



# ARION CONSULTANTS

3 September 2019

RE: Little Crooked Lake Assessment 2019

Arion Consultants assessed Little Crooked Lake on August 22, 2019 collecting data to calculate the Indiana TSI and complete dissolved oxygen and temperature profiles.

The temperature profile measured on August 22, 2019 shows that Little Crooked Lake was stratified at the time of sampling (Figure 1). During thermal stratification, the bottom waters (hypolimnion) of Little Crooked Lake are isolated from the well-mixed epilimnion (surface waters) by temperature-induced density differences. The boundary between the two well-mixed zones where temperature changes most rapidly depth is called the metalimnion.

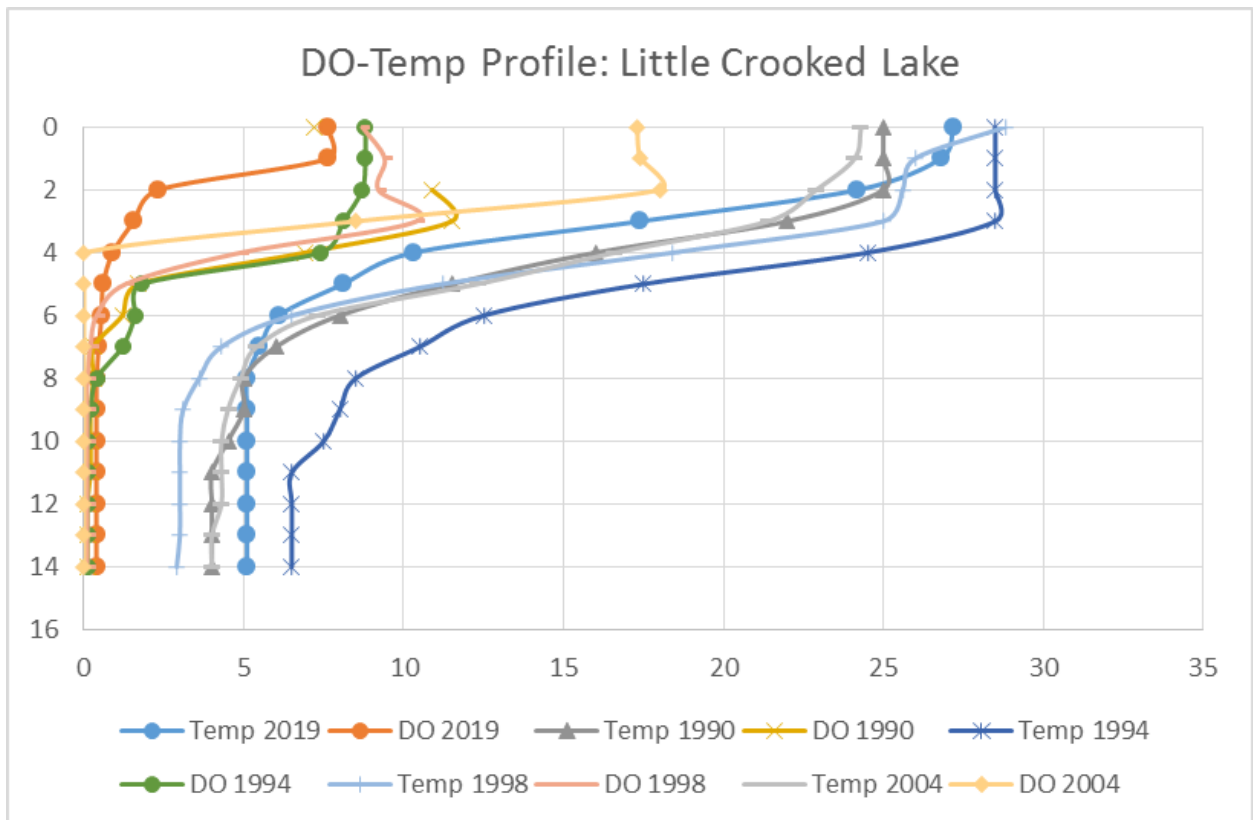


Figure 1. Dissolved oxygen-temperature profiles for Little Crooked Lake.

The dissolved oxygen profile collected mirrors the temperature profile and is general consistent with historic dissolved oxygen profiles measured in Little Crooked Lake with dissolved oxygen



8802 W. Washington St.  
Indianapolis, IN  
46231

Phone (765) 337-9100  
E-mail [speel@arionconsultants.com](mailto:speel@arionconsultants.com)  
Web [www.arionconsultants.com](http://www.arionconsultants.com)



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dropping to 0 mg/L between 4 and 6 meters (Figure 1). During the 2019 assessment, a large volume of the water column was insufficiently oxygenated leaving only 21% of the water column fully oxygenated. More than 80% of the water column was anoxic (dissolved oxygen measured 0 mg/L).

**Indiana TSI:** The Indiana Trophic State Index was developed by the Indiana Stream Pollution Control Board and published in 1986 (IDEM, 1986). The original ITSI differed slightly from the one in use today. Today's ITSI uses ten different water quality parameters to calculate a score. The 2019 assessment results in an ITSI score of 44, which rates as eutrophic. The majority of trophic points originate from the high plankton density (20 points). The majority of algae present are chlorella, a single-cell, colony-forming green algae. Additional points are due to the poor water transparency, low levels of dissolved oxygen in the lake's deeper waters, and high levels of total phosphorus and ammonia-nitrogen in the lake's deeper waters.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
Secchi Depth Transparency	3.5 feet		6
Light Transmission @ 3 ft.	42%		3
1% Light Level	4.1		
% Saturation @ 5 ft.	92%		0
Total Phosphorous	0.07 mg/L	0.41 mg/L	4
Orthophosphate	0.04 mg/L	0.29 mg/L	3
Nitrate-Nitrogen	0.2 mg/L	0.3 mg/L	0
Ammonia-Nitrogen	0.4 mg/L	4.2 mg/L	4
Organic Nitrogen	0.04 mg/L	0.40 mg/L	0
% Water Column Oxidic	21%		4
Plankton Density	430,556		20
Blue-Green Dominance	13%		0
Chlorophyll <i>a</i>	58 ug/L		--
			44

eutrophic

**Carlson's TSI:** Because the Indiana TSI has not been statistically validated and because of its heavy reliance on algal parameters, the Carlson TSI may be more appropriate for evaluating Indiana lake data. Developed by Bob Carlson (1977), the Carlson TSI is the most widely used and accepted TSI. Carlson analyzed summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among



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the three parameters. He developed mathematical equations for these relationships, and these relationships form the basis for the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll a, or total phosphorus. Data for one parameter can also be used to predict a value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass (Figure 1).

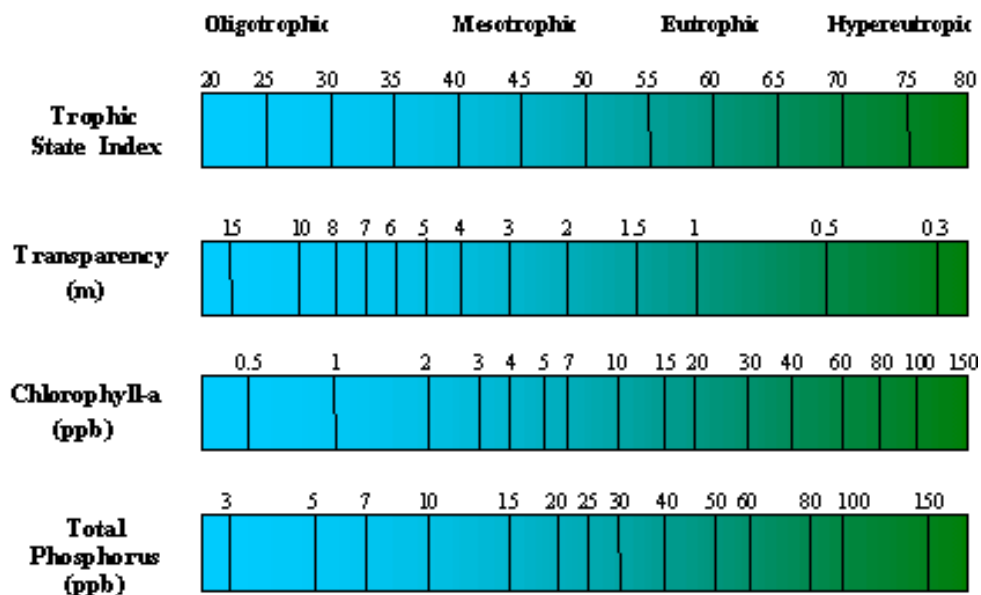


Figure 1. Carlson's Trophic State Index.

Analysis of Little Crooked Lake's total phosphorus Carlson's TSI score (83) suggests Little Crooked Lake is hypereutrophic, while the transparency score (58) indicates Little Crooked Lake is eutrophic and the chlorophyll a score (70) suggests that the lake eutrophic to hypereutrophic. This analysis is relatively consistent with the results obtained when comparing the Little Crooked Lake data to the Indiana TSI data, which suggested Little Crooked Lake is eutrophic.

**Comparison with Other Indiana Lakes:** The Lake Clearwater results can also be compared with other Indiana lakes. Table 1 presents data from 355 Indiana lakes collected during July and August from 1994 to 2015 under the Indiana Clean Lakes Program. The set of data summarized in the table are mean values obtained by averaging the epilimnetic and hypolimnetic pollutant concentrations in samples from each of the 355 lakes. The table is then populated with the minimum mean sample, maximum mean sample, and median sample for all lakes. It should be noted that a wide variety of conditions, including geography, morphometry, time of year, and



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watershed characteristics, can influence the water quality of lakes. Thus, it is difficult to predict and even explain the reasons for the water quality of a given lake.

**Table 1. Little Crooked Lake water quality compared with water quality characteristics of 355 Indiana lakes sampled from 1994 through 2015 by the Indiana Clean Lakes Program. Means of epilimnion and hypolimnion samples were used for all nitrogen and phosphorus parameters. Squares shaded yellow denote those values in excess of the median lake concentration.**

	Secchi Disk (ft)	NO <sub>3</sub> (mg/L)	NH <sub>4</sub> (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	Chl a (µg/L)
Minimum	0.3	0.013	0.018	0.230	0.010	0.010	1.33
Maximum	52.5	21.124	32.677	4.894	2.844	4.894	380.4
Median	5.6	0.028	0.063	1.069	0.010	0.051	4.92
Little Crooked Lake	3.5	0.25	2.3	0.22	0.17	0.24	58

Overall, Little Crooked Lake possesses water quality poorer than most lakes in Indiana. Little Crooked Lake's Secchi disk transparency measured poorer than the Indiana median. While nitrate-nitrogen measured above median concentrations, concentrations are overall relatively low. Phosphorus is typically the limiting nutrient in aquatic systems, and orthophosphorus and total phosphorus concentration measure above the median for Indiana lakes. Total phosphorus concentrations are especially high in the lake's bottom waters. Chlorophyll *a* concentrations measure above the median concentration for Indiana lakes. Despite the high plankton density, blue-green algae comprised a very small component of Little Crooked Lake's plankton population with green algae the dominant algae.

**Comparison with Historic Data:** Data collected from Little Crooked Lake in 2019 indicate little change over time. Both nitrogen and phosphorus concentrations collected during the spring and summer measured within ranges historically found within Little Crooked Lake. While nitrate-nitrogen concentrations were lower than historical concentrations, these changes are not significant. Chlorophyll *a* concentrations measured in the main lake in the spring were higher than historic averages; however, this sampling occurred following a significant rain which resulted in a green algae bloom. Concentrations measured during the summer sampling were on par with historic average chlorophyll *a* concentrations.



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**Table 2. Little Crooked Lake's Clean Lakes Program sample data and 2019 data compared with 355 Indiana lakes sampled from 1994 through 2015 by the Indiana Clean Lakes Program.**

	Secchi Disk (m)	NO <sub>3</sub> (mg/L)	NH <sub>4</sub> (mg/L)	TKN (mg/L)	TP (mg/L)	SRP (mg/L)	Chl-a (µg/L)
Median	1.7	0.028	0.063	1.069	0.051	0.010	4.92
Maximum	16	21.124	32.677	41.461	4.894	2.844	380.38
Minimum	0.1	0.013*	0.018*	0.230*	0.010*	0.010*	1.33*
L. Crooked Lake 1990	2.9	0.643	1.525	1.404	0.351	0.401	--
L. Crooked Lake 1994	3.5	0.178	2.905	3.184	0.912	0.604	4.09
L. Crooked Lake 1998	2.7	0.022	3.609	4.150	1.294	0.785	4.06
L. Crooked Lake 2004	0.9	0.013	3.113	4.901	0.945	0.699	21.62
L. Crooked Lake 2019	1.1	0.250	2.300	0.220	0.240	0.170	58.00

\*laboratory detection level.

Data collected from Little Crooked Lake indicate lower than typical total and dissolved phosphorus concentrations. Ammonia-nitrogen and total Kjeldahl nitrogen also measure lower than typical levels for Little Crooked Lake; however, nitrate-nitrogen concentrations exceed historic numbers in Little Crooked Lake. Little Crooked Lake's plankton community has historically been dominated by blue-green algae. In 2019, the community was dominated by green algae. The presence of chlorella, a single-cell, colony-forming green algae is apparent in the high chlorophyll a concentration present in Little Crooked Lake at the time of sampling.



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