Appendix A: Precipitation Data

Table A1. Summary of 2020 and long-term precipitation data measured at the New Hope, MN station (Station ID: 215838).

Month	2020 Precipitation (inches)	1992-2020 Monthly Average Precipitation (inches)	Departure from Historical Average (inches)
January	0.87	1.02	-0.15
February	0.57	1.07	-0.50
March	2.57	1.84	0.73
April	1.66	3.18	-1.52
May	4.10	4.34	-0.24
June	3.47	4.55	-1.08
July	2.45	4.61	-2.16
August	5.50	4.26	1.24
September	1.03	3.25	-2.22
October	2.54	2.92	-0.38
November	0.68	1.82	-1.14
December	1.15	1.46	-0.31
TOTAL	26.6	34.3	-7.7

65th Avenue

Figure B1. Flow at the 65th Ave sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

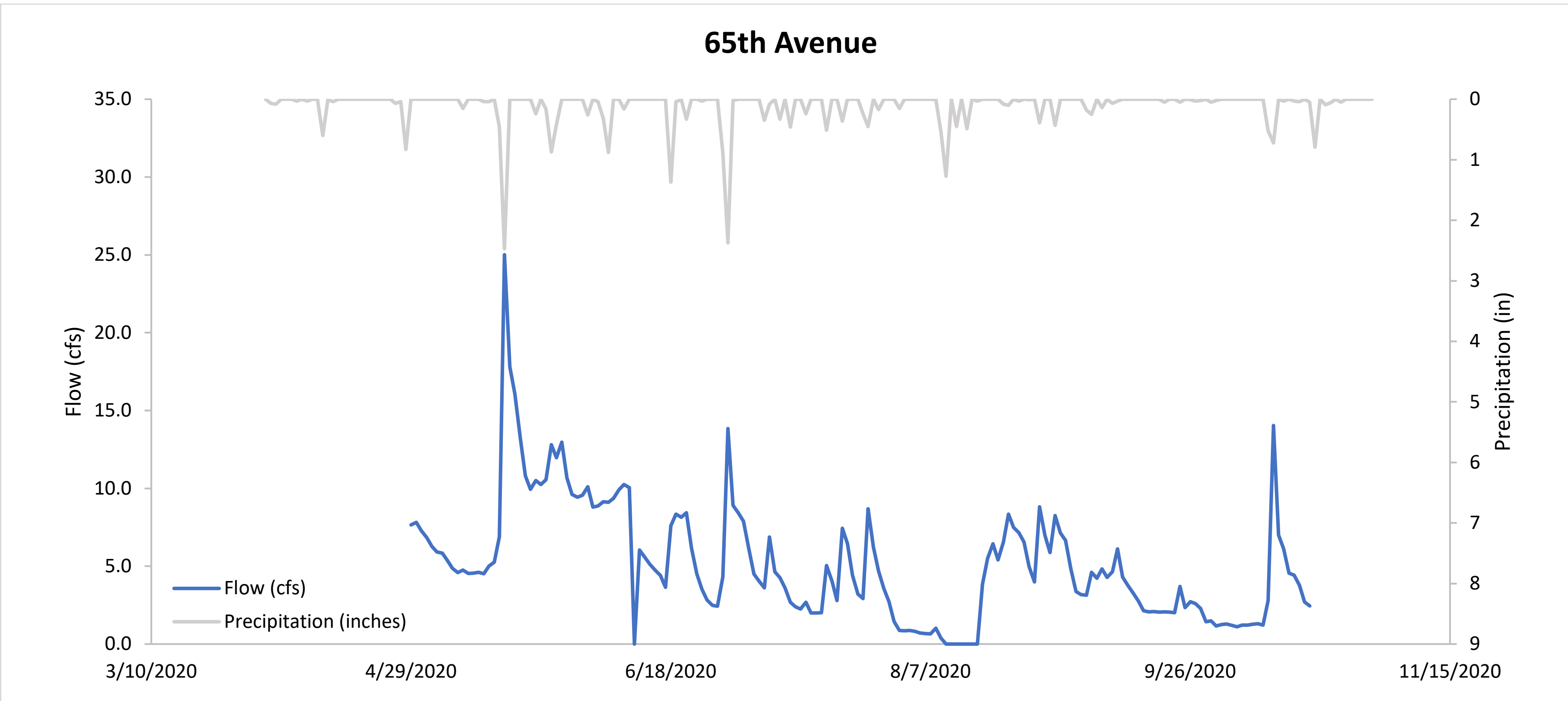


Table B1. Water quality data from the 65th Ave site measured in 2020. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS), chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	pH	Sp. Cond. [µS/cm]	Salinity [ppt]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]	VSS [mg/L]	TKN [mg/L]
3/17/2020	10:35	5.6	13.96	6.8	1278	0.64	0.05	~0.01	5	207	12	3	0.88
4/15/2020	08:15	4.9	13.98	6.6	1394	0.7	0.06	0.01	3	302.9	41	~2	0.91
5/22/2020	07:50	16.2	9.04	7.2	873	0.43	0.05	0.02	4	153.8	81	~2	0.88
6/2/2020	08:10	25.2	6.39	8.1	1104	0.55	0.07	~0.01	~2	162.8	40	~1	0.95
6/16/2020	08:50	20.0	8.3	7.3	1319	0.66	0.05	0.02	3	231.4	36	~1	0.93
7/10/2020	08:40	22.1	8	7.2	1240	0.62	0.08	0.04		222.1	49		0.95
8/4/2020	08:50	16.9	9.17	7.6	1484	0.75	0.07	0.04	~2	287	61	~1	0.89
8/12/2020	10:05	17.3	8.41	7.8	522	0.25	0.16	0.03	12	95.1	1120	8	1.40
9/1/2020	08:25	17.7	8.05	8.2	630	0.31	0.11	0.03	7	103	308	4	0.94
10/6/2020	08:00	--	--	--	--	--	0.108	0.035	~2	288		~2	0.76
11/3/2020	11:45	13.7	10.11	8.24	1563	0.79	0.06	0.027	~2	258	100	~1	0.91
11/3/2020	11:46	13.7	10.11	8.24	1563	0.79	0.06	0.03	~2	263	77	~1	0.94
11/17/2020	08:25	6.8	11.85	8.18	1538	0.78	0.061	0.029	~2	363	236	~2	0.90
12/1/2020	09:10	11.89	--	--	7.91	1532	0.77	0.073	0.038	~2	271	62	~1
12/23/2020	11:00	10.07	--	--	6.51	1686	0.85	0.096	--	--	503	--	--

Table B2. Other water quality data from the 65th Ave site measured on three different dates in 2020. Parameters measured include Alkalinity, Ammonia, CBOD5-day, Chemical Oxygen Demand, Dissolved Phosphorus, Hardness (CaCO3), Nitrate/Nitrate, Nitrate/Nitrite, Nitrite/Nitrite, Sulfate, TBOD5-day, Total Cadmium, Total Chromium, Total Copper, Total Dissolved Solids, Total Lead, Total Nickel, Total Organic Carbon, and Total Zinc.

Date/Time	6/2/2020 8:10	6/16/2020 8:50	**06/18/2020 17:40	9/1/2020 8:25
Alkalinity [mg/l]	--	263	--	--
Ammonia [mg/l]	--	0.15	--	--
CBOD5-day [mg/l]	--	1.7	--	--
Chemical Oxygen Demand [mg/l]	--	23	85	--
Dissolved Phosphorous [mg/l]	--	~0.02	--	--
Hardness (CaCO3) [mg/l]	--	391	--	--
Nitrate / Nitrate [mg/l]	--	0.57	--	--
Nitrate-Nitrite [mg/l]	--	0.64	--	--
Nitrite / Nitrite [mg/l]	--	0.07	--	--
Sulfate [mg/l]	--	83.4	--	--
TBOD5-day [mg/l]	--	2	--	--
Total Cadmium [mg/l]	<0.00006	<0.00006	--	<0.00006
Total Chromium [mg/l]	~0.0002	~0.00019	--	~0.0004
Total Copper [mg/l]	~0.00053	~0.00075	--	0.0016
Total Dissolved Solids [mg/l]	--	764	--	--
Total Lead [mg/l]	<0.00026	<0.00026	--	~0.00055
Total Nickel [mg/l]	0.0016	0.0024	--	0.0012
Total Organic Carbon [mg/l]	--	5.1	--	--
Total Zinc [mg/l]	~0.0043	0.0112	--	0.0078

** Sample taken from a storm capture day

Table B3. Storm water quality data from the 65th Ave site in 2020. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	Time	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]	VSS [mg/L]	TKN [mg/L]
3/19/2020	11:10	3/19/2020	12:15	0.21	0.02	40	--	16	1.6
4/28/2020	09:00	4/28/2020	16:47	0.16	0.02	46	688	18	1.4
5/16/2020	20:07	5/17/2020	03:24	0.12	0.01	31	1986	14	1.1
6/18/2020	17:40	6/18/2020	20:20	0.27	0.02	82	20100	24	1.6
6/29/2020	00:06	6/29/2020	04:51	0.11	~0.01	48	1986	14	0.92
7/7/2020	08:25	7/07/2020	09:40	0.42	0.01	126	200000	41	2.6
11/9/2020	14:15	11/9/2020	15:30	0.371	0.068	68	18300	31	2.1
11/11/2020	11:30	11/11/2020	13:35	0.166	0.054	50	9800	24	1.6

Environmental Preserve

Figure B2. Flow at the Environmental Preserve sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis. Stage height was not recorded from 5/23/19 to 6/4/19 due to instrumental error, so data is missing during this window.

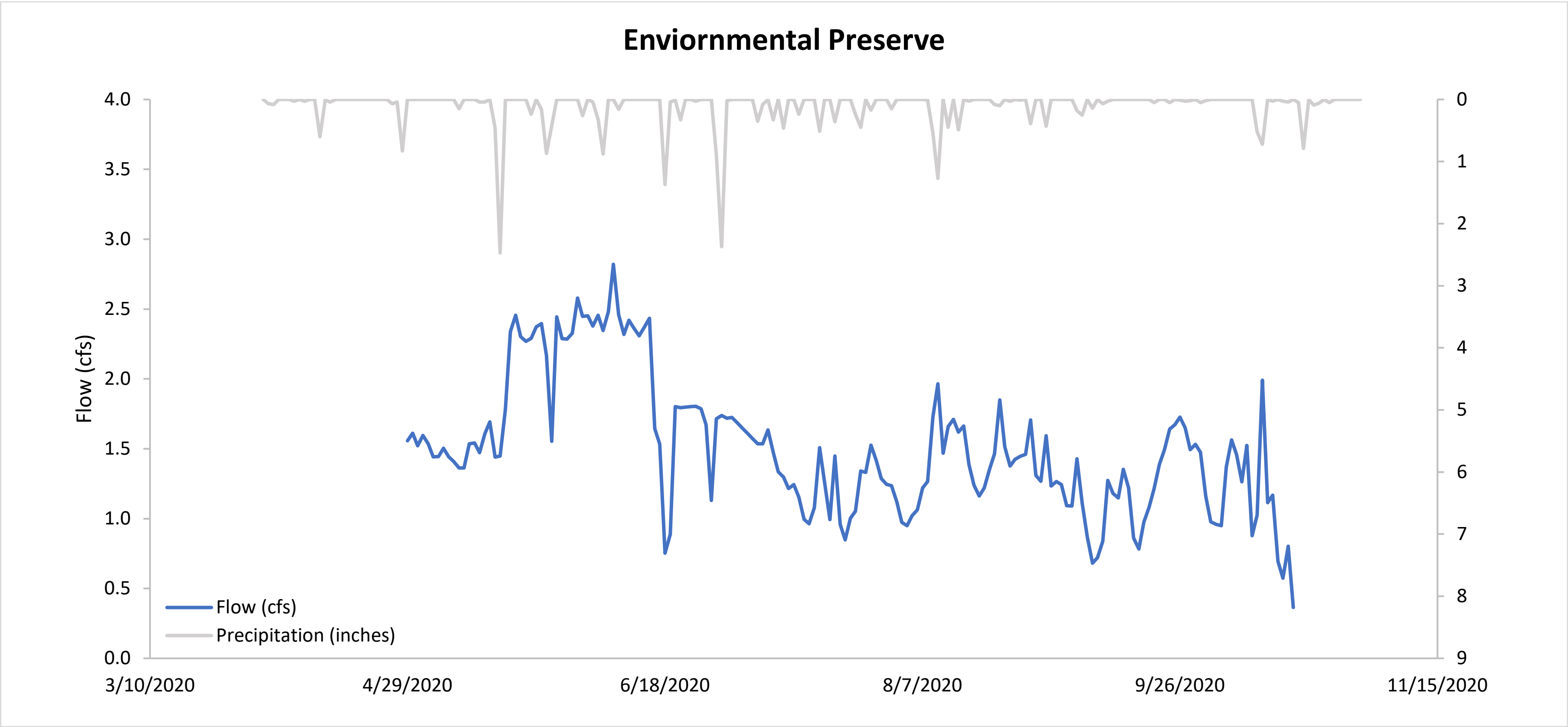


Table B4. Water quality data from the Environmental Preserve stream site measured in 2020. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [μS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
4/24/2020	11:30	13.19	12.81	126.8	8.26	914.9	12.81	0.045	0.01	4.5	77.8	4.1
5/18/2020	14:00	16.276	9.27	94.7	9.27	820	297.5	0.073	0.017	14.6	NA	325.5
6/3/2020	07:15	16.69	6.93	71.4	7.28	909	157.3	0.07	0.024	8.8	NA	290.9
7/2/2020	10:30	23.62	7.56	89.3	7.23	421.1	414.3	0.062	0.028	6.6	NA	387.3
7/27/2020	11:00	22.3	7.37	87.9	9.1	772.4	269	.107	.062	13.1	N/A	344.8
8/27/2020	08:50	21.57	6.67	75.7	7.38	807	311.5	0.083	0.04	7.8	67.6	478.6
9/30/2020	10:30	13.682	9.32	93.3	8.37	858	85.4	.055	.025	4.2	70.7	260.3
10/27/2020	09:30	1.057	11.99	86.6	7.64	929	122.2	0.056	0.019	10.1	71.8	73.8

Table B5. Storm water quality data from the Environmental Preserve stream site measured in 2020. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	Time	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
**5/17/2020	16:00	N/A	N/A	0.101	0.02	39	1413.6
10/12/2020	08:25	10/12/2020	9:40	0.165	0.034	31	866.4
10/21/2020	02:41	10/21/2020	8:26	0.085	0.018	21.8	60.2

**storm sample was taken as a grab sample from the stream during high flow.

Table B6. Nutrient and Chemical Loading for the 65th Ave and ENVP sites calculated for monitoring period.

Site	Annual TP load (lbs)	Annual TSS load (lbs)	Annual Chloride load (lbs)
65th Ave	899	210,174	599,051
ENVP	120	22,760	13,166

* ENVP Load was calculated from April 29th – October 19th, 2020.

** 65th Avenue Load was calculated from March 12th – December 31st, 2020.

Appendix C: 2020 Shingle Creek Stream Data

OVERVIEW

Shingle Creek (AUID 07010206-506) is impaired for chloride, aquatic life (macroinvertebrate IBI), and aquatic use (*E. coli*). Bass Creek (07010206-784), a headwater stream to Shingle Creek, is impaired for chloride and aquatic life (Fish IBI). West Mississippi streams have not been assessed. The Shingle Creek and West Mississippi Third Generation Watershed Management Plan includes annual monitoring of four stream locations in the Shingle Creek Watershed, one on Basset Creek (BCP) and three on Shingle Creek (SC-3, SC-0, and USGS), and rotating monitoring of two sites in the West Mississippi Watershed (ENVP, Mattson Brook, Oxbow, and 65th Ave). The primary purpose of the stream monitoring program is to assess progress toward achieving the TMDLs and state water quality standards for the impaired streams and to track water quality of unimpaired streams. Activities included in the stream monitoring program include routine and storm water quality, flow, and conductivity monitoring. Three of the Shingle Creek sites (BCP, SC-3, and SC-0) and two rotating West Mississippi sites are monitored routinely during the growing season (April through October) for multiple water quality parameters. Shingle Creek sites are monitored once a month in the winter (November through March) for chloride concentrations. The USGS site is only monitored in the winter for chloride.

In Section 1.0, we provide an overview of the various stream sampling methodologies (Section 1.0) used to collect routine water quality (Section 1.1), storm water quality (Section 1.2), flow and load calculations (Section 1.3), and conductivity (Section 1.4) data at the stream sites. In Sections 2.0 and beyond we summarize activities and results from 2020 monitoring for each of the four sites monitored.

Results and discussions for each Shingle Creek stream can be found in the following order:

- Section 2.0 – BCP
- Section 3.0 – SC-3
- Section 4.0 – SC-0
- Section 5.0 – USGS
- Section 6.0 – Rainfall

See Appendix B for West Mississippi streams data.

1.0 Sampling Methods

1.1 ROUTINE WATER QUALITY

Shingle Creek and West Mississippi streams are within highly urban areas but serve as important water features to the cities they flow through. The streams flow through various parks and have multiple miles of adjacent walking paths. The streams are home to many animals including muskrats, fish, crayfish, and ducks. The Minnesota Pollution Control Agency (MPCA) monitors and assesses streams around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor the thousands of streams in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA in sampling and collecting information on the state of water quality of its streams. The Commission is focused on sampling total suspended solids, total phosphorus, total dissolved phosphorus, soluble reactive phosphorus, chloride, and *E. coli*. In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its streams.

Routine stream monitoring samples are typically collected twice per month starting in April and ending in October. For three streams (BCP, SC-3, and SC-0), water samples are collected and assessed for total suspended solids (TSS), total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (ortho-P), chloride, and *E. coli*. In addition to these chemical parameters, *in-situ* readings of physical parameters are also taken. A YSI or similar multimeter water quality sonde is used to collect these measurements. Parameters measured include dissolved oxygen (DO) concentration, water temperature, pH, oxidation-reduction potential (ORP), and specific conductivity. During the late fall, winter, and early spring chloride samples and physical parameters are taken at the three previously mentioned stream sites and one additional site (USGS).

Stream stage height at BCP, SC-3, SC-0, and West Mississippi monitoring sites is measured using an automated water sampler (ISCO model 6712) which is deployed in early April until late October. The ISCO water sampler is connected to a pressure transducer deployed in the stream (ISCO 720 Submerged Probe Flow Module). Stage height is periodically adjusted throughout the monitoring season using stream tape-down measurements taken in the field. Tape-down measurement are the distance to water from a known, fixed elevation in or near the stream. Stream stage height is converted to flow (discharge) measurements during data processing. The process is described in Section 1.3. Flow data are collected year-round at the USGS gage site 05288705 on Shingle Creek.

Flow data, lab samples, and *in-situ* data are used to understand the cycling of chemicals and nutrients in the stream system, identify watershed pollutant loads, and indicate areas of excess chemicals and nutrients.

1.2 STORM WATER QUALITY

Storm water quality samples are typically collected from April through October when a storm event of 0.5 inches or greater occurs. Storm samples are taken each year at BCP, SC-3, and SC-0 sites, and at West Mississippi sites chosen for routine monitoring that year. Storm event water samples are collected using the ISCO automated water sampler at 15-minute intervals. Discrete water samples are composited and sent to the lab for analysis of TSS, TP, TDP, OP, and *E. coli*. No physical parameters are measured during storm events.

1.3 FLOW AND LOAD CALCULATIONS

ISCO-measured state height is converted to flow measurements at the end of each field season. Field staff measure streamflow using a FlowTracker Handheld IDV (San Diego, CA) periodically throughout the monitoring season. Field staff developed a relationship between stream stage height and stream flow measured in the field. This relationship is fit with a polynomial equation that relates stage height to flow for the time that the ISCO is deployed (April through October). During winter months when the ISCO is not deployed at field sites, flow at SC-0, SC-3, and BCP is linearly interpolated using data from the USGS gage on Shingle Creek.

Flow and routine water quality samples are used together to generate load calculations for various water quality pollutants. Loads were estimated as the total streamflow volume at each site multiplied by the flow-weighted mean concentration (FWMC) of a given water quality parameter. Flow weighted mean concentrations are calculated as:

$$FWMC = \frac{\sum_{l}^{n} c_i * q_i}{\sum_{l}^{n} q_i}$$

Where c_i is the pollutant concentration of the i^{th} sample and q_i is the streamflow of the i^{th} sample.

1.4 CONTINUOUS SPECIFIC CONDUCTIVITY MONITORING

Specific conductivity and temperature probes (AquaTroll 500, In-Situ Inc., Fort Collins, CO) are deployed at BCP, SC-3, and SC-0 sites year-round. Conductivity and temperature are measured by the probe in 15-minute intervals and data are downloaded periodically. A linear relationship between continuously monitored specific conductivity and chloride concentrations measured from grab samples is modeled. The linear relationship between chloride and specific conductivity allows us to estimate chloride concentrations in the stream throughout the entire year.

Table C1. Water quality data from the Bass Creek Park (BCP) stream site measured in 2020. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride and Escherichia coli (E. coli). Note that there is no data from January and February because water was frozen at this site during sampling events.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
1/14/2020	10:45	0	9.99	70.6	7.56	916.4	483					177	
2/11/2020	08:30	-0.09	9.31	65.5	6.91	1631.1	478					374	
3/10/2020	09:00	-0.032	9.47	65	7.18	1385	262					313	
4/10/2020	08:00	3.16	9.78	75.4	7.32	883.1	391					191	
4/24/2020	09:00	8.83	10.12	90.9	7.51	1587.1	346	0.043	0.003	0.016	4.8	367	201.4
5/5/2020	10:00	12.51	8.6	83.5	8.08	789.3	341	0.044	0.009	0.018	5.6		727
5/18/2020	10:45	11.58	8.06	74.2	9.18	644	353.1	0.066	0.025	0.035	4.8		866.4
6/3/2020	06:30	18.292	3.62	38.6	7.18	824	152.1	0.068	0.028	0.032	2.7		488.4
6/16/2020	09:30	18.45	4.68	51.4	7.06	773	740	0.078	0.031	0.046	1.7		344.8
7/2/2020	14:00	27.89	7.00	99.8	7.55	847	371	0.158	0.098	0.113	2.1		410.6
7/16/2020	11:30	20.716	5.76	64.4	8.35	1126	310.7	.125	.034	.043	7.8		
7/27/2020	13:30	24.54	9.25	114.9	8.91	652	252	0.16	0.086	0.098	19.5		387.3
8/11/2020	11:15	19.53	6.69	73	8.16	625	346.3	0.118	0.041	0.077	3		866.4
8/27/2020	11:10	23.61	5.84	71.6	7.78	691	291.6	0.127	0.06	0.079	2.9	117	201.4
9/10/2020	14:45	12.44	9.3	88.6	7.89	720	131.7	0.089	0.015	0.022	8.5	119	235.9
9/30/2020	10:00	13.04	5.38	53.1	8.57	1141	109.7	.117	.013	.022	8.7	141	
10/27/2020	12:30	1.011	10.66	77	4.51	1268	89.6	0.068	0.017	0.033	5.8	235	52.9
11/19/2020	08:49	2.38	8.9	67.8	7.22	1222	460					305	
12/17/2020	12:45	2.16	13.17	98.6	7.69	1980.4	398					480	

Table C2. Storm water quality data from the Bass Creek Park (BCP) stream site measured in 2020. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
5/16/2020	02:59	5/16/2020	8:44	0.173	0.024	0.04	53.8	2419.6
5/26/2020	22:36	5/27/2020	3:44	0.111	0.023	0.039	18.4	> 2419.6
6/18/2020	17:51	6/18/2020	23:49	0.069	0.058	0.069	11.4	17329
8/9/2020	12:26	8/9/2020	17:42	0.301	0.047	0.063	65	> 2419.6
8/28/2020	04:58	8/28/2020	10:48	0.23	0.073	0.074	33.8	> 2419.6
8/31/2020	04:13	8/31/2020	9:43	0.197	0.054	0.068	38	> 2419.6

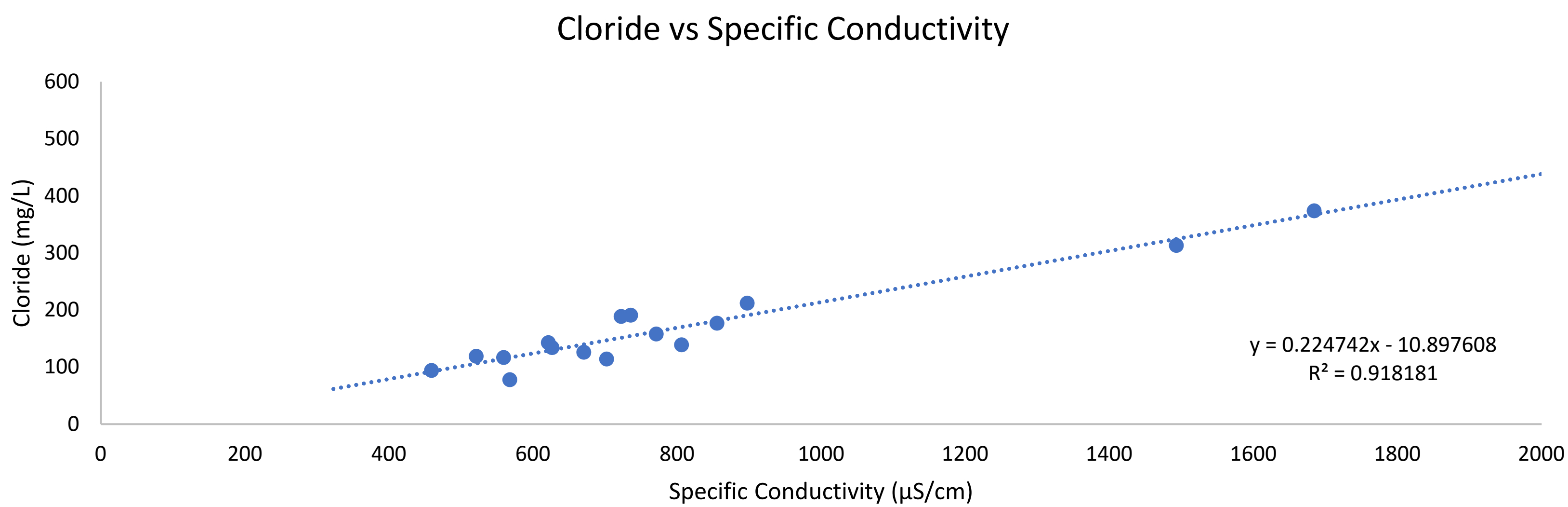


Figure C1. Relationship between probe measured specific conductivity and sampled chloride at the Shingle Creek BCP stream site from 2019-2020. Linear regression line represents the relationship between specific conductivity and chloride with an R squared value of 0.918.

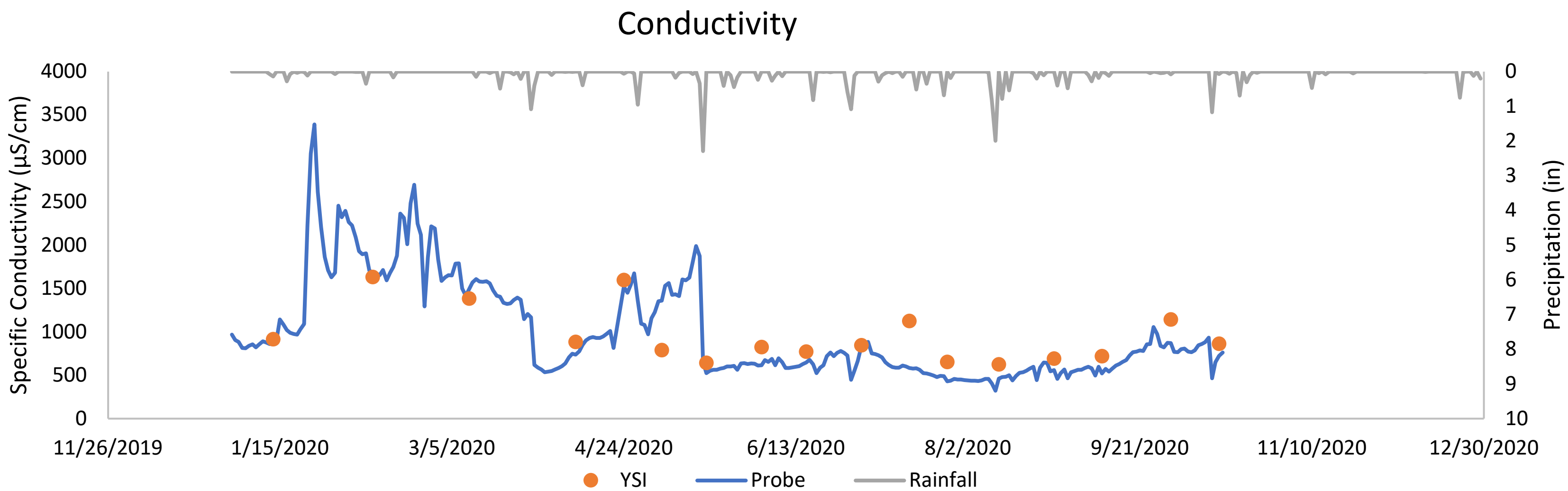


Figure C2. Continuous (AquaTroll 500) and *in-situ* (YSI) specific conductivity measurements at the BCP site in 2020.

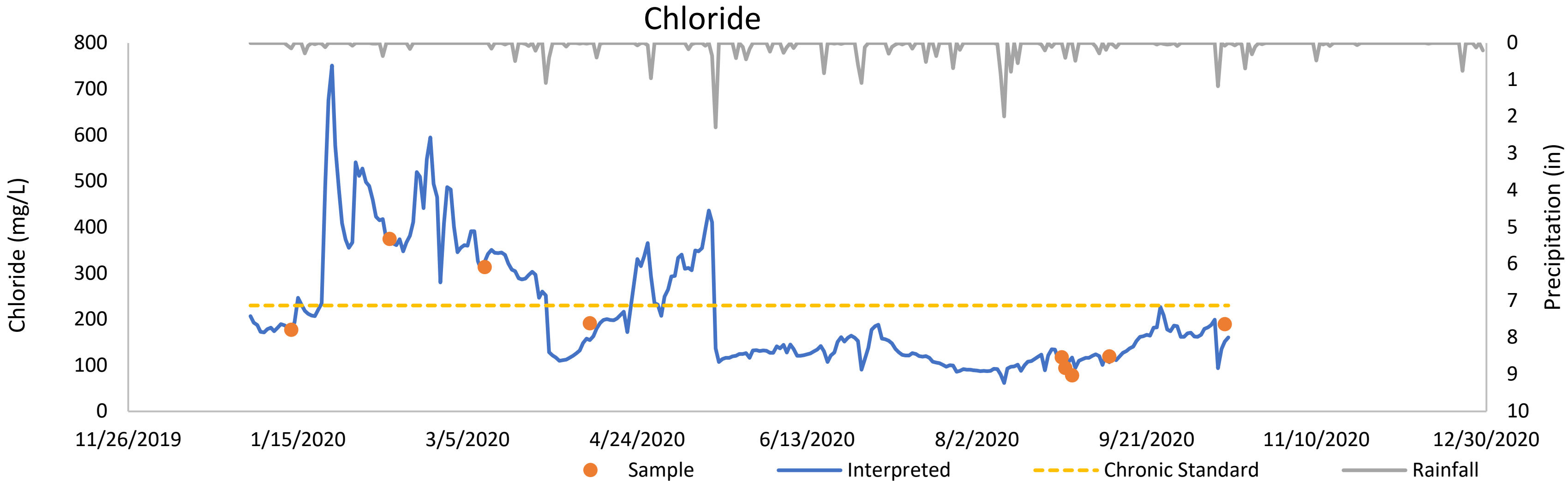


Figure C3. Interpreted and sampled chloride data from the Shingle Creek BCP stream site measured in 2020. Chloride was interpreted using the linear relationship generated between specific conductivity data and chloride at this site. The chronic standard for chloride is 230 mg/L.

Table C3. BCP historic load calculations including TP, TSS and Chloride load calculations for 2020.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2014	6,837	1,881	101	776	42	106,971	6			4,281	0.23	13,736	0.74		
2015	1,493	792	192	531	129	107,640	23.1			1,856	0.148	5,123	1.14		
2016	4,107	1,024	99	854	82	189,576	18.2					1,707	0.16		
2017	5,537	1,670	119												
2018	2,754	9,701	139												
2019	6,753	2,114	124												
2020	2,562	479	90			231,824	13.9							1,009,950	156

Table C4. Water quality data from the Shingle Creek SC-3 stream site measured in 2020. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride (mg/L) and Escherichia coli (E. coli). Note that there is no data from January and February because water was frozen at this site during sampling events.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
1/14/2020	11:00	1.39	9.5	69.9	6.95	1344.3	545					272	
2/11/2020	09:00	1.05	8.79	63.4	7.01	1922.1	436					423	
3/10/2020	10:15	0.146	11.31	78	7.41	13.41	241.4					306	
4/10/2020	08:30	4.88	10.2	82.1	7.07	849.6	398					171	
4/24/2020	10:15	10.24	8.38	77.5	7.35	1156.9	346	0.053	0.005	0.012	5.2	188	156.5
5/5/2020	11:00	13.1	9.26	91.2	8.05	1134.8	332	0.06	0.011	0.024	2.7		135.4
5/18/2020	11:45	11.469	7.78	71.5	9.1	640	383.4	0.087	0.016	0.035	13.4		770.1
6/3/2020	06:45	19.744	4.61	50.5	6.93	921	155	0.091	0.03	0.038	3.2		260.3
6/16/2020	10:45	19.76	4.72	53.3	7.14	934	739.9	0.107	0.024	0.038	7.1		980.4
7/2/2020	13:30	24.58	5.06	68.9	7.88	722	320.9	0.124	0.066	0.068	5.6		648.8
7/16/2020	10:45	19.39	3.48	38.0	8.10	1260	307.7	.082	.027	.032	5.7		344.8
7/27/2020	12:30	23.95	5.73	70.3	8.78	532.7	263	0.162	0.019	0.036	14.6		816.4
8/11/2020	12:00	20.291	6.09	67.5	8.47	485.1	383	0.193	0.024	0.054	29		1046.2
8/27/2020	10:40	24.01	4.24	52.3	7.51	757	278.2	0.155	0.062	0.086	6.1	126	770.1
9/10/2020	14:00	11.761	7.56	70.6	7.42	639	131.8	0.172	0.022	0.035	56.4	90.1	1299.7
9/30/2020	09:30	13.456	3.61	35.7	7.88	1008	87.6	.073	.014	.01	4.3	116	
10/14/2020	12:45	11.93	5.45	52.5	6.95	556	89.8	0.126	0.026	0.054	11.6	97	1203.3
10/27/2020	11:30	1.084	10.16	73.4	7.21	1007	78.9	0.081	0.015	0.034	7	186	104.3
11/19/2020	9:15	3.25	9.52	74	7.45	1165	451					198	
12/17/2020	13:00	3.52	8.34	24.2	2.8	1361.1	3.39					150	

Table C5. Storm water quality data from the Shingle Creek SC-3 stream site measured in 2020. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Start Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
**5/17/2020	17:30			0.114	0.027	0.038	23.2	1203.3
6/9/2020	15:46	6/9/2020	21:16	0.166	0.041	0.07	12	980.4
6/18/2020	17:48	6/18/2020	20:33	0.319	0.048	0.076	72	24196
8/9/2020	12:19	8/9/2020	13:19	0.305	0.02	0.028	110	> 2419.6
8/28/2020	04:53	8/28/2020	7:38	0.332	0.114	0.121	59	> 2419.6
8/31/2020	01:32	8/31/2020	5:07	0.174	0.05	0.066	19.2	> 2419.6

**storm sample was taken as a grab sample from the stream during high flow

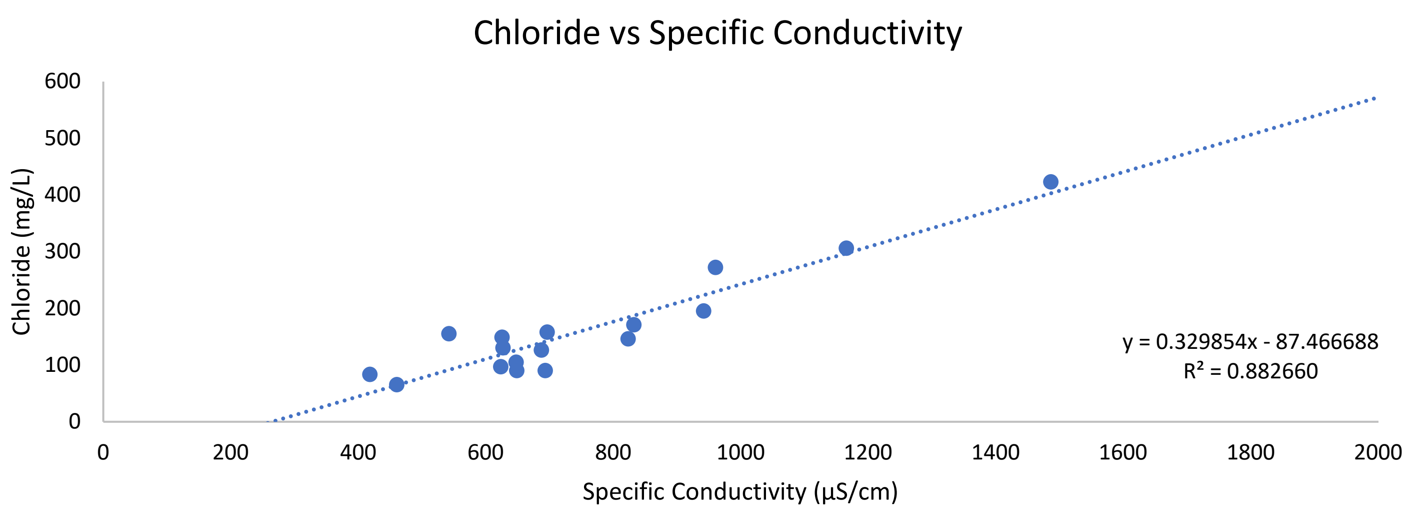


Figure C4. Relationship between probe measured specific conductivity and sampled chloride at the Shingle Creek SC-3 stream site from 2019-2020. Linear regression line represents the relationship between specific conductivity and chloride with an R squared value of 0.882.

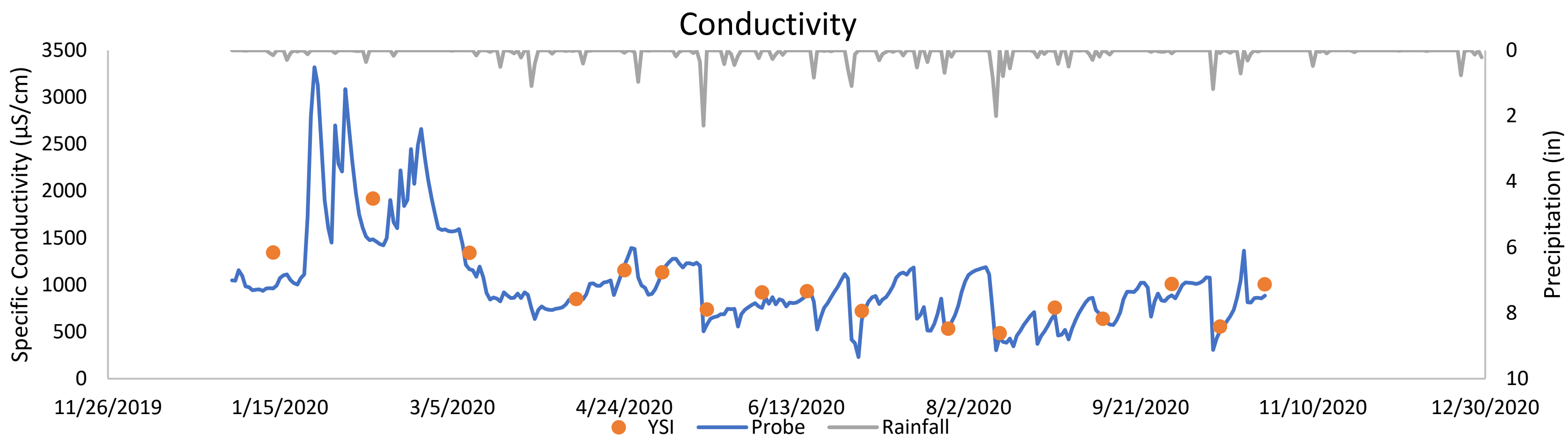


Figure C5. Continuous (Probe) and In-situ (YSI) Specific Conductivity measurements at the SC-3 site in 2020.

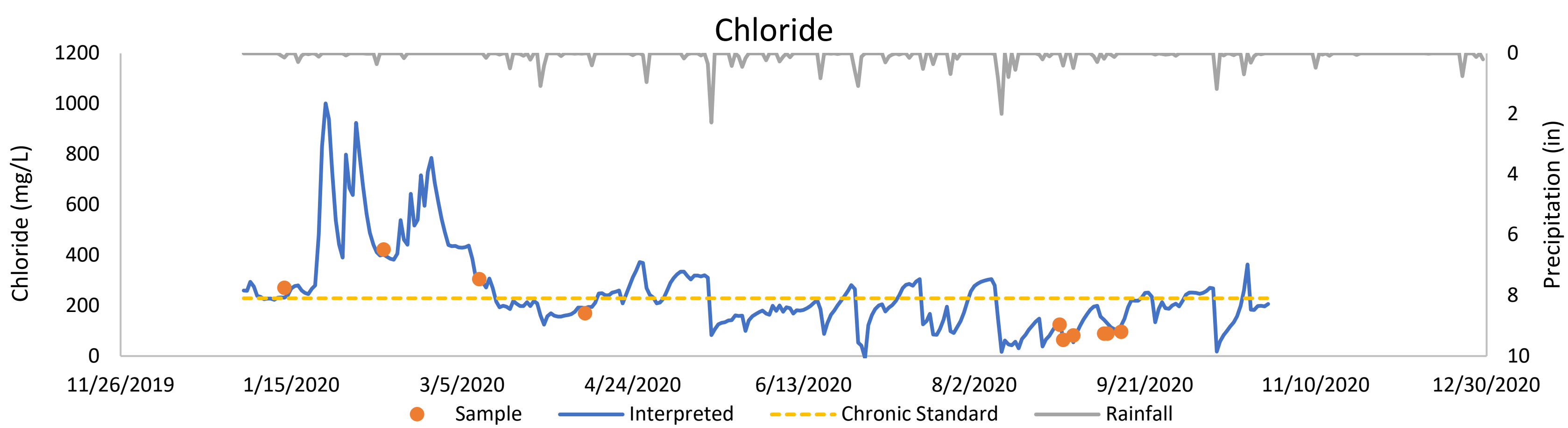


Figure C6. Interpreted and sampled Chloride data from the Shingle Creek SC-3 stream site measured in 2020. Chloride interpreted by the linear relationship generated between Conductivity data and Chloride at this site. The chronic standard for chloride is 230mg/L.

Table C6. SC-3 historic load calculations including estimated TP, TSS and chloride loads in 2020.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	7,355	4,189	209	1,543	77	599,657	30	255,736	13	6,173	0.31				
2005	10,616	5,500	191	2,640	92	464,200	16	215,600	7	8,800	0.30	35,200	1.22		
2006	3,843	2,200	211	880	84	451,000	43	138,600	13			20,240	1.94		
2007	6,270	2,200	129	880	52	391,600	23	105,600	6	3,960	0.23	24,200	1.42		
2008	2,962	880	109	220	27	85,800	11	92,400	11	1,540	0.19	8,580	1.07		
2009	961	220	84			33,000	13	15,400	6	440	0.17	1,320	0.51		
2010	4,799	1,980	152	660	51	391,600	30	147,400	11	4,180	0.32	17,820	1.37		
2011	10,099	3,192	116	719	26	591,218	22	211,470	8	3,326	0.12	25,419	0.93		
2012	5,147	2,024	145	615	44	287,380	21	108,114	8			12,572	0.90		
2013	7,033	4,110	215	1,012	53	633,717	33	395,899	21			43,336	2.27		
2014	11,736	5,042	158	1,594	54	983,344	31			8,865	0.28	34,023	1.07		
2015	5,159	2,334	166	1,289	75	293,355	20.9			2,101	0.15	15,950	1.14		
2016	17,247	4,301	149	3,588	108	796,091	54.7					7169	0.201		
2017	13,130	2,928	88												
2018	7,010	2,620	148												
2019	19,593	5,563	112												
2020	6,620	1,501	89			231,824	13.8							2,952,334	177

Table C7. Water quality data from the Shingle Creek SC-0 stream site measured in 2020. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DOsat), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
1/14/2020	11:30	0.6	11.35	11.35	7.6	1174.4	611					178	
2/11/2020	09:30	0.24	11.59	11.59	7.13	1476	490					235	
3/10/2020	09:30	2.134	11.08	80.7	7.31	1187	270.7					237	
4/10/2020	09:00	5.75	11.56	95.1	7.74	1007.4	391					182	
4/24/2020	13:45	15.1	18.5	190.7	8.28	1156.9	367	0.039	0.004	0.012	5.3	173	27.5
5/5/2020	11:45	14.31	12.9	130.3	8.52	1040	331	0.053	0.005	0.016	3.6		17.5
5/18/2020	12:30	12.31	8.71	81.5	9.21	517	362.5	0.091	0.015	0.029	12		517.2
6/3/2020	07:45	20.794	4.34	48.6	9.78	825	139.1	0.084	0.022	0.035	6.3		111.9
6/16/2020	11:15	19.96	5.39	61.1	7.25	1090	740.4	0.075	0.018	0.028	6		238.2
7/2/2020	11:45	29.92	4.84	59.7	6.92	711	404.7	0.114	0.062	0.063	7		435.2
7/16/2020	10:15	19.736	5.27	57.9	7.94	1175	310.3	.078	.027	.027	4.7		344.8
7/27/2020	9:00	22.63	4.36	52.2	8.71	645.9	262	0.083	0.028	0.035	6.7		1413.6
8/11/2020	13:00	21.906	6.07	69.4	8.15	428.6	326.6	0.123	0.023	0.042	12		488.4
8/27/2020	10:00	23.22	4.62	56.2	7.31	887	308	0.11	0.029	0.054	4.9	138	648.8
9/10/2020	14:45	12.377	8.64	82.3	7.66	948	135.5	0.069	0.027	0.04	5.6	110	260.3
9/30/2020	08:45	13.682	6.39	63.5	8.19	858	85.4	.073	.022	.041	2	234	
10/14/2020	12:00	12.479	6.05	59.0	7.22	595	97.3	0.114	0.016	0.038	7.8	74.2	261.3
10/27/2020	10:30	0.863	10.86	78.1	7.35	1146	107.1	0.083	0.009	0.027	10.2	207	80.5
11/19/2020	09:52	4.16	10.06	80.5	7.45	1376	386					246	
12/17/2020	13:30	0.52	11.22	80.2	8.01	1368.4	325					218	

Table C8. Storm water quality data from the Shingle Creek SC-0 stream site measured in 2020. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Start Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
5/16/2020	21:27	5/17/2020	3:12	0.132	0.004	0.024	29.2	2419.6
5/26/2020	20:46	5/27/2020	2:20	0.132	0.005	0.027	33	> 2419.6
6/9/2020	16:50	6/9/2020	20:47	0.095	0.009	0.032	5.4	1553.1
6/18/2020	18:16	6/18/2020	19:31	0.348	0.018	0.041	91.3	> 24196
8/9/2020	12:36	8/9/2020	17:36	0.304	0.005	0.019	102	> 2419.6
8/28/2020	5:09	8/28/2020	10:39	0.258	0.073	0.085	39.5	> 2419.6
8/31/2020	4:41	8/31/2020	10:11	0.128	0.025	0.041	22.5	> 2419.6
10/12/2020	9:00	10/12/2020	9:45	0.172	0.014	0.047	21.1	> 2419.6

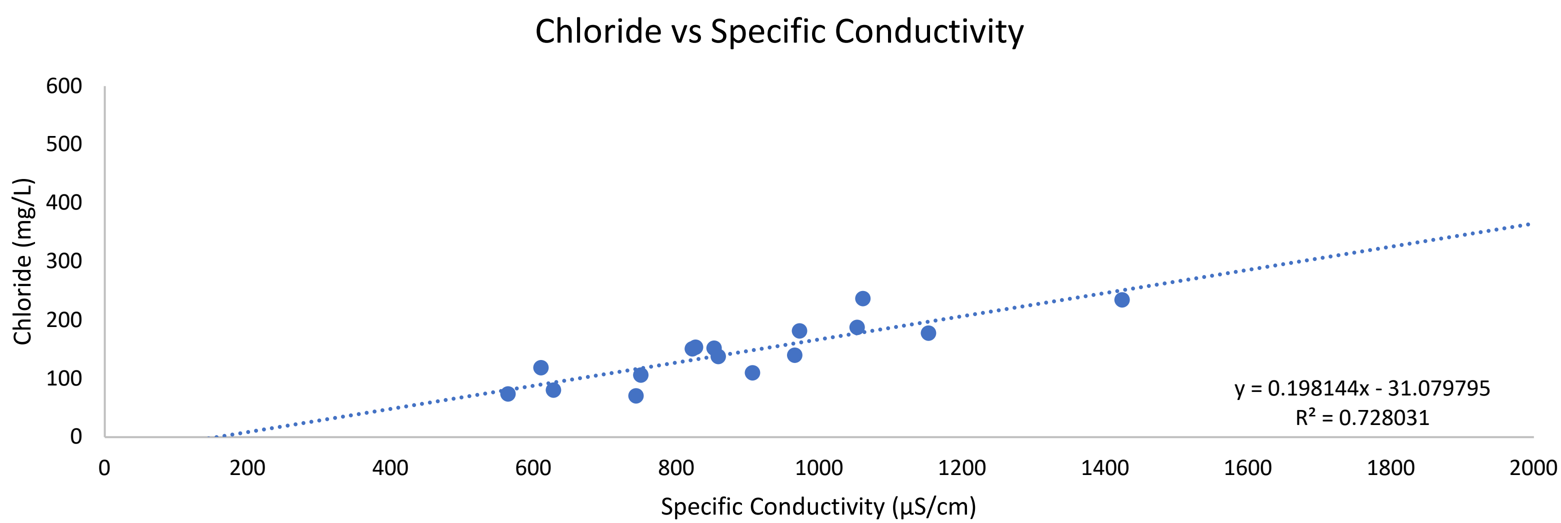


Figure C7. Relationship between probe measured specific conductivity and sampled chloride at the Shingle Creek SC-0 stream site from 2019-2020. Linear regression line represents the relationship between specific conductivity and chloride with an R squared value of 0.728.

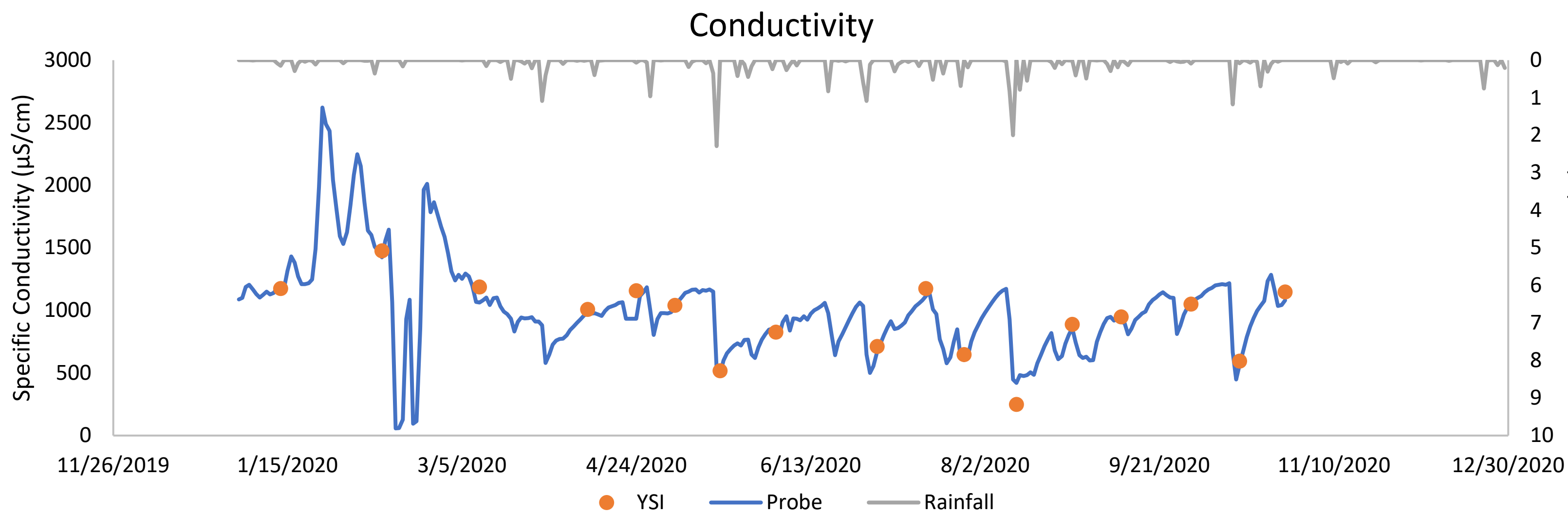


Figure C8. Continuous (Probe) and In-situ (YSI) Specific Conductivity measurements at the SC0 site in 2020.

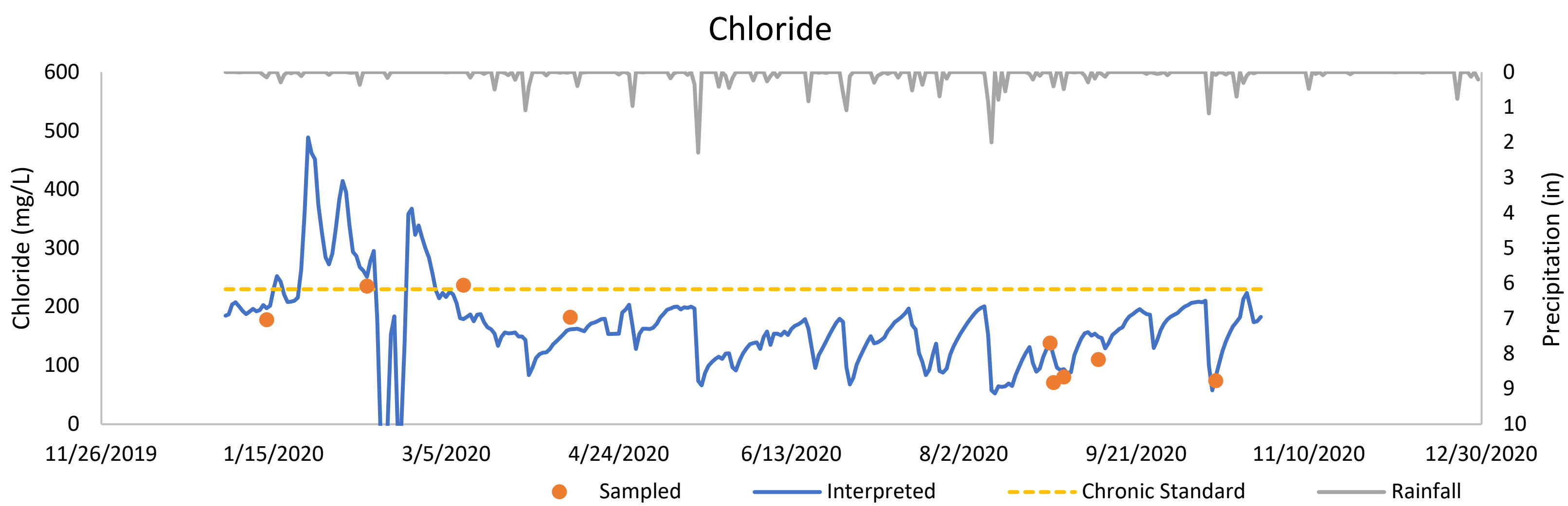


Figure C9. Interpreted and sampled Chloride data from the Shingle Creek SC-0 stream site measured in 2020. Chloride interpreted by the linear relationship generated between Conductivity data and Chloride at this site. The chronic standard for chloride is 230mg/L.

Table C9. SC-0 historic load calculations including TP, TSS and Chloride load calculations for 2020.

SC-0 Pollutant Load Trends

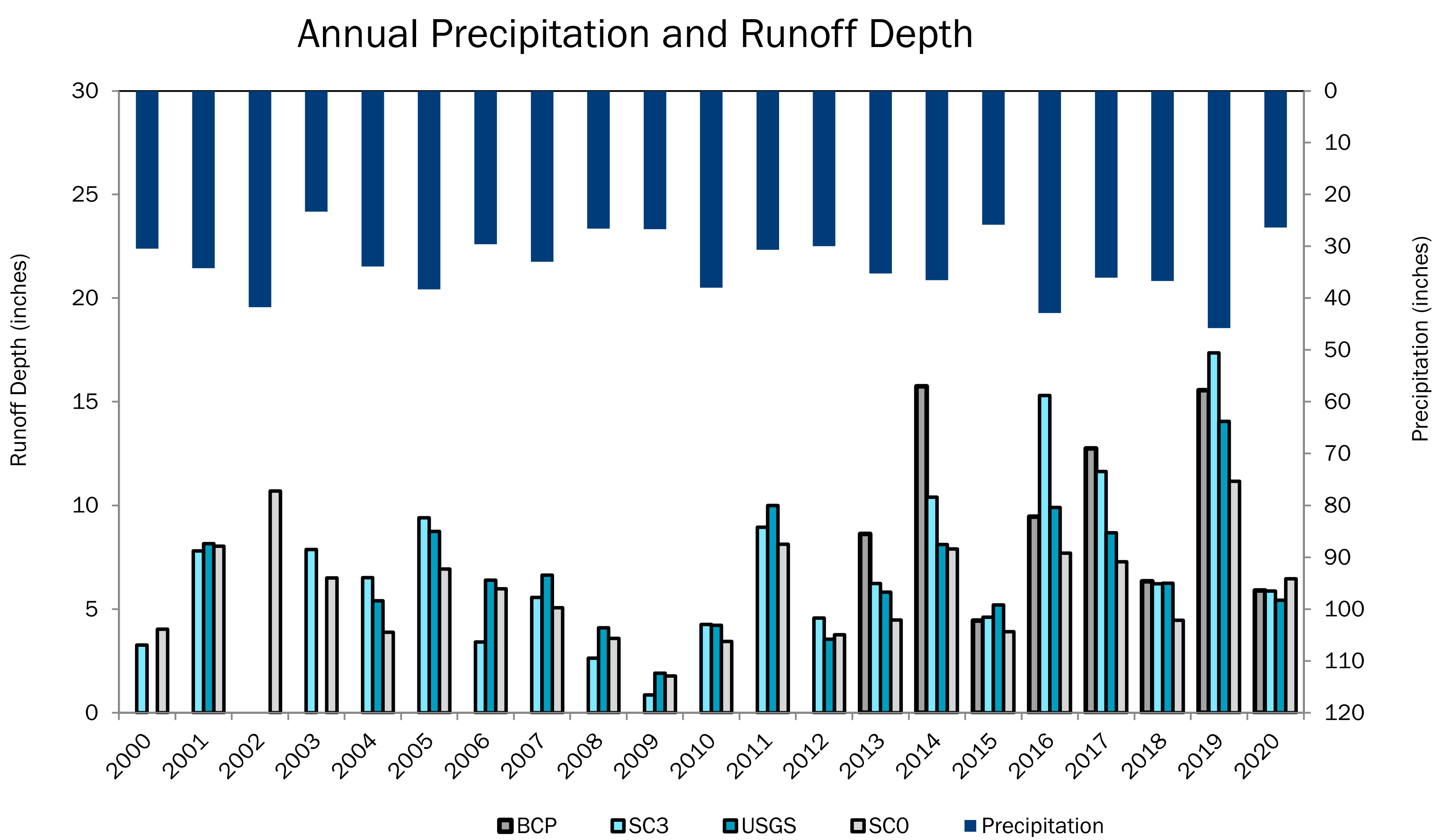
Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	8,612	3,748	160	882	38	749,572	32	308,647	13	4,409	0.19	--	--		
2005	15,367	6,820	163	1,320	32	1,577,400	38	1,031,800	25	13,420	0.32	52,800	1.26		
2006	13,255	5,060	140	1,540	43	1,095,600	30	459,800	13	--	--	39,600	1.10		
2007	11,239	3,960	130	880	29	811,800	27	431,200	14	9,240	0.30	38,720	1.27		
2008	7,950	3,080	142	660	31	367,400	17	248,600	12	6,380	0.30	25,080	1.16		
2009	3,917	880	83	220	21	231,000	22	92,400	9	1,320	0.12	5,720	0.54		
2010	7,634	3,300	159	660	32	561,000	27	233,200	11	3,740	0.18	22,000	1.06		
2011	18,023	5,814	119	1,255	26	1,098,478	22	465,297	9	14,807	0.30	54,294	1.11		
2012	7,943	3,384	157	579	27	648,520	30	286,019	13			21,219	0.98		
2013	9,916	4,382	163	511	19	660,628	24	583,448	22			36,177	1.34		
2014	17,483	5,945	125	1,131	24	1,239,189	26					55,102	1.16		
2015	8,630	2,187	113	1,679	71	683,057	29.1			4,680	0.073	23,688	1.01		
2016	17,007	4,241	148	3,538	72	785,013	58					7,069	0.309		
2017	16,149	3,601	88												
2018	9,886	2,850	114												
2019	24,763	7,001	112												
2020	14,340	3,047	84			438,045	12.1							4,726,436	131

Note: Annual flows presented in acre-feet/year, pollutant loads in pounds/year, and pollutant flow weighted mean concentrations in mg/L

Table C10. Water quality data from the United States Geological Survey (USGS) stream site measured in 2020. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	Chloride [mg/L]
1/14/2020	11:45	0.97	9.88	71.1	7.48	1274.8	584	199
2/11/2020	09:45	1.82	10.05	72.6	6.92	1542.8	485	286
3/10/2020	09:45	2.229	10.68	78	7.29	1236	224.4	238
4/10/2020	08:45	5.79	11.01	90.7	7.63	1068.1	353	191
11/19/2020	09:40	3.66	10.01	78.8	7.43	1370	397	274
12/17/2020	13:15	3.1	9.16	70.3	8.22	1401	327	210

Figure C10. Historic Annual Runoff Depth and Precipitation over the Subwatershed area for each stream site including: BCP, SC3, USGS and SC0 (2000 – 2020).



Appendix D: Wetland Monitoring

Both Commissions have participated in the Hennepin County Department of Environment and Energy Wetland Health Evaluation Program (WHEP) since 2006. The WHEP program uses trained adult volunteers to monitor and assess wetland plant and animal communities in order to score monitored wetlands on an Index of Biological Integrity for macroinvertebrates and for vegetation.

In 2020 the Minneapolis Park and Recreation Board staff assessed 6 sites across Hennepin County. On a scale of 1 to 30, the macroinvertebrate IBI scores ranged from a low of 5 (poor) to a high of 19 (excellent), with most of the sites in the 19-25 (excellent) range. On a scale of 1 to 35, the vegetation IBI scores ranged from 7 (poor) to 35 (excellent). This is unsurprising as most urban wetlands exhibit variable macroinvertebrate and vegetative diversity due to their altered hydrology and pollutant and sediment conveyed by storm sewers. It is not uncommon for a site to score well on one metric and poorly on the other, illustrating the difficulty of “rating” wetlands.

1.1.1 2020 Monitoring

Due to limitations from the COVID-19 pandemic, only one wetland site within the Shingle Creek and West Mississippi Watersheds was monitored in 2020. Site MP-19 is in Minneapolis (Figure D-1). The site is in Webber Park just to the West of Shingle Creek, about a kilometer above the creek outlet to the Mississippi River. Since MP-19 was last monitored in 2016, the waterbody has improved from poor to excellent condition in the invertebrate category and stayed moderate in the vegetation category (Table D-1).

Figure D-1. Wetland in Webber Park (MP-19), Minneapolis.

Table D-1. WHEP site MP-19 Webber Stormwater.

Year	2016	2020
Invertebrate	(poor)	21 (excellent)
Vegetation	(moderate)	19 (moderate)

Appendix E: 2020 Lake Monitoring

OVERVIEW

The Shingle Creek Third Generation Watershed Management Plan includes a rotating schedule of intensive monitoring on all lakes in the Shingle Creek Watershed. The primary purpose of the intensive lake monitoring program is to evaluate protection efforts for lakes that are not impaired, and to assess progress toward achieving the TMDLs and state water quality standards for all impaired lakes throughout the watershed. Activities included in the intensive lake monitoring program include water quality monitoring, aquatic vegetation surveys, and fish sampling coordinated with the Minnesota Department of Natural Resources (DNR).

In Section 1.0, we provide an overview of the various sampling methodologies (Section 1.0) used to collect water quality (Section 1.1), phytoplankton and zooplankton sampling (Section 1.2), submersed aquatic vegetation (Section 1.3), and fisheries (Section 1.4) data on the lakes within Shingle Creek watershed. In Sections 2.0 and beyond we summarize activities and results from 2020 monitoring for each of the five lakes monitored.

Results and discussions for each lake can be found in the following order:

- Section 2.0 – Eagle Lake
- Section 3.0 – Pike Lake
- Section 4.0 – Bass Lake
- Section 5.0 – Pomerleau Lake
- Section 6.0 – Crystal Lake

1.0 Sampling Methods

1.1 WATER QUALITY

Lakes are central to Minnesota's economy and our way of life, making it imperative that we protect our high-quality lakes and work to restore those with poor water quality. The Minnesota Pollution Control Agency (MPCA) monitors and assesses lakes around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor the more than 10,000 lakes in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA in sampling and collecting information on the state of water quality of its lakes. The Commission is focused on sampling total phosphorus (nutrient), chlorophyll-*a* (pigment in algae), and Secchi depth (a measure of water clarity). In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its lakes.

Routine lake sampling occurs on a rotating basis. For a lake that is selected for sampling in a given year, water samples are typically collected twice per month starting in May and ending in September. For all lakes, surface water samples are collected and assessed for total phosphorus (TP), soluble reactive phosphorus (ortho-P), total suspended solids (TSS), and chlorophyll-*a* (chl-*a*). In some of the deeper lakes, a hypolimnetic (deep) water sample is collected and tested for TP and ortho-P. In addition to these chemical parameters, a physical profile of the lake is assessed in the deepest part of the lake. A profile typically consists of measurements at the water's surface and at each meter below the surface throughout the entire water column. A YSI or similar multimeter probe is used to collect these measurements. Parameters measured include dissolved oxygen (DO), dissolved oxygen percent saturation, temperature, pH, oxidation reduction potential (ORP) and specific conductivity. Additionally, a Secchi disk reading is taken during every assessment to record the relative level of water transparency.

Lake profiles are used to better understand the chemical and nutrient cycling processes occurring within the lake, in addition to the stressors that may be contributing to biological impairments. The surface water chemical information is used for multiple reasons, one of which is to compare to the North Central Hardwood Forest (NCHF) ecoregions water quality standards established by the MPCA (Table 1.1).

Table 1.1. MPCA water quality standards for the NCHF ecoregion by lake type.

Lake Type	TP (ug/L)	Chl-*a* (ug/L)	Secchi (m)
Deep	40	14	1.4
Shallow	60	20	1.0

1.2 PHYTOPLANKTON AND ZOOPLANKTON SAMPLING

The phytoplankton and zooplankton communities are a key part of the lake ecosystem. They represent the base of the food chain and are often indicators of nutrient regimes and water quality.

We began routine sampling for phytoplankton and zooplankton communities in 2020 by sampling each lake in early and late summer.

Both phytoplankton and zooplankton samples are taken by towing a plankton net with a known mesh size and net diameter vertically through the water column. The sample is transferred to a bottle and a known volume is subsampled for identification. Plankton were identified to the genera classification.

Five different phytoplankton genera were identified in Shingle Creek lakes in 2020: Cyanobacteria, Chlorophyta, Dinoflagellate, Diatom, and Golden Algae. Cyanobacteria are commonly known as blue green algae and have the potential to form toxic blooms which are detrimental to human and ecosystem health. Cyanobacteria are indicative of nutrient rich, calm water. Cyanobacteria are not a preferred food source for zooplankton and they out compete other phytoplankton which are more important to the food chain. Chlorophyta are commonly known as green algae, they are prolific in mid-summer when harmful algae blooms (HABs) are not present. Green algae are a good sink for dissolved nutrients and are an important food source for zooplankton. Dinoflagellates are ubiquitous in freshwater lakes; they are an important part of the food chain and are indicative of low nutrients. Diatoms are most prevalent in the early growing season and they are a very important part of the food chain. Golden algae are similar to diatoms but are more uncommon in freshwater systems and can be found in the benthos.

Changes in phytoplankton composition are important for understanding:

- Pre and post management; indications of management impacts on water quality and all trophic cascades.
- Seasonal changes in nutrients and mixing regimes
- Food chain health throughout the growing season
- Risk of HAB formation

The most common composition change in a healthy lake ecosystem will shift from diatoms in the early spring to green algae in mid-summer to cyanobacteria in late summer. However, it is important to note that in healthy system that no one genera should be the only one represented. One hundred percent of one genera indicates an imbalance in the ecosystem in which one genera was able to completely out compete the others.

1.3 SUBMERSED AQUATIC VEGETATION

In healthy lake ecosystems aquatic vegetation will grow throughout the littoral area (< or = 15 feet depth) and consist of a diverse native community (Figure 1.1). A well vegetated littoral area promotes and facilitates the health of a lake's ecosystem by providing critical spawning, foraging and nursery habitat for aquatic insects, amphibians, birds, and fishes. The littoral area is also important for human recreation and aesthetic enjoyment.

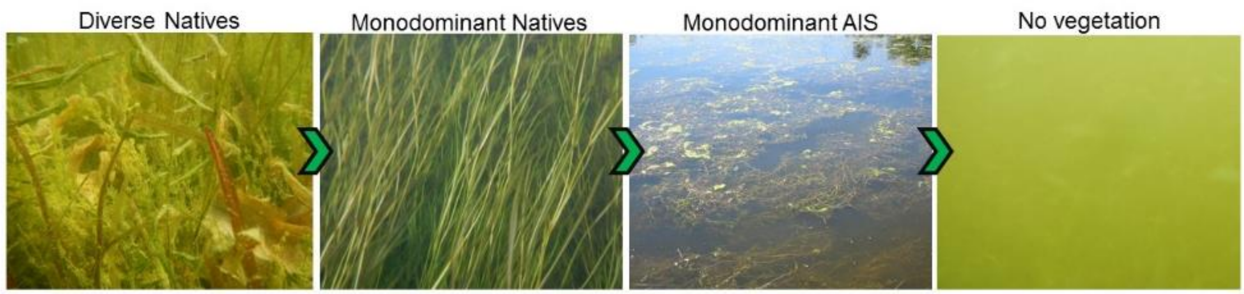


Figure 1.1. Biotic community health continuum portrayed using submersed aquatic vegetation.

The relative health of the SAV community can be assessed with the DNR's Floristic Quality Index (FQI). The FQI is an assessment tool used to determine the biological health of the SAV community. The FQI utilizes species richness and the habitat specificity (C-score) of each species identified to score community health (Equation 1.1). C-score is an index of how desirable or tolerant a group of species is, and DNR standard C-Scores range from 1 to 10 (with 1 being the worst and 10 being the best). FQI scores are compared to a threshold for context and classification of biological impairment status. Lakes with greater FQI scores and taxa richness are typically comprised of diverse native communities with abundant plant growth across the entire littoral area. As health begins to deteriorate within the lake, we typically see a reduced diversity, introduction of invasive species, increasing monodominant communities, and decreased growth across the entire littoral area. Extremely degraded lakes become void of plant growth and become dominated by phytoplankton and/or harmful algae blooms. The biological thresholds for deep lakes in the Central Hardwood Forest ecoregion are a FQI score of 18.6 and 12 taxa. The biological thresholds for shallow lakes in this ecoregion are 17.8 and 11, respectively.

Equation 1.1. Definition of the DNR's Floristic Quality Index (FQI).

$$FQI = \overline{C_{Score}} * \sqrt{No. of\ Species}$$

To assess the presence, abundance, and health of the submersed aquatic vegetation (SAV) community, two point-intercept surveys are typically conducted: late spring (typically May or June) and late summer survey (typically July or August). Late spring surveys are primarily conducted to understand the presence and distribution of *Potamogeton crispus* (curly-leaf pondweed, CLP), a plant with high spring growth and early growing season senescence. Late summer surveys provide the greatest assessment of SAV community, abundance, and spatial distribution. Therefore, if a single survey is conducted on a lake, targeting the late summer survey timeframe is recommended.

To sample the SAV community, computer software is used to overlay a grid of points (distance between points is lake specific) across the entire lake. The resulting points serve as predetermined sampling locations. To limit sampling of vegetation where it is not expected to grow, all deep lakes within Shingle Creek are capped to a maximum sampling depth of 20 feet or more (lake specific), therefore, all sampling points in depths beyond the designated cap are removed from the sampling grid. This results in a lake specific number of sampling locations, however, the sampling protocol and reporting of each lake is similar and allows comparisons to be made across systems.

At each survey location a double sided weighted 14-tine rake is thrown from the boat, allowed to sink, and pulled across the lake bottom to represent approximately 1 m^2 of lake area. We refer to this process as a rake toss. For each rake toss, vegetation is removed from the rake, identified to the

species level, placed in a perforated bucket, weighed and assigned a proportion of the total biomass based on visual approximation (i.e. 80% of total weight was curly-leaf pondweed and 20% of total weight was coontail). All biomass values are reported in wet weights (kg).
**Note: Lily species, duckweed species, and filamentous algae are not included in any biomass measurements due to difficulty in collecting a representative sample with the sample rake, however, their locations and C-Score values are recorded and factored into the lake FQI score.*

We developed a model to estimate the total SAV biomass within the lake. Depth was stratified into four intervals (0-5, 5-10, 10-15, >15 feet) to more accurately account for spatial variation in vegetation growth and improve model accuracy. For each species we calculate a depth interval specific frequency of occurrence, an average rake toss biomass, and a depth interval lake area. Multiplying these three parameters results in a species-specific total biomass/depth interval. All species-specific depth interval biomasses are then summed within each depth interval to calculate depth specific biomasses and all depth intervals are summed to calculate a total lake biomass (Equation 1.2). The total lake biomass estimation uses the individual surveyed data point information to extrapolate coverage estimates across the entire basin. This is not meant to serve as an exact biomass calculation, rather, this estimate is useful to 1) make relative comparisons to other observed species, 2) be used to compare to future sampling efforts, and 3) provide general information to assist aquatic vegetation management planning.

Continuous sonar readings were also collected during each survey trip using a Lowrance HDS Sonar/GPS unit. This data was processed using CiBioBase software (https://www.cibiobase.com/) to map water depth and vegetation biovolume. Biovolume differs from biomass in that it provides context to vegetation water column saturation. The higher the biovolume the more saturated the water column is with vegetation. Sonar readings in depths <2 feet are subject to extreme 'sonar noise' and therefore are not always accurate. Additionally, sonar readings do not detect surface floating vegetation (i.e. pad part of Lily species, duckweed).

Equation 1.2. Definition of total in-lake submersed aquatic vegetation biomass.

$$Total\ Lake\ Biomass = \sum ([Depth\ Interval]\ (\overline{Species\ Biomass} * Species\ \%\ Occurence * Basin\ Area))$$

1.4 FISHERIES SURVEYS

Fish communities are sampled using various techniques and equipment to target specific aspects of the fish community or due to the type of system being sampled. During the 2020 Shingle Creek lakes monitoring season we used one survey technique/assessment method to assess the fisheries communities (Section 1.4.1).

1.4.1 Common Carp Population Evaluation (Lakes of Water Quality Concern)

The common carp (*Cyprinus carpio*) is a widespread aquatic invasive species that can have deleterious effects on lake ecosystems. Common carp uproot aquatic vegetation, resuspend lake bottom sediments and increase available nutrients that can fuel algal growth leading to ecosystem degradation. Significant water quality degradation has been shown to begin at common carp densities of 100 kg/hectare (89 lbs./ acre) (Bajer 2012). Efforts aimed at restoring water quality that do not reduce the presence of common carp have limited success in long term restoration, therefore, survey efforts are used to determine common carp densities and whether there is a need for carp management. Common carp population assessments implement boat electrofishing techniques that target the carp population within a lake. Carp are targeted along shoreline habitats with captured carp total length measured, weighed, and tallied. A regression model is then used to extrapolate the abundance and density of common carp with the lake. Inputs into the regression model include the amount of time fished (shocking time), the total number of fish captured, and total biomass captured.

2.0 Eagle Lake

2.1 INTRODUCTION & SAMPLING OVERVIEW

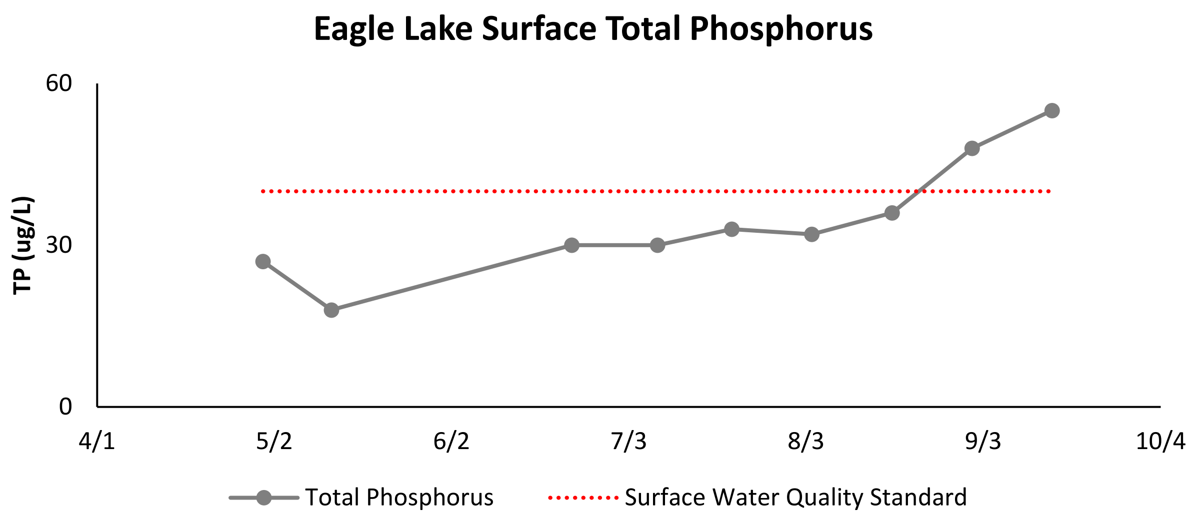
Eagle Lake is located in the city of Maple Grove within Hennepin County, MN. Eagle Lake is classified as a deep lake and has an approximate surface area of 296 acres, 199 acres of littoral area (i.e., area less than 15 feet deep), 5.1 miles of shoreline, and a maximum depth of 34 feet. The list below summarizes the year in which each type of sampling was most recently performed on Eagle Lake:

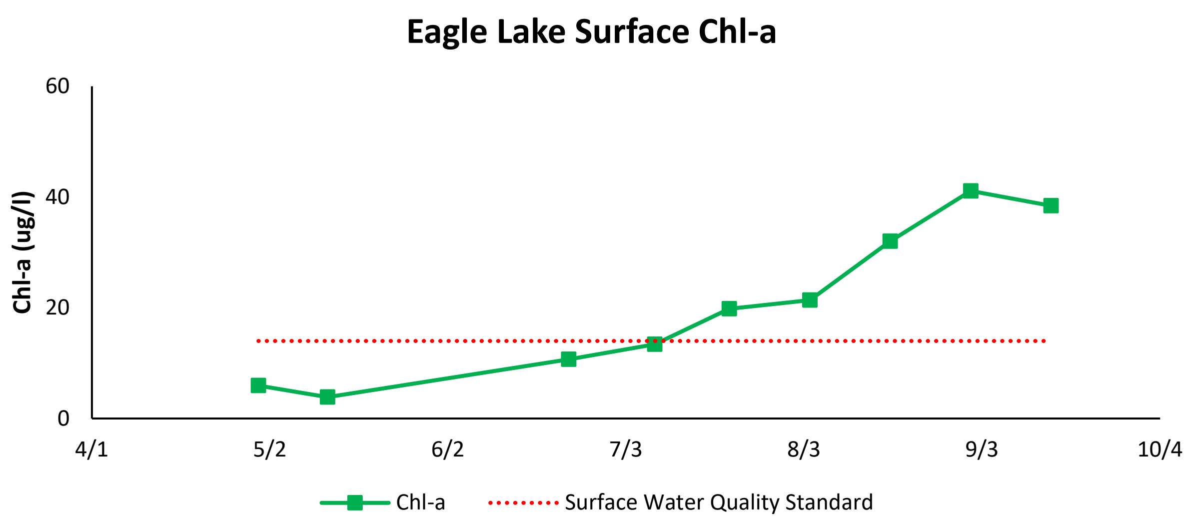
- Water Quality - 2020
- SAV – 2020
- Phytoplankton/Zooplankton - 2020
- Fisheries – Not assessed
- Carp – Not assessed

2.2 WATER QUALITY

Water was collected biweekly from early May through mid-September 2020 for a total of 11 samples. Surface TP measurements remained below the State's deep lake standard of 40 ug/L for most of the monitoring season (Figure 2.2.1). Chlorophyll-a and Secchi depth measurements remailed below the standard during the beginning of the monitoring season, but measurements exceeded the State standards late summer.

Historic data show similar patterns as 2020 monitoring data; average yearly TP concentrations are typically below or near the state standard, while chlorophyll and Secchi depth exceed the state standard (Figure 2.2.1). The most recent trend analysis for Eagle Lake indicates an increasing (improving) trend in Secchi depth and a decreasing (improving) trend in TP concentrations (Wenck 2020). TP samples taken from the hypolimnion followed a similar pattern to previous years, with peak TP concentrations occurring in August and then decreasing during the rest of the monitoring season (Figure 2.2.3). The decrease in hypolimnion TP concentrations near the end of the monitoring season may indicate the ability of lake sediments to re-bind P under oxygenated conditions as lakes mix in the fall.





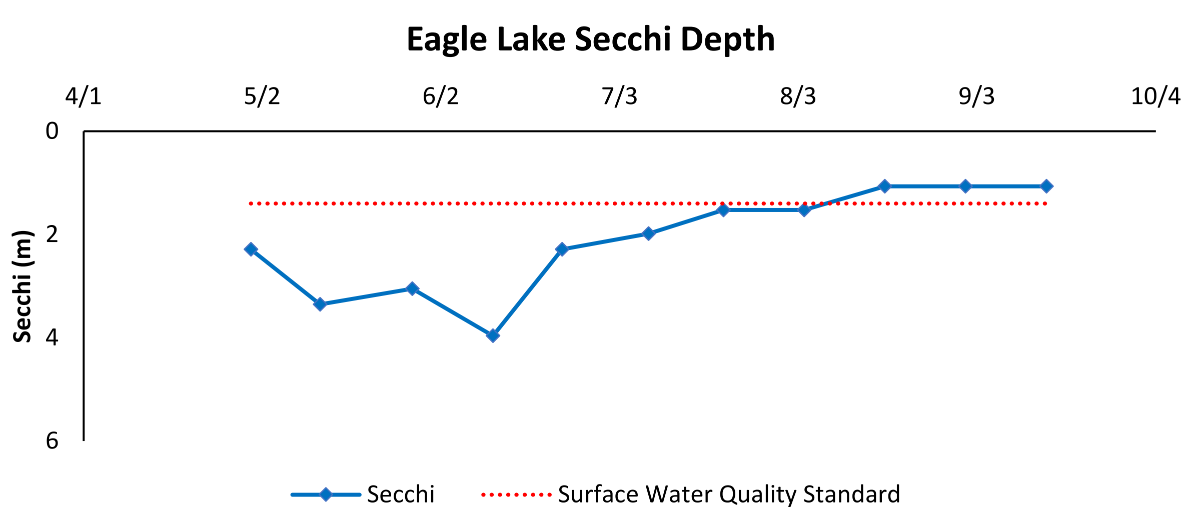


Figure 2.2.1. Seasonal TP, chl-*a*, and Secchi measurements and standards.

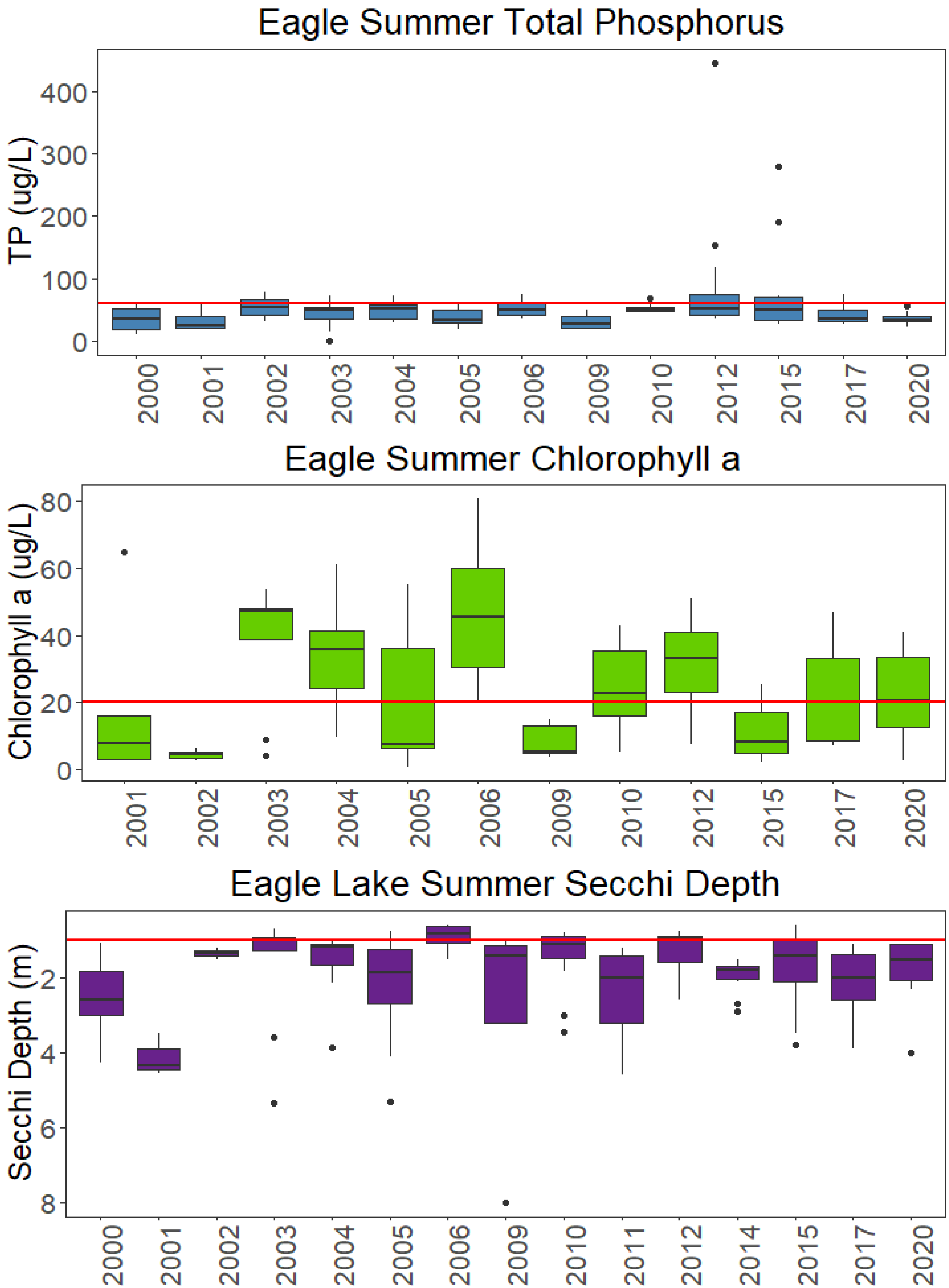


Figure 2.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

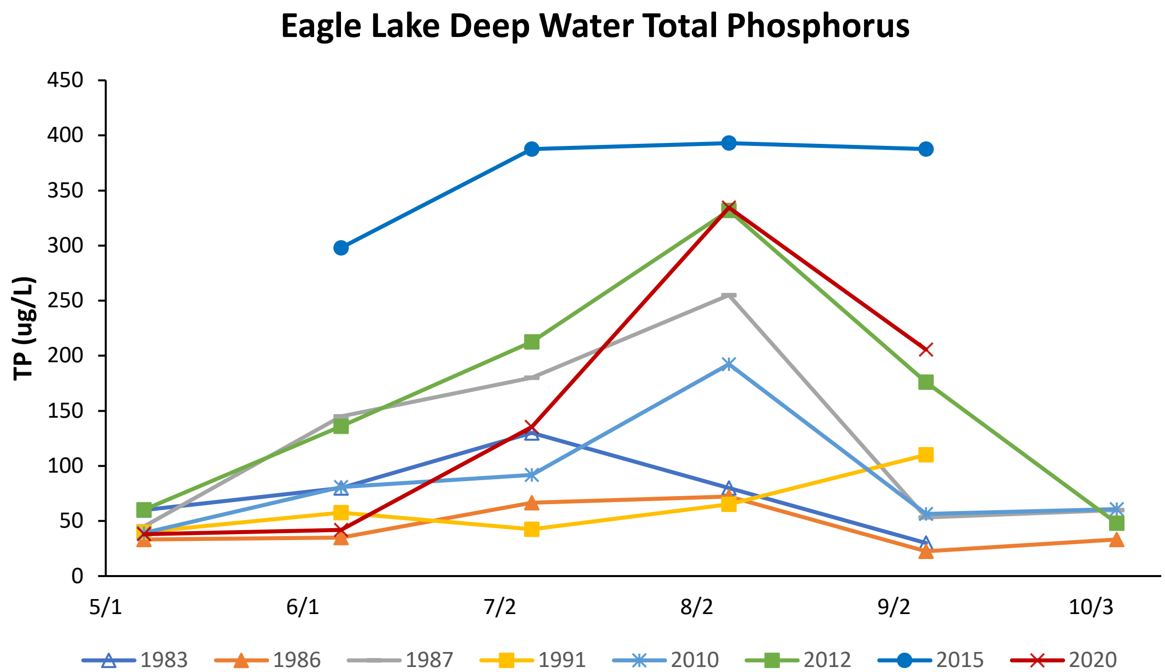
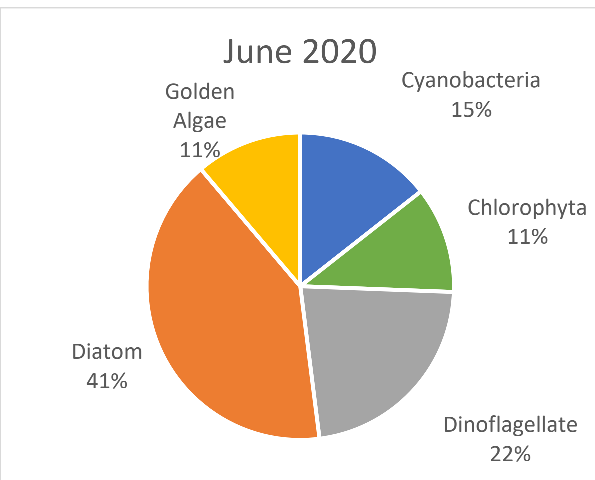


Figure 2.2.3. Eagle Lake historic total phosphorus concentrations in the hypolimnion.

2.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton composition were measured in June and August 2020 to compare the relative percentages of each genera and changes throughout the season.



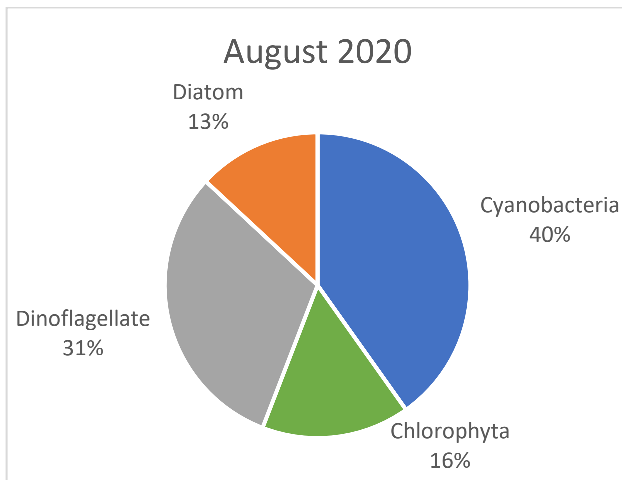
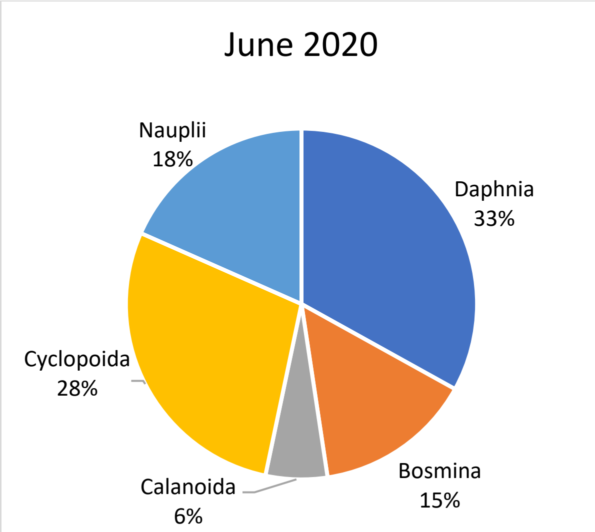


Figure 2.3.1: Phytoplankton relative percentage from June and August 2020.

Eagle lake experienced a shift in phytoplankton dominance from diatoms and golden algae (similar genera) to cyanobacteria later in the summer. Dominance of diatoms and golden algae are good food sources to fish and zooplankton. With the warmer water temperature in August, there was a shift to slight dominance of cyanobacteria. This is a typical composition shift in a healthy freshwater ecosystem. Diatoms and golden algae are competitive in colder water and cyanobacteria are more competitive in warmer water and high nutrients. Cyanobacteria at 40% abundance is dominant but is not indicative of a cyanobacteria bloom.



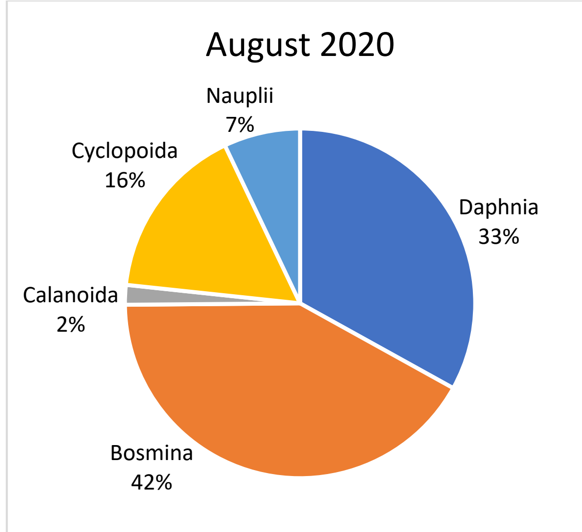


Figure 2.3.2: Zooplankton relative percentage from June and August 2020.

In June, daphnia, and cyclopoida dominate the zooplankton make up in Eagle lake. However, as the summer progresses, a higher percent of the organisms are bosmina. Bosmina are smaller and tend to be out competed early in the season, but later in the season can thrive as the food source shifts (Heiskary 2016). Bosmina can survive on poorer quality food sources like the cyanobacteria that we see increasing later in the season in Eagle lake.

2.4 SUMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on June 19, 2020 and August 13, 2020 to document the spring and summer submersed aquatic vegetation in Eagle Lake. (These surveys will be referred to as the spring and summer surveys.) During the spring survey, the lake had 64% vegetative cover, with 84 of the 131 survey points containing vegetation. The lake had higher vegetative cover during the summer survey, with 58% vegetative coverage, or 73 of 126 survey points covered in vegetation (Table 2.3.1). Eagle lake is classified as a deep lake that is mostly littoral, with 199 of its 296 acres in the littoral zone (i.e., in water less than 15 feet deep).

Table 2.3.1. Survey statistics.

Index	Result	
	6/19/2020	8/13/2020
Total Points	131	126
Littoral Points	112	110
Total Vegetated Points	84	73
% Littoral Points with Vegetation	75%	66%

During both surveys, biovolume, or the volume of water occupied by vegetation, was highest in shallow areas (Figure 2.3.1). Biomass and species richness showed the same trend (Table 2.3.2). For instance, areas between 0 and 5 feet had more than ten times the biomass than the areas at 5 to 10 feet (Table 2.3.2). Further, during the spring survey, 19 species were observed in 0 to 5 feet versus only five species in 5 to 10 feet (Table 2.3.2), during the summer survey species observations followed a similar trend with 22 species observed in 0 to 5 feet and 6 in depths of 5-10 feet (Table 2.3.2). Two species were discovered at a depth of 11.2 feet and none in depths greater than 15 feet during the spring survey, while no vegetation was observed in water depths greater than 10 feet during the summer survey. This is a natural trend due to light limitation. However, in more pristine lakes with greater clarity, this transition is more gradual, with light reaching depths greater than 15 feet, and consequently vegetation growing in these greater depths.

Table 2.3.2. Comparison of community composition with depth.

Depth (ft.)	Lake Acres (acres)	6/19/2020				8/13/2020			
		Sample points at this depth (#/%)		Species Observed (#)	Biomass (kg)	Sample points at this depth (#/%)		Species Observed (#)	Biomass (kg)
0-5 ft.	112	68	52	18	127,601	60	48	22	148,975
5-10 ft.	36	20	15	5	10,687	26	21	6	19,771
10-15 ft.	49	24	18	2	328	24	19	0	0
>15 ft.	100	19	15	0	0	16	12	0	0

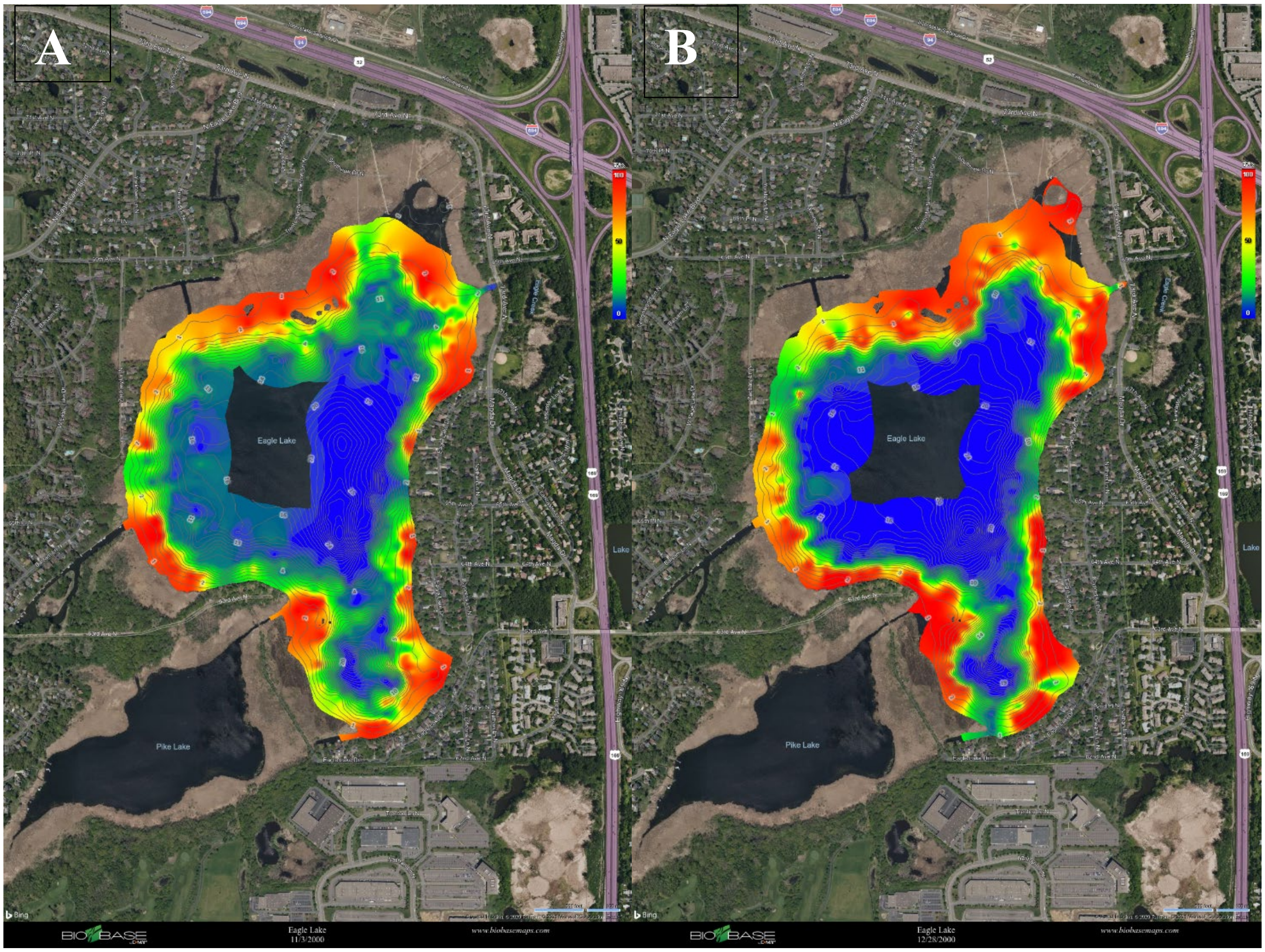


Figure 2.3.1. Biovolume heat maps for Eagle Lake during the June (A) and July (B) 2020 surveys. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

Eagle Lake's June survey showed that the lake has great diversity, with 18 observed taxa, a C-score of 5.3, and an FQI of 22.6 (Table 2.3.3). The spring survey values exceed the Central Hardwood Forest Ecoregion deep lake standards, of 12 observed taxa and an FQI of 18.6. (Table 2.3.3) Species composition in Eagle lake did not include any dominant species (>50% occurrence) (Table 2.3.4). The most abundant species during the spring survey was coontail and it was present at an occurrence of 44%. (Table 2.3.5). Coontail is native but thrives in eutrophic waters and often grows in undesirable, monodominant stands. It was also one of two species observed at depths greater than 10 feet (Table 2.3.5). The second most abundant species, which was also observed at depths greater than 10 feet, was flat stem pondweed which had an occurrence of 37% in the spring. The only non-native species found during the surveys was curly-leaf pondweed (CLP), CLP is often detrimental to native vegetation abundance and water quality. It has a competitive advantage in that it grows under the ice before other native plants can establish in the spring, therefore occupying the nutrients and available space before natives can establish natives early in the growing season. In addition, it senesces in the mid-summer and releases its nutrients back into the water which can create water quality issues. CLP had an occurrence of 14% (Table 2.3.4). Desirable native plants were less dominant, but also established throughout the lake, such as star duckweed (27% occurrence) and yellow water lily (10% occurrence). Thirteen other native submerged and emergent plants were observed during the spring survey. Including muskgrass, waterweed, water star grass, lesser duckweed, northern watermilfoil, bushy pondweed, white water lily, Illinois pondweed, soft stem bullrush, sago pondweed, greater bladderwort, water celery, and watermeal. There plants were rarely observed, with occurrences at less than 8% of the survey locations (Table 2.3.4) and in water no greater than 10 feet. (Table 2.3.5). Even though several species were observed rarely, it is encouraging to see high species diversity.

Table 2.3.3. Species diversity statistics.

Index	Result*	
	6/19/2020	8/13/2020
Observed Taxa	18	23
Average C-score	5.3	5.8
Lake Floristic Quality Index (FQI)	22.6*	27.0*

*The standards for number of taxa and FQI in Eagle Lake are 12 and 18.6, respectively.

During the July survey the lake further increased its observed taxa to 23 species and therefore an increased FQI of 27.0, again exceeding the Central Hardwood Forest Ecoregion deep lake standards, of 12 observed taxa and an FQI of 18.6. (Table 2.3.3). Like the spring survey the species composition during the summer survey in Eagle lake did not include any dominant species (>50% occurrence) (Table 2.3.4). Coontail remained the most common with a 44% lake wide occurrence (Table 2.3.4). Flat stem pondweed, a native favorable species, had the second highest occurrence, observed at 32% of the lake, slightly lower than in the spring. Five taxa including southern naiad, Fries pondweed, narrowleaf pondweed, arrowhead, and greater duckweed, were not observed in the spring but were observed in the summer and all were observed to be rare (<8% occurrence) (Table 2.3.4). Many of the species that were observed in the spring survey as rare (<8% occurrence) increased in occurrence throughout the lake during the summer survey, lesser duckweed, white water lily, greater bladderwort, water celery, and watermeal all increased in occurrence by five to twelve percentage points. Only five species observed as rare in the spring decreased in occurrence muskgrass, waterweed, water star grass, northern watermilfoil, and yellow water lily decreased by one to four percent occurrence (Table 2.3.4). Other species observed were star duckweed, bushy pondweed, Illinois pondweed, soft stem bullrush, which ranged in occurrence from 2% to 25% and are all favorable (Table 2.3.4). Furthermore, no species were observed in depths greater than 10 feet, likely because water clarity decreased in summer months (Section 2.2) and thus light limitation increased (Table 2.3.5). As expected, CLP was only observed at 2% occurrence in the summer survey, because it senesces after spring. That said, it is encouraging that in the lower abundance of CLP, favorable native plants are able to persist in higher occurrences. Sago pondweed was the only species observed in the spring that was not again observed during the summer survey (Table 2.3.4).

Table 2.3.4. Species occurrence during 2020 surveys.

Common Name	Scientific Name	% Lake Occurrence	
		6/19/2020	8/13/2020
Coontail	*Ceratophyllum demersum*	44	44
Muskgrass	*Chara sp.*	8	7
Waterweed (Canadian)	*Elodea canadensis*	2	1
Water Star Grass	*Heteranthera dubia*	2	1
Duckweed (lesser)	*Lemna minor*	2	10
Duckweed (star)	*Lemna trisulca*	27	25
Northern watermilfoil	*Myriophyllum sibiricum*	5	1

Bushy pondweed	*Najas flexilis*	2	2
Southern naiad	*Najas guadalupensis*	--	2
Yellow waterlily	*Nuphar variegata*	10	9
White waterlily	*Nymphaea odorata*	7	15
Curly-leaf pondweed	*Potamogeton crispus*	14	2
Illinois pondweed	*Potamogeton illinoensis*	5	6
Fries pondweed	*Potamogeton friesii*	--	2
Narrowleaf pondweed species	*Potamogeton sp.*	--	2
Flat-stem pondweed	*Potamogeton zosteriformis*	37	32
Arrowhead	*Sagittaria sp.*	--	1
Soft-Stem bulrush	*Schoenoplectus tabernaemontani*	1	3
Duckweed (greater)	*Spirodela polyrhiza*	--	2
Sago Pondweed	*Stuckenia pectinata*	1	--
Greater Bladderwort	*Utricularia vulgaris*	4	9
Water celery	*Valliseria americana*	3	15
Watermeal	*Wolffia sp.*	1	8

Table 2.3.5. SAV species occurrence by depth.

Common Name	% Occurrence by Depth							
	6/10/2020				7/30/2020			
	0-5	5-10	10-15	>15	0-5	5-10	10-15	>15
Coontail	75	25	4	--	77	27	--	--
Muskgrass	15	5	--	--	15	--	--	--
Waterweed (Canadian)	3	--	--	--	2	--	--	--
Water Star Grass	3	--	--	--	2	--	--	--
Duckweed (lesser)	4	--	--	--	20	--	--	--
Duckweed (star)	49	10	--	--	45	12	--	--
Northern watermilfoil	10	--	--	--	2	--	--	--
Bushy pondweed	3	--	--	--	5	--	--	--
Southern naiad	--	--	--	--	2	4	--	--
Yellow waterlily	19	--	--	--	32	--	--	--
White waterlily	13	--	--	--	17	--	--	--
Curly-leaf pondweed	16	35	--	--	3	4	--	--
Illinois pondweed	9	--	--	--	12	--	--	--
Fries pondweed	--	--	--	--	3	--	--	--
Narrowleaf pondweed species	--	--	--	--	2	4	--	--
Flat-stem pondweed	57	45	4	--	58	15	--	--
Arrowhead	--	--	--	--	2	--	--	--
Soft-Stem bulrush	2	--	--	--	5	--	--	--
Duckweed (greater)	--	--	--	--	5	--	--	--
Sago Pondweed	2	--	--	--	--	--	--	--
Greater Bladderwort	7	--	--	--	18	--	--	--
Water celery	6	--	--	--	32	--	--	--
Watermeal	2	--	--	--	17	--	--	--

In conclusion, species richness and FQI met the Central Hardwood Forest Ecoregion deep lake standards in both the spring and summer surveys, and the lake appears to be in good vegetative health with a good mix of native aquatic submerged, aquatic emergent, and floating leaf species. CLP was the only non-native species found during both surveys and appeared at a relatively moderate rate compared to other native SAV in the lake. Due to high recreational use on Eagle Lake, it is recommended to continually monitor the SAV community to detect any future negative changes to the plant community and to ensure the long term ecosystem and vegetative community health and continually provide recreational opportunities for citizens using the lake.

3.0 Pike Lake

3.1 INTRODUCTION & SAMPLING OVERVIEW

Pike Lake is located in Maple Grove within Hennepin County, MN. Upper Pike is classified as a shallow lake and has an approximate surface area of 57 acres, of which 55 are littoral (i.e., area less than 15 feet deep), and a maximum depth of 22 feet. The list below summarizes the year in which each type of sampling was most recently performed on Pike Lake:

- Water Quality - 2020
- SAV – 2020
- Phytoplankton/Zooplankton - 2020
- Fisheries – Not assessed
- Carp – Not assessed

3.2 WATER QUALITY

The lake was monitored once per month from late May through mid-September 2020 for a total of 11 samples. Surface TP and chlorophyll-*a* concentrations in Pike Lake were in good condition early in the season but declined in later summer and exceeded the eutrophication standards (Figure 3.2.1). Water clarity was consistently high throughout the entire monitoring season. Both surface TP and chlorophyll-*a* peaked during the last sampling of the season in mid-September, indicating an algae bloom related to phosphorus availability. TP samples taken from the hypolimnion were high throughout the monitoring season and indicate the potential of internal phosphorus loading from lake sediments (Figure 3.2.3).

Water quality in 2020 was comparatively good compared to historic data (Figure 3.2.2). Secchi depth was noticeably deeper in 2020 that recent years. TP and chlorophyll concentrations are historically at or slightly above the shallow lake standard. The most recent trend analysis shows a decreasing (improving) trend in Pike Lake TP concentrations (Wenck 2020).

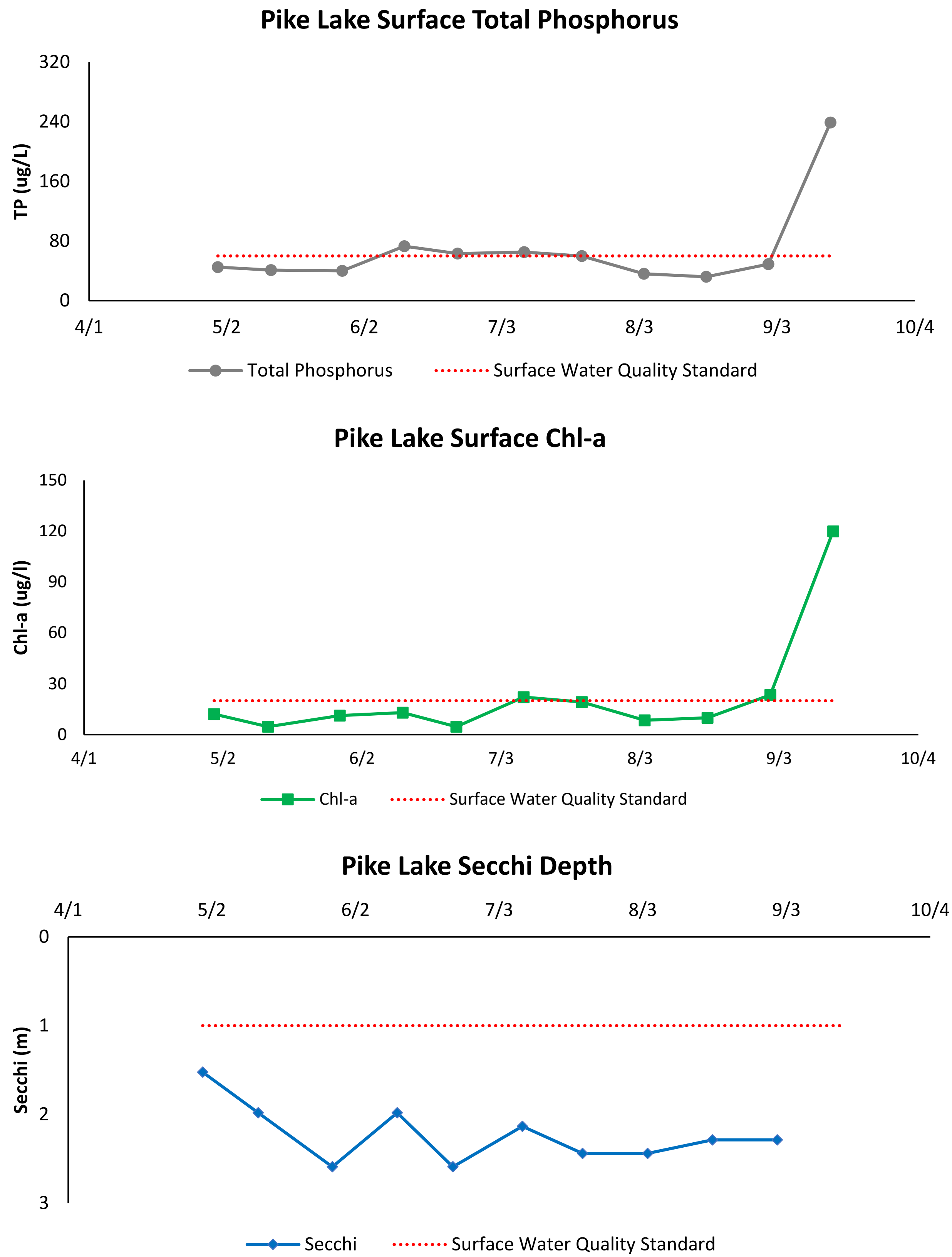


Figure 3.2.1. Seasonal TP, chl-*a*, and Secchi measurements and standards.

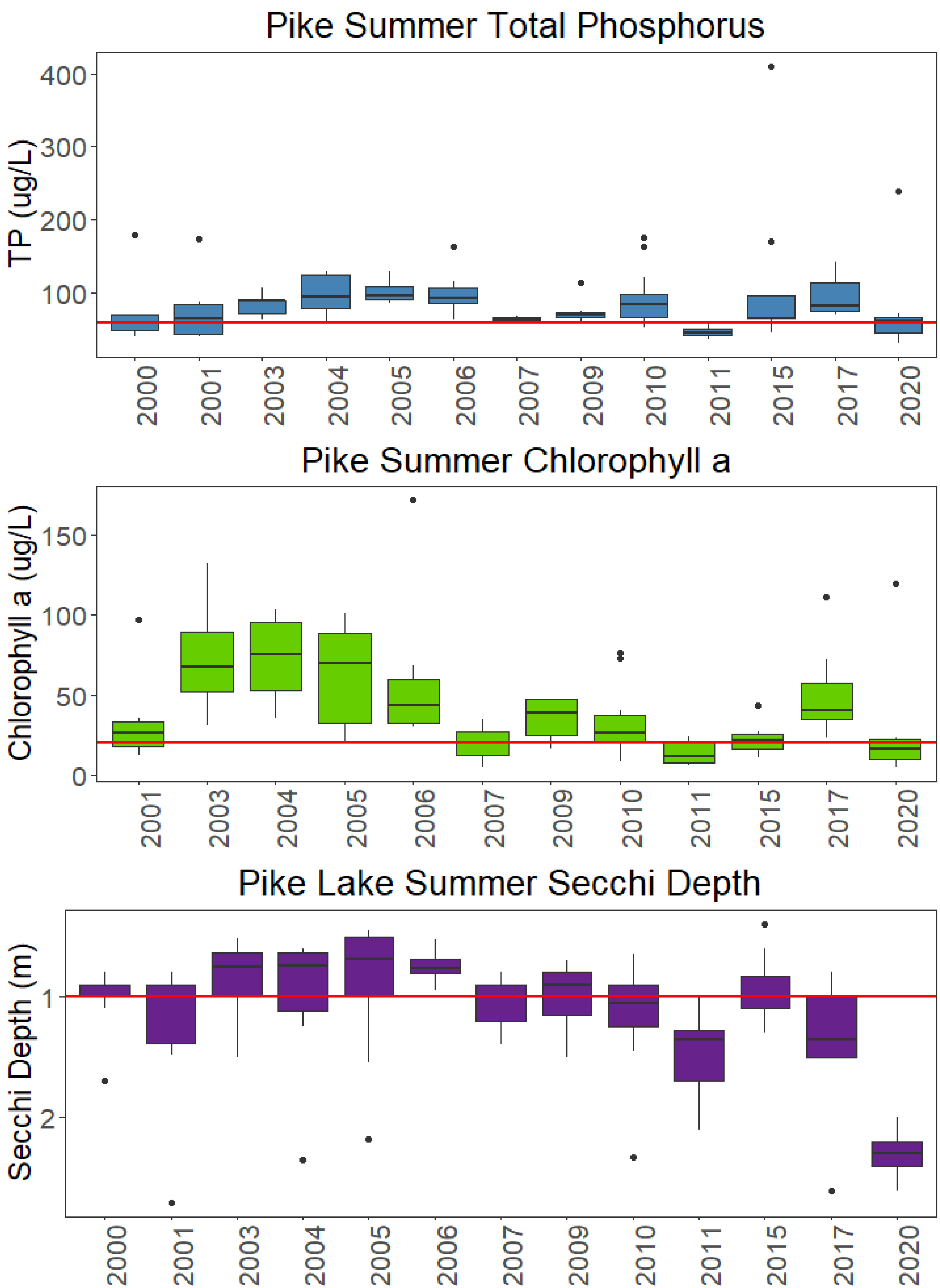


Figure 3.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

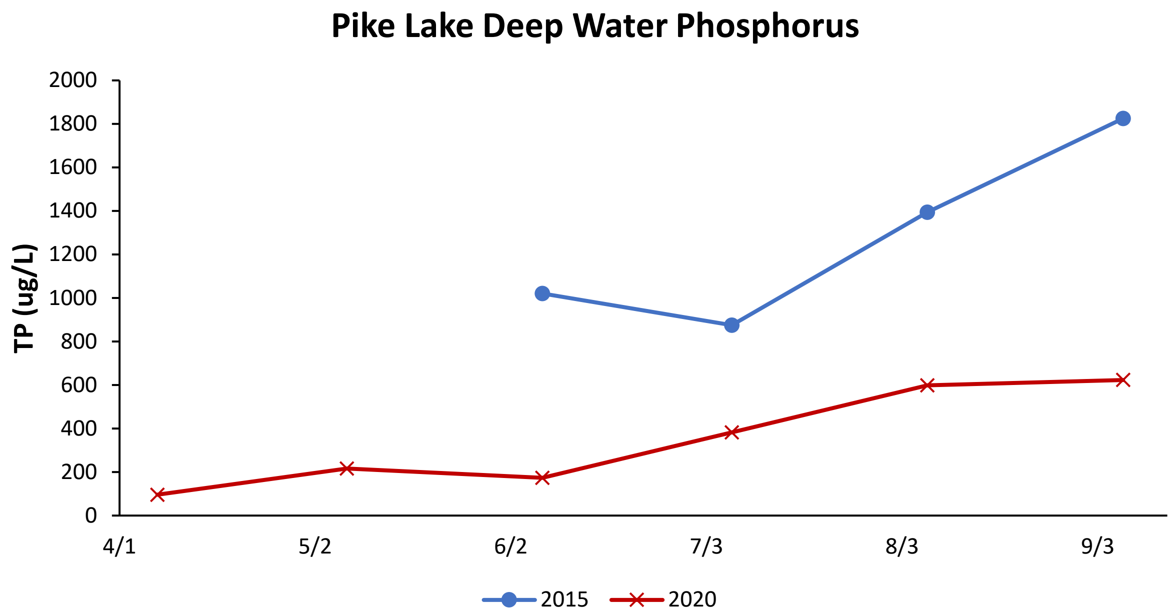


Figure 3.2.3. Pike Lake historic and 2020 total phosphorus concentrations in the hypolimnion.

3.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton composition was measured for two samples in June and August 2020 to compare the relative percentages of each genera.

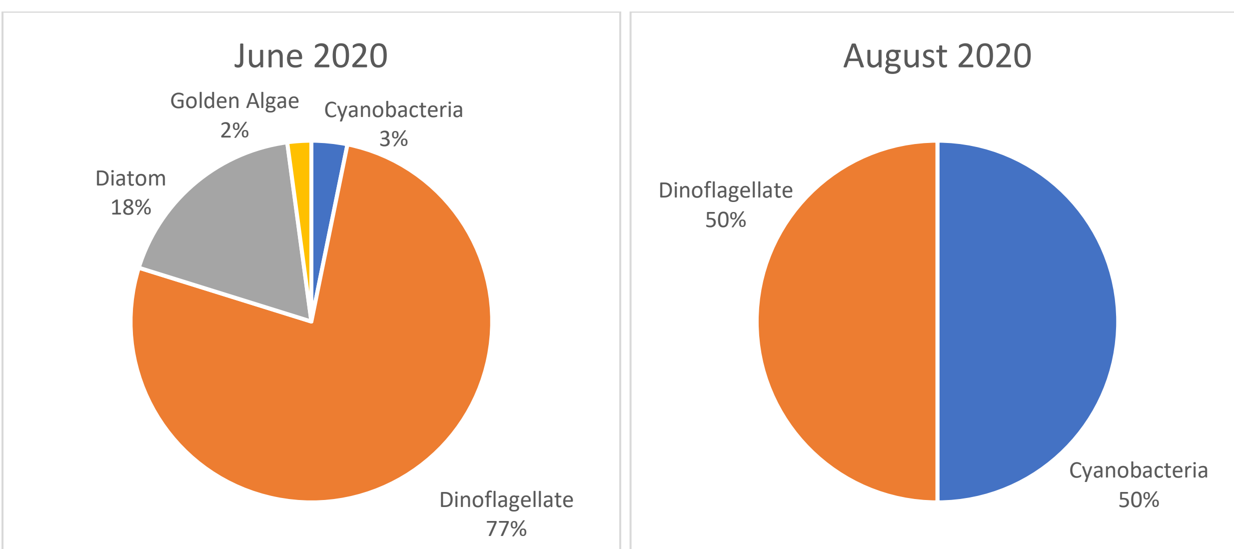


Figure 5.3.1: Phytoplankton relative percentage from June and August 2020.

Pike lake was dominated by the dinoflagellates and rotifers in June 2020. Rotifers are a great food sources and are indicative of lower nutrients and cooler waters. In August 2020, the sample had very low concentrations of phytoplankton with only a few rotifers and cyanobacteria present in equal abundance. The low concentration of rotifers compared to the June sample shows a collapse in the population, probably due to warmer temperatures.

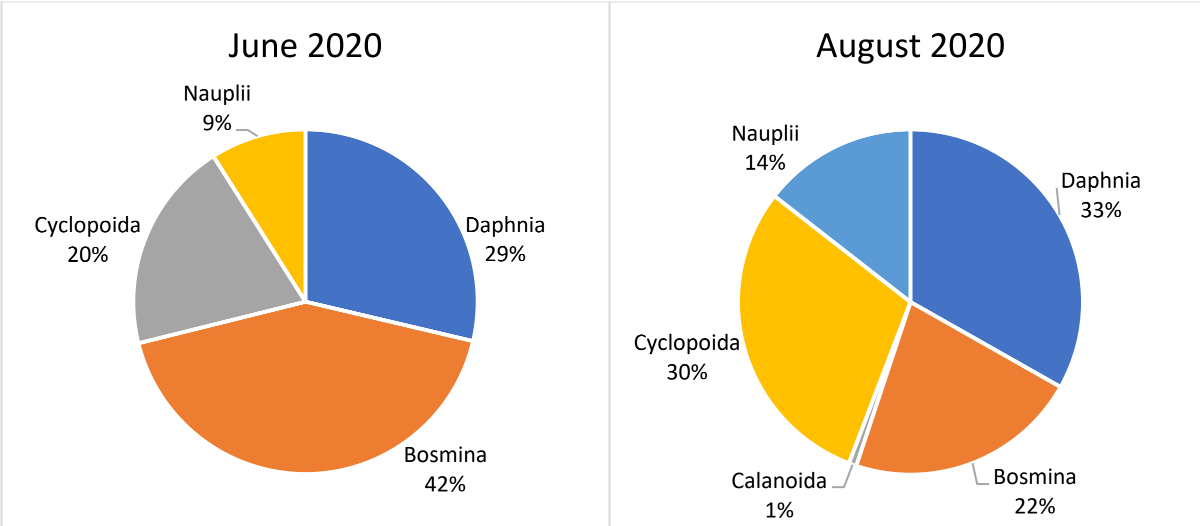


Figure 5.3.2: Zooplankton relative percentage from June and August 2020.

Pike Lake was dominated by bosmina and daphnia in June and saw a slight increase in daphnia and cyclopoida going into August. The balance of zooplankton in the late season indicates a plentiful food source even if the food is mostly cyanobacteria and dinoflagellate, such that there is less competition among groups.

3.4 SUMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on June 16, 2020 and August 12, 2020 to document the spring and summer submersed aquatic vegetation in Pike Lake. (These surveys will be referred to as the spring and summer surveys.) During the spring survey, the lake had 58% vegetative cover, with 60 of the 106 survey points containing vegetation. The lake had similar vegetative cover during the summer survey, with 58% vegetative coverage, or 63 of 108 survey points covered in vegetation (Table 3.3.1). Pike lake is classified as a shallow lake and is mostly littoral, with 55 of its 57 acres in the littoral zone (i.e., in water less than 15 feet deep).

Table 3.3.1. Survey statistics.

Index	Result	
	6/16/2020	8/12/2020
Total Points	106	108
Littoral Points	103	105
Total Vegetated Points	60	63
% Littoral Points with Vegetation	58%	58%

During both surveys, biovolume, or the volume of water occupied by vegetation, was highest in shallow areas (Figure 3.3.1). Biomass and species richness showed the same trend (Table 3.3.2). For instance, areas between 0 and 5 feet had more than three times the biomass than the areas at 10 to 15 feet (Table 3.3.2). Further, during the spring survey, 11 species were observed in 0 to 5 feet versus only four species in 10 to 10 feet (Table 3.3.2), during the summer survey species observations followed a similar trend with 11 species observed in 0 to 5 feet and five in depths of 10-15 feet (Table 3.3.2). Two species were discovered at a depth of 13.1 feet and none in depths greater than 15 feet during the spring survey, similarly in the summer survey two species were observed at a maximum depth of 12.6 feet. This is a natural trend due to light limitation. However, in more pristine lakes with greater clarity, this transition is more gradual, with light reaching depths greater than 15 feet, and consequently vegetation growing in these greater depths.

Table 3.3.2. Comparison of community composition with depth.

Depth (ft.)	Lake Acres (acres)	6/16/2020				8/12/2020			
		Sample points at this depth (#/%)		Species Observed (#)	Biomass (kg)	Sample points at this depth (#/%)		Species Observed (#)	Biomass (kg)
0-5 ft.	112	15	14	11	103,582	39	36	11	38,576
5-10 ft.	36	43	41	11	65,456	25	23	9	44,364
10-15 ft.	49	45	42	4	8,385	41	3	5	12,464
>15 ft.	100	3	3	0	0	3	3	0	0

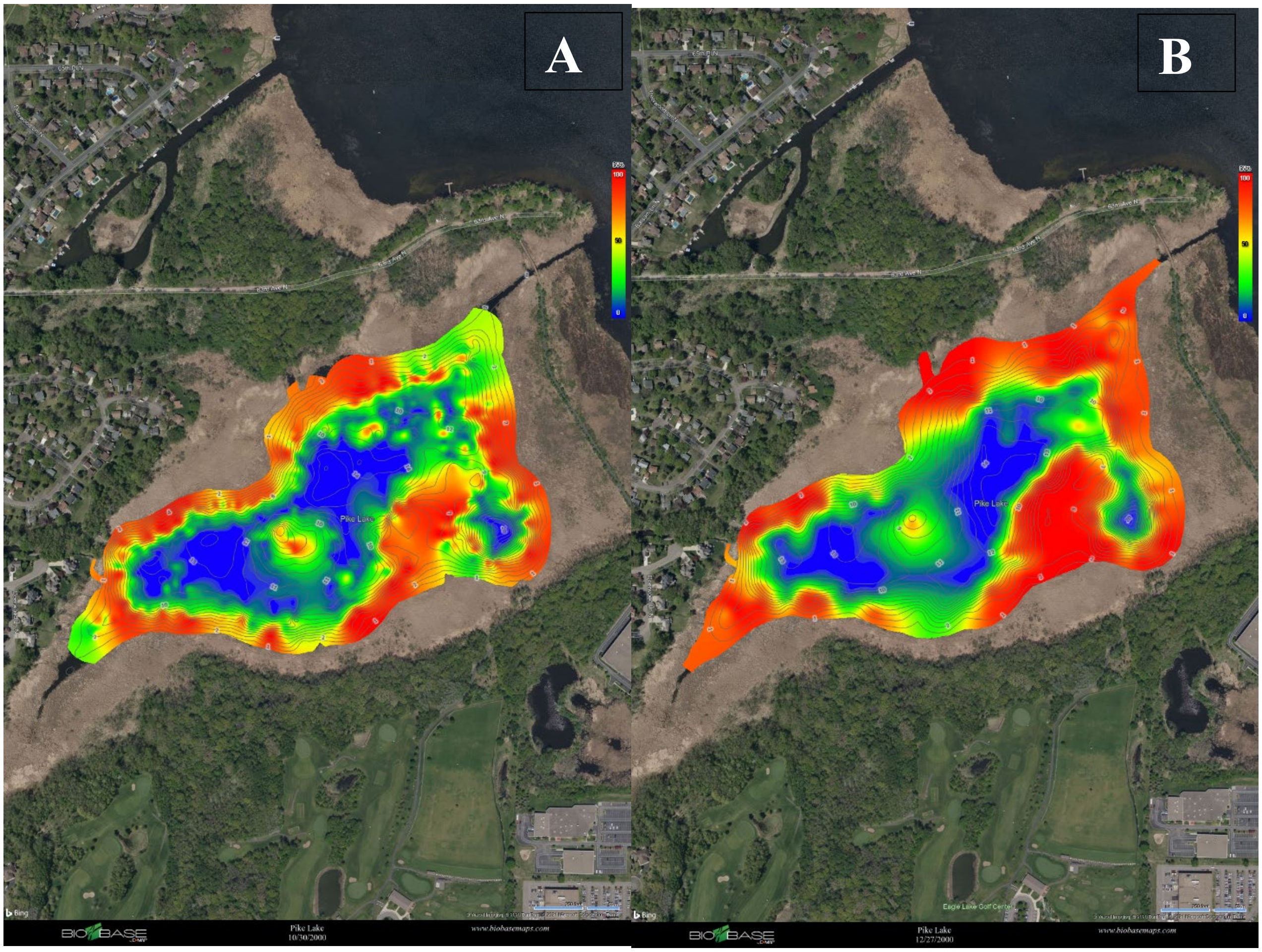


Figure 3.3.1. Biovolume heat maps for Pike Lake during the June (A) and July (B) 2020 surveys. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

Pike Lake's June survey showed that the lake has good diversity, with 12 observed taxa, a C-score of 4.75, and an FQI of 16.5 (Table 3.3.3). While the taxa surpassed the standard, the FQI value still fell slightly short of the Central Hardwood Forest Ecoregion shallow lake standards, which require an FQI of 17.8. Coontail was a dominant species during the June survey with an observed occurrence of 55% (Table 3.3.4). Coontail is native but thrives in eutrophic waters and often grows in undesirable, monodominant stands. It was also one of only four species observed at depths greater than 10 feet (Table 3.3.5). Desirable native plants were established throughout the lake, such as flat stem pondweed (24% occurrence), white water lily (13% occurrence) and floating leaf species, lesser duckweed (21% occurrence) and watermeal (21% occurrence). Waterweed, both Eurasian and northern water milfoil, sago pondweed, star duckweed, and yellow water lily were rarely observed, with occurrences at less than 9% of the survey locations (Table 3.3.4). Even though several species were observed rarely, it is encouraging to see high species diversity. Curly-leaf pondweed (CLP), a non-native species that is detrimental to other vegetation and water quality. CLP had an occurrence of 19% throughout the lake and was the only invasive species observed in Pike Lake during either survey (Table 3.3.4).

Table 3.3.3. Species diversity statistics.

Index	Result*	
	6/16/2020	8/12/2020
Observed Taxa	12	12
Average C-score	4.75	5.41
Lake Floristic Quality Index (FQI)	16.5*	18.8*

*The standards for number of taxa and FQI in Pike Lake are 11 and 17.8, respectively.

During the summer survey both species richness and FQI slightly exceeded the Central Hardwood Forest Ecoregion standards, which require 11 observed taxa and an FQI of 17.8. The survey found 12 observed taxa, a C-score of 5.41, and an FQI of 18.8 (Table 3.3.3). A greater number of native species were observed in the summer as well as no observations of non native species. Interestingly, coontail remained the single dominant species in the summer survey at 57% occurrence. Non rooted and floating plants had the next highest occurrences in the lake with watermeal occurring at 33% of the sample points, lesser duckweed occurring at 31% of the points and star duckweed occurring at 28% of the sample points. Other prevalent species were, white water lily, and flat stem pondweed, which ranged in occurrence from 17% to 23% and are both favorable (Table 3.3.4). Muskgrass, waterweed, Eurasian and northern water milfoil, yellow waterlily, and greater bladderwort were observed to be rare during this survey (<10% occurrence) (Table 3.3.4). As expected, CLP was not observed in the summer survey, because it senesces after spring. That said, it is encouraging that in the absence of CLP, favorable native plants are able to persist in high occurrences.

Table 3.3.4. Species occurrence during 2020 surveys.

Common Name	Scientific Name	% Lake Occurrence	
		6/16/2020	8/12/2020
Curly-leaf pondweed	*Potamogeton crispus*	19	--
Muskgrass	*Chara sp.*	--	2
Coontail	*Ceratophyllum demersum*	55	57
Waterweed (Canadian)	*Elodea canadensis*	7	6
Northern Water Milfoil	*Myriophyllum sibiricum*	1	1
Eurasian Water Milfoil	*Myriophyllum spicatum*	3	3
White Waterlily	*Nymphaea odorata*	13	23
Yellow Waterlily	*Nuphar variegata*	8	6
Duckweed (star)	*Lemna trisulca*	9	28
Duckweed (lesser)	*Lemna minor*	21	31
Flat-stem pondweed	*Potamogeton zosteriformis*	24	17
Sago Pondweed	*Stuckenia pectinata*	2	--
Greater Bladderwort	*Utricularia vulgaris*	--	1
Watermeal	*Wolffia sp.*	21	33

Table 3.3.5. SAV species occurrence by depth.

Common Name	% Occurrence by Depth							
	6/16/2020				8/12/2020			
	0-5	5-10	10-15	>15	0-5	5-10	10-15	>15
Curly-leaf pondweed	40	30	2	--	--	--	--	--
Muskgrass	--	--	--	--	3	4	--	--
Coontail	87	84	20	--	92	84	12	--
Waterweed (Canadian)	27	7	--	--	13	4	--	--
Northern Water Milfoil	--	2	--	--	3	--	--	--
Eurasian Water Milfoil	7	5	--	--	8	--	--	--
White Waterlily	47	16	--	--	62	4	--	--
Yellow Waterlily	7	16	--	--	15	--	--	--
Duckweed (star)	20	12	2	--	56	24	5	--
Duckweed (lesser)	53	33	--	--	72	16	2	--
Flat-stem pondweed	53	35	4	--	23	27	5	--
Sago Pondweed	13	--	--	--	--	--	--	--
Greater Bladderwort	--	--	--	--	--	4	--	--
Watermeal	53	33	--	--	77	20	2	--

In conclusion, both species richness and FQI slightly surpassed the Central Hardwood Forest Ecoregion shallow lake standards during the summer survey, and the spring vegetation community nearly met the standards coming close with 12 observed taxa compared to the standard of 11 and an FQI of 16.5 compared to the standard of 17.8. It appears that Pike lake is at a very stable point currently, with not much change between the spring and summer surveys and with both surveys meeting or nearly meeting the shallow lake standards. In addition, the CLP abundance is relatively low and sensed by late summer, and it does not appear to be causing any major impairments to water quality or recreation.

4.0 Bass Lake

4.1 INTRODUCTION & SAMPLING OVERVIEW

Bass Lake is located in the city of Plymouth within Hennepin County, MN. Bass Lake is classified as a shallow lake and has an approximate surface area of 176 acres, 148 acres of littoral area (i.e., area less than 15 feet deep), 3.2 miles of shoreline, and a maximum depth of 31 feet. The list below summarizes the year in which each type of sampling was most recently performed on Bass Lake:

- Water Quality – 2020
- Phytoplankton/Zooplankton - 2020
- SAV – 2019
- Fisheries - 2017
- Carp – 2017

Bass Lake received an alum treatment on May 15, 2019 to mitigate internal phosphorus loading (Figures 4.1.1 and 4.1.2). Alum was applied to a 35-*a*cre area of the lake that consisted of all parts of the lake 14 feet and deeper. Alum was applied at 789 gallons/acre. The second alum treatment occurred in September 2020 following the monitoring season. Alum was applied at the same dose as in 2019.

Figure 4.1.1. A barge applies alum to Bass Lake.

Figure 4.1.2. The alum application barge.

4.2 WATER QUALITY

Water was collected twice per month from early May through mid-September in 2020 for a total of 11 sampling events. Surface TP in Bass Lake remained below the shallow lake standard during the entire monitoring season in 2020 (Figure 4.2.1). Chlorophyll-*a* concentrations and Secchi depth declined in mid-summer and exceeded the eutrophication standards, indicating a mid-summer algae bloom. Chlorophyll-*a* and Secchi depth were beginning to improve during the last lake sampling in mid-September.

Water quality in Bass Lake has exceeded eutrophication standards historically; however, there appears to be a significant impact of the 2019 alum treatment on water quality. The most recent trend analysis on Bass Lake showed a decreasing (improving) trend in TP concentrations (Wenck 2020). TP samples taken from the hypolimnion in 2020 remained low throughout the monitoring season, similar to 2019 monitoring data, indicating the efficacy of the 2019 alum treatment (Figure 4.2.3). The Bass Lake inlet monitored by Three Rivers Parks shows high TP concentrations, suggesting that there may still be a significant watershed load of P to the lake (Figure 4.2.4).

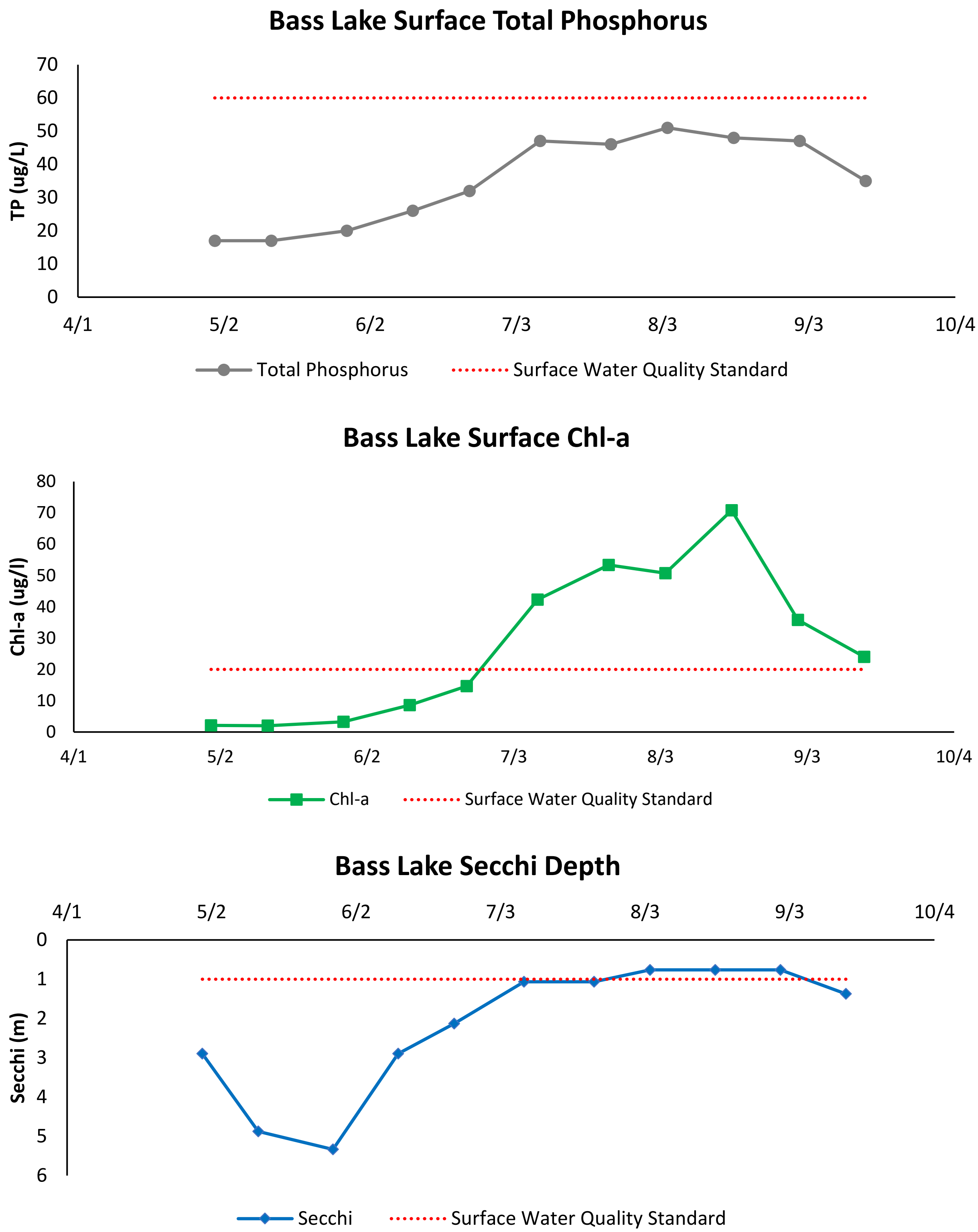


Figure 4.2.1. Seasonal TP, chl-*a*, and Secchi measurements and standards.

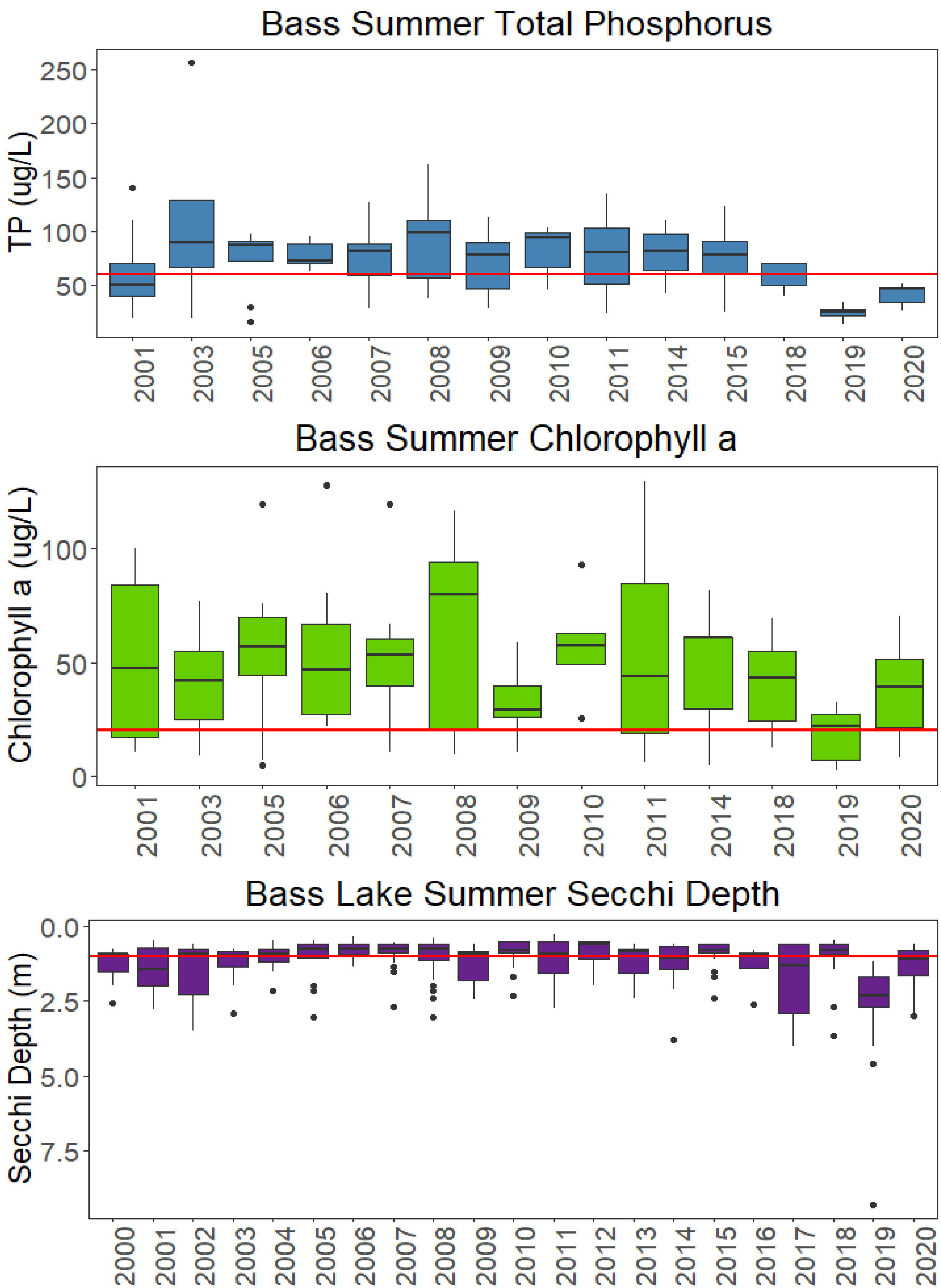


Figure 4.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

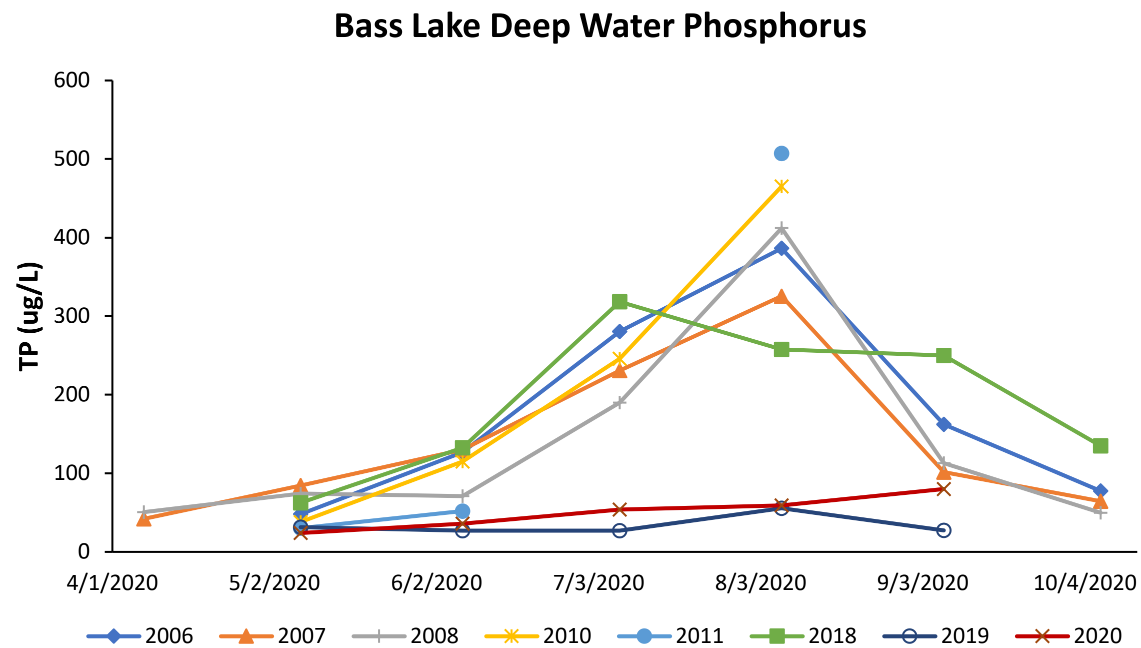


Figure 4.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summer in several years from 2006 to 2020. Due to alum inactivation of sediment, in 2019 and 2020, phosphorus does not appear to accumulate in the hypolimnion over the summer.

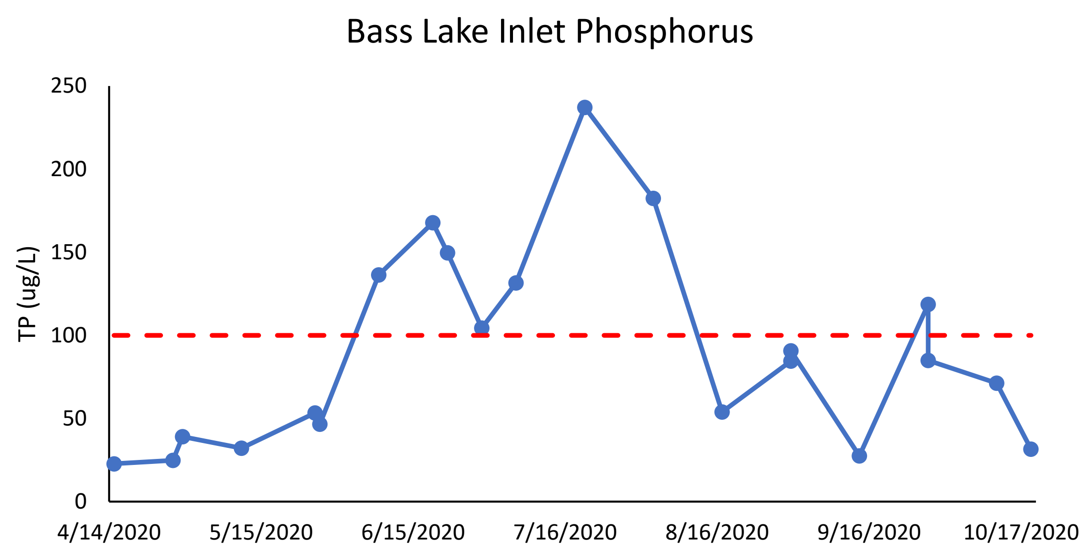


Figure 4.2.4. Total phosphorus (TP) throughout the summer at sampling station BL3, an inlet to Bass Lake (data was collected by Three Rivers Park District).

4.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton composition was measured for two samples in June and August 2020 to compare the relative percentages of each genera.

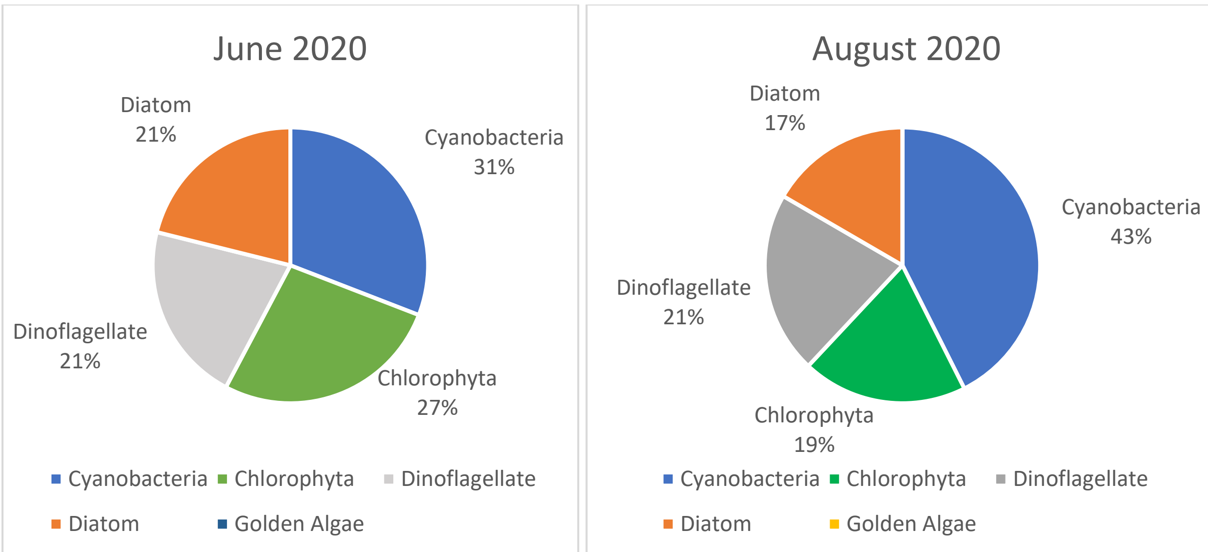


Figure 4.3.1: Phytoplankton relative percentage from June and August 2020.

In June 2020, there was an even distribution of all of the phytoplankton genera which is indicative of a healthy food chain. With the warmer water temperature in August, there is a slight shift in the relative percentages of diatoms and green algae to a slight dominance of cyanobacteria. This is a typical composition shift as cyanobacteria are more competitive in warmer water but is not indicative of a cyanobacteria bloom.

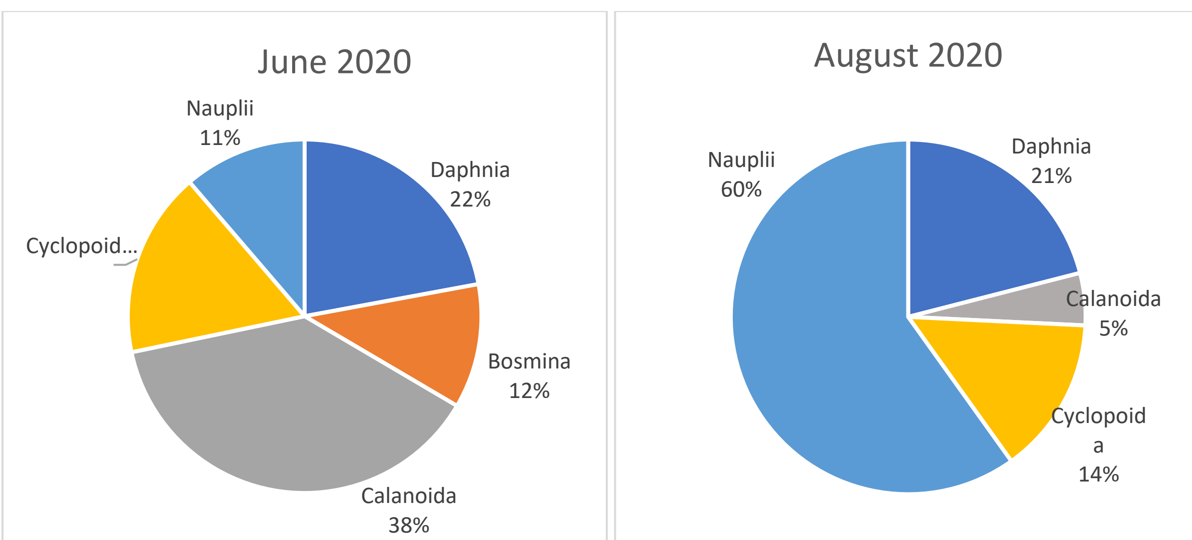


Figure 4.3.1: Zooplankton relative percentage from June and August 2020.

In June 2020, Calanoids were the predominate zooplankton in Bass lake. However, as the summer progressed Nauplii became the dominate species at 60%. Nauplii are the egg stage of many species of zooplankton. The large percentage of the egg stage may indicate that the timing or location of sampling occurred after a fresh hatch.

4.4 SUBMERSED AQUATIC VEGETATION

A point-intercept aquatic vegetation survey was not conducted on Bass Lake during the 2020 monitoring season. However, in an ongoing effort to combat curly leaf pondweed (CLP) a CLP delineation was conducted on April 16, 2020 to document and determine the extent of CLP in Bass lake and consider future management options (Figure 4.4.1). Three distinct treatment areas were delineated and treated.

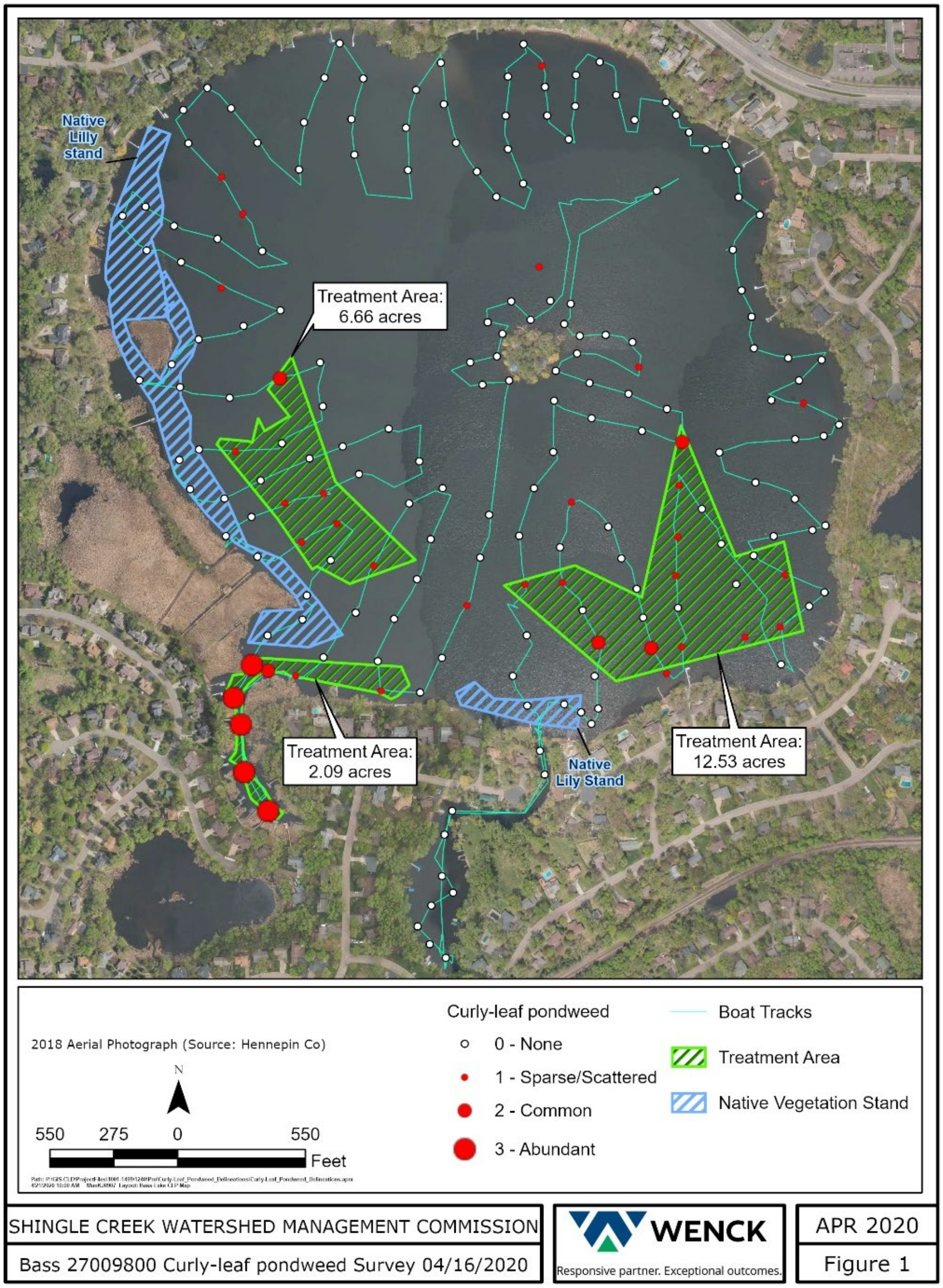


Figure 4.4.1: 2020 Bass Lake CLP Delineation

5.0 Pomerleau Lake

5.1 INTRODUCTION & SAMPLING OVERVIEW

Pomerleau Lake is located in the city of Plymouth within Hennepin County, MN. Pomerleau Lake is classified as a deep lake and has an approximate surface area of 30.5 acres, 21 acres of littoral area (i.e., area less than 15 feet deep), 0.78 miles of shoreline, and a maximum depth of 26 feet. The list below summarizes the year in which each type of sampling was most recently performed on Pomerleau Lake:

- Water Quality – 2020
- Phytoplankton/zooplankton – 2020
- SAV – 2019
- Fisheries – 2004
- Carp – 2018

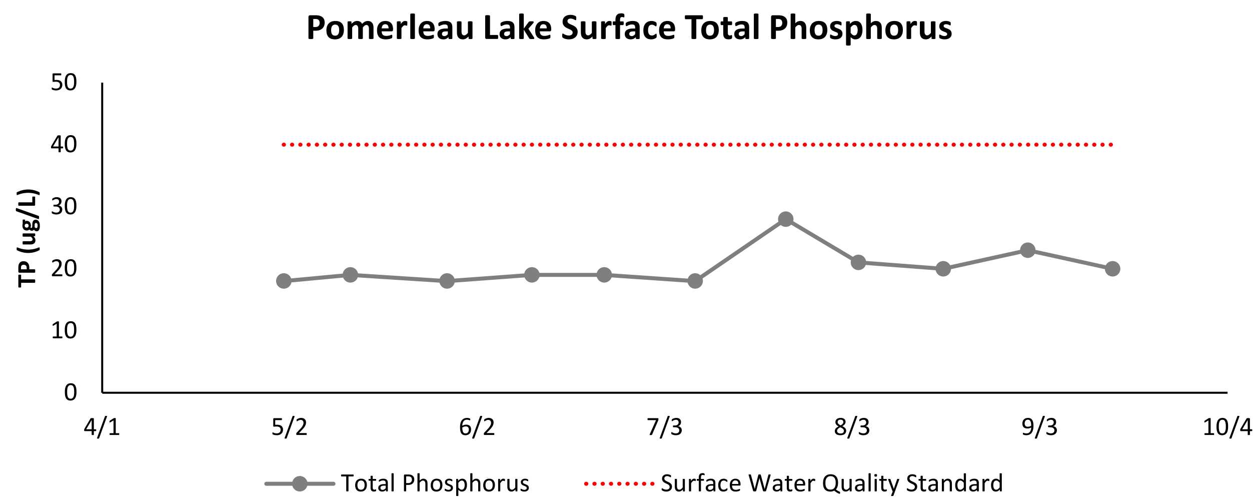
Pomerleau Lake also received an alum treatment on May 13, 2019 to mitigate internal loading (Figure 5.1.1). Alum was applied to a 14-*a*cre area of the lake seven feet and deeper. Alum was applied at 1,374 gallons/acre. Pomerleau Lake received a second dose of alum in September 2020 following the monitoring season. Alum was applied to the same area and at the same dose as in 2019.

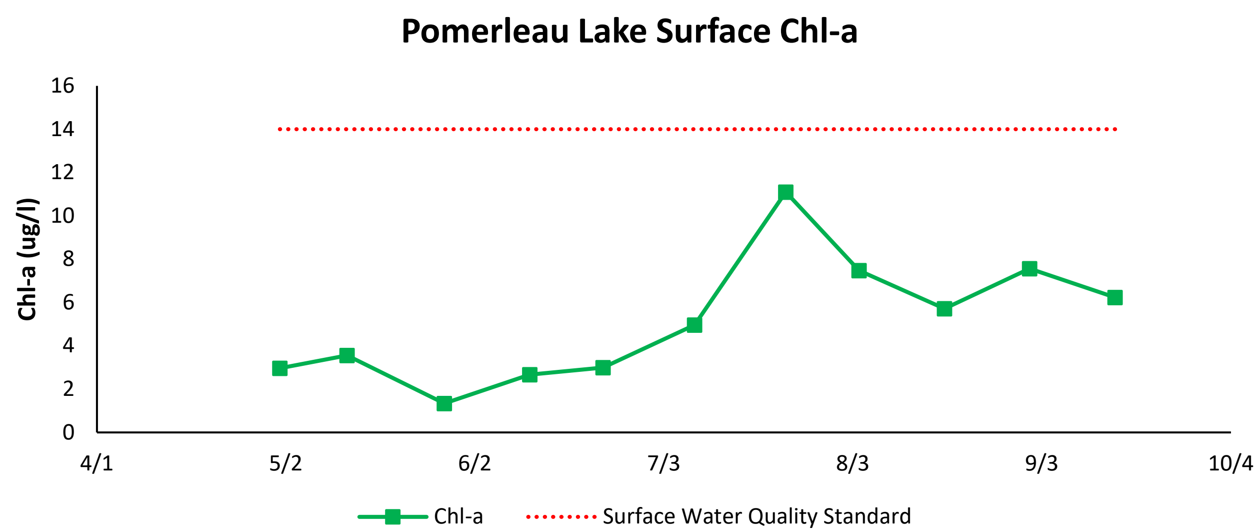
Figure 5.1.1. Photos from the alum treatment on Pomerleau Lake in May 2019.

5.2 WATER QUALITY

Water quality was monitored twice per month from early May through mid-September in 2020for a total of 11 samples. Likely as a result of the May 2019 alum treatment, water quality was still substantially improved from past summers. All three eutrophication standards (total phosphorus, chlorophyll-*a*, and Secchi depth) were met throughout the growing season; not a single data point exceeded standards (Figure 5.2.1).

Historic data show that eutrophication standards have generally not been met, although water quality has appeared to improve in recent years, with 2017-2020 growing season surface water averages generally meeting standards (Figure 5.2.2). Although 2017 and 2018 water quality were already improved compared to past seasons it is clear, based on hypolimnetic (deep) total phosphorus data, that the May 2019 alum treatment was the likely cause of the improved water quality in 2019. Whereas in past years, hypolimnetic total phosphorus concentrations increased throughout the season—a signature of internal loading from sediments—in 2019, hypolimnetic phosphorus concentrations did not increase (Figure 5.2.3). Hypolimnetic P remained low in 2020. This is a sign that alum inactivated sediment phosphorus and prevented it from getting released into the water column, where it could mix into surface waters and cause algae blooms.





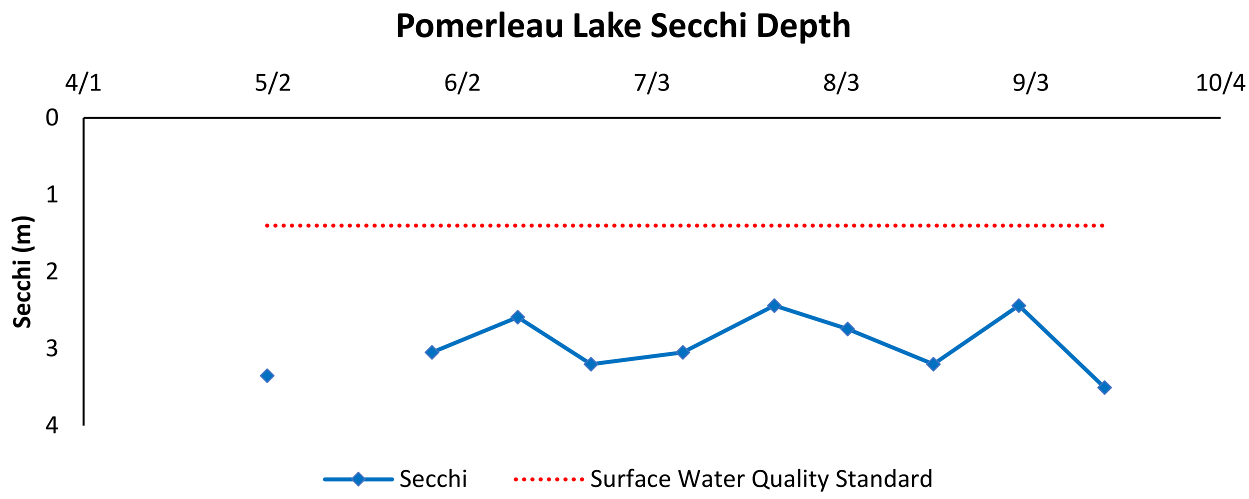


Figure 3.2.1. Seasonal TP, chl-*a*, and Secchi measurements and standards.

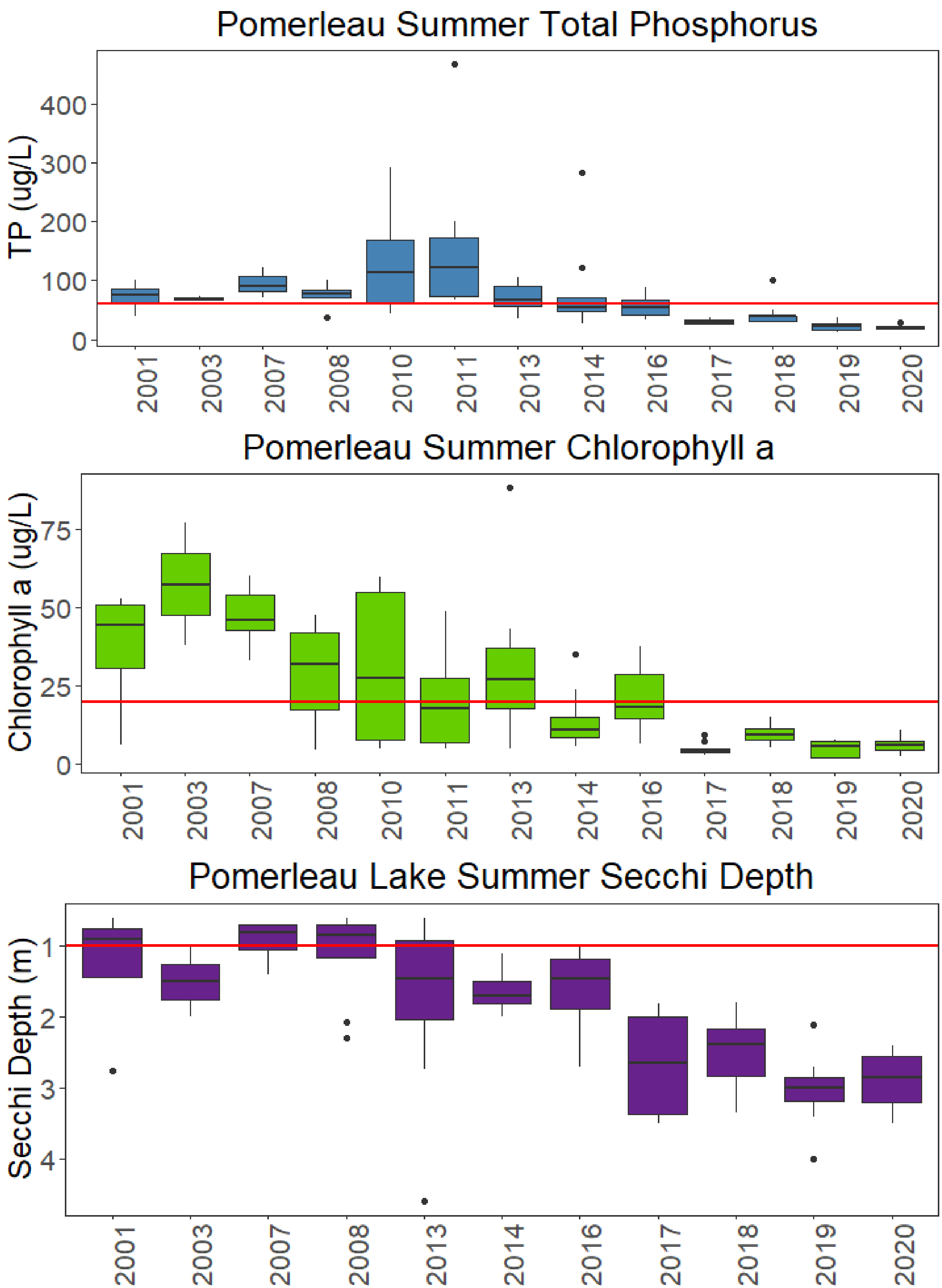


Figure 5.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

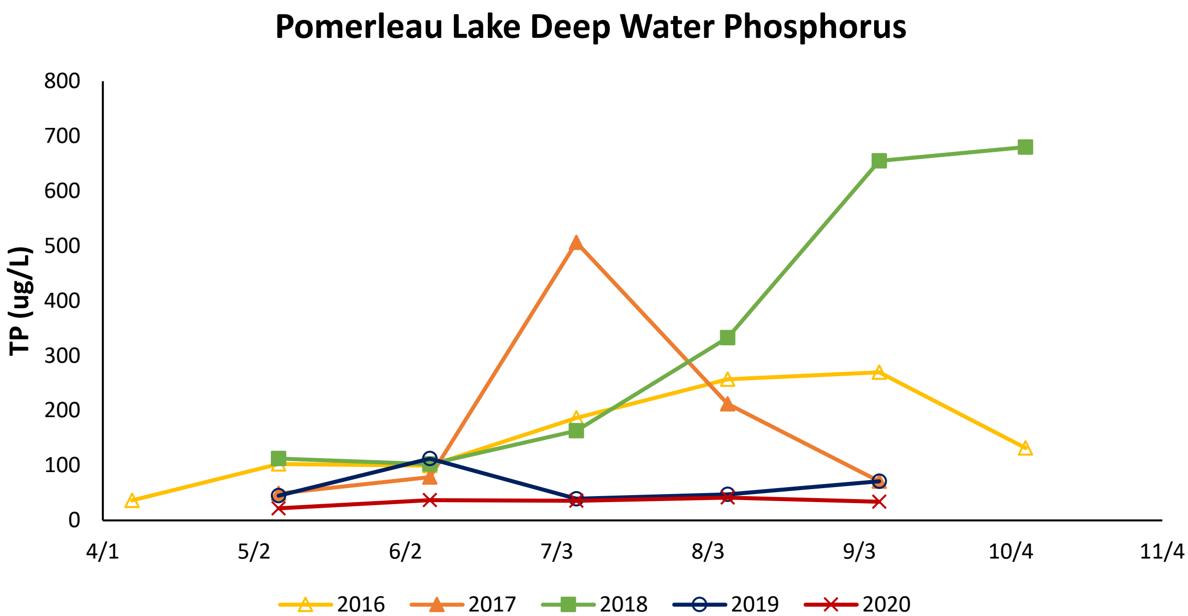


Figure 5.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summer in 2016 through 2020. Due to alum inactivation of sediment, in 2019 and 2020, phosphorus does not appear to accumulate in the hypolimnion over the summer.

Figure 5.2.4. Wenck staff using a Van Dorn sampler to pull a hypolimnetic (deep) water sample from Pomerleau Lake on 7/30/19.

5.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton composition was measured for two samples in June and August 2020 to compare the relative percentages of each genera.

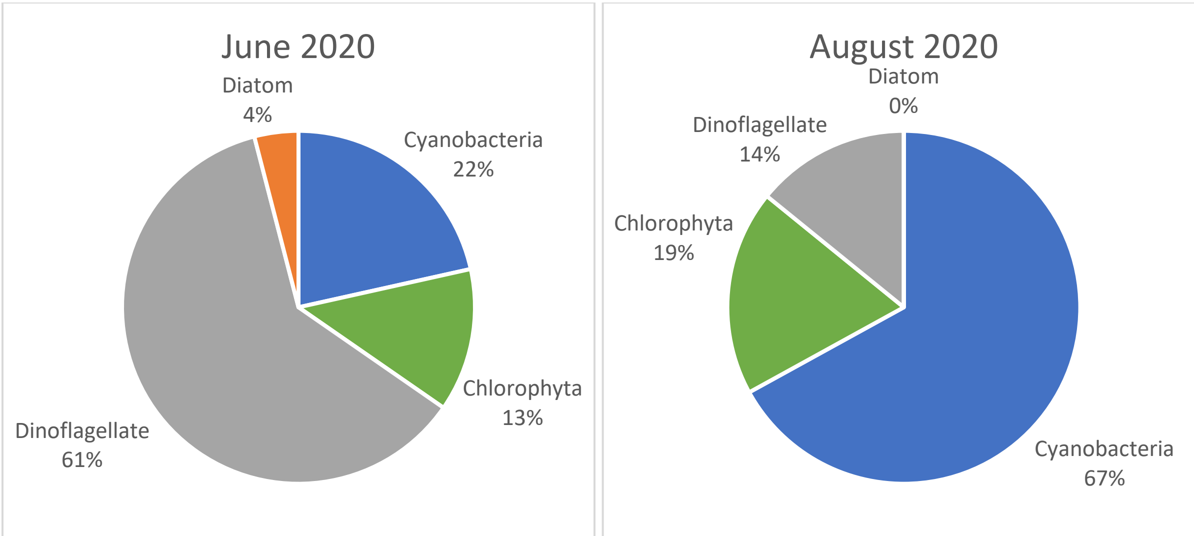


Figure 3.3.1: Phytoplankton relative percentage from June and August 2020.

Pomerleau lake experienced a shift in phytoplankton dominance from dinoflagellates that are competitive in cooler lower nutrient water to cyanobacteria that dominate in warm nutrient rich waters. Dominance of dinoflagellates are advantageous for fish and zooplankton. However, 67% dominance of cyanobacteria can be indicative of a HAB.

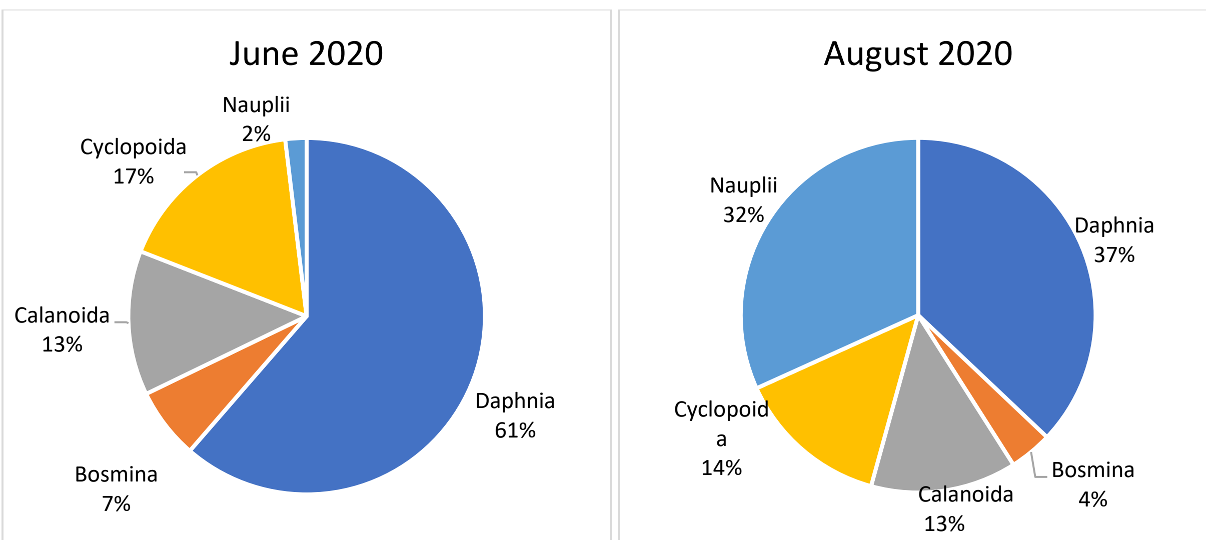


Figure 3.3.2: Zooplankton relative percentage from June and August 2020.

In June, Daphnids started out as the predominate species in Pomerleau which tends to be typical in early season when food is abundant, and predation is low. As the summer progresses Nauplii (egg stage zooplankton) become more predominate indicating the reproductive health is good. The egg stage also does not feed and therefor can survive easier than feeding stages of zooplankton when the food source is poor - like the cyanobacteria seen predominate in August.

5.4 SUBMERSED AQUATIC VEGETATION

A point-intercept aquatic vegetation survey was not conducted on Pomerleau Lake during the 2020 monitoring season. However, in an effort to continually monitor curly leaf pondweed (CLP) a CLP delineation was conducted on April 15, 2020 to document and determine the extent of CLP in Pomerleau lake and provide data to guide future management options (Figure 5.4.1).

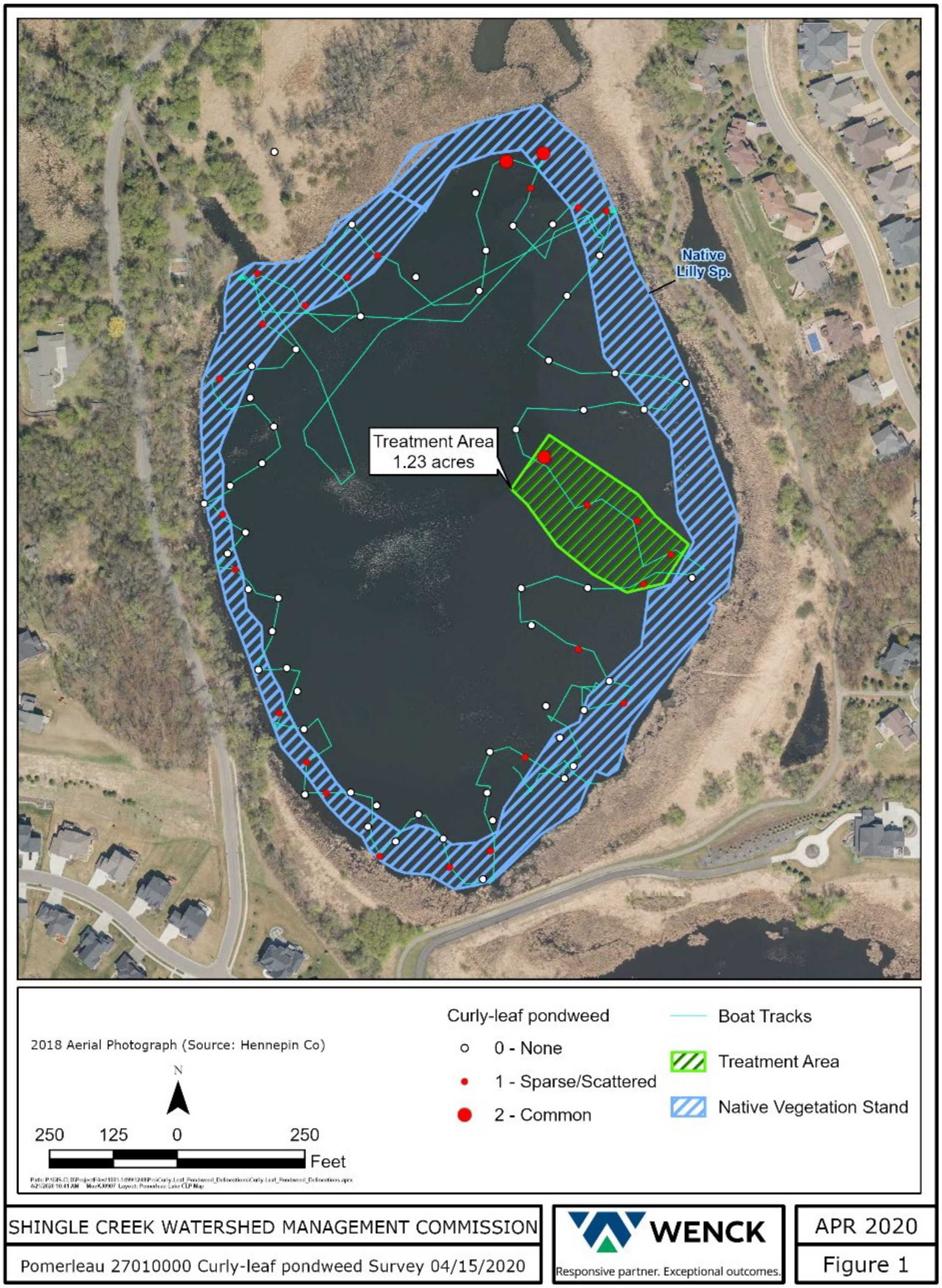


Figure 5.4.1: Pomerleau Lake CLP Delineation.

6.0 Crystal Lake

6.1 INTRODUCTION & SAMPLING OVERVIEW

Crystal Lake is in Robbinsdale, MN within Hennepin County. Middle Twin Lake is classified as a deep lake and has an approximate surface area of 79 acres, 53 acres of littoral area (i.e., area less than 15 feet deep), an average depth of 9.8 feet, and a maximum depth of 39 feet. The list below summarizes the year in which each type of sampling was most recently performed on Crystal Lake:

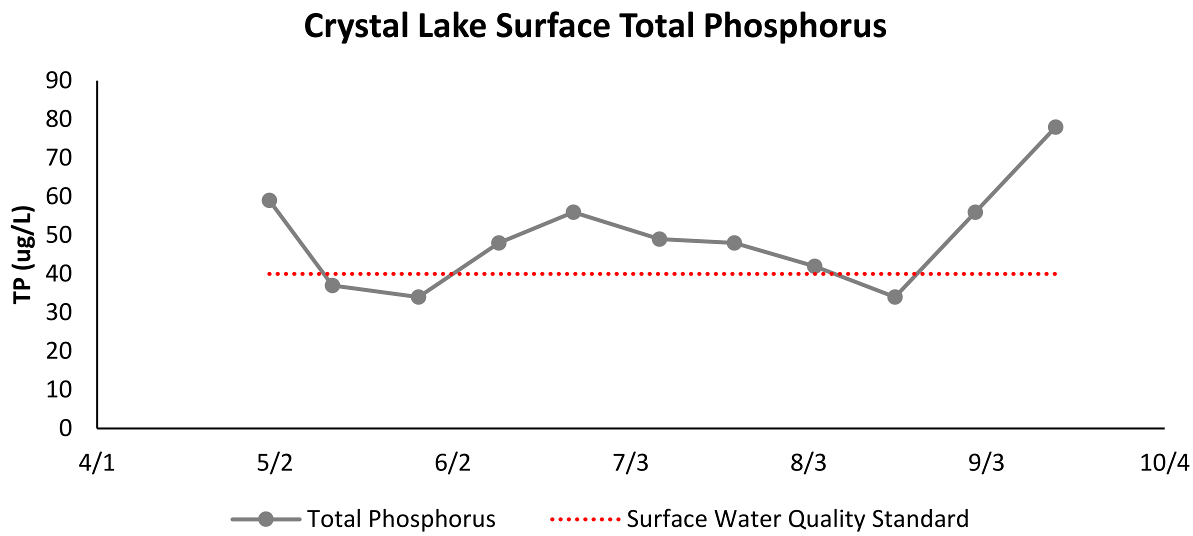
- Water Quality - 2020
- SAV – 2020
- Phytoplankton/Zooplankton - 2020
- Fisheries – not assessed
- Carp – 2020

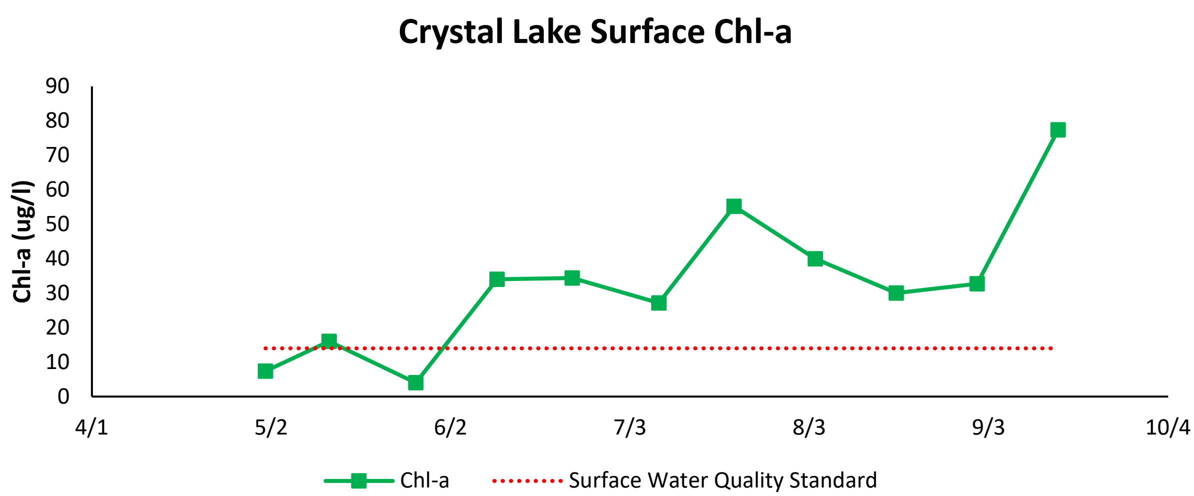
6.2 WATER QUALITY

The lake was monitored biweekly early May through mid-September in 2020 for a total of 11 samples. Crystal Lake water quality was generally poor, and exceed the eutrophication standards during most sampling events (Figure 6.2.1). Peak TP and chlorophyll concentrations occurred in mid-September indicating an algae bloom driven by the availability of phosphorus.

Historic water quality data from Crystal Lake show the lake generally does not meet the deep lake standards (Figure 6.2.2). Average monitoring season TP concentrations have been below the impairment threshold the last two years; however, chlorophyll and Secchi depth do not meet standards. Deep water phosphorus concentrations are higher than at the surface (Figure 6.2.3). In 2020, deep water TP concentrations peaked in August, indicating the release of phosphorus from lake sediments under low oxygen conditions. The most recent trend analysis done on Crystal Lake water quality data indicates an increasing (degrading) trend in TP concentrations.

An alum application planned for 2021 will help address the lake's internal loading and help improve water clarity.





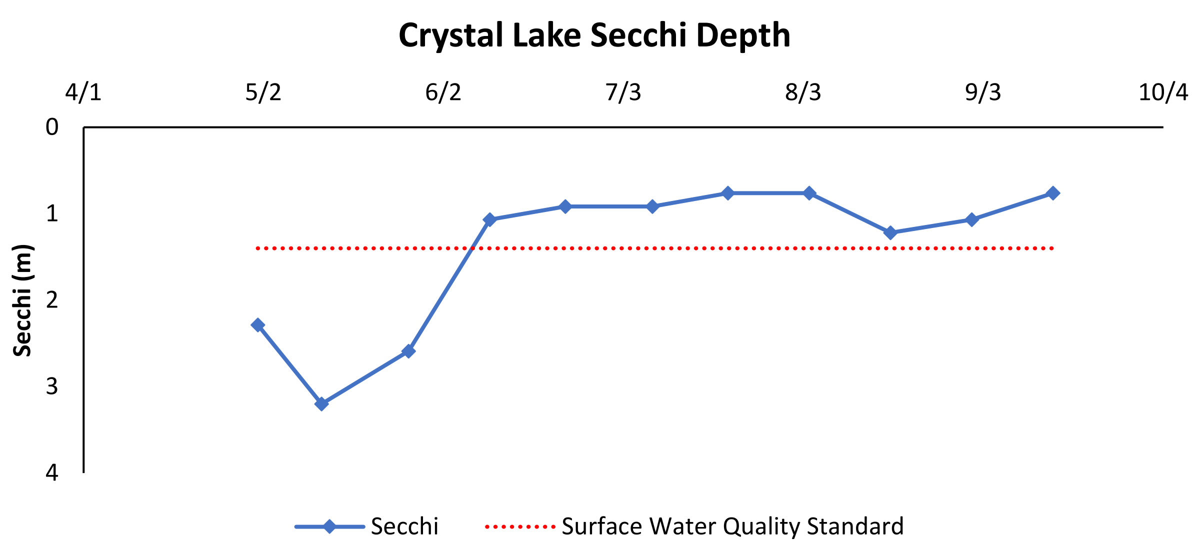
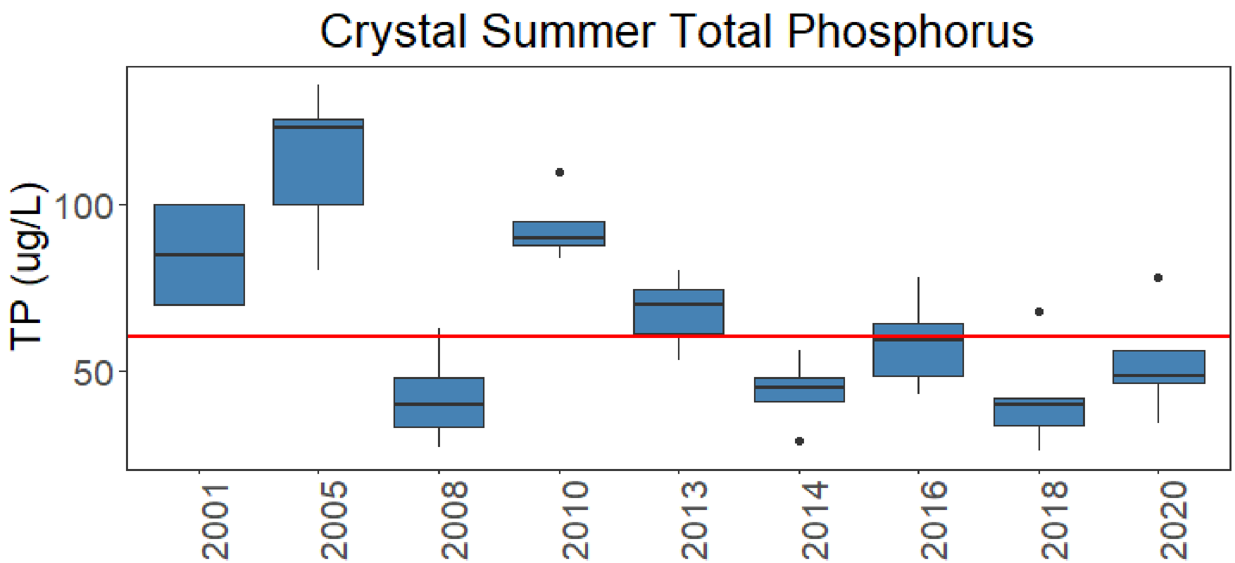
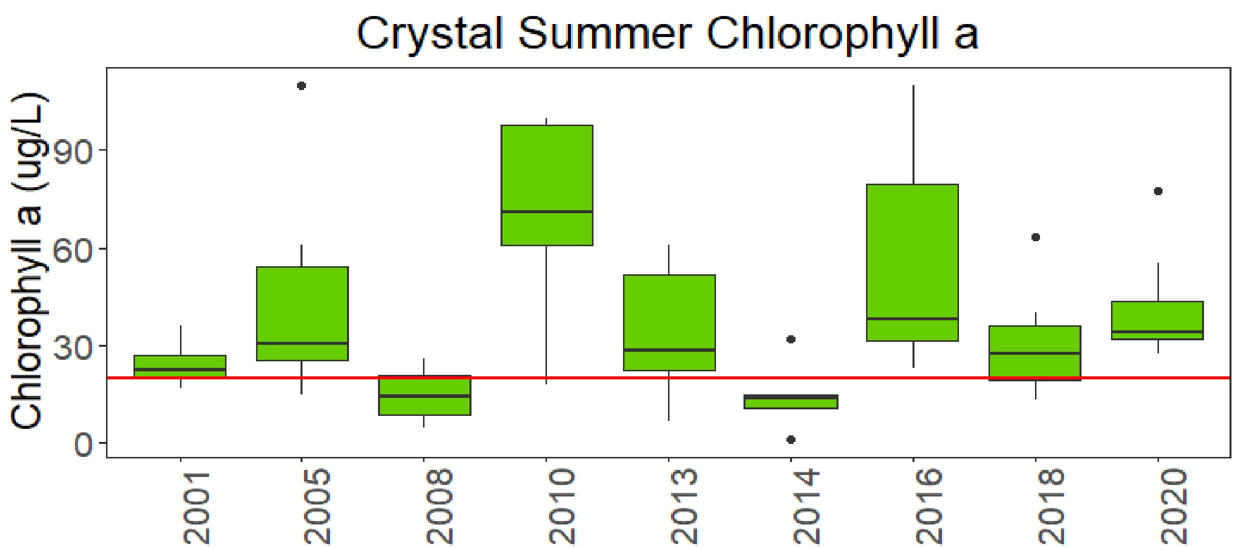


Figure 6.2.1. Seasonal TP, chl-*a*, and Secchi measurements and standards.


Crystal Summer Total Phosphorus
TP (ug/L)
100
50
2001
2005
2008
2010
2013
2014
2016
2018
2020


Crystal Summer Chlorophyll a
Chlorophyll a (ug/L)
90
60
30
0
2001
2005
2008
2010
2013
2014
2016
2018
2020

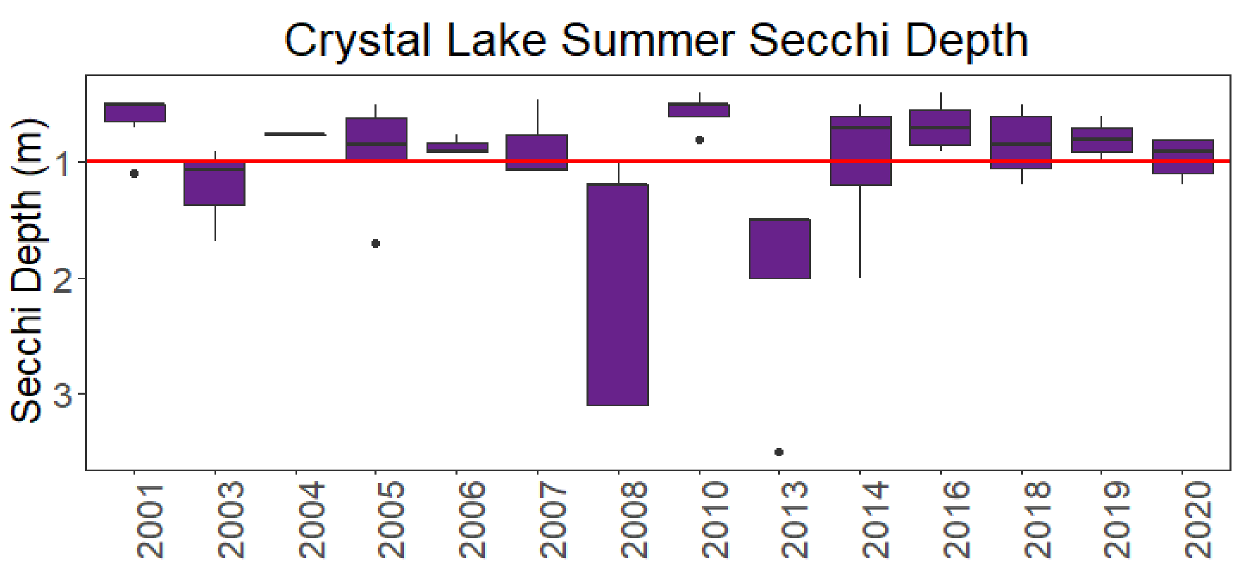

Crystal Lake Summer Secchi Depth
Secchi Depth (m)
1
2
3
2001
2003
2004
2005
2006
2007
2008
2010
2013
2014
2016
2018
2019
2020

Figure 6.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

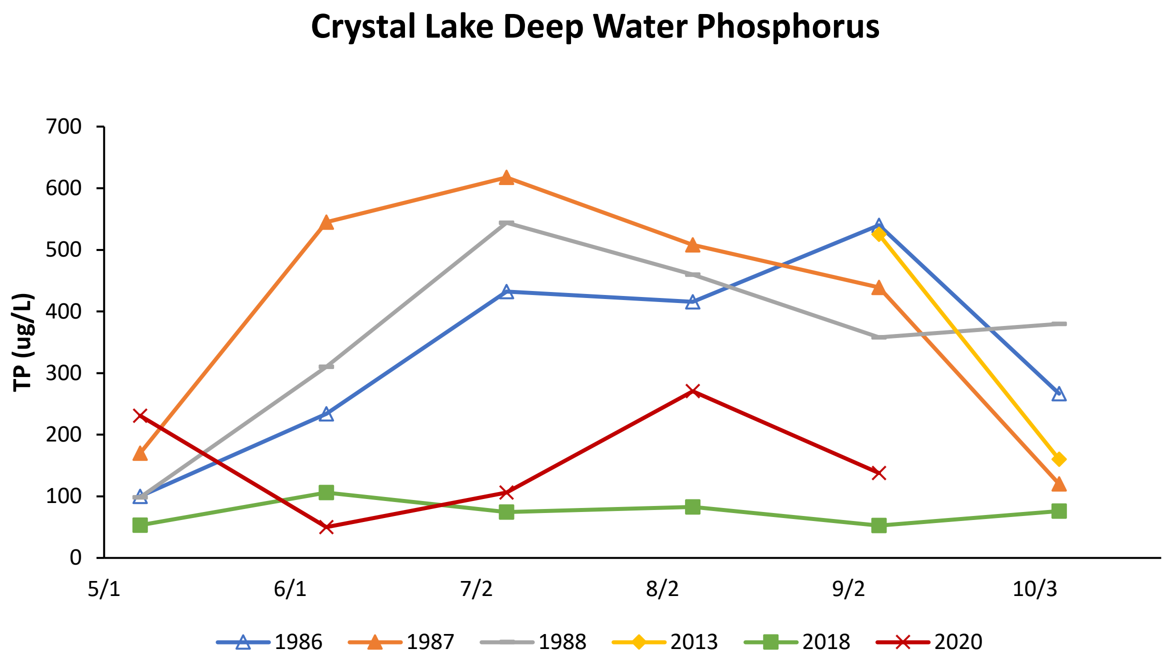
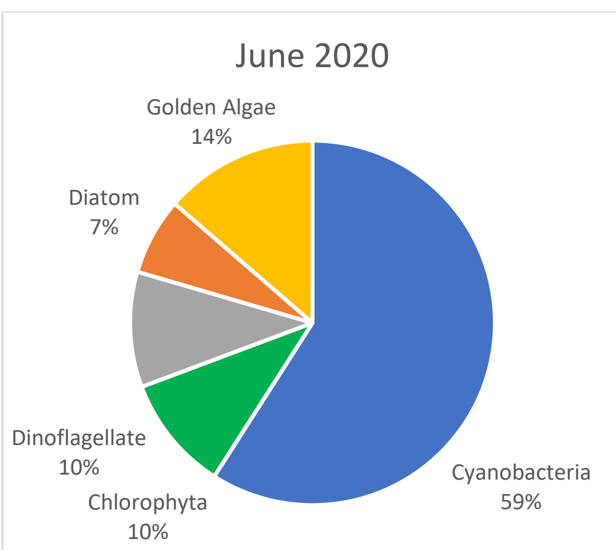


Figure 6.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summer for available years.

6.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton composition were measured for two samples in June and August 2020 to compare the relative percentages of each genera.



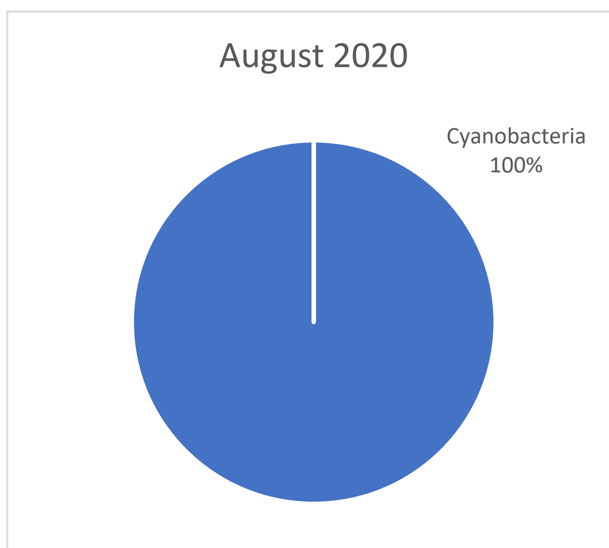


Figure 6.3.1: Phytoplankton relative percentage from June and August 2020.

Crystal lake experienced a large *Microcystis* bloom in the summer of 2020. Cyanobacteria was already dominate in June and that dominance increased to 100% in August. In August 2020, the only species of phytoplankton identified was *Microcystis* in very high concentrations. *Microcystis* is a common bloom forming cyanobacteria that is capable of producing toxins, especially if it is the only cyanobacteria species.

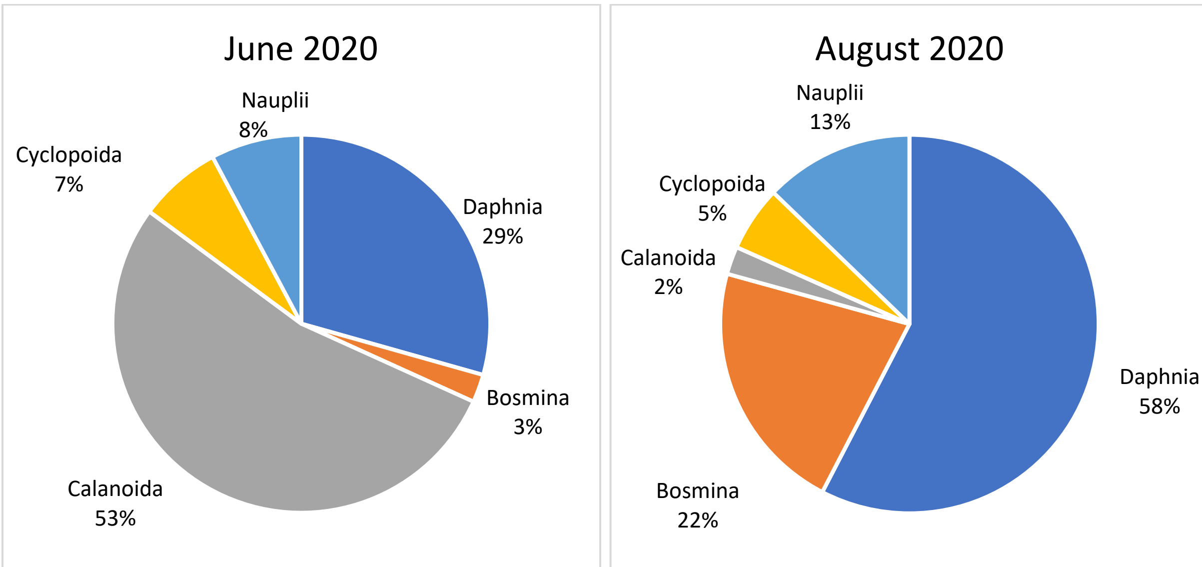


Figure 6.3.2: Zooplankton relative percentage from June and August 2020.

In June, a high percentage of Calanoids are preasent as well as Daphnia. As the season progresses a higher percent of daphnia are found present. Daphnia can graze on poor-quality food like cyanobacteria, explaining their abundance in late summer.

6.4 SUMERGED AQUATIC VEGETATION

A point-intercept aquatic vegetation survey was conducted on June 10, 2020 to document the late summer submersed aquatic vegetation in Crystal Lake. A total of 88 survey points were assessed, and 7 of these points were vegetated (Table 6.4.1). Crystal Lake is classified as a deep lake, with a maximum depth of 39 feet, while 53 of its 79 acres are in the littoral zone (i.e., water less than 15 feet deep). All 7 vegetated points were observed in the littoral zone, and the littoral zone was 12% covered in vegetation.

Table 6.4.1. Survey statistics.

Index	Result	Index	Result
Total Points	88	Vegetated Points	7
Littoral Points	57	Littoral Points with Vegetation	12%

Biovolume, or the volume of water occupied by vegetation, was extremely low or void of any aquatic plant life. (Figure 6.4.1). Biomass and species richness showed the same trend (Table 6.4.2). One species was observed in 0 to 5 feet and two in the 5 to 10 foot range (Table 6.4.2). No vegetation was observed in water depths greater than 7.5 feet.

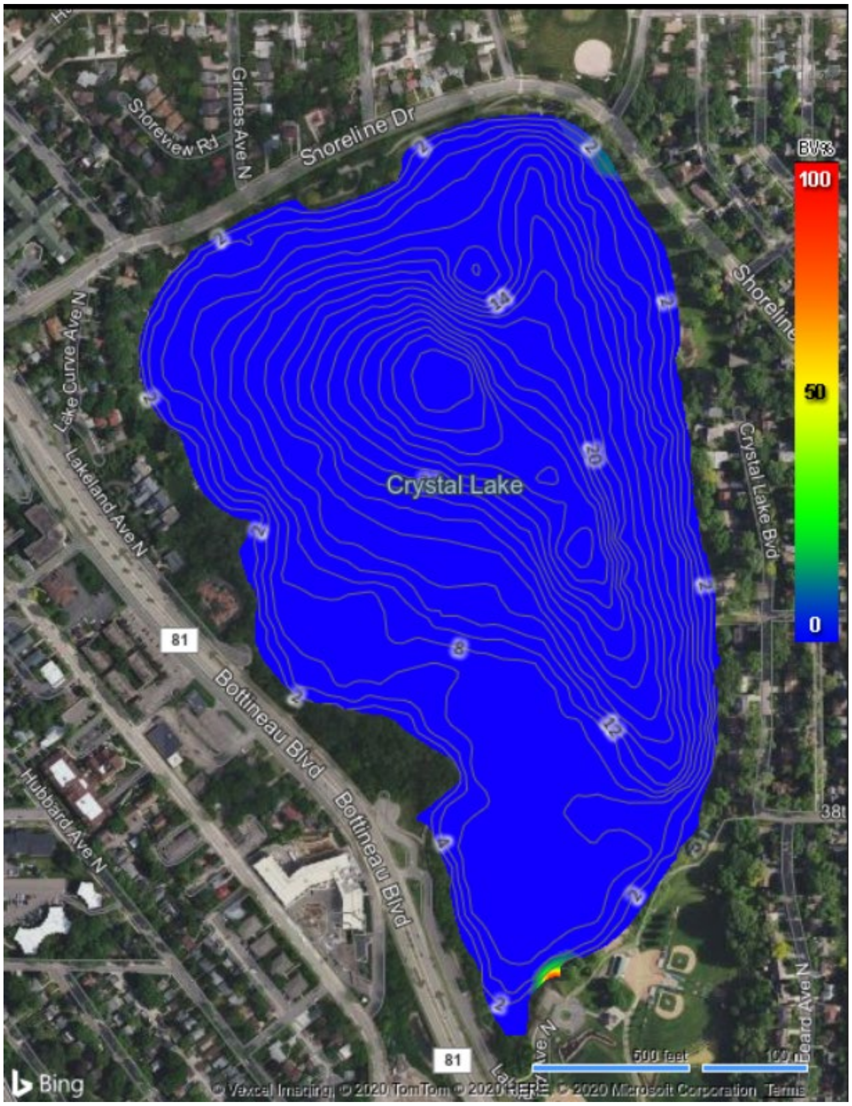


Figure 6.4.1. Biovolume heat map of Crystal Lake. In the heatmap, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

Table 6.4.2. Comparison of community composition with depth.

Depth (ft.)	Lake Area (acres)	Sample points at this depth (#/%)		Species Observed (#)	Estimated Lake wide Biomass (kg)
0- 5	21	8	9	1	<1
5- 10	15	34	38	2	67
10- 15	18	15	17	0	0
> 15	25	31	35	0	0

Aquatic vegetation species richness of Crystal Lake was low and did not have high enough quantity or quality of species to meet deep lake standards for the Central Hardwood Forest Ecoregion (Table

6.4.3). Two species were observed in the lake, which is below the deep lake species richness standard of 12. These observed species had an average C-score of 4.5 (Table 6.4.3). Floristic quality index (FQI), an index based on the number of species observed and quality (i.e., C-score) of each species, was 6.4, which is below the deep lake FQI standard of 18.6 (Table 6.4.3).

Table 6.4.3. Species diversity statistics.

Index	Result*
Observed Taxa	2
Average C-score	4.5
Lake Floristic Quality Index (FQI)	6.4

*The standards for number of taxa and FQI in Crystal Lake are 12 and 18.6, respectively.

Species composition on Crystal lake did not include any dominant species (>50% occurrence). Curly leaf pondweed (CLP) an aquatic invasive species and white water lily, a native emergent aquatic species were the only observed species in the 2020 aquatic vegetation survey (Table 6.4.4, Figures 6.4.2). Curly leaf pondweed was found in two locations in the lake in depths between 6 to 7.5 feet and had a littoral occurrence of 3.5% and white water lily was observed in depths of 3.9 to 6.6 feet with a littoral occurrence of 10.5%. Percent occurrence is defined as the number of survey points at which a plant species was observed divided by the total number of points surveyed on a lake or within a specific depth range (Table 6.4.4).

Table 6.4.4. SAV species occurrence by depth on 6/10/2020.

Common Name	Scientific Name	% Lake Occurrence by Depth		
		0-5 ft.	5-10 ft.	10-15 ft.
Curly Leaf Pondweed	*Potamogeton crispus*	25	0	--
White waterlily	*Nymphaea ordata*	12	6	--

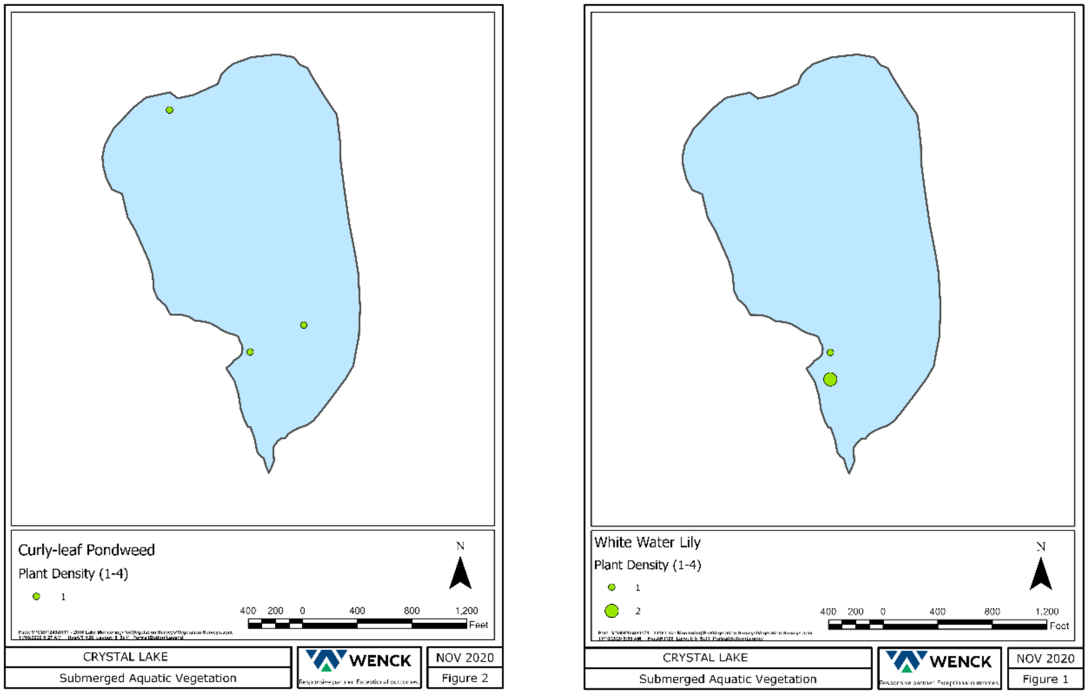


Figure 6.4.2. Distribution and density of Curly-leaf pondweed and white waterlily in Crystal Lake

Crystal Lake did not have native rooted or unrooted submerged aquatic vegetation during the 2020 survey. The only rooted submerged aquatic species was CLP. CLP, an aquatic invasive species, has the potential to negatively impact water quality and recreation when present in great abundance. CLP grows under ice, which means populations can reach maximum growth in May and June, when growth of most native vegetation is still hindered by short day length. This attribute gives CLP an extreme competitive advantage, causing it to form dense stands that shade out other native species and prevent them from sprouting. CLP's early season grown leads to senescence in early summer. This means that as the plant senesces and is decomposed by bacteria, the nutrients stored in its stems and leaves are released into the water column and may promote algae blooms. It will be important to continually monitor the SAV community on Crystal lake to ensure a nuisance level of CLP does not establish.

6.5 CARP POPULATION ASSESSMENT

The abundance and biomass density of common carp populations present in Crystal Lake were assessed in 2020. The purpose of the surveys was to provide initial estimates of carp biomass to inform carp management strategies on the lake. All field work for these assessments was performed following all regulations regarding aquatic invasive species management under MNDNR special research permit #29790. The population present in Crystal Lake exceeded biomass density thresholds known to be problematic at the time of sampling (95% confidence).

Seventy-nine common carp were captured during 1 hour of electrofishing (79 catch per unit effort, CPUE). Carp sampled had an average total length of 17.7 inches and weight of 2.05 lbs (Figures 6.5.1 and 6.5.2). With this CPUE, we estimated a common carp population in Crystal Lake of 12,011 individuals and an average biomass density of 311 lbs/acre (Table 6.5.1). The lower bound of the 95% confidence interval for average biomass density was 129.2 lbs/acre; above the threshold for water quality impairment (89 lbs/acre). Common carp in Crystal Lake are likely contributing to impaired water quality through their behavior of bottom feeding. During bottom feeding, carp uproot vegetation and facilitate the release of sediment phosphorus to the water column.

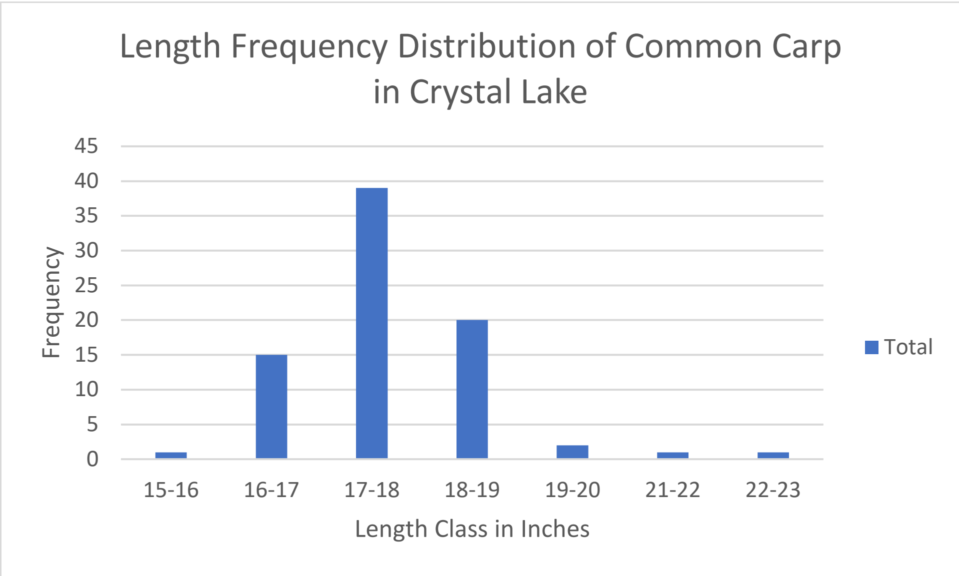


Figure 6.5.1. Length Frequency Distribution of Common Carp in Crystal Lake

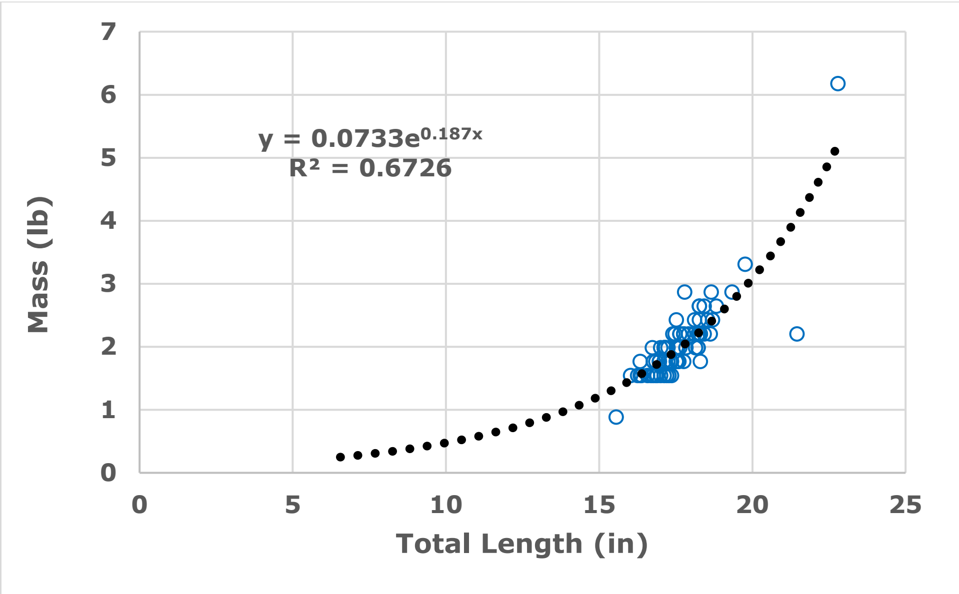


Figure 6.5.2. Length/weight regression of Common carp sample from Crystal Lake

Table 6.5.1. Common Carp electrofishing Survey Results for Crystal Lake.

Lake	Crystal Lake
Size (acre)	79.1
Sample Date	9/16/2020
# Sampled	79
# Transects	3
E-fish Time (hour)	1.0
Average Length (in)	17.7
Average Weight (lb)	2.051
CPUE Transect 1 (carp/hr)	105
CPUE Transect 2 (carp/hr)	60
CPUE Transect 3 (carp/hr)	72
Average Catch Per Unit Effort (carp/hr)	79.0
CPUE 95% Confidence (+/-)	46.6
Estimated Density (carp/acre)	152
Estimated Population Size (Abundance)	12,011
Biomass Present (lb)	24,641
Average Biomass Density (lbs/acre)	311
ABD 95% Confidence (+/- lbs/acre)	183.7
Critical WQ Threshold (lb/acre)	89

7.0 References

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