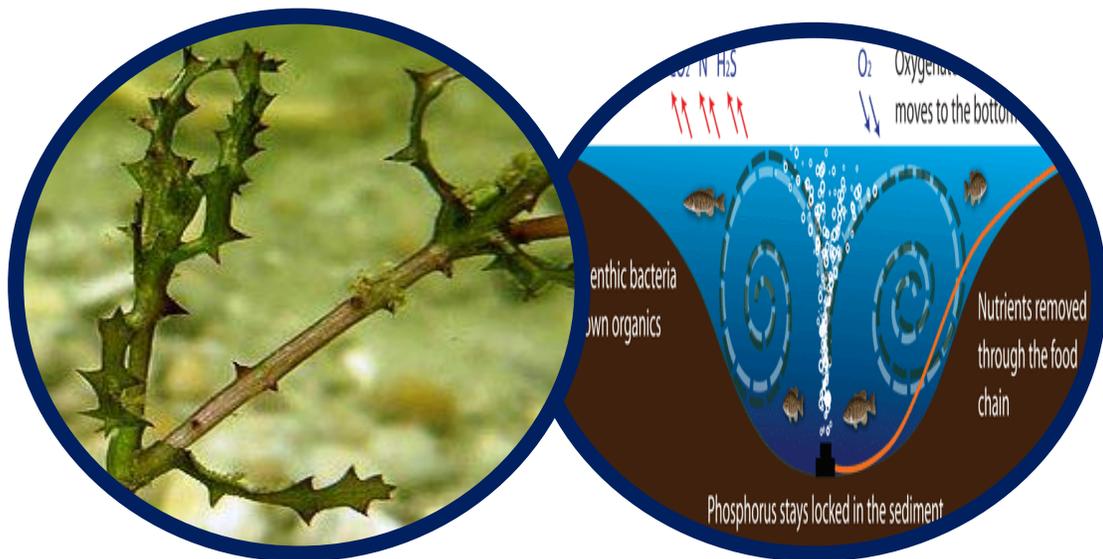

Prepared for: Austin Lake Governmental Lake Board (ALGLB)
Pursuant to MDEQ Permit No. WRP008788
December, 2018

TABLE OF CONTENTS

FIGURES

TABLES

NAME	PAGE

Austin Lake Baseline Aeration Data 2017 and Year 1 Post-Aeration Data (2018) Kalamazoo County, Michigan

1.0 PROJECT INTRODUCTION & SUMMARY

Austin Lake is a 1,132-acre natural, glacial origin lake with nearly 6.49 miles of shoreline, a maximum water depth of 8 feet and an average depth of approximately 5.0 feet. The lake is located sections 23, 24, 25, 26, 35, and 36 in the City of Portage (T.3S, R.11W) in Kalamazoo County, Michigan. The lake altitude is approximately 856 feet above sea level. Austin Lake has a lake perimeter of approximately 6.49 miles. The volume of the lake is estimated to be approximately 5,660 acre-feet of water.

The hydrology of Austin Lake is complex in that the lake receives water inputs from precipitation, Pfizer discharge, surface runoff, and indirect flows from Gourdneck Creek via two intermittent inlets which are West and Long Lakes. Water diversion from Upjohn Company's recharge pond to Austin Lake began in 1967. If the water level of Austin Lake is unusually high, it may flow backwards into West Lake which may then become an intermittent outlet under those conditions. Water loss results from evaporation, groundwater recharge, and outputs to the dam. Previous studies by Straw et al., 1978 determined that approximately 2,600 acre-feet of water are lost annually via evaporation. In addition, groundwater recharge is estimated at approximately 1,500 acre-feet per year. The direction of groundwater flow is from the north and south of Austin Lake (US Department of Interior, 1973), which indicates the presence of a groundwater divide. In 1936, a connection channel was constructed between West and Austin Lakes and in 1938 a channel was constructed between Long and Austin Lakes. The existing legal lake level for Austin Lake is at 856.0 feet, established by the Circuit Court in 1925.

Excess sediments created from a combination of internal and external loading are largely confined to the lake South Basin and have led to accumulation of sediments which have decreased overall lake water depth in some areas. As a result of this, laminar flow aeration (LFA) was implemented in 2013 and continues to date. Improvements such as the improvement in dissolved oxygen near the sediment/water interface, declines in Eurasian Watermilfoil, and reduction in sediment organic muck and ammonia have been determined by evaluations from Restorative Lake Sciences (RLS).

1.1   Summary of Austin Lake South Basin Aeration Operations:

Laminar Flow Aeration (LFA) was installed in the South Basin of Austin Lake in July of 2013. Operation began in August of 2013.   There are 27 ceramic diffusers and 28,500 feet of self-sinking airline in addition to three 5 hp compressors. This report serves as the baseline data requirement for MDEQ aeration permit WRP008788 which was issued as a renewal of the existing LFA system on October 31, 2017. Per Rule 91 permits obtained by Lake Savers, LLC, bioaugmentation (microbes and enzymes) were added to the South Basin of Austin Lake in 2014, 2015, 2016, and 2018. They were not added in 2017 due to administrative issues.

1.2   Summary of Aeration Operation Purpose/Goals:

Austin Lake is a 1,090-acre inland, public, lake and is utilized by many for fishing, swimming, boating, and waterfront living. The South Basin of Austin Lake had become excessively mucky with organic sediments that were becoming anoxic and causing many issues for lake residents. Although muck reduction methods such as dredging and other types of aeration were considered in the past few decades, the Austin Lake Governmental Lake Board (ALGLB) desired a more cost-effective technology for muck reduction. The residents desired a lake restoration strategy that would reduce the muck in the South Basin and by doing so would improve the overall use of the entire lake. The ALGLB developed the following objectives:

The primary objectives of the implemented LFA system for the Austin Lake South Basin includes:

  1) Reduction of excessive muck/organic matter in the South Basin.
  2) Increase in dissolved oxygen at the sediment/water interface
  3) The objectives above without reducing water quality in the South Basin

2.0   AUSTIN LAKE SOUTH BASIN SAMPLING METHODS & PARAMETERS

2.1   Summary of Equipment/Sampling Devices/Replicates/Parameters Measured:

Restorative Lake Sciences originally sampled 3 deep basin sites in the South Basin of Austin Lake under the previous MDEQ LFA permit. Under the newly issued permit No. WRP008788, RLS sampled 4 required deep basin locations which can be found in Figure 1 below. Baseline water quality data was required for the period of October 1-15, 2017 and thus water sampling occurred on October 12, 2017. Year 1 water quality data was collected on May 1, 2018, July 3, 2018, and September 14, 2018.

All chemical water samples were collected at the specified depths (mid-depth of the 4 deep basin sampling sites) using a 4-liter VanDorn horizontal water sampler with weighted messenger (Wildco® brand).   Water quality physical parameters (such as water temperature, dissolved oxygen,

conductivity, and pH) were measured with a calibrated Eureka Manta 2® multi-probe meter at mid-depth of the 4 deep basin sampling sites. Total phosphorus was titrated and analyzed in the laboratory according to method SM 4500-P E. Ortho-phosphorus was titrated and analyzed in the laboratory according to method SM 4500-P E. Total suspended solids were analyzed for each sample using SM 2540 D-97. All of the aforementioned chemical parameters were analyzed at Trace Analytical Laboratories in Muskegon, Michigan.

Chlorophyll-*a* was analyzed using method SM 10200H by Trace Analytical Laboratories in Muskegon, Michigan. Prior to analysis of the samples as described above, water samples were placed in clean, unpreserved polyethylene bottles for ortho-phosphorus and total suspended solids and placed in H_2SO_4-preserved, clean, polyethylene bottles for total phosphorus analysis. Chlorophyll-*a* samples were placed in glass brown amber 1-liter bottles with glutaraldehyde as a preservative and analyzed within 1 week after collection. All water samples were maintained on ice in a large cooler prior to being placed into the laboratory fridge. Samples used for microscopic analysis of algal community composition were preserved with glutaraldehyde and counted with a Sedgewick Rafter® Counting Cell under high power objective on a bright-field Accuscope® and/or Zeiss® compound microscope. Multiple 1 micro-liter (µL) aliquots were used to determine the relative abundance of algal genera in the samples.

2.2   Sampling Dates and Locations:

Restorative Lake Sciences sampled 4 deep basin locations on October 12, 2017. Additional data was collected at the 4 sites as required by the MDEQ for the new LFA permit on May 1, 2018, July 3, 2018, and September 14, 2018. All water quality samples were collected from the sampling locations according to Figure 1.
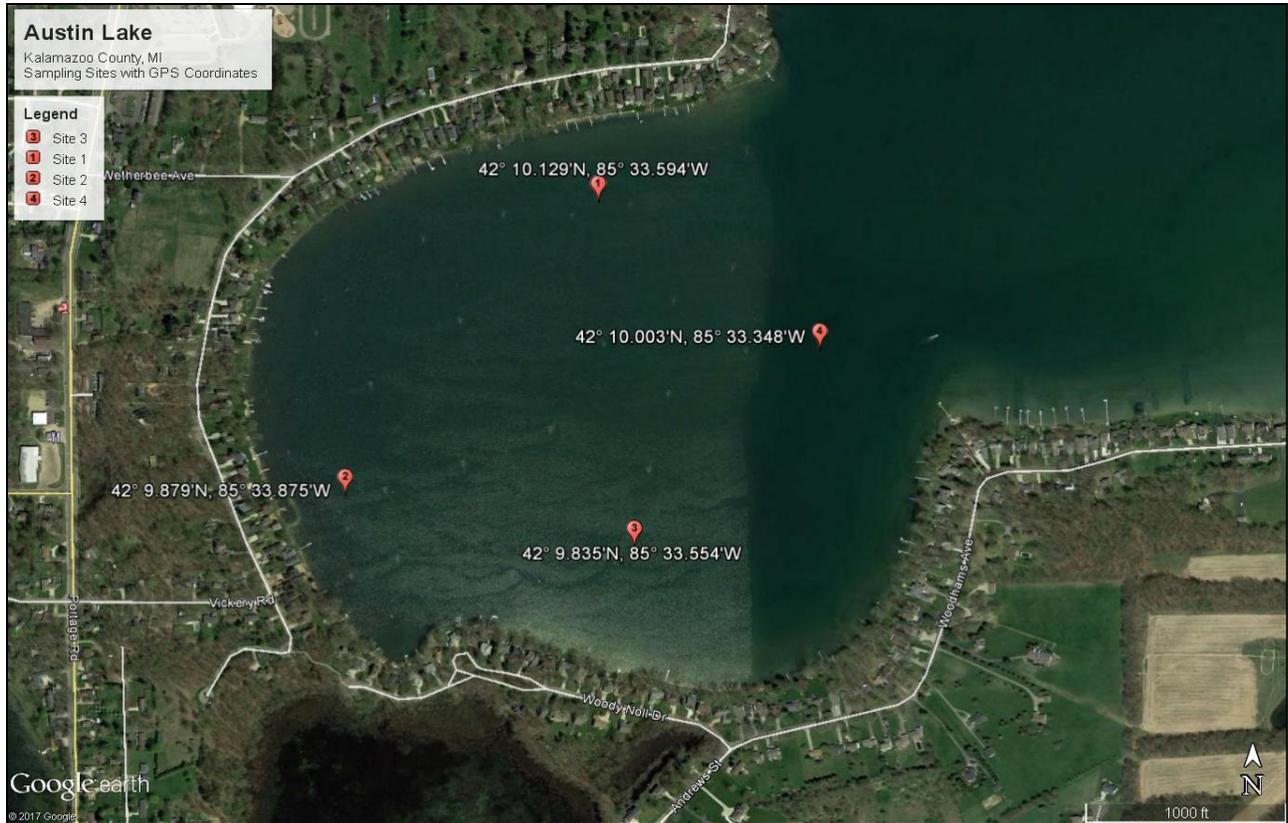
Figure 1. 2017 (baseline) and 2018 (year 1) water quality sampling locations in the South Basin of Austin Lake, Kalamazoo County, MI.

3.0 AUSTIN LAKE SOUTH BASIN 2017 BASELINE WATER QUALITY SAMPLING RESULTS

All 2017 baseline physical water quality data is shown in tables 1-4 below. Baseline chemical water quality data is shown in tables 5-8 below.

3.1   Austin Lake South Basin Baseline Physical Water Quality Data Tables:

Pre-Aeration Data Tables: Site Deep Basins #1-#4

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. $\mu S\ cm^{-1}$	Secchi ft.
0	16.2	9.4	8.9	699	5.0+
2.5	16.2	9.4	8.9	699	
5.0	16.2	8.7	8.7	735	

Table 1. Austin Lake water quality parameter data collected in deep basin #1 on October 12, 2017.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. $\mu S\ cm^{-1}$	Secchi ft.
0	16.4	9.4	8.9	701	4.0+
2.0	16.4	9.2	8.9	701	
4.0	16.4	9.2	8.9	701	

Table 2. Austin Lake water quality parameter data collected in deep basin #2 on October 12, 2017.

Depth ft.	Water Temp °C	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Secchi ft.
0	16.1	9.5	8.9	699	5.0+
2.5	16.1	9.4	8.9	699	
5.0	16.1	9.5	8.9	699	

Table 3. Austin Lake water quality parameter data collected in deep basin #3 on October 12, 2017.

Depth ft.	Water Temp °C	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Secchi ft.
0	16.3	9.2	8.9	700	5.0+
2.5	16.3	9.4	8.9	700	
5.0	16.3	8.4	8.9	700	

Table 4. Austin Lake water quality parameter data collected in deep basin #4 on October 12, 2017.

3.2   Austin Lake South Basin Baseline Chemical Water Quality Data Tables:

Pre-Aeration Data Tables: Site Deep Basis #1-#4

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.010	<0.010	<10	2.40

Table 5.   Austin Lake baseline chemical water quality parameter data collected from the deep basin site #1 on October 12, 2017.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2	<0.010	<0.010	<10	-7.48

Table 6.   Austin Lake baseline chemical water quality parameter data collected from the deep basin #2 site on October 12, 2017.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.018	<0.010	<10	0.801

Table 7.   Austin Lake baseline chemical water quality parameter data collected from the deep basin site #3 on October 12, 2017.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (μg/L)
2.5	0.012	<0.010	<10	0.534

Table 8.   Austin Lake baseline chemical water quality parameter data collected from the deep basin #4 site on October 12, 2017.

3.3   Austin Lake South Basin Baseline Phytoplankton Community:

Algal Community Composition Data Graph (Figure 2):

The algal genera were determined from composite water samples collected over the deep basins of the South Basin of Austin Lake on October 12, 2017 were analyzed with a compound bright field microscope. The genera present included the Chlorophyta (green algae): *Scenedesmus* sp., *Chlorella* sp., *Staurastrum* sp., *Cladophora* sp.,   *Mougeotia* sp., and *Radiococcus* sp., The Cyanophyta (blue-green algae): G*leocapsa* sp.; the Bascillariophyta (diatoms*): Synedra* sp., *Navicula* sp., *Cymbella* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of alga but less blue-green algae is desirable.
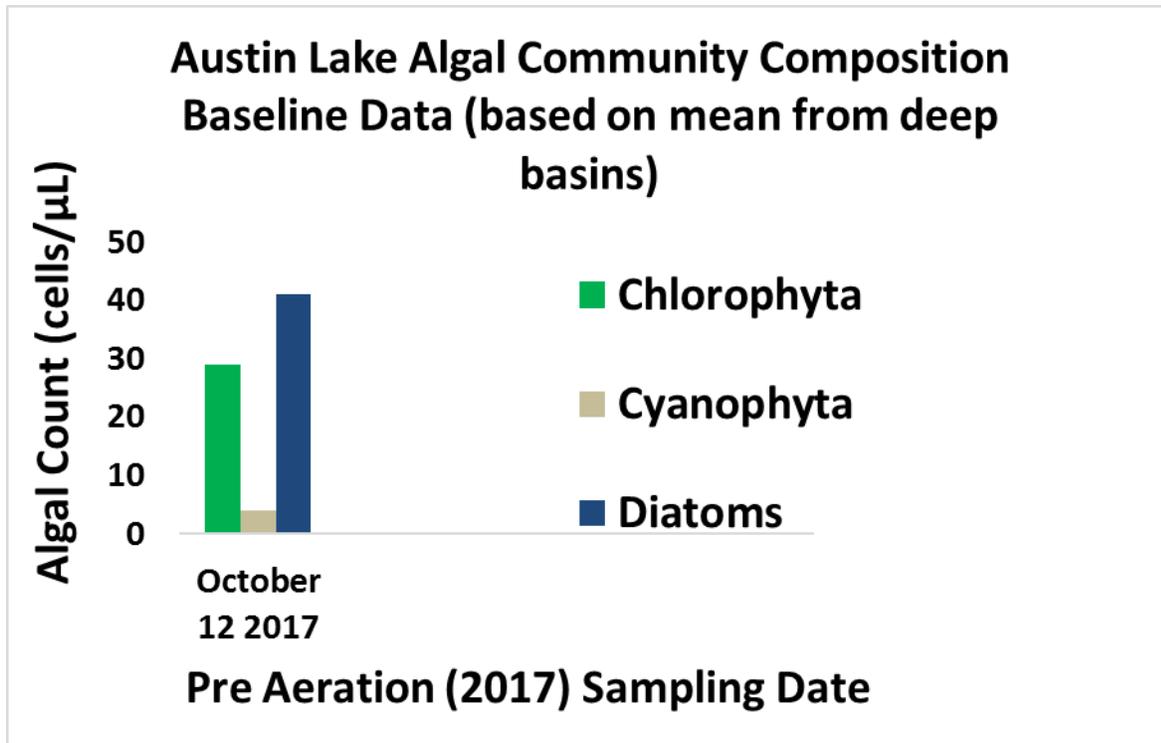
Figure 2. Relative abundance of algal taxa in the South Basin of Austin Lake (October 12, 2017).

3.4   Austin Lake South Basin Aquatic Vegetation Biovolume Scan:

An aquatic vegetation biovolume scan of the South Basin of Austin Lake was conducted on October 12, 2017 using a Lowrance HDS 8® sonar unit with GPS.   BioBase software was used to create an aquatic vegetation biovolume map (Figure 3) of the South Basin as a baseline. The biovolume map below shows the relative aquatic vegetation biovolume in the South Basin of Austin Lake. The blue areas represent no vegetation whereas green areas represent low-growing vegetation and red areas represent high-growing vegetation. Table 9 shows the percentage of the various biovolume categories that exist in the South Basin area. The majority of the South Basin is either non-vegetated (blue color) or has low-lying aquatic vegetation (green).
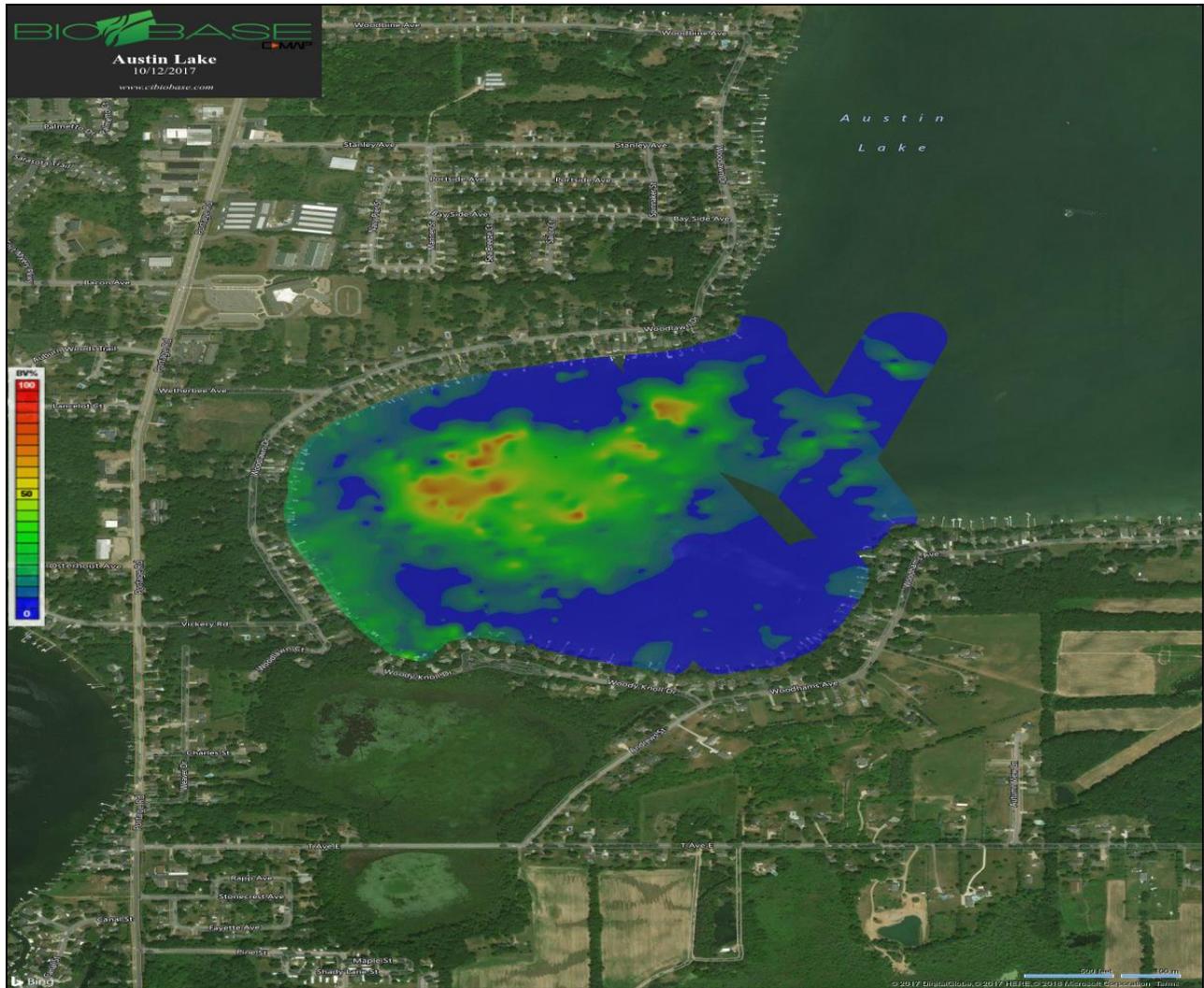
Figure 3. An aquatic vegetation biovolume scan map of the South Basin Austin Lake (October 12, 2017. RLS). Note: This scan will be completed again around the same time in 2018.

Aquatic Vegetation Biovolume Category (%)	Percent of South Basin Occupied
0-20	79.8%
20-40	9.8%
40-60	3.6%
60-80	2.7%
>80	4.2%

Table 9. Aquatic vegetation biovolume in the South Basin of Austin Lake (October 12, 2017).

3.5 Austin Lake South Basin Bottom Hardness Scan:

A sediment bottom hardness scan of the South Basin of Austin Lake using a Lowrance HDS 8® sonar unit with GPS software was used to create an aquatic sediment bottom hardness map (Figure 4) of the lake on October 12, 2017 as a baseline. The areas light beige in color represent soft, mucky bottom whereas areas that are red represent firmer bottom. Colors in the orange family represent intermediate bottom hardness types. This baseline information is important since it allows us to determine if the aeration system has reduced muck throughout the lake bottom in the future. Table 10 shows the area of the South Basin occupied by each sediment hardness category.

Figure 4. A bottom sediment hardness map of the Austin Lake South Basin (October 12, 2017. RLS).

Sediment Bottom Hardness Category	Percent of South Basin Occupied
0-0.1 (beige)	2.6%
0.1-0.2 (dk beige)	24.0%
0.2-0.3 (lt orange)	34.4%
0.3-0.4 (dk orange)	21.5%
0.4-0.5 (red)	17.4%

Table 10. Sediment bottom hardness in the South Basin of Austin Lake (October 12, 2017).

3.6   2017 Austin Lake South Basin Depths:

RLS collected baseline depth measurements from the surface to the bottom at each of the following locations with the use of a calibrated device. Water level was noted on the USGS staff gauge website for Austin Lake measured at the same time of sampling. On October 12, 2017, the gauge height was 6.08'.

Site	Depth (ft.)	Site	Depth (ft.)
2730	3.3	2731	2.7
2732	2.7	2733	2.7
2734	2.7	2735	2.8
2736	1.8	2737	3.1
2738	4.2	2739	4.3
2740	4.6	2741	4.3
2742	4.3	2743	3.8
2744	3.2	2745	2.6
2746	4.5	2747	4.9
2748	4.7	2749	4.8
2750	5.1	2751	4.9
2752	5.6	2753	4.8
2754	3.7	2755	3.9
2756	2.3	2757	4.5
2758	4.8	2759	5.6
2760	4.7	2761	4.8
2762	4.7	2763	4.4
2764	5.1	2765	4.3
2766	5.1	2767	4.4
2768	6.0	2769	5.8
2770	4.3	2771	5.1
2772	5.3	2773	4.4
2774	4.8	2775	5.0
2776	5.1	2777	2.6
2778	4.1	2779	5.2
2780	5.8	2781	4.9
2782	4.6	2783	5.4
2784	5.2	2785	4.9
2786	6.1	2787	8.4
2788	6.4	2789	4.6
2790	4.7	2791	5.1
2792	6.7	2793	4.7

Table 11. Depth Measurements in the South Basin of Austin Lake (October 12, 2017).

**4.0   AUSTIN LAKE SOUTH BASIN 2018 YEAR 1WATER QUALITY SAMPLING
RESULTS**

All Year 1 (2018) physical water quality data is shown in tables 12-23 below. In addition, Year 1
(2018) chemical water quality data is shown in tables 24-35 below.

4.1   Austin Lake South Basin Baseline Physical Water Quality Data Tables:

a.   Post-Aeration Data Tables: May 1, 2018

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Secchi ft.
0	16.1	10.1	8.6	647	5.0+
2.0	16.0	10.3	8.6	647	
4.0	16.0	10.3	8.6	647	

**Table 12. Austin Lake water quality parameter data collected in
deep basin #1 on May 1, 2018.**

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Secchi ft.
0	17.0	10.3	8.6	647	4.0+
2.0	16.8	10.4	8.6	648	
4.0	16.7	10.4	8.6	647	

**Table 13. Austin Lake water quality parameter data collected in
deep basin #2 on May 1, 2018.**

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Secchi ft.
0	16.1	10.3	8.6	647	4.0+
2.0	16.0	10.4	8.6	647	
4.0	16.1	9.8	8.6	647	

Table 14. Austin Lake water quality parameter data collected in deep basin #3 on May 1, 2018.

Depth ft.	Water Temp ºC	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Secchi ft.
0	15.8	11.0	8.7	648	4.0+
2.0	15.8	10.5	8.6	648	
4.0	15.8	10.2	8.7	648	

Table 15. Austin Lake water quality parameter data collected in deep basin #4 on May 1, 2018.

b.   Post-Aeration Data Tables: July 3, 2018

Depth ft.	Water Temp ºC	DO mg L⁻¹	pH S.U.	Cond. µS cm⁻¹	Secchi ft.
0	30.4	8.7	8.7	595	5.0+
1.0	30.5	8.8	8.7	595	
2.0	30.5	8.9	8.7	595	
3.0	30.4	8.9	8.7	595	
4.0	30.4	8.9	8.7	595	
5.0	30.4	8.9	8.7	595	

Table 16. Austin Lake water quality parameter data collected in deep basin #1 on July 3, 2018.

Depth ft.	Water Temp ºC	DO mg L⁻¹	pH S.U.	Cond. µS cm⁻¹	Secchi ft.
0	30.6	8.6	8.7	597	4.0+
1.0	30.6	8.7	8.7	597	
2.0	30.6	8.7	8.7	597	
3.0	30.6	8.7	8.7	597	
4.0	30.6	8.0	8.7	597	

Table 17. Austin Lake water quality parameter data collected in deep basin #2 on July 3, 2018.

Depth ft.	Water Temp °C	DO mg L⁻¹	pH S.U.	Cond. µS cm⁻¹	Secchi ft.
0	30.3	8.3	8.7	596	5.0+
1.0	30.3	8.4	8.7	595	
2.0	30.3	8.6	8.7	596	
3.0	30.3	8.6	8.7	596	
4.0	30.3	8.6	8.7	596	
5.0	30.3	8.6	8.7	596	

Table 18. Austin Lake water quality parameter data collected in deep basin #3 on July 3, 2018.

Depth ft.	Water Temp °C	DO mg L⁻¹	pH S.U.	Cond. µS cm⁻¹	Secchi ft.
0	30.2	8.3	8.6	600	5.0+
1.0	30.2	8.4	8.6	599	
2.0	30.2	8.4	8.6	599	
3.0	30.2	8.4	8.7	599	
4.0	30.2	8.4	8.7	599	
5.0	30.2	8.4	8.7	599	

Table 19. Austin Lake water quality parameter data collected in deep basin #4 on July 3, 2018.

c.   Post-Aeration Data Tables: September 14, 2018

Depth (m).	Water Temp °C	DO mg L⁻¹	pH S.U.	Cond. µS cm⁻¹	Secchi ft.
0	23.8	8.8	8.9	621	5.0+
0.5	23.4	9.6	9.0	614	
1.0	23.0	10.3	9.1	610	

Table 20. Austin Lake water quality parameter data collected in deep basin #1 on September 14, 2018.

Depth (m).	Water Temp °C	DO mg L⁻¹	pH S.U.	Cond. µS cm⁻¹	Secchi ft.
0	24.0	9.5	9.0	615	4.0+
0.5	23.3	10.0	9.0	617	
1.0	22.8	10.5	9.0	612	

Table 21. Austin Lake water quality parameter data collected in deep basin #2 on September 14, 2018.

Depth (m)	Water Temp ^oC	DO mg L^{-1}	pH S.U.	Cond. $\mu S\ cm^{-1}$	Secchi ft.
0	23.4	9.4	8.9	615	5.0+
0.5	23.2	9.7	8.9	616	
1.0	23.1	10.3	8.9	614	
1.5	22.9	10.4	8.9	615	

Table 22. Austin Lake water quality parameter data collected in deep basin #3 on September 14, 2018.

Depth (m).	Water Temp ^oC	DO mg L^{-1}	pH S.U.	Cond. $\mu S\ cm^{-1}$	Secchi ft.
0	23.3	9.4	8.7	624	5.0+
0.5	23.0	9.8	8.9	623	
1.0	22.8	10.2	8.9	623	
1.5	22.5	10.5	8.9	622	
2.0	22.5	10.7	8.9	621	
2.5	22.3	10.8	8.9	621	

Table 23. Austin Lake water quality parameter data collected in deep basin #4 on September 14, 2018.

4.2   Austin Lake South Basin Baseline Chemical Water Quality Data Tables:

a.   Post-Aeration Data Tables: May 1, 2018

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.016	<0.010	<0.010	<0.50	<10	-0.712

Table 24.   Austin Lake post-aeration chemical water quality parameter data collected from the deep basin site #1 on May 1, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.0	0.021	<0.010	<0.010	<0.50	<10	-1.34

Table 25.   Austin Lake post-aeration chemical water quality parameter data collected from the deep basin #2 site on May 1, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.0	0.013	<0.010	0.016	<0.50	<10	-8.54

Table 26.   Austin Lake post-aeration chemical water quality parameter data collected from the deep basin site #3 on May 1, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.012	<0.010	<0.010	<0.50	<10	0.534

Table 27. Austin Lake post-aeration chemical water quality parameter data collected from the deep basin #4 site on May 1, 2018.

b.   Post-Aeration Data Tables: July 3, 2018

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	<0.010	<0.010	<0.50	22	0.267

Table 28. Austin Lake post-aeration chemical water quality parameter data collected from the deep basin site #1 on July 3, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.010	<0.010	<0.50	<10	2.67

Table 29. Austin Lake post-aeration chemical water quality parameter data collected from the deep basin #2 site on July 3, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.013	<0.010	<0.50	16	-1.34

Table 30. Austin Lake post-aeration chemical water quality parameter data collected from the deep basin site #3 on July 3, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	0.012	<0.010	<0.50	16	1.07

Table 31.   Austin Lake post-aeration chemical water quality parameter data collected from the deep basin #4 site on July 3, 2018.

c.   Post-Aeration Data Tables: September 14, 2018

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	<0.010	<0.010	0.028	0.68	<10	-0.801

Table 32.   Austin Lake post-aeration chemical water quality parameter data collected from the deep basin site #1 on September 14, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.0	<0.010	<0.010	0.012	0.62	<10	-0.534

Table 33.   Austin Lake post-aeration chemical water quality parameter data collected from the deep basin #2 site on September 14, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	<0.010	<0.010	<0.010	0.60	<10	0.801

Table 34. Austin Lake post-aeration chemical water quality parameter data collected from the deep basin site #3 on September 14, 2018.

Depth (ft.)	Total Phosphorus (mg/L)	Ortho-Phosphorus (mg/L)	TIN (mg/L)	TKN (mg/L)	Total Suspended Solids (mg/L)	Chlorophyll-a (µg/L)
2.5	<0.010	<0.010	<0.010	0.64	<10	-0.801

Table 35. Austin Lake post-aeration chemical water quality parameter data collected from the deep basin #4 site on September 14, 2018.

4.3   Austin Lake South Basin Baseline Phytoplankton Community:

Algal Community Composition Data Graph (Figure 5):

The algal genera were determined from composite water samples collected over the deep basins of the South Basin of Austin Lake on May 1, 2018, July 3, 2018, and September 14, 2018 were analyzed with a Zeiss® compound bright field microscope. The genera present included the Chlorophyta (green algae): *Scenedesmus* sp., *Chlorella* sp., *Mougeotia* sp., Rhizoclonium sp., *Staurastrum* sp., *Cladophora* sp.,   and *Radiococcus* sp., The Cyanophyta (blue-green algae): G*leocapsa* sp.; the Bascillariophyta (diatoms): *Navicula* sp., *Rhoicosphenia* sp., *Synedra* sp., *Cymbella* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of alga but less blue-green algae is desirable.
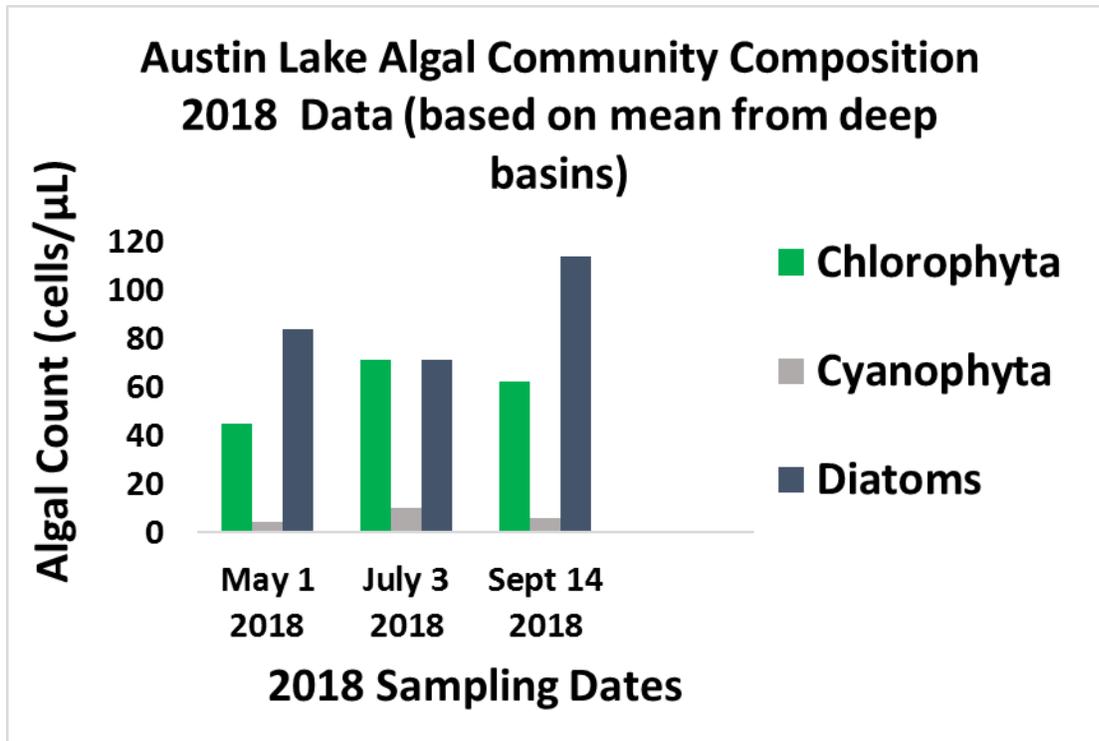
Figure 5. Relative abundance of algal taxa in the South Basin of Austin Lake (May 1, 2018, July 3, 2018, and September 14, 2018).

4.4   Austin Lake South Basin Aquatic Vegetation Biovolume Scan:

An aquatic vegetation biovolume scan of the South Basin of Austin Lake was conducted on September 14, 2018 using a Lowrance HDS 8® sonar unit with GPS.   BioBase software was used to create an aquatic vegetation biovolume map (Figure 6) of the South Basin as a baseline. The biovolume map below shows the relative aquatic vegetation biovolume in the South Basin of Austin Lake. The blue areas represent no vegetation whereas green areas represent low-growing vegetation and red areas represent high-growing vegetation. Table 36 shows the percentage of the various biovolume categories that exist in the South Basin area. The majority of the South Basin is either non-vegetated (blue color) or has low-lying aquatic vegetation (green).
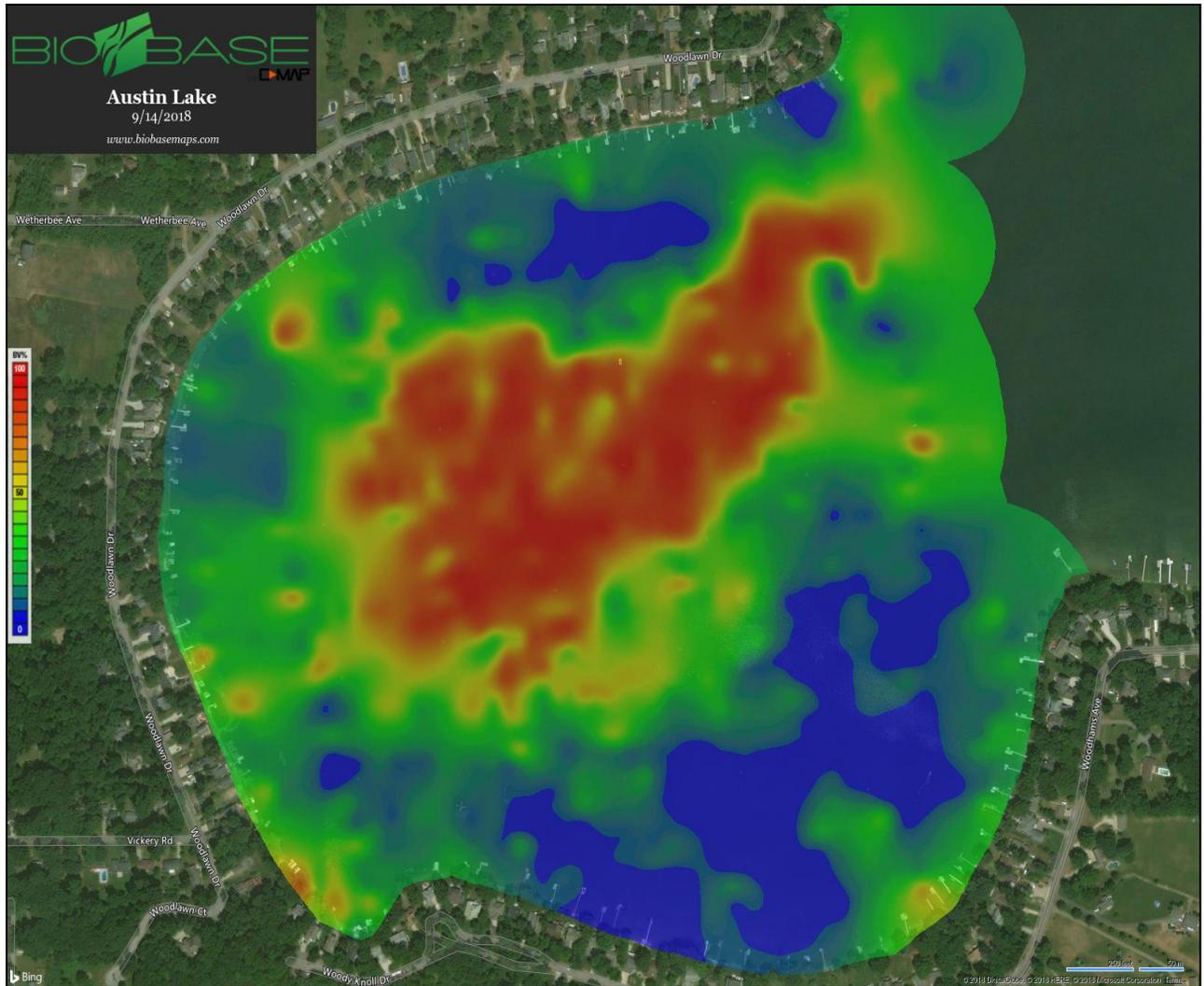
Figure 6. An aquatic vegetation biovolume scan map of the South Basin Austin Lake (September 14, 2018. RLS).

Aquatic Vegetation Biovolume Category (%)	Percent of South Basin Occupied 2018
0-20	53.2
20-40	9.1
40-60	6.6
60-80	7.6
>80	23.5

Table 36. Aquatic vegetation biovolume in the South Basin of Austin Lake (September 14, 2018).

4.5   Austin Lake South Basin Bottom Hardness Scan:

A sediment bottom hardness scan of the South Basin of Austin Lake using a Lowrance HDS 8® sonar unit with GPS software was used to create an aquatic sediment bottom hardness map (Figure 7) of the lake on September 14, 2018 as a post-aeration scan. The areas light beige in color represent soft, mucky bottom whereas areas that are red represent firmer bottom. Colors in the orange family represent intermediate bottom hardness types. This information is important since it allows us to determine if the aeration system has reduced muck throughout the lake bottom in the future. Table 37 shows the area of the South Basin occupied by each sediment hardness category.
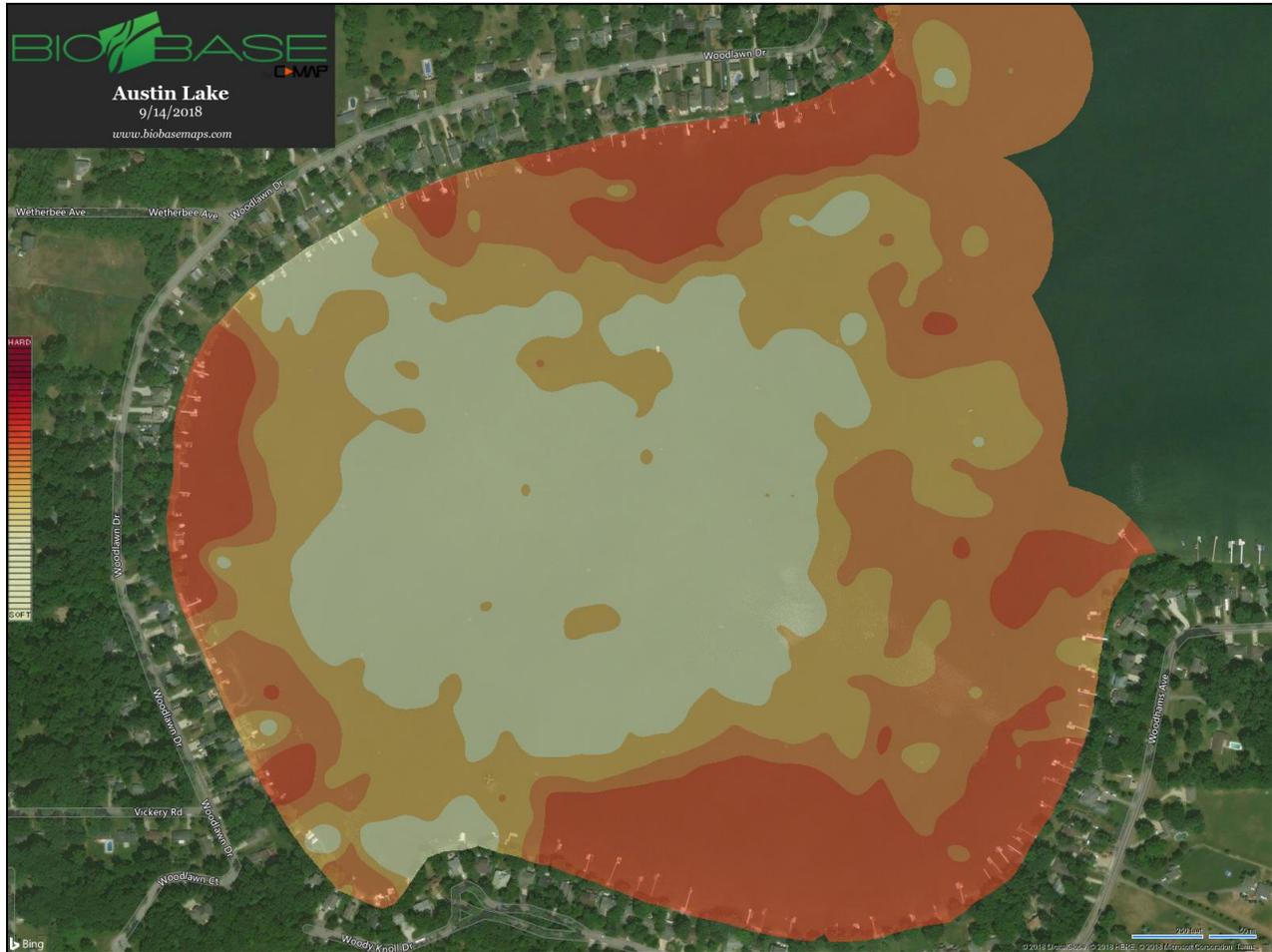
Figure 7. A bottom sediment hardness map of the Austin Lake South Basin (September 14, 2018. RLS).

Sediment Bottom Hardness Category	Percent of South Basin Occupied 2017	Percent of South Basin Occupied 2018
0-0.1 (beige)	2.6	3.8
0.1-0.2 (dk beige)	24.0	20.2
0.2-0.3 (lt orange)	34.4	27.3
0.3-0.4 (dk orange)	21.5	29.1
0.4-0.5 (red)	17.4	19.7

Table 37. Sediment bottom hardness in the South Basin of Austin Lake (September 14, 2018).

4.6   2018 Austin Lake South Basin Depths:

RLS collected post-aeration depth measurements from the surface to the bottom at each of the following locations with the use of a calibrated device. Water level was noted on the USGS staff gauge website for Austin Lake measured at the same time of sampling. On September 14, 2018, the gauge height was 6.27'.

Site	Depth (ft.)	Site	Depth (ft.)
2730	3.7	2731	3.4
2732	3.0	2733	3.5
2734	3.5	2735	2.9
2736	3.8	2737	4.2
2738	5.0	2739	4.4
2740	5.1	2741	5.4
2742	5.2	2743	4.9
2744	4.2	2745	4.3
2746	5.1	2747	5.6
2748	6.0	2749	5.9
2750	5.2	2751	5.4
2752	5.8	2753	5.3
2754	4.9	2755	4.6
2756	3.0	2757	5.3
2758	6.1	2759	6.2
2760	5.4	2761	5.4
2762	6.1	2763	6.0
2764	5.9	2765	5.6
2766	5.5	2767	5.3
2768	6.3	2769	6.1
2770	6.1	2771	6.2
2772	5.6	2773	5.5
2774	5.4	2775	5.3
2776	6.1	2777	3.1
2778	3.2	2779	5.5
2780	5.7	2781	5.6
2782	6.0	2783	6.5
2784	5.9	2785	5.5
2786	4.2	2787	8.6
2788	6.8	2789	5.3
2790	5.6	2791	5.6
2792	7.0	2793	5.0

Table 38. Depth Measurements in the South Basin of Austin Lake (September 14, 2018).

5.0   AUSTIN LAKE SOUTH BASIN 2017-2018 COMPARISONS

5.1   Austin Lake Water Quality Data Comparisons

Descriptive statistics of the 2017 and 2018 data were created for each water quality parameter and are shown in Table 39 below. Based on these numbers, the following could be stated:

1.   Mean water temperature was slightly higher in 2018 (post-aeration) but this could be due to seasonal effects since the 2017 data was collected solely in October (due to late issuance of the permit) which is cooler than the measurements in May, July, and September of 2018.
2.   The mean pH of the lake water was slightly higher in 2018 post-aeration than pre-aeration but the standard deviation makes that difference not significant.
3.   The mean dissolved oxygen (DO) was slightly higher post-aeration than pre-aeration but the standard deviation makes that difference not significant.
4.   The mean conductivity was lower post-aeration and the standard deviation supports that the conductivity was reduced. This may have been due to decreased salts in the water or due to the LFA system.
5.   The mean Secchi transparency was the same both post-aeration and pre-aeration as all values are still reading beyond the depths measured. Thus, the LFA system is not resulting in measurable declines in water clarity.
6.   The mean chlorophyll-a concentration was lower post-aeration than pre-aeration but due to the large standard deviation, this would not likely be significant. Thus, the LFA system does not appear to be affecting chlorophyll-a concentrations.
7.   The mean total phosphorus (TP) was only marginally lower post-aeration.
8.   The mean ortho-phosphorus was the same post-aeration at below detection limits.
9.   The mean total suspended solids (TSS) was slightly higher post-aeration but still within favorable limits and may not be significant due to a large standard deviation. Concentrations under 20 mg/L are ideal.

Parameter	Pre-Aeration (2017) Means ± SD	Post-Aeration (2018) Means ± SD
Water Temp (°C)	16.3±0.1	25.1±5.8
pH (S.U.)	8.9±0.1	8.7±0.1
Dissolved Oxygen (mg/l)	9.2±0.3	9.4±0.9
Conductivity (mS/cm)	703±10	615±20
Secchi Transparency (ft.)	4.8±0.5	4.7±0.5
Chlorophyll-a (µg/l)	0.934±1.0	0.400±0.800
Total Phosphorus (mg/l)	0.013±0.0	0.012±0.0
Ortho-Phosphorus (mg/l)	0.010±0.0	0.010±0.0
Total Suspended Solids (mg/l)	10±0.0	11.5±3.7

Table 39. Descriptive statistics of all water quality parameters before (2017) and after aeration (2018) in Austin Lake.

5.2   Austin Lake Bottom Scan Data Comparisons

The bottom hardness scan was conducted in 2018 as in 2017 and the results are shown in Table 40 below. The sediments with the hardest readings are in the .3-.4 and >.4 categories. These are relative hardness categories based on the sediment algorithm data calculations from the software. Measurable increases in the firmest categories were noted in 2018 with only a minor increase in the softest category. This supports the muck loss data for 2018 which was favorable. This data indicates that the LFA system is effectively reducing soft muck in the bottom of the South Basin.

Sediment Bottom Hardness Category	Percent of South Basin Occupied 2017	Percent of South Basin Occupied 2018
0-0.1 (beige)	2.6	3.8
0.1-0.2 (dk beige)	24.0	20.2
0.2-0.3 (lt orange)	34.4	27.3
0.3-0.4 (dk orange)	21.5	29.1
0.4-0.5 (red)	17.4	19.7

Table 40. Sediment bottom hardness comparisons pre (2017) and post (2018) aeration in the South Basin of Austin Lake.

5.3   Austin Lake Sediment Loss Data Comparisons

Water depth measurements were conducted at each of the previous sampling sites (control and diffuser) in 2018 as in 2017. These differences are shown below in Tables 41 and 42. Overall, there was a significant loss in the muck sediment of the South Basin in 2018. The average loss of muck in the diffuser sites was 0.48 feet (5.8") and the average loss of muck on the control sites was 0.50 feet (6.0").

Austin Lake South Basin Depth Measurements			
Waypoint	2017 Depth	2018 Depth	Difference (feet)
2732	2.7	2.81	0.11
2738	4.2	4.81	0.61
2742	4.3	5.01	0.71
2746	4.5	4.91	0.41
2748	4.7	5.81	1.11
2750	5.1	5.01	-0.09
2757	4.5	5.11	0.61
2759	5.6	6.01	0.41
2761	4.8	5.21	0.41
2768	6	6.11	0.11
2770	4.3	5.91	1.61
2772	5.3	5.41	0.11
2774	4.8	5.21	0.41
2776	5.1	5.91	0.81
2780	5.8	5.51	-0.29
2783	5.4	6.31	0.91
2785	4.9	5.31	0.41
2791	5.1	5.41	0.31

Table 41. Changes in sediment loss in the South Basin from 2017-2018 in the diffuser sampling locations.

Austin Lake South Basin Depth Measurements			
Waypoint	2017	2018	Difference (feet)
2730	3.3	3.51	0.21
2731	2.7	3.21	0.51
2733	2.7	3.31	0.61
2734	2.7	3.31	0.61
2735	2.8	2.71	-0.09
2736	1.8	3.61	1.81
2737	3.1	4.01	0.91
2739	4.3	4.21	-0.09
2740	4.6	4.91	0.31
2741	4.3	5.21	0.91
2743	3.8	4.71	0.91
2744	3.2	4.01	0.81
2745	2.6	4.11	1.51
2747	4.9	5.41	0.51
2749	4.8	5.71	0.91
2751	4.9	5.21	0.31
2752	5.6	5.61	0.01
2753	4.8	5.11	0.31
2754	3.7	4.71	1.01
2755	3.9	4.41	0.51
2756	2.3	2.81	0.51
2758	4.8	5.91	1.11
2760	4.7	5.21	0.51
2762	4.7	5.91	1.21
2763	4.4	5.81	1.41
2764	5.1	5.71	0.61
2765	4.3	5.41	1.11
2766	5.1	5.31	0.21
2767	4.4	5.11	0.71
2769	5.8	5.91	0.11
2771	5.1	6.01	0.91

2773	4.4	5.31	0.91
2775	5	5.11	0.11
2777	2.6	2.91	0.31
2778	4.1	3.01	-1.09
2779	5.2	5.31	0.11
2781	4.9	5.41	0.51
2782	4.6	5.81	1.21
2784	5.2	5.71	0.51
2786	6.1	4.01	-2.09
2787	8.4	8.41	0.01
2788	6.4	6.61	0.21
2789	4.6	5.11	0.51
2790	4.7	5.41	0.71
2792	6.7	6.81	0.11
2793	4.7	4.81	0.11

Table 42. Changes in sediment loss in the South Basin from 2017-2018 in the control sampling locations.

5.4   Austin Lake Aquatic Vegetation Data Comparisons

The whole-lake scanning also resulted in the maps shown above that show the early and late season aquatic vegetation biovolume which is the relative heights of all aquatic plants above the lake bottom. Table 43 below shows the data which results from the software algorithm. It is encouraging that the lowest biovolume category (<20%) had a substantial increase which means the aquatic plants that are low-growing are being favored. Loss of the highest biovolume category corresponds to a loss in emergent lily pads in the South Basin.

.

Biovolume Category	2017 Biovolume	2018 Biovolume
0-5	16.0	38.6
5-20	8.0	4.0
20-40	10.9	2.5
40-60	10.0	2.9
60-80	8.5	8.5
>80	46.5	43.5

Table 43. Aquatic vegetation biovolume data for Austin Lake pre (2017) and post aeration (2018).

6.0   AUSTIN LAKE 2017 & 2018 COMPARISON CONCLUSIONS AND PROFESSIONAL RECOMMENDATIONS

The LFA system is having some positive effects on water quality especially in relation to sediment bottom hardness (increases), aquatic vegetation biovolume (decreases), and conductivity (decreases) and total phosphorus (decreases). This is especially notable in 2018 given the increased flooding and associated runoff on a regional basis.   This indicates that the LFA system, along with bioaugmentation, is reducing sediment muck, nutrients, and high-growing aquatic vegetation within the lake.

 RLS recommends continuation of the LFA system given these benefits and will continue to monitor the system as a part of the existing lake management plan prepared by RLS as well as per the MDEQ permit for the LFA system. The bottom hardness scans should be analyzed each year along with the continued method for measuring muck loss.

APPENDIX A

2018 FIELD DATA SHEETS AND LABORATORY REPORTS