Water Quality Monitoring

Ryerson Lake
2019 Water Quality Monitoring Report

Prepared for:
Ryerson Lake Improvement Board
c/o Newaygo County Drain Office
306 South North Street
P.O. Box 885
White Cloud, MI 49349

Prepared by:
Progressive AE
1811 4 Mile Road, NE
Grand Rapids, MI 49525-2442
616/361-2664

February 2020

Project No: 52190102

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Introduction

Water quality monitoring of Ryerson Lake was conducted by Progressive AE for the Ryerson Lake Improvement Board in April and August of 2019 to evaluate baseline water quality conditions in the lake. This report contains background information on the various water quality parameters sampled and a discussion of the data collected to date.

Lakes can be classified into three broad categories based on their productivity or ability to support plant and animal life. The three basic lake classifications are “oligotrophic,” “mesotrophic,” and “eutrophic” (Figure 1). Oligotrophic lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient dissolved oxygen in the cool, deep bottom waters during late summer to support coldwater fish such as trout and whitefish. By contrast, eutrophic lakes are generally shallow, turbid, and support abundant aquatic plant growth. In deep eutrophic lakes, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, these lakes can only support warmwater fish such as bass and pike. Lakes that fall between these two extremes are called mesotrophic lakes. In a recent assessment of Michigan’s lakes, the U.S. Geological Survey estimated that statewide about 25% of lakes are oligotrophic, 52% are mesotrophic and 23% are eutrophic (Fuller and Taricska 2012).

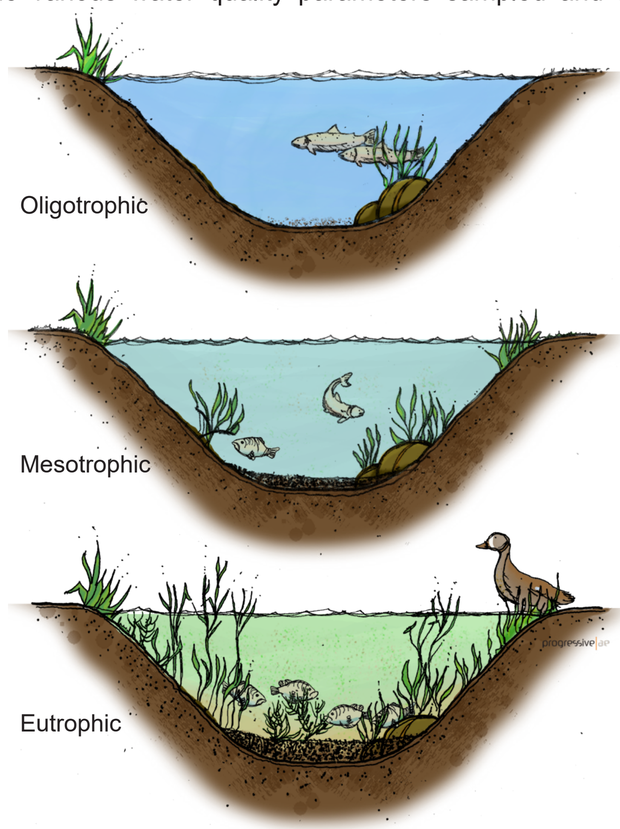

Figure 1. Lake classification.

Under natural conditions, most lakes will ultimately evolve to a eutrophic state as they gradually fill with sediment and organic matter transported to the lake from the surrounding watershed. As the lake becomes shallower, the process accelerates. When aquatic plants become abundant, the lake slowly begins to fill in as sediment and decaying plant matter accumulate on the lake bottom. Eventually, terrestrial plants become established and the lake is transformed to a marshland. The natural lake aging process can be greatly accelerated if excessive amounts of sediment and nutrients (which stimulate aquatic plant growth) enter the lake from the surrounding watershed. Because these added inputs are usually associated with human activity, this accelerated lake aging process is often referred to as *cultural eutrophication*.

There are many ways to measure lake water quality, but there are a few important physical, chemical, and biological parameters that indicate the overall condition of a lake. These measurements include temperature, dissolved oxygen, total phosphorus, chlorophyll-*a*, and Secchi transparency.

TEMPERATURE

Temperature is important in determining the type of organisms that may live in a lake. For example, trout prefer temperatures below 68°F. Temperature also determines how water mixes in a lake. As the ice cover breaks up on a lake in the spring, the water temperature becomes uniform from the surface to the bottom. This period is referred to as "spring turnover" because water mixes throughout the entire water column. As the surface waters warm, they are underlain by a colder, more dense strata of water. This process is called thermal stratification. Once thermal stratification occurs, there is little mixing of the warm surface waters with the cooler bottom waters. The transition layer that separates these layers is referred to as the "thermocline." The thermocline is characterized as the zone where temperature drops rapidly with depth. As fall approaches, the warm surface waters begin to cool and become more dense. Eventually, the surface temperature drops to a point that allows the lake to undergo complete mixing. This period is referred to as "fall turnover." As the season progresses and ice begins to form on the lake, the lake may stratify again. However, during winter stratification, the surface waters (at or near 32°F) are underlain by slightly warmer water (about 39°F). This is sometimes referred to as "inverse stratification" and occurs because water is most dense at a temperature of about 39°F. As the lake ice melts in the spring, these stratification cycles are repeated (Figure 2). Shallow lakes do not stratify. Lakes that are 15 to 30 feet deep may stratify and destratify with storm events several times during the 2019.

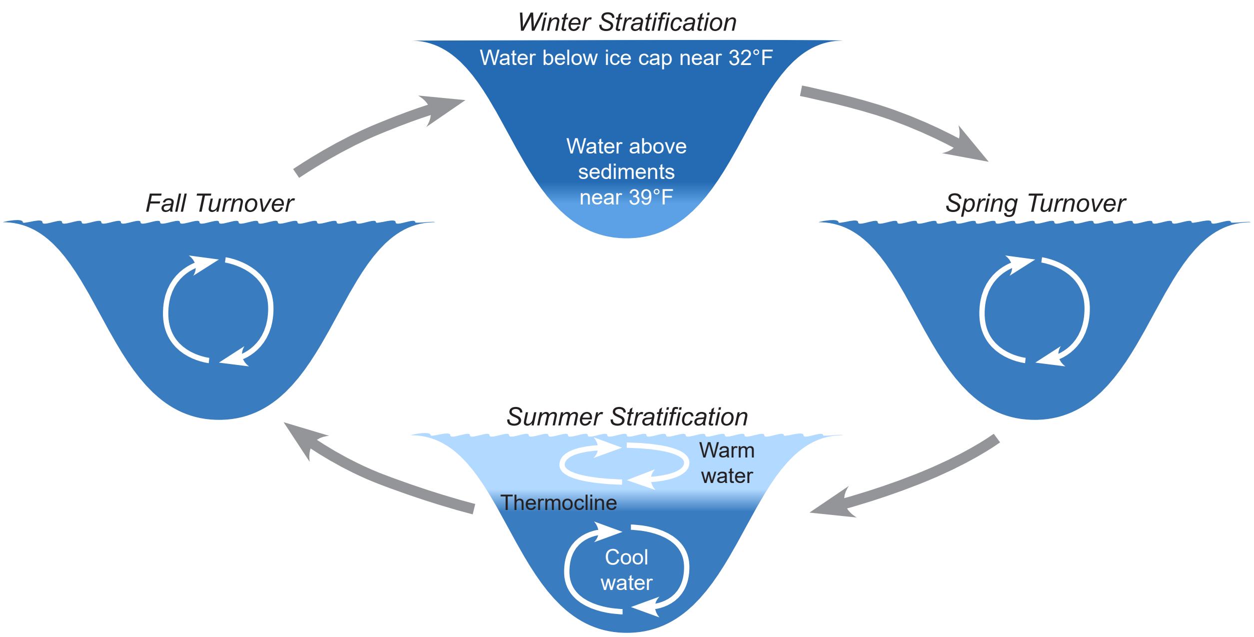

Figure 2. Seasonal thermal stratification cycles.

DISSOLVED OXYGEN

An important factor influencing lake water quality is the quantity of dissolved oxygen in the water column. The major inputs of dissolved oxygen to lakes are the atmosphere and photosynthetic activity by aquatic plants. An oxygen level of about 5 mg/L (milligrams per liter, or parts per million) is required to support warmwater fish. In lakes deep enough to exhibit thermal stratification, oxygen levels are often reduced or depleted below the thermocline once the lake has stratified. This is because deep water is cut off from plant photosynthesis and the atmosphere, and oxygen is consumed by bacteria that use oxygen as they decompose organic matter (plant and animal remains) at the bottom of the lake. Bottom-water oxygen depletion is a common occurrence in eutrophic and some mesotrophic lakes. Thus, eutrophic and most mesotrophic lakes cannot support coldwater fish because the cool, deep water (that the fish require to live) does not contain sufficient oxygen.

PHOSPHORUS

The quantity of phosphorus present in the water column is especially important since phosphorus is the nutrient that most often controls aquatic plant growth and the rate at which a lake ages and becomes more eutrophic. In the presence of oxygen, lake sediments act as a phosphorus trap, retaining phosphorus and, thus, making it unavailable for algae growth. However, if bottom-water oxygen is depleted, phosphorus will be released from the sediments and may be available to promote aquatic plant growth. In some lakes, the internal release of phosphorus from the bottom sediments is the primary source of phosphorus loading (or input).

By reducing the amount of phosphorus in a lake, it may be possible to control the amount of aquatic plant growth. In general, lakes with a phosphorus concentration greater than 20 μg/L (micrograms per liter, or parts per billion) are able to support abundant plant growth and are classified as nutrient-enriched or eutrophic.

CHLOROPHYLL-*A*

Chlorophyll-*a* is a pigment that imparts the green color to plants and algae. A rough estimate of the quantity of algae present in lake water can be made by measuring the amount of chlorophyll-*a* in the water column. A chlorophyll-*a* concentration greater than 6 μg/L is considered characteristic of a eutrophic condition.

SECCHI TRANSPARENCY

A Secchi disk is often used to estimate water clarity. The measurement is made by fastening a round, black and white, 8-inch disk to a calibrated line (Figure 3). The disk is lowered over the deepest point of the lake until it is no longer visible, and the depth is noted. The disk is then raised until it reappears. The average between these two depths is the Secchi transparency. Generally, it has been found that aquatic plants can grow at a depth of approximately twice the Secchi transparency measurement. In eutrophic lakes, water clarity is often reduced by algae growth in the water column, and Secchi disk readings of 7.5 feet or less are common.

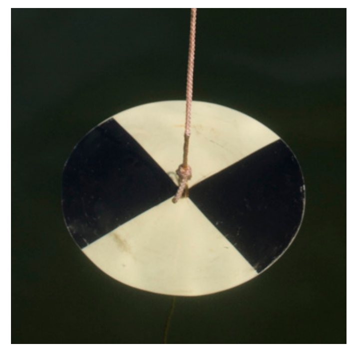

Figure 3. Secchi disk.

LAKE CLASSIFICATION CRITERIA

Ordinarily, as phosphorus inputs (both internal and external) to a lake increase, the amount of algae will also increase. Thus, the lake will exhibit increased chlorophyll-*a* levels and decreased transparency. A summary of lake classification criteria developed by the Michigan Department of Natural Resources (Warbach et al. 1990) is shown in Table 1.

TABLE 1

LAKE CLASSIFICATION CRITERIA

Lake Classification	Total Phosphorus (μg/L)[1]	Chlorophyll-*a* (μg/L)[1]	Secchi Transparency (feet)
Oligotrophic	Less than 10	Less than 2.2	Greater than 15.0
Mesotrophic	10 to 20	2.2 to 6.0	7.5 to 15.0
Eutrophic	Greater than 20	Greater than 6.0	Less than 7.5

1 μg/L = micrograms per liter = parts per billion.

SAMPLING METHODS

Water quality sampling was conducted in the spring and summer of 2019 over the deep basin within Ryerson Lake (Figure 5). Temperature was measured using a YSI Model 550A probe. Samples were collected with a Van Dorn sampler at 10-foot intervals from just below the surface to just above the lake bottom. Samples were analyzed for dissolved oxygen, total phosphorus, and orthophosphorus. Dissolved oxygen samples were fixed in the field and then transported to Progressive AE for analysis using the modified Winkler method (Standard Methods procedure 4500-O-C). Remaining samples were placed on ice and transported to Summit Laboratories[1] and to Progressive AE for analysis. Total phosphorus and orthophosphorus were analyzed at Summit using Standard Methods procedure 4500 P. In addition to the depth-interval samples at each deep basin, Secchi transparency was measured and composite chlorophyll-*a* samples were collected from the surface to a depth equal to twice the Secchi transparency. Chlorophyll-*a* samples were analyzed by Summit using Standard Methods procedure 10200 H.

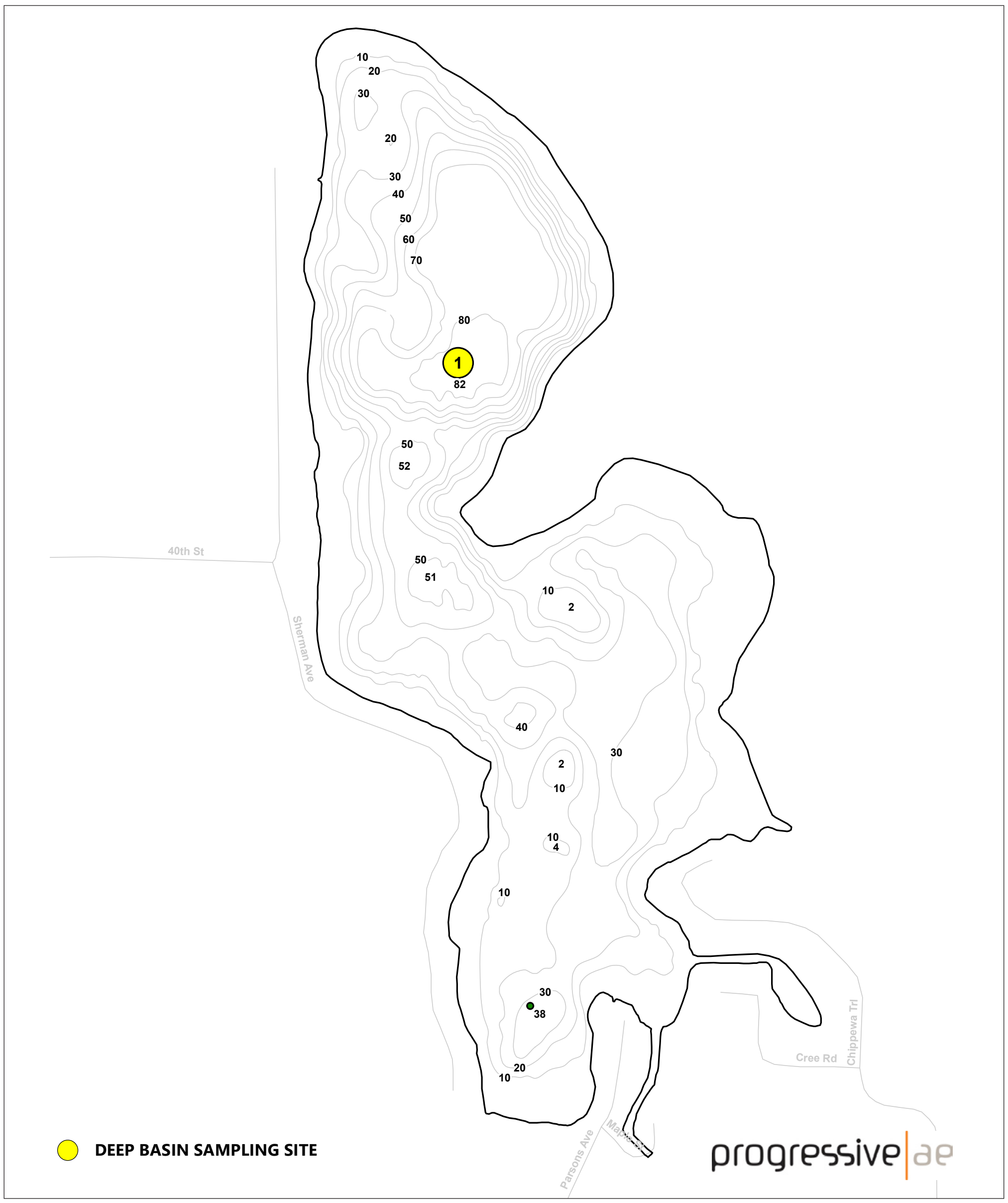

Figure 4. Ryerson Lake sampling location map.

1 Summit Laboratory, 900 Godfrey Ave SW, Grand Rapids, MI 49503.

Ryerson Lake Water Quality

Water quality monitoring results for Ryerson Lake indicate the following:

- During the April sampling, the lake was not completely mixed which indicates that the spring turnover may have been incomplete (i.e., the lake did not mix completely from top to bottom, Table 2). In August, the lake was stratified into distinct layers. The thermocline, where temperature drops rapidly with depth, occurred at about 15 feet.
- During both sampling periods, dissolved oxygen levels in the upper strata of water were sufficient to support fish while the bottom waters of the lake were anoxic and uninhabitable for fish. Although Ryerson Lake supports a viable cool- and warmwater fishery (Jude 2015), the lake lacks a summer refuge for coldwater fish.
- Total phosphorus levels in the upper strata of water were elevated in spring and moderate in summer. During both sampling periods, phosphorus levels in the anoxic (oxygen-depleted) bottom waters were substantially elevated. The bottom water phosphorus level in August was over 60 times greater than the surface water phosphorus concentration. These data suggest that internal phosphorus release from the anoxic deep-water sediments in Ryerson Lake is occurring. Much of the phosphorus in the bottom waters is ortho phosphorus, a dissolved form of phosphorus readily available for aquatic plant and algae growth during spring and fall turnover.
- Secchi transparency was low during both sampling periods and chlorophyll-*a* data indicate algae growth in the open waters of the lake was sparse (Table 3). The reduced transparency in Ryerson Lake may be related to the presence of naturally-occurring tannins in the water column that impart a brownish hue to the water.
- Current and historical water quality data (Table 4 and Appendix A) indicate Ryerson Lake is meso-eutrophic (borderline between eutrophic and mesotrophic). The lake has elevated phosphorus levels and dissolved oxygen depletion characteristic of a eutrophic lake while Secchi transparency and chlorophyll-a readings are more consistent with mesotrophic conditions.

TABLE 2
RYERSON LAKE 2019 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]	Ortho Phosphorus (µg/L)[2]
23-Apr-19	1	50	13.8	29	<10
23-Apr-19	10	50	13.8	46	<10
23-Apr-19	20	44	12.7	29	<10
23-Apr-19	30	44	11.8	38	<10
23-Apr-19	40	42	11.6	43	<10
23-Apr-19	50	41	10.2	46	<10
23-Apr-19	60	40	6.7	66	23
23-Apr-19	70	39	0.8	182	123
23-Apr-19	80	38	0.3	292	234
21-Aug-19	1	77	9.2	<10	<10
21-Aug-19	10	76	8.6	10	<10
21-Aug-19	20	55	2.0	24	<10
21-Aug-19	30	47	0.4	81	64
21-Aug-19	40	45	0.3	124	93
21-Aug-19	50	43	0.4	153	137
21-Aug-19	60	42	0.4	202	180
21-Aug-19	70	41	0.0	393	364
21-Aug-19	80	40	0.0	632	596

TABLE 3
RYERSON LAKE 2019 SURFACE WATER QUALITY DATA

Date	Sample Site	Chlorophyll-*a* (µg/L)[2]	Secchi Transparency (feet)
23-Apr-19	1	2	5.5
21-Aug-19	1	2	6.0

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE 4
RYERSON LAKE SUMMARY STATISTICS (1997-2019)

	Total Phosphorus (µg/L)[1]	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
Mean	112	3.4	7.8
Standard deviation	145	3.3	2.9
Median	56	2.5	7.5
Minimum	3	0.0	3.5
Maximum	832	15.2	16.0
Number of samples	418	48	50

1 µg/L = micrograms per liter = parts per billion.

References

Buchanan T.J. and W.P. Somers. 1969. Discharge measurements at gaging stations. U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A8.

Fuller, L.M. and C.K. Taricska. 2012. Water-Quality Characteristics of Michigan's Inland Lakes, 2001-10: U.S. Geological Survey Scientific Investigations Report 2011-5233, 53 p., plus CD-ROM.

Jude, D. J. 2015. A Fishery Survey of Ryerson Lake with Recommendations and a Management Plan.

Michigan Department of Environment, Great Lakes, and Energy. 2019. Water Quality Parameters, accessed January 16, 2019, https://www.michigan.gov/documents/deq/wrd-npdes-water-quality_570237_7.pdf.

Michigan Department of Environmental Quality. 2012. Michigan National Lakes Assessment Project 2007. MI/DEQ/WRD-12/006.

Warbach, J.D., M.A. Wyckoff, and K. Williams. 1990. Protecting Inland Lakes: A Watershed Management Guidebook. Michigan Department of Natural Resources, Land and Water Management Division.

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems, third edition. Academic Press. San Diego, CA.1006 pp.

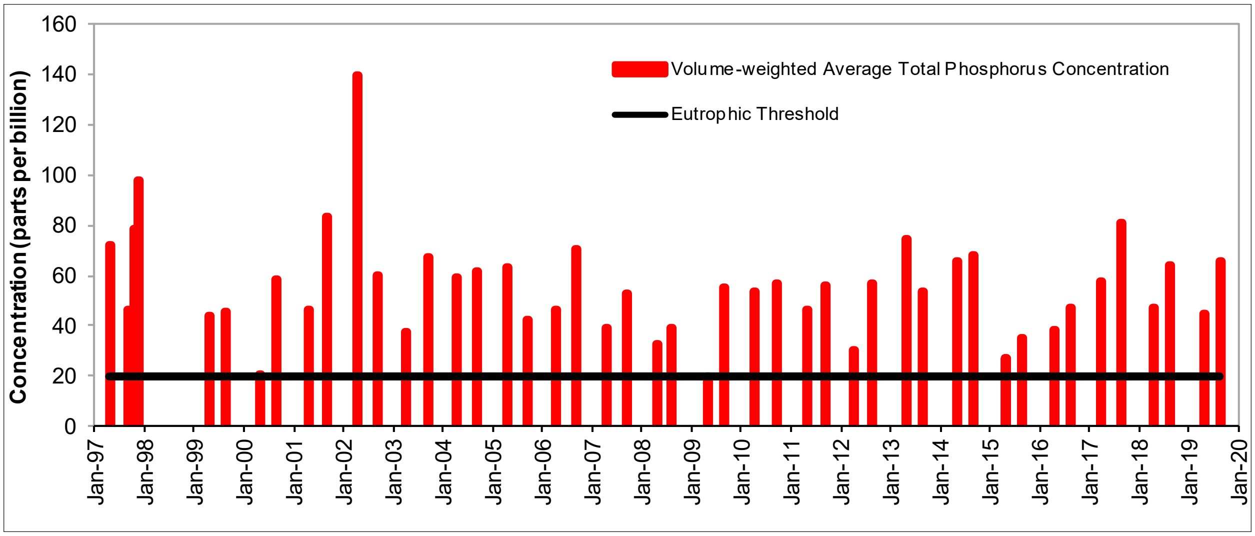

Figure 5. Volume-weighted average total phosphorus concentrations, 1997 - 2019.

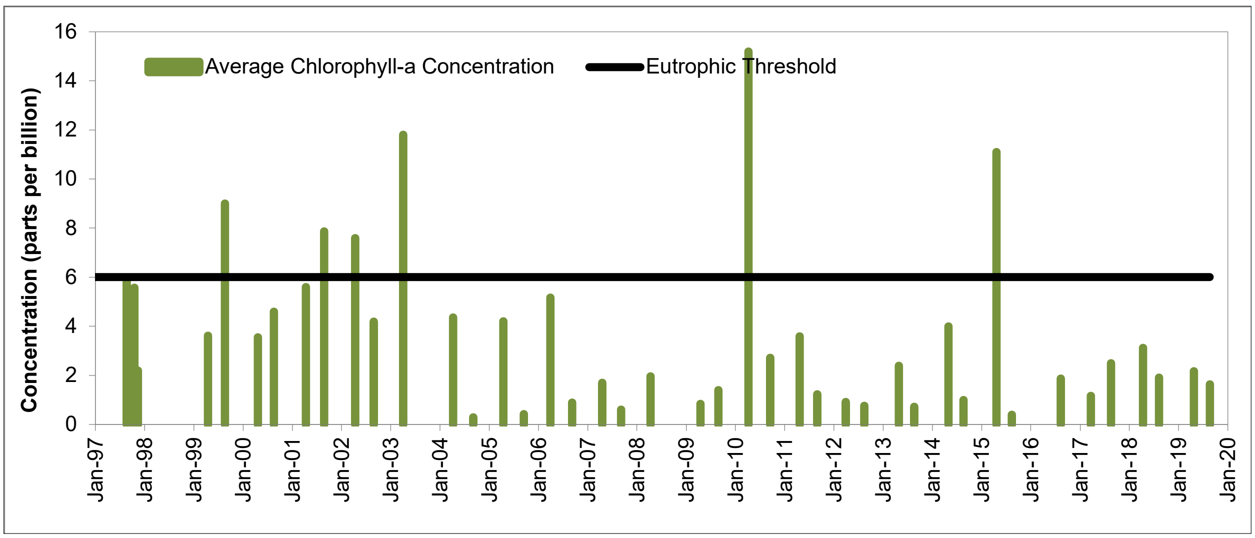

Figure 6. Chlorophyll-*a* concentrations, 1997 - 2019.

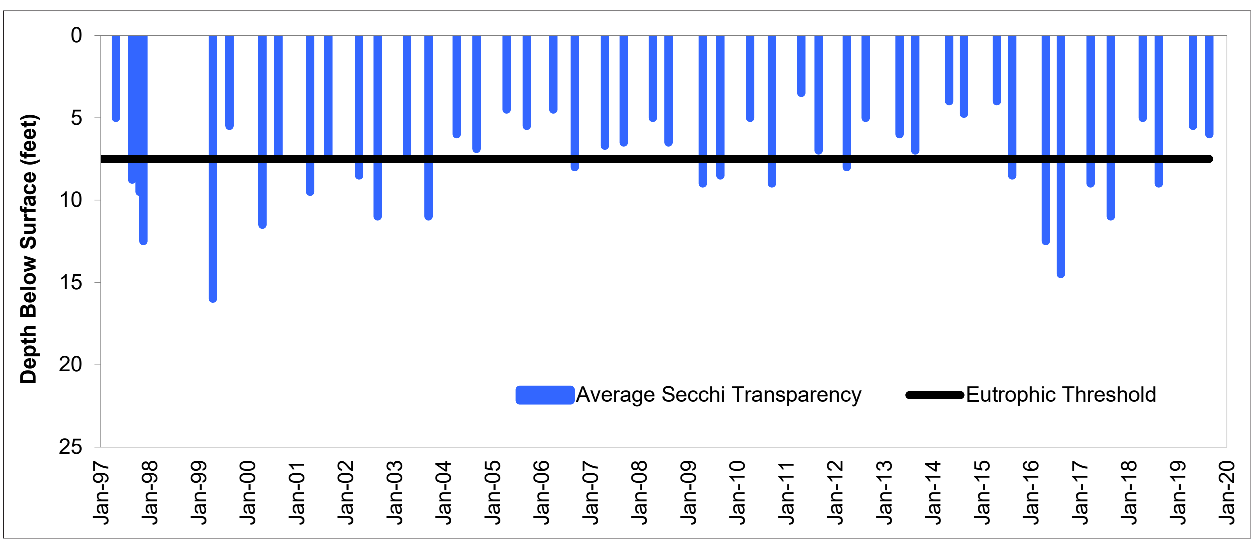

Figure 7. Secchi transparency measurements, 1997 - 2019.

Appendix A
Ryerson Lake Historical Water Quality Data

TABLE A1
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
22-Apr-97	1	45	15.0	104
22-Apr-97	10	45	14.6	
22-Apr-97	20	43	11.6	58
22-Apr-97	30	43	10.9	
22-Apr-97	40	42	10.8	50
22-Apr-97	50	42	10.8	
22-Apr-97	60	42	11.3	84
22-Apr-97	70	41	9.9	
22-Apr-97	80	41	11.2	76
22-Apr-97	1	46	12.8	48
22-Apr-97	15	48	13.0	62
22-Apr-97	25	43	9.8	64
22-Apr-97	35	43	8.8	
22-Apr-97	42	43	7.6	62
21-Aug-97	1	70	8.5	3
21-Aug-97	10	70	8.5	3
21-Aug-97	20	69	7.3	3
21-Aug-97	30	57	0.5	17
21-Aug-97	40	54	0.5	174
21-Aug-97	50	51	0.4	167
21-Aug-97	60	52	0.3	153
21-Aug-97	70	52	0.3	243
21-Aug-97	80	50	0.0	372
21-Aug-97	1	70	8.2	3
21-Aug-97	10	69	8.2	5
21-Aug-97	20	70	8.3	5
21-Aug-97	30	57	0.4	249

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
16-Oct-97	1	59	8.0	14
16-Oct-97	10	59	7.9	21
16-Oct-97	20	56	7.7	21
16-Oct-97	30	57	3.3	26
16-Oct-97	40	49	0.3	253
16-Oct-97	50	47	0.3	255
16-Oct-97	60	45	0.5	227
16-Oct-97	80	45	0.0	556
16-Oct-97	1	57	8.4	25
16-Oct-97	10	56	8.5	21
16-Oct-97	20	54	8.3	49
16-Oct-97	35	51	0.8	616
12-Nov-97	1	46	7.2	70
12-Nov-97	40	45	7.0	72
12-Nov-97	80	44	0.0	533
12-Nov-97	1	46	8.9	50
12-Nov-97	20	45	8.4	54
12-Nov-97	35	45	8.7	50
14-Apr-99	1	50	11.5	32
14-Apr-99	10	48	11.4	48
14-Apr-99	20	46	10.8	41
14-Apr-99	30	45	10.4	37
14-Apr-99	40	44	10.1	32
14-Apr-99	50	42	7.7	54
14-Apr-99	60	40	4.8	83
14-Apr-99	70	40	1.8	80
14-Apr-99	80	40	1.4	75

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (μg/L)[2]
18-Aug-99	1	74	8.4	3
18-Aug-99	10	73	9.0	5
18-Aug-99	20	66	2.0	13
18-Aug-99	30	49	0.4	70
18-Aug-99	40	46	0.4	132
18-Aug-99	50	44	0.4	131
18-Aug-99	60	42	0.4	131
18-Aug-99	70	41	0.1	156
18-Aug-99	80	41	0.0	253
18-Apr-00	1	48	11.6	10
18-Apr-00	10	48	11.6	17
18-Apr-00	20	47	11.5	6
18-Apr-00	30	46	11.2	7
18-Apr-00	40	45	10.9	39
18-Apr-00	50	44	10.0	20
18-Apr-00	60	42	4.4	68
18-Apr-00	70	41	0.8	121
18-Apr-00	80	41	0.3	183
16-Aug-00	1	76	7.9	11
16-Aug-00	10	76	7.5	10
16-Aug-00	20	62	2.1	14
16-Aug-00	30	49	2.3	67
16-Aug-00	40	47	2.4	108
16-Aug-00	50	45	2.5	133
16-Aug-00	60	43	2.6	187
16-Aug-00	70	42	2.7	406
16-Aug-00	80	42	3.1	556

1 mg/L = milligrams per liter = parts per million.
2 μg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (μg/L)[2]
10-Apr-01	1	46	9.9	35
10-Apr-01	10	45	9.6	38
10-Apr-01	20	44	8.4	42
10-Apr-01	30	42	7.0	50
10-Apr-01	40	41	5.8	50
10-Apr-01	50	41	4.7	63
10-Apr-01	60	40	3.5	75
10-Apr-01	70	39	2.0	101
10-Apr-01	80	39	0.8	118
23-Aug-01	1	76	7.2	18
23-Aug-01	10	73	6.6	19
23-Aug-01	20	65	0.7	32
23-Aug-01	30	51	0.6	163
23-Aug-01	40	47	0.6	173
23-Aug-01	50	44	0.7	167
23-Aug-01	60	42	0.7	195
23-Aug-01	70	41	0.4	293
23-Aug-01	80	41	0.0	509
11-Apr-02	1	41	9.7	95
11-Apr-02	10	41	9.8	207
11-Apr-02	20	40	9.7	261
11-Apr-02	30	40	9.7	54
11-Apr-02	40	40	9.8	36
11-Apr-02	50	40	9.7	40
11-Apr-02	60	40	9.6	38
11-Apr-02	70	40	9.7	47
11-Apr-02	80	40	9.9	43

1 mg/L = milligrams per liter = parts per million.
2 μg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
27-Aug-02	1	76	7.3	11
27-Aug-02	10	75	6.6	15
27-Aug-02	20	65	0.7	16
27-Aug-02	30	50	0.4	93
27-Aug-02	40	45	0.3	116
27-Aug-02	50	43	0.4	116
27-Aug-02	60	42	0.3	153
27-Aug-02	70	42	0.3	375
27-Aug-02	80	42	0.3	500
3-Apr-03	1			29
3-Apr-03	10	42	9.3	31
3-Apr-03	20	42	9.2	44
3-Apr-03	30	41	7.6	29
3-Apr-03	40	40	6.6	31
3-Apr-03	50	40	4.4	36
3-Apr-03	60	40	1.9	55
3-Apr-03	70	40	0.9	94
3-Apr-03	80	40	1.0	170
10-Sep-03	1	73	7.3	15
10-Sep-03	10	72	6.8	21
10-Sep-03	20	69	3.1	17
10-Sep-03	30	51	0.1	73
10-Sep-03	40	45	0.0	136
10-Sep-03	50	43	0.0	145
10-Sep-03	60	41	0.0	197
10-Sep-03	70	41	0.0	408
10-Sep-03	80	41	0.0	618

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
7-Apr-04	1	46	13.4	49
7-Apr-04	10	43	12.7	57
7-Apr-04	20	42	11.4	54
7-Apr-04	30	41	10.4	60
7-Apr-04	40	40	9.4	63
7-Apr-04	50	40	8.1	77
7-Apr-04	60	40	8.0	77
7-Apr-04	70	40	7.7	84
7-Apr-04	80	39	7.4	137
3-Sep-04	1	73	9.0	13
3-Sep-04	10	71	7.8	13
3-Sep-04	20	63	0.6	25
3-Sep-04	30	51	0.6	31
3-Sep-04	40	47	0.7	191
3-Sep-04	50	43	0.8	189
3-Sep-04	60	42	0.9	195
3-Sep-04	70	41	1.0	355
3-Sep-04	80	41	1.1	18
14-Apr-05	1	51	14.5	62
14-Apr-05	10	49	10.7	73
14-Apr-05	20	44	9.2	43
14-Apr-05	30	41	9.4	56
14-Apr-05	40	40	4.6	57
14-Apr-05	50	39	3.1	73
14-Apr-05	60	39	2.7	104
14-Apr-05	70	39	0.5	139
14-Apr-05	80	39	3.9	70

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
12-Sep-05	1	76	8.8	12
12-Sep-05	10	74	8.9	16
12-Sep-05	20	53	2.1	18
12-Sep-05	30	46	2.0	14
12-Sep-05	40	43	2.0	86
12-Sep-05	50	41	2.0	100
12-Sep-05	60	41	0.9	166
12-Sep-05	70	40	0.9	316
12-Sep-05	80	40	0.8	159
29-Mar-06	1	40	13.6	47
29-Mar-06	10	39	12.9	46
29-Mar-06	20	39	10.4	47
29-Mar-06	30	39	11.6	44
29-Mar-06	40	39	11.1	47
29-Mar-06	50	38	12.4	46
29-Mar-06	60	38	12.5	47
29-Mar-06	70	38	11.5	40
29-Mar-06	80	38	12.0	43
6-Sep-06	1	73	8.7	17
6-Sep-06	10	72	7.8	22
6-Sep-06	20	62	0.7	30
6-Sep-06	30	47	0.0	95
6-Sep-06	40	44	0.2	134
6-Sep-06	50	43	0.2	142
6-Sep-06	60	43	0.2	203
6-Sep-06	70	42	0.0	347
6-Sep-06	80	42	0.0	497

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
17-Apr-07	1	41	11.7	33
17-Apr-07	10	40	10.7	35
17-Apr-07	20	41	10.2	48
17-Apr-07	30	40	10.1	31
17-Apr-07	40	40	10.3	42
17-Apr-07	50	40	10.8	38
17-Apr-07	60	40	10.2	43
17-Apr-07	70	40	9.3	49
17-Apr-07	80	40	0.8	167
5-Sep-07	1	79	10.2	13
5-Sep-07	10	76	9.5	21
5-Sep-07	20	61	2.2	21
5-Sep-07	30	45	0.9	24
5-Sep-07	40	43	0.6	72
5-Sep-07	50	42	0.6	93
5-Sep-07	60	42	0.8	205
5-Sep-07	70	42	0.5	430
5-Sep-07	80	42	0.3	545
10-Apr-08	1	41	10.5	29
10-Apr-08	10	41	8.7	31
10-Apr-08	20	41	10.8	33
10-Apr-08	30	41	9.9	36
10-Apr-08	40	40	8.5	18
10-Apr-08	50	39	8.9	37
10-Apr-08	60	40	8.6	48
10-Apr-08	70	40	6.7	62
10-Apr-08	80	40	4.8	80

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
4-Aug-08	1	81	8.4	10
4-Aug-08	10	79	7.3	15
4-Aug-08	20	62	3.0	10
4-Aug-08	30	48	0.0	20
4-Aug-08	40	47	0.0	44
4-Aug-08	50	43	0.0	101
4-Aug-08	60	45	0.0	168
4-Aug-08	70	44	0.0	266
4-Aug-08	80	44	0.0	495
16-Apr-09	1	50	12.9	17
16-Apr-09	10	46	13.0	14
16-Apr-09	20	44	13.4	10
16-Apr-09	30	43	11.3	29
16-Apr-09	40	42	10.9	29
16-Apr-09	50	42	10.2	22
16-Apr-09	60	41	9.7	32
16-Apr-09	70	41	9.4	32
16-Apr-09	80	41	0.7	168
27-Aug-09	1	74	8.5	21
27-Aug-09	10	74	8.5	20
27-Aug-09	20	62	4.8	19
27-Aug-09	30	48	1.0	19
27-Aug-09	40	45	0.7	89
27-Aug-09	50	44	0.3	144
27-Aug-09	60	42	0.6	189
27-Aug-09	70	42	0.0	381
27-Aug-09	80	42	0.0	585

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
6-Apr-10	1	52	12.5	32
6-Apr-10	10	51	12.7	70
6-Apr-10	20	47	12.3	20
6-Apr-10	30	45	9.3	51
6-Apr-10	40	42	6.7	63
6-Apr-10	50	40	2.1	78
6-Apr-10	60	40	0.6	83
6-Apr-10	70	40	0.8	96
6-Apr-10	80	39	1.1	231
14-Sep-10	1	67	8.7	<10
14-Sep-10	10	67	8.5	<10
14-Sep-10	20	66	5.8	<10
14-Sep-10	30	50	0.0	26
14-Sep-10	40	45	0.0	144
14-Sep-10	50	43	1.0	131
14-Sep-10	60	40	0.8	218
14-Sep-10	70	40	0.0	433
14-Sep-10	80	40	0.0	599
21-Apr-11	1	43	11.6	42
21-Apr-11	10	43	10.7	45
21-Apr-11	20	43	11.3	44
21-Apr-11	30	43	11.4	42
21-Apr-11	40	43	10.4	45
21-Apr-11	50	40	7.6	47
21-Apr-11	60	39	9.5	61
21-Apr-11	70	39	9.0	75
21-Apr-11	80	39	4.9	111

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
29-Aug-11	1	76	7.2	<10
29-Aug-11	10	74	4.8	<10
29-Aug-11	20	57	1.9	16
29-Aug-11	30	48	1.5	19
29-Aug-11	40	45	0.0	114
29-Aug-11	50	43	0.0	149
29-Aug-11	60	41	0.0	234
29-Aug-11	70	40	0.0	400
29-Aug-11	80	40	0.0	609
27-Mar-12	1	54	9.9	19
27-Mar-12	10	53	10.6	21
27-Mar-12	20	50	9.7	34
27-Mar-12	30	40	8.1	35
27-Mar-12	40	40	8.4	35
27-Mar-12	50	39	7.5	35
27-Mar-12	60	39	7.1	44
27-Mar-12	70	38	4.6	68
27-Mar-12	80	38	2.8	95
13-Aug-12	1	74	9.7	11
13-Aug-12	10	74	9.5	13
13-Aug-12	20	64	3.3	14
13-Aug-12	30	50	0.0	41
13-Aug-12	40	45	1.0	98
13-Aug-12	50	42	0.9	140
13-Aug-12	60	40	0.4	198
13-Aug-12	70	40	0.0	385
13-Aug-12	80	40	0.0	832

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
25-Apr-13	1	42	10.5	70
25-Apr-13	10	42	10.5	69
25-Apr-13	20	42	10.9	71
25-Apr-13	30	42	10.3	71
25-Apr-13	40	41	10.0	73
25-Apr-13	50	41	9.5	72
25-Apr-13	60	41	8.2	79
25-Apr-13	70	39	1.4	164
25-Apr-13	80	39	0.5	235
19-Aug-13	1	75	10.5	8
19-Aug-13	10	71	10.0	7
19-Aug-13	20	51	10.4	9
19-Aug-13	30	45	2.6	14
19-Aug-13	40	44	0.6	132
19-Aug-13	50	43	0.3	159
19-Aug-13	60	42	0.3	216
19-Aug-13	70	41	0.0	366
19-Aug-13	80	41	0.0	693
30-Apr-14	1	49	14.0	67
30-Apr-14	10	48	11.9	66
30-Apr-14	20	47	8.8	52
30-Apr-14	30	46	11.0	52
30-Apr-14	40	43	8.7	63
30-Apr-14	50	41	4.8	73
30-Apr-14	60	39	0.2	105
30-Apr-14	70	39	0.4	120
30-Apr-14	80	39	0.6	184

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
18-Aug-14	1	74	9.2	24
18-Aug-14	10	72	9.2	23
18-Aug-14	20	55	2.7	21
18-Aug-14	30	47	0.3	72
18-Aug-14	40	45	0.4	135
18-Aug-14	50	43	0.3	140
18-Aug-14	60	41	0.2	221
18-Aug-14	70	40	0.1	294
18-Aug-14	80	40	0.0	707
20-Apr-15	1	53	13.5	39
20-Apr-15	10	51	13.2	27
20-Apr-15	20	46	12.0	11
20-Apr-15	30	43	9.4	10
20-Apr-15	40	42	8.7	11
20-Apr-15	50	40	5.5	26
20-Apr-15	60	39	1.2	68
20-Apr-15	70	38	0.3	121
20-Apr-15	80	38	0.2	132
13-Aug-15	1	76	9.7	20
13-Aug-15	10	76	8.5	<5
13-Aug-15	20	60	1.2	5
13-Aug-15	30	46	0.7	11
13-Aug-15	40	43	0.2	69
13-Aug-15	50	42	0.4	84
13-Aug-15	60	40	0.4	116
13-Aug-15	70	40	0.3	233
13-Aug-15	80	39	0.0	645

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
18-Apr-16	1	58	11.8	27
18-Apr-16	10	47	11.4	34
18-Apr-16	20	43	10.8	38
18-Apr-16	30	42	10.1	45
18-Apr-16	40	42	10.2	43
18-Apr-16	50	42	10.1	49
18-Apr-16	60	42	10.0	46
18-Apr-16	70	42	9.2	60
18-Apr-16	80	42	9.0	70
10-Aug-16	1	80	8.5	<10
10-Aug-16	10	80	8.5	<10
10-Aug-16	20	57	1.1	<10
10-Aug-16	30	46	1.0	11
10-Aug-16	40	44	1.0	112
10-Aug-16	50	43	0.7	143
10-Aug-16	60	42	0.4	182
10-Aug-16	70	42	1.0	295
10-Aug-16	80		0.2	594
20-Mar-17	1	38	9.3	57
20-Mar-17	10	38	9.5	60
20-Mar-17	20	38	10.2	55
20-Mar-17	30	38	8.3	55
20-Mar-17	40	38	9.7	63
20-Mar-17	50	38	9.5	58
20-Mar-17	60	38	10.9	57
20-Mar-17	70	38	10.3	66
20-Mar-17	80	38	10.3	64

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A1 (continued)
RYERSON LAKE 1997-2018 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
16-Aug-17	1	76	9.1	12
16-Aug-17	10	74	8.6	12
16-Aug-17	20	64	1.3	33
16-Aug-17	30	49	1.0	65
16-Aug-17	40	46	1.3	154
16-Aug-17	50	44	0.9	200
16-Aug-17	60	43	0.9	298
16-Aug-17	70	42	0.5	525
16-Aug-17	80	42	0.2	781
12-Apr-18	1	42	10.0	46
12-Apr-18	10	41	11.0	49
12-Apr-18	20	41	10.4	44
12-Apr-18	30	41	12.5	45
12-Apr-18	40	40	12.0	50
12-Apr-18	50	40	12.4	48
12-Apr-18	60	40	11.1	52
12-Apr-18	70	40	10.6	47
12-Apr-18	80	40	11.0	52
9-Aug-18	1	79	8.9	15
9-Aug-18	10	79	9.2	98
9-Aug-18	20	56	1.9	25
9-Aug-18	30	45	1.9	<10
9-Aug-18	40	43	1.8	16
9-Aug-18	50	42	1.8	123
9-Aug-18	60	42	1.2	170
9-Aug-18	70	41	1.2	273
9-Aug-18	80	41	0.6	649

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE A2
RYERSON LAKE 1997-2018 SURFACE WATER QUALITY DATA

Date	Sample Site	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
22-Apr-97	1		5.0
22-Apr-97	2		5.0
21-Aug-97	1	6	9.5
21-Aug-97	2	6	8.0
16-Oct-97	1	7	10.0
16-Oct-97	2	4	9.0
12-Nov-97	1	2	12.0
12-Nov-97	2	3	13.0
14-Apr-99	1	4	16.0
18-Aug-99	1	9	5.5
18-Apr-00	1	4	11.5
16-Aug-00	1	5	7.5
10-Apr-01	1	6	9.5
23-Aug-01	1	8	7.5
11-Apr-02	1	8	8.5
27-Aug-02	1	4	11.0
3-Apr-03	1	12	7.5
10-Sep-03	1	0	11.0
7-Apr-04	1	4	6.0
3-Sep-04	1	0	6.9
14-Apr-05	1	4	4.5
12-Sep-05	1	0	5.5
29-Mar-06	1	5	4.5
6-Sep-06	1	1	8.0
17-Apr-07	1	2	6.7
5-Sep-07	1	1	6.5
10-Apr-08	1	2	5.0
4-Aug-08	1	0	6.5
16-Apr-09	1	1	9.0
27-Aug-09	1	1	8.5
06-Apr-10	1	15	5.0
14-Sep-10	1	3	9.0
21-Apr-11	1	4	3.5

1 µg/L = micrograms per liter = parts per billion

TABLE A2 (continued)
RYERSON LAKE 1997-2018 SURFACE WATER QUALITY DATA

Date	Sample Site	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
29-Aug-11	1	1	7.0
27-Mar-12	1	1	8.0
13-Aug-12	1	1	5.0
25-Apr-13	1	2	6.0
19-Aug-13	1	1	7.0
30-Apr-14	1	4	4.0
18-Aug-14	1	1	4.8
20-Apr-15	1	11	4.0
13-Aug-15	1	0	8.5
18-Apr-16	1	0	12.5
10-Aug-16	1	2	14.5
20-Mar-17	1	1	9.0
16-Aug-17	1	3	11.0
12-Apr-18	1	3	5.0
9-Aug-18	1	2	9.0

1 µg/L = micrograms per liter = parts per billion