Eagle Lake Laminar Flow Aeration Accumulative Evaluation Report

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Prepared by: Dr. Jennifer Jermalowicz-Jones, CLP

Restorative Lake Sciences

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1.0 INTRODUCTION:

Eagle Lake is located in Section 8,9,16 and 17 of Texas Township (T.3S, R.12W) in Kalamazoo County, Michigan. The lake has a surface area of approximately 230 acres (Michigan Department of Natural Resources, 2004) and is classified as a eutrophic (nutrient-enriched) aquatic ecosystem with three distinct deep basins. The entire lake serves as a littoral (shallow) zone.

Eagle Lake contains a volume of approximately 1,120 acre-feet of water and has a mean depth of 4.9 feet and a maximum depth of 12 feet. The maximum depth was confirmed by RLS scientists in 2014 with the use of a bottom-scanning GPS system that created a modernized depth contour bathymetric map (Figure 1). Eagle Lake receives water from a groundwater well that pumps at a rate of 1,000-1,200 gallons per minute (USGS, 1970) and the lake does not contain an inlet or outlet but contains some springs.

Eagle Lake has a lake perimeter of approximately 4.5 miles (Michigan Department of Natural Resources, 1999). The longest point across the lake (fetch) is 0.7 feet and thus the lake may produce sizeable waves during high winds.

Previous limnological surveys of the lake indicate that the lake is mesotrophic, with moderate Secchi disk transparency and nutrients such as phosphorus and a balanced community of aquatic plant and algae growth. The excessive organic muck in the areas of the lake extending beyond the sandy shoreline is impairing recreational abilities and thus a muck reduction technology such as the use of laminar flow aeration (LFA) with bioaugmentation was pursued and was installed in the lake during the summer of 2017 to improve previously studied impairments of the lake which are discussed below. Bacterial augmentation (MuckAway®) began in 2017 and has continued through 2023 and is proposed to continue.

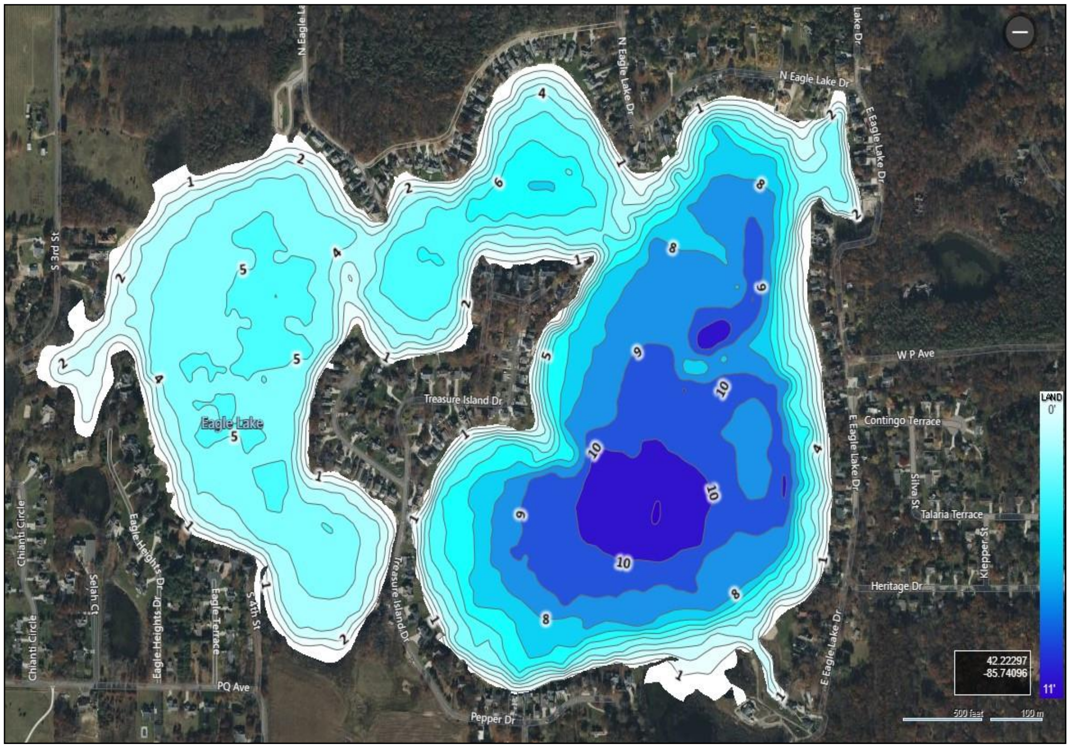

Figure 1. Eagle Lake bathymetric scan map (RLS, 2023).

1.1 Summary of operations

a. LFA Operations: Actual installation of the LFA system occurred in early June of 2017 due to electrical installation delays and took approximately two weeks to complete. The LFA system was officially turned on June 21, 2017. NOTE: Since the May 10, 2017 data was collected prior to LFA operation, it should also be considered baseline and will be presented as such below.

The LFA system began operating on the following dates below each year and ended operations on the following dates below for each year as required by the permit:

- 2023 operated from 4/21/23 to 10/15/23
- 2022 operated from 7/20/22 to 10/15/22 (permit delay)
- 2021 operated from 5/21/21 to 10/15/21
- 2020 not operated
- 2019 operated from 4/21/19 to 10/15/19
- 2018 operated from 4/21/18 to 10/15/18
- 2017 operated from 6/21/17 to 10/15/17

According to PLM, bioaugmentation treatments were conducted on the following dates under a Rule 97 permit from EGLE which was issued in 2017:

8/8/2023

8/4/2022

8/6/2021

6/30/2021

8/6/2020

6/30/2020

8/19/2019

7/19/2019

6/18/2019

8/24/2018

8/3/2018

7/13/2018

8/28/2017

8/3/2017

7/11/2017

b. **Goals and Objectives:** Eagle Lake is a well-recreated lake and is utilized by many for fishing, swimming, boating, and waterfront living. The lake has become dominated by aggressive watermilfoil and pondweed growth and has a very mucky bottom throughout most of the lake. The local residents have desired a more holistic approach to addressing both the aquatic plant issues as well as the muck reduction with the ability to use aquatic herbicides for aquatic plant control as needed. The residents desired a lake restoration strategy that would make the lake healthier and accomplish the following objectives:

The primary objectives of the implemented LFA system for Eagle Lake include:

1) Reduction of nuisance rooted submersed aquatic vegetation such as milfoil and pondweed
2) Reduction of muck in problem areas
3) Added in 2017: Reduction of phosphorus in the lake that contribute to aquatic vegetation and algae growth.

Since the water quality of Eagle Lake was deemed favorable, the primary objectives of the LFA system for Eagle Lake were to reduce sediment “muck” and reduce “excessive aquatic vegetation” as well as reduce phosphorus. The first bottom hardness scan and biovolume scan was conducted in 2014 to be used as a baseline for muck conditions in Eagle Lake. Additional scans were completed in 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2023. Other goals were originally discussed but were not the focus of the implementation of the technology according to the lake association. Table 1 below summarizes the key goals, methods of evaluation, and the baseline values along with annual and ideal goals.

Table 1. Eagle Lake primary goals and method of evaluation (2014-2023).

Goal	Method of Evaluation	Baseline	Annual Goal	Ideal Goal
Reduce muck on bottom of Eagle Lake	BioBase bottom hardness scan using Lowrance HDS® system with specialized transducer	Consolidated bottom categories values 0.9% (2014)	Increase consolidated bottom categories by 5%	Increase consolidated bottom categories by 10% (not met at 0.0% in 2023)
Reduce excessive aquatic vegetation biovolume	BioBase biovolume scan using Lowrance HDS® system with specialized transducer	SAV dense biovolume value of 44.2% (2014)	Reduce dense biovolume by 2%	Reduce dense biovolume by 2-5% (met at 0.0% in 2023)
Reduce phosphorus throughout the water column	Measure TP and SRP in water column with NELAP-lab (SM 4500-P E)	Mean TP = 0.050 mg/L (2014)	Reduce TP 0.010 mg/L	Reduce TP to below 0.025 mg/L (met at 0.021 mg/L in 2023).

c. **Summary of Lake Management Activities:** RLS is the lake manager for Eagle Lake and developed Table 2 below to show the treatment history for the lake. Selective aquatic herbicide treatments have been ongoing for invasive aquatic plants and nuisance pondweed growth.

Table 2. Comprehensive aquatic plant management history in Eagle Lake (2010-2023).

Date	Activity Done	Acreage	Total Acreage
6-19-2010	Harvesting	57	
8-2-2010	Harvesting	1	
5-18-2011	Algae Treatment	1.25	
5-18-2011	Renovate G Treatment	1.75	
5-18-2011	Renovate OTF Treatment	3.75	
5-18-2011	Diquat Treatment	1.25	8
6-10-2011	Harvesting	73	
6-14-2011	Reward Invasive Treatment	4.5	
6-14-2011	Reward Native Treatment	14	
6-14-2011	Algae Treatment	1	19.5
7-28-2011	Clipper Treatment of Lake	3.75	
8-15-2011	Diquat Treatment	2	
9-14-2011	Habitat Treatment	1	
5-8-2012	Clipper Treatment	2.5	
5-8-2012	Sculpin Treatment	13	
5-8-2012	Renovate OTF Treatment	16.7	32.2
6-5-2012	Clipper Treatment 200 ppb	1	
6-5-2012	Clipper Treatment 120 ppb	1	2
6-14-2012	Harvesting	66.5	
4-23-2013	Sonar AS Treatment	5.27	
5-9-2013	Sonar AS Treatment	2.16	
6-8-2013	Algae Treatment	10	
6-25-2013	Harvesting	32.5	
7-15-2013	Clipper Treatment	0.5	
7-15-2013	Algae Treatment	5.5	6
8-21-2013	Algae Treatment	10.5	
6-10-2014	Aquathol K Treatment	30	
6-12-2014	Diquat Treatment	0.55	
6-12-2014	Aquathol K/Hydrothol Treatment	1	
6-12-2014	Clipper Treatment 200 ppb	2.3	3.85
6-15-2014	Harvesting	25	
6-18-2014	Harvesting	75	
7-23-2015	Aquathol K Treatment	0.9	
7-23-2015	Renovate OTF Treatment	0.8	1.7
5-26-2016	Aquathol K Treatment	49.25	
5-26-2016	Renovate OTF Treatment	5.62	
5-26-2016	Clipper Treatment 200 ppb	2.2	57.07

6-21-2016	Clipper Treatment	2.2	
9-28-2016	Renovate OTF Treatment	0.6	
10-6-2016	Renovate OTF Treatment	2.6	
5-22-2017	Aquathol K Treatment	1	
5-22-2017	Renovate OTF Treatment	10	11
6-8-2017	Diquat Treatment	2	
6-14-2017	Aquathol K Treatment	60	
6-14-2017	Diquat Treatment	6	
6-14-2017	Komeen Crystal Treatment	1	67
8-3-2017	Renovate OTF Treatment	1.4	
8-3-2017	Clipper Treatment 200 ppb	0.1	1.5
6-14-2018	Aquathol K Treatment	74	
6-14-2018	Renovate OTF Treatment	1	
6-14-2018	Clipper Treatment 400 ppb	1	76
6-21-2018	Algae Treatment	37.84	
8-8-2018	Aquathol K Treatment	1.16	
8-8-2018	Diquat Treatment	1.25	2.41
6-3-2019	Aquathol K Treatment	32.5	
6-3-2019	Renovate OTF Treatment	5	37.5
6-27-2019	Renovate OTF Treatment	5.2	
6-9-2020	Diquat Treatment	12.25	
6-18-2020	Renovate OTF Treatment	1.2	
8-26-2020	Renovate OTF Treatment	10.75	
8-26-2020	Diquat Treatment	16	26.75
5-27-2021	Diquat Treatment	12	
5-27-2021	Aquathol K/Hydrothol Treatment	32.5	44.5
6-7-2022	Diquat Treatment	20	
6-7-2022	Aquathol K/ Hydrothol Treatment	25	45
9-7-2022	Renovate OTF Treatment	1	
9-7-2022	Diquat & ProcellaCOR Treatment	7.5	8.5
9-13-2022	Flumioxazin Treatment	5.45	
6-15-2023	Diquat Treatment	110	

2.0 SAMPLING METHODS

2.1 Summary of equipment used, replicates, and diffuser locations

Numerous water quality parameters were added for requirements in the 2017 guidance and thus only trends with similar parameters and methods could be created. In the future, these discrepancies should be resolved for optimum comparisons of data over time. Table 3 below displays all of the sampling dates and water quality parameters measured along with the number of sampling locations. If LFA were to continue in Eagle Lake, RLS recommends consistent measurements at the N=5 sampling locations given the large size of the lake as in recent years (Figure 2). Additionally, the required sediment organic matter and particle size sample locations are shown in Figure 3.

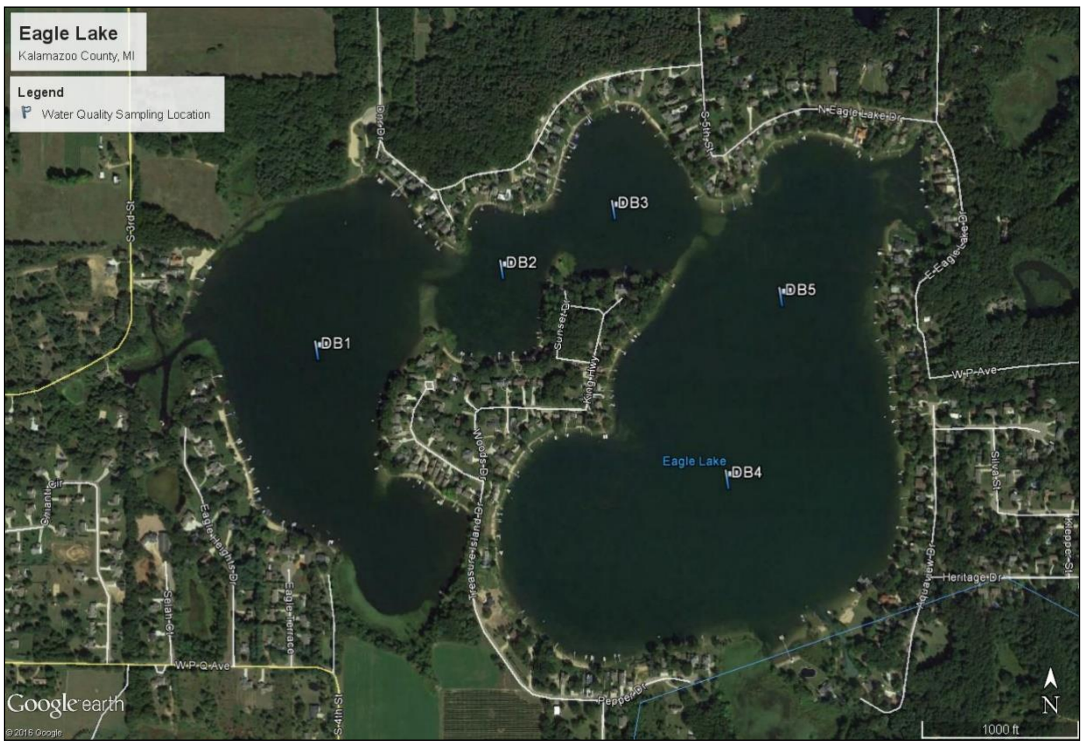

Figure 2. Aerial photo of Eagle Lake with the deep basin water quality sampling locations as required in the 2017 EGLE LFA Guidance (2017-2023).

Figure 3. Eagle Lake sediment organic matter and particle size sampling location map (2021 and 2023).

a-b. Sampling Equipment, Locations, and Sampling dates:

Table 3. Summary table of Eagle Lake LFA evaluation water quality sampling dates, locations, and parameters measured (2013-2022).

Date	# Sampling Locations	LFA Parameters Measured
7-8-2014	3	At top and bottom depths (temp, DO, pH, Cond, total alkalinity, TP, TKN) and profile Secchi. N=11 sediment organic matter % samples.
7-17-2015	3	At top and bottom depths (temp, DO, pH, Cond, total alkalinity, TP, TKN) and profile Secchi.
5-13-2016	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
6-21-2016	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
9-15-2016	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
5-10-2017	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
7-25-2017	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.

9-11-2017	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
5-2-2018	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
7-7-2018	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
9-4-2018	5	At top, mid, bottom depths (temp, DO, pH, Cond, Secchi, TP, SRP, TSS) and Chl-a and profile Secchi.
10-4-2019	6	At top and bottom depths (temp, DO, pH, Cond, total alkalinity, TP, TKN) and profile Secchi.
7-28-2020	6	At top and bottom depths (temp, DO, pH, Cond, total alkalinity, TP, TKN) and profile Secchi.
5-28-2021	5	At 0.5-meter increment depths (temp, DO, pH, Cond), and at mid-depth in sites #1-5 (TP, SRP, TSS, TKN, TIN) and composite Chl-a and profile Secchi.
7-21-2021	5	At 0.5-meter increment depths (temp, DO, pH, Cond), and at top, middle, and bottom depths in sites #4-5 and at mid-depth at sites #1-3 (TP, SRP, TSS, TKN, TIN) and composite Chl-a and profile Secchi.
10-29-2021	5	At 0.5-meter increment depths (temp, DO, pH, Cond), and at top, middle, and bottom depths in sites #4-5 and at mid-depth at sites #1-3 (TP, SRP, TSS, TKN, TIN) and composite Chl-a and profile Secchi. N=12 sediment organic matter and particle size.
7-26-2022	6	At top and bottom depths (temp, DO, pH, Cond, total alkalinity, TP, TKN) and profile Secchi.
5-8-2023	5	At 0.5-meter increment depths (temp, DO, pH, Cond), and at top, middle, and bottom depths in sites #4-5 and at mid-depth at sites #1-3 (TP, SRP, TSS, TKN, TIN) and composite Chl-a and profile Secchi.
7-6-2023	5	At 0.5-meter increment depths (temp, DO, pH, Cond), and at top, middle, and bottom depths in sites #4-5 and at mid-depth at sites #1-3 (TP, SRP, TSS, TKN, TIN) and composite Chl-a and profile Secchi.
9-5-2023	5	At 0.5-meter increment depths (temp, DO, pH, Cond), and at top, middle, and bottom depths in sites #4-5 and at mid-depth at sites #1-3 (TP, SRP, TSS, TKN, TIN) and composite Chl-a and profile Secchi.

c. **Sampling methods:** Beginning in 2017 when the EGLE LFA Guidance was issued, all chemical water samples were collected at the specified depths (one each at the top, middle, and bottom depths of the deep basin sampling site) 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 top, middle, and bottom depths of the deep basin sampling site. 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.

Total inorganic nitrogen (TIN) was titrated and analyzed in the laboratory according to methods EPA 300.0 (Rev 2.1) and EPA 350.1 (Rev 2.0). Total Kjeldahl nitrogen (TKN) was titrated and analyzed in the laboratory according to method EPA 351.2 (Rev 2.0). All of the aforementioned chemical parameters were analyzed at Trace Analytical Laboratories in Muskegon, Michigan. All physical data was entered onto field sheets that were previously submitted with the required LFA reports. All laboratory reports were also submitted with the required LFA reports. Future reports will include new field sheets and laboratory reports in the Appendices.

Chlorophyll-*a* was analyzed using method SM 10200H by Trace Analytical Laboratories in Muskegon, Michigan. Chlorophyll-*a* samples were placed in glass brown, amber 1-liter bottles and taken to the laboratory for analysis immediately after sampling which as requested by the lab did not require preservation. On field days where an immediate laboratory delivery is not possible, then the preservative magnesium carbonate was used in accordance with the 2017 EGLE Guidance document. All water samples were maintained on ice in a large cooler prior to being taken directly to the laboratory. Samples used for microscopic analysis of algal community composition were analyzed within 24 hours after collection and counted with a Sedgewick Rafter® Counting Cell under high power objective on a bright-field Zeiss® compound microscope. Multiple 1 milliliter (mL) aliquots were used to determine the relative abundance of algal genera in the samples. Zooplankton samples were rinsed into the collection bottle from the collection tow net, where an Alka Seltzer® tablet was then placed along with 70% ethyl alcohol solution. The sample was then quantified for zooplankton community composition using a Ward counting wheel under a Zeiss® dissection microscope.

3.0 SAMPLING RESULTS

The following sections display the means and standard deviations for all physical and chemical water quality parameters. In addition, summary tables for other parameters such as biovolume, sediment hardness, zooplankton, and algal community composition are included. RLS will update these tables and graphs annually to include all newly collected data in future years.

3.1 Summary of field data

This section displays the descriptive statistics of physical and chemical water quality data parameters collected in Eagle Lake from 2014-2023 (Tables 4 and 5).

a. Physical water quality data parameter means with standard deviations:

Table 4. Summary of physical water quality data parameter means and standard deviations from Eagle Lake water quality samples (2014-2023).

Year	Mean Water Temp (°F)	Mean DO (mg/L)	Mean pH (S.U.)	Mean conductivity (mS/cm)	Mean Secchi Depth (feet)
2014	72.7±2.5	9.0±0.6	8.4±0.1	319±5.2	7.9±1.4
2015	76.8±0.3	7.1±1.0	8.2±0.1	173±18	11.5±0.7
2016	69.1±3.9	8.5±1.3	8.2±0.2	153±23	8.3±2.1
2017	73.4±4.0	9.2±1.1	8.7±0.4	167±24	7.7±1.9
2018	73.4±5.3	8.7±2.0	8.4±0.4	176±27	9.0±1.9
2019	69.3±1.4	7.9±0.8	8.1±0.1	213±6.3	9.0±1.4
2020	80.6±2.1	6.8±1.5	8.2±0.2	213±19	7.8±1.8
2021	73.4±2.5	9.1±1.2	8.6±0.3	189±13	7.5±1.8
2022	79.9±0.8	7.3±1.0	8.3±0.1	238±6.8	8.1±2.0
2023	72.1±5.7	9.2±2.6	8.4±0.4	286±130	7.4±1.4

b. Chemical water quality data parameter means with standard deviations:

Table 5. Summary of chemical water quality data parameter means and standard deviations from Eagle Lake water quality samples (2014-2023).

Year	TP (mg/L)	SRP (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	Chl-a (µg/L)
2014	<0.050±0.0	--	--	0.6±0.1	--	--
2015	0.028±0.0	--	--	0.5±0.0	--	--
2016	0.014±0.0	0.011±0.0	14±28	--	--	0.460±0.9
2017	0.014±0.0	0.010±0.0	18.3±45.6	--	--	0.107±0.2
2018	0.017±0.0	0.010±0.0	15.0±33	--	--	0.225±0.4
2019	0.013±0.0	--	--	0.7±0.1	--	--
2020	0.023±0.0	--	--	0.9±0.0	--	--
2021	0.019±0.0	0.025±0.0	11.6±3.6	0.9±0.1	0.018±0.0	2.3±2.2
2022	0.026±0.0	--	--	0.9±0.2	--	--
2023	0.021±0.0	0.010±0.0	13.0±12.8	1.2±1.8	0.027±0.3	0.071±0.2

c. **Summary graphs of depth versus physical water quality parameters (Figures 4a-d)**: (water temperature, dissolved oxygen, pH, conductivity). Since Eagle Lake is a shallow water system with depths not greater than 12.0 feet, it does not strongly stratify. To demonstrate this, RLS has graphed the 2023 data of depth versus the parameters listed above. RLS will continue to include and append future depth versus physical water quality parameter data in future years.

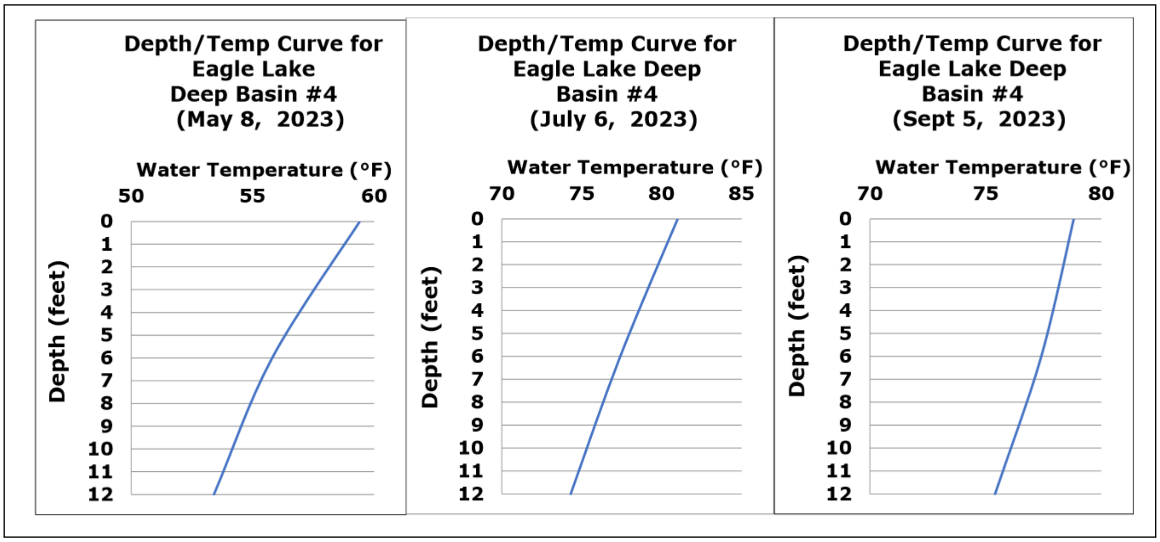

Figure 4a. Graphs of depth versus water temperature in the deepest basin of Eagle Lake (2023).

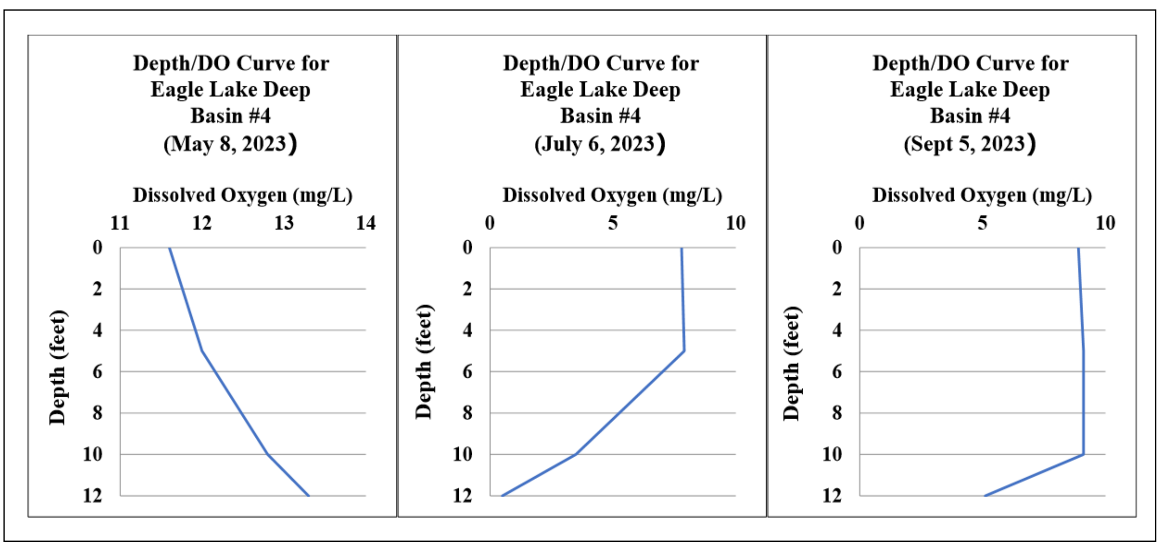

Figure 4b. Graphs of depth versus dissolved oxygen in the deepest basin of Eagle Lake (2023).

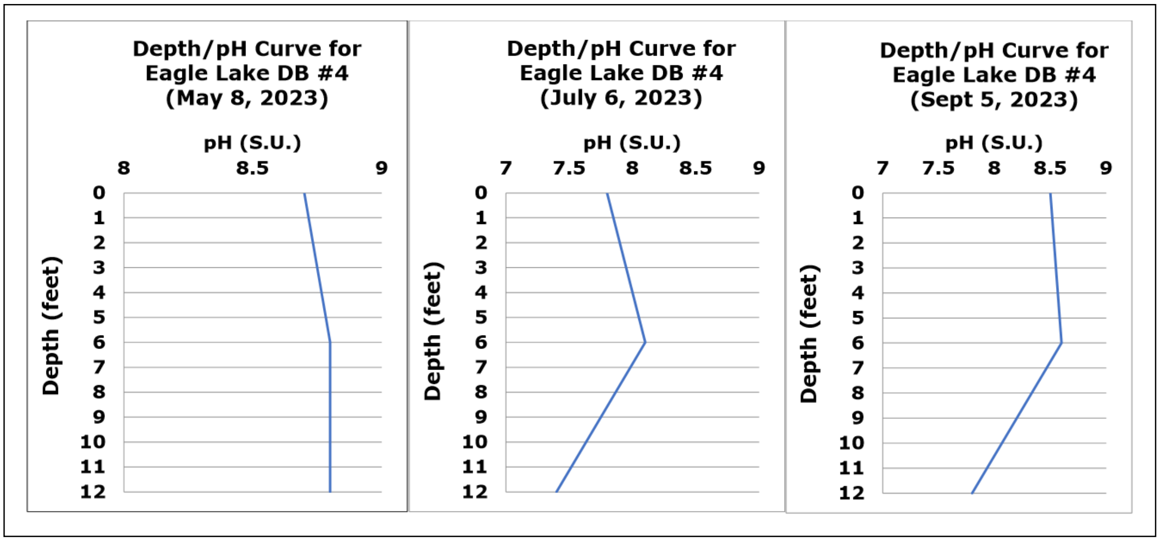

Figure 4c. Graphs of depth versus pH in the deepest basin of Eagle Lake (2023).

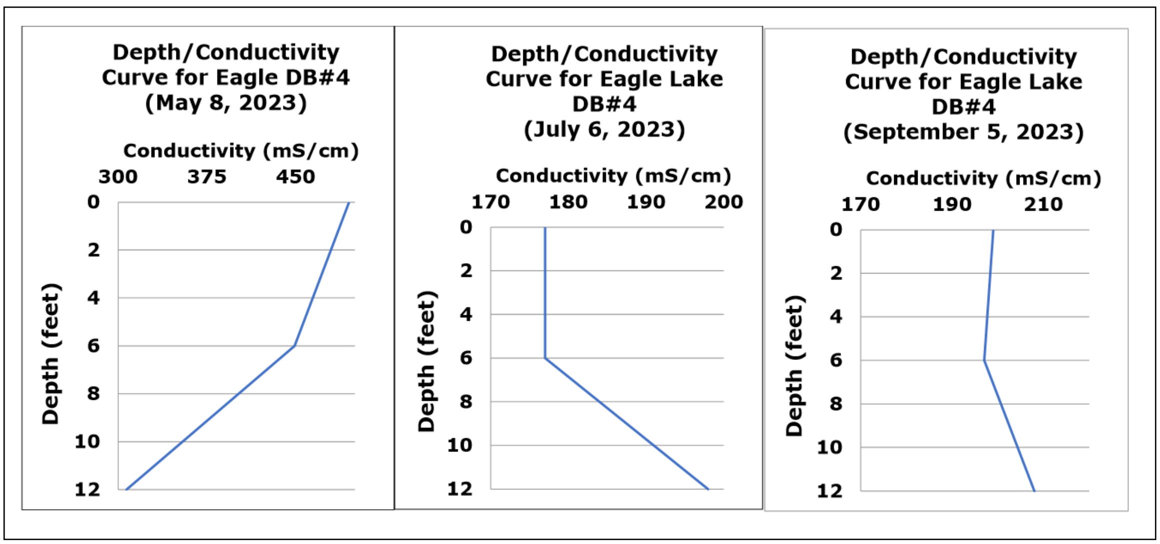

Figure 4d. Graphs of depth versus conductivity in the deepest basin of Eagle Lake (2023).

d. Summary of Phytoplankton, Zooplankton, and Macrophytes

The measurement of zooplankton was not required until the new guidance was issued in 2017 and thus no prior data on that parameter exists. Figure 5 below summarizes the changes in algal taxa relative abundance with time. Figure 6 displays the change in zooplankton taxa over time. RLS has measured aquatic vegetation biovolume through the development of aquatic vegetation biovolume maps (Figure 7). The algorithm developed by BioBase® allows for estimation of biovolume and thus the maps can be quantified with time (Table 6).

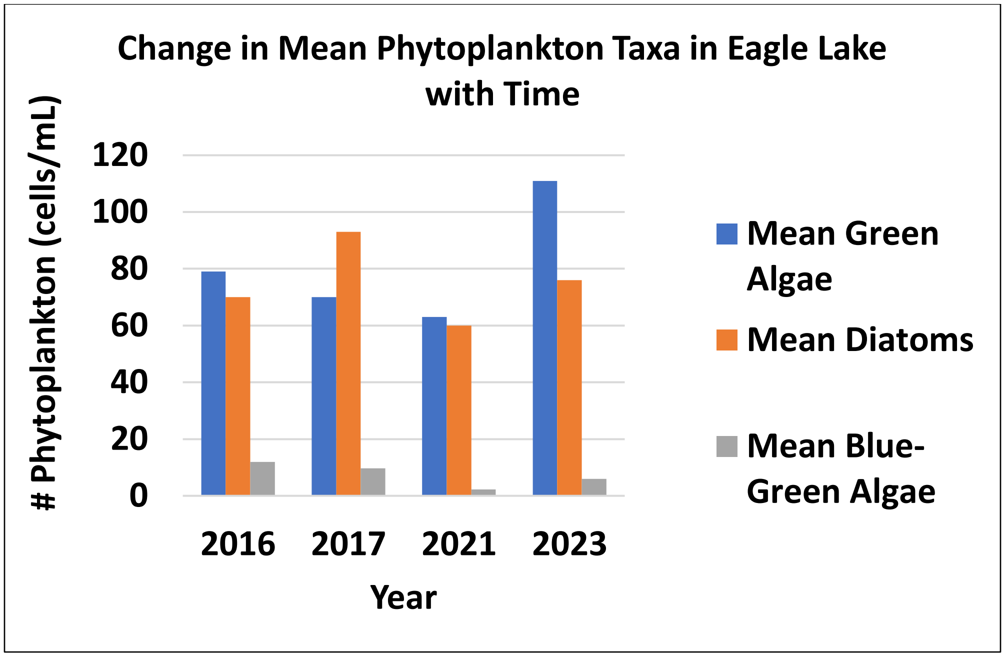

Figure 5. Summary of Eagle Lake trends in algal taxa with time (2016-2023).

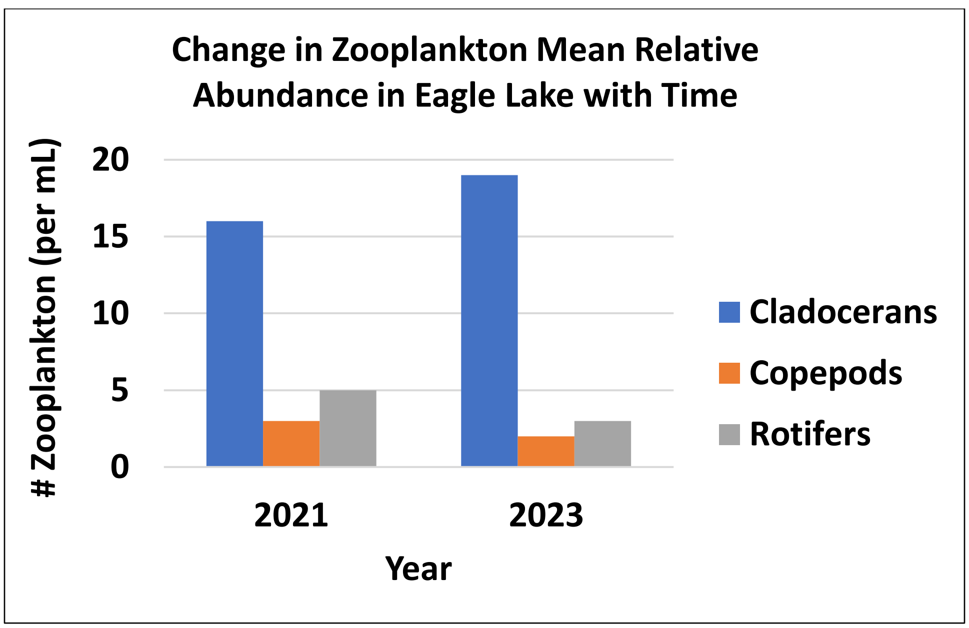

Figure 6. Summary of Eagle Lake trends in zooplankton taxa with time (2021 and 2023).

Table 6. Changes in annual aquatic vegetation biovolume in Eagle Lake, Kalamazoo County, MI (2014-2023).

Biovolume Category	2014	2015	2016	2017	2018	2019	2020	2021	2023
0-20%	23.7	40.5	20.9	18.2	37.9	58.5	20.2	22.1	13.7
20-40%	11.0	9.2	5.8	15.1	24.8	25.0	47.0	25.3	53.1
40-60%	9.3	6.7	6.3	13.8	11.3	13.8	19.7	37.1	32.7
60-80%	11.9	5.9	8.1	11.4	6.7	2.2	7.6	9.1	0.4
>80%	44.2	37.7	58.9	41.6	19.5	0.6	5.5	6.4	0.0

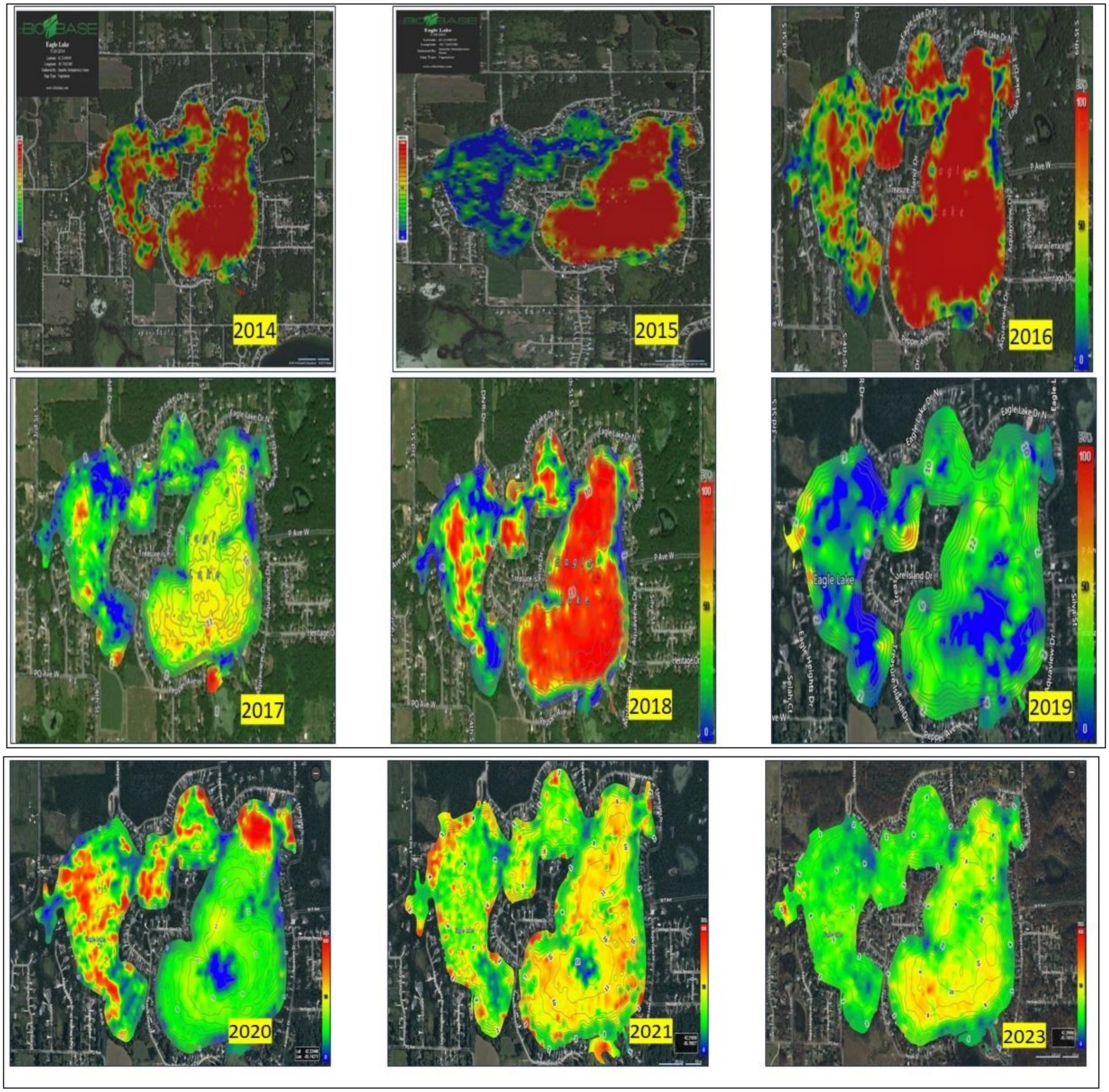

Figure 7. Eagle Lake aquatic vegetation biovolume scan maps (2016-2023).

e. Summary of sediment organic matter and particle size data

The following data displays the sediment relative hardness scans along with sediment organic matter samples and particle size data. The sediment hardness scans do not distinguish between soft and hard bottom but rather determine the relative consolidation of sediments in areas over time. All years demonstrate a low quantity of the least consolidated category (<0.1%) which is favorable. It is difficult to assess the impacts the LFA and bioaugmentation program have had on reductions of unconsolidated bottom, given that the system was inoperable for many years due to an unprecedented flood which made the compressors inoperable. However, it is interesting that the most consolidated sediment categories (0.3-0.4 and >0.4) increased for a few years after operation began with a decrease during the inoperable years. It may possibly indicate that the continual decay of dense pondweeds and aquatic vegetation relies on the system for degradation of organic materials.

Table 7 demonstrates that the majority of sediments in Eagle Lake are sand and not gravel or fines. This would make the allowable faction for breakdown lower over time as bioaugmentation and LFA have been shown to reduce only organic and fine sediments. Tables 8-9 display the sediment organic matter percentage and particle size data for 2021 and 2023, respectively. Figure 8 compares the mean organic matter percentages in 2021 and 2023 which are really both post-LFA years but were compromised due to inoperation of the LFA from flooding. Figure 9 displays the annual sediment hardness scan maps over time.

Table 7. Eagle Lake sediment bottom hardness comparisons (2014-2023).

Hardness Category	2014	2015	2016	2017	2018	2019	2020	2021	2023
<0.1	0.43	0.04	0.01	0.0	0	0.02	0	2.2	0.03
0.1-0.2	10.4	0.21	0.1	0.2	0.1	2.0	0.07	42.9	9.9
0.2-0.3	72.0	25.2	7.8	70.4	47.3	67.7	55.9	51.2	86.5
0.3-0.4	16.3	50.5	71.2	28.2	48.3	29.8	42.3	3.8	3.6
>0.4	0.9	24.1	20.9	1.3	4.4	0.6	1.7	0.0	0.0

Table 8. Sediment particle size and composition data (October 29, 2021).

Sample Site	% OM	% Gravel	% Sand	% Fines
1	57.0	0	98.9	1.1
2	54.0	0	95.2	4.8
3	50.0	0	86.7	13.3
4	48.0	0	98.0	2.0
5	52.0	0	97.2	2.8
6	60.0	0	94.8	5.2
7	65.0	0	98.1	1.9
8	61.0	0	95.6	4.4
9	76.0	0	98.1	1.9
10	79.0	0	96.5	3.5
11	65.0	0	98.7	1.3
12	62.0	0	96.3	3.7

Table 9. Sediment particle size and composition data (September 27, 2023).

Sample Site	% OM	% Gravel	% Sand	% Fines
1	40	0	59.5	40.5
2	45	0	81.8	18.2
3	46	0	78.7	21.3
4	44	0	77.3	22.7
5	42	0	73.1	26.9
6	47	0	84.3	15.7
7	51	0	76.6	23.4
8	54	0	81.1	18.9
9	59	0	79.5	20.5
10	70	0	73.9	26.1

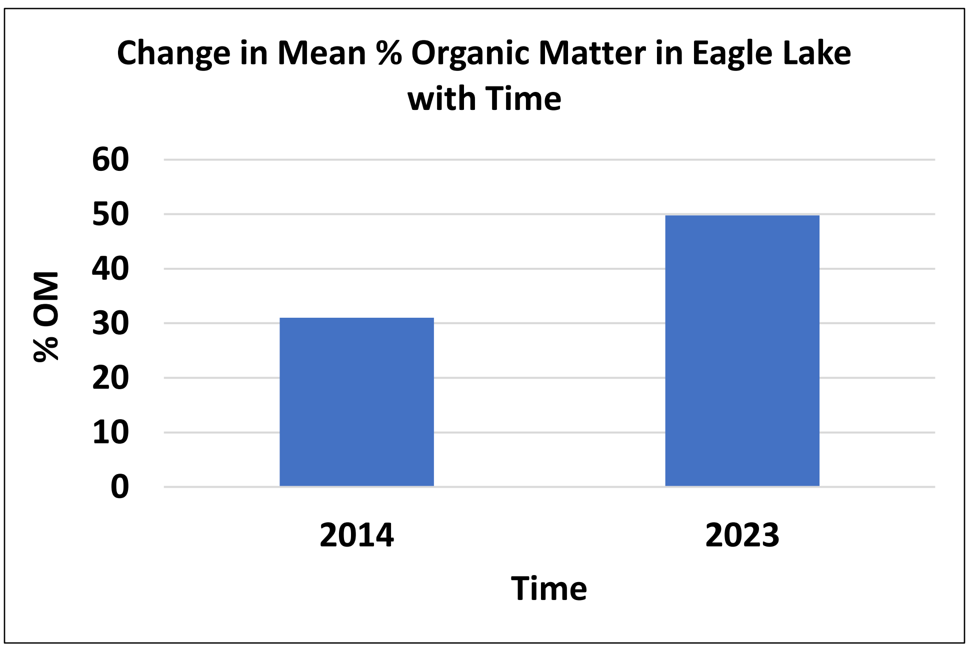

Figure 8. Change in mean percentage of organic matter (OM) in Eagle Lake with time (2014 and 2023).

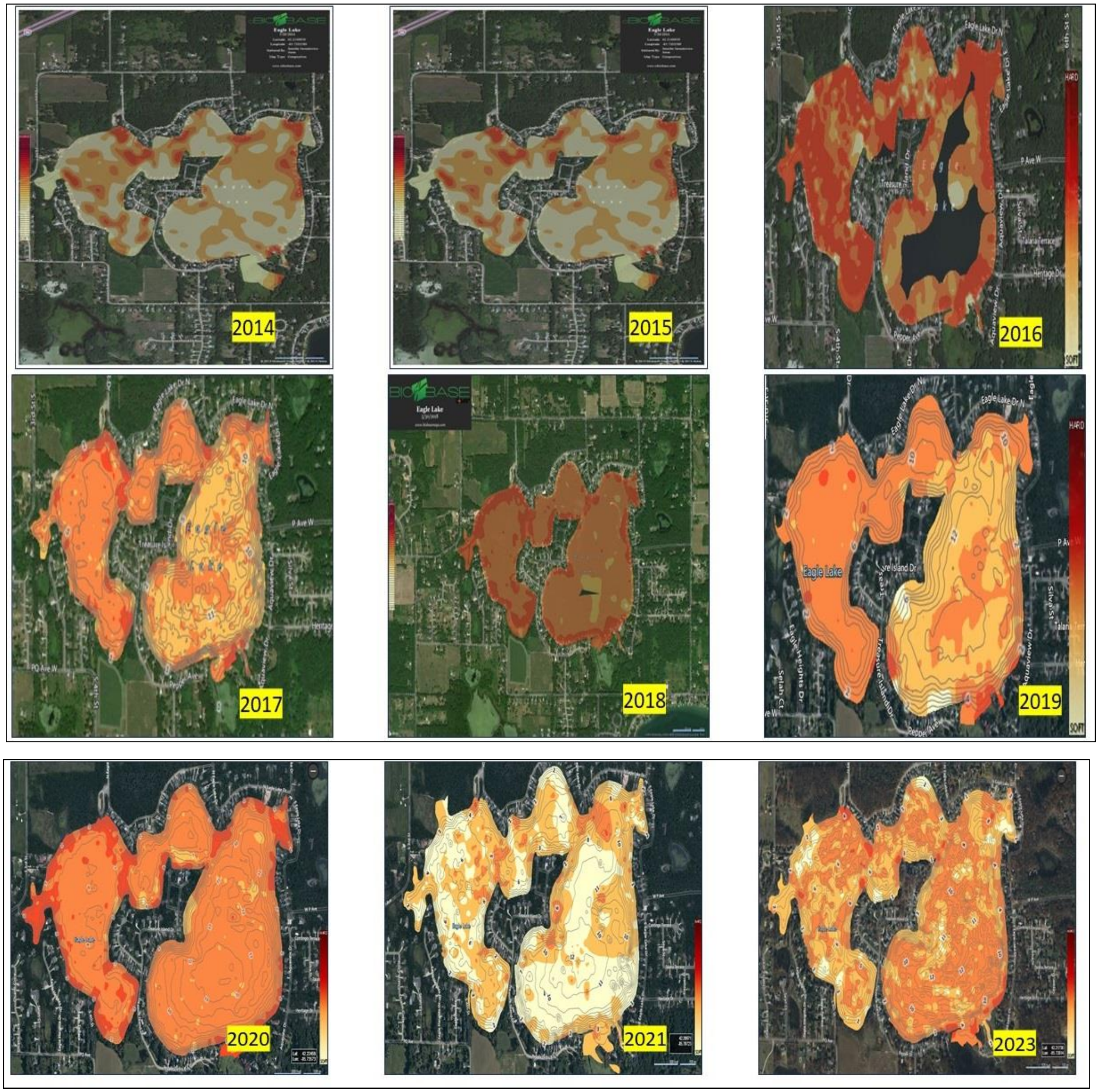

Figure 9. Eagle Lake sediment bottom hardness scan maps (2014-2023).

4.0 Conclusions:

a. **Summary of Trends for Water Quality Parameters:** In order to evaluate the trends or changes in water quality parameters over time, RLS has graphed the collected data to date and will amend these graphs in the future if the project continues to allow for comprehensive trends of each parameter over time.

There may be some data gaps as the scope of work as required by EGLE guidance changed significantly since the issuance of the May 2017 Guidance document. Figures 10-20 below demonstrate the changes in specific water quality parameters in Eagle Lake with time.

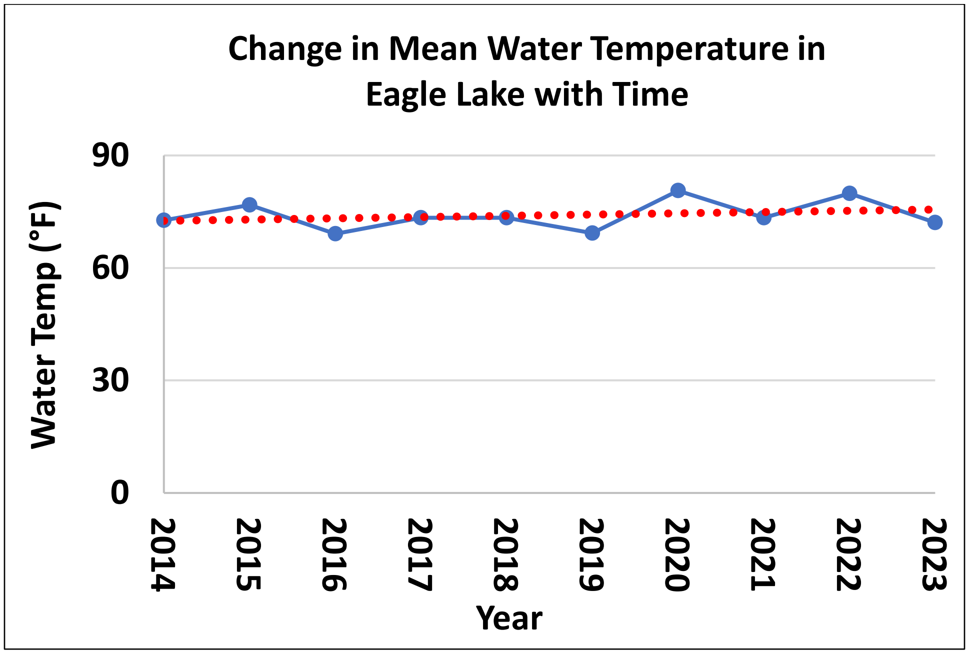

Figure 10. Trend in mean water temperature with time in Eagle Lake.

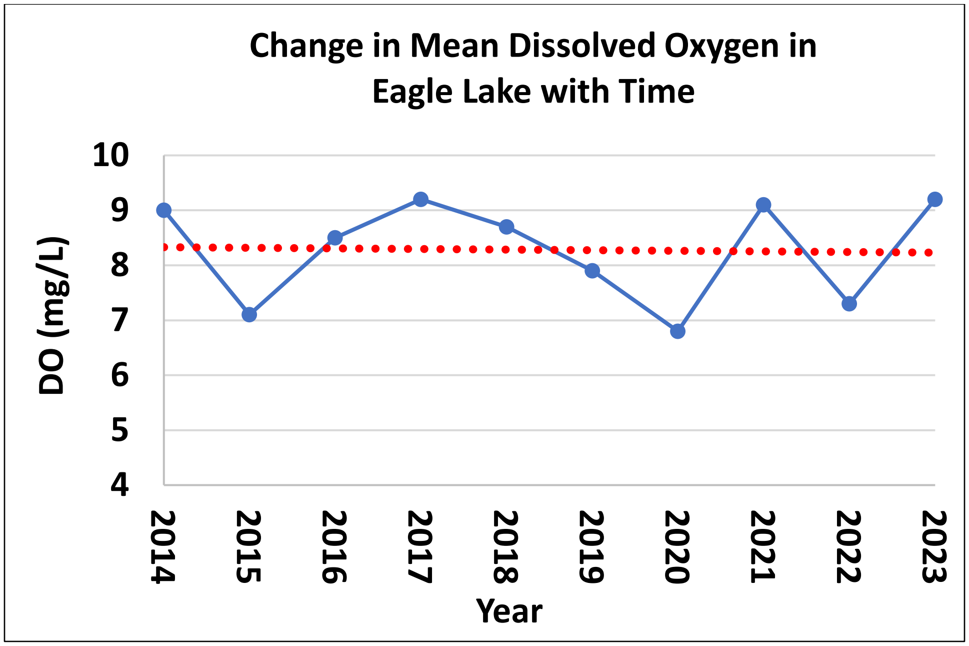

Figure 11. Trend in mean dissolved oxygen with time in Eagle Lake.

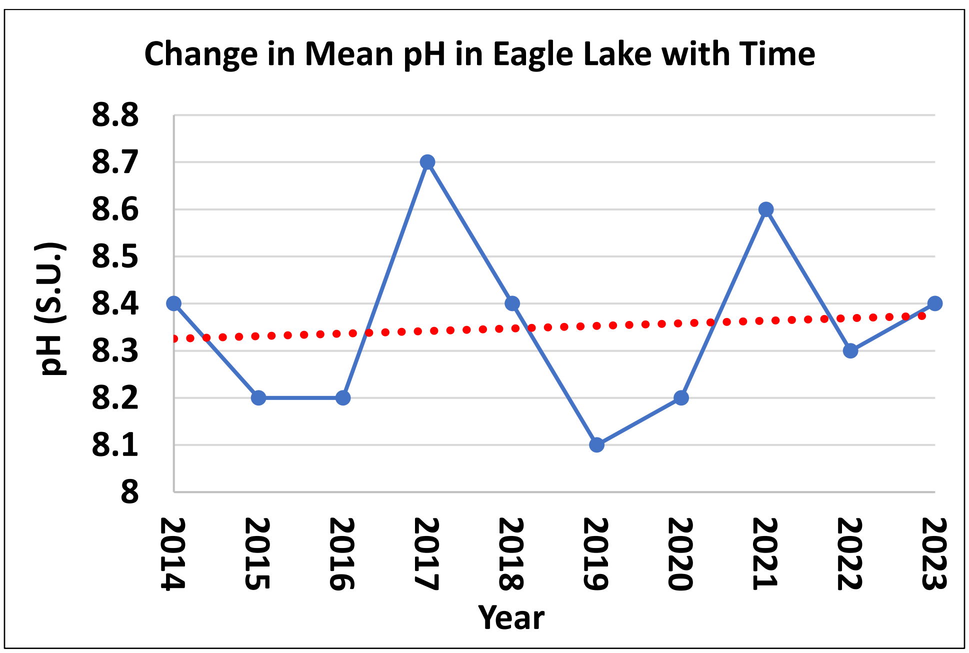

Figure 12. Trend in mean pH with time in Eagle Lake.

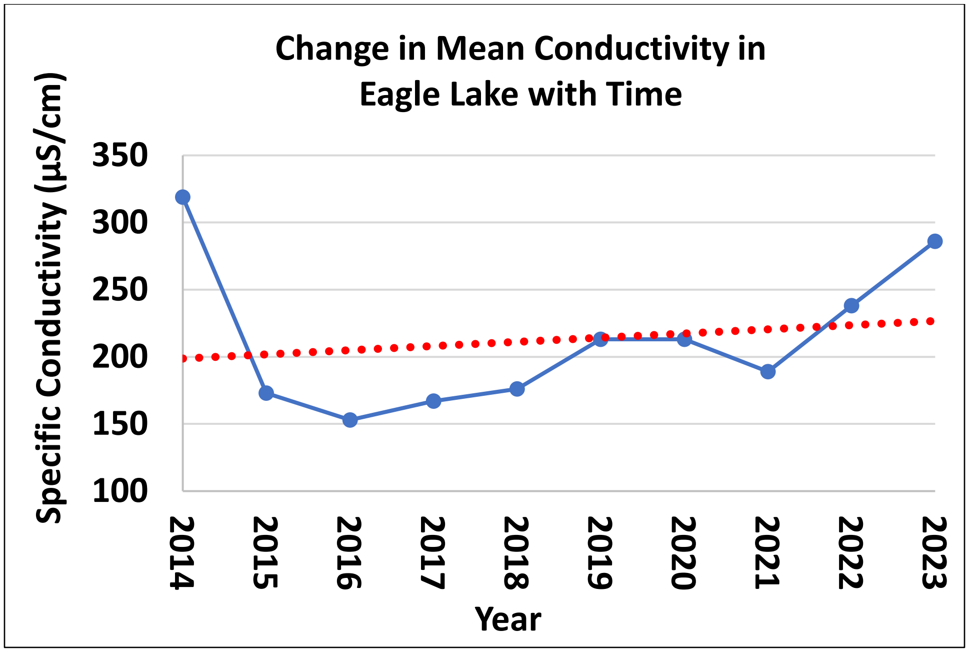

Figure 13. Trend in mean conductivity with time in Eagle Lake.

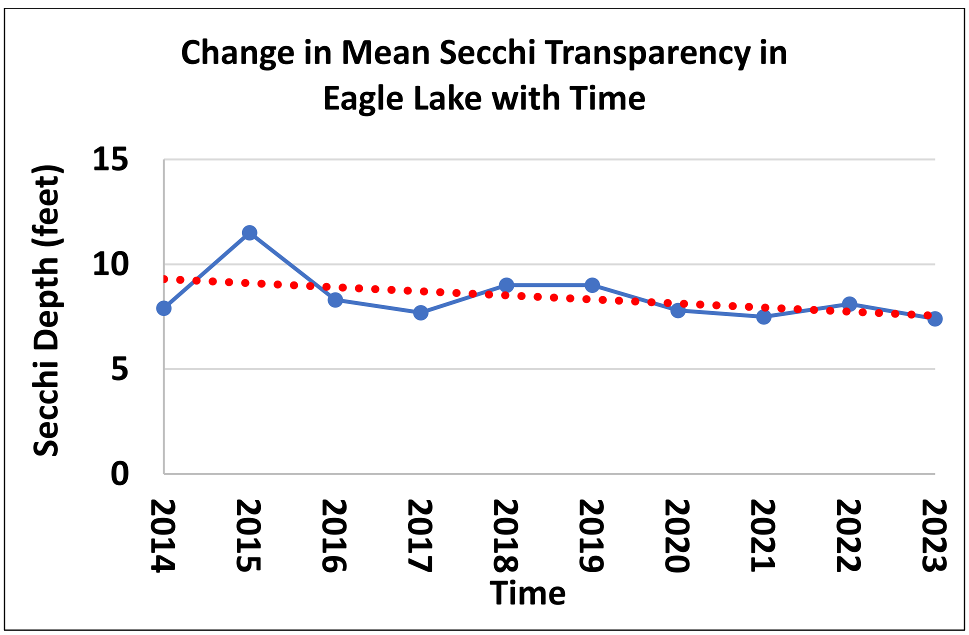

Figure 14. Trend in mean Secchi transparency with time in Eagle Lake.

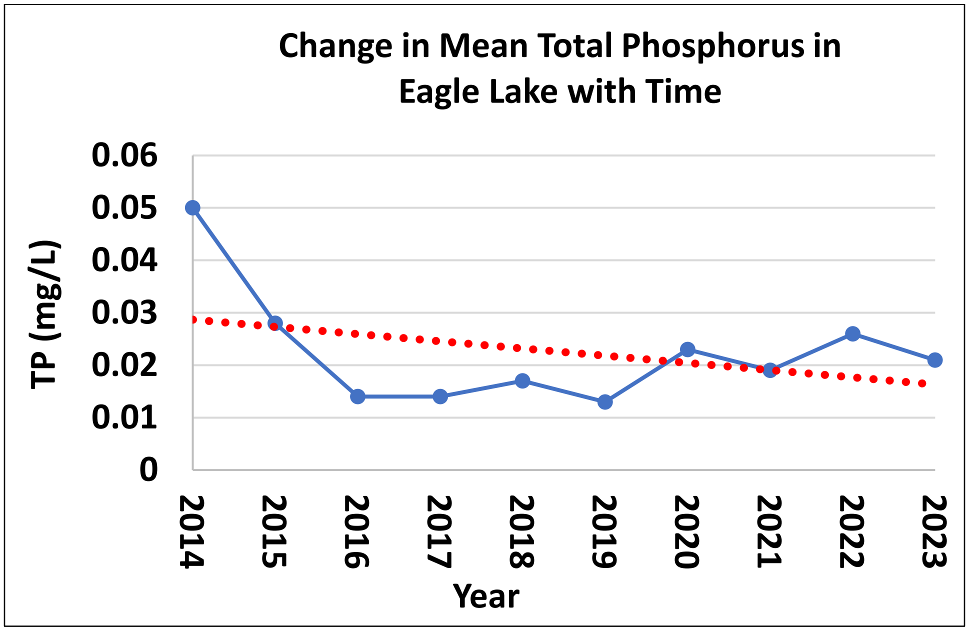

Figure 15. Trend in mean total phosphorus with time in Eagle Lake.

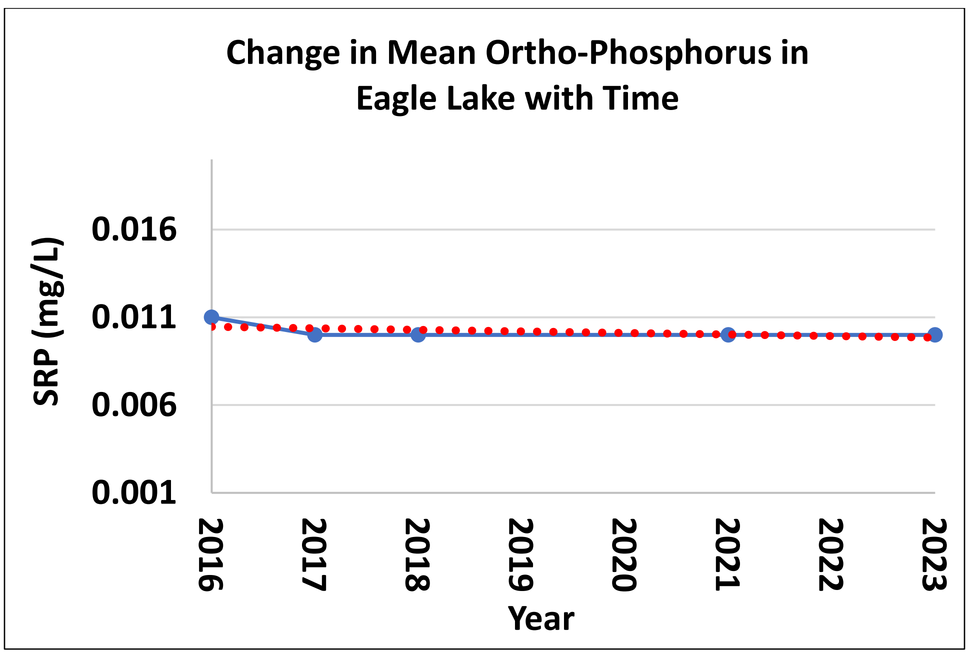

Figure 16. Trend in mean soluble reactive phosphorus (ortho-P) with time in Eagle Lake.

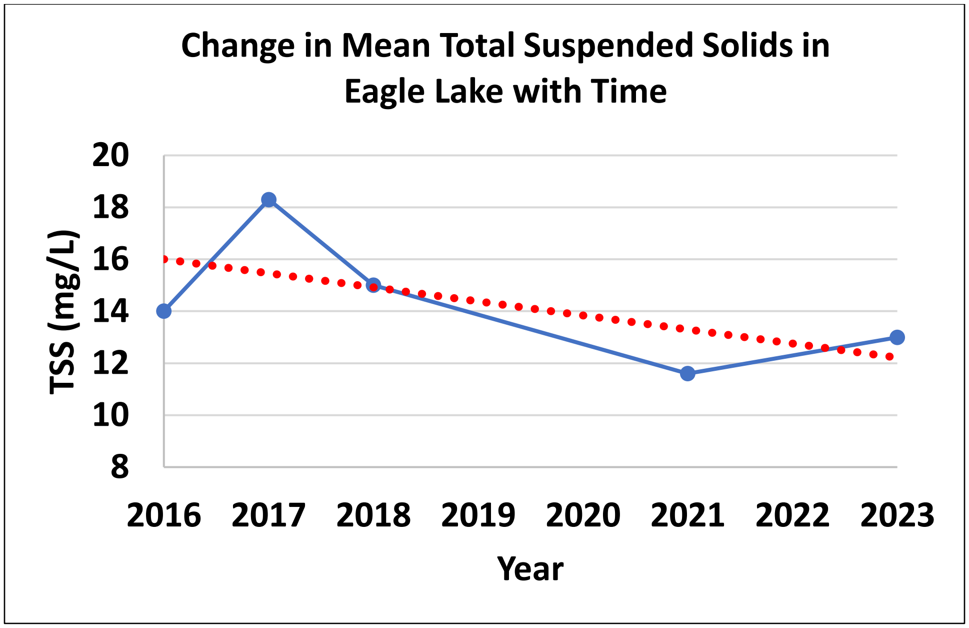

Figure 17. Trend in mean total suspended solids with time in Eagle Lake.

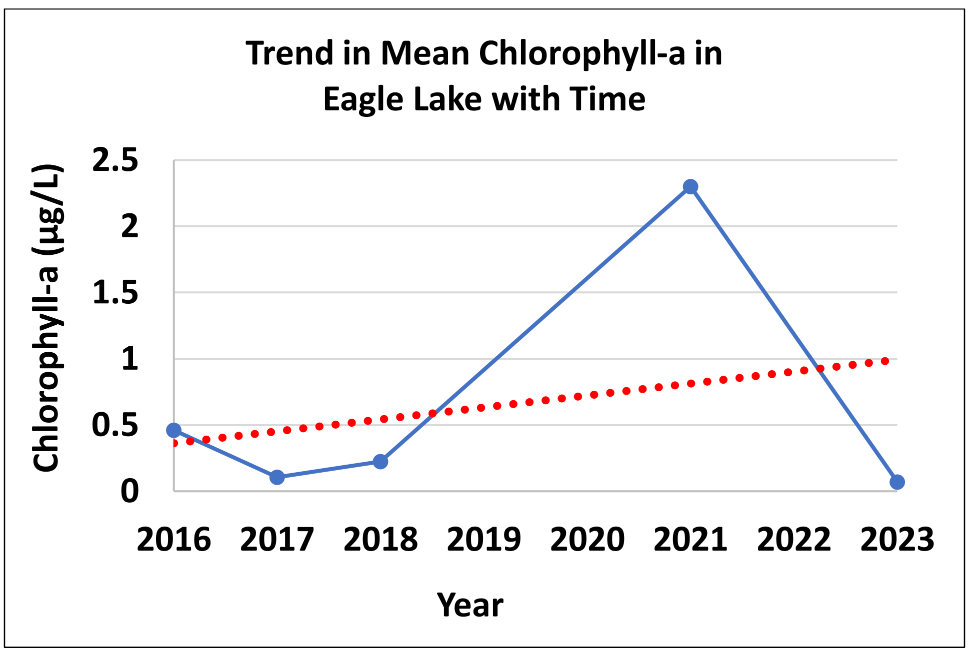

Figure 18. Trend in mean chlorophyll-a with time in Eagle Lake.

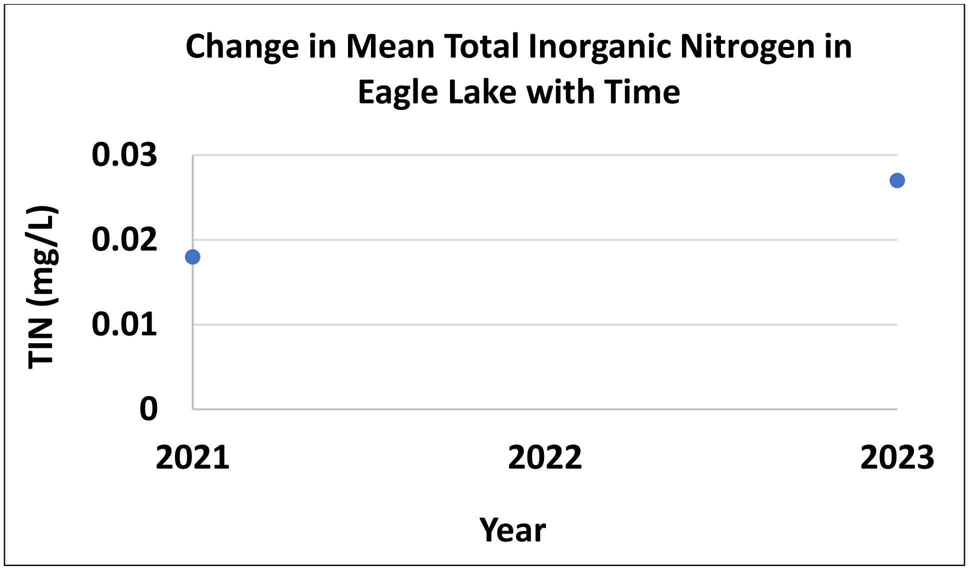

Figure 19. Trend in mean total inorganic nitrogen with time in Eagle Lake.

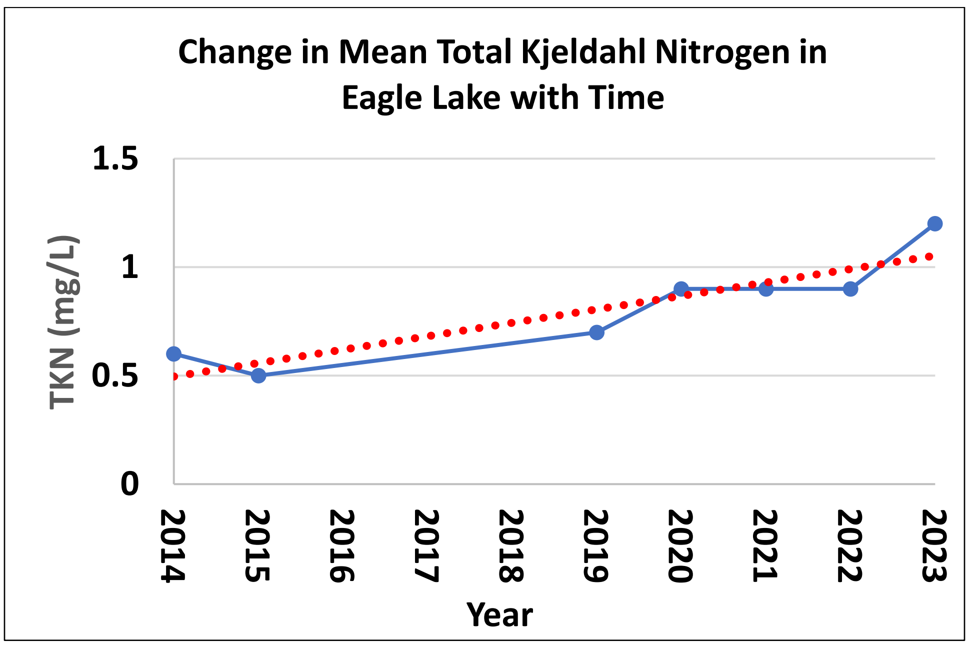

Figure 20. Trend in mean total Kjeldahl nitrogen with time in Eagle Lake.

Based on these graphs, the overall conclusions are offered:

1. The mean water temperature has increased slightly with time and is favorable.
2. The mean DO has been consistent over time and concentrations are favorable.
3. The mean pH has increased over time and the values are favorable.
4. The mean conductivity has increased slightly over time and the values are favorable.
5. The mean Secchi transparency has declined slightly but is favorable given the lake depths.
6. The mean TP has declined with time and remains below the eutrophic threshold.
7. The mean SRP has declined slightly with time and also remains below the eutrophic threshold.
8. The mean TSS has slightly declined over time and remains favorable.
9. The mean chlorophyll-a has increased over time and is favorable.
10. There is not enough data available on the TIN to determine a definitive trend. This will be monitored again in 2024 and future years to develop a sound trend.
11. The mean TKN has increased with time but is favorable.
12. The green algae and diatoms have overall increased with time and the blue-green algae has declined with time. These are favorable results.
13. The zooplankton taxa of cladocerans increased with time and there was a decrease in copepods and rotifers. The reason for this is unclear but the increase in cladocerans is favorable for the lake fishery.
14. The has been a decline in softest bottom category (<0.1) but also a slight decline in the most consolidated category (>0.4). The high abundance of submersed aquatic vegetation may contribute substantial loads of dying organic material to the lake bottom during years when it is most dense. Thus, this variable may continuously fluctuate in Eagle Lake.
15. Aquatic vegetation biovolume varies each year, especially due to lake management treatments. The highest biovolume category (>80%) has declined over time from 44.2% to 0.0% which is likely due to successful reduction in milfoil and Curly-leaf Pondweed canopies from treatments. There has also been a measurable decline in the lowest-growing category (0-20%) from 23.7% to 13.7% which means that taller pondweeds are becoming more prevalent with time. This is why periodic treatments of dense native pondweeds may be needed over time.

b. Lake Management Activities and Confounding Variables

RLS is the lake manager of Eagle Lake and has provided a detailed history on the lake management activities in Table 2 above. The primary priority for the management of aquatic vegetation is invasive species such as Eurasian Watermilfoil and Curly-leaf Pondweed. Since the lake is so shallow, periodic management of dense native pondweeds is needed to allow for recreation and safe navigation activities on the lake. Given that the lake vegetation is regularly treated, we cannot conclude that any reductions in submersed aquatic vegetation are due to effects of the laminar flow aeration system.

Additionally, the years lost during the LFA evaluation period due to uncontrolled flooding and compressor damage has not allowed for a fair assessment of the performance of the system and thus more consistent years are needed.

Concluding Statement:

Eagle Lake is a medium-sized mesotrophic aquatic system that is developed and heavily used for recreational activities. The benefits of the existing LFA system are scientifically modest but riparian perceptions are also important. The system is not resulting in any unfavorable water quality impairments but more operable time with a functioning LFA system is needed to conclude efficacy with scientific confidence. The significant improvements listed above include a reduction in phosphorus and ortho-phosphorus and total suspended solids, and reduction in dense aquatic vegetation biovolume (the latter may be attributed also to herbicide treatments). If the current laminar flow aeration program is continued, it will be critical for the Eagle Lake Texas Association and RLS to follow the latest Guidance requirements for a more complete dataset and ensure that the LFA system is property operating now that flooding and lake level control are being addressed with long-term solutions.