

LAKE LEMON MONITORING PROGRAM
2017-2018 Results Summary



Prepared for:

Lake Lemon Conservancy District

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Lake Lemon 2017-2018 Water Monitoring Overview

Indiana University has been contracted by the Lake Lemon Conservancy District since 1998 to monitor water quality of the lake and incoming tributaries. Figure 1 shows the sampling locations for Lake Lemon and the tributaries in 2017. Full sampling methods can be found on the Lake Lemon Conservancy District website.



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

Lake Lemon 2017-2018 Summary Results

Temperature and dissolved oxygen measurements were collected from each meter depth to allow for a full profile. 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 four sampling events at Riddle Point (Figure 1). The August dissolved oxygen concentrations averaged 8.1 mg/L in the epilimnion, a slight increase of approximately 0.5 mg/L respectively from the sample collected during July of 2017. Anoxic conditions develop below 3 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 keep this area of the lake well mixed and oxygenated (Figure 2).

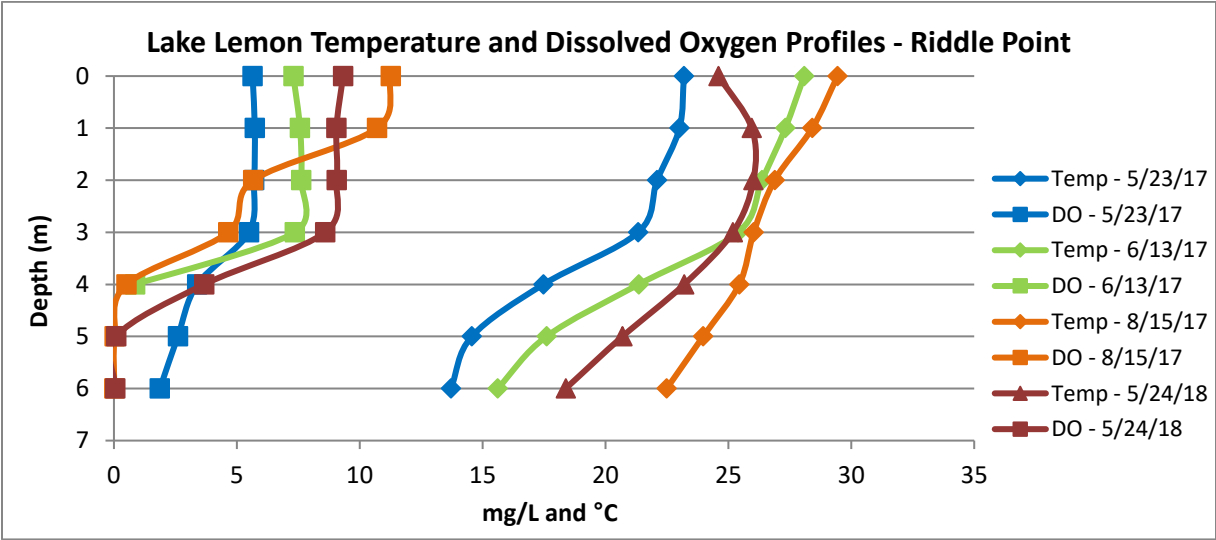


Figure 1. Temperature and dissolved oxygen profiles from all sample dates in from Indiana University at Riddle Point in 2017-2018.

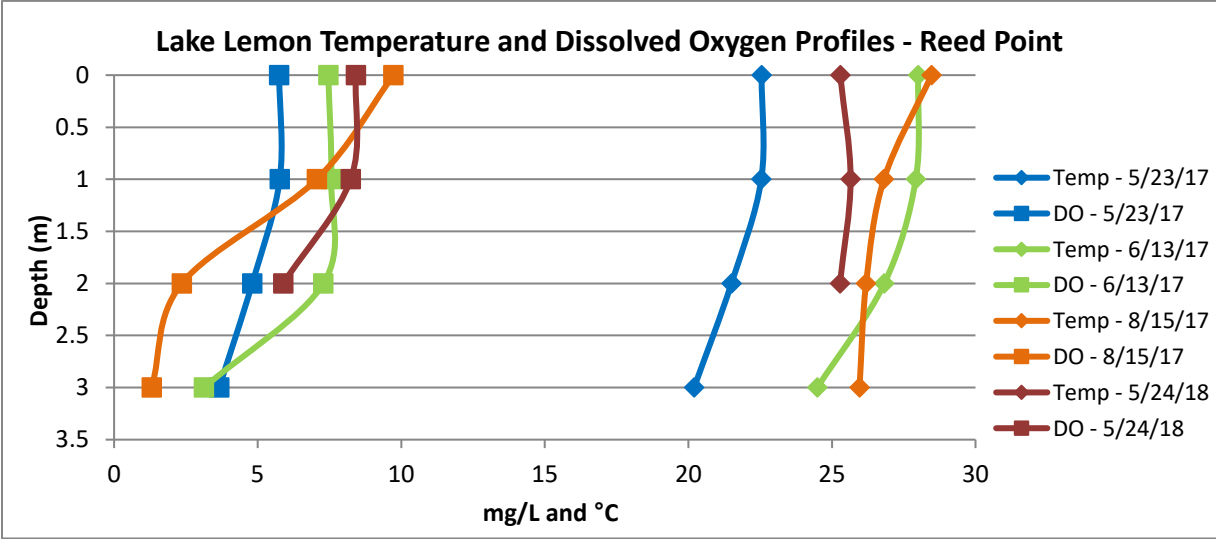


Figure 2. Temperature and dissolved oxygen profiles from all sample dates in from Indiana University at Reed Point in 2017-2018.

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

Table 1. Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 5/23/2017.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	1.2	--	0.8
Light trans @ 3' (%)	23.4	--	16.4
1% Light Level (ft)	11.75	--	7.25
% Water Column Oxic	82.2	--	100
pH	7.45	6.5	7.4
Conductivity (uS/cm))	6.5	176.5	159
Alkalinity (mg/L)	142	66	50
Total Suspended Solids (mg/L)	5.14	9.67	4.57
Nitrate (mg/L)	0.036	0.056	0.061
Ammonia (mg/L)	0.014	0.113	0.014
Total Organic Nitrogen (mg/L)	0.285	0.599	
Orthophosphate (mg/L)	0.015	0.017	0.215
Total Phosphorus (mg/L)	0.027	0.027	0.013
Chlorophyll- <i>a</i> (ug/L)	1.86	--	0.03
Plankton (Cells/ml)	**	--	**
Plankton (#/L)	**	--	**
Blue-green dominance NU (%)	**	--	**
Blue-green dominance – cells/ml (%)	**	--	**

* Method Detection Limit

**Pending final analysis

Table 2. Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 6/13/17.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	1.6	--	0.75
Light trans @ 3' (%)	24.8	--	--
1% Light Level (ft)	6.25	--	--
% Water Column Oxic		--	100
pH	7.9	7.0	7.8
Conductivity (uS/cm)	177	190	186
Alkalinity (mg/L)	56	66	78
Total Suspended Solids (mg/L)	--	5.00	4.70
Nitrate (mg/L)	0.009*	0.009*	0.009*
Ammonia (mg/L)	0.015*	0.078*	0.015*
Total Organic Nitrogen (mg/L)	0.132	0.550	0.282
Orthophosphate (mg/L)	0.006	0.024	0.006
Total Phosphorus (mg/L)	0.03	0.049	0.050
Chlorophyll-a (ug/L)	--	--	--
Plankton (Cells/ml)	**	--	**
Plankton (#/L)	**	--	**
Blue-green dominance NU (%)	**	--	**
Blue-green dominance – cells/ml (%)	**	--	**

* Method Detection Limit

**Pending final analysis

Table 3. Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 8/15/17.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	0.5	--	0.6
Light trans @ 3' (%)	4.4	--	--
1% Light Level (ft)	3.6	--	--
% Water Column Oxic	39	--	100
pH	8.8	7.1	7.8
Conductivity (uS/cm))	--	259	186.1
Alkalinity (mg/L)	75	84	78
Total Suspended Solids (mg/L)	4	9.3	18.0
Nitrate (mg/L)	0.009*	0.009*	0.009*
Ammonia (mg/L)	0.015*	0.077	0.015*
Total Organic Nitrogen (mg/L)	--	0.984	0.950
Orthophosphate (mg/L)	0.009	0.009	0.007
Total Phosphorus (mg/L)	--	0.080	0.084
Chlorophyll-a (ug/L)	39.0	--	29.7
Plankton (Cells/ml)	**	--	**
Plankton (#/L)	**	--	**
Blue-green dominance NU (%)	**	--	**
Blue-green dominance – cells/ml (%)	**	--	**

* Method Detection Limit

**Pending final analysis

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 1.86 $\mu\text{g/L}$ in May to 38.97 $\mu\text{g/L}$ in August. Chlorophyll-*a* concentrations $>7 \mu\text{g/L}$ 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 (Figure 3 and 4).

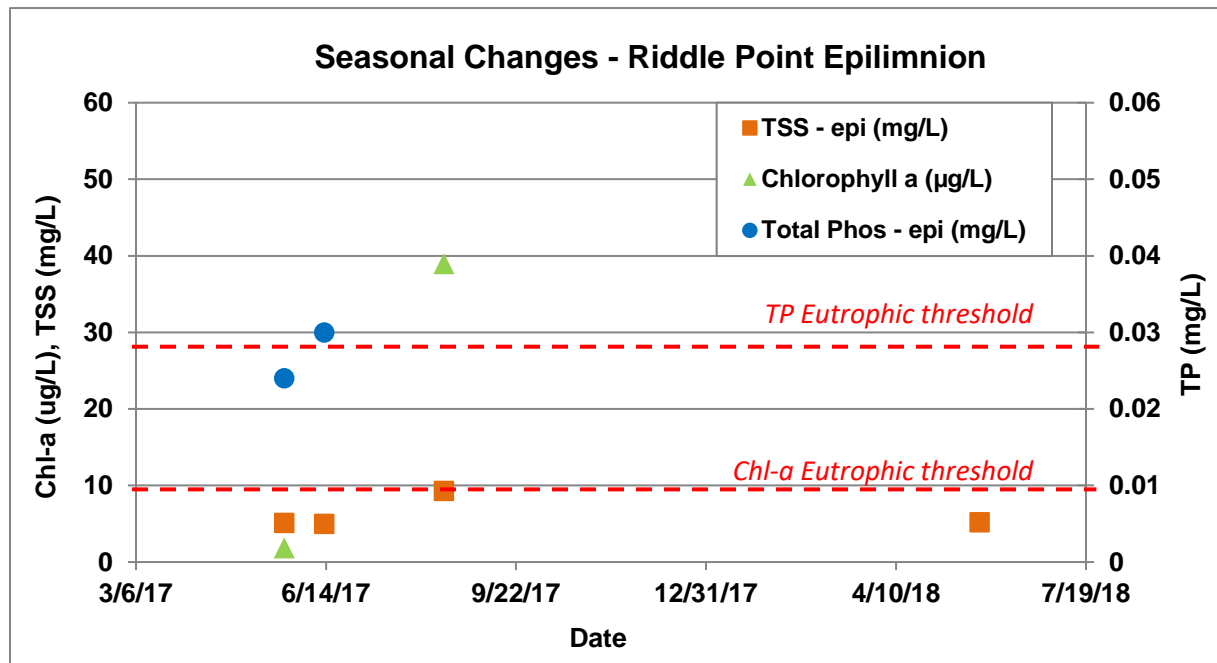


Figure 3. Seasonal changes in total phosphorus, total suspended solids, and chlorophyll-*a* in the surface waters (epilimnion) at Riddle Point in Lake Lemon in 2017-2018. (2018 only includes TSS)

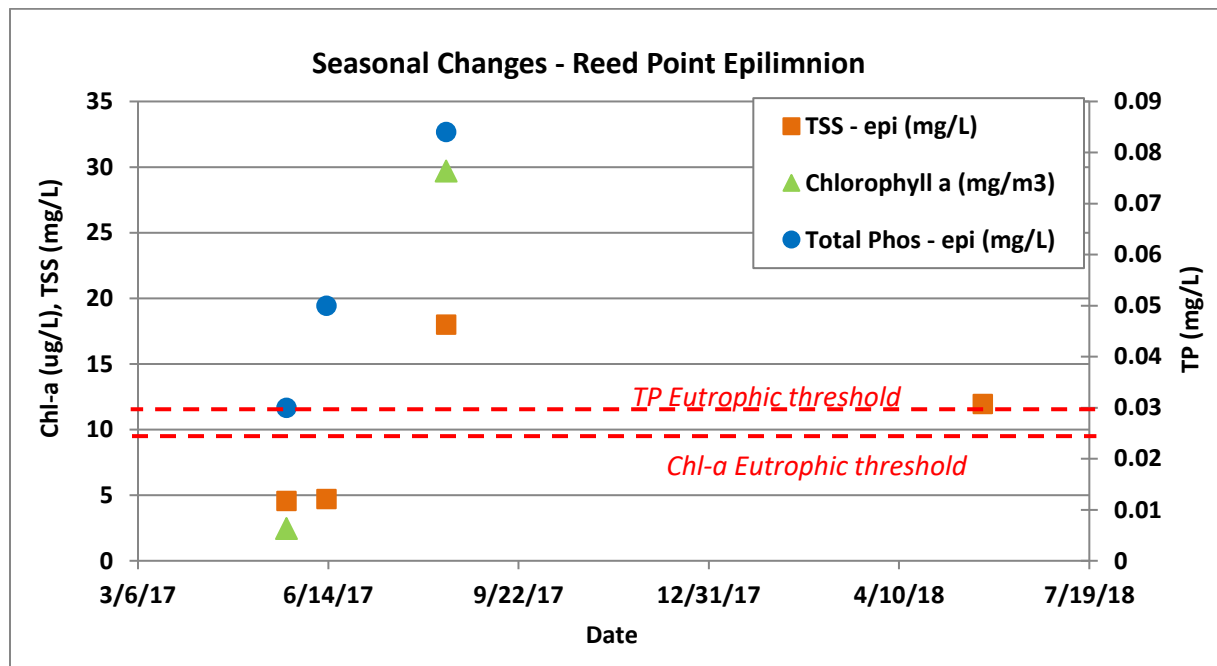


Figure 4. Seasonal changes in total phosphorus, total suspended solids, and chlorophyll-*a* in the surface waters (epilimnion) at Reed Point in Lake Lemon in 2017-2018. (2018 only includes TSS)

Tributary Samples of total suspended solids (TSS) and *E. coli* were collected in 2017. Additional *E. coli* and TSS samples were collected during lake sampling events. Increased precipitation in the spring of 2017 lead to high bacteria concentrations and increased turbidity. The state standard for full body contact and recreation is 200 colonies per 100mls. In 2018 turbidity a measure of suspended material in the water will be collected in place of TSS as it is a direct correlation to the measurement.

Table 4. Total suspended solids and *E. coli* for 2017 and 2018.

	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)	TSS (mg/L)	TSS (mg/L)	TSS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Turbidity (NTU)
	4/28/17	4/29/17 (Storm)	5/23/17	6/13/17	8/15/17	5/24/18	6/14/18 (Storm)	4/29/17 (Storm)	5/23/17	6/13/17	8/14/17	5/24/18	6/14/18 (Storm)
Riddle Point	\	\	10	0	4	\	\	\	5.1	5.0	9.3	3.42	\
Reed Point	\	\	40	8	0	\	\	\	4.3	4.7	18	3.78	\
Chitwood #1	30	11,100	110	12	30	790	4,000	\	\	5.3	33	12.5	17.9
Chitwood #2	\	4,600	130	24	28	92	1,100	\	\	2.7	22	8.1	13.4
Chitwood Channel	80	4,000	840	85	100	800	2,100	\	\	11.0	44	10.9	52.1
Chitwood Stream	640	1,200	1,770	490	320	550	3,300	\	\	\	\	3.73	202
Beanblossom Creek	\	4,100	660	20	40	68	5,100	317	8.0	4.6	6.3	4.09	32
Bear Creek	\	2,500	260	2,160	84	350	8,800	270	1.6	4	6.7	5.2	110
Knobb Creek	\	1,900	320	900	\	\		231	0.5	0.5	6.4		
Knobb Creek (Adjusted 2017)	\	1,600	2060	830	\	630	10,000	\	\	1.5	\	37.5	220

*Knobb Creek (Adjusted 2017) had no water during August sampling in 2017. The stream flowing into the Chitwood area from across the road was very low during August sample event.

In order to help identify the problem areas for bacteria and sediment, multiple sampling sites have been added for the 2017 and 2018 monitoring season (Figure 5). Site selection was done in collaboration with the District Manager in an attempt to address concerns of citizens and to identify solutions for bacteria challenges. Results of the bacteria intensification can be seen in figure 6 and 7. Storm events on 4/29/2017 and 6/14/2018 show worst case scenarios for bacteria. These concentrations are well over full body contact standards during many sampling events.



Figure 5. Sampling locations for the Lake Lemon Water Monitoring Program for the Chitwood area for 2017 and 2018.

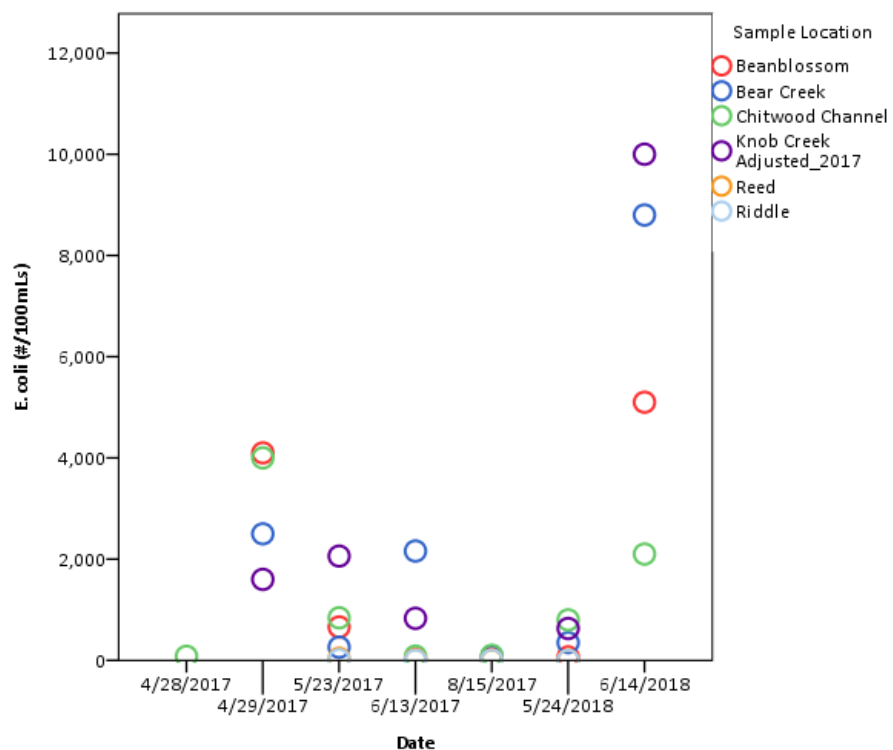


Figure 6. Seasonal changes in *E. coli* concentrations in lake and tributary samples of Lake Lemon in 2017 and 2018. Samples collected on 4/28/2017 are for baseline data before storm and only included the Chitwood area. Samples collected on 4/29/2017 and 6/14/2018 are storm samples.

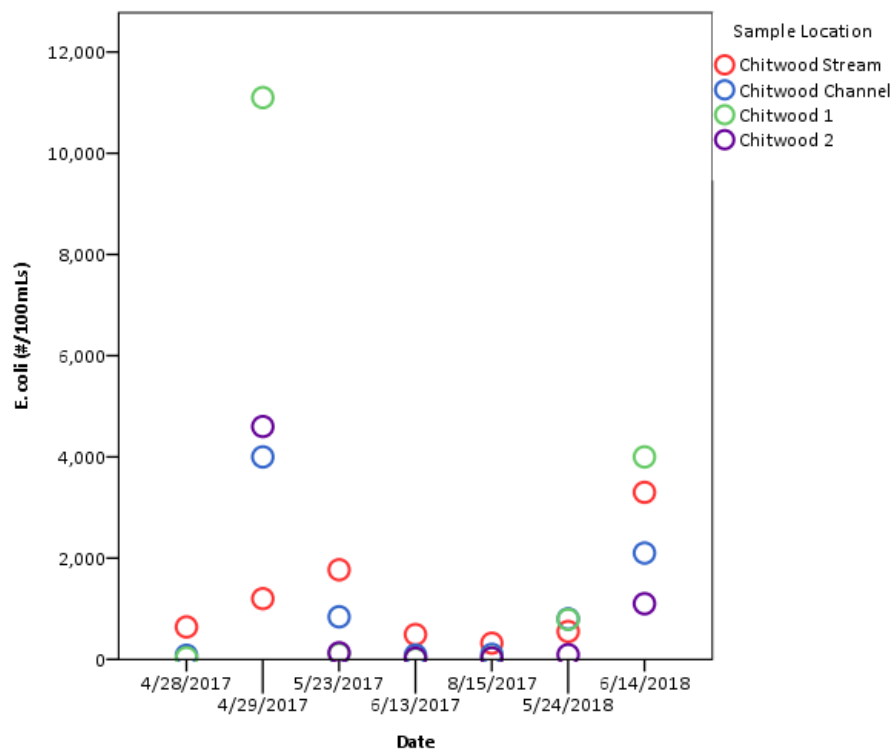


Figure 7. Seasonal changes in *E. coli* concentrations in Chitwood area as part of the Lake Lemon watershed in 2017 and 2018. Note that 4/29/2017 and 6/14/2018 indicate storm events.

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.

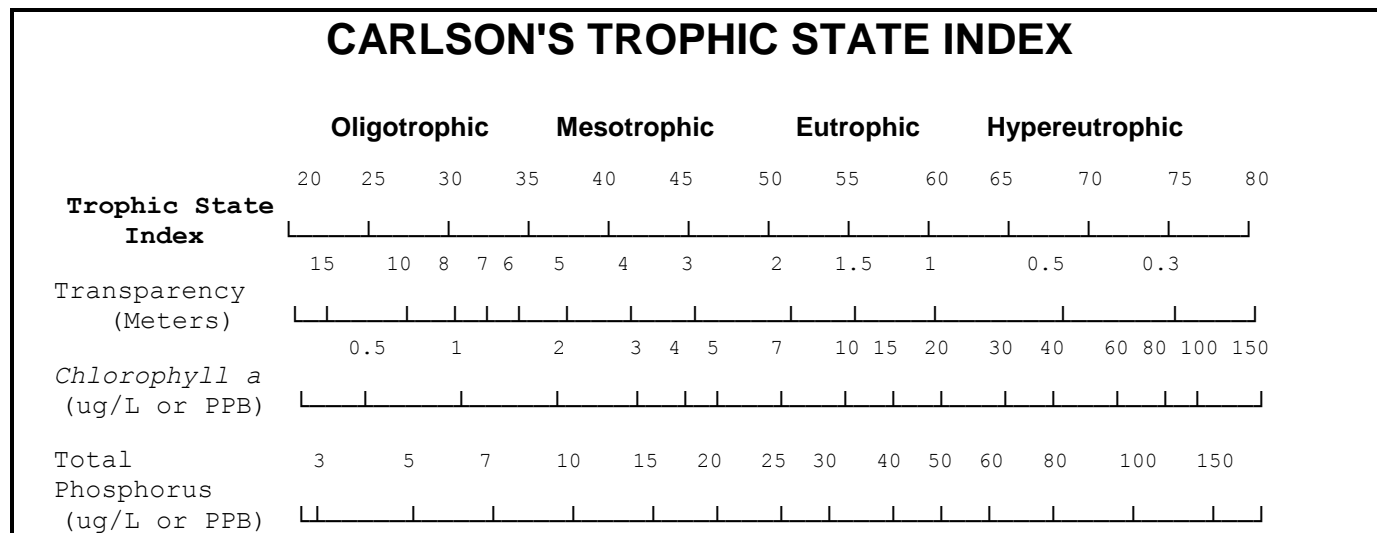


Figure 8. Carlson's trophic state index.

Table 6. Characteristics of trophic state categories.

Classification	Transparency	Nutrients	Algae	D.O.	Fish
<i>Oligotrophic</i>	clear	Low TP < 6 µg/L	few algae	Hypo has D.O.	can support salmonids (trout and salmon)
<i>Mesotrophic</i>	Less clear	Moderate TP 10-30 µg/L	healthy populations of algae	Less D.O. in hypo	lack of salmonids
<i>Eutrophic</i>	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.
<i>Hypereutrophic</i>	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.

Using Riddle Point Carlson TSI scores to look at the historic trend for Lake Lemon shows that the lake is generally characterized as eutrophic. Figures 9-11 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.

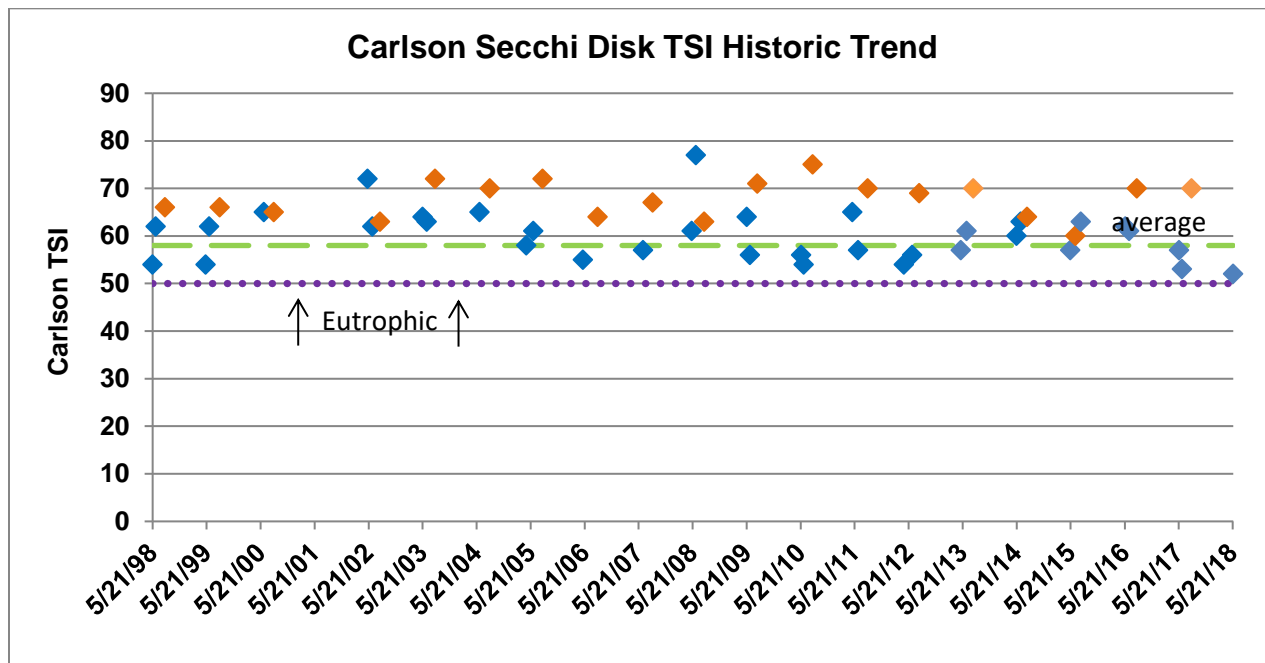


Figure 9. The 20-year historic trend for Carlson Secchi disk TSI scores. Orange represents the August samples. The green dashed line illustrates the 1-year mean. The purple dotted line illustrates eutrophic status for the Carlson TSI.

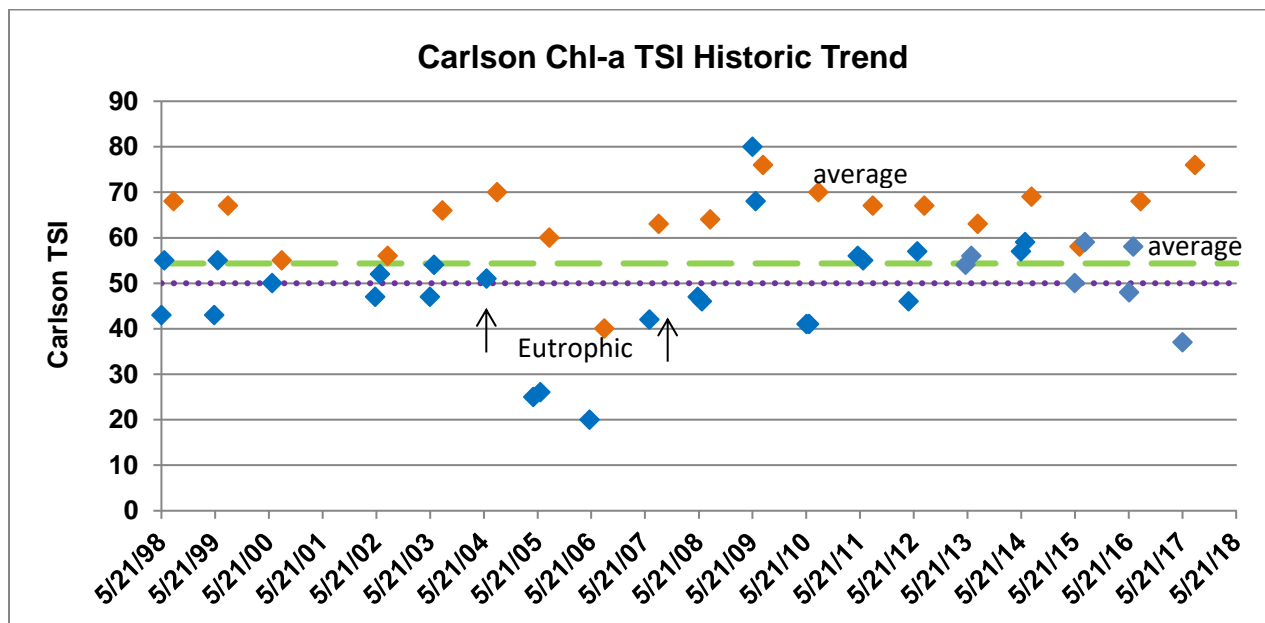


Figure 10. The 19-year historic trend for Carlson chlorophyll-*a* TSI scores. Most August samples, shown in orange, score above the mean for eutrophic status. The 19-year mean is just above the Carlson TSI eutrophic status score of 50 (purple dotted line). Does not include 2018 data.

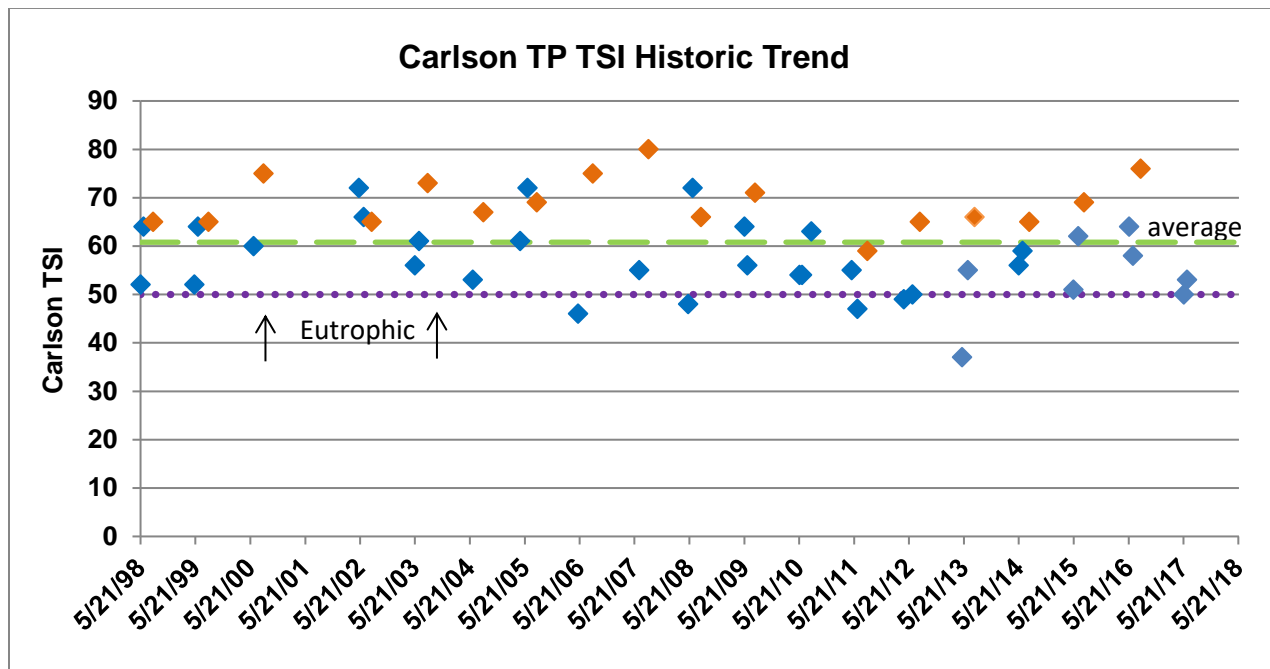


Figure 11. The 19-year historic trend for Carlson total phosphorus TSI scores. All August samples, shown in orange, score above the mean for eutrophic status. The green dashed line illustrates the 19-year mean. The purple dotted line illustrates eutrophic status for the Carlson TSI. Does not include 2018 data.

In late August and early September of 2016, “rust colored water” in the one of the overflow ponds was reported to IU. IU collected plankton samples from the surface of the pond and determined it was a *Cylindrospermopsis* bloom, a type of blue-green algae that is known to produce harmful algal toxins (more information at <http://www.in.gov/dnr/fishwild/3630.htm>). *Cylindrospermopsis* was found in the lake in 2005 at high concentrations; however it did not produce toxins during that bloom. Due to concerns of this algae and the frequent use of the overflow ponds by anglers, samples are being collected from the overflow pond (Figure 12) for chlorophyll-a and plankton throughout the summer. In the summer of 2017 the chlorophyll-a concentration was 150 µg/L respectively. *Cylindrospermopsis* was dominant in the water samples collected in July and August of 2017, but were not present in the May sample of 2018. We will continue to monitor and update the Lake Manger as we collect more information.

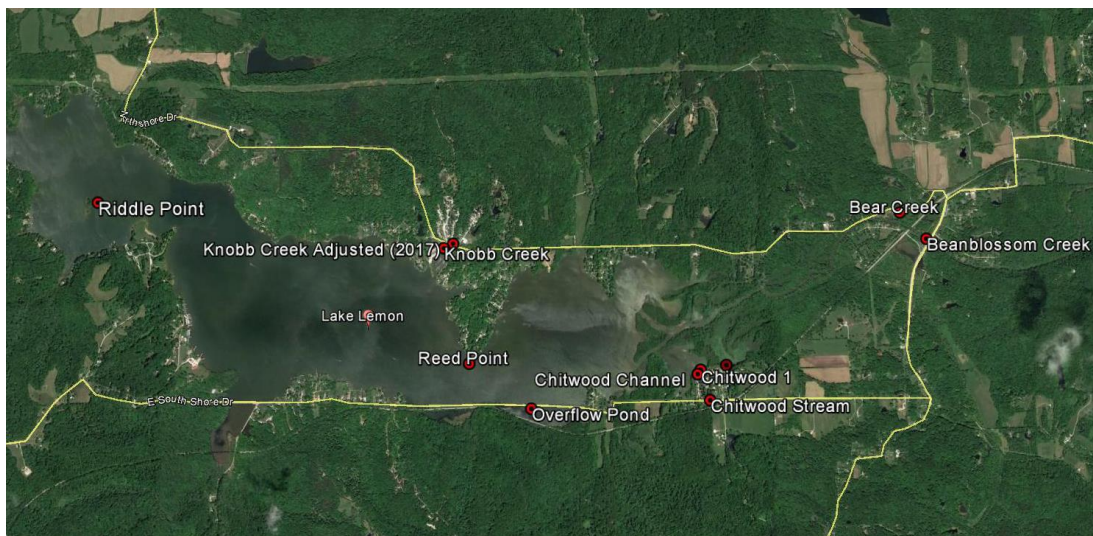


Figure 12. Sampling locations for the Lake Lemon Water Monitoring Program for the Chitwood area for 2017 and 2018.

Lake Lemon Water Monitoring Conclusions and Recommendations

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