LAKE LEMON MONITORING PROGRAM

2020 Results Summary

Prepared for:

Lake Lemon Conservancy District

Prepared by:

Sarah Powers

School of Public & Environmental Affairs

Indiana University

Bloomington, Indiana 47405

Lake Lemon 2020 Water Monitoring Overview

The Lake Lemon Conservancy District (LLCD) began contracting Indiana University in 1998 to monitor water quality of the lake and incoming tributaries. Figure 1 shows the sampling locations for Lake Lemon and the tributaries in 2020. IU has provided full sampling methods to the LLCD. Figure 2 displays precipitation during the sampling season with individual sampling events indicated. Two storm event samples were collected on May 18 and July 23, 2020.

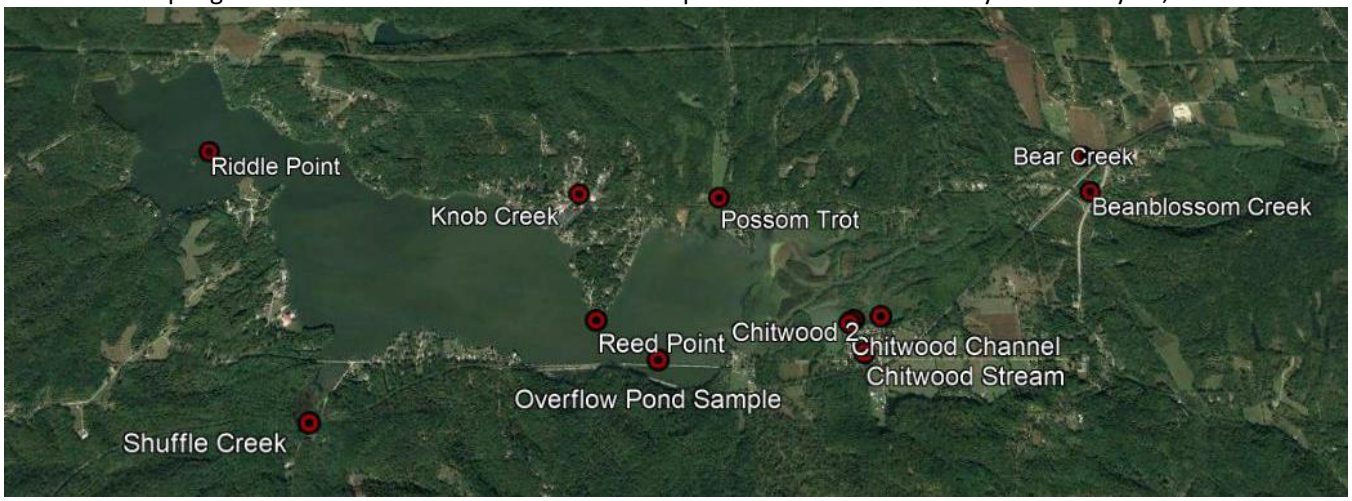

Figure 1. Sampling locations for the Lake Lemon Water Monitoring Program.

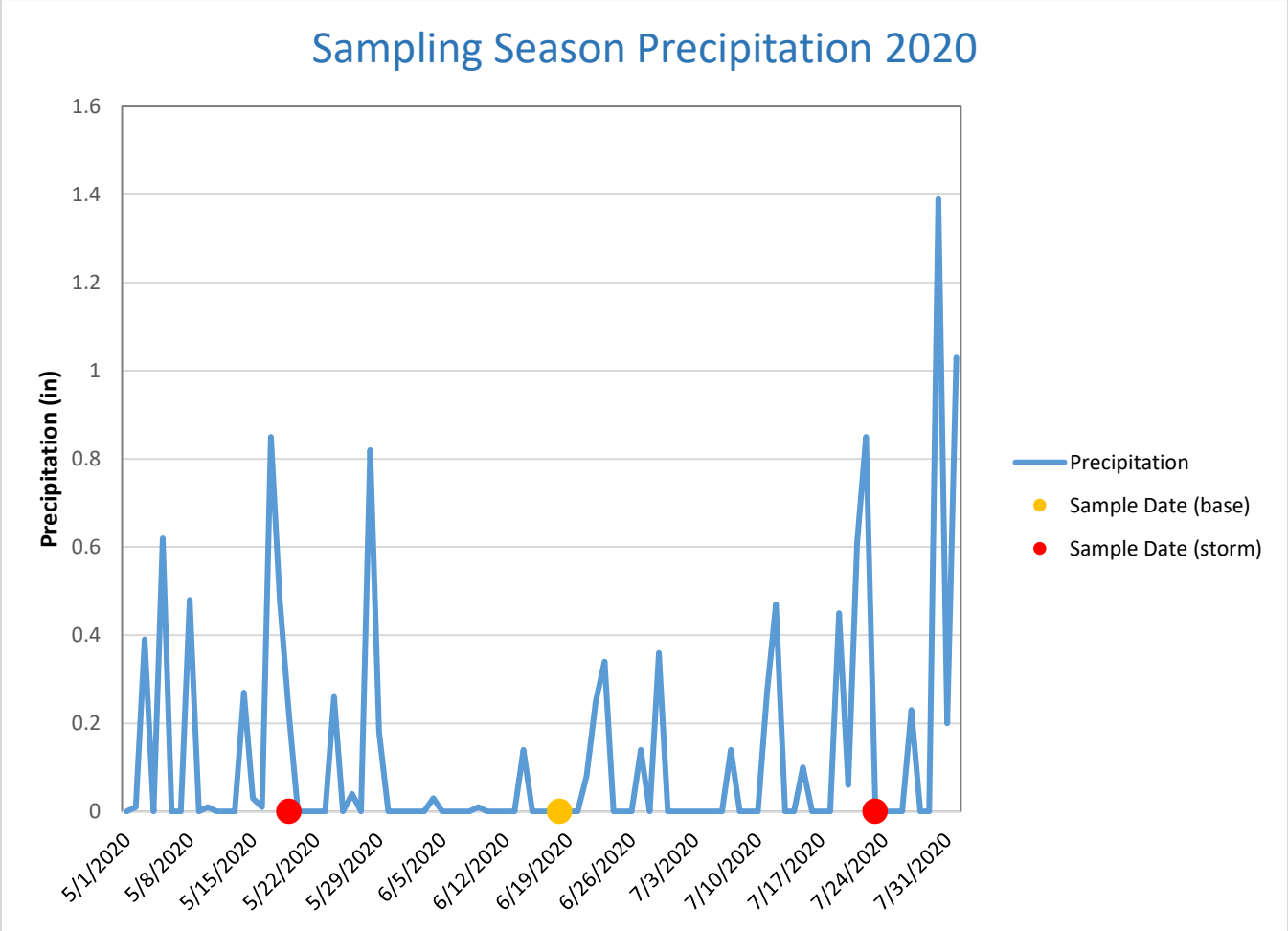

Figure 2. Precipitation amounts during the 2020 sampling season.

Lake Lemon 2020 Summary Results

Temperature and Dissolved Oxygen IU collected a full profile of temperature and dissolved oxygen from one-meter depth increments through the water column at Riddle and Reed Point in Lake Lemon. The temperature profile illustrates the seasonal variation in water temperature and thermal stratification that occurs as the surface water warms. The upper 3 meters of water remained oxygenated during all three sampling events at Riddle Point (Figure 3). The late July dissolved oxygen concentrations averaged 8.825 mg/L in the epilimnion, a slight decrease of approximately 0.3 mg/L respectively from the sample collected during July of 2019 at Riddle Point. Anoxic conditions develop below 4 meters depth as organic matter on the lake bottom creates biochemical oxygen demand (BOD) that breaks down the organic matter consuming available oxygen. Stratification of the surface water reduces mixing of oxygen in the deeper water. The shallow depth of Reed Point and lake turbulence usually keep this area of the lake well mixed and oxygenated, however later this season, we saw hypoxic conditions approaching anoxia at 3 meters depth in June and July (Figure 4).

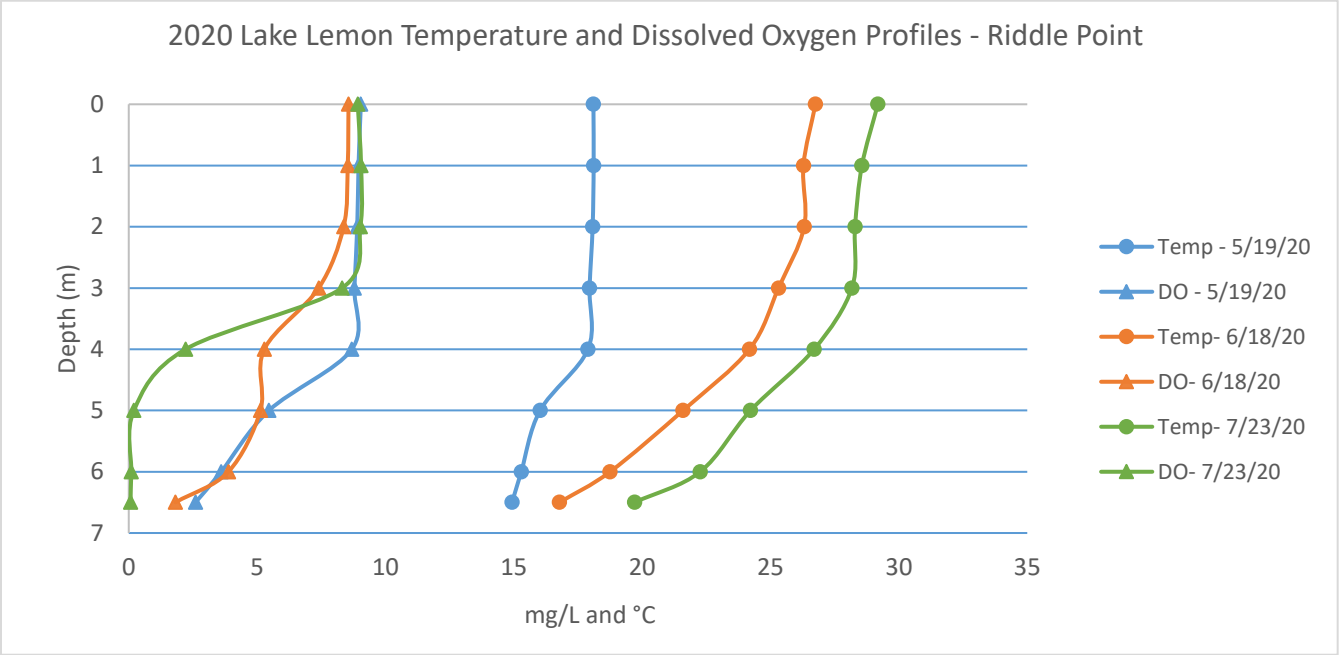

Figure 3. Temperature and dissolved oxygen profiles from all sample dates from Indiana University at Riddle Point in 2020.

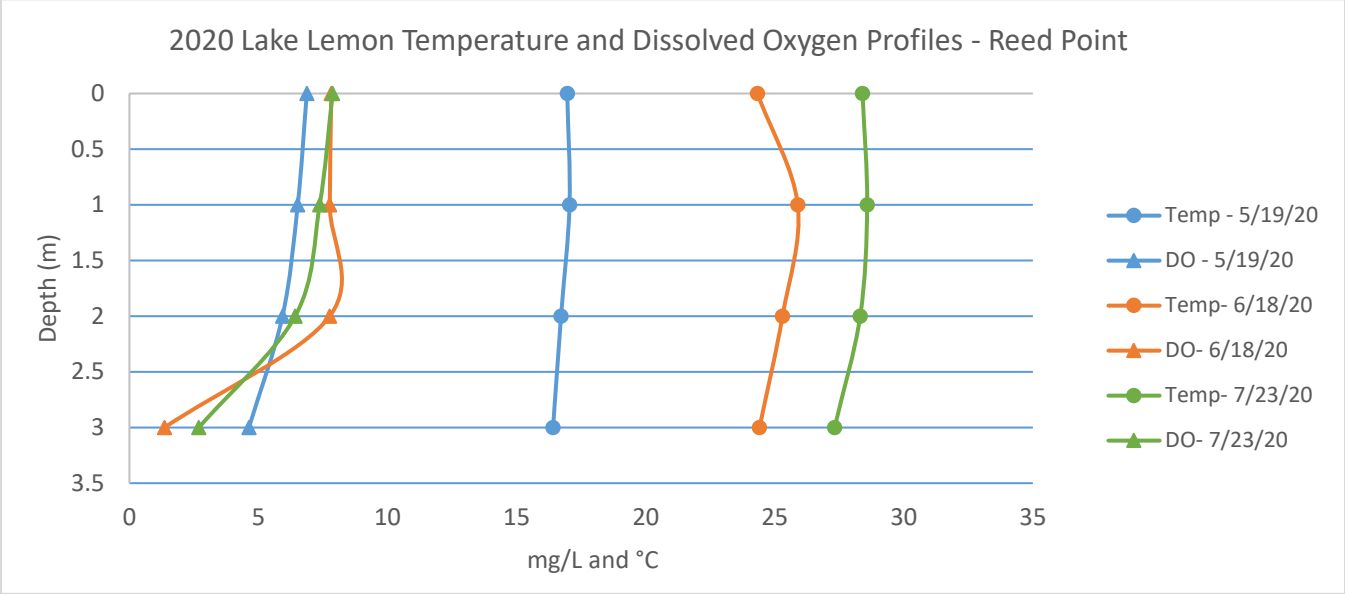

Figure 4. Temperature and dissolved oxygen profiles from all sample dates from Indiana University at Reed Point in 2020.

Water Quality Summary IU collected epilimnion samples from the top 2 meters of the water column and hypolimnion at 6 meters depth (19.7 ft) at Riddle Point. IU collected samples in the epilimnion only at Reed Point.

Table 1. Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 5/19/2020.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	1.15	--	0.45
Light trans @ 1m (%)	12.9	--	5.1
1% Light Level (ft)	6	--	5
% Water Column Oxic	100	--	100
pH	7.35	10.81	7.28
Conductivity (uS/cm))	174.59	168.75	170.31
Alkalinity (mg/L)	50.7	--	51.8
Nitrate (mg/L)	0.06	0.0625	0.17
Ammonia (mg/L)	0.039	0.077	0.051
Total Nitrogen (mg/L)	0.406	0.357	0.569
Orthophosphate (mg/L)	0.006	0.003	0.005
Total Phosphorus (mg/L)	0.019	0.020	0.028
Chlorophyll-*a* (ug/L)	6.80	--	7.39
Plankton (Cells/ml)	2,699	--	2,449
Plankton (#/L)	1,319,409	--	1,174,829
% HAB Biovolume	0	--	3
% Blue-green Biovolume	10	--	15
***E. coli* (#/100 mls)**	96	--	912

Table 2. Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 6/18/2020.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	1.0	--	1.45
Light trans @ 1m (%)	15.0	--	9.9
1% Light Level (ft)	9.5	--	5
% Water Column Oxic	100	--	100
pH	7.33	6.95	8
Conductivity (uS/cm)	177	212.8	201.01
Alkalinity (mg/L)	61.7	66.0	65.7
Nitrate (mg/L)	0.026	0.0215	0.063
Ammonia (mg/L)	< 0.014	0.0715	< 0.014
Total Nitrogen (mg/L)	0.527	0.578	0.6385
Orthophosphate (mg/L)	0.004	0.0875	0.007
Total Phosphorus (mg/L)	0.039	0.043	0.051
Chlorophyll-a (ug/L)	7.69	--	9.74
Plankton (Cells/ml)	10,292	--	13,627
Plankton (#/L)	2,517,321	--	3,427,236
% HAB Biovolume	8	--	11
% Blue-green Biovolume	21	--	33
***E. coli* (#/100 mls)**	4	--	4

Table 3. Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 7/23/2020.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	0.7	--	0.6
Light trans @ 1m (%)	6.2	--	3.9
1% Light Level (ft)	6	--	5
% Water Column Oxic	100	--	100
pH	10.6	9.2	10.31
Conductivity (uS/cm)	203.58	267.23	214.54
Alkalinity (mg/L)	69.45	96.5	72.5
Nitrate (mg/L)	< 0.008	0.0165	< 0.008
Ammonia (mg/L)	< 0.014	0.5305	< 0.014
Total Nitrogen (mg/L)	0.787	1.0695	0.761
Orthophosphate (mg/L)	0.004	0.090	0.005
Total Phosphorus (mg/L)	0.041	0.1525	0.060
Chlorophyll-a (ug/L)	9.95	--	13.26
Plankton (Cells/ml)	252,585	--	217,151
Plankton (#/L)	48,331,043	--	46,229,801
% HAB Biovolume	90	--	67
% Blue-green Biovolume	3	--	12
***E. coli* (#/100 mls)**	0	--	0

Chlorophyll-*a*, which is a measure of the primary pigment in algae, is a direct measure of algal productivity. In the integrated samples from the surface to the 2-meter depth, the chlorophyll-*a* concentrations ranged from 6.80 µg/L in May to 13.26 µg/L in late July. Chlorophyll-*a* concentrations >7 µg/L are indicative of eutrophic lake conditions. Overall, we see a seasonal pattern of nutrient increase by late summer as total phosphorous concentrations increase, which is characteristic of Lake Lemon. This pattern is mirrored by increases in chlorophyll-*a* concentrations. This suggests that conditions exist for increasing growth of algae (Figures 5 and 6).

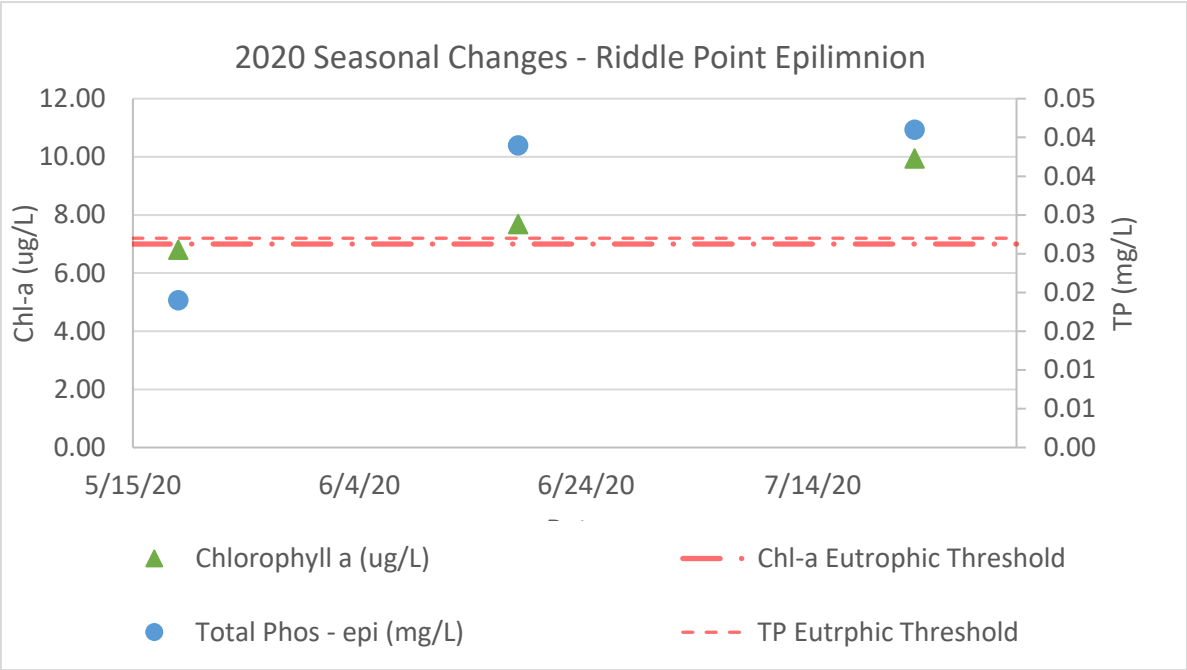

Figure 5. Seasonal changes in total phosphorus and chlorophyll-*a* in the surface waters (epilimnion) at Riddle Point in Lake Lemon in 2020.

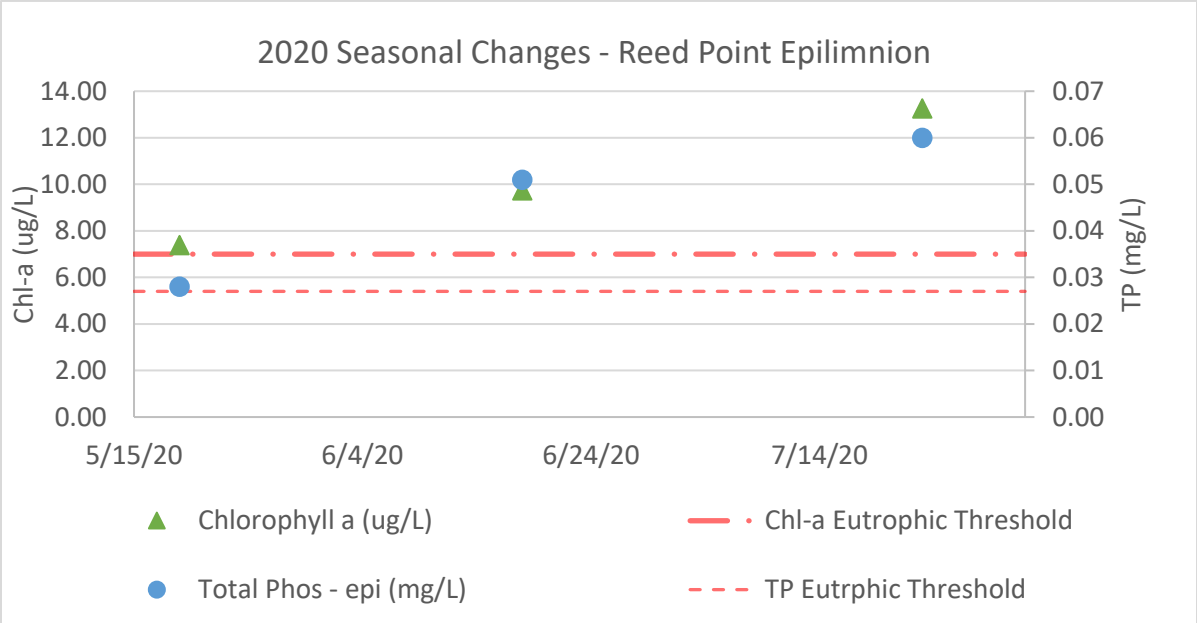

Figure 6. Seasonal changes in total phosphorus and chlorophyll-*a* in the surface waters (epilimnion) at Reed Point in Lake Lemon in 2020.

Beach and Tributary Samples IU collected turbidity and E. coli samples around the Lake Lemon watershed in 2020 (Tables 4 and 5). The state standard for full body contact and recreation is 200 colonies per 100mLs.

Table 4. Tributary E. coli for 2020.

	E. coli (#/100 mls)	*E. coli* (#/100 mls)
	5/20/20	**7/23/20**
Chitwood #1	11,100	100
Chitwood #2	576	120
Chitwood Channel	860	80
Chitwood Stream	650	3,200
Beanblossom Creek	2,000	1,200
Bear Creek	240	1,000
Knobb Creek	1,440	160
Possom Trot	180	100
Shuffle Creek	100	60

Table 5. Beach E. coli for 2020.

Lake Lemon Beach	*E. coli* (#/100 mls)
5/25/20	8
6/2/20	10
6/9/20	3
6/17/20	10
7/6/20	130
7/13/20	48
7/20/20	150
7/27/20	26
8/3/20	140
8/11/20	124
8/20/20	16
8/25/20	4
8/27/20	4
9/2/20	0

In order to help identify the problem areas for bacteria and sediment, IU has continued sampling at additional sampling sites (Figures 7 and 8). The LLCD and IU selected sites in an attempt to address concerns of citizens and to identify solutions for bacteria challenges. Storm sample collections on 5/19/2020 and 7/23/200 demonstrate possible worst-case scenarios for bacteria in the lake. These concentrations are well over full body contact standards during many sampling events.

Figure 7. Sampling locations for the Lake Lemon Water Monitoring Program for the Chitwood area for 2017 to 2020.

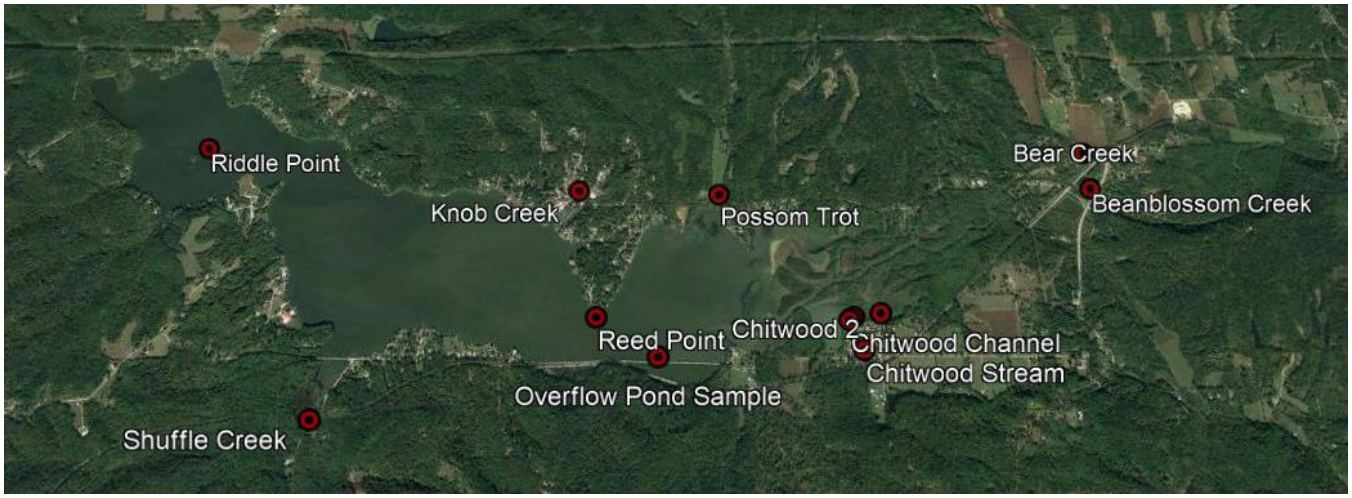

Figure 8. Sampling locations for the Lake Lemon Water Monitoring Program for the Chitwood area for 2020.

The LLCD Board asked us to look at the historical bacteria trends. The results from sampling events at the Chitwood sites show the water exceeds EPA standards for recreation over 50% of the time, for *E. coli* from 2015-2020 (Figure 9).

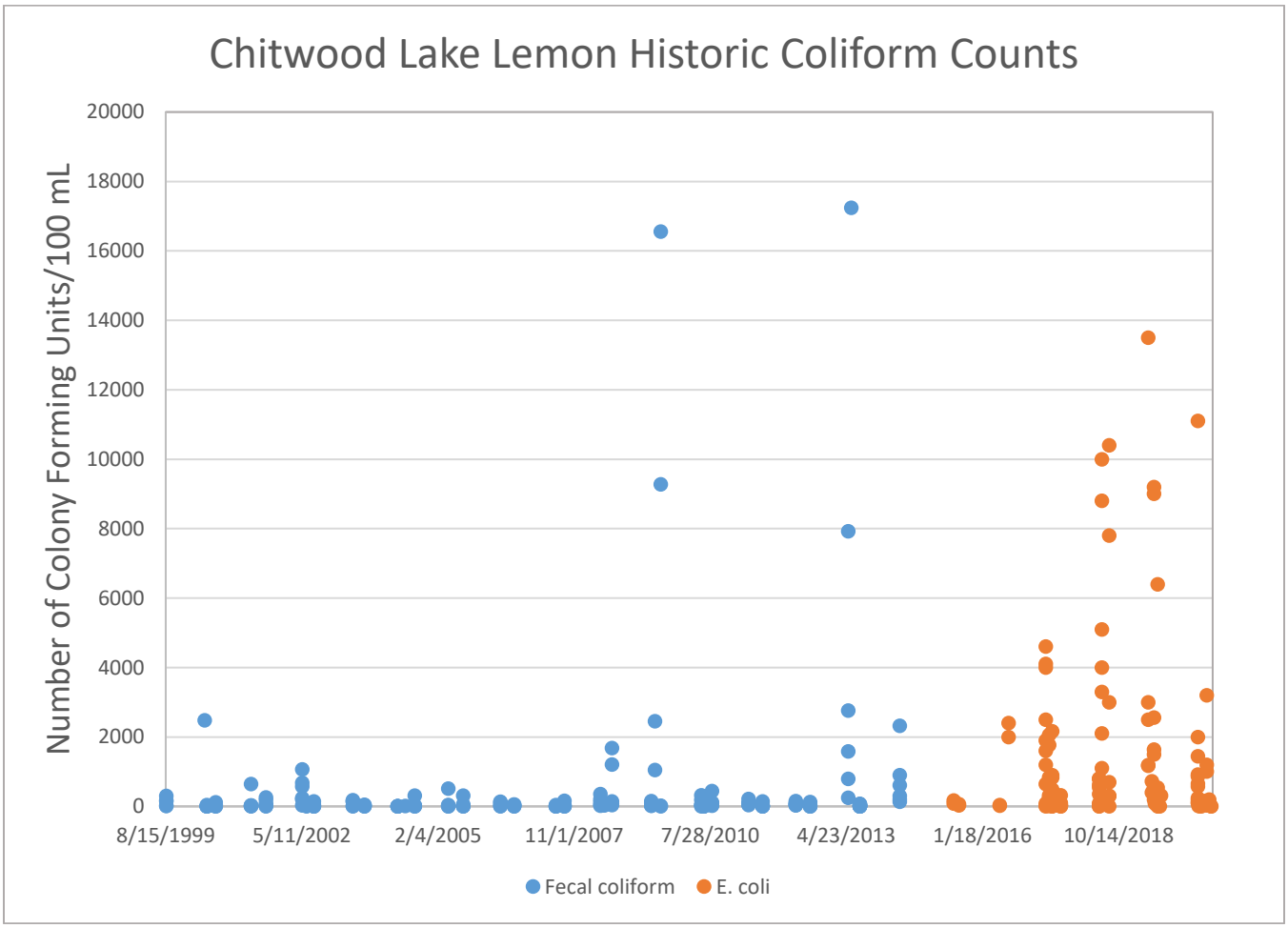

Figure 9. Changes in Fecal Coliform and *E. coli* concentrations in Chitwood area as part of the Lake Lemon watershed during sample events from 1999 to 2020. Note that 72 of the 134 events from 2015 to 2020 exceeded 200 CFU/100 mLs. (Five outliers were removed for display purposes).

Trophic State. The trophic state of a lake helps characterize the level of productivity and the expected life that may exist in a lake. The overall classifications of lakes can help with comparison across lakes as well as from year to year. We use Carlson's Trophic State as it was developed based on lakes similar to those in Indiana.

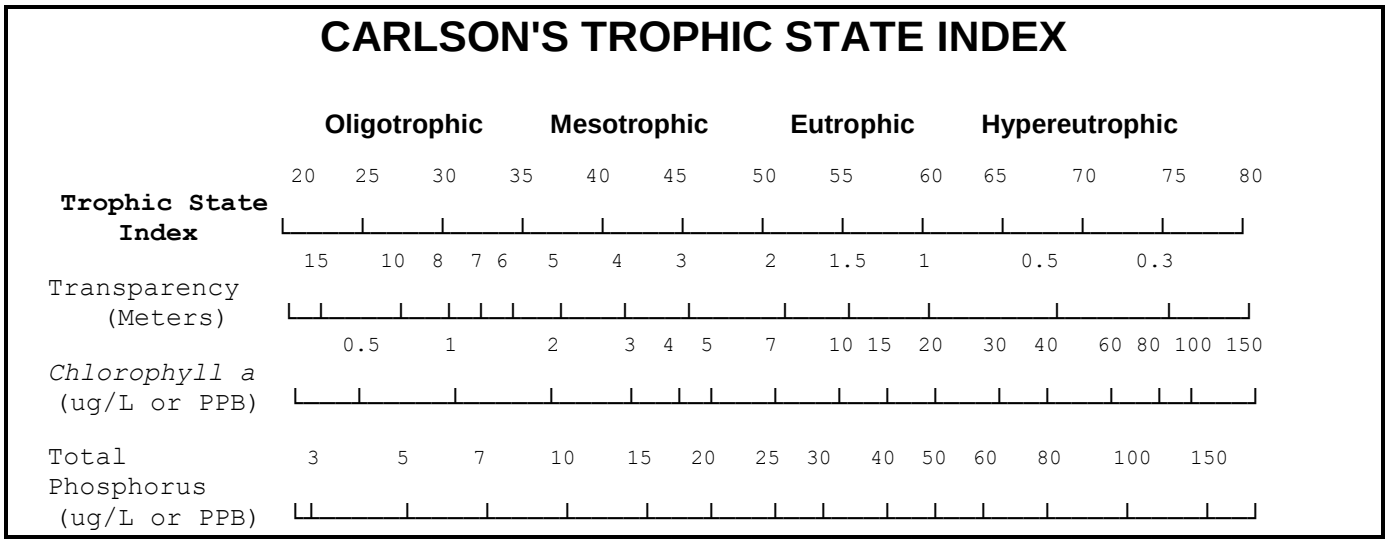

Figure 10. Carlson's trophic state index.

Table 6. Characteristics of trophic state categories.

Classification	Transparency	Nutrients	Algae	D.O.	Fish
Oligotrophic	clear	Low TP < 6 µg/L	few algae	Hypo has D.O.	can support salmonids (trout and salmon)
Mesotrophic	Less clear	Moderate TP 10-30 µg/L	healthy populations of algae	Less D.O. in hypo	lack of salmonids
Eutrophic	transparency <2 meters	High TP > 35 µg/L	abundant algae and weeds	No D.O. in the hypo during the summer	Warmwater fisheries only. Bass may dominate.
Hypereutrophic	transparency <1 meter	extremely high TP > 80 µg/L	thick algal scum Dense weeds	No D.O. in the hypo during the summer	Rough dominate. Summer fish kills possible.

We use Riddle Point Carlson TSI scores to look at the historic trend for Lake Lemon demonstrating that the lake is generally characterized as eutrophic. Figures 11-13 illustrate the Carlson TSI historic trends for Secchi disk, total phosphorus, and chlorophyll-*a*. Overall, a pattern of seasonal variation of lower scores (less eutrophic) in the spring and increasing trophic state to eutrophic/hypereutrophic status by late summer.

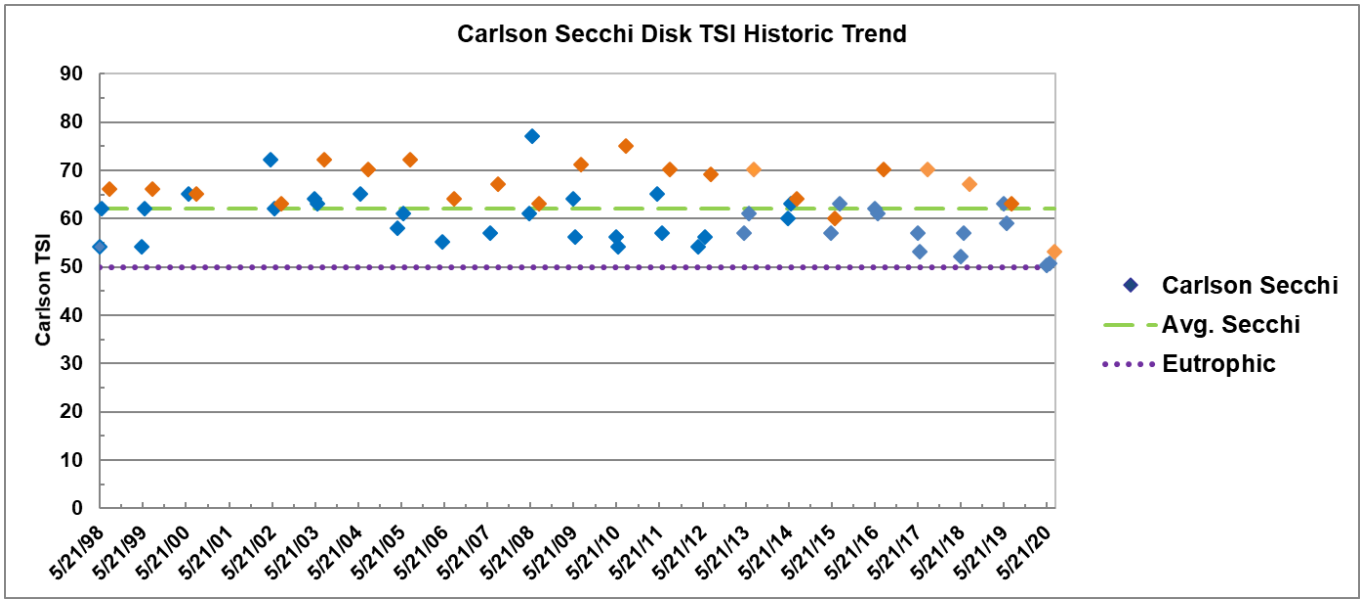

Figure 11. The 22-year historic trend for Carlson Secchi disk TSI scores in blue and orange. Orange diamonds represent the last summer samples, usually late July or August. The 22-year mean for Secchi disk readings of 62 is above the Carlson TSI eutrophic status score of 50 (purple dotted line).

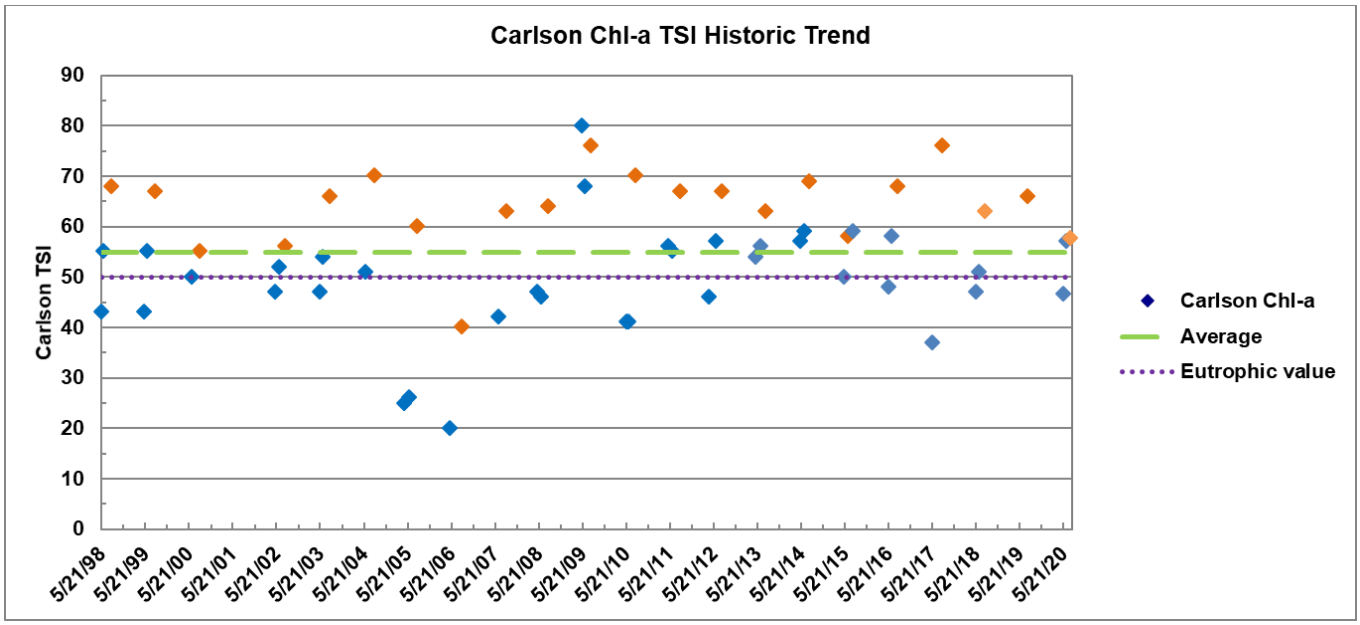

Figure 12. The 22-year historic trend for Carlson chlorophyll-*a* TSI scores in blue and orange. Most late-summer samples, shown in orange, score above the mean for eutrophic status. The 22-year mean is just above the Carlson TSI eutrophic status score of 50 (purple dotted line).

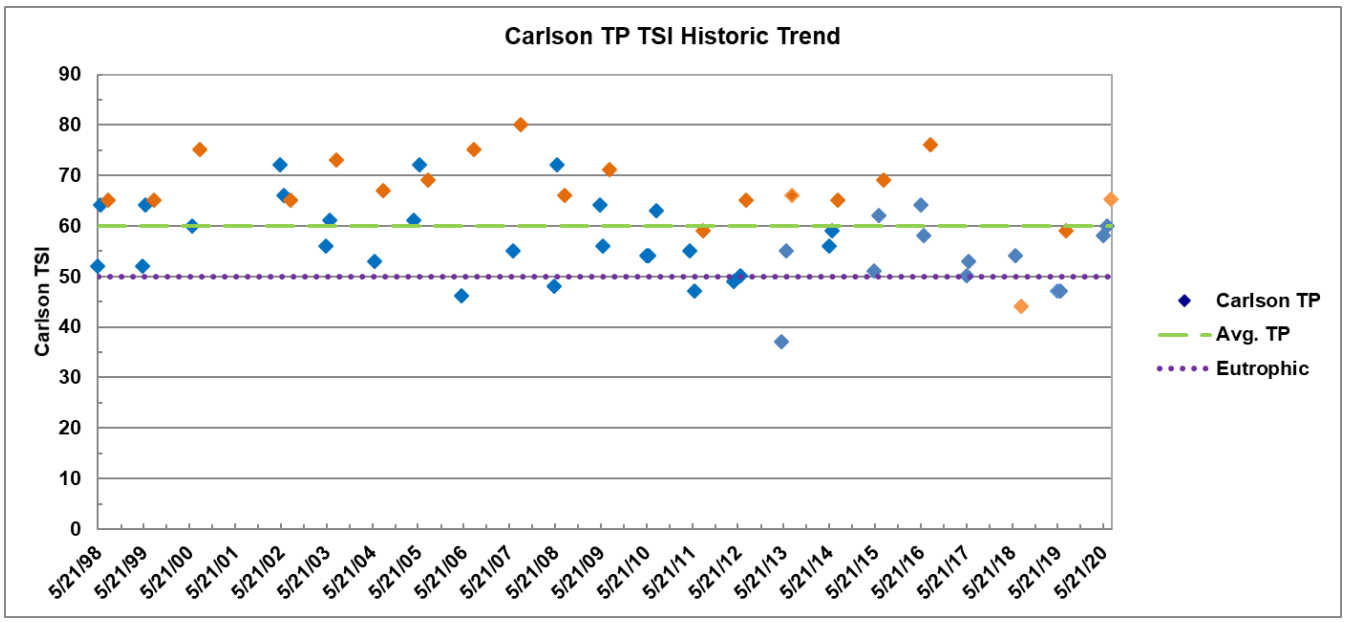

Figure 13. The 21-year historic trend for Carlson total phosphorus TSI scores in blue and orange. All late-summer samples, shown in orange, score above the mean for eutrophic status save for one in 2018. The 22-year mean for TP of 60 is above the Carlson TSI eutrophic status score of 50 (purple dotted line).

Lake Lemon Water Monitoring Conclusions and Recommendations

Harmful algal blooms (HABs), algae groups that are known toxin producers, continue to be an area of concern for the lake. May and June samples at Riddle Point remained below the 100,000 cells/mL threshold for recreation advisories. The late July sample did exceed this threshold at approximately 252,600 cells/mL with over 90% of biovolume in the HAB grouping. In previous recommendations we have discussed development of a HAB response plan. We have been working with the Lake Manager to develop this plan. As part of the plan, we recommend continuing to monitor algal blooms this summer and use the contract lab Phycotech for a speed and consistency. We recommend bi-weekly beach monitoring for HABs and will continue to monitor the Overflow Pond, Reed, and Riddle Point during normal sampling events in May and July/August. We recommend placing signage at the boat launch and beach that provides information on HABs and the use of a color-coded warning system for recreation. The LLCD should also purchase rapid toxin test from Abraxis for algal toxin monitoring should we identify a bloom. https://abraxis.eurofins-technologies.com/home/products/rapid-test-kits/algal-toxins/algal-toxin-test-strip-kits/

Bacteria issues still are a challenge in the incoming tributaries to the lake. We will continue to monitor the stream inlets but recommend that we reduce the number of samples in the Chitwood area as they are currently working on plans to correct the challenges. We recommend collecting one sample at the outlet of the channel network as it mixes with the lake. We recommend continuing to monitor the additional add on sites from last summer to try to identify additional areas of concern. Bacteria source tracking analysis is being done in the Beanblossom Watershed in late April or early May (weather dependent) and will hopefully offer better understanding of where we should target future efforts.

Additional data was collected by the O'Neill School Limnology Lab on the Overflow Pond with additional samples collected for comparison at other sites. That data was not included in this report as it was not part of the original project scope and contract. We will do additional analysis of that data upon request. All data from that analysis has been shared with the Lake Manager.

Further conclusions and recommendations are pending discussion with Lake Manager and Board of Directors.