Appendix A: Precipitation Data

Table A1. Summary of 2018 and long-term precipitation data measured at the New Hope weather station.

Month	2018 Precipitation (inches)	1992-2018 Monthly Average Precipitation (inches)	Departure from Long-Term Average (inches)
January	1.34	1.01	0.33
February	1.54	1.00	0.54
March	1.50	1.73	-0.23
April	2.77	3.12	-0.35
May	2.59	4.09	-1.50
June	4.56	4.49	0.07
July	4.18	4.47	-0.29
August	3.55	3.99	-0.44
September	7.72	3.17	4.55
October	3.53	2.74	0.79
November	1.63	1.78	-0.15
December	1.81	1.40	0.41
TOTAL	36.72	32.99	3.73

Appendix B: 2018 West Mississippi Stream Data

Figure B1. Stage height of the Oxbow storm sewer sampling station. The light blue line represents all stage height measurements (taken every 15 minutes) and the dark blue line represents daily averages of stage height. Daily precipitation totals are represented in gray on the secondary axis.

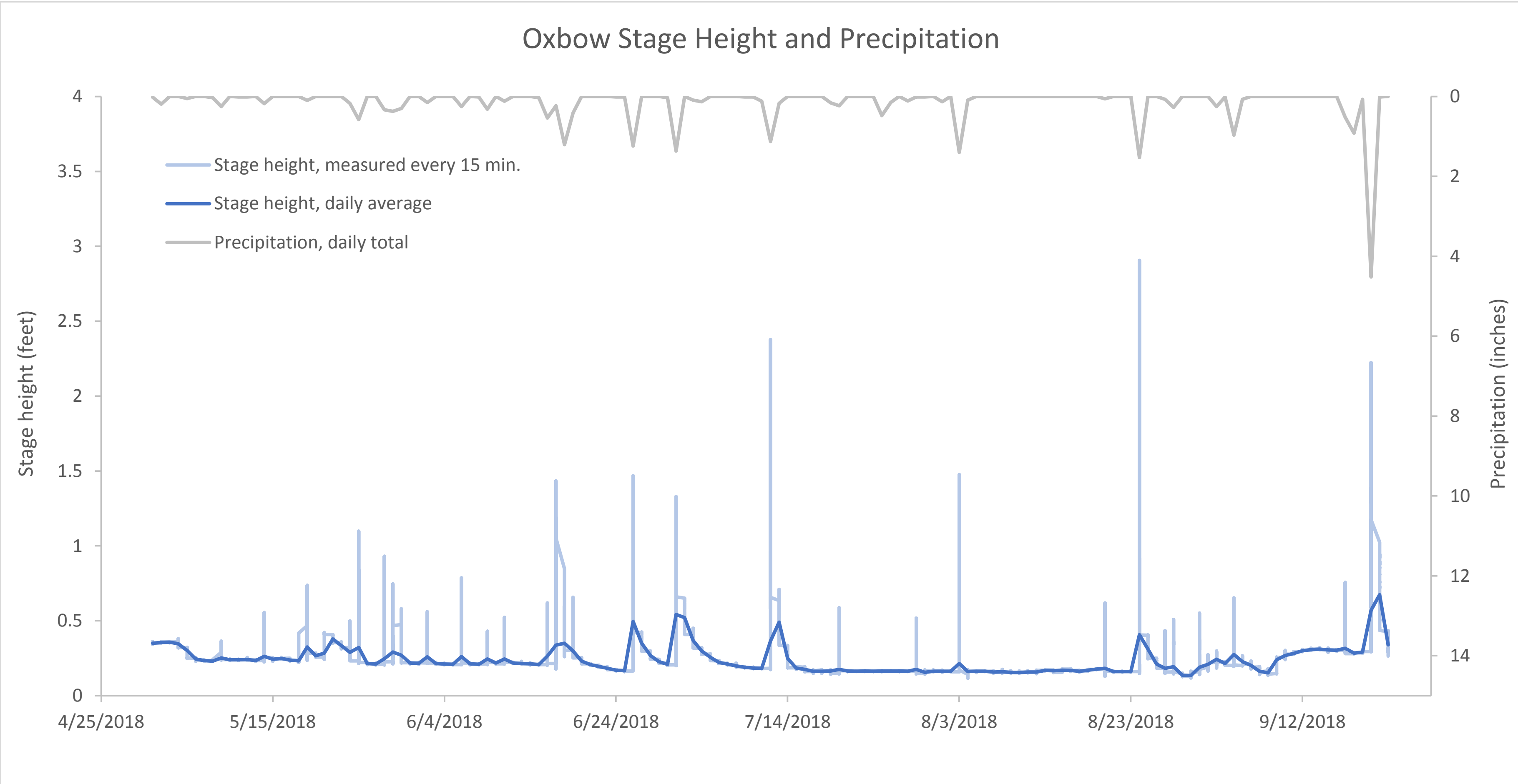

Figure B2. Stage height of the Environmental Preserve stream sampling station. The light blue line represents all measurements (taken every 15 minutes) and the dark blue line represents daily averages of stage height. Daily precipitation totals are represented in gray on the secondary axis.

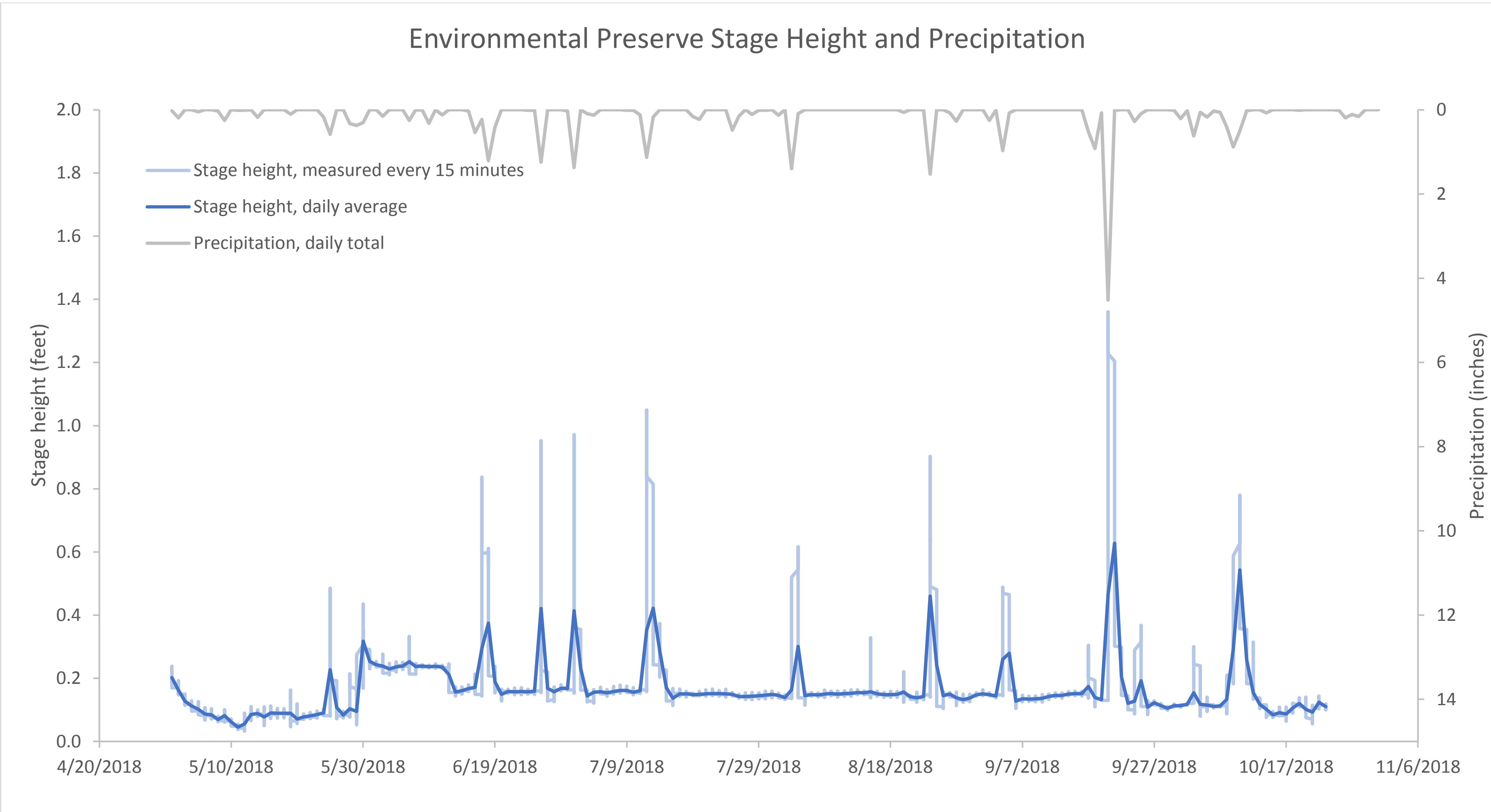

Table B1. Water quality data from the Oxbow outfall site measured in 2018. Parameters measured include temperature (temp), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (Sp. Cond.), total phosphorus (TP), orthophosphate (OrthoP), total suspended solids (TSS) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]
5/1/2018	10:45	8.48	7.76	69.1	7.14	912	0.028	0.030	1.2	85.9
5/30/2018	10:00	11.58	8.44	78.0	7.46	823	0.029	0.025	1.2	72.2
6/12/2018	15:00	13.43	8.44	81.4	7.47	833	0.025	0.026	< 1	74.2
7/11/2018	15:00	15.47	7.39	90.0	7.56	818	0.034	0.036	1.4	77.1
8/7/2018	10:30	13.82	8.66	86.7	7.78	815	0.044	0.032	2.80	77.3
8/21/2018	14:30	13.94	7.63	76.7	7.72	811	0.027	0.033	1.00	79.3
10/23/2018	9:15	13.24	7.13	68.9	6.11	788	0.036	0.040	2.20	69.0

Table B2. Water quality data from the Environmental Preserve stream site measured in 2018. 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) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]
5/1/2018	9:00	13.77	9.80	98.7	7.72	967	0.072	0.004	5.8	84.1
5/30/2018	10:45	20.51	6.92	77.0	7.52	694	0.113	0.014	13.0	75.8
6/12/2018	16:00	21.68	7.85	89.4	7.73	879	0.086	0.029	4.0	83.6
7/11/2018	14:15	25.7	7.39	93.3	7.94	814	0.101	0.033	15.4	73.4
8/7/2018	11:15	20.41	7.54	86.4	8.06	776	0.085	0.034	5.4	68.5
8/21/2018	15:00	21.21	7.47	86.6	8.19	772	0.128	0.038	46.2	74.0
10/23/2018	10:00	6.00	10.22	83.5	6.25	844	0.081	0.029	9.8	69.1

Appendix C: 2018 Shingle Creek Stream Data

Figure C1. Daily flow in cubic feet per second (cfs) for all monitored Shingle Creek locations, including SC-3, SC-0 and BCP. Daily precipitation totals are represented in gray on the secondary axis.

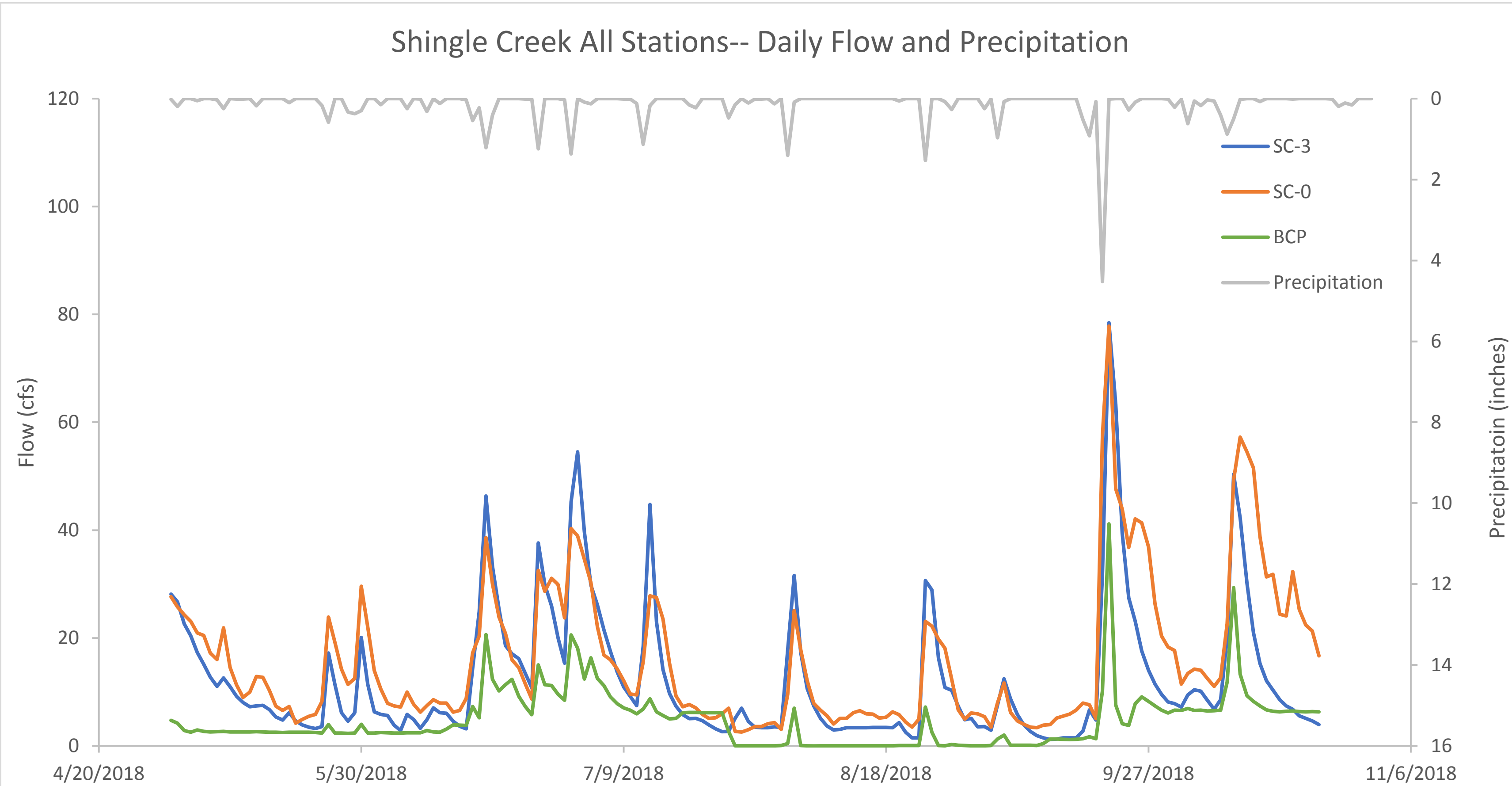

Figure C2. Annual precipitation and runoff depth for Shingle Creek stream sites.

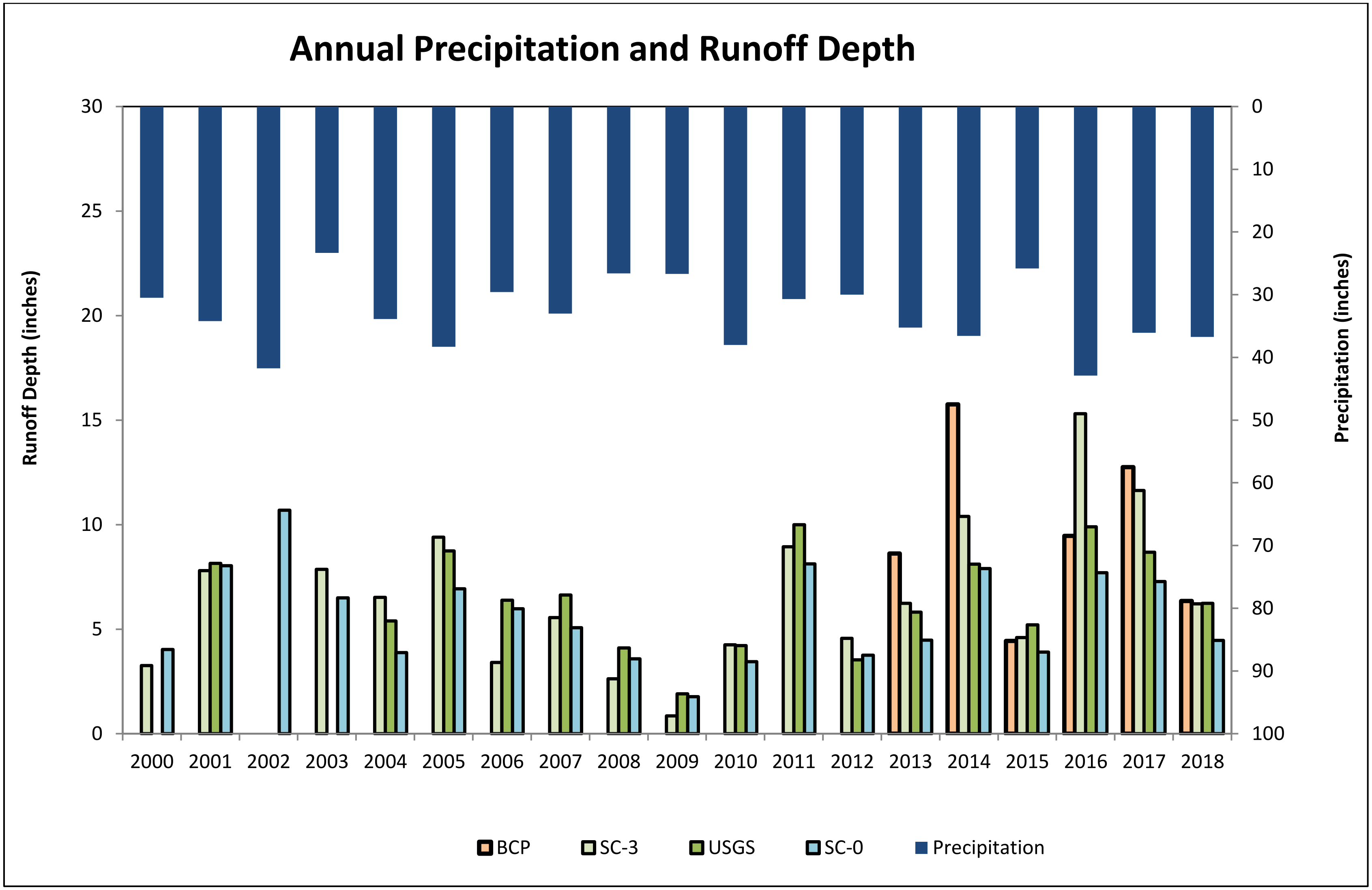

Table C1. Water quality data from the Shingle Creek SC-0 stream site measured in 2018. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (Sp. Cond.), total phosphorus (TP), orthophosphate (OrthoP), total dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), nitrate/nitrite (NO3/NO2), total suspended solids (TSS) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TKN [mg/L]	NO3/NO2 [mg/L]	TSS [mg/L]	Chloride [mg/L]
1/24/2018	10:30	-0.19	8.82	-	8.30	2915	-	-	-	-	-	-	700.0
2/8/2018	15:00	0.12	10.31	71.0	7.27	1748	-	-	-	-	-	-	775.0
3/19/2018	16:00	4.15	10.86	83.5	7.20	1212	-	-	-	-	-	-	225.0
4/5/2018	14:10	4.00	12.96	100	8.08	2068	-	-	-	-	-	-	574.0
4/19/2018	14:30	5.92	12.84	103.5	8.09	1515	-	-	-	-	-	-	391.0
5/1/2018	13:30	15.04	12.94	133.0	8.06	897	0.065	0.005	0.019	0.556	0.151	5.2	136.0
5/16/2018	12:10	18.74	8.89	95.5	7.42	1261	0.080	0.008	0.018	0.76	0.146	7.8	211.0
5/30/2018	12:30	21.85	3.52	40.1	7.48	782	0.134	0.048	0.064	1.67	0.178	8.4	126.0
6/12/2018	16:45	20.94	5.11	57.2	7.74	1077	0.077	0.021	0.023	-	0.479	3.2	162.0
6/27/2018	14:30	21.34	4.87	57.0	7.58	543	0.130	0.054	0.069	0.618	2.550	11.6	83.9
7/11/2018	13:30	24.57	5.06	62.8	7.64	882	0.070	0.028	0.037	0.649	0.236	4.4	143.0
7/25/2018	15:30	23.83	6.69	81.1	7.81	599	0.232	0.105	0.125	0.981	0.302	44.4	77.2
8/7/2018	12:30	21.97	5.29	62.4	7.85	676	0.087	0.030	-	0.62	0.180	3.0	104.0
8/21/2018	15:45	20.87	6.17	71.0	8.01	1209	0.048	0.024	-	0.499	0.232	2.4	177.0
9/11/2018	14:00	19.68	6.75	76.4	7.68	948	0.043	0.021	-	0.53	0.457	< 1	137.0
9/25/2018	11:45	15.81	6.59	68.9	7.82	556	0.079	0.035	0.052	0.757	0.159	10.2	97.9
10/11/2018	15:00	7.79	9.03	78.0	7.42	440	0.082	0.021	0.032	0.618	0.176	13.1	72.4
10/23/2018	11:30	7.32	8.29	69.7	5.94	981	0.058	0.022	0.020	0.700	0.337	5.5	139.0
11/16/2018	10:15	2.70	9.61	73.2	6.57	1139	-	-	-	-	-	-	188.0
12/14/2018	11:14	1.85	11.25	80.8	8.40	1409	-	-	-	-	-	-	219.0

Table C2. Water quality data from the Shingle Creek SC-3 stream site measured in 2018. 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 dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), nitrate/nitrite (NO3/NO2), total suspended solids (TSS) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TKN [mg/L]	NO3/NO2 [mg/L]	TSS [mg/L]	Chloride [mg/L]
1/24/2018	9:45	0.79	4.83	-	8.17	3863	-	-	-	-	-	-	1075
3/19/2018	14:45	0.56	9.14	64.2	7.25	1795	-	-	-	-	-	-	400
4/5/2018	13:45	0.86	10.40	73.6	8.81	2147	-	-	-	-	-	-	548
4/19/2018	14:00	4.46	12.00	93.1	8.13	1438	-	-	-	-	-	-	342
5/1/2018	14:10	13.63	11.76	118.1	7.31	720	0.053	0.008	0.021	0.505	0.048	3.2	129
5/16/2018	14:45	18.36	7.62	81.1	7.28	1337	0.092	0.011	0.028	0.792	<0.030	5.4	282
5/30/2018	11:30	21.52	4.19	47.2	7.67	934	0.164	0.069	0.093	1.35	0.250	6.0	229
6/12/2018	14:00	19.85	3.65	40.0	7.23	1128	0.135	0.068	0.096	-	0.150	2.8	245
6/27/2018	16:00	20.98	5.14	59.7	7.73	698.5	0.146	0.082	0.101	0.644	2.400	6.8	134
7/11/2018	10:30	22.38	4.74	56.2	7.77	765.8	0.131	0.064	0.084	0.784	0.061	4.8	139
7/25/2018	13:30	21.68	4.33	50.8	7.57	1058.6	0.133	0.024	0.044	0.581	0.103	5.8	169
8/7/2018	13:15	21.48	4.88	57.1	8.16	694.8	0.170	0.084	-	0.891	0.079	7.8	137
8/21/2018	14:00	20.31	1.78	19.0	8.50	360.3	0.224	0.104	-	1.44	0.252	12.8	42
9/11/2018	15:00	19.97	6.16	70.3	7.92	800.5	0.114	0.028	-	0.687	0.123	8.8	135
9/25/2018	10:45	15.57	6.80	70.5	7.75	523.7	0.088	0.038	0.055	0.693	0.069	6.5	108
10/11/2018	14:15	8.08	8.17	71.2	7.25	437.5	0.063	0.023	0.031	0.443	0.084	8.9	83
10/23/2018	13:00	6.25	7.61	62.3	6.38	731.7	0.052	0.018	0.027	0.652	<0.030	3.1	130
11/16/2018	9:45	0.60	8.94	64.4	6.30	911.7	-	-	-	-	-	-	187
12/14/2018	11:15	0.68	8.37	58.6	8.56	1370	-	-	-	-	-	-	245

Table C3. Water quality data from the Bass Creek Park (BCP) stream site measured in 2018. 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 dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), nitrate/nitrite (NO3/NO2), total suspended solids (TSS) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TKN [mg/L]	NO3/NO2 [mg/L]	TSS [mg/L]	Chloride [mg/L]
3/19/2018	14:30	0.03	9.09	62.6	7.26	2181	-	-	-	-	-	-	500
4/5/2018	13:15	0.90	9.10	64.7	8.89	1553	-	-	-	-	-	-	357
4/19/2018	13:30	3.15	11.17	84.2	8.27	1059	-	-	-	-	-	-	242
5/1/2018	15:30	15.40	9.75	101.6	7.43	727	0.067	0.018	0.030	0.639	0.069	2..0	127
5/16/2018	15:45	23.85	9.64	114.2	7.26	1507	0.093	0.013	0.027	0.853	<0.030	5.2	353
5/30/2018	8:30	19.94	2.91	32.0	7.67	989	0.266	0.139	0.167	4.600	0.130	6.2	231
6/12/2018	13:00	20.85	6.05	67.7	6.90	837	0.166	0.062	0.100	-	0.101	4.0	164
6/27/2018	12:45	21.61	5.35	63.2	7.44	701	0.120	0.076	0.089	0.620	4.950	2.0	127
7/11/2018	9:15	22.33	3.34	39.8	7.64	694	0.176	0.085	0.117	0.793	0.108	2.2	129
7/25/2018	10:45	22.19	4.12	48.5	7.83	960	0.111	0.042	0.069	0.742	0.120	4.4	196
8/7/2018	13:45	21.33	4.35	50.4	8.11	852	0.197	0.074	-	0.895	0.140	3.0	180
8/21/2018	13:15	20.18	4.27	47.6	8.11	1188	0.106	0.035	-	1.200	0.093	8.0	250
9/11/2018	15:30	22.49	6.70	80.0	8.02	893	0.120	0.044	-	0.735	0.144	1.6	174
9/25/2018	9:45	15.66	6.39	66.6	7.67	615	0.071	0.038	0.056	0.671	0.056	5.2	130
10/11/2018	13:00	7.59	8.85	76.3	7.18	588	0.054	0.029	0.035	1.310	0.158	4.0	118
10/23/2018	14:00	5.49	8.46	66.8	6.38	906	0.036	0.021	0.125	1.140	<0.030	10.7	168
11/16/2018	9:00	0.19	9.71	68.9	6.32	1028	-	-	-	-	-	-	219
12/14/2018	11:00	0.15	6.80	45.6	8.61	1535	-	-	-	-	-	-	229

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 2018 volunteers assessed 33 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 27 (excellent), with most of the sites in the 7-11 (poor) range. On a scale of 1 to 35, the vegetation IBI scores ranged from 9 (poor) to 27 (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 2018 Monitoring

Four sites were monitored in 2018: two in West Mississippi (one in Brooklyn Park, one in Champlin) and two in Shingle Creek (Plymouth and Brooklyn Park).

West Mississippi

Bartusch Park in Champlin (Figure D -1), in the northwest quadrant of 109^{th} and Maryland Avenues N. This is a deeper wetland, so it is able to support more organisms (Table D-1).

Table D-1. WHEP site CH-3, Bartusch Park, Champlin.

Year	2015	2017	2018
Invertebrate	20 (moderate)	15 (moderate)	15 (moderate)
Vegetation	21 (moderate)	15 (poor)	15 (poor)

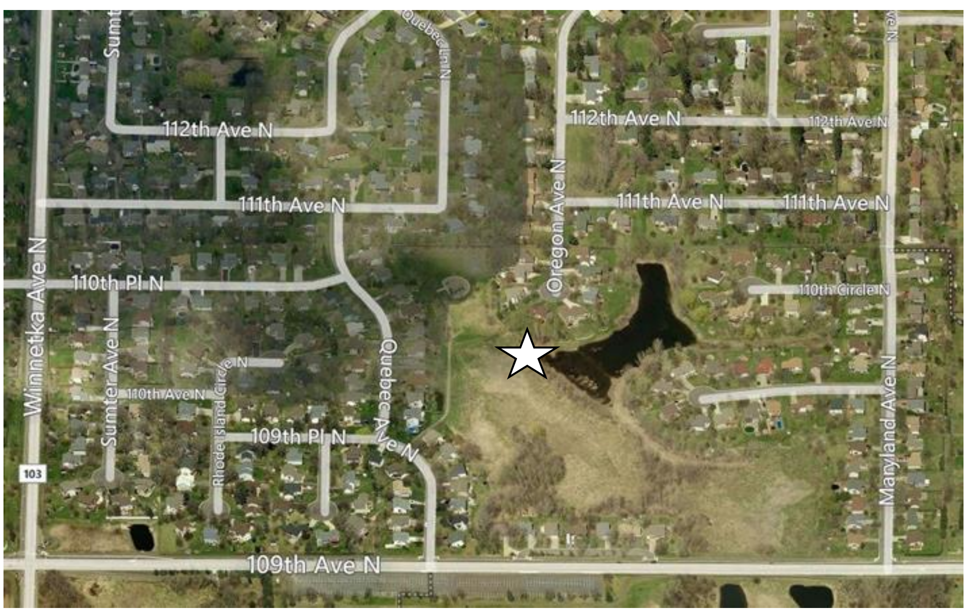

Figure D-1. Bartusch Park wetland in Champlin.

The Oxbow Ponds site is in a series of ponds and remnant wetlands north of "Oxbow Lake" near Regent and 101st Avenues North (Figure D-2) related to the 2002 development of Oxbow Commons. This area has rapidly developed in the past ten years, contains protected and mitigation wetlands, and is in an area where other wetlands have lost their hydrology. This site scored moderately well on both metrics in previous years but in 2017 and 2018 was rated Poor (Table D-2).

Table D-2. WHEP site BP-4, Oxbow Ponds, Brooklyn Park.

Year	2012	2013	2014	2017	2018
Invertebrate	16 (moderate)	16 (moderate)	24 (excellent)	9 (poor)	9 (poor)
Vegetation	16 (moderate)	21 (moderate)	21 (moderate)	11 (poor)	11 (poor)

Figure D-2. Oxbow Ponds wetland in Brooklyn Park.

Shingle Creek

Site BP-5 is in Brookdale Park, in a series of wetlands just south of Shingle Creek, downstream of Noble Avenue and "monkey falls." Old records show that before the Creek was straightened and channelized through the park, it meandered through these wetlands. (Table D-3 and Figure D-3). This wetland had some of the better scores of the WHEP wetlands in the watersheds until 2018 when both metrics were poor.

Table G-3. WHEP site BP-5, Brookdale Park, Brooklyn Park.

Year	2014	2015	2018
Invertebrate	24 (excellent)	16 (moderate)	8 (poor)
Vegetation	15 (moderate)	25 (moderate)	13 (poor)

Site PL-7 is in Three Ponds Park in Plymouth (Figure D-4), south of Bass Lake Road and east of Zachary Lane. This wetland scored very low for both macroinvertebrates and vegetation in both 2017 and 2018 (Table D-4).

Table D-4. WHEP site PL-7, Three Ponds Park, Plymouth.

Year	2017	2018
Invertebrate	8 (poor)	8 (poor)
Vegetation	13 (poor)	13 (poor)

Figure D-3. Wetlands in Brookdale Park, Brooklyn Park.

Figure D-4. Wetlands in Three Ponds Park, Plymouth.

Wetlands previously monitored but not in 2018 include:

West Mississippi

In 2008 and 2009 a wetland in Brooklyn Park's Jewel Park was monitored (Table D-5). Typical of small remnant wetlands in the watershed, this site is dominated by cattails and this monoculture greatly reduces both invertebrate and plant diversity.

Table D-5 WHEP site BP-3, Jewel Park, Brooklyn Park.

Year	2008	2009
Invertebrate	10 (poor)	20 (moderate)
Vegetation	7 (poor)	10 (poor)

A mitigation wetland in Champlin was monitored for four years as site CH-1. It is a large pond/wetland east of TH 169 between 109th and 114th Avenues North. It scored poorly on vegetation (Table D-6), which is a reflection of the stormwater discharged into it.

Table D-6. WHEP site CH-1, Mitigation Wetland, Champlin.

Year	2010	2011	2012	2013
Invertebrate	8 (poor)	16 (moderate)	18 (moderate)	18 (moderate)
Vegetation	11 (poor)	15 (poor)	7 (poor)	15 (poor)

A wetland in Brooklyn Park's Environmental Preserve has been monitored frequently, and serves as a reference and training site. This higher-quality wetland receives stormwater from a large area to the west that has developed in the last 10-15 years. This area is served by a number of detention ponds to treat runoff, and the health of BP-1 is one indicator of the effectiveness of that treatment in protecting downstream resources. Invertebrate health appears to be degrading and should be further explored.

Table D-7. WHEP site BP-1, Environmental Preserve, Brooklyn Park.

Year	2006	2007	2008	2009	2010	2011	2015	2016
Invertebrate	28 (ex)	22 (mod)	21 (mod)	20 (mod)	20 (mod)	18 (mod)	18/20 (mod)	7 (poor)
Vegetation	13 (poor)	19 (mod)	22 (mod)	19 (mod)	19 (mod)	20 (mod)	23/27 (mod/ex)	17 (mod)

Zane Sports Park, riparian to Century Channel in Brooklyn Park. It scores poorly for macroinvertebrates (Table D-8), likely because the water levels in the wetland fluctuate. Because it receives runoff through Century Channel that is likely high in sediment and nutrients, plant diversity is low.

Table D-8. WHEP site BP-7, Zane Sports Park, Brooklyn Park.

Year	2015	2016
Invertebrate	8 (poor)	8 (poor)
Vegetation	17 (moderate)	19 (moderate)

Shingle Creek

A wetland in Brooklyn Park just north of Palmer Lake was monitored in 2007-2009. The results (Table D-9) illustrate how variable biotic health can be based on precipitation.

Table D-9. WHEP site BP-2, Brookdale Drive Wetland, Brooklyn Park.

	2007	2008	2009
Invertebrate	16 (moderate)	20 (moderate)	13 (poor)
Vegetation	15 (poor)	7 (poor)	10 (poor)

A mitigation wetland in Palmer Lake Park just south of Palmer Lake was monitored for four years (Table D-10). Biotic quality varied, likely due to variations in precipitation.

Table D-10. WHEP site BC-1, South Palmer Lake, Brooklyn Center.

Year	2010	2011	2012	2013
Invertebrate	24 (excellent)	18 (moderate)	22 (moderate)	22 (moderate)
Vegetation	17 (moderate)	11 (poor)	19 (moderate)	17 (moderate)

Site BC-2 is a stormwater pond constructed in an upland area of the west side of the Palmer Lake Basin. This pond receives runoff from a large neighborhood to the west that had previously flowed untreated in the basin (Table D-11.)

Table D-11. WHEP site BC-2, West Palmer Lake, Brooklyn Center.

Year	2012	2013	2014
Invertebrate	14 (poor)	14 (poor)	16 (moderate)
Vegetation	17 (moderate)	19 (moderate)	19 (moderate)

Wetland 639W in Crystal has in the past been monitored. This site showed moderate invertebrate and vegetative diversity (Table D-12).

Table D-12. WHEP site CR-1, Wetland 639W, Crystal.

Year	2012	2013	2014
Invertebrate	16 (moderate)	16 (moderate)	22 (moderate)
Vegetation	13 (poor)	17 (moderate)	19 (moderate)

The site BP-6 is in Greenhaven Park in Brooklyn Park. This wetland is riparian to Shingle Creek, which flows north, turns almost 90 degrees to the east and flows under Bottineau Boulevard and past Wal-Mart (Table D-13).

Table D-13. WHEP site BP-6, Greenhaven Park, Brooklyn Park.

Year	2014
Invertebrate	22 (moderate)
Vegetation	25 (moderate)

One of the first sites monitored through this program was in Plymouth in Timber Shores Park in the wetland complex at the outlet of Bass Lake (Table D-14.).

Table D-14. WHEP site PL-6, Timber Shores, Plymouth.

Year	2005	2006	2008	2009	2010	2015	2016
Invertebrate	10 (poor)	16 (mode)	22 (mod)	24 (ex)	18/22 (mod)	22 (mod)	13 (mod)
Vegetation	15 (poor)	15 (poor)	17 (mod)	15 (poor)	25/15 (mod/poor)	13(poor)	21 (mod)

Appendix E: 2018 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 Department of Natural Resources (DNR).

Here we provide an overview of the various sampling methodologies (Section 1.0) used to collect water quality (Section 1.1), submerged aquatic vegetation (Section 1.2), and fisheries (Section 1.3) data on the lakes with Shingle Creek watershed. In Sections 2.0 and beyond we summarize the most recent assessments in each lake (fish, plants, water) providing results and discussions for each lake as a new section.

Results and summarizes can be found in the following order:

A) Upper Single Creek Management Unit:
   - Section 2.0 – Bass Lake

B) Lower Single Creek Management Unit:
   - Section 3.0 – Upper Twin Lake
   - Section 4.0 – Middle Twin Lake
   - Section 5.0 – Lower Twin Lake
   - Section 6.0 – Ryan Lake
   - Section 7.0 – 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 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 WMC 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 the water's total phosphorus (nutrient), chlorophyll-a (pigment in algae), and Secchi depth (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 sample schedule. Lakes that are selected for sampling in a given year typically collect bi-monthly samples starting in May and ending in October. All lakes sampled collect surface water samples that are 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 taking measurements starting at the water's surface and continuing every meter (or half meter in shallow lakes) throughout the entire water column. A YSI or similar multimeter probe is used to collect dissolved oxygen (DO; mg/L), DO %, temperature, pH, oxidation reduction potential (ORP) and specific conductivity at each step in the profile. Additionally, a Secchi disk reading is taken during every assessment to relate 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 understanding 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 (mg/L)	Chl-a (mg/L)	Secchi (m)
Deep	40	14	>1.4
Shallow	60	20	>1.0

1.2 SUBMERGED 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 an important area for recreational activities and aesthetical services to lakeshore property owners with diverse communities often causing little to no recreational and aesthetic impairment.

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

The relative health of the SAV community can be assessed with the MnDNR'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). 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.

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

To assess the presence, abundance and health of the submerged 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 curly leaf pondweed (*Potamogeton crispus;* CLP) while late summer surveys provide the greatest assessment of SAV health, 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 15 or 20 feet (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 then retrieved across the lake bottom to represent approximately 1m^2 of vegetation sampling. 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 are recorded.*

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. Depths intervals not existing within a lake (i.e. >15 feet) were removed from the analysis and reporting. 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 <2ft 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.

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

1.3 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. We outline five survey technique/ assessment methods that were implemented on Shingle Creek lakes in 2017.

1.3.1 Trap and Gill Net Surveys (Deep Lakes)

MnDNR survey game fish populations using standardized trap and gill net survey methods to assess gamefish populations within lakes. MnDNR standard trap and gill net surveys consist of setting trap and gill nets at predetermined locations based on lake size (Schlagenhaft 1993). The trap and gill nets are meant to tangle or entrap fish over a 12-24 hour period. Trap nets contain a lead net perpendicular to shore with a series of hoops and funnels at the end of the net that direct and entrap fish. The gill nets catch fish via gill entanglement and consist of multi-sized mesh panels. The gill nets are typically set in deeper (~8-12 feet), open water habitats. Fish captured from trap and gill net assessments are identified, total length measured and weighed.

1.3.2 Mini-fyke and Gill Net Surveys (Shallow Lakes)

Mini-fyke net and gill net assessments are implemented on shallow lake ecosystems (max depth < 15 feet) and follows the sampling techniques of shallow lake researchers (Herwig *et al.* 2010). Three mini-fyke nets and one gill net are used to tangle or entrap fish over a 12-24 hour period. Mini-fyke nets contain a lead net perpendicular to shore with a series of hoops and funnels at the end of the net that direct and entrap fish. The gill net catches fish via gill entanglement and consist of multi-sized mesh panels. The gill nets are typically set along the deepest contour within the basin. Fish captured are identified, summed and total biomass weighed.

1.3.3 Nearshore Surveys (Any Lake)

The MnDNR developed protocols and has begun implementing nearshore surveys to capture and identify more non-game type species (i.e. darter species, shiner species) using beach seines and backpack electroshocking equipment (here after: nearshore surveys). Nearshore sampling is an active method of fishing that targets all fish within shoreline habitats. Nearshore survey points are relatively equidistant from each other across the shoreline with the number of sampling locations determined by lake size (Bacigalupi et al. 2015). Beach seine tows consist of pulling a net throughout the water column to entrap fish. Electrofishing uses electrical charges that temporarily stun fish so they can be netted. Fish from nearshore assessments are identified and summed.

1.3.4 IBI Assessment (Select Deep Lakes)

Lake classes were developed by the MnDNR to characterize and group lakes based on physical and chemical differences (Schupp 1992). Historically, the classification system provided a systematic approach to manage fisheries (i.e. game fish populations) within Minnesota. Since that time the MnDNR has been developing specific tools that utilize fish community information to relate the health of a given lake. Minnesota lakes that fall within lake classes 22–25, 27-39 and 41-43 can be partitioned into one of four distinct IBIs.

Known as Indices of Biotic Integrity (IBIs), these tools are comprised of multiple metrics that score a lake’s health based on the fish species captured. Fish species vary in their ability to tolerate various kinds, magnitudes and frequency of disturbance, therefore, the species present and their abundances can be used to infer the amount of disturbance a given lake is/has experienced. Primary disturbances used during IBI development were shoreline degradation, urbanization, agriculture landuse and nutrient loading. IBI tools attempt to account for the expected variability of a fish community due to natural phenomenon (i.e. habitat complexity, system productivity), yet are coarse enough to encompass multiple lake classes. They are comprised of multiple metrics that integrate aspects of species richness, community assemblage and trophic composition that have been correlated to changes in disturbance levels. The IBI tools vary in the number of metrics (8 – 15 metrics) with some metrics becoming gear type specific or lake size adjusted within a given IBI. Combining all individual metrics within a given IBI tool results in a single score that relates the relative health of the lake. IBI scores range from 0 – 100, with 100 being the highest score possible reflecting the most pristine and natural community for a given lake class.

Fisheries survey information from trap and gill net surveys are combined with nearshore survey results in certain situations to rate conduct the IBI health assessment.

1.3.5 Common Carp Population Evaluation (Any Lake)

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). 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) and number and total biomass.

2.0 Bass Lake

2.1 SAMPLING SUMMARY

Below is a summary reporting from the most recent survey efforts for each area of the monitoring program. Bass Lake's most recent sampling efforts were completed:

- Water Quality - 2018
- SAV – 2018
- Fisheries - 2017
- Carp – 2017

2.2 WATER QUALITY

Water was collected bi-weekly starting in May and went through October 2018 for a total of 12 samples. All three water quality standards (total phosphorus, chlorophyll-a, and Secchi depth) were exceeded starting in June or July and remained throughout the growing season (Figure 2.1). Total phosphorus in Bass Lake increased throughout the spring and remained relatively constant above the water quality standard for the duration of summer.

Chlorophyll-a concentrations increased throughout the growing season, peaking at about 70 ug/L in August and decreasing through late summer and early fall. Secchi disk depths recorded throughout the summer months did not meet the water quality standard and remained constant around 0.6 meters.

Historic data for state standard water quality metrics dates as far back as 1994 on Bass Lake (Figure 2.2). Review of historic water quality has TP and Chl-a concentrations along with Secchi disk annual averages generally not meeting state standards with no strong trends observed.

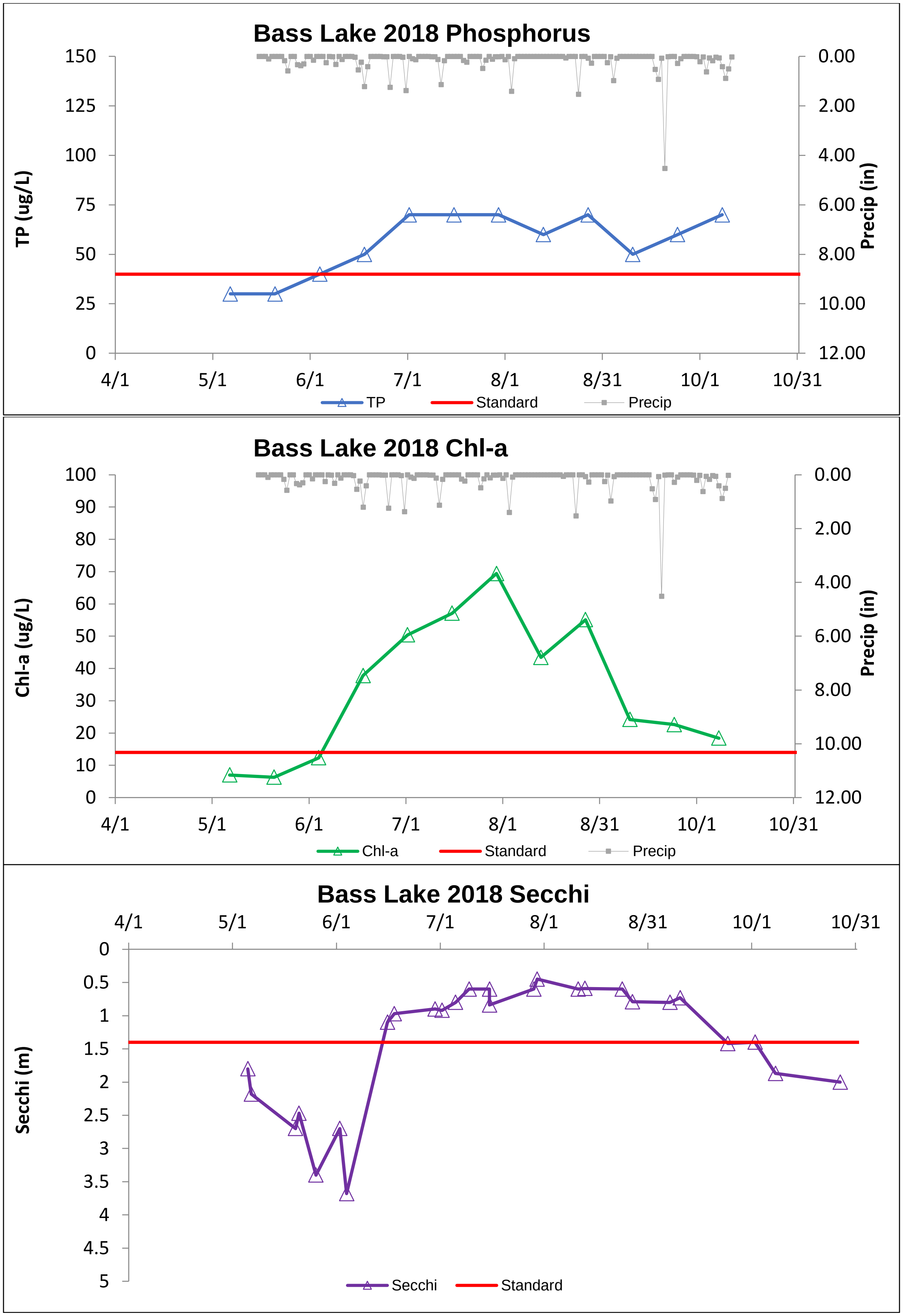

Figure 2.1. Seasonal TP, Chla, and Secchi measurements and water standards.

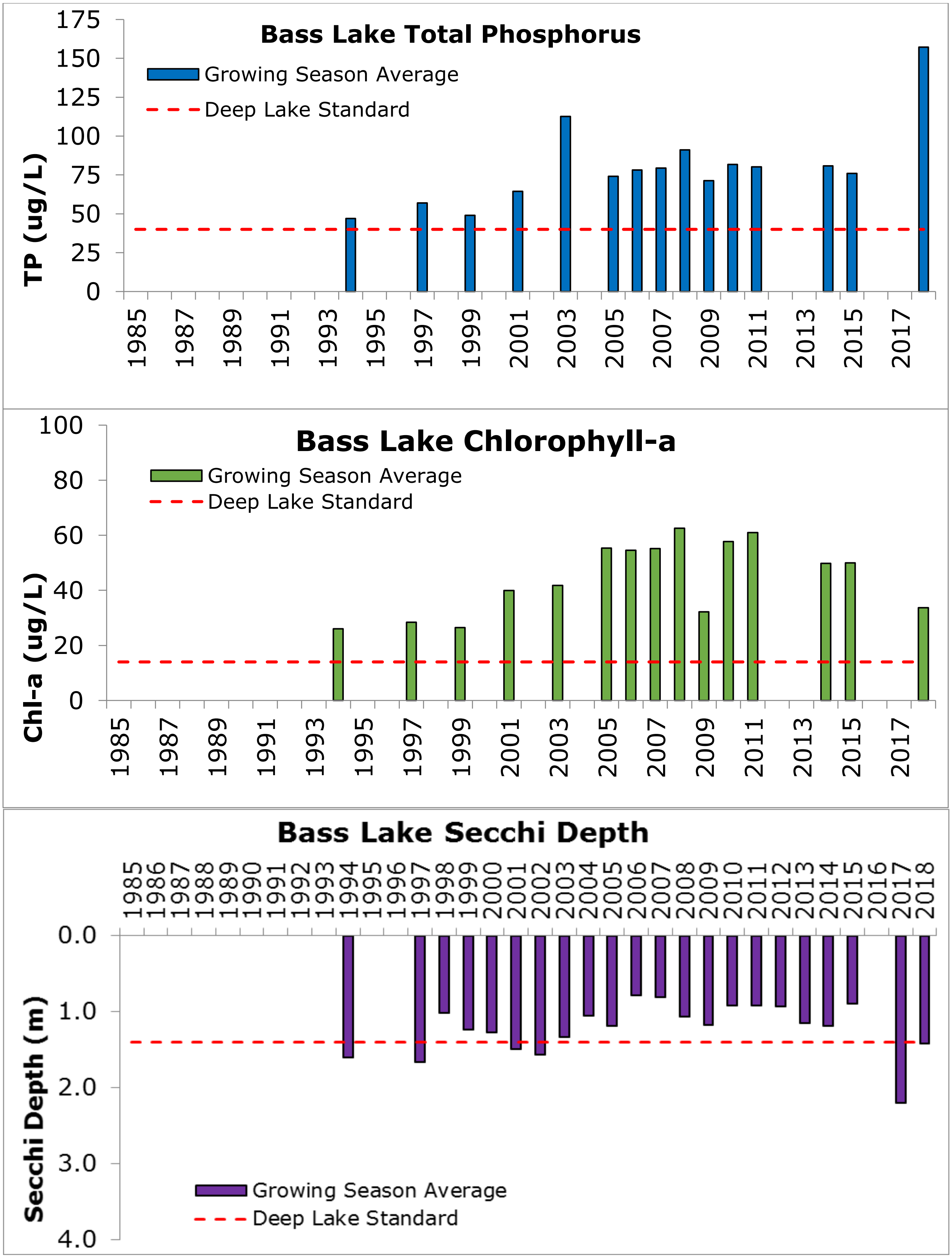

Figure 2.2. Annual average TP, Chl-a, and Secchi measurements and water standards.

2.3 SUBMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted by Wenck Associates to document the late spring and late summer submerged aquatic vegetation in Bass Lake in 2018. Bass Lake is located in the city of Plymouth within Hennepin County, MN. Bass Lake has an approximate surface area of 176 acres, with 148 acres of littoral acres (areas less than 15 feet deep), 3.22 miles of shoreline, and a maximum depth of 31 feet.

A total of 103 to 104 survey points were assessed on Bass Lake in 2018 surveys (Table 2.3). Vegetation coverage decreased between May and August surveys with littoral plant coverage decreasing from 82% of locations to 36%. Taxa richness also decreased over the open water season with 11 species observed during the May survey and 10 species observed during the August survey. The quality of observed species (average C-Score; Table 2.3) observed a slight increase in the August assessment. Overall, the vegetation community lacked both quantity and quality of species and scored below the Central Hardwood Forest Ecoregion FQI deep lake standard of 18.6 and deep lake species richness standard of 12 taxa.

Table 2.3. SAV quality and quantity indices.

	5/21/2018	8/16/2018
Total Observations	103	104
Littoral Observations	91	95
Total Vegetated points	75	34
% of Littoral with Vegetation	82%	36%
Lake Taxa*	11	10
Average C-Score	5.5	5.8
FQI*	18.1	18.3

*The lake taxa standard and FQI standards for Bass Lake are 12 taxa and an FQI of 18.6.

Sampling efforts were summarized by 5 ft depth intervals within the littoral zone to observe shifts and changes in community composition (Table 2.4). The majority of the lake is occupied by the littoral zone, with only 28 of the 176 total acres deeper than 15 feet. The majority of the observed biomass was within the 0-5 ft depth range, and total biomass did not change significantly throughout the summer. Overall, a decrease in plant abundance and species richness was observed as depth increased in both surveys. This is a natural trend due to light limitation, however, in pristine lake conditions the transition is typically much more gradual and extends beyond the littoral depth range. This trend was more pronounced in comparing the August to May surveys. Decreased plant abundance and species diversity later in the growing season can be an indicator of decreasing water quality and greater light limitation within the lake. Review of the max depth of vegetation growth was 10.8 ft in May and 13.1 ft in August, however, the August max growth depth appeared to be an outlier as the next observed plant was at 6.4 ft.

Table 2.4. Biomass summarized by lake depth.

Depth	Lake Acres	5/21/2018 Total Sample Points		5/21/2018 Species	5/21/2018 Est. Lake Biomass (wt; kg)	8/16/2018 Total Sample Points		8/16/2018 Species	8/16/2018 Est. Lake Biomass (wt; kg)
0-5 ft	67	22	21.4%	11	76,000	28	26.9%	10	119,000
5-10 ft	61	55	53.4%	6	28,000	60	57.7%	3	1,147
10- 15 ft	20	14	13.6%	3	1,034	7	6.7%	1	12
>15ft	28	12	11.7%	0	0	9	8.7%	0	0

Curly-leaf pondweed (CLP), coontail, and muskgrass were the most abundant species observed in May, however, none of these species appeared to be dominant across the lake (occurrence <50%). Lilies, duckweed and a few rooted plant species comprised the rest of the community with occurrences at or less than 10% of the survey locations.

No species appeared to dominate Bass Lake in August. Coontail was the most abundant species observed in August, however, was only observed at 28% of the sampling locations. Coontail is a native species that can grow very dense and in shallow nutrient rich waters, often creating recreational and aesthetic nuisances. Similar to the spring assessment, lilies, duckweed and rooted plant species comprised the remainder of the vegetation community with occurrence at or less than 9% of the survey locations.

Species that were present in May but not in August included CLP, northern water milfoil, and star duckweed. Ribbon-leaved pondweed was present only in August. With the exception of CLP, all these species were observed to be rare (<5% occurrence) across the lake. It is likely that these rare species persisted during both surveys but were simply not observed due to their limited occurrence. CLP is known to senesce by late summer, therefore, the absence of this species is expected between surveys (Figure 2.1).

Table 2.3. Summary of species observations and biomass estimates.

Common Name:	Scientific Name:	5/21/2018 % Lake Occurrence	8/16/2018 % Lake Occurrence
curly-leaf pondweed	*Potamogeton crispus*	46	--
coontail	*Ceratophyllum demersum*	39	28
muskgrass	*Chara sp.*	26	1
waterweed (Canadian)	*Elodea canadensis*	10	5
yellow waterlily	*Nuphar variegata*	7	7
white waterlily	*Nymphaea odorata*	6	8
very small pondweed	*Potamogeton pusillus*	5	2
water milfoil (northern)	*Myriophyllum sibiricum*	2	--
duckweed (star)	*Lemna trisulca*	1	--
duckweed (lesser)	*Lemna minor*	1	9
water celery	*Vallisneria americana*	1	8
ribbon-leaved pondweed	*Potamogeton epihydrus*	--	1

All 11 species observed in May were found in the shallowest depth range of the lake with decreasing species as depth interval increased (Table 2.4). Of these 11 species, two appeared to dominate the vegetation community within different depth intervals. Coontail dominated the shallow-depth interval, while CLP dominated the mid-depth interval.

Muskgrass and waterweed were abundant in all three littoral depth intervals, while waterlilies were abundant in only the shallow-depth interval. Other native species were rarely observed in the shallow and mid-depth intervals and were not observed in the deep depth interval.

Similar to May, all species observed in the August survey were found within the shallowest depth interval (Table 2.4). The two inlet bays on the southern portion of Bass Lake were both rich in waterlilies. A more significant decline in species was observed as depth interval increased with only one species being observed in the deep depth interval. Coontail appeared to be the only species that dominated a depth interval and was observed across all three littoral depth intervals. Only three species, coontail, Canadian waterweed, and lesser duckweed, were observed at depths greater than 5 feet.

The percentage of species observations decreased as water depth increased during both surveys, which is expected since vegetation typically is more abundant in shallow water. However, the limited number of species and the rapid decrease are suggestive of water quality impairments rather than nature declines in richness and occurrence.

Table 2.4. SAV species occurrence by depth.

Common Name:	5/21/2018			8/16/2018		
	% Occurrence by Depth (ft)			% Occurrence by Depth (ft)		
	0-5	5-10	10-15	0-5	5-10	10-15
curly-leaf pondweed	23	71	21	--	--	--
coontail	95	35	--	71	13	14
muskgrass	23	36	14	4	--	--
waterweed (Canadian)	14	11	7	11	3	--
yellow waterlily	32	--	--	25	--	--
white waterlily	27	--	--	29	--	--
very small pondweed	9	5	--	7	--	--
water milfoil (northern)	5	2	--	--	--	--
duckweed (star)	5	--	--	--	--	--
duckweed (lesser)	5	--	--	29	2	--
water celery	5	--	--	29	--	--
ribbon-leaved pondweed	--	--	--	4	--	--

*Note: Species are in the same order as they appeared in Table 2.3.

The decline in species richness, abundance, and depth of growth across the growing season was concerning for the health of Bass Lake. The late summer SAV community is typically more diverse, has greater abundance, and has species that utilize all depth intervals in healthy ecosystems. Healthy SAV communities provide other organisms with a diverse array of habitats to forage and find refuge in. The sudden decline in SAV community abundance and diversity as depth increases is an indicator that nutrient loading is a problem within Bass Lake. Lakes that have high nutrient loading typically see an impaired FQI score, limited species diversity, and experience a decline in water clarity over the summer as water column nutrients are taken up by phytoplankton algae leading to increased lake turbidity and a shading impact on the SAV community.

Filamentous algae grows well in areas of limited wind/wave disturbance, high sediment nutrients, and greater light penetration. It appears that nearshore conditions in Bass Lake are favorable to support filamentous algae growth as the algae was observed in areas across the lake during the August survey. Filamentous algae is a concern for many lake recreators and property owners as it can create dense surface mats that impede navigation and are visually distracting. Filamentous algae typically require high nutrient conditions, however, the location and source of the high nutrients differs from the high nutrients that facilitate phytoplankton algae (water column algae) growth. Bass Lake may be experiencing high nutrient loading that are facilitating both forms of algae growth that are causing water quality and recreational impairments to the lake.

In 2019, Bass Lake is undergoing an aluminum sulfate treatment. The intention of this treatment is to improve water quality and clarity in the lake. The treatment works by permanently binding to phosphorus that becomes released from lake sediments under anoxic conditions. This binding process keeps nutrients from entering the water column where phytoplankton algae can take it up and cause water clarity degradation. The resulting increased water clarity is anticipated to stimulate vegetation growth across the lake with increased native plant abundance and species diversity. This is the desired improvement of the treatment and would be viewed as an ecological health improvement to the lake. The anticipated increased light attenuation within the lake may also stimulate filamentous algae growth, which could limit SAV restoration within the lake. It appears that lake conditions are suitable to foster filamentous algae growth and improved water clarity may allow it to become more abundant and expansive within the lake. There is currently a limited ability to predict and prevent filamentous algae growth, therefore, continued monitoring post treatment will remain important and further research may be warranted to control filamentous algae growth.

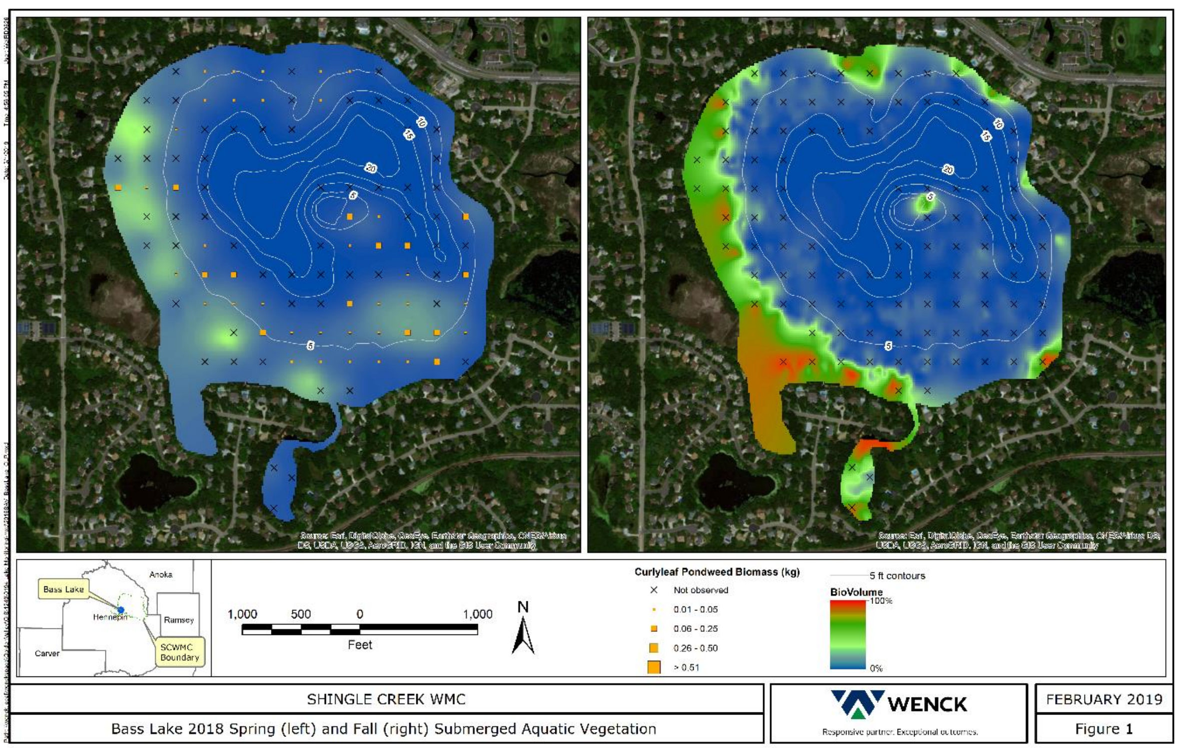

Figure 2.3. Curly leaf pondweed observations and biomass and total vegetation biovolume.

During the surveys two SAV species were of notable occurrence: curlyleaf pondweed and Coontail. CLP is an aquatic invasive species that spreads across the lake by forming turions that by early summer break off and fall to the lake bottom as the plant dies back (senesces). The turions are distributed across the lake by currents and wave action and germinate into new plants in the early fall. CLP is dormant through late summer often leaving previously vegetated areas void of plants during the later summer months before it begins to sprout again in the fall. Since the plant grows under the ice and reaches its maximum growth in May and June, when most native plant growth is still hindered by cool water temperatures, it has an extreme competitive advantage. Due to this advantage over native species, CLP can form dense stands that shade out areas and prevent other species from sprouting. When the plant begins to senesce in early summer the nutrients stored in the stems and leaves of the plants are released back into the lake and can promote phytoplankton algae growth. The timing of the large pulse of nutrients to the lake (typically mid-summer) can cause excess algal blooms or impact water quality negatively in other ways.

Coontail, a native species, was highly abundant at shallow (0-5 ft) depths and may impair aquatic recreation. In shallow depths coontail often grows throughout the water column, reducing recreational enjoyment (i.e. boating, fishing, swimming). Land owners are permitted through the DNR to remove and/or chemically treat areas of the shoreline for all aquatic vegetation to allow recreational opportunity. However, care and caution to removing desirable and ecologically beneficial plants is warranted to prevent the further spread and introduction of less desirable or invasive species to these areas.

Overall, the health of the SAV community of Bass Lake is being impaired by nutrient stressors. Efforts to restore water quality and reduce nutrient loading in the lake are underway. The 2019 planned activities are anticipated to significantly enhance the abundance, occurrence, and diversity of species within Bass Lake. The possible sudden and drastic change in water quality and the SAV community may create social concerns, however, activities are permitted by the DNR to control SAV growth and landowners are encouraged to consider this for continued use and enjoyment of the lake under improved ecosystem health.

2.4 FISHERIES

Fisheries assessments were conducted on Bass Lake from 8/28/2017 – 8/30/2017. A trap and gill net survey, a nearshore survey, an IBI assessment and common carp population evaluation were conducted. These efforts were conducted to evaluate the fish community, compare it to historic information, determine the overall health of the fish community and to determine if common carp population persist at ecologically detrimental densities.

2.4.1 Trap and Gill Net Surveys

Trap net surveying resulted in relatively low numbers of fish collected with bluegill sunfish being the most abundant species captured (Table 2.5). Size distribution of captured fish is summarized in Table 2.6. Many of the trap net locations were within dense lily pad and/or other submerged aquatic vegetation (SAV) stands that fish may have a difficult time swimming in.

Table 2.5. 2017 trap net fish summary on Bass Lake.

Species	Count	% of GN catch	Total Weight (lbs)
black crappie	2	3.4	0.6
bluegill	48	80.0	8.0
northern pike	3	5.0	3.9
pumpkinseed	5	8.3	0.5
yellow perch	2	3.3	0.5

Table 2.6. 2017 trap net size distribution summary on Bass Lake.

Species	Number of fish in slot (inches)									
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39
black crappie	--	--	2	--	--	--	--	--	--	--
bluegill	19	20	9	--	--	--	--	--	--	--
northern pike	--	--	1	--	--	1	--	1	--	--
pumpkinseed	4	--	1	--	--	--	--	--	--	--
yellow perch	--	1	--	1	--	--	--	--	--	--

The MnDNR conducted trap net assessments in 1981, 1986 and 1991 using the same five trap net locations as this survey. Blue Water Science (Steve McComas) conducted an assessment in 2012 setting a total of 12 trap nets in various locations with some nets reset for a second day of sampling in the same location. Blue Water Science reported two net sets malfunctioned during the 2012 survey. It is unclear why sampling did not occur in the same locations as the historical MnDNR surveys, however the same number of nets were set. To make results comparable to historic and 2017 sampling efforts we removed the catch totals from the day 2 resample, the locations that sampled on the island and the nets that malfunctioned. This resulted in five trap nets remaining in areas close to that which were historically sampled. We further caution comparison to the 2012 assessment as it was conducted after fall turnover and likely past peak vegetation growth, thus changing the behavior and location of fish within the lake.

The number of fish observed during the trap net assessment has decreased significantly since 1981 (Table 2.7). It is difficult to state beyond speculation what (if any) factors resulted in significantly lower catch rates without historic vegetation and water quality information. Changes in the fish community could be associated to improvements in water quality and subsequent changes in the vegetation community. For example, black bullhead are a disturbance and poor water quality tolerant species. The abundance of black bullhead within the lake appears to have significantly declined over the years likely due to water quality improvements or increased predation by other fish. The management activities within Bass Lake ecosystem could have stimulated submerged aquatic vegetation (SAV) growth. This increased SAV growth may have resulted in select species (i.e. Coontail) that can grow very dense and inhibit catchability of fish. Therefore, the decreased numbers of bluegill may not be the result of declining populations but rather a change in capture efficiency within the lake. The timing of more recent survey efforts may also influence catch rates, the 2017 sampling efforts likely occurred shortly after peak vegetation growth, while MnDNR efforts that occurred in July may have occurred pre-peak growth limiting interference of SAV on net catch. Future trap net assessments should focus on early to mid-July sampling time frames in the event that season changes in vegetation growth have impeded catch rates.

Table 2.7. Historic trap net fish summary on Bass Lake.

Species	MnDNR			McComas**	Wenck
	7/16/1981	7/14/1986	7/8/1991	10/9/2012	8/29/2017
black bullhead	39	729	241	--	--
black crappie	51	20	89	11	2
bluegill	129	739	719	178	48
brown bullhead	1	6	11	--	--
common carp	5	--	5	--	--
golden shiner	3	--	2	--	--
green sunfish	--	13	--	1	--

Species	MnDNR			McComas**	Wenck
	7/16/ 1981	7/14/ 1986	7/8/ 1991	10/9/2012	8/29/ 2017
hybrid sunfish	36	91	2	--	--
largemouth bass	1	3	4	4	--
northern pike	--	--	2	1	3
pumpkinseed	20	--	17	22	5
yellow perch	--	--	--	2	2
white crappie	--	--	1	--	--
white sucker	--	--	1	--	--

**Adjusted results

Gill net surveying resulted in eight species being observed (Table 2.8) across various sizes (Table 2.9). Black crappie and sunfish species comprised the majority of the total gill net catch. Golden shiner and black bullhead were two species observed only in our gill net catch. Most fish captured were less than nine inches in length, however, numerous large northern pike were observed in the nets and ranged from 25 to 36 inches.

The MnDNR had conducted gill net assessments in 1981, 1986 and 1991 using the same two gill net locations (and those used during 2017). Blue Water Science did not conduct a gill net assessment in 2012 (Table 2.10). The historic gill net survey results indicate black bullhead have steadily and significantly declined while northern pike and bluegill have increased since the 1981 survey. The community shifts appear to have shifted to favor less tolerant species and species that are associated with improved water quality and habitat conditions.

Table 2.8. 2017 gill net fish summary on Bass Lake.

Species	Count	% of GN catch	Total Weight (lbs)
black bullhead	4	2.6	3.6
black crappie	57	37.7	10.6
bluegill	47	31.1	11.3
golden shiner	3	2.0	0.3
green sunfish	1	0.7	0.2
northern pike	20	13.2	97.1
pumpkinseed	8	5.3	0.9
yellow perch	11	7.3	1.2

Table 2.9. 2017 gill net size distribution summary on Bass Lake.

Species	Number of fish in slot (inches)									
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39
black bullhead	--	--	1	2	1	--	--	--	--	--
black crappie	8	26	23	--	--	--	--	--	--	--
bluegill	7	15	25	--	--	--	--	--	--	--
golden shiner	--	3	--	--	--	--	--	--	--	--
green sunfish	--	1	--	--	--	--	--	--	--	--
northern pike	--	--	--	--	--	--	4	6	9	1
pumpkinseed	4	4	--	--	--	--	--	--	--	--
yellow perch	--	10	1	--	--	--	--	--	--	--

Table 2.10. Historic gill net fish summary on Bass Lake.

Species	MnDNR			McComas **	Wenck
	7/16/ 1981	7/14/ 1986	7/8/ 1991	10/9/ 2012	8/29/ 2017
black bullhead	287	140	65	NA	4
black crappie	3	16	77	NA	57
bluegill	--	13	18	NA	47
brown bullhead	--	9	7	NA	--
golden shiner	--	2	55	NA	3
green sunfish	--	--	--	NA	1
largemouth bass	1	--	1	NA	--
northern pike	2	6	12	NA	20
pumpkinseed	--	--	7	NA	8
walleye	--	--	1	NA	--
Yellow perch	--	--	--	NA	11

**Adjusted results

2.4.2 Nearshore Survey

Select sampling locations were difficult due to dense vegetation growth (lily pads, coontail) or sudden deep water conditions (cattail fringe to unwadable waters). Efforts to sample these locations were still made with only one location being skipped with the seine sampling. IBI protocol allows for occasional missed sampling locations due to natural conditions, therefore, sampling requirements were still met and accurate metrics scoring produced. Nearshore surveying resulted in nine species being observed with bluegill dominating the catch total (Table 2.11). Many of the bluegill captured were young of year individuals that were between 2.5 and 3.5 cm in length. Largemouth bass and central mudminnow were species observed only during the nearshore survey efforts. Length and weight measurements were not taken on nearshore surveyed fish.

Table 2.11. 2017 nearshore survey counts by species.

Species	EFB	Seine	Total
black crappie	--	14	14
bluegill	210	4268	4478
central mudminnow	11	4	15
green sunfish	22	7	29
hybrid sunfish	2	9	11
largemouth bass	9	43	52
northern pike	1	10	11
pumpkinseed	7	47	54
yellow perch	--	5	5

2.4.3 IBI Assessment

Bass Lake is a small, alkaline and productive system with a relatively large littoral area (<15 depth) compared to other Minnesota lakes. Based on these characteristics the MnDNR has classified Bass Lake as a lake class 38 lake. Lake class 38 is assessed with IBI tool #7. IBI tool #7 lakes tend to exist in southern and western Minnesota (lake classes 38, 41-43) and are generally comprised of relatively simple fish communities that may have a history of periodic winterkills, are naturally mesotrophic to eutrophic systems (moderate to high productivity), exist in relatively disturbed watersheds, and the basins are comprised of greater than 80% littoral habitat (<15 feet water depth). The three other IBI tools score lakes that have greater lake complexity, they tend to be deeper and less productive, they are often comprised of less disturbed watersheds and various levels of shoreline degradation.

IBI tool #7 is comprised of species richness, community assemblage and trophic composition (Table 2.12). Metrics 1-4 are scored based on the number of species observed within each category. Metrics 2-4 are adjusted based on lake size as larger lakes are expected to contain more fish species. In general, a lake scores higher with no or few tolerant species and many insectivore, small benthic dwelling and vegetation dwelling species. Metrics 5-8 are scored based on the composition of the community. These metrics are also gear specific to account for where these species are typically observed within the lake and to make variables independent of each other. In general, a lake scores higher with higher proportions of insectivore, vegetation dwelling and top carnivore species and lower proportions of tolerant species.

Table 2.12. IBI Tool #7 metrics.

Metric #	Metric
1	# of tolerant species
2	# of insectivore species *
3	# of small benthic dwelling species *
4	# of vegetation-dwelling species *
5	Pptn. of vegetation-dwelling individuals in the NS
6	Pptn. biomass of insectivores in TN
7	Pptn. biomass of tolerant species in TN
8	Pptn. biomass of habitat dependent top carnivores sampled in GN

*lake size adjusted

The IBI score can be compared to state defined impairment thresholds and to similar lakes that are scored using the same IBI tool. Viewing individual metric scores, course community differences and comparing to future datasets provides context to the Bass Lake fish community health. The IBI is intended to represent the amount of human disturbances on a lake and often correlate to water quality conditions. They do not assume a cause/effect relationship between fish and water quality, but, efforts made to improve and restore water quality and a diverse healthy vegetation community can lead to enhancements in the fish community.

The IBI assessment resulted in an overall IBI score of 56.8 which is well above the MnDNR biological impairment threshold (score = 36). The IBI scored well on metrics 6-8 due to the presence of bluegill and no observed tolerant species in the trap nets and the high biomass of northern pike and black crappie in the gill nets (Table 2.13). The IBI scored less well on metrics 1-5 due to limited diversity within insectivore, small benthic dwelling and vegetation dwelling species (Table 2.13). The limited diversity of these species could be the result of limited habitat within the lake. The lake appears to have a high diversity of submerged aquatic vegetation, however, is also dominated by dense growth of select species (i.e. Coontail) which may be providing limited habitat for vegetation dwelling species and/or the substrate needed to support various benthic dwellers. Overall the numbers of certain species/ category (i.e. small benthic dwelling species, vegetation dwelling species) is limiting within Bass Lake, however, the proportion and abundance of the species that do occur is in good condition. Bass Lake is represented by a simple yet healthy fish community.

Table 2.13. Metric, metric scores and community composition for Bass Lake IBI scoring.

Metric #	Metric	Metric Value	Metric Score
1	# of tolerant species	2	0.94
2	# of insectivore species *	6	-0.04
3	# of small benthic dwelling species *	0	-0.96
4	# of vegetation-dwelling species *	2	0.04
5	Pptn. of vegetation-dwelling individuals in the NS	0.6%	-0.38
6	Pptn. biomass of insectivores in TN	66.7%	3.48
7	Pptn. biomass of tolerant species in TN	0%	3.08
8	Pptn. biomass of habitat dependent top carnivores sampled in GN	86.0%	2.58

* Lake size adjusted

2.5 CARP

A common carp population assessment was conducted on 8/30/2017. We captured one common carp during the boat electrofishing surveying. The individual weighed 0.2 pounds and measured 6.5 inches in length. Modeling suggests that approximately 647 carp exist within Bass Lake at an estimated density of 0.8 kg of carp biomass per hectare which is well below the 100 kg/ha impairment threshold. These results suggest that the presence of common carp within Bass Lake is limited and likely not a primary driver of poor water quality conditions or significant habitat degradation.

3.0 Upper Twin Lake

3.1 SAMPLING OVERVIEW

Below is a summary reporting from the most recent survey efforts for each area of the monitoring program. Upper Twin Lake most recent sampling efforts were completed:

- Water Quality - 2018
- SAV – 2018
- Fisheries - 2018
- Carp – 2018

3.2 WATER QUALITY

All three water quality standards (total phosphorus, chlorophyll-a, and Secchi depth) were exceeded throughout the entire summer 2018 in Upper Twin Lake (Figure 3.1). The chlorophyll-a and total phosphorus increased during the spring, peaked in early August and decreased in late summer and early fall. The Secchi depth was consistently low, around 0.3 m, throughout the 2018 summer season. The 2018 water quality is worse than in previous decade. This trend is most noticeable in the total phosphorus and chlorophyll-a.

Review of historic data for state standard water quality metrics dated as far back as 1990 on Upper Twin Lake (Figure 3.2). Review of historic water quality has TP and Chl-a concentrations along with Secchi disk annual averages generally not meeting state standards.

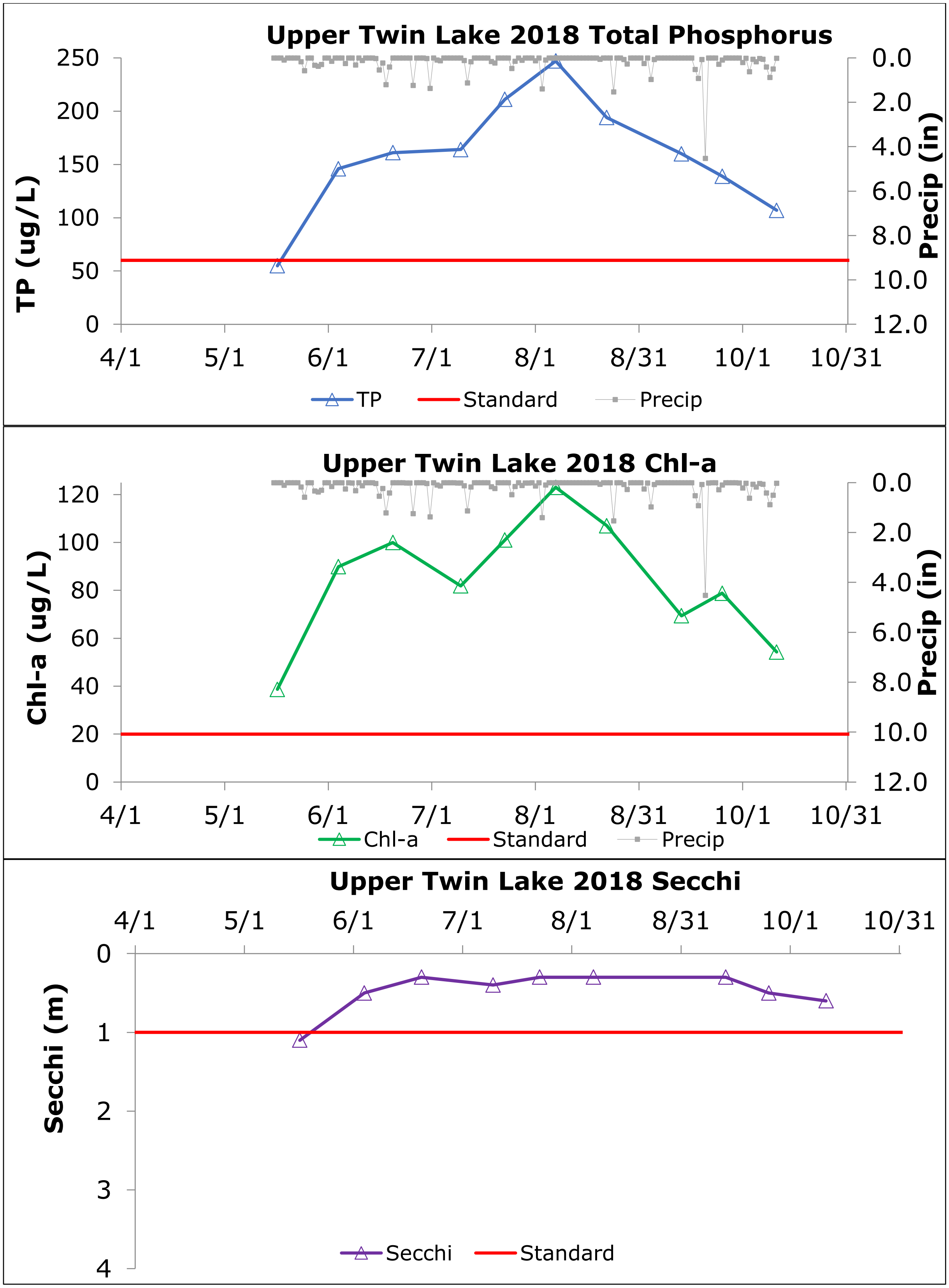

Figure 3.1. 2018 TP, Chla, and Secchi measurements and water quality standards.

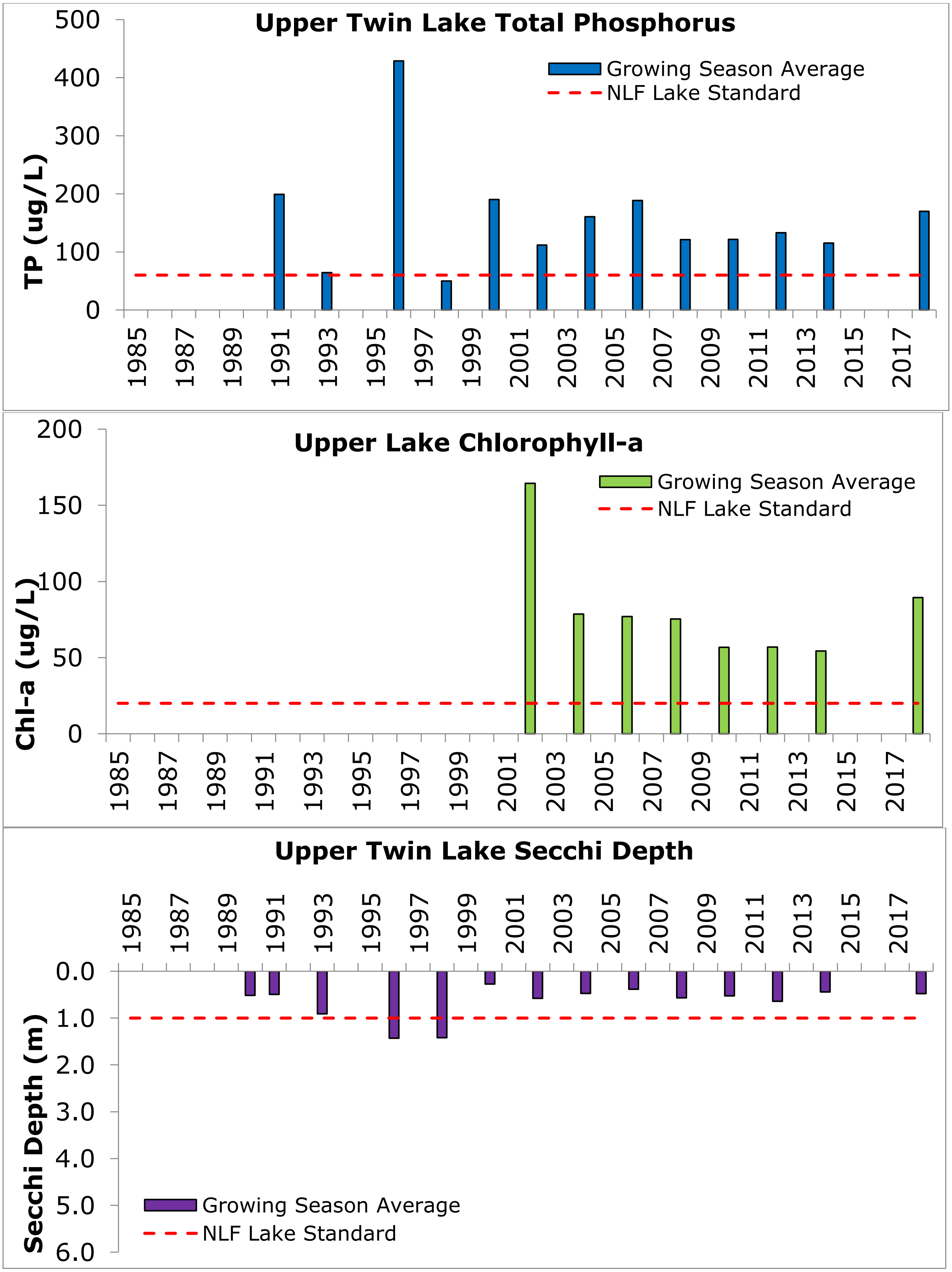

Figure 3.2. Summer average TP, Chla, and Secchi measurements and water quality standards.

3.3 SUBMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted to document the early summer and late summer submerged aquatic vegetation in Upper Twin Lake in 2018. Upper Twin Lake is in the cities of Brooklyn Center and Crystal within Hennepin County, MN. It has an approximate surface area of 116.2 acres, with 116.2 acres of littoral acres (areas less than 15 feet deep), 2.6 miles of shoreline, and a maximum depth of 8 feet.

Eighty-six and seventy-one survey points were assessed on Upper Twin Lake during the 2018 surveys (Table 3.1). Due to dense stands of lily growth, areas of the lake were not accessible in the late season survey. Vegetation coverage was low but remained consistent between May and August surveys (Figure 3.3). The biovolume in the southern and eastern bays and the southern tip of the island chain of Upper Twin Lake is likely due to errors in CiBioBase caused by resuspension of sediment in regions with < 2 ft depth. Overall taxa richness was very low and decreased over the open water season with two species observed during the August survey. The vegetation community lacked both quantity and quality of species and scored below the Central Hardwood Forest Ecoregion FQI shallow lake standard of 17.8 and shallow lake species richness standard of 11 taxa.

Table 3.1. SAV quality and quantity indices.

	5/22/2018	8/14/2018
Total Observations	86	71
Littoral Observations	86	71
Total Vegetated Points	32	26
% of Littoral with Vegetation	37%	37%
Lake Taxa	5	2
Average C-Score	4.2	6
Lake FQI	9.4	8.5

We summarized sampling efforts and community characteristics by 5 foot depth intervals within the littoral zone to observe changes in community composition (Table 3.2). The estimated lake biomass and the species richness decreases throughout the season. Biomass decreased between sampling events with no weighable species present in August. The max depth of vegetation growth became more shallow, from 5.7 feet in May to 4.3 feet in August. The decrease in maximum growth depth, biomass and species richness is likely due to increased turbidity in the water column as the season progresses. In healthy lake conditions, the vegetation community's transition is typically much more gradual.

Although, no single species was dominant (% Lake Occurrence > 50%) in 2018, white waterlily was the most abundant species observed during both the May and August surveys (Table 3.3). CLP was observed in eastern part of the main basin in May (Figure 3.3). By August, the only plants observed were white and yellow waterlilies. The CLP disappeared due to a combination of natural processes and the lake undergoing herbicide application.

Table 3.2. Comparison of community composition with depth.

		5/22/2018				8/14/2018			
Depth	**Lake Acres**	**Total Sample Points**		**Species**	**Est. Lake Biomass (wt; kg)**	**Total Sample Points**		**Species**	**Est. Lake Biomass (wt; kg)**
0-5 ft	83	43	50%	5	9,330	42	59%	2	--
5-10 ft	64	43	50%	1	1,670	29	41%	0	0.00

Table 3.3. Summary of species observations and biomass estimates.

Common Name:	Scientific Name:	5/22/2018 % Lake Occurrence	8/14/2018 % Lake Occurrence
white waterlily	Nymphaea odorata	27	37
coontail	Ceratophyllum demersum	17	--
curly-leaf pondweed	Potamogeton crispus	10	--
Canadian waterweed	Elodea canadensis	2	--
yellow waterlily	Nuphar variegata	2	7

In May, all five species were observed in the shallowest depth range. White waterlily was a dominant species throughout the open water season in the shallowest range (Table 3.4). Although lilies were the predominant vegetation during 2018, coontail and CLP were also present at low abundance in the spring in the shallowest depth range. CLP was the only species which was observed in the depths greater than 5 feet in the lake, although its was rare (<5% occurrence).

Table 3.4. SAV species occurrence by depth.

Common Name:	5/22/2018 % Occurrence by Depth (ft)		8/14/2018 % Occurrence by Depth (ft)	
	0-5	5-10	0-5	5-10
white waterlily	53	0	62	0
coontail	35	0	0	0
curly-leaf pondweed	16	5	0	0
Canadian waterweed	5	0	0	0
yellow waterlily	5	0	12	0

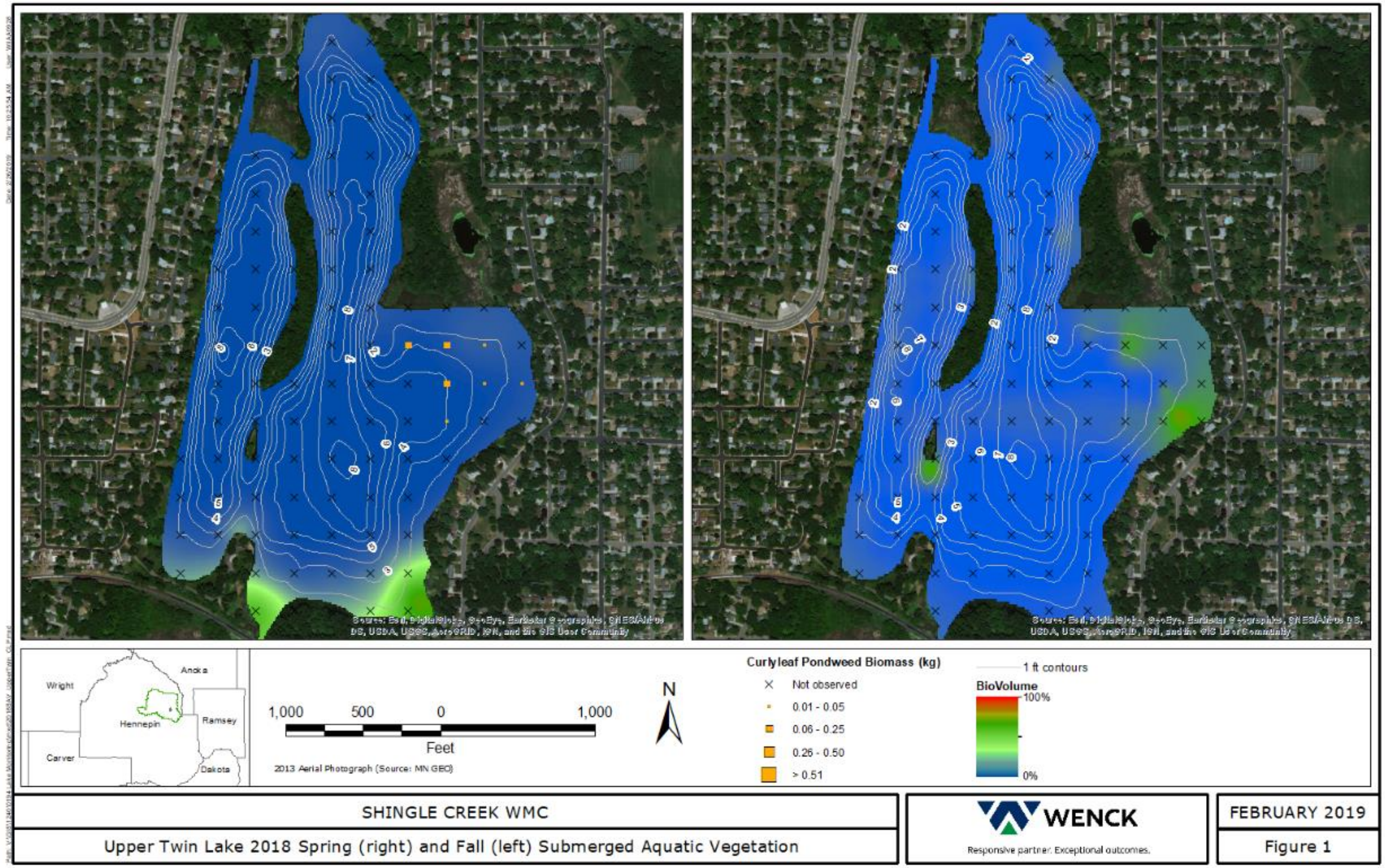

Figure 3.3. 2018 Upper Twin Lake curlyleaf pondweed biomass and total submerged aquatic vegetation biomass.

The overall lack of vegetation, species richness, abundance, and depth of growth across the growing season was concerning for the health of Upper Twin Lake. The late summer SAV community in a healthy shallow lake system is typically more diverse, has greater abundance, and has species that utilize all depths of the lake. A diverse SAV community is important to the lake as it provides other organisms with a diverse array of habitats to forage and find refuge. The limited occurrence of an SAV community and poor water conditions in the lake are a strong indication nutrient loading is a problem within Upper Twin Lake.

The fact that the only species that remained in the lake during the fall survey were lilies is concerning. Lily species are not necessarily an indication of high nutrient concerns, but rather indicate that wave energy is limited. It is the absence of all other species and the sole presence of lilies that conveys concerns about nutrient loading. The high levels of algal turbidity likely outcompeted many SAV species through a shading affect, leaving much of the lake void of any species. Lilies were able to persist into the late season because they were able to reach the water's surface before transparency became severely degraded.

The Twin Lake chain is currently undergoing a carp management project to reduce the negative water quality and habitat degradation caused by an overabundance of the fish. The current densities of common carp are high enough to cause significant water quality impairments and habitat degradation. In addition to facilitating high algal turbidity, the carp observed are likely uprooting and displacing much of the SAV. By observation the lake sediment is very soft and organic based, making SAV displacement easy. Carp removals began in 2018 and are continuing on the lake in 2019 and likely in years to come. With reduced carp in Upper Twin it is possible that the SAV community may rebound.

In response to the carp management project and the anticipated resurgence and response of increased SAV presence within Upper Twin Lake, the Commission developed and is undertaking responsibility of CLP herbicide treatment for 2018, 2019 and 2020. Annual permits are submitted to the MnDNR to conduct lake wide CLP delineation and treatment where needed. Due to harsh winter conditions (i.e. late winter with heavy snow) the amount of CLP typically observed (~30-40 acres) within the lake was reduced and only 9.4 acres of the lake contained CLP. All 9.4 acres were treated in 2018.

The whole lake application has required approval and permission to treat acreages above the normally permitted acreage on the lake. CLP often outcompetes native species due to its unique early season reproduction. Therefore, the intention of treatments is intended to reduce the presence and occurrence of CLP to allow natives species the chance to root and become dominant as carp are removed and water quality improves within the lake. Even with the control of CLP, it is unclear whether a viable seed bank persists within the lake to replenish a native community. The soft sediments and destructive foraging behavior of carp may have destroyed a large portion of the seed bank, leaving lake managers with limited options to restore a native community.

Continued efforts to monitor the SAV will remain important to promote and encourage the restoration efforts needed to create a healthy lake ecosystem. Predicting the exact response of the SAV community to in-lake management practices is difficult; however, we can expect to see an increase in vegetation diversity, abundance and depth of occurrence. The possible sudden and drastic change in the SAV community may create social concerns and recreation impediments, however, individual landowner vegetation management activities are permitted by the MnDNR to control SAV growth. Landowners are encouraged to consider this for continued use and enjoyment of the lake under improved ecosystem health.

3.4 FISHERIES

The MnDNR recently conducted standard trap and gill net surveys along with Fish IBI assessments on the Twin Lakes. Below is reported findings from the MnDNR,

"Twin Lake is a 217-acre, Class 35 lake in Hennepin County. Twin Lake consists of three distinct basins that are connected by navigable channels. Although this survey treats the lake as one waterbody, the three basins are different from one another. The south and middle basins have less algae and vegetation, with maximum depths of 20 and 44 feet, respectively, and provide better habitat conditions for fish species. The north basin, with a maximum depth of 8 feet, is characterized by abundant algae and submerged vegetation during summer months, and hosts a higher abundance of Common Carp and Black Bullhead. Water clarity is lower in the north basin than in the middle and south; Secchi depth was 2.5 feet in both the middle and south basins, and was 1.0 ft in the north basin. Although habitat quality and fish populations are different among the basins, dissolved oxygen was depleted from the water column at 10 feet in all basins during mid-June 2018 sampling. Twin Lake is infested with Eurasian watermilfoil. The primary boat launch is located on the south basin. The lake is primarily managed for Northern Pike; however Walleye, Yellow Perch and Largemouth Bass have been privately stocked since 2014. Shingle Creek Watershed Management Commission is working with Aquatic Biologists at Wenck Associates on an effort to improve water quality in the lake by controlling Common Carp and Black Bullhead populations.

In 2018, Northern Pike were caught at a rate of 4.7 fish per gill net, between the first quartile and median for Lake Class 35. Fish ranged in length from 19.4 inches to 33.9 inches, with an average size of 25.5 inches and 3.75 pounds. Black Bullhead were highly abundant in the 2018 survey. The catch rate of 101.0 fish per gill net greatly exceeds the Class-35 third quartile of 38.0 fish per gill net. Fish ranged between 5.7 and 10.0 inches, and 88% of the sample was between 6.5 and 8.5 inches. Common Carp were caught at a rate of 1.33 per gill net, above the Class-35 median of 0.33 fish per gill net. The trap net catch rate, 0.89 fish per net, also was between the median and third quartile for Class-35 lakes. Most of the Common Carp were sampled in the north basin. The fish were adult-size; gill-netted Common Carp ranged between 17.2 and 20.3 inches, and trap-netted carp ranged between 17.7 and 20.2 inches. Black Crappie abundance was high in 2018, although quality size was lacking. The catch rate of 13.8 fish per gill net exceeds the Class-35 third quartile of 10.5 fish per gill net. Black Crappie ranged in length from 4.1 to 7.3 inches, with an average of 6.2 inches and 0.12 pounds. Yellow Perch were moderately abundant in 2018. The catch rate of 9.8 fish per gill net was just under the Class-35 median of 10.0 fish per net. Fish ranged from 5.1 inches to 7.7 inches, and averaged 6.4 inches and 0.12 pounds. Bluegill were highly abundant in 2018. The catch rate of 62.7 fish per trap net greatly exceeds the Class-35 third quartile of 28.1 fish per trap net. Size structure was poor; only 5% of the sample exceeded 6 inches, and only one fish exceeded 7 inches. Three Walleye were sampled in 2018; one in the gill nets and two in the trap nets. The fish measured 20.7 inches, 14.7 inches, and 19.7 inches. These are very low catches. Four Largemouth Bass were sampled in 2018; however, boat electrofishing was not conducted. Bass caught in the gill nets and trap nets ranged in size from 7.2 to 13.5 inches. It is likely the bass population is self-sustaining, given the size range. Future boat electrofishing could evaluate that population. Perhaps, with continued efforts by Wenck Associates and Shingle Creek Watershed Management Commission, water quality can be improved and rough fish populations reduced. Twin Lake seems to naturally support game fish populations of Northern Pike, Bluegill and Black Crappie.

A targeted survey was conducted on Twin Lake during the week of June 20, 2018 by Area Fisheries staff. Sampling methods targeted nearshore, small-bodied fish and included seining and backpack electrofishing. Ten sampling stations were evenly spaced around the lake and each of the sites was sampled by backpack electrofishing. The stations were located in a variety of habitats, including sites with sandy substrate and little vegetation as well as sites with soft substrates and very dense vegetation. A 50-foot seine was used to sample at 4 stations, and a 15-foot seine was used to sample at 5 stations. Sampling captured 12 fishes, and Bluegill, Green Sunfish, and Largemouth Bass and were most abundant. Other fishes caught were Johnny Darter, Black Crappie, Black Bullhead, Golden Shiner, hybrid sunfish, Pumpkinseed, Yellow Perch, Black Crappie, Northern Pike, and Bowfin (Dogfish). The nearshore data were combined with trap net and gill net data from a June 2018 standard survey to describe the fish community and provide a Fish-based IBI (FIBI) score. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. In Minnesota lakes, certain fish species cannot survive without clean water and a healthy habitat (e.g. Blackchin Shiner, Iowa Darter, and Rock Bass), while other species are tolerant of degraded conditions (e.g. Fathead Minnow and Green Sunfish). The FIBI score, composed of several fish community diversity and composition metrics, indicates the overall health of a lake by comparing it to what is expected for a healthy lake. For additional information on the FIBI, search for "lake index of biological integrity" on the mndnr.gov website. Data from this survey indicates Twin Lake is in poor health as indicated by an FIBI score below the impairment threshold for aquatic life use determined for similar lakes."

3.5 CARP

As part of the Carp Management Project, multiple population assessments were conducted on each of the three lakes (Table 3.5). Population estimates conducted in July (2017 and 2018) were subject to extreme poor water visibility and extreme difficulty sampling in shallow areas due to high density of white water lily. This made capturing carp very difficult and estimates from these dates are suspected by underestimates of the true population means.

Table 3.5. Summary of common carp assessments conduct on the Twin Lake systems.

Lake	Date	n	Shock Time (hour)	Average Weight (kg)	CPUE	Estimated Density (carp/ha)	Biomass mean (kg/ha)	Estimated Population Size
Upper	9/9/2016	41	0.9	1.2	45.6	217.61	261.8	10,233
	9/29/2016	48	0.8	1.3	60.0	285.64	367.5	13,432
	7/27/2017	27	0.88	1.8	30.7	147.55	272.3	6,939
	7/30/2018	20	1	1.73	20.0	97.24	168.2	4,573
Middle	9/9/2016	24	0.7	1.2	34.3	164.53	190.8	3,729
	9/29/2016	23	0.5	1.5	46.0	219.70	337.3	4,979
	7/27/2017	13	0.72	1.5	18.1	88.08	131.3	1,996
	7/30/2018	12	1	2.03	4.0	59.56	120.9	1,350
Lower	9/2/2016	6	0.9	1.0	6.7	34.44	35.6	410
	9/29/2016	5	0.5	1.9	10.0	50.14	95.7	597
	7/27/2017	7	0.6	1.6	11.7	57.99	91.9	690
	7/30/2018	6	0.7	1.47	8.6	43.41	63.8	516

Population assessments removal goals were developed for the chain of lakes from the 2016 and 2017. Modeling efforts predicted about 14,334 ±941 individuals or 20,068 ±1,067 kg of carp in the system with initial modeling suggesting the removal of 49% of the population to achieve the 100 kg/ha critical density threshold (Table 3.6). To account for individual growth of the carp within the system, the biomass doubling scenario was realistic and removal target from this scenario became the targeted goal for removals within the system.

Table 3.6. Initial removal target goals.

Scenario	Targeted Removal #s		
	Individuals	Biomass (kg)	% of population
Current Biomass	7,095	9,946	49%
If, Biomass Doubles	10,715	15,007	75%
If, Biomass Triples	11,921	16,694	83%

Carp tracking revealed a large winter schooling of carp in Middle Twin Lake, and a winter seining effort was conducted on 1/18/2018. Through that effort 4,827 kg of carp and ~6,803 kg of black bullhead were removed from Middle Twin Lake. Issues occurred during the effort that affected capture of carp and we estimate that ~ 65% of the carp escaped the netting effort (an additional 9,000 kg of carp). Therefore, carp removal targets were not achieved, however, the unexpected haul of black bullhead was viewed as a success and a fish population that is also a concern for water quality within the system.

The winter seine effort also observed a 1.8 kg/carp average (1.4 kg/ carp during population estimates) which suggest that carp are larger, and biomass is greater than expected within the system. Overall, the removal effort was successful and a step in the right direction to improve water quality issues resulting from the fish community. However, additional efforts to remove carp are needed to achieve updated removal targets (Table 3.7).

Table 3.7. Additional target removal goal.

Scenario	Targeted Removal #s		
	Individuals	Biomass (kg)	% of Initial Goal (Ind, Biomass)
Current Biomass	4,432	5,118	31%, 25%
If, Biomass Doubles	8,052	10,179	56%, 51%
If, Biomass Triples	9,258	11,866	65%, 59%

The updated removal goal is to remove an additional 22,440 lbs of carp (~8,052 individuals), which would bring the estimated carp density to 50 kg/ha (half of the critical threshold). Cost benefit analysis suggested that another winter seining event in 2019 would likely provide the best removal option for carp in 2019. Assuming we could achieve at minimum a similar removal rate as 2018, we would anticipate removing ~4,500 kg of carp (~45% of removal goal). This would put the Twin Lakes near the 100kg/ha threshold and halfway to the target goal. There is the possibility that removals are more efficient and have an added value of bullhead removal as well. However, attempted winter removals were completed in 2019 and contracted commercial fisherman was unable to conduct a successful carp removal from the lake. Continued efforts to remove carp will occur in spring of 2019. Ryan Creek spring seining is the next cost-effective removal option. We estimate that another 1,500- 2,000 kg of carp.

4.0 Middle Twin Lake

4.1 SAMPLING OVERVIEW

Below is a summary reporting from the most recent survey efforts for each area of the monitoring program. Middle Twin Lake most recent sampling efforts were completed:

- Water Quality - 2018
- SAV – 2018
- Fisheries – 2018 by MnDNR; see Section 3.4
- Carp – 2018; see Section 3.5

4.2 WATER QUALITY

The total phosphorus (TP) and chlorophyll-a (Chla) concentrations in Middle Twin Lake exceeded the 2018 deep lake standards (Figure 4.1). However, Middle Twin Lake is meeting the standard for Secchi depth. The TP concentration is very close to meeting the standard as it has been since the large reductions achieved between 2009-2010. The Chla is still exceeding standards and has been for the past decade. The total phosphorus is above the standard in the early spring and late fall and below the standard in July through mid-September. The peak TP concentration occurs in mid-October. In deep lakes like Middle Twin, this could be caused from TP release from the hypolimnion during the destratification of the water column as the air temperature decreases. The Chla follows a similar trend as the TP, however the Chla is consistently exceeding the deep lake standard during 2018. The Secchi depth decreases as the season progresses and exceeds or is near the standard after mid-June.

Review of historic data for state standard water quality metrics dated as far back as 1985 on Upper Twin Lake (Figure 4.2). Review of historic water quality has TP and Chla concentrations along with Secchi disk annual averages have demonstrated significant changes over the monitoring records with the majority of sampling records not meeting state standards.

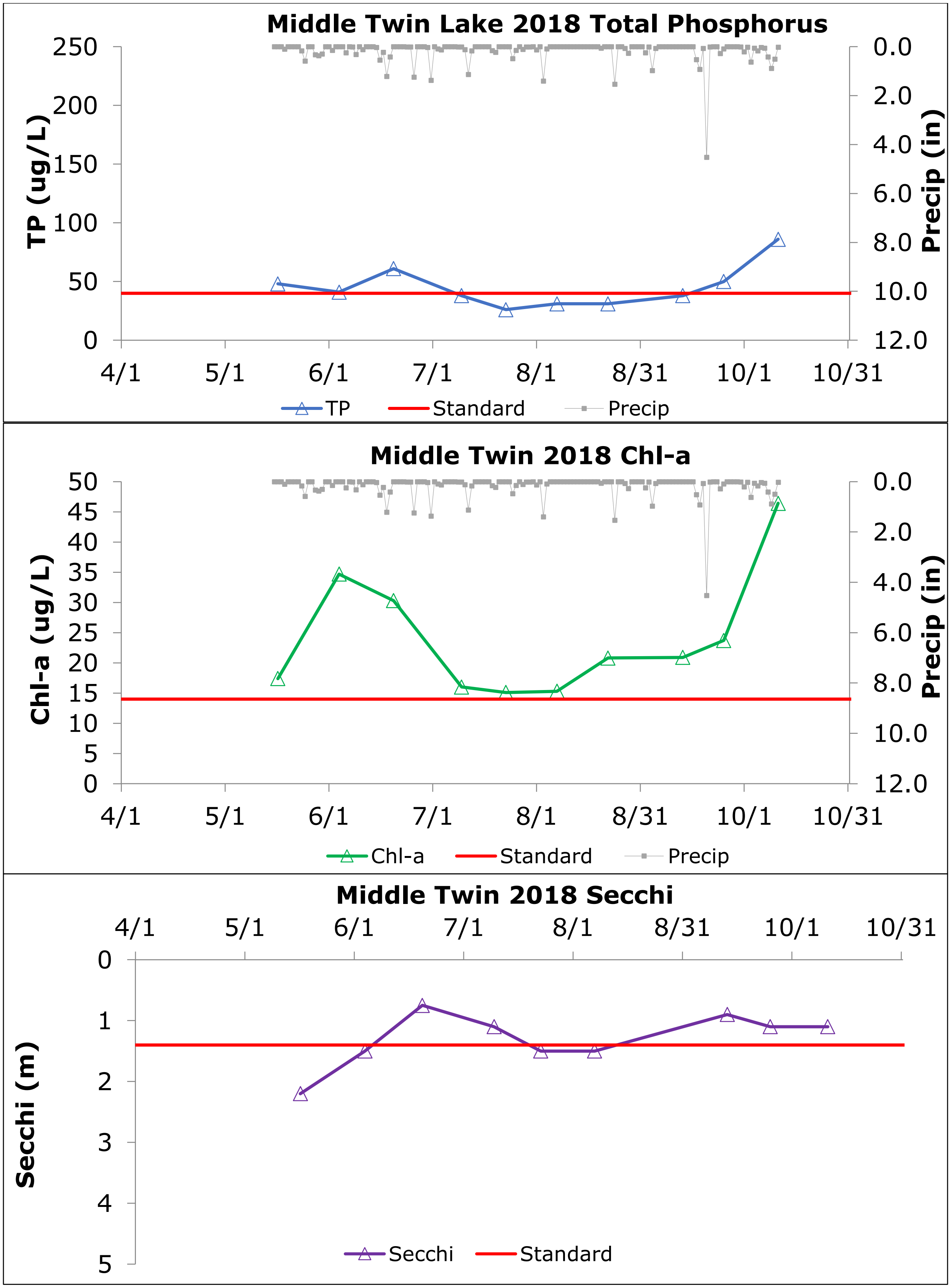

Figure 4.1. 2018 TP, Chla, and Secchi measurements and water quality standards.

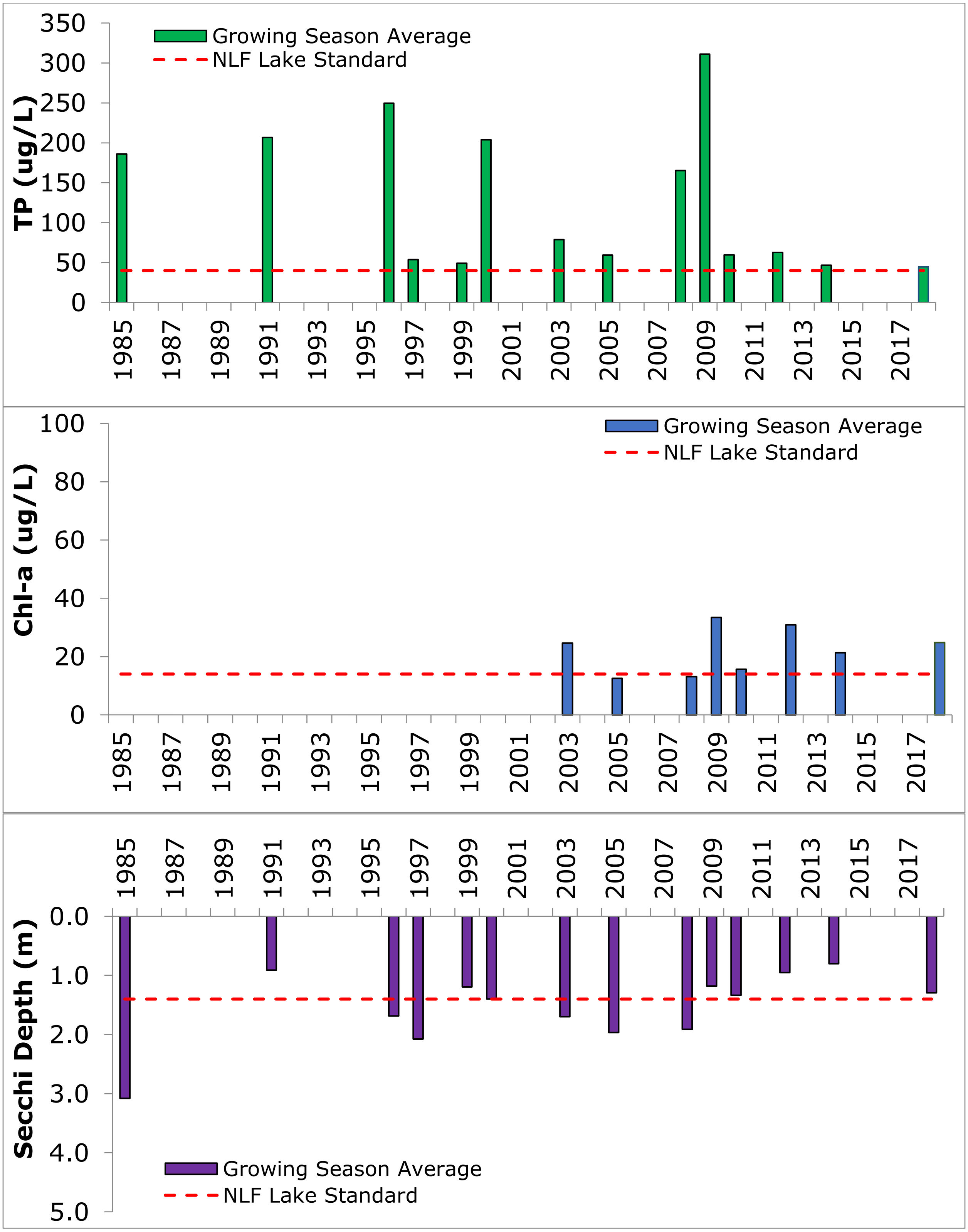

Figure 4.2. Summer average TP, Chla, and Secchi measurements and water quality standards.

4.3 SUBMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted by Wenck Associates to document the early summer and late summer submerged aquatic vegetation in Middle Twin Lake in 2018. Middle Twin Lake is located in the city of Robbinsdale within Hennepin County, MN. Upper Twin Lake has an approximate surface area of 56 acres, with 28 acres of littoral acres (areas less than 15 feet deep), 1.54 miles of shoreline, and a maximum depth of 44 feet.

A total of 52 and 53 survey points were assessed on Middle Twin Lake in June and August of 2018, respectively (Table 4.1). Vegetation coverage decreased from June to August. Although the lake taxa increased slightly from spring to fall, the quality of observed species (average C-Score; Table 4.1) decreased from spring to fall. Overall, the vegetation community lacked both quantity and quality of species and consistently scored below the Central Hardwood Forest Ecoregion FQI shallow lake standard of 18.6 and deep lake species richness standard of 12 taxa.

Table 4.1. SAV quality and quantity indices.

	6/1/2018	8/14/2018
Total Observations	52	53
Littoral Observations	50	52
Total Vegetated points	41	33
% of Littoral with Vegetation	82	63
Lake Taxa	7	9
Average C-Score	4.9	4
Lake FQI	4.9	13.0

The total SAV biovolume was distributed in the northern and the southwest portions of the lake. The biovolume was concentrated on the same regions throughout the season but was significantly higher in May (Figure 4.3). We summarized sampling efforts by 5ft depth intervals within the littoral zone to observe changes in community composition (Table 4.2). The greatest sampling effort occurred within the 0-5 feet depth intervals. The estimated lake biomass decreased from spring to fall at all depth intervals. In the fall there were no longer any SAV observed at 10-15 feet. Species were identified in the 10-15 feet in May and disappeared in August. Overall, we observed a decrease in plant abundance and species richness as depth increased in both surveys. Decreases in SAV with depth is due to light attenuation within the water column leading to light limitation. The decrease in both estimated biomass and species observation was more pronounced in comparing the August to May surveys. Review of the max depth of vegetation growth was 13.4 feet in May and 8.3 feet. Decreased plant abundance, species diversity, and max depth of vegetation growth at deeper depth intervals later in the growing season can be an indicator of decreasing water quality which exaggerates light limitation within the lake due to increases in algal turbidity.

Table 4.2. Comparison of community composition with depth.

	6/1/2018				8/14/2018			
Depth	Total Sample Points		Species	Est. Lake Biomass (wt; kg)	Total Sample Points		Species	Est. Lake Biomass (wt; kg)
0-5 ft	29	55.8%	7	29,755	32	60%	9	16,847
5-10 ft	13	25.0%	4	2,820	12	23%	3	2,293
10- 15 ft	8	15.4%	4	2,934	8	15%	0	--

Coontail was dominant (occurrence ≥50%) throughout the entire open season (Table 4.3). There were two AIS observed during the 2018 survey, curly leaf pondweed (CLP); (Figure 4.3) Eurasian watermilfoil (EWM); (Figure 4.4). CLP was abundant in May became rare (<5% occurrence) in August. As CLP subside in the August survey, we begin to observe several different pondweed species, Sago, flat-stemmed, and leafy pondweeds. EWM was observed in both sampling efforts and is a species that should be watched so that it does not become a dominant species within the lake.

Table 4.3. Summary of species observations and biomass estimates.

		6/1/2018	8/14/2018
Common Name	**Scientific Name**	**% Lake Occurrence**	**% Lake Occurrence**
coontail	*Ceratophyllum demersum*	67	57
white waterlily	*Nymphaea odorata*	38	26
curly-leaf pondweed	*Potamogeton crispus*	40	2
Eurasian water milfoil	*Myriophyllum spicatum*	19	25
Narrowleaf pondweed	*Potamogeton sp.*	4	--
duckweed	*Lemna minor*	2	--
yellow waterlily	*Nuphar variegata*	2	2
sago pondweed	*Stuckenia pectinata*	--	11
flat-stemmed pondweed	*Potamogeton zosteriformis*	--	8
Canadian waterweed	*Elodea canadensis*	--	4
leafy pondweed	*Potamogeton foliosus*	--	2

Many of the shallowest areas on Middle Twin were dominated by undesirable species (coontail, EWM, CLP) (Table 4.4). Species occurrence and diversity quickly decreased as depth increased with no specimens observed in the 10-15 depths during the August survey.

Table 4.4. SAV species occurrence by depth.

	6/1/2018			8/14/2018		
Common Name	**% Occurrence by Depth (ft)**			**% Occurrence by Depth (ft)**		
	0-5	**5-10**	**10-15**	**0-5**	**5-10**	**10-15**
coontail	86	54	38	81	33	0
white waterlily	69	0	0	41	8	0
curly-leaf pondweed	55	31	13	3	0	0
Eurasian water milfoil	24	8	25	38	8	0
Narrowleaf pondweed	3	8	0	0	0	0
duckweed	3	0	0	0	0	0
yellow waterlily	3	0	0	3	0	0
sago pondweed	0	0	0	19	0	0
flat-stemmed pondweed	0	0	0	13	0	0
Canadian waterweed	0	0	0	6	0	0
leafy pondweed	0	0	0	3	0	0

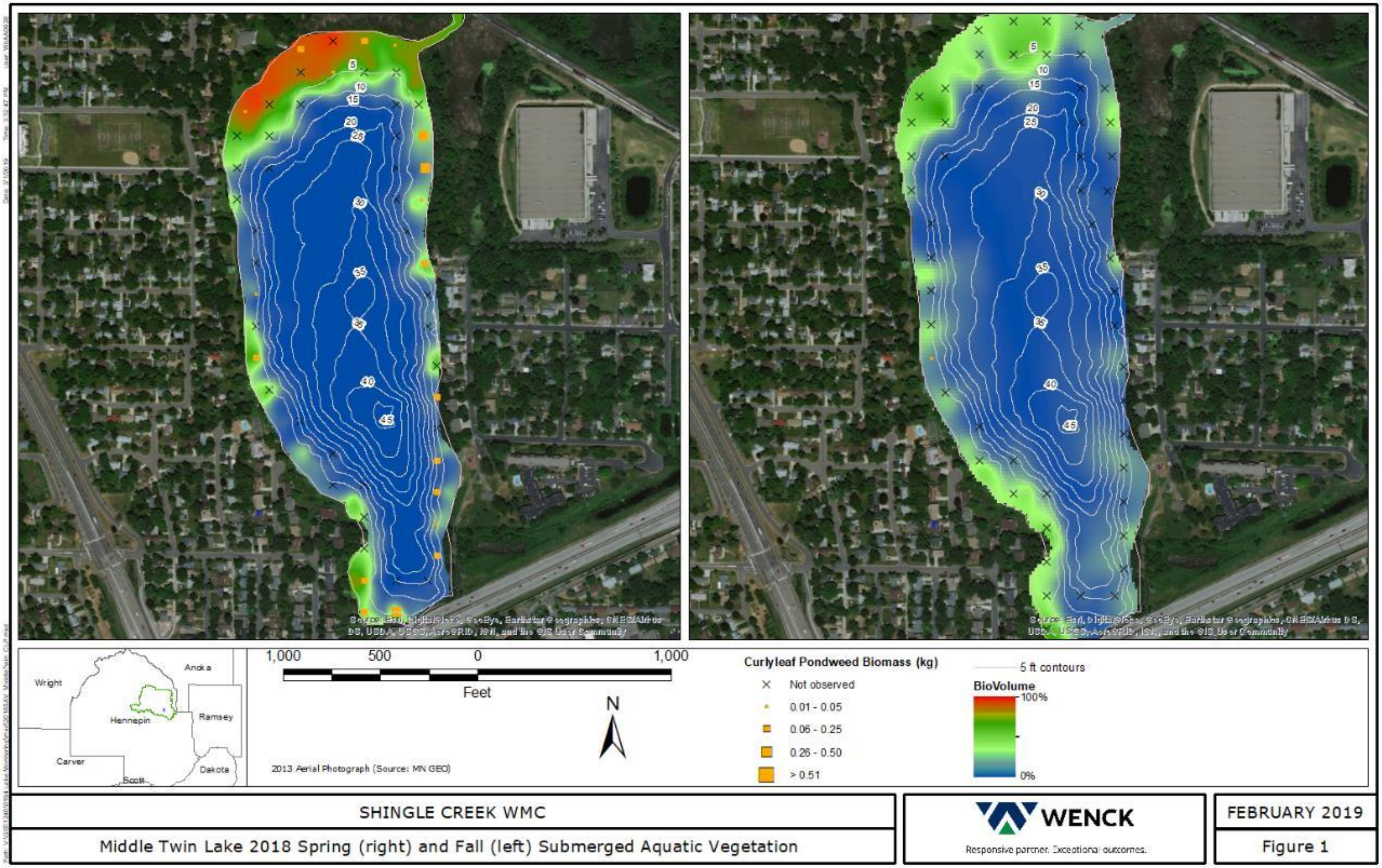

Figure 4.3. 2018 Middle Twin Lake curly leaf pondweed biomass and total submerged aquatic vegetation biovolume.

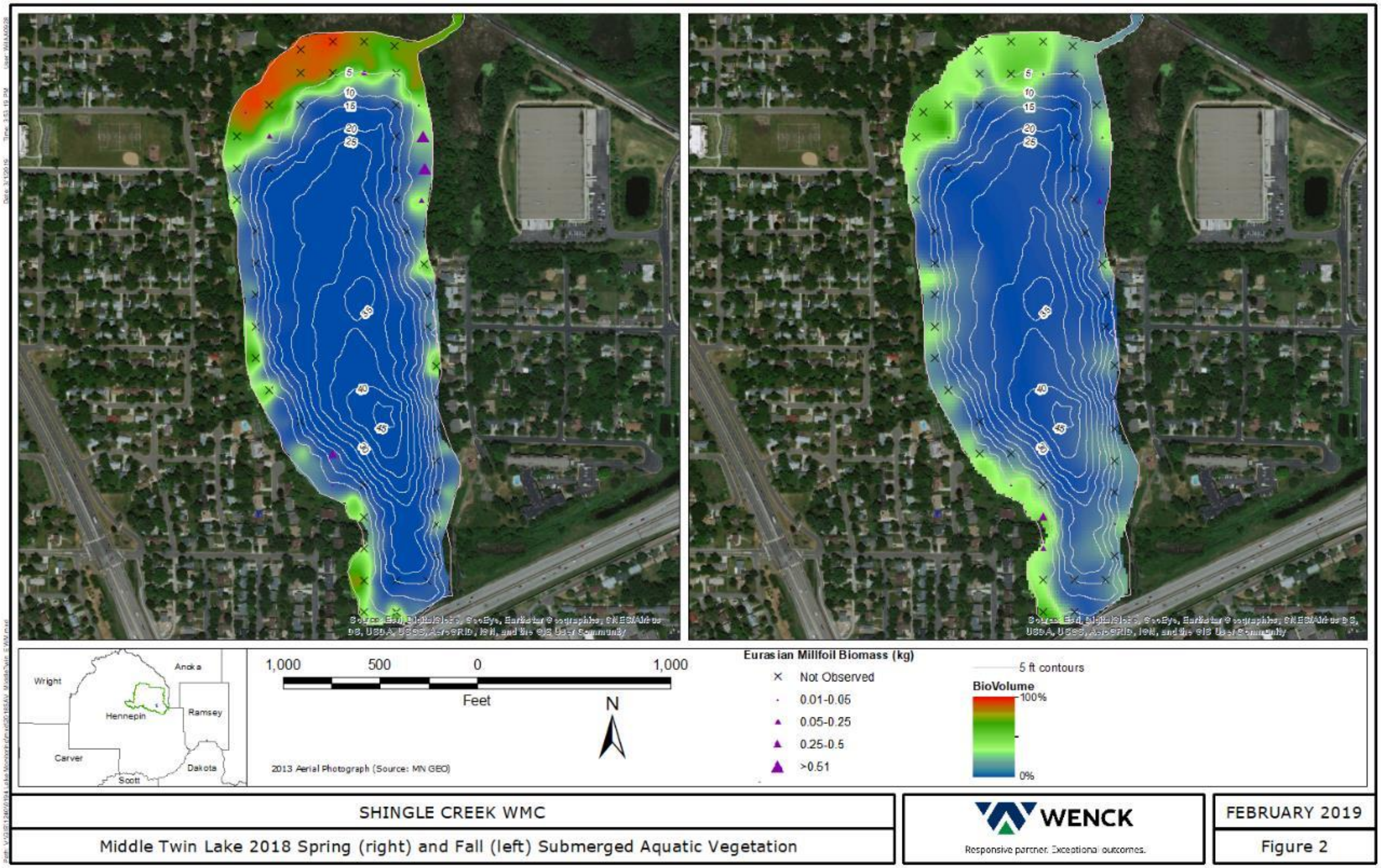

Figure 4.4. 2018 Middle Twin Lake Eurasian watermilfoil biomass and total submerged aquatic vegetation biovolume.

Overall the SAV community in Middle Twin is an impacted system with a need to improve. The presence of both CLP and EWM are a concern for water quality and lake health could require management actions if they become more prominent within the basin. The low FQI is also a concern for lake ecosystem health as it is a sign of inadequate species quality and quantity. A good sign was the late season occurrence of native pondweed species that were not observed in the early season survey, however, their occurrence was limited.

EWM was sparsely observed across the shoreline habitat of Middle Twin Lake. EMW is a concern for lakes because it is an aggressive AIS. EWM can form dense mats at the water's surface that inhibit water recreation. There is also a risk that EWM growth that is unchecked will overtake habitat and outcompete native aquatic plants, potentially lowering diversity. Since EWM are perennial with senescence in the fall, dense communities of EWM provide unsuitable shelter, food, and nesting habitat for native animals. Land owners are permitted through the DNR to remove and/or chemically treat areas of the shoreline for all aquatic vegetation to allow recreational opportunity. However, care and caution to removing desirable and ecologically beneficial plants is warranted to prevent the further spread and introduction of less desirable or invasive species to these areas.

4.4 FISHERIES

See section 3.4.

4.5 CARP

See section 3.5.

5.0 Lower Twin Lake

5.1 SAMPLING OVERVIEW

Below is a summary reporting from the most recent survey efforts for each area of the monitoring program. Lower Twin Lake most recent sampling efforts were completed:

- Water Quality - 2018
- SAV – 2018
- Fisheries – 2018 by MnDNR
- Carp – 2018

5.2 WATER QUALITY

All three water quality parameters (TP, Chla and Secchi depth) are meeting the shallow lake standard for 2018 (Figure 5.1), as they have been for the past decade (Figure 5.2). The TP concentration and Secchi depth has improved in 2018 as compared to recent years. The TP concentration is higher during the early spring and has a high peak (exceeding the shallow lake standard) in mid-October. This could be caused from TP release from the hypolimnion during the destratification of the water column as the air temperature decreases. The Chla twice with the absolute maximum peak in mid-June and a secondary peak in mid-September/ October. The Secchi depth mimics the double peaks observed in Chla, likely as a response to increased algal turbidity during peak Chla concentrations.

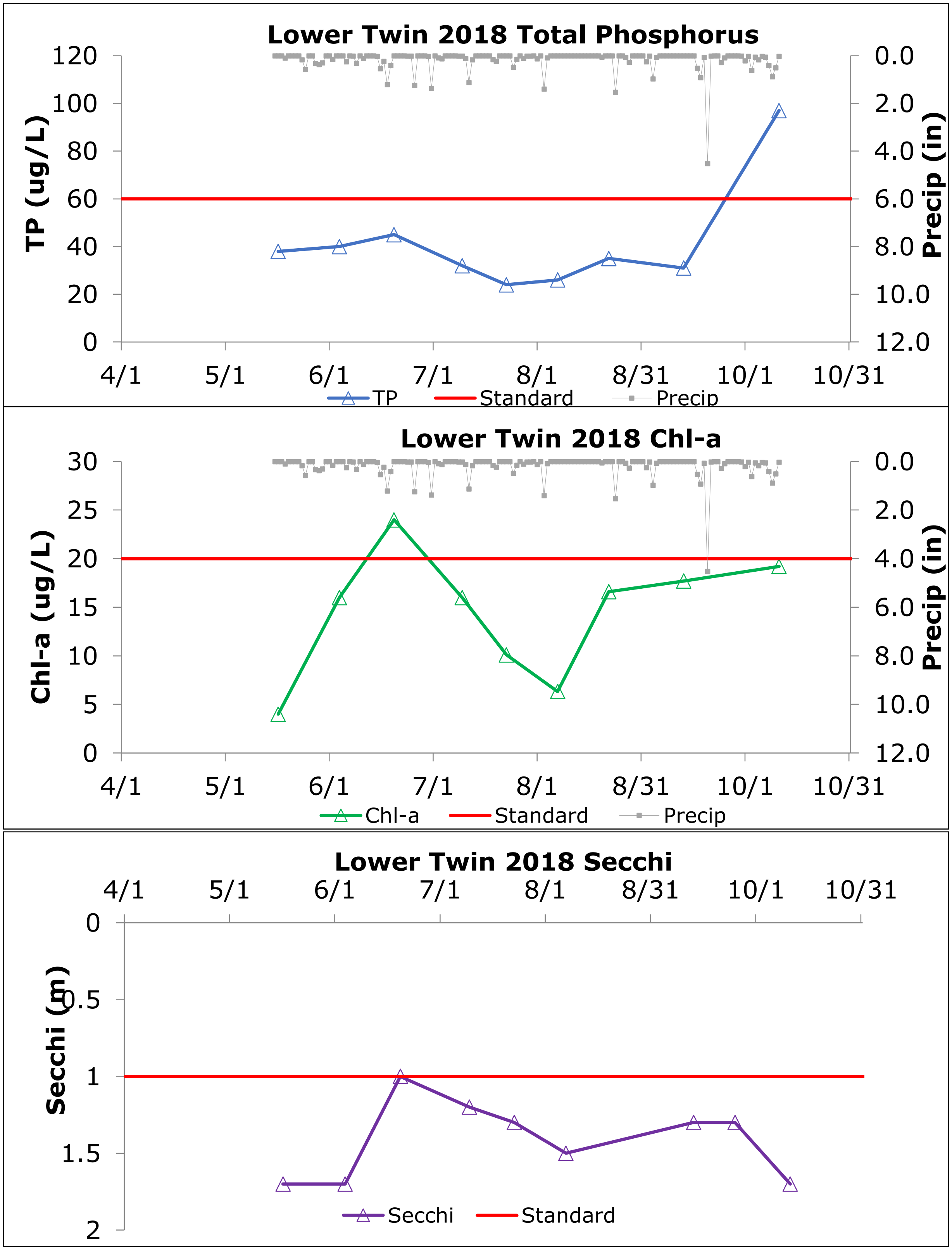

Figure 5.1. 2018 TP, chla, and Secchi measurements and water quality standards.

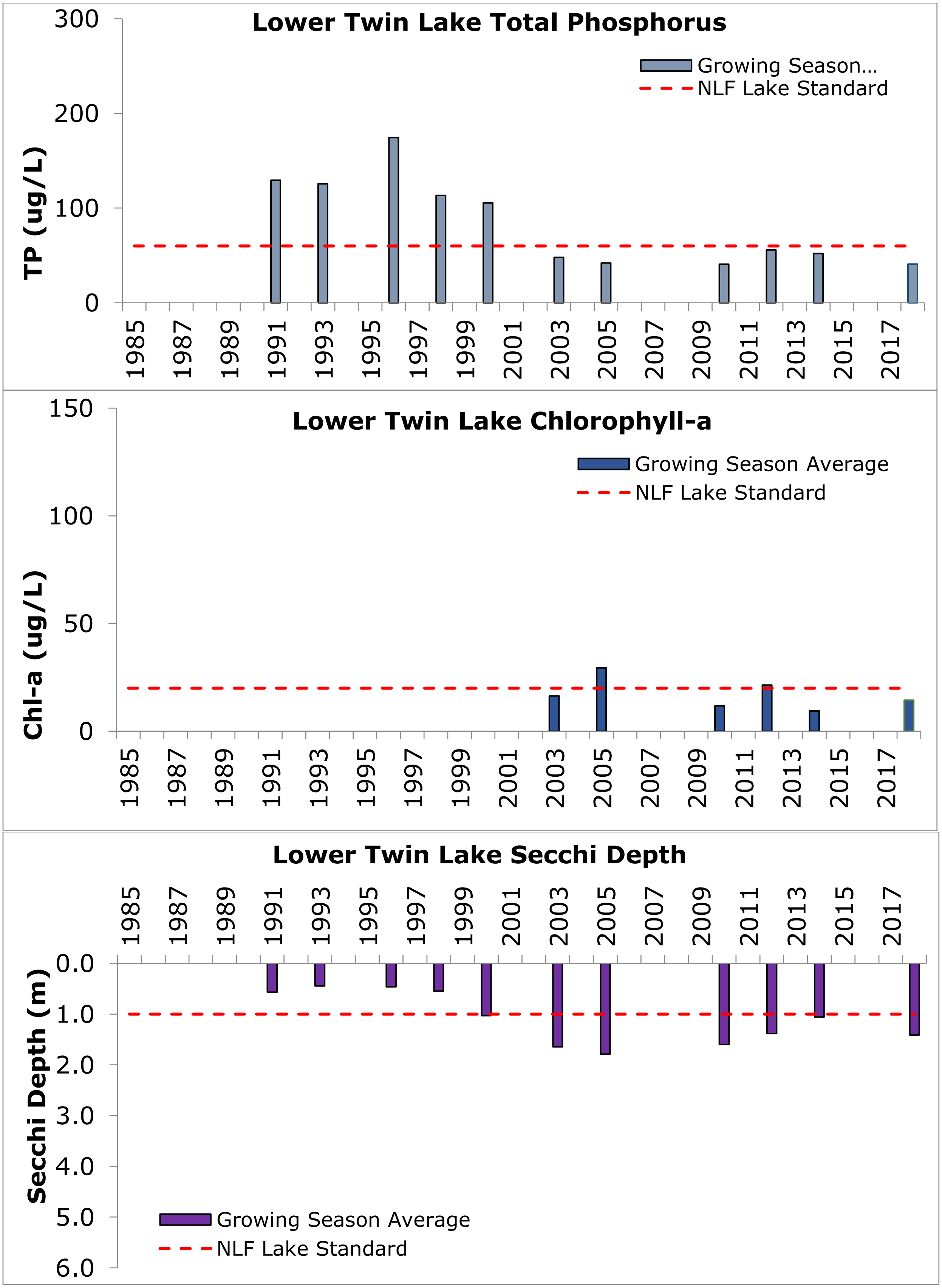

Figure 5.2. Summer average TP, chla, and Secchi measurements and water quality standards.

5.3 SUBMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted to document the early summer and late summer submerged aquatic vegetation in Lower Twin Lake in 2018. Lower Twin has an approximate surface area of 33 acres, with 23 acres of littoral acres (areas less than 15 feet deep), 1.26 miles of shoreline, and a maximum depth of 20 feet.

Thirty-eight survey points were assessed on Lower Twin Lake in 2018 surveys (Table 5.1). Vegetation coverage increased between May and August surveys. Although only three species were observed during the 2018 surveys. Overall, the vegetation community had high coverage but lacked quality of species and scored below the Central Hardwood Forest Ecoregion FQI shallow lake standard of 17.8 and shallow lake species richness standard of 11 taxa.

Table 5.1. SAV quality and quantity indices.

	6/1/2018	8/14/2018
Total Observations	38	38
Littoral Observations	36	36
Total Vegetated Points	24	26
% of Littoral with Vegetation	67	72
Lake Taxa	3	3
Average C-Score	4.0	5
Lake FQI	6.9	8.7

We summarized sampling efforts by 5 ft depth intervals within the littoral zone to observe shifts and changes in community composition (Table 5.2). The biomass and biovolume was highest in the shallowest regions of lake, especially in the eastern bay (Figures 5.3). The biomass remains consistent in the shallow interval from spring to fall and decreases at the 5-10 feet from spring to fall. The lake was limited in species diversity across the lake with only three species being observed in each survey. There was a sudden void of vegetation after the 10 foot depth interval. The maximum depth of plant growth was 6.4 feet in both May and August. Overall, the lake both diversity of species and spatial coverage of SAV in areas and at depths in which SAV could be expected to grow under healthy lake conditions.

Table 5.2. Comparison of community composition with depth.

		6/1/2018				8/14/2018			
Depth	Lake Acres	Total Sample Points		Species	Est. Lake Biomass (wt; kg)	Total Sample Points		Species	Est. Lake Biomass (wt; kg)
0-5 ft	14	20	52.6%	3	40,817	23	61%	2	40,817
5-10 ft	6	14	36.8%	3	3,189	11	29%	3	905
10-15 ft	3	2	5.3%	0	0.00	2	5%	0	0
>15ft	9	2	5.3%	0	0.00	2	5%	0	0

Community composition was limited to a total of four species within the basin. White waterlily and coontail were both dominant (≥50% occurrence) in both surveys (Table 5.3). Curly leaf pondweed was present and sparse within the lake (Figure 1). Flat-stemmed pondweed was not observed in the early season survey, however, did have a rare presence (<5% occurrence) within the basin in August. The amount of flat-stemmed pondweed within the lake was minimal and likely provided little to no ecological benefit.

Table 5.3. Summary of species observations and biomass estimates.

Common Name	Scientific Name	6/1/2018 % Lake Occurrence	8/14/2018 % Lake Occurrence
white waterlily	*Nymphaea odorata*	53	50
coontail	*Ceratophyllum demersum*	50	58
curly leaf pondweed	*Potamogeton crispus*	21	--
flat-stemmed pondweed	*Potamogeton zosteriformis*	--	3

White waterlily and coontail were dominant and most abundant in the shallowest depth interval (Table 5.4). Both species were observed in depth from 5-6.4 feet with no occurrence beyond. Flat stem pondweed only occurred once in the 5-10 foot interval. Overall, the limited occurrence of species and spatial coverage of vegetation within the lake limit depth related inferences.

Table 5.4. SAV species occurrence by depth.

Common Name	6/1/2018 % Occurrence by Depth (ft)			8/14/2018 % Occurrence by Depth (ft)		
	0-5	5-10	10-15	0-5	5-10	10-15
white waterlily	75	36	0	78	9	0
coontail	74	36	0	78	36	0
curly leaf pondweed	25	21	0	0	0	0
flat-stemmed pondweed	0	0	0	0	9	0

The limited species diversity, abundance, and depth of maximum plant growth reveal a degraded SAV community and overall lake health. The lack of species diversity and SAV occurrences across all depth intervals limits the amount of food and shelter provided to biota and the lakes ability to process nutrients. Typically, lakes with poor FQI scores and low species diversity are being impacted by high nutrient loading. However, Lower Twin Lake was recently delisted based on improved water quality, so that may not be the factor limiting the rebound of the SAV community in the lake. Efforts to improve the SAV community are needed to improve the health of the lake ecosystem.

The lake is currently dominated by coontail and white waterlily which can be an indication of high nutrient loading occurring in lake systems. Lilies characteristically grow where there is relatively limited wave energy (i.e. the east bay of Lower Twin), however, lilies themselves do not indicate water quality issues. Floating leaf plants are able to escape highly turbid waters and the resulting low light conditions by breaching the water surface and collecting ambient light directly. Coontail is a native, non-rooted vascular plant that also tends to do very well in poor water quality conditions. It has the ability to grow very large and dense mats, saturating much of the water column and outcompeting other species for available light. Monodominant and dense coontail growth has been associated with high sediment nutrient conditions, which are believed to facilitate the accelerated growth of the species. Therefore, a legacy impact of historic poor water conditions could be limiting the resurgence of species within the lake.

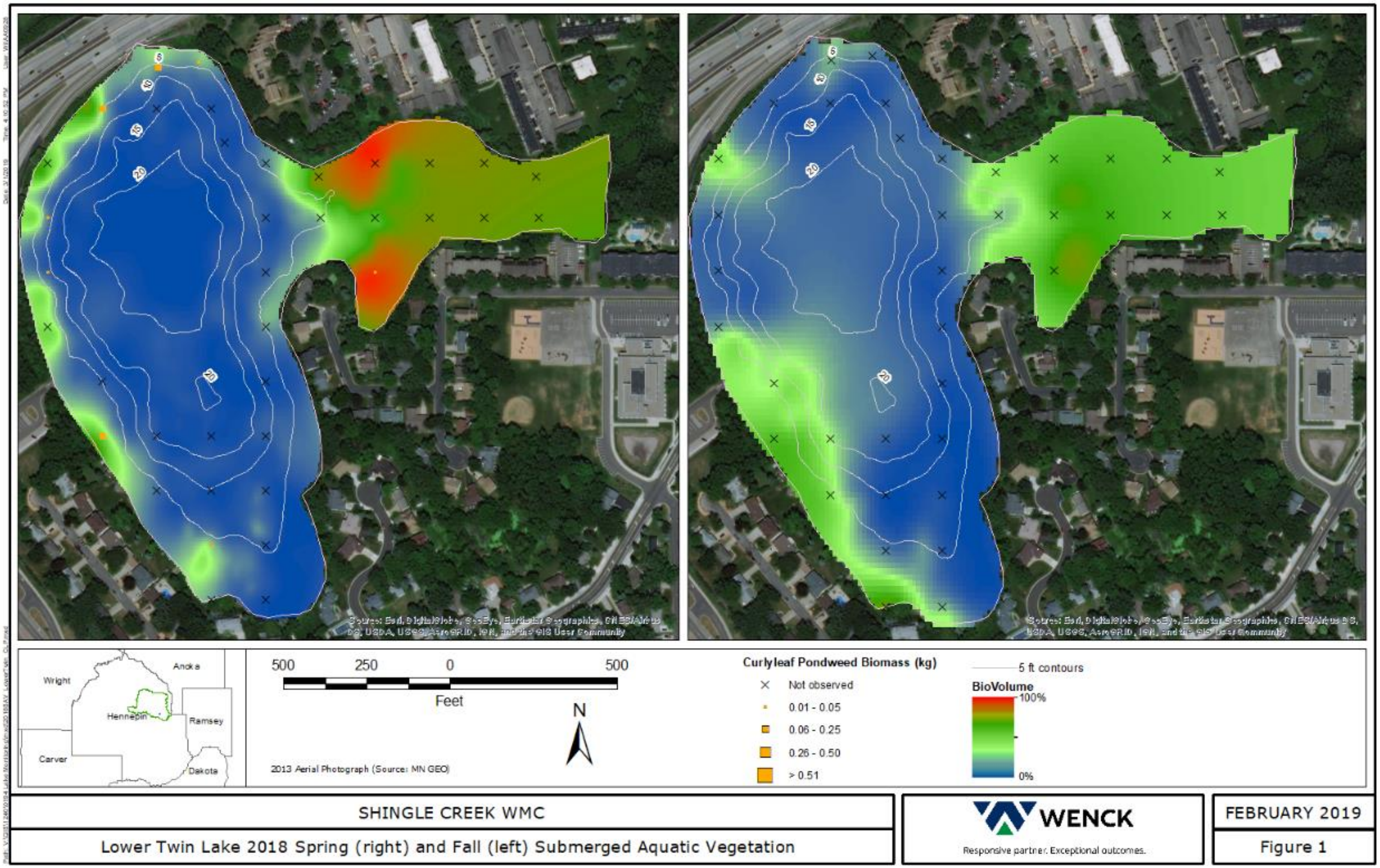

Figure 5.1. 2018 Lower Twin Curly Leaf Pondweed biomass and total submerged aquatic vegetation biovolume.

The Twin Lake chain of lakes is also currently undergoing a carp management project that is focused on reducing the negative water quality and habitat degradation caused by an overabundance of the fish. Carp removals began in 2018 and are continuing of the lake in 2019 and likely in years to come. With reduced carp in Lower Twin it is possible that the SAV community may rebound which would indicate that carp were most likely having a direct impact of Lower Twin vegetation though uprooting and displacing species.

Continued efforts to monitor the SAV by the Commission or Lake Association will remain important to promote and encourage the restoration efforts needed to create a healthy lake ecosystem. The ability to predict the exact response of the SAV community to in-lake management practices does not exist; however, we can expect to see an increase in vegetation diversity, abundance and depth of occurrence. The possible sudden and drastic change in the SAV community may create social concerns and recreation impediments, however, individual vegetation management activities are permitted by the DNR to control SAV growth. Landowners are encouraged to consider this for continued use and enjoyment of the lake under improved ecosystem health.

5.4 FISHERIES

See section 3.4.

5.5 CARP

See section 3.5.

6.0 Ryan Lake

6.1 SAMPLING OVERVIEW

Below is a summary reporting from the most recent survey efforts for each area of the monitoring program. Ryan Lake most recent sampling efforts were completed:

- Water Quality - 2018
- SAV – 2018
- Fisheries – MnDNR planned for 2018 (but did not assess)
- Carp – Not assessed

6.2 WATER QUALITY

Total phosphorus, chlorophyll-a, and Secchi depth were monitored in Ryan Lake in 2018 (Figure 6.1). The total phosphorus and chlorophyll-a concentrations varied throughout the summer, peaking in August at about 75 ug/L and 32 ug/L, respectively. Both parameters exceeded the water quality standard frequently throughout the growing season. On average, the total phosphorus concentration was 42 ug/L, which just exceeds the standard of 40 ug/L and is comparable to historic annual averages in Ryan Lake. The 2018 average chlorophyll-a concentration was 13 ug/L, which is just under the water quality standard of 14 ug/L and is slightly higher than historic annual averages in Ryan Lake. The Secchi depth in Ryan Lake was high in the early summer, with 2 m being the shortest depth (in July and August). The water quality standard of 1.4 m for Secchi depth in Ryan Lake was met throughout the summer, which is indicative of good water clarity. On average, the Secchi depth standard was met, with an average of 2.8 m compared to the standard of 1.4 m. This is comparable to, but better than historic annual averages in Ryan Lake (Figure 6.2).

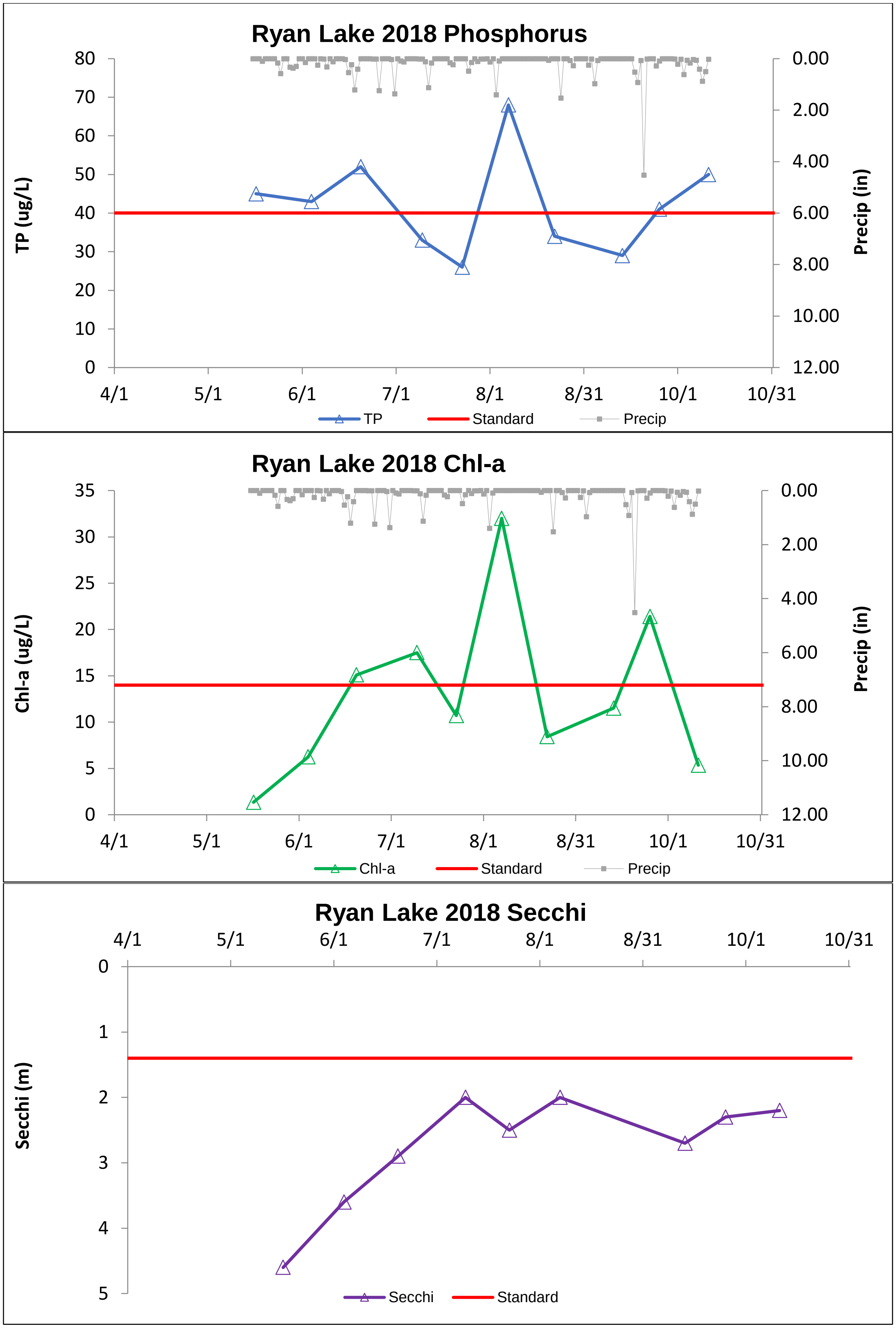

Figure 6.1 2018 TP, chla, and Secchi measurements and water quality standards.

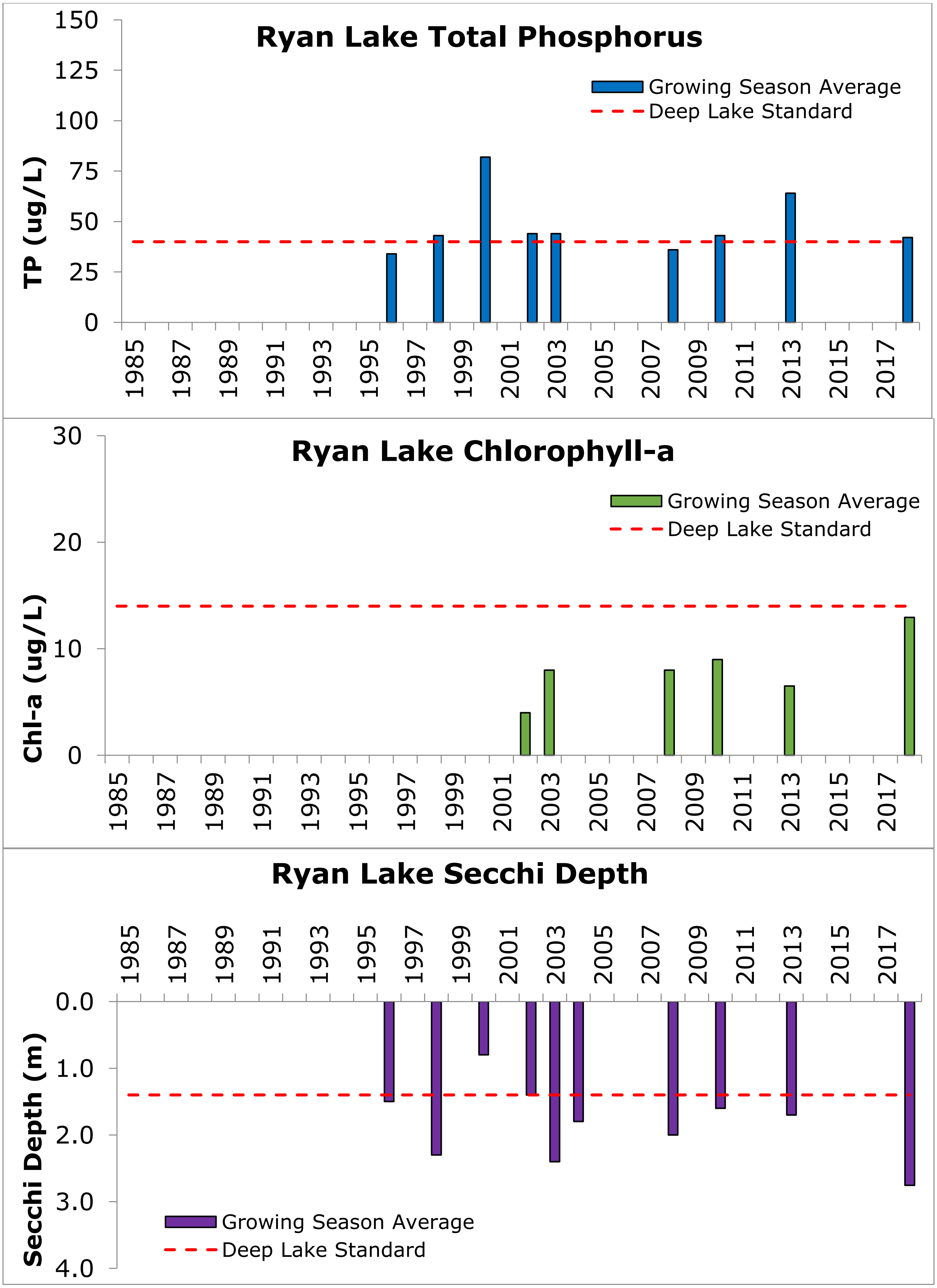

Figure 6.2. Summer average TP, chla, and Secchi measurements and water quality standards.

6.3 SUBMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted to document the late spring and late summer submerged aquatic vegetation in Ryan Lake in 2018. Ryan Lake has an approximate surface area of 26 acres, with 18 acres of littoral acres (areas less than 15 feet deep), 0.93 miles of shoreline, and a maximum depth of 36 feet.

A total of 33 survey points were assessed on Ryan Lake in each of the 2018 surveys (Table 6.1). Vegetation coverage increased between May and August surveys with littoral plant coverage increasing from 89% of locations to 96%. Taxa richness remained constant over the open water season with six species observed during each survey. The quality of observed species (average C-Score; Table 6.1) displayed a slight increase in the August assessment. Overall, the vegetation community lacked both quantity and quality of species and scored below the Central Hardwood Forest Ecoregion FQI deep lake standard of 18.6 and deep lake species richness standard of 12 taxa.

Table 6.1. SAV quality and quantity indices.

	5/23/2018	8/7/2018
Total Observations	33	33
Littoral Observations	27	26
Total Vegetated points	24	28
% of Littoral with Vegetation	89	96
Lake Taxa*	6	6
Average C-Score	4.2	4.3
FQI*	10.3	10.6

*The lake taxa standard and floristic quality index (FQI) standards for Ryan Lake are 12 taxa and an FQI of 18.6

Sampling efforts were summarized by 5 foot depth intervals within the littoral zone to observe shifts and changes in community composition (Table 6.2). The majority of the lake is occupied by the littoral zone, with only eight of the 26 total acres deeper than 15 feet. The majority of the observed biomass was within the 0-5 ft depth range, and total biomass significantly increased throughout the summer. Overall, a decrease in plant abundance and species richness was observed as depth increased in both surveys. This is a natural trend due to light limitation; in pristine lake conditions the transition is typically much more gradual and extends beyond the littoral depth range. This trend was more pronounced in comparing the August to May surveys. Decreased plant abundance and species diversity later in the growing season can be an indicator of decreasing water quality and greater light limitation within the lake. Review of the max depth of vegetation growth was 7.8 feet in May and 29.2 feet in August, however, the August max growth depth appeared to be an outlier as the next observed plant was at 16.0 feet. It is likely that the sharp bathymetry in the lake resulted in a recording of a depth (29.2 feet) and not representative of the rake toss location.

Table 6.2. Biomass summarized by lake depth.

		5/23/2018				8/7/2018			
Depth	Lake Acres	Total Sample Points		Species	Est. Lake Biomass (wt; kg)	Total Sample Points		Species	Est. Lake Biomass (wt; kg)
0-5 ft	14	21	63.6%	6	39,890	20	61%	6	105,884
5-10 ft	2	5	15.2%	3	5,908	6	18%	4	21,377
10-15 ft	2	1	3.0%	0	0	0	0%	0	0
>15ft	8	6	18.2%	0	0	7	21%	1	231

Coontail was the dominant species (occurrence >50%) in Ryan Lake during the May survey. Other abundant species were Canadian waterweed and flat-stemmed pondweed. Waterlilies, curly-leaf pondweed (CLP), and duckweed were rarely observed, with occurrences at less than 8% of the survey locations.

In August, coontail continued to be a dominant species present throughout 85% of the lake. Duckweed, sago pondweed, and white waterlilies were also abundant in Ryan Lake. The presence of Canadian waterweed significantly decreased throughout the growing season and was rarely observed in August.

Species that were present in May but not in August included curly-leaf pondweed and flat-stemmed pondweed. Sago pondweed and yellow waterlilies were present only in August. Flat-stemmed pondweed and sago pondweed were abundant when observed, while CLP and yellow waterlilies were observed to be rare (<5% occurrence) across the lake. Curly-leaf pondweed is known to senesce by late summer, therefore, the absence of this species is expected between surveys. CLP was the only aquatic invasive species (AIS) observed in Ryan Lake (Figure 6.3).

Table 6.3. Summary of species observations and biomass estimates.

		5/23/2018	**8/7/2018**
Common Name	**Scientific Name:**	**% Lake Occurrence**	**% Lake Occurrence**
coontail	*Ceratophyllum demersum*	72	85
Canadian waterweed	*Elodea canadensis*	41	9
flat-stemmed pondweed	*Potamogeton zosteriformis*	24	--
white waterlily	*Nymphaea odorata*	7	12
curly-leaf pondweed	*Potamogeton crispus*	3	--
duckweed (lesser)	*Lemna minor*	3	45
sago pondweed	*Stuckenia pectinata*	--	27
yellow waterlily	*Nuphar variegata*	--	6

All six species observed in May were found in the shallowest depth range of the lake with decreasing species as depth interval increased (Table 6.4). Of these six species, two appeared to dominate the vegetation community within different depth intervals. Coontail dominated the shallow depth interval, while coontail and Canadian waterweed co-dominated the mid-depth interval. Flat-stemmed pondweed was abundant in both the shallow and mid-depth intervals. No vegetation was observed in the deep interval. Other native species were rarely observed in the shallow and mid-depth intervals and were not observed in the deep depth interval.

Similar to May, all species observed in the August survey were found within the shallowest depth interval (Table 6.4). A similar decline in species was observed as depth interval increased. Coontail and duckweed appeared to be the only species that dominated a depth interval. Four of the total six observed species were observed at depths greater than 5 feet. The percentage of species observations decreased as water depth increased during both surveys, which is expected since vegetation typically is more abundant in shallow water.

Table 6.4. SAV species occurrence by depth.

Common Name	5/21/2018 % Occurrence by Depth (ft)			8/16/2018 % Occurrence by Depth (ft)		
	0-5	5-10	10-15	0-5	5-10	10-15
coontail	90	100	--	95	100	--
waterweed (Canadian)	45	100	--	14	--	--
flat-stemmed pondweed	30	33	--	--	--	--
white waterlily	10	--	--	14	20	--
curly-leaf pondweed	5	--	--	--	--	--
duckweed (lesser)	5	--	--	67	20	--
sago pondweed	--	--	--	33	40	--
yellow waterlily	--	--	--	10	--	--

*Note: Species are in the same order as they appeared in Table 6.3.

An increase in species richness, abundance, and depth of growth across the growing season is typically an indication of relatively good health of a lake ecosystem. Ryan Lake displayed some of these characteristics, however, the strong dominance of high nutrient tolerant species (Coontail and duckweeds) likely is limiting the presence and occurrence of more species across Ryan Lake. In healthy lakes, the late summer SAV community is typically more diverse, has greater abundance, and has species that utilize all depth intervals.

Coontail, a native species, was extremely dominant at shallow (0-10 foot) depths. In addition to the dominant spatial coverage across the lake it also grew very large and dense saturating most of the water column. These factors likely reduced the ability of other SAV species to grow within the lake due to light competition. In addition to the possible biological impairment caused by coontail, coontail within the lake is also causing recreational impairments. There is no boat launch but there is a canoe launch on Ryan Lake and a popular eastern fishing pier. Since coontail is saturating almost the entire water column in the shallow areas, accessing the lake and/or fishing from the pier becomes difficult. Efforts to reduce, remove, and replace coontail growth with other species of SAV in these areas would improve recreation opportunities on the lake.

Vegetation management on Ryan Lake is currently a low priority for the Commission, however, if pursued, lake management should consider improving water quality and possible sediment/nutrient amendments to enhance the SAV community. Water clarity is typically very high early in the season (Secchi >15 ft) that quickly declines throughout the open water season. Decreased water quality and increased algal turbidity reduces desired SAV species and is believed to contribute to the dominance of coontail within the lake. Coontail is a non-rooted vascular plant that grows well in high sediment nutrient conditions. A sediment amendment practice in the growth areas that prevents or slows the release of nutrients may serve as a method to limit nutrients for coontail and promote the growth of other rooted native plant species.

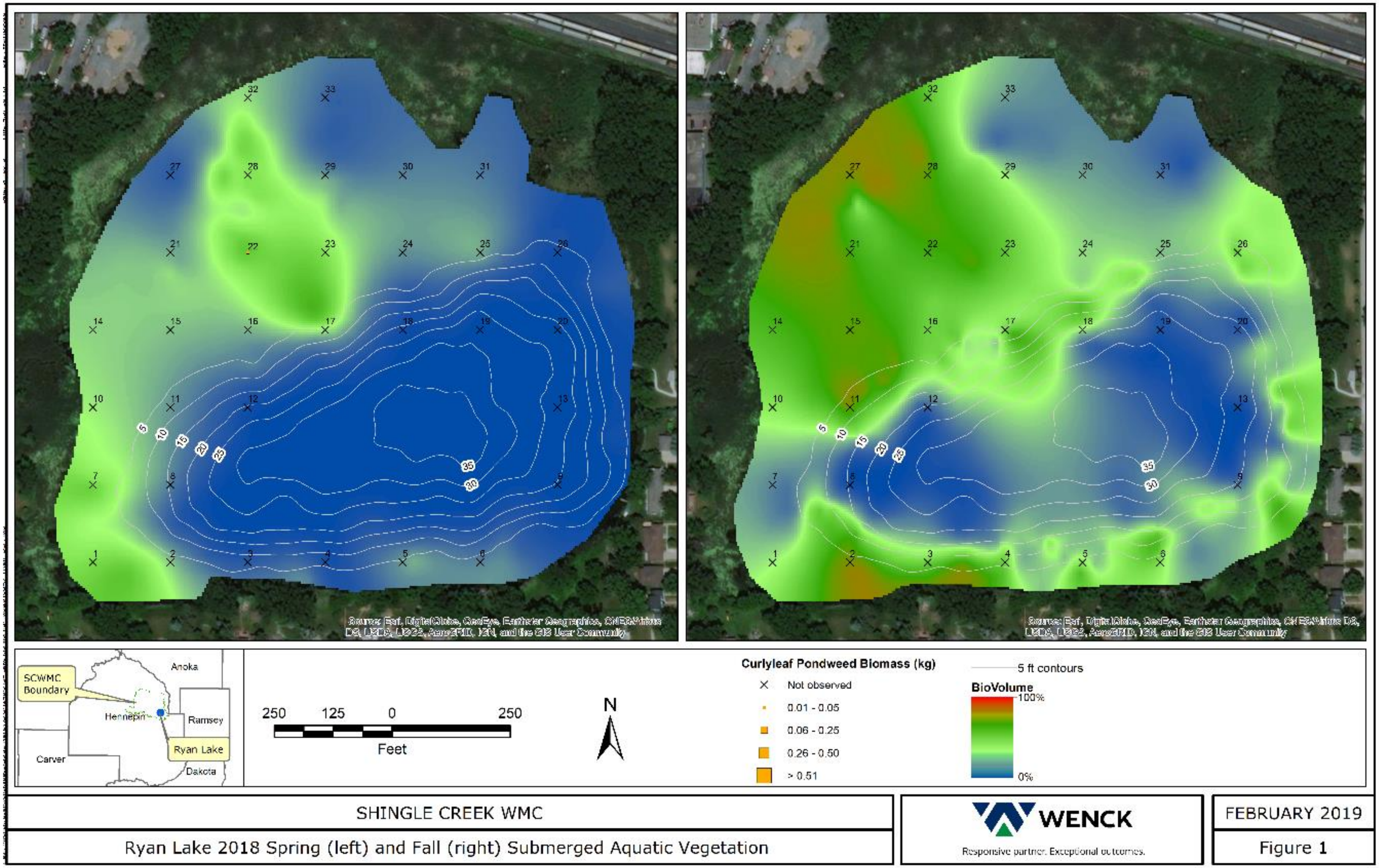

Figure 6.1. 2018 Ryan Lake curly leaf pondweed biomass and total submerged aquatic vegetation biovolume.

6.4 FISHERIES

No fisheries assessment was officially conducted. Wenck did not conduct fish assessment due to MnDNR reporting that they would be conducting netting activities in 2018. The MnDNR did not notify Wenck or the Commission of the status change to not sampling in the early spring. Therefore, no official fish sampling was conducted and not conclusions can be drawn about the community in 2018.

The MnDNR did attempt to stock Walleye in the lake to serve as a rearing pond, however, late season surveys revealed that the Walleye did not survive.

6.5 CARP

Common carp were observed both alive and dead (after partial winter kill) within Ryan Lake. Therefore, it is possible that common carp are a concern for Ryan Lake. It is uncertain the role that Ryan Lake played in contributing carp into the Twin Lakes and whether the lake could be a carp nursery. A fish barrier was placed upstream of the lake along Ryan Creek as part of the carp management project on the system, therefore, immigration between Ryan and the Twin lakes has been blocked and should assist with reducing the number of carp within the lakes.

7.0 Crystal Lake

7.1 SAMPLING OVERVIEW

Below is a summary reporting from the most recent survey efforts for each area of the monitoring program. Crystal Lake most recent sampling efforts were completed:

- Water Quality - 2018
- SAV – 2018
- Fisheries – 2004; MnDNR planning to update in 2019
- Carp – 2018

7.2 WATER QUALITY

Total phosphorus, chlorophyll-a, and Secchi depth were monitored throughout 2018 (Figure 7.1). The phosphorus concentrations in Crystal Lake exceeded the 40 ug/L standard in June but remained below the standard for the remainder of the summer until late September. In October, the total phosphorus concentration peaked at 78 ug/L. The average total phosphorus concentration in 2018 was 43 ug/L, which is just above the standard and is significantly lower than historical. Chla concentrations exceeded the water quality standard throughout the summer. The chla concentrations peaked in August, which is typical for a lake with high turbidity and nutrient loading. The average chlorophyll-a concentration in 2018 was 28 ug/L, which is double the water quality standard, but is comparable to measurements from the last decade. Throughout the summer, the Secchi depth in Crystal lake was less than the 1.5 meter standard and got progressively worse throughout the growing season. The average Secchi depth in 2018 was 1.03 meters, which does not meet the water quality standard. This is comparable to historic Secchi depth averages in Crystal Lake (Figure 7.2).

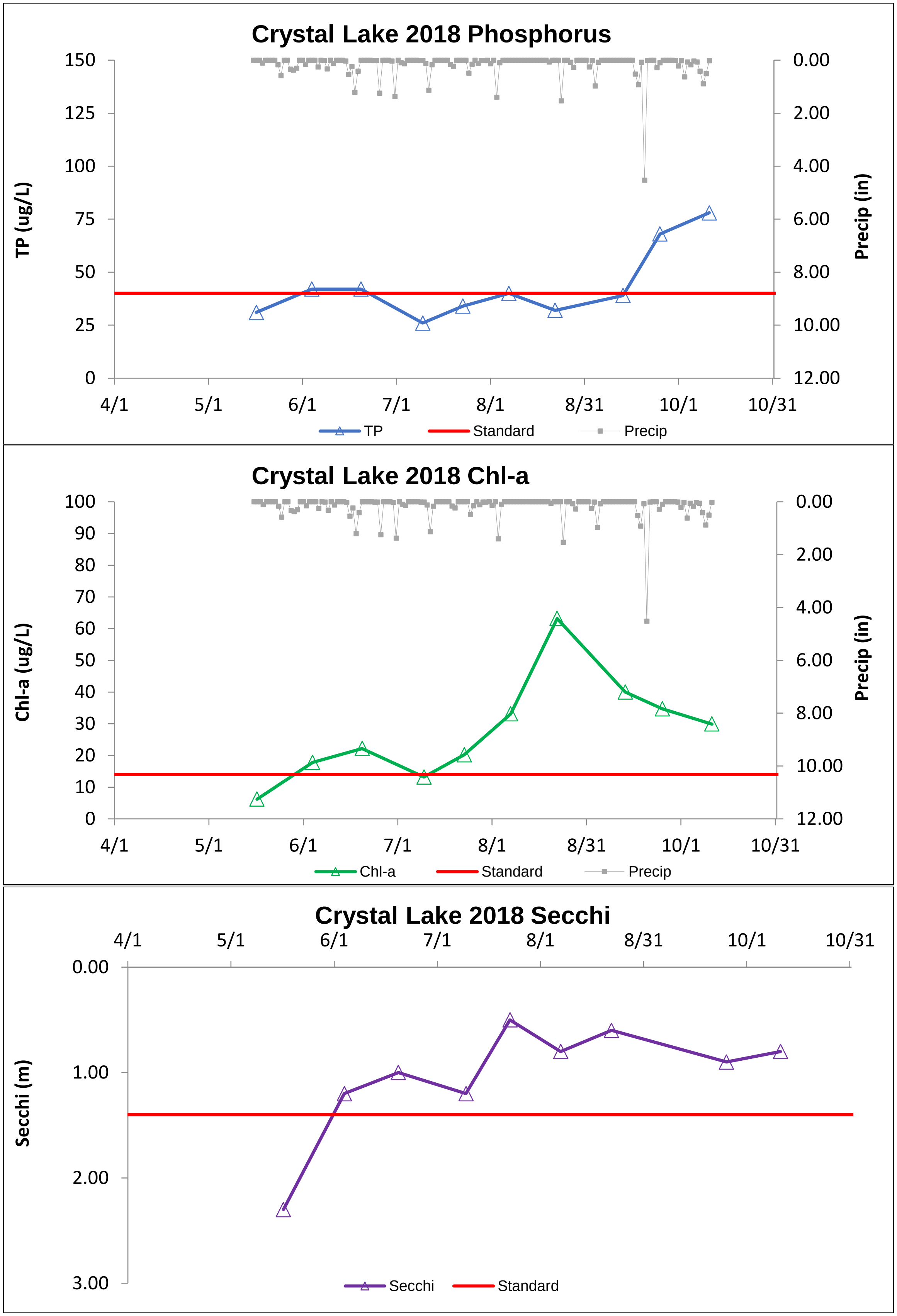

Figure 7.1. 2018 TP, chla, and Secchi measurements and water quality standards.

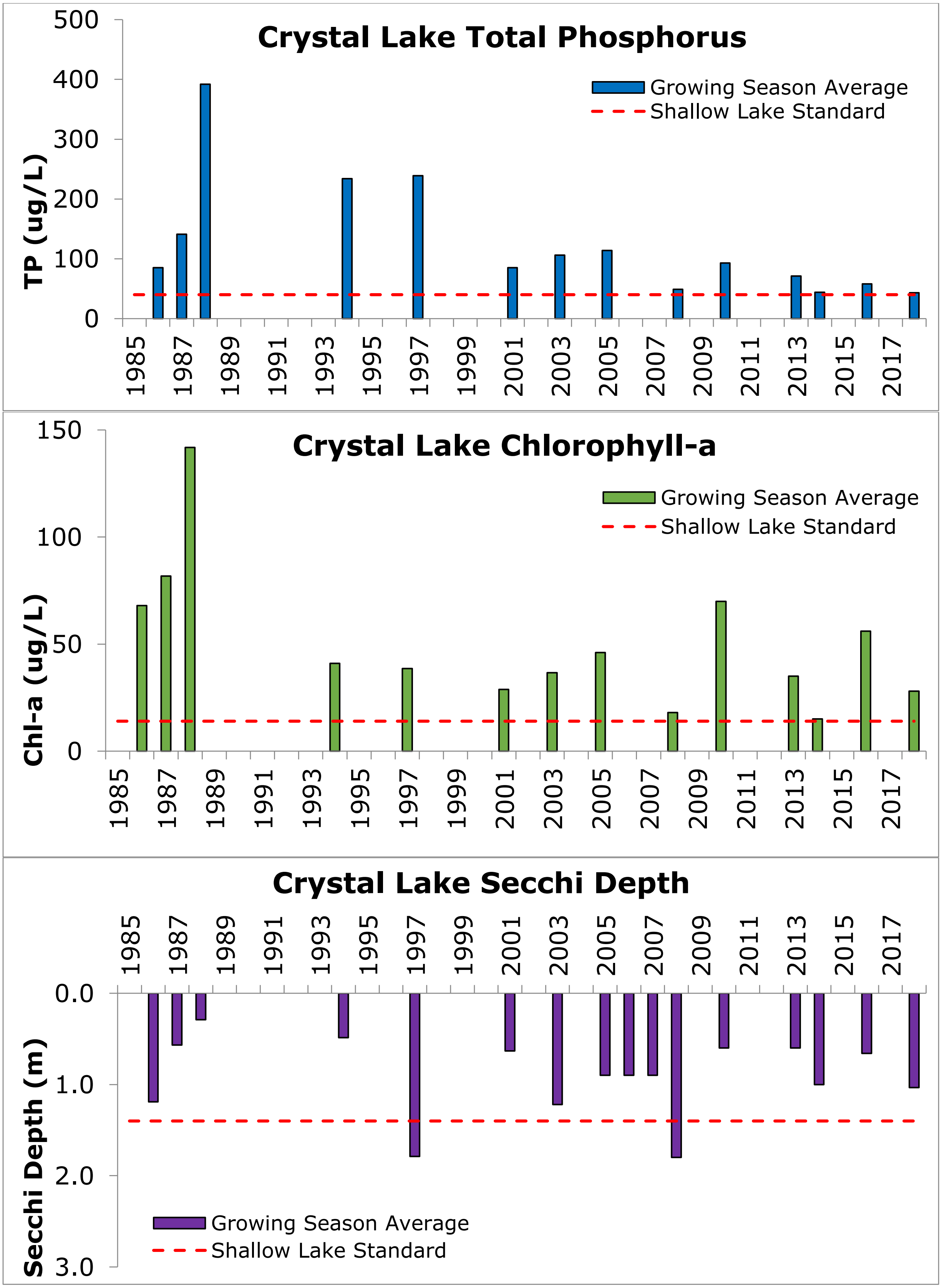

Figure 7.2. Summer average TP, chla, and Secchi measurements and water quality standards.

7.3 SUBMERGED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted to document the late spring and late summer submerged aquatic vegetation in Crystal Lake in 2018. Crystal Lake has an approximate surface area of 81 acres, with 55 acres of littoral acres (areas less than 15 feet deep), 1.55 miles of shoreline, and a maximum depth of 39 feet.

A total of 58 survey points were assessed on Crystal Lake in each 2018 survey (Table 7.1). Almost no vegetation was observed in either the May and August. Taxa richness decreased over the open water season from two species to one species. Overall, the vegetation community lacked both quantity and quality of species and scored significantly below the Central Hardwood Forest Ecoregion FQI deep lake standard of 18.6 and deep lake species richness standard of 12 taxa (Table 7.1).

Table 7.1. SAV quality and quantity indices.

	5/23/2018	8/7/2018
Total Observations	58	58
Littoral Observations	45	45
Total Vegetated points	2	2
% of Littoral with Vegetation	4	4
Lake Taxa*	2	1
Average C-Score	4.5	6
FQI*	6.4	6.0

*The lake taxa standard and floristic quality index (FQI) standards for Crystal Lake are 12 taxa and an FQI of 18.6.

Sampling efforts were summarized by 5 foot depth intervals within the littoral zone to observe shifts and changes in community composition (Table 7.2), however, due to lack of SAV in the lack no depth analysis is possible.

Curly-leaf pondweed (CLP) and white waterlily were the only species observed in May and white waterlily was the only species observed in August. Curly-leaf pondweed is known to senesce by late summer, therefore, the absence of this species is expected between surveys (Figure 7.3). Both of the species were rarely observed, with occurrences less than 5% (Table 7.3) across the entire lake. Where the species were observed there tended to be only a few to a single strand of vegetation observed with their occurrence being in the shallow depths of the lake (Table 7.4).

Table 7.2. Biomass summarized by lake depth.

		5/23/2018				8/7/2018			
Depth	**Lake Acres**	**Total Sample Points**		**Species**	**Est. Lake Biomass (wt; kg)**	**Total Sample Points**		**Species**	**Est. Lake Biomass (wt; kg)**
0-5 ft	15	16	27.6%	2	175	9	16%	1	NA
5-10 ft	26	21	36.2%	0	0	29	50%	1	NA
10-15 ft	14	8	13.8%	0	0	7	12%	0	0
>15ft	26	13	22.4%	0	0	13	22%	0	0

* Depth intervals with NA biomass indicate the presence of species for which biomass could not be accurately sampled.

Table 7.3. Summary of species observations and biomass estimates.

Common Name	Scientific Name	5/23/2018 % Lake Occurrence	8/7/2018 % Lake Occurrence
white waterlily	*Nymphaea odorata*	2	3
curly-leaf pondweed	*Potamogeton crispus*	2	--

Table 7.4. SAV species occurrence by depth.

Common Name	5/23/2018 % Occurrence by Depth (ft)			8/7/2018 % Occurrence by Depth (ft)		
	0-5	5-10	10-15	0-5	5-10	10-15
white waterlily	6	0	0	11	3	0
curly-leaf pondweed	6	0	0	0	0	0

Crystal Lake's vegetation community is among the poorest and most degraded possible. The vegetation that does exist is so limited that it cannot provide any significant level of food or cover for other aquatic organisms.

It is not exactly clear why there is a lack of vegetation within the lake. Common carp population assessment conducted outside of this assessment indicated densities that would only cause slight water quality and habitat degradation. Review of water quality monitoring did observe impaired water quality, however, not to levels where that would be able to explain the absences of SAV. It is unclear if the combination of carp and poor water quality may explain the lack of vegetation, however, other systems within Shingle Creek watershed have been observed to have worse water quality and higher carp densities have a greater SAV presence within the lake.

One factor not assessed that is important to SAV growth is sediment composition. SAV typically does not grow well or abundantly in non-organic materials (i.e. sand, gravel, cobble). It is unclear the current sediment composition across Crystal Lake and whether that may be contributing to the suppression of a healthy SAV community. We also did not explore or assess whether a viable seed bank persists within the lake, nor did we assess for other chemical pollutants that may be acting as an herbicide.

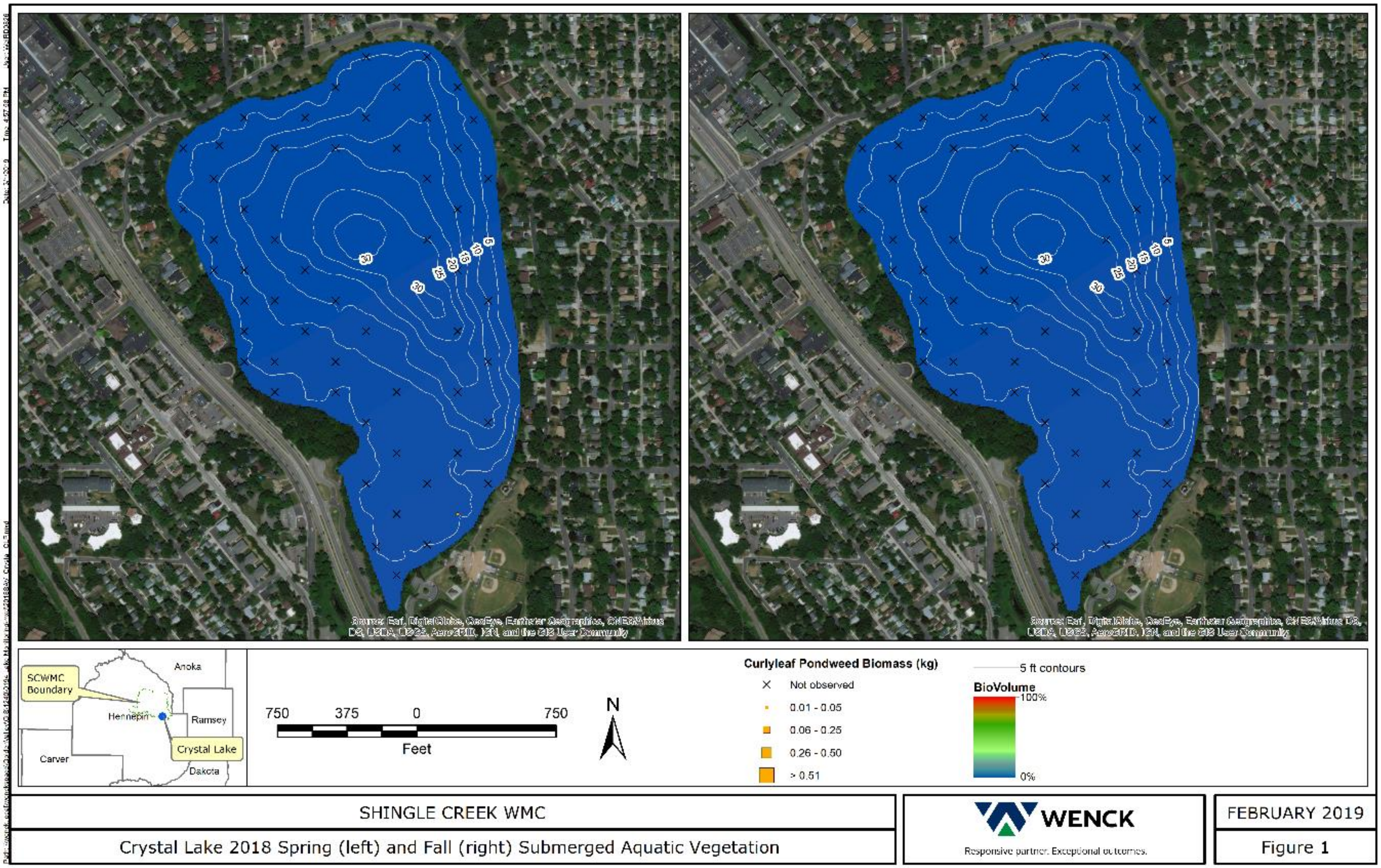

Figure 7.3. 2018 Crystal Lake total submerged aquatic vegetation biovolume.

7.4 FISHERIES

The fish community was last assessed by the MnDNR in 2004. Below is the report developed about the fish community. It is not known how the fish community may have changed in the intervening 15 years.

Crystal Lake is located in Robbinsdale with city parks on the north and south ends of the lake. Both parks provide shorefishing opportunities, and a fishing pier is located on the northern end of the lake. Boaters can access Crystal Lake at the public access on the southern end of the lake. Crystal Lake is primarily a panfish lake, and has been stocked with tiger muskellunge fingerlings every 2 to 4 years since 1994, most recently in 2001. The city of Robbinsdale maintains winter aerators to prevent winterkill, and has been working to reduce storm water input to Crystal Lake to improve the water quality. Small panfish dominate the fish community at Crystal Lake. Bluegills were sampled at an abundance above the 75th percentile for this lake type and were smaller than average. Black crappie abundance was lower than in previous surveys, but numbers were still above average when compared to similar lakes. Northern pike were the most abundant predator species sampled in survey nets, but were less abundant than during the previous survey. The catch of 2.8 northern pike per gill net is just above the 25th percentile for class 30 lakes. Four year-classes of northern pike were represented in the survey, ages 4 to 7. The average age of the northern pike sampled increased from 3.0 in 1998 to 5.3 in 2004. During the 1998 survey it was noted that historical northern pike spawning areas on the southern end of the lake had been filled, and the area converted to ball fields. Four tiger muskellunge from the 2001 stocking were sampled in gill nets, an average abundance of 0.67 fish per net. Tiger muskellunge are a cross between a male northern pike and a female muskellunge. Largemouth bass were present in the trap net samples representing 3 year-classes. Growth rates were average. Important prey species in Crystal Lake are golden shiners and yellow perch. Golden shiners were the most abundant forage species. Yellow perch were also abundant, and were present in gill nets at a level just below the third quartile. The yellow perch sampled in gill nets had a mean length of 6.5 inches; growth was average. Yellow bullhead, white sucker, pumpkinseed sunfish, green sunfish, hybrid sunfish, and one 18.1-inch walleye were also present in net samples. Eighteen painted turtles, 8 snapping turtles, and 1 exotic eastern slider turtle were sampled.

7.5 CARP

A common carp population assessment was conducted on Crystal Lake in 2018. Boat electrofishing was completed to sample three shoreline transects for approximately 20 minutes each under MnDNR permit approval. Sampling transects ended up covering the entire shoreline area of the lake. All common carp observed were netted (some carp are inevitably missed), counted and measured for total length (weight was extrapolated from length using a regression model) prior to being released.

A total of 25 common carp were captured during the 9/28/2018 assessment. The average total length was 44.7 cm (17.6 inches) and weight was 1.21 kg (2.7 pounds). Carp were captured in all three transects. Using results of this assessment and the regression equation described above, it is estimated that the lake has a common carp density of ~104 carp/ha (~42 carp/acre) and a biomass density of about 126 kg/ha (277 lbs/acre). Extrapolating this density across the entire basin suggests that there are ~3,320 individual carp within the lake. Table 7.5 provides a summary of the 9/28/2018 common carp survey results for the main-lake.

Table 7.5. Summary of Crystal Lake 9/28/2018 common carp assessment.

Carp Collected	Shock Time (hour)	Ave Length (cm)	Ave Weight (kg)	Biomass Mean (kg/ha)	Estimated Population Size
25	1.17	44.7	1.21	126	3,320

Crystal Lake currently has carp biomass densities greater than the recommended 100 kg/ha threshold. These results suggest common carp are a contributing factor to water quality impairments and habitat degradation within Crystal Lake. To achieve density levels right at the 100 kg/ha threshold would require the removal of ~681 carp or ~3,202 kg (7,059 lbs) of carp from the system. Removal goals below the 100 kg/ha threshold would account for potential growth of individuals that are removed from the system.

The current density of carp suggests that some level of water quality and habitat impairment may be resulting from carp within the lake. However, the current density of carp and the current water quality and habitat within Crystal Lake suggests either 1) carp densities were significantly underestimated during the assessment (i.e. cool weather) or 2) other factors are having a much greater impact of Crystal Lake. Carp densities slightly over the critical threshold should still demonstrate moderate water quality conditions and submerged aquatic vegetation within the lake. Water quality and habitat surveys on Crystal Lake show it to be highly impaired (beyond what the results of this carp assessment should be) (Photo 7.1). A carp management strategy should be part of any future lake management strategies.

Photo 7.1. Algal dominant surface water photos taken from the boat launch on Crystal Lake at the time of carp survey.