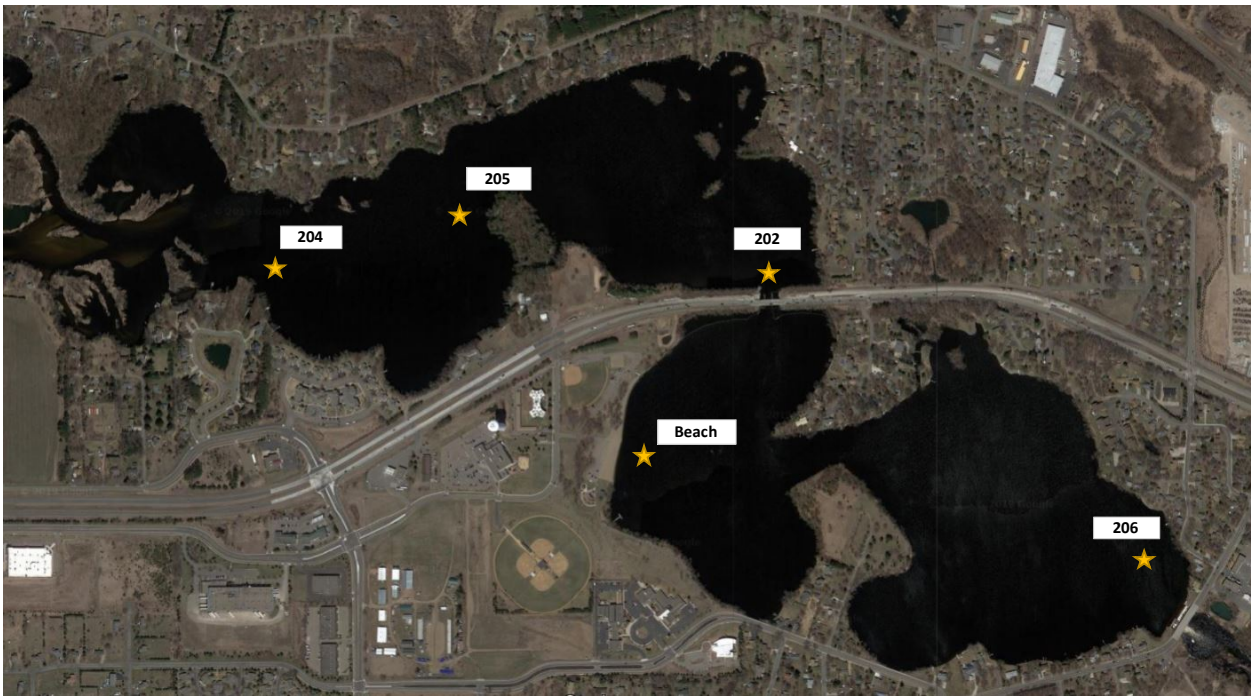
2019 Lake Orono Water Quality Monitoring Summary

Data collected by Lake Orono Improvement Association volunteers
Report by Sherburne Soil & Water Conservation District, Jan 2020

Phosphorus, Chlorophyll-a

In 2019, trained volunteers with the Lake Orono Improvement Association collected water quality in several locations on Upper and Lower Lake Orono. The map below shows the approximate sampling locations.

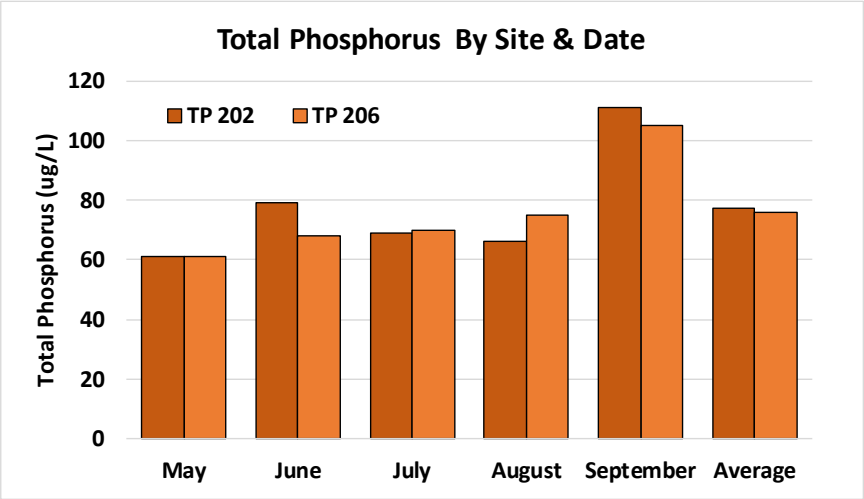


The following parameters were collected in 2019:

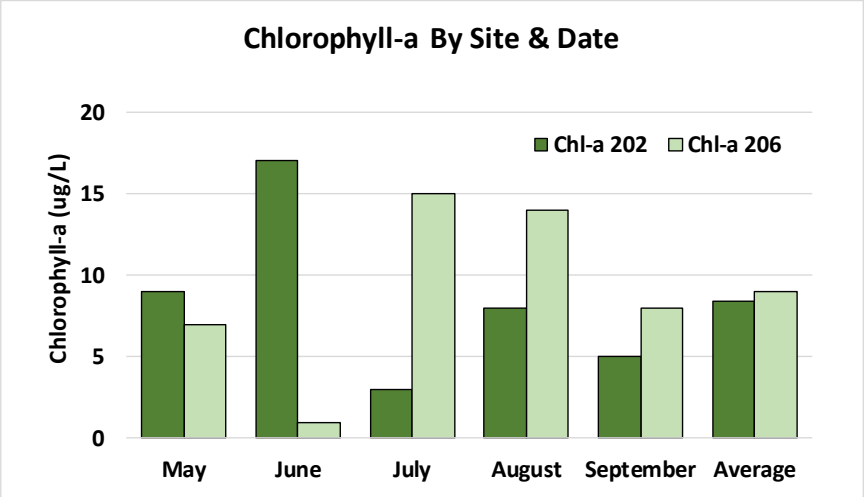
- Total Phosphorus: monthly May-Sept, Sites 202 and 206
- Chlorophyll-a: monthly May-Sept, Sites 202 and 206
- Secchi Disk Clarity: monthly May-Sept, Sites 204,205,202 and 206
- Dissolved Oxygen: five times June-Sept, Sites 204,205,202, Beach and 206
- Temperature: five times June-Sept, Sites 204,205,202, Beach and 206

The next few pages display the collected data graphically and provides short interpretations on the relationships observed between these parameters. Datasets are provided in Appendix A.

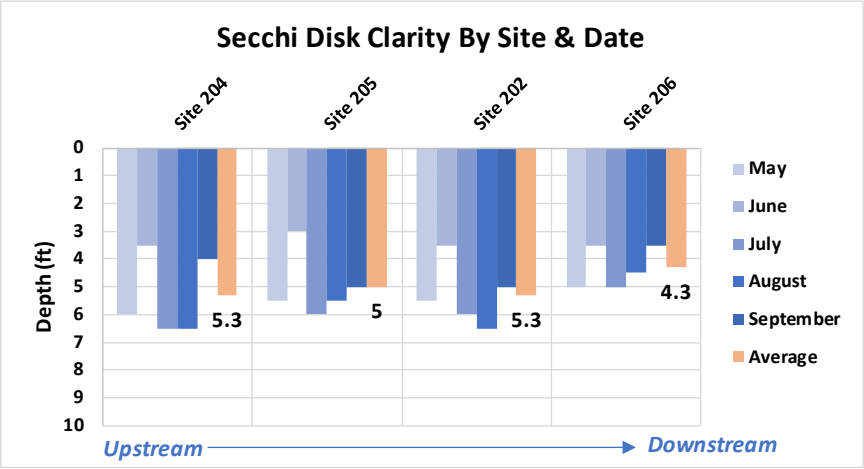
Phosphorus, Chlorophyll-a and Secchi Disk Clarity 2019 Trends



Total phosphorus content remained fairly consistent between upstream and downstream sites in 2019. The shallow lake standard is 60 ug/L, which was exceeded every month. The river standard for the Elk River is 100 ug/L.

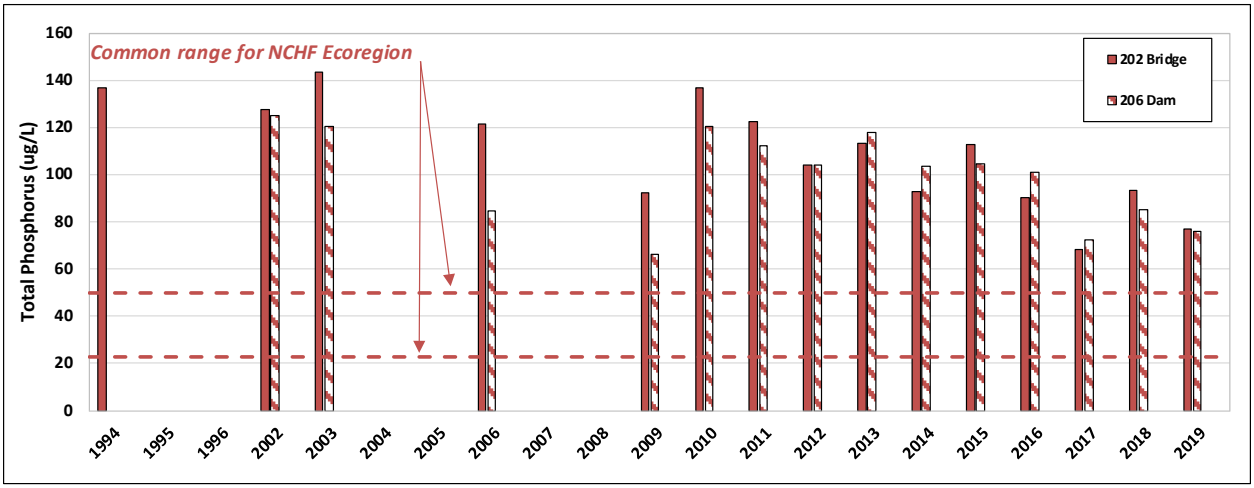


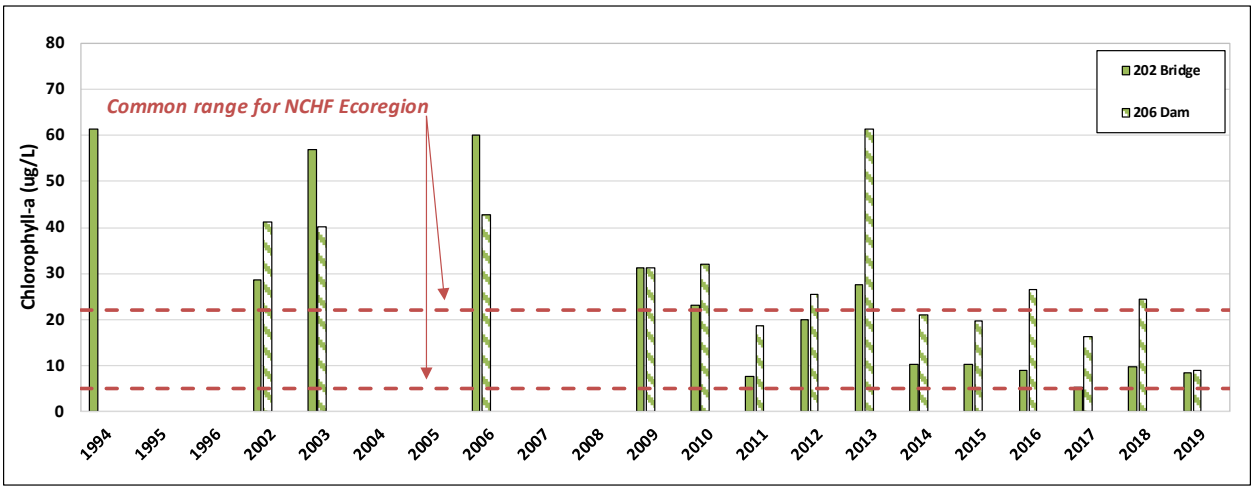
Chlorophyll-a varied greatly in June, July and August and moderately in May and September. Overall, the average algae content is similar between site locations. 2019 was the wettest year on record – one explanation for observed differences could be the flushing of algae from upstream waters during certain time periods.

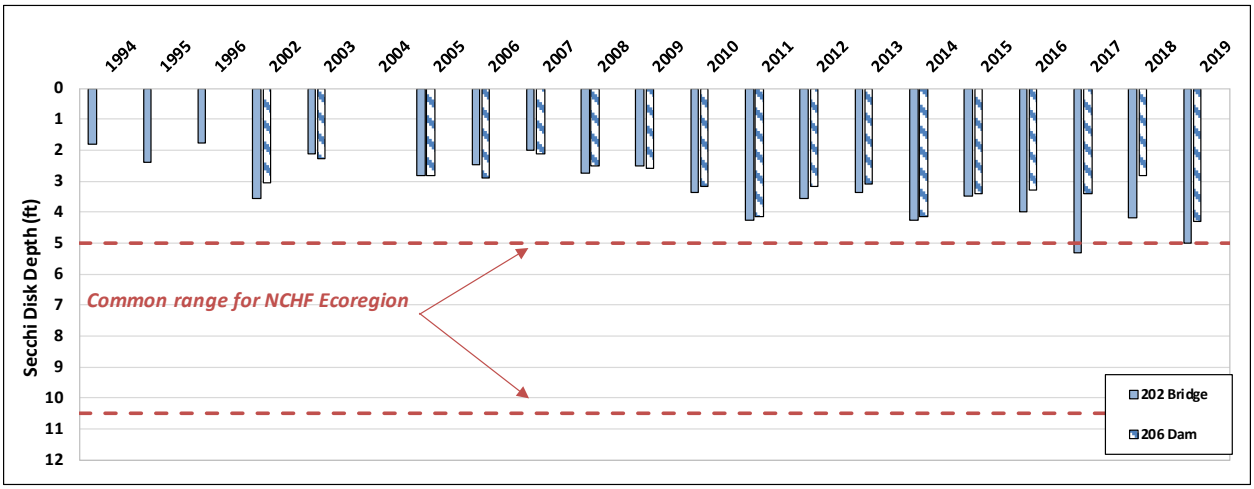


Secchi disk clarity followed a similar monthly trend at the four sites in which it was monitored. The three sites in the upper basin (204, 205, 202) held slightly better clarity in 2019 than the lower basin site (206)

Phosphorus, Chlorophyll-a and Secchi Disk Clarity Long-Term Trends





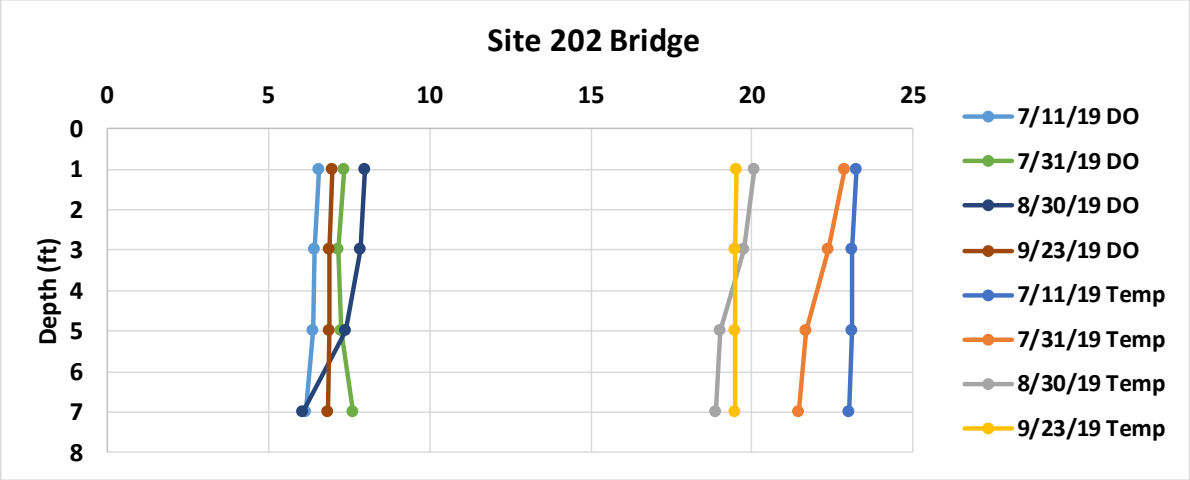


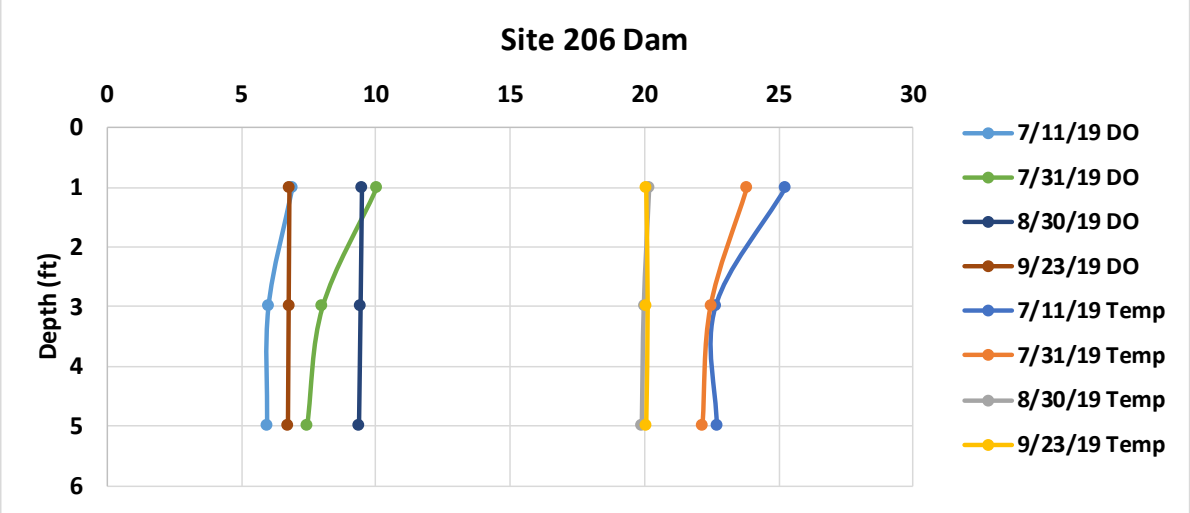
Water quality continues to show improvements in Lake Orono, given by decreasing trends in phosphorus and chlorophyll-a for both basins, and gradually increasing Secchi disk clarity. Common ranges for regional lakes are included in each chart above (red dashed lines). Lake Orono standards for the three parameters are 60 ug/L (phosphorus), 20 ug/L (chlorophyll-a) and 3.3 ft (Secchi disk).

Dissolved Oxygen and Temperature 2019 Trends

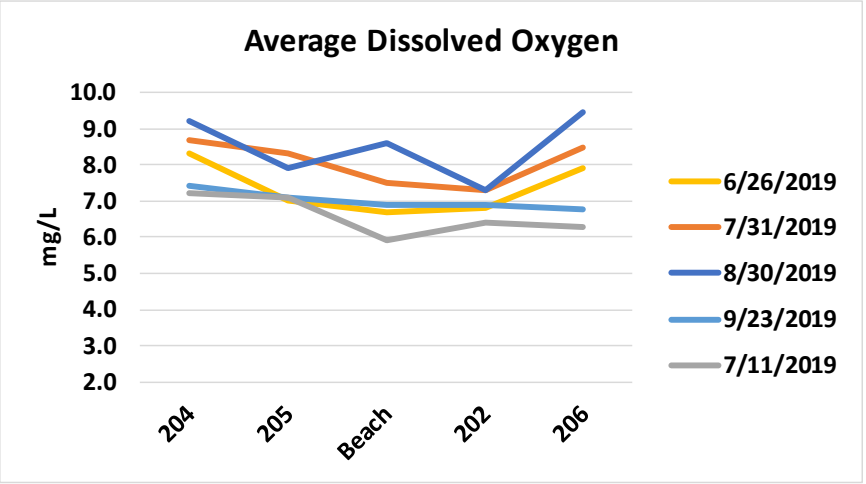
These parameters are collected in what is termed a "profile". In other words, at the same sampling multiple measurements are made at the surface, mid-depth and bottom of the water column to determine if changes are occurring with depth. The charts below show both dissolved oxygen in mg/L ("DO") and temperature in degrees C ("temp") on the same graph for two sites (202 and 206). These graphs indicate that there was very little difference from surface to bottom with regards to these parameters during each sampling event. On deep lakes with no or little flow-through, there can be wide variances in temperature or oxygen from the surface to the bottom. Due to Orono's shallow depth and high flow-through rate from the Elk River, the lake likely experiences very little stratification in temperature or oxygen.

<u>Water column dissolved oxygen and temperature for Site 202 and 206</u>

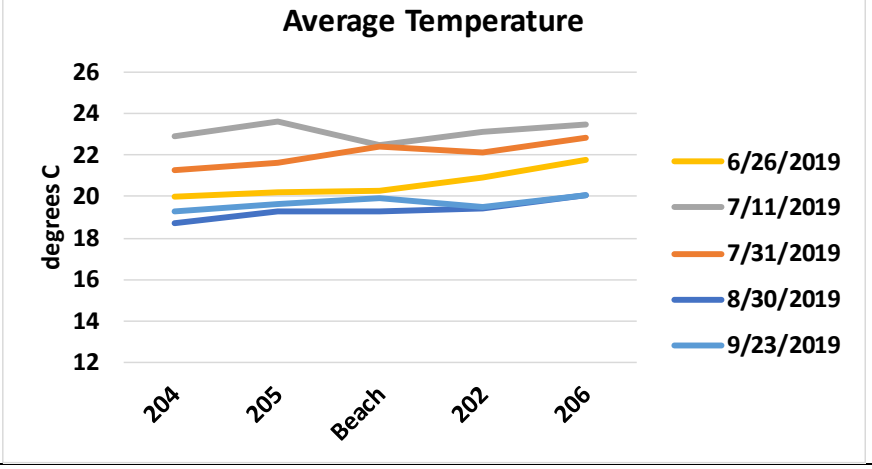




Average dissolved oxygen and temperature by site, 2019



Dissolved oxygen fluctuated a bit between sites, but not substantially. Oxygen was not observed to decrease below 5.7 mg/L on any occasion – below 2.0 mg/L would be problematic for some fish species and may begin to facilitate anoxic release of phosphorus from sediments.



Temperature did not fluctuate much between sites in 2019. Some of the warmest temperatures were seen in July (21 C-22 C or 70 F-74 F) while somewhat colder temperatures were seen in August and September. High precipitation may have moved fresh, colder water in to the lake in the summer months.

Conclusions:

1. Dissolved Oxygen
    a. Almost no variance in dissolved oxygen occurred within the water column at each site. Oxygen fluctuations may occur on more of a diurnal basis as opposed to a seasonal basis. Diurnal fluctuations are due to the sun's cycle, which regulates algae and oxygen production. Oxygen concentrations may decrease during the night, but this is difficult to capture with standard monitoring equipment and may not be too impactful on Lake Orono's conditions.
    b. In general, the furthest upstream site (204) was observed to have dissolved oxygen roughly 0.5 mg/L higher than the furthest downstream site (206). This is a fairly small and almost negligible difference, but is consistent with each of the sampling time periods. A higher amount of biological oxygen demand could be expected in the lower basin of Lake Orono due to higher organic matter and less movement of water. Also, moving water and colder water (see bullet point 2 below) can physically hold higher oxygen content.

c. Future monitoring of dissolved oxygen likely is not necessary as this study indicates fluctuations in the water column will be difficult to measure through traditional sampling means.

2. Temperature
    a. A difference in temperature by site was not expected as it is known the lake flushes itself very quickly (every 3-4 days) so water turnover is high.
    b. Temperature showed little variance between sites and varied by 5°C to 6°C over the course of the summer.
    c. The temperature was on average about 1.0°C higher at the downstream site (206) compared to the furthest upstream site (204). This was not unexpected – the Elk River collects water from several tributaries which receive some groundwater input (colder water). Water slows as it enters Lake Orono and sits in the sun for several days before discharging over the dam and thus, it warms slightly during this time.
    d. It is known that temperature impacts the growth of algae; most algae will increase their growth rate with an increase in temperature up to an optimum temperature level, which varies with each species of algae. A commonly reported range for algae cultures (in a lab) is between 16°C and 30°C, optimum temperatures are sometimes reported at 20°C to 24°C. It is suspected, but difficult to say with certainty, that a difference of 1°C from upper to lower Lake Orono would make a measurable difference in algae content on a lakewide basis. Additionally, there could be other factors to consider. Algae content varied from upper to lower Lake Orono greatest in June July and August.
    e. Future monitoring of temperature could be done but may not prove useful as demonstrated differences are negligible throughout the water column and minimal between sites.
3. Phosphorus
    a. Phosphorus concentrations were similar between the upper and lower basins of Lake Orono during each sampling event and as a seasonal average.
    b. There was no observed correlations between phosphorus data and the data collected for dissolved oxygen and temperature.
    c. While 2019 Lake Orono phosphorus concentrations exceeded the state standard of 60 ug/L, long term trend data indicates a steady decrease in average annual concentrations for both basins of the lake.
4. Chlorophyll-a
    a. Concentrations varied greatly on three occasions and moderately on the remaining two sampling events. Concentrations were found to be higher in the upper basin of Lake Orono in May and June, and higher in the lower basin in July, August and September. The annual average for the summer between two basins is nearly equal.
    b. The LOIS has observed differences in chlorophyll-a between the upper and lower basins for a number of years. On numerous occasions, the lower basin has held a higher average concentration than the upper basin. There are a number of identified potential factors for this difference, including temperature, dissolved oxygen, presence of aquatic plants and zooplankton, precipitation/runoff and timing of sample collection, flushing or pulses of algae from upstream waters and timing of sample collection, irregular flow within the lake, and others. It is assumed there is no sample collection or laboratory error.

c. The reason for the difference in upper and lower Lake Orono chlorophyll-a remains uncertain after this study. Each year is variable, and this year saw some differences between basin on individual collection dates but a very similar average for the summer. The collected data indicate that temperature and dissolved oxygen content may not play a significant role in this process, but the data is also a "snapshot" in what occurs within the lake.
d. Should the LOIA or City of Elk River wish to investigate this difference further, advanced study might be necessary. One factor to consider might be the presence of zooplankton in the upper versus lower basis. Zooplankton feed on algae, so high numbers of zooplankton could diminish algae (and thus result in a lower chlorophyll-a value). The upper basin of the lake, with confirmed higher quantities of aquatic vegetation, could hold higher zooplankton populations as the zooplankters have adequate refuge to hide from prey (fish). In the lower basin, which is generally deeper and less vegetated, zooplankton are exposed to prey and thus have a smaller population size. A comparative analysis of zooplankton populations by basin may give substance to this theory.
e. The upper basin of Lake Orono has met the state standard for chlorophyll-a in each of the past six years, while the lower basin has met this standard for 4 of the 6 past years (including 2019).

5. Secchi Disk Clarity
    a. Clarity varied by month but followed a consistent general trend by site, regardless of chlorophyll-a concentration. These two parameters, often correlated, had a very weak correlation in 2019.
    b. It is possible that other factors are influencing the clarity of the water. Any type of "solids" in the water can influence its clarity. Solids can include non-dissolved minerals, sediments, organic matter and algae. An additional factor for water clarity is the dissolved components that stain the water. This is similar to coffee grounds staining water, or a tea bag staining water. Organic material in the watershed may dissolve to produce a discoloration of the water.
    c. The LOIA or City of Elk River could investigate adding two water chemistry parameters to their 2020 sampling regime – True Color and Total Suspended Solids. Data from these parameters might shed light on how other factors besides chlorophyll-a are influencing the clarity of the water in the lake.

Appendix A: Compiled Water Quality Monitoring Data

Site 206 Dam	6/26/19 Temp	6/26/19 DO	7/11/19 Temp	7/11/19 DO	7/31/19 Temp	7/31/19 DO	8/30/19 Temp	8/30/19 DO	9/23/19 Temp	9/23/19 DO
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
1			25.22	6.92	23.79	10.02	20.2	9.51	20.07	6.81
2										
3			22.63	6.02	22.46	8.02	19.98	9.45	20.08	6.78
4	21.79	7.92								
4.5										
5			22.68	5.97	22.17	7.45	19.9	9.38	20.07	6.75
6										
7										
Average	21.8	7.9	23.5	6.3	22.8	8.5	20.0	9.4	20.1	6.8

Site 205	6/26/19 Temp	6/26/19 DO	7/11/19 Temp	7/11/19 DO	7/31/19 Temp	7/31/19 DO	8/30/19 Temp	8/30/19 DO	9/23/19 Temp	9/23/19 DO
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
1			23.73	7.34	21.71	8.26	19.18	8.29		7.19
2	20.16	6.98								
3			23.57	7.09	21.52	8.31	19.17	8.26	19.61	7.10
4			23.48	6.91	21.5	8.3	19.61	7.19		
5										
Average	20.2	7.0	23.6	7.1	21.6	8.3	19.3	7.9	19.6	7.1

Site 204	6/26/19 Temp	6/26/19 DO	7/11/19 Temp	7/11/19 DO	7/31/19 Temp	7/31/19 DO	8/30/19 Temp	8/30/19 DO	9/23/19 Temp	9/23/19 DO
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
1			22.91	7.23	21.33	8.75	18.74	9.12	19.26	1.43*
2										
3	20.02	8.25	22.91	7.18	21.36	8.73	18.81	9.12	19.29	7.40
4					21.35	8.73	18.64	9.27		
4.5			22.94	7.17						
5										
Average	20.0	8.3	22.9	7.2	21.3	8.7	18.7	9.2	19.3	7.4

**Suspect an error in reading or documentation with this value*

Site 202	6/26/19 Temp	6/26/19 DO	7/11/19 Temp	7/11/19 DO	7/31/19 Temp	7/31/19 DO	8/30/19 Temp	8/30/19 DO	9/23/19 Temp	9/23/19 DO
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
1			23.24	6.59	22.87	7.37	20.09	7.99	19.51	6.98
2										
3			23.12	6.43	22.37	7.15	19.74	7.85	19.47	6.89
4										
4.5	20.90	6.83								
5			23.11	6.38	21.68	7.25	19.01	7.41	19.47	6.88
6										
7			23.00	6.17	21.46	7.62	18.86	6.08	19.46	6.86
Average	20.9	6.8	23.1	6.4	22.1	7.3	19.4	7.3	19.5	6.9

Beach Middle	6/26/19 Temp	6/26/19 DO	7/11/19 Temp	7/11/19 DO	7/31/19 Temp	7/31/19 DO	8/30/19 Temp	8/30/19 DO	9/23/19 Temp	9/23/19 DO
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
1			22.97	6.32	23.53	8.27	19.89	9.46	20.38	7.00
2										
3			22.28	5.7	21.8	7.23	19.03	8.22	19.75	6.83
3.5	20.31	6.7								
4			22.17	5.67	21.72	6.98	18.86	8.19	19.63	6.86
4.5										
5										
6										
7										
Average	20.3	6.7	22.5	5.9	22.4	7.5	19.3	8.6	19.9	6.9

Site 204					
Date	Chlorophyll-a	Total Phosphorus	Secchi	Avg Temp	Avg DO
5/31/2019			6		
6/26/2019			3.5	20	8.3
7/11/2019				22.9	7.2
7/31/2019			6.5	21.3	8.7
8/30/2019			6.5	18.7	9.2
9/23/2019			4	19.3	7.4

Site 205					
Date	Chlorophyll-a	Total Phosphorus	Secchi	Avg Temp	Avg DO
5/31/2019			5.5		
6/26/2019			3	20.2	7.0
7/11/2019				23.6	7.1
7/31/2019			6	21.6	8.3
8/30/2019			5.5	19.3	7.9
9/23/2019			5	19.6	7.1

Beach Site					
Date	Chlorophyll-a	Total Phosphorus	Secchi	Avg Temp	Avg DO
5/31/2019					
6/26/2019				20.3	6.7
7/11/2019				22.5	5.9
7/31/2019				22.4	7.5
8/30/2019				19.3	8.6
9/23/2019				19.9	6.9

Site 202 Bridge					
Date	Chl-a 202	TP 202	Secchi	Avg Temp	Avg DO
5/31/2019	9	61	5.5		
6/26/2019	17	79	3.5	20.9	6.8
7/11/2019				23.1	6.4
7/31/2019	3	69	6	22.1	7.3
8/30/2019	8	66	6.5	19.4	7.3
9/23/2019	5	111	5	19.5	6.9
Average	8.4	77.2			

Site 206 Dam					
Date	Chl-a 206	TP 206	Secchi	Avg Temp	Avg DO
5/31/2019	7	61	5		
6/26/2019	1	68	3.5	21.8	7.9
7/11/2019				23.5	6.3
7/31/2019	15	70	5	22.8	8.5
8/30/2019	14	75	4.5	20.0	9.4
9/23/2019	8	105	3.5	20.1	6.8
Average	9	75.8			

		Secchi disk value (ft)			
	Date	Site 204	Site 205	Site 202	Site 206
May	5/31/2019	6	5.5	5.5	5
June	6/26/2019	3.5	3	3.5	3.5
July	7/31/2019	6.5	6	6	5
August	8/30/2019	6.5	5.5	6.5	4.5
Septembe	9/23/2019	4	5	5	3.5
	Average	5.3	5	5.3	4.3
		Upstream	→		Downstream

Average Values						
Site	202	206	202	206	202	206
Year	Secchi		Chla		TP	
1994	1.8		61.3		137.0	
1995	2.4					
1996	1.8					
2002	3.5	3.0	28.5	41.2	127.4	125.2
2003	2.1	2.3	56.8	40.3	143.3	120.3
2004						
2005	2.8	2.8				
2006	2.4	2.9	60.0	42.8	121.2	84.8
2007	2.0	2.1				
2008	2.7	2.5				
2009	2.5	2.6	31.3	31.3	92.2	66.4
2010	3.3	3.1	23.1	32.0	136.5	120.5
2011	4.3	4.1	7.7	18.8	122.3	112.3
2012	3.5	3.1	20.1	25.6	104.2	104.2
2013	3.3	3.1	27.6	61.3	113.0	118.0
2014	4.3	4.1	10.3	21.0	93.0	103.5
2015	3.5	3.4	10.4	19.8	112.5	104.8
2016	4.0	3.3	9.1	26.4	90.0	100.8
2017	5.3	3.4	5.4	16.4	68.4	72.4
2018	4.2	2.8	9.8	24.4	93.4	85.2
2019	5.0	4.3	8.4	9.0	77.2	75.8
	3.2	**3.1**	**24.6**	**29.3**	**108.8**	**99.6**