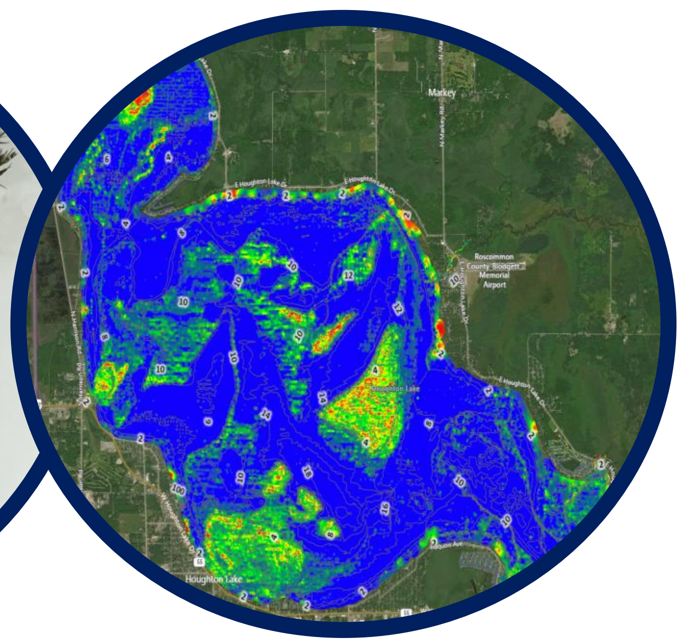
Houghton Lake 2021 Annual Report, and 2022-2026 Feasibility Study Management Recommendations



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1

Houghton Lake 2021 Annual Report and 2022-2026 Management Recommendations Report

The following Houghton Lake report is a summary of key lake findings collected in 2021 with recommendations for continued improvement program 2022-2026.

The overall condition of Houghton Lake has been improving over the past few years due to rigorous aquatic vegetation surveys and selective spot-treatments to control invasive aquatic plant species such as hybrid Eurasian Watermilfoil (EWM), and Starry Stonewort. Both of these species are declining in Houghton Lake and providing space for the now 28 native aquatic plant species that are so important to the ecological balance of Houghton Lake.

The water quality of Houghton Lake is overall good with nutrients varying each year due to rainfall/runoff. The dissolved oxygen is abundant, and the pH is ideal for an inland lake. The specific conductivity is moderate and favorable. The water clarity is fair to good, and the algal communities are diverse and a good source of primary productivity for the fishery. The sediment macroinvertebrate community is also healthy relative to taxa and relative abundance, and this may change annually due to environmental conditions.

RLS recommends continued intense aquatic vegetation community surveys of the entire lake and canals and spot-treatments as needed for management of invasive species only. The canals and Middle Grounds areas have proven to require earlier survey dates than the remainder of the lake due to germination patterns. The use of high-dose liquid triclopyr in the Middle Grounds was necessary given the dense growth observed in 2021 and previous use of ProcellaCOR® herbicide. Rotation of herbicides is important to reduce the probability of tolerance to one used in a given year for a specific area. Wild Rice is re-establishing in North Bay, Middle

Grounds, and Muddy Bay. Wild Rice was planted in Muddy Bay in 2020 and showed a 98.8% germination success in 2021. RLS will determine if more seeding is needed in 2022. In Section 6 of this report, RLS offers management recommendations for the new 5-year program for Houghton Lake as public hearings will be held in 2022. An annual budget is adopted by the Houghton Lake Improvement Board each year and will change each year based on timely management needs and prices.

Section

2

Houghton Lake Water Quality Data (2021)

Water Quality Parameters Measured

There are numerous water quality parameters that can be measured on an inland lake, but several are the most critical indicators of lake health. The parameters measured in Houghton Lake in 2021 and in previous years included: water temperature (measured in °C or °F), dissolved oxygen (measured in mg/L), pH (measured in standard units-SU), conductivity (measured in micro-Siemens per centimeter-µS/cm), total alkalinity or hardness (measured in mg of calcium carbonate per liter-mg $CaCO_3$/L), total dissolved solids (mg/L), secchi transparency (feet), total phosphorus, ortho-phosphorus, and total Kjeldahl nitrogen (all in mg/L), chlorophyll-*a* (in µg/L), and algal community composition. Graphs that show trends for some parameters of each year are displayed below. Water quality was measured in the deep basins of Houghton Lake on October 26, 2021 (Figure 1). Additional water quality samples were collected in the tributaries (Figure 2) and in the canals (Figure 3).

Trend data was calculated using mean values of each parameter over the sampling locations. Table 1 below demonstrates how lakes are classified based on key parameters. Houghton Lake would be considered meso-eutrophic (relatively productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation growth but has good water clarity and moderately low planktonic algal growth. General water quality classification criteria are defined in Table 1. 2021 water quality data for Houghton Lake are shown below in Tables 2-7. Water quality data for the tributaries and canals are shown in Tables 8-12.

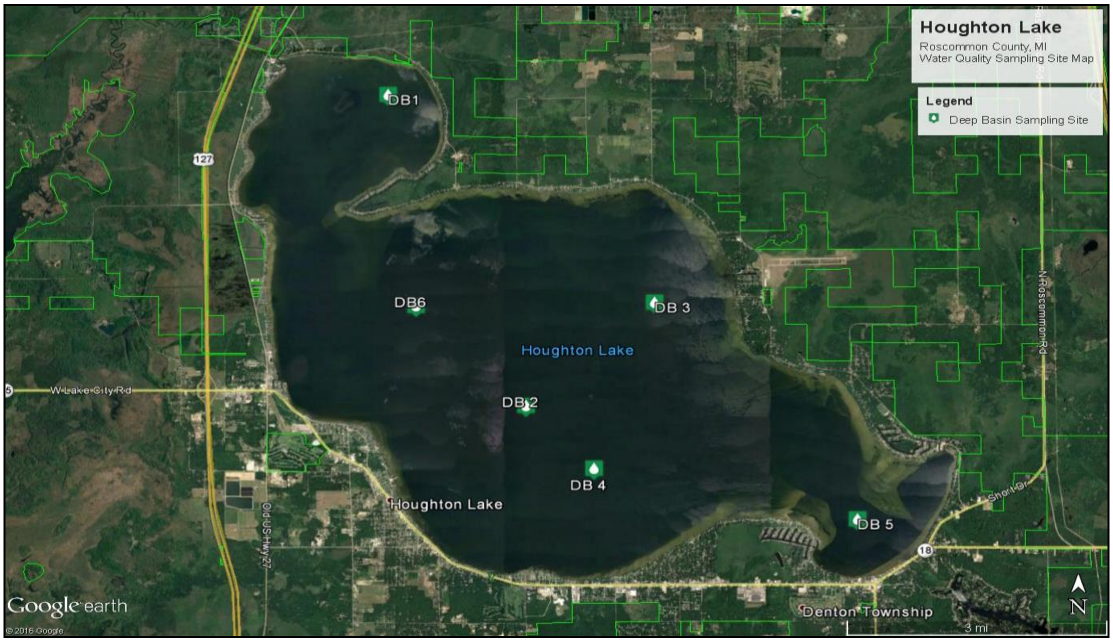

Figure 1. Deep basin water quality sampling locations in Houghton Lake (2016-2021).

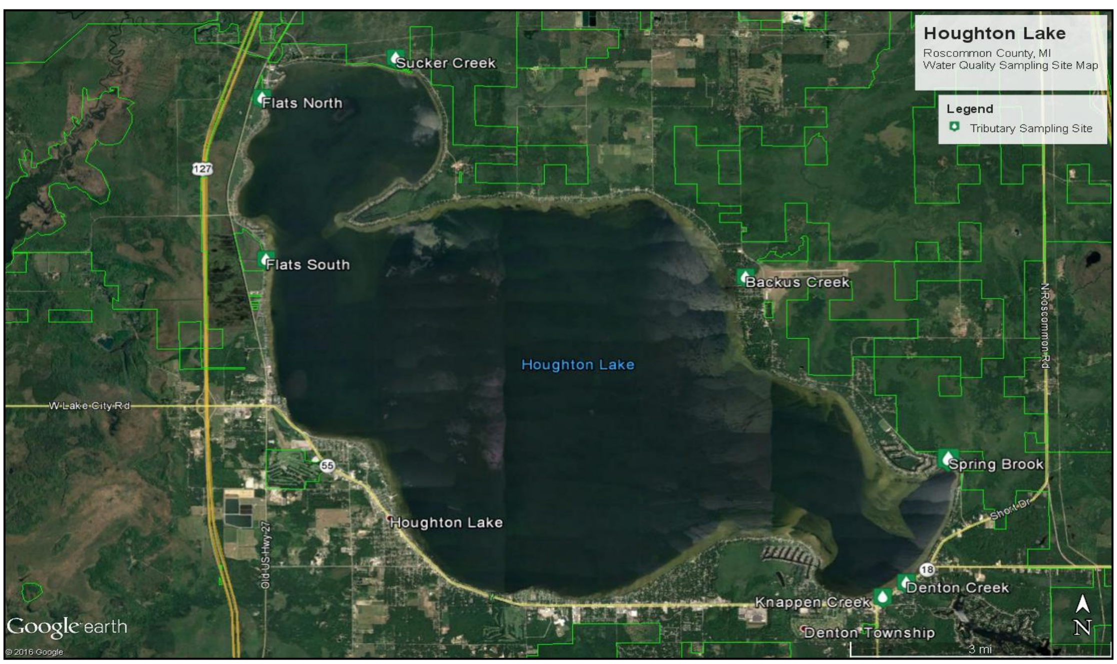

Figure 2. Tributary water quality sampling locations around Houghton Lake (2016-2021).

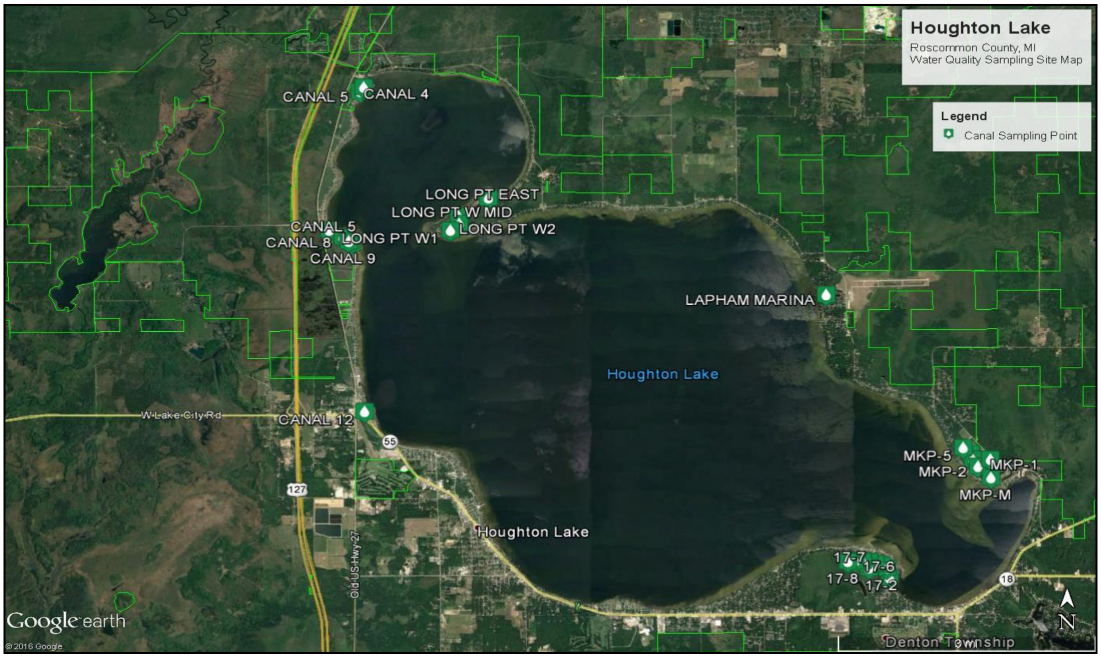

Figure 3. Houghton Lake canals water quality sampling locations (2016-2021).

Table 1. Lake trophic classification (MDNR).

Lake Trophic Status	*Total Phosphorus ($\mu g\ L^{-1}$)*	*Chlorophyll-a ($\mu g\ L^{-1}$)*	*Secchi Transparency (feet)*
Oligotrophic	**< 10.0**	**< 2.2**	**> 15.0**
Mesotrophic	**10.0 – 20.0**	**2.2 – 6.0**	**7.5 – 15.0**
Eutrophic	**> 20.0**	**> 6.0**	**< 7.5**

Houghton Lake Deep Basin Water Quality Data Tables:

Table 2. Houghton Lake water quality parameter data collected in deep basin #1 on October 26, 2021.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	9.1	11.7	8.4	321	1.1	209	0.010	<0.010	<0.5
2.5	9.1	11.5	8.4	321	1.7	210	0.012	<0.010	<0.5
5.0	9.1	11.5	8.4	336	1.7	212	0.012	<0.010	<0.5

Table 3. Houghton Lake water quality parameter data collected in deep basin #2 on October 26, 2021.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	10.1	11.5	8.3	234	1.7	150	0.015	<0.010	<0.5
8.0	10.1	11.1	8.3	234	1.7	150	0.015	<0.010	1.3
16.0	10.0	10.9	8.3	234	1.7	150	0.020	<0.010	5.6

Table 4. Houghton Lake water quality parameter data collected in deep basin #3 on October 26, 2021.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	10.8	11.3	8.3	231	1.3	148	0.014	<0.010	<0.5
8.0	10.7	10.8	8.3	232	1.3	148	0.016	<0.010	<0.5
16.0	10.7	10.1	8.3	232	1.6	148	0.015	<0.010	<0.5

Table 5. Houghton Lake water quality parameter data collected in deep basin #4 on October 26, 2021.

Depth ft.	*Water Temp ºC*	*DO mg L-1*	*pH S.U.*	*Cond. µS cm-1*	*Turb. NTU*	*TDS mg L-1*	*TP mg L-1*	*Ortho-P mg L-1*	*TKN mg L-1*
0	10.5	11.6	8.4	242	0.7	162	0.012	<0.010	<0.5
10.0	10.4	11.2	8.4	232	1.3	149	0.012	<0.010	<0.5
20.0	9.9	10.9	8.3	256	1.4	151	0.024	<0.010	<0.5

Table 6. Houghton Lake water quality parameter data collected in deep basin #5 on October 26, 2021.

Depth ft.	*Water Temp ºC*	*DO mg L-1*	*pH S.U.*	*Cond. µS cm-1*	*Turb. NTU*	*TDS mg L-1*	*TP mg L-1*	*Ortho-P mg L-1*	*TKN mg L-1*
0	10.4	11.8	8.4	234	0.9	150	0.010	<0.010	<0.5
10.0	10.3	11.1	8.4	234	1.8	150	0.011	<0.010	<0.5
20.0	9.9	11.0	8.4	294	2.2	189	0.013	<0.010	<0.5

Table 7. Houghton Lake water quality parameter data collected in deep basin #6 on October 26, 2021.

Depth ft.	*Water Temp ºC*	*DO mg L-1*	*pH S.U.*	*Cond. µS cm-1*	*Turb. NTU*	*TDS mg L-1*	*TP mg L-1*	*Ortho-P mg L-1*	*TKN mg L-1*
0	10.2	11.1	8.3	232	0.9	148	0.013	<0.010	<0.5
6.0	10.1	10.9	8.3	231	0.6	148	0.015	<0.010	<0.5
12.0	10.1	10.8	8.3	326	1.7	214	0.015	<0.010	<0.5

Houghton Lake Canal Water Quality Data Tables:

Table 8. Houghton Lake water quality parameter data collected in the Chippewa canals on October 26, 2021. Note: All samples were collected at a mid-depth of 3.0 feet. Site CM refers to the middle of the canal series.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
C1	**10.9**	**8.2**	**8.3**	**326**	**1.6**	**214**	**0.040**
C2	**10.2**	**7.9**	**8.1**	**328**	**1.6**	**215**	**0.030**
C3	**10.7**	**7.6**	**8.1**	**334**	**1.8**	**220**	**0.030**
C4	**10.3**	**7.8**	**8.3**	**334**	**1.5**	**220**	**0.040**
C5	**10.3**	**7.9**	**8.3**	**319**	**1.4**	**208**	**0.050**
C6	**10.3**	**8.6**	**8.1**	**320**	**1.4**	**209**	**0.030**
C7	**10.0**	**8.4**	**8.1**	**328**	**1.9**	**215**	**0.040**
C8	**10.6**	**7.9**	**8.1**	**328**	**2.2**	**215**	**0.040**
CM	**10.8**	**8.1**	**8.4**	**329**	**2.7**	**216**	**0.040**

Table 9. Houghton Lake water quality parameter data collected in the McKinley Park (MPK) canals on October 26, 2021. Note: All samples were collected at mid-depth of 3.0 feet. Site MPK M refers to the middle of the canal series.

Canal Site	*Water Temp ºC*	*DO mg L^-1^*	*pH S.U.*	*Cond. µS cm^-1^*	*Turb. NTU*	*TDS mg L^-1^*	*TP mg L^-1^*
MPK 1	10.9	9.5	8.1	230	2.1	145	0.040
MPK 2	10.8	9.7	7.9	230	2.3	145	0.030
MPK 3	10.8	8.7	7.9	235	1.9	148	0.030
MPK 4	10.8	8.2	7.9	235	2.6	148	0.030
MPK 5	10.9	8.6	8.1	229	2.9	144	0.050
MPK M	10.7	8.9	8.3	229	2.4	144	0.050

Table 10. Houghton Lake water quality parameter data collected in the Lapham and Long Point canals on October 26, 2021. Note: All samples were collected at mid-depth of 3.0 feet.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
LAPHAM	10.7	9.5	7.5	226	1.6	145	0.025
L POINT MID	10.9	8.0	7.3	228	1.5	148	0.040
L POINT W1	10.6	8.2	7.3	235	1.6	153	0.040
L POINT W2	10.7	8.4	7.5	235	1.9	153	0.030
L POINT E	10.7	7.9	7.5	221	1.6	141	0.030

Table 11. Houghton Lake water quality parameter data collected in the canals north and west of Long Point canals #4-12 on October 26, 2021. Note: All samples were collected at mid-depth of 3.0 feet. Canal #5 was too shallow to enter.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
CANAL 4	10.8	9.8	8.0	234	1.8	150	0.030
CANAL 5	--	--	--	--	--	--	--
CANAL 6	10.9	10.0	8.0	232	1.4	141	0.025
CANAL 8	10.7	9.2	8.0	243	1.6	142	0.030
CANAL 9	10.9	9.6	8.0	249	2.2	170	0.030
CANAL 10	10.2	9.2	8.1	255	1.9	168	0.020
CANAL 12	10.5	9.7	8.2	241	2.4	176	0.040

Houghton Lake Tributary Water Quality Data Table:

Table 12. Houghton Lake water quality parameter data collected in the tributaries and flats on October 26, 2021.

Tributary Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. mS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TSS mg L^{-1}*	*TP mg L^{-1}*	*TKN mg L^{-1}*
DENTON CRK	11.5	9.8	7.4	197	1.5	126	<10	0.011	0.7
SPRING BROOK	10.2	9.5	7.4	233	2.1	152	<10	0.020	0.5
BACKUS CRK	8.9	9.9	7.4	101	1.3	64	<10	0.010	<0.5
FLATS N	8.9	8.8	7.4	200	2.8	127	<10	0.020	0.7
FLATS S	9.2	9.0	7.3	202	2.6	128	<10	0.020	0.5
SUCKER CRK	9.0	10.8	7.9	138	1.9	88	<10	0.011	<0.5
KNAPPEN CRK	8.8	11.2	7.7	226	1.6	145	20	<0.010	0.8

Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters. Dissolved oxygen was measured in milligrams per liter (mg L^{-1}) with the use of a calibrated Eureka Manta II® dissolved oxygen meter. During the summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. Dissolved oxygen concentrations during the October 26, 2021 sampling event averaged 11.2 mg L^{-1}. Figure 4 below shows the changes in mean DO with time in Houghton Lake.

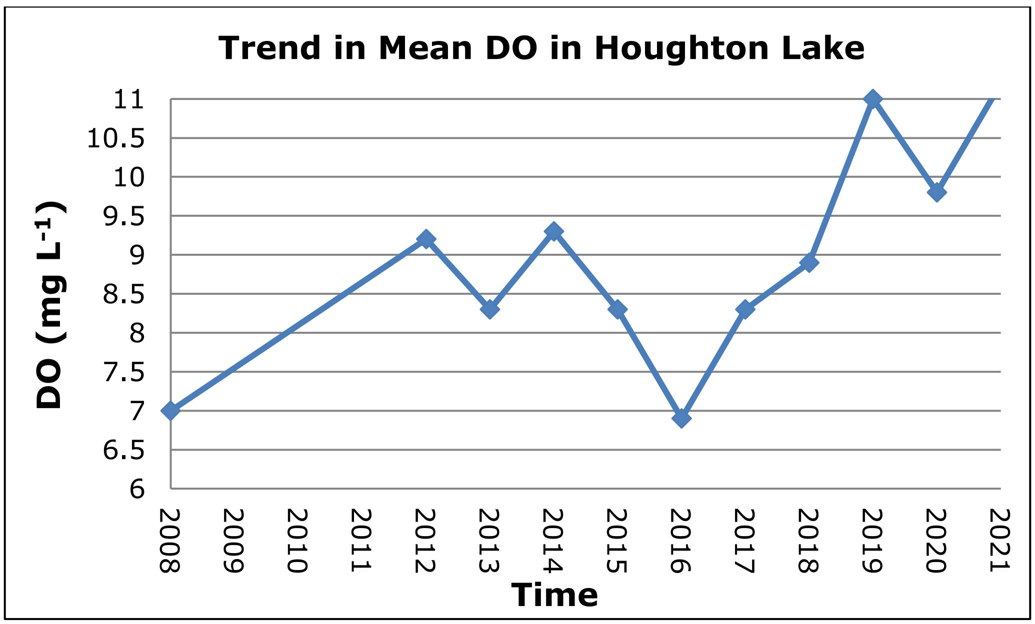

Figure 4. Changes in mean DO with time in Houghton Lake.

Water Clarity (Transparency)

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Houghton Lake was adequate on October 26, 2021 (mean of 6.2 feet; Figure 5) to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake.

Secchi transparency is variable and depends on the number of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement. Other parameters such as turbidity (measured in NTU's) and Total Dissolved Solids (measured in mg/L) are correlated with water clarity and show an increase as clarity decreases.

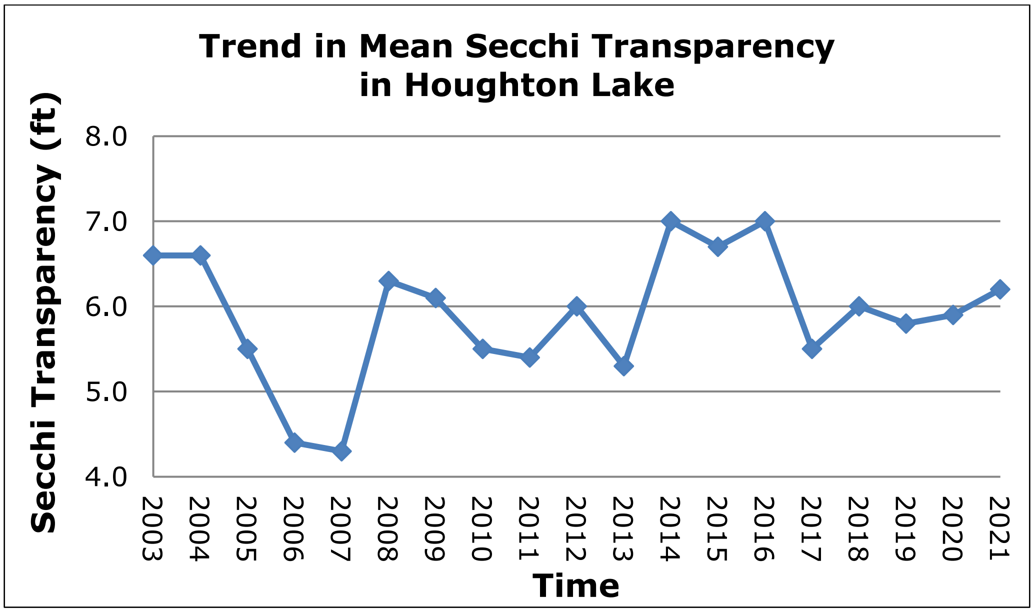

Figure 5. Changes in mean Secchi Transparency with time in Houghton Lake.

Total Phosphorus & Ortho-Phosphorus

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. TP concentrations are usually higher at increased depths due to higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Fortunately, even though the TP levels in Houghton Lake are moderate, the dissolved oxygen levels are high enough at the bottom to not result in the release of phosphorus from the bottom. The mean TP concentration on October 26, 2021 was 0.014 mg L^{-1} (Figure 6), which is lower than in recent years and was below the eutrophic threshold. Ortho-phosphorus or "soluble reactive phosphorus" refers to the proportion of phosphorus that is bioavailable to aquatic life. Higher concentrations of ortho-phosphorus concentrations in the lake result in increased uptake of the nutrient by aquatic plants and algae. The ortho-phosphorus concentrations in the deep basins of Houghton Lake were all ≤ 0.010 mg L^{-1}, which were quite low. The mean TP in the canals was higher at 0.034 mg L^{-1}. The mean TP in the tributaries was lower at 0.015 mg L^{-1}.

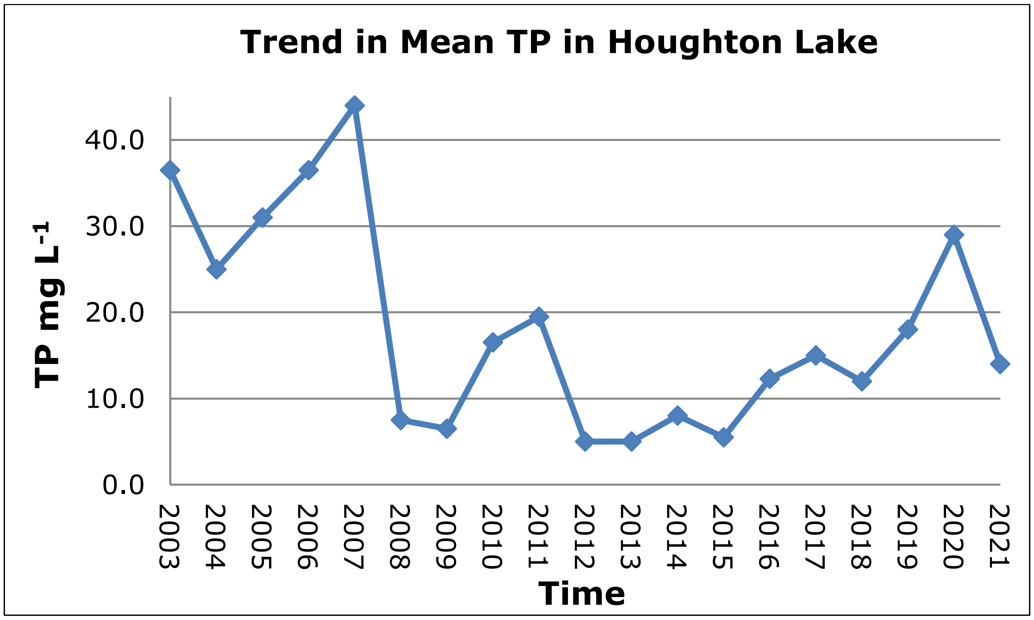

Figure 6. Changes in mean TP with time in Houghton Lake.

Total Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of ammonia (NH_3^+), and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e., burning of fossil fuels), wastewater sources from developed areas (i.e., runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through ground or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of 0.66 mg L^{-1} may be classified as oligotrophic, those with a mean TKN value of 0.75 mg L^{-1} may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg L^{-1} may be classified as eutrophic. The mean TKN concentration in Houghton Lake on October 26, 2021 averaged 0.8 mg L^{-1}, which is moderately low for an inland lake and similar to last year. The TKN in the tributaries ranged from <0.5-0.8 mg L^{-1}.

Total Alkalinity

Lakes with high alkalinity (> 150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having "hard" water. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water. The alkalinity of Houghton Lake was moderately low on October 26, 2021 (mean of 87 mg L^{-1} of $CaCO_3$) and indicates a slightly soft-water lake.

Turbidity, Total Dissolved & Suspended Solids

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, storm water discharge, urban runoff, re-suspension of bottom sediments, and in smaller lakes by large bottom-feeding fish such as carp. Particles suspended in the water column absorb heat from the sun and raise water temperatures. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity was measured in Nephelometric Turbidity Units (NTU's) with the use of a calibrated turbidimeter. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that.

The turbidity of Houghton Lake was quite low and was ≤2.2 NTU's during the 2021 sampling event. Spring values may be higher due to increased watershed inputs from spring runoff and/or from increased algal blooms in the water column from resultant runoff contributions. The turbidity of the canals was ≤2.9 NTU's and is favorable due to less wind and sediment re-suspension. The turbidity of the tributaries was ≤2.8 NTU's which is favorable.

Total dissolved solids (TDS) is a measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. TDS was measured with the use of a calibrated Eureka Manta II® TDS probe in mg L^{-1}. Spring values may be higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS in Houghton Lake was ≤214 mg L^{-1} for the deep basins on October 26, 2021, which is moderate for an inland lake but higher than last year.

The preferred range for TDS in surface waters is between 0-1,000 mg L^{-1} but the lower values are most favorable. The TDS in the canals was ≤220 mg L^{-1} which is higher than the lake and likely due to the presence of tannins from the forests and wetlands near the canals and increased rainfall and runoff in 2021. The TDS of the tributaries was ≤152 mg L^{-1}.

Total Suspended Solids

Total suspended solids (TSS) refers to the quantity of solid particles detected in the water that reduce light penetration and create turbidity in the water. The TSS samples measured in the Houghton Lake tributaries ranged from ≤10-20 mg L^{-1}, which is overall low for all of the tribs. The ideal concentration for TSS in inland lakes and streams is ≤ 20 mg L^{-1}. TSS may increase during periods of heavy rainfall/runoff.

pH

Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). Houghton Lake is considered “slightly basic” on the pH scale. The pH of Houghton Lake averaged 8.3 S.U. (Figure 7) on October 26, 2021 which is ideal for an inland lake. The pH of the canals ranged from 7.3-8.4 S.U. and the pH of the tributaries ranged from 7.3-7.9 S.U. All of these values are normal and favorable for aquatic environments.

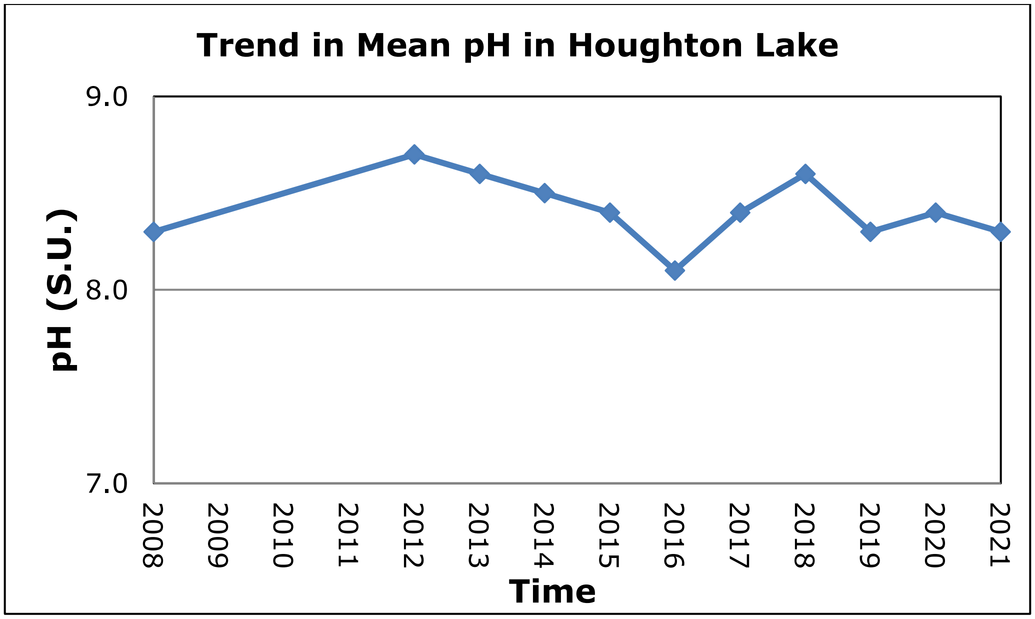

Figure 7. Changes in mean pH with time in Houghton Lake.

Conductivity

Conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances and was measured with a calibrated Eureka Manta II® probe. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. The conductivity in Houghton Lake ranged from 231-336 µS/cm on October 26, 2021. The conductivity of the canals ranged from 221-334 µS/cm and the conductivity in the tributaries ranged from 101-233 µS/cm. Severe water quality impairments do not occur until values exceed 800 µS/cm and are toxic to aquatic life around 1,000 µS/cm.

Chlorophyll-*a* and Algal Species Composition

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg/L are found in nutrient-poor or oligotrophic lakes. The mean chlorophyll-*a* concentration measured on October 26, 2021 (Figure 8) was 2.4 µg L^{-1} which was higher than in recent years and may be attributed to a much warmer summer with dry climate.

The algal genera were determined from composite water samples collected over the deep basins of Houghton Lake in 2021 were analyzed with a compound Zeiss® bright field microscope. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Chlorella* sp., *Spirogyra* sp., *Cladophora* sp., *Scenedesmus* sp., *Mougeotia* sp., *Radiococcus* sp., *Pandorina* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae): *Oscillatoria* sp., and the Bascillariophyta (diatoms): *Navicula* sp., *Cymbella* sp., *Synedra* sp., *Fragillaria* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of algae with an abundance of diatoms that are indicative of great water quality.

Blue-green algae have been problematic in the McKinley Canal system in recent years and thus a Phoslock® treatment was conducted on July 8, 2021 and August 2, 2021. *In situ* fluorimeter readings collected by RLS in the canals on June 9, 2021 ranged from 8-10 µ/L whereas August 30, 2021 readings ranged from 4-6 µg/L. This is a favorable reduction in the blue-green algae and more treatment may be recommended in future years.

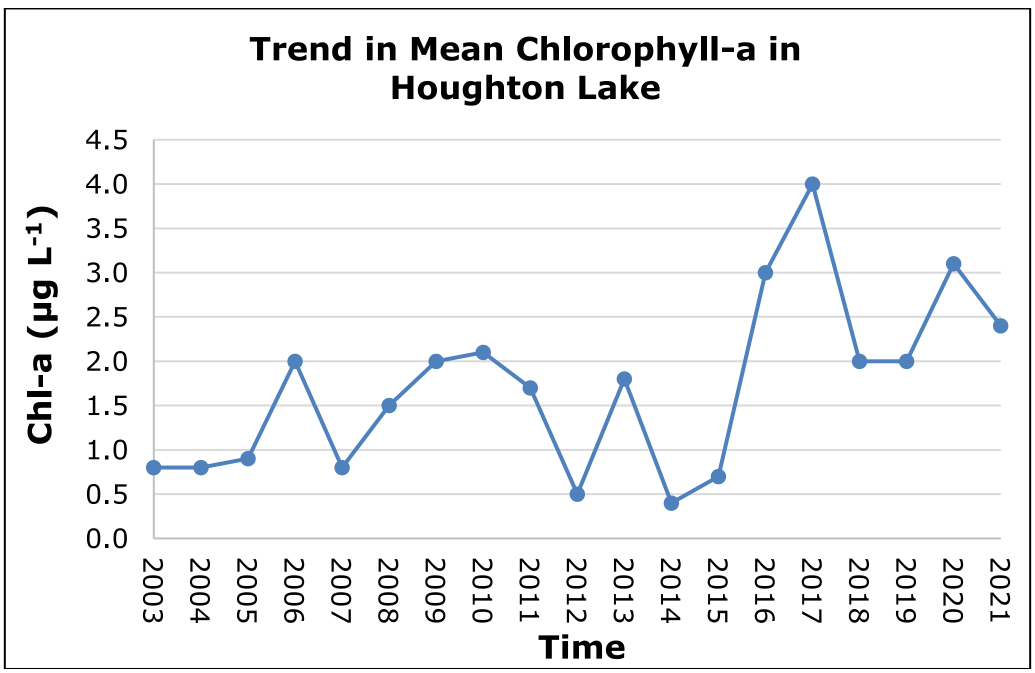

Figure 8. Changes in mean Chl-*a* with time in Houghton Lake.

Section

3

Aquatic Vegetation Data (2021)

Status of Native Aquatic Vegetation in Houghton Lake

The native aquatic vegetation present in Houghton Lake is essential for the overall health of the lake and the support of the lake fishery. The June 9-17 2021 whole-lake survey using the GPS Point-Intercept method as in Figure 9 below determined that there were a total of 28 native aquatic plant species in Houghton Lake. These included 19 native submersed species, 3 floating-leaved species, and 6 emergent species. This indicates a very high biodiversity of aquatic vegetation in Houghton Lake that may change each year due to climate and germination conditions. The overall % cover of the lake by native aquatic plants has been low relative to the lake size due to the great mean depth and thus these plants should be protected. The overall aquatic vegetation biovolume has increased in 2021 which is a positive sign that more low-growing native aquatic plants are thriving. The aquatic plant species found in the main open waters of the lake are shown below in Table 13. Aquatic vegetation biovolume is displayed in Figure 10 below.

The EWM was significantly reduced in the Middle Grounds after the ProcellaCOR® treatment in 2019-20; however, the systemic herbicide triclopyr (Renovate 3® at doses of 4-5 gallons per acre) was used in 2021 since the EWM significantly rebounded in the Middle Grounds and use of the same product was not recommended. The Wild Rice population in the Middle Grounds is showing signs of slow re-establishment and thus treatments in this area will continue to include protective buffer zones to allow for this establishment. The triclopyr treatment in the Middle Grounds was very successful given the high doses and site visits in August determined much of the milfoil was senescing.

The open waters of the lake are also quite diverse but have much less relative abundance than Middle Grounds. The most vegetated areas of open water in the lake include the southwest corner and Muddy Bay with some areas of density in North Bay. The milfoil in the North Bay has responded very well to treatments and native aquatic plants are increasing in that bay.

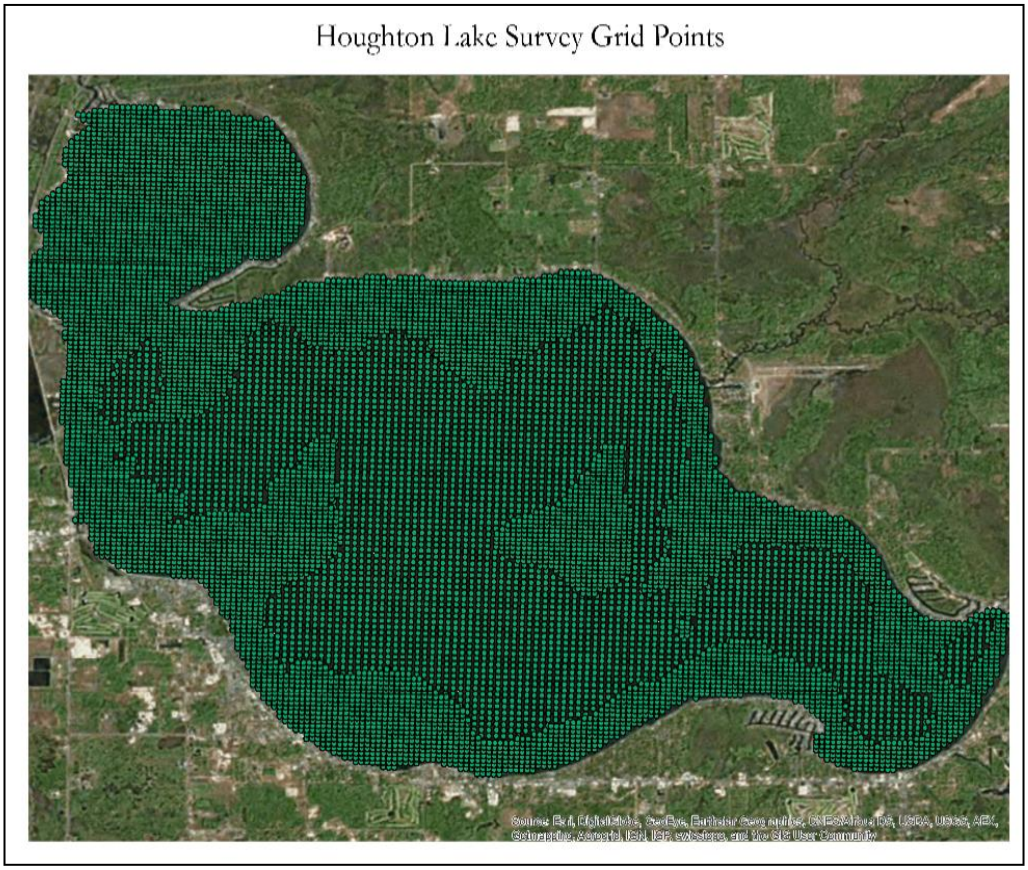

Figure 9. GPS Sampling Points in Houghton Lake (RLS).

Table 13. Aquatic plant species relative abundance (frequency) in the main portion of the lake with vegetation present excluding canals (June 9-17, 2021).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found (% of total)
Muskgrass	*Chara vulgaris*	2,427	846	85	12	31.0
Curly-leaf Pondweed	*Potamogeton crispus*	89	86	17	5	1.8
Thin-leaf Pondweed	*Stuckenia pectinatus*	11	5	2	1	0.2
Flat-stem Pondweed	*Potamogeton zosteriformis*	1	0	0	0	0.01
Fern-leaf Pondweed	*Potamogeton robbinsii*	2	0	0	0	0.02
Variable-leaf Pondweed	*Potamogeton gramineus*	12	0	0	0	0.1
White-stem Pondweed	*Potamogeton praelongus*	310	224	6	0	5.0
Clasping-leaf Pondweed	*Potamogeton richardsonii*	158	23	20	14	2.0
Illinois Pondweed	*Potamogeton illinoensis*	211	77	24	2	2.9
Large-leaf Pondweed	*Potamogeton amplifolius*	90	5	0	0	0.9
Floating-leaf Pondweed	*Potamogeton natans*	6	5	0	0	0.1
Slender Pondweed	*Potamogeton pusillus*	11	5	2	1	0.2
Wild Celery	*Vallisneria americana*	31	0	0	0	0.3
Northern Watermilfoil	*Myriophyllum sibiricum*	18	0	0	0	0.2
Coontail	*Ceratophyllum demersum*	1	0	0	0	0.01
Common Waterweed	*Elodea canadensis*	168	177	20	5	3.4
Bladderwort	*Utricularia vulgaris*	40	4	0	0	0.4
Southern Naiad	*Najas guadalupensis*	3	0	0	0	0.02
Brittle Naiad	*Najas minor*	4	0	0	0	0.04
Slender Naiad	*Najas flexilis*	1	0	1	0	0.02
Starry Stonewort	*Nitellopsis obtusa*	20	0	0	0	0.2
White Waterlily	*Nymphaea odorata*	2	0	0	0	0.02
Yellow Waterlily	*Nuphar varigata*	2	4	0	0	0.06
Watershield	*Brasenia schreberi*	1	0	0	0	0.01
Cattails	*Typha latifolia*	1	0	0	0	0.01
Swamp Loosestrife	*Decodon verticillata*	1	0	0	0	0.01
Bulrushes	*Schoenoplectus acutus*	4	5	0	0	0.08
Pickerelweed	*Pontedaria cordata*	1	0	0	0	0.01
Wild Rice	*Zizania aquatica*	27	1	0	0	0.3

Note: There were a total of 10,872 points surveyed in the main lake (excluding canals) and of those 4,334 contained aquatic plants (38% contained vegetation). The remainder of the points fall in deep water zones that lack vegetation.

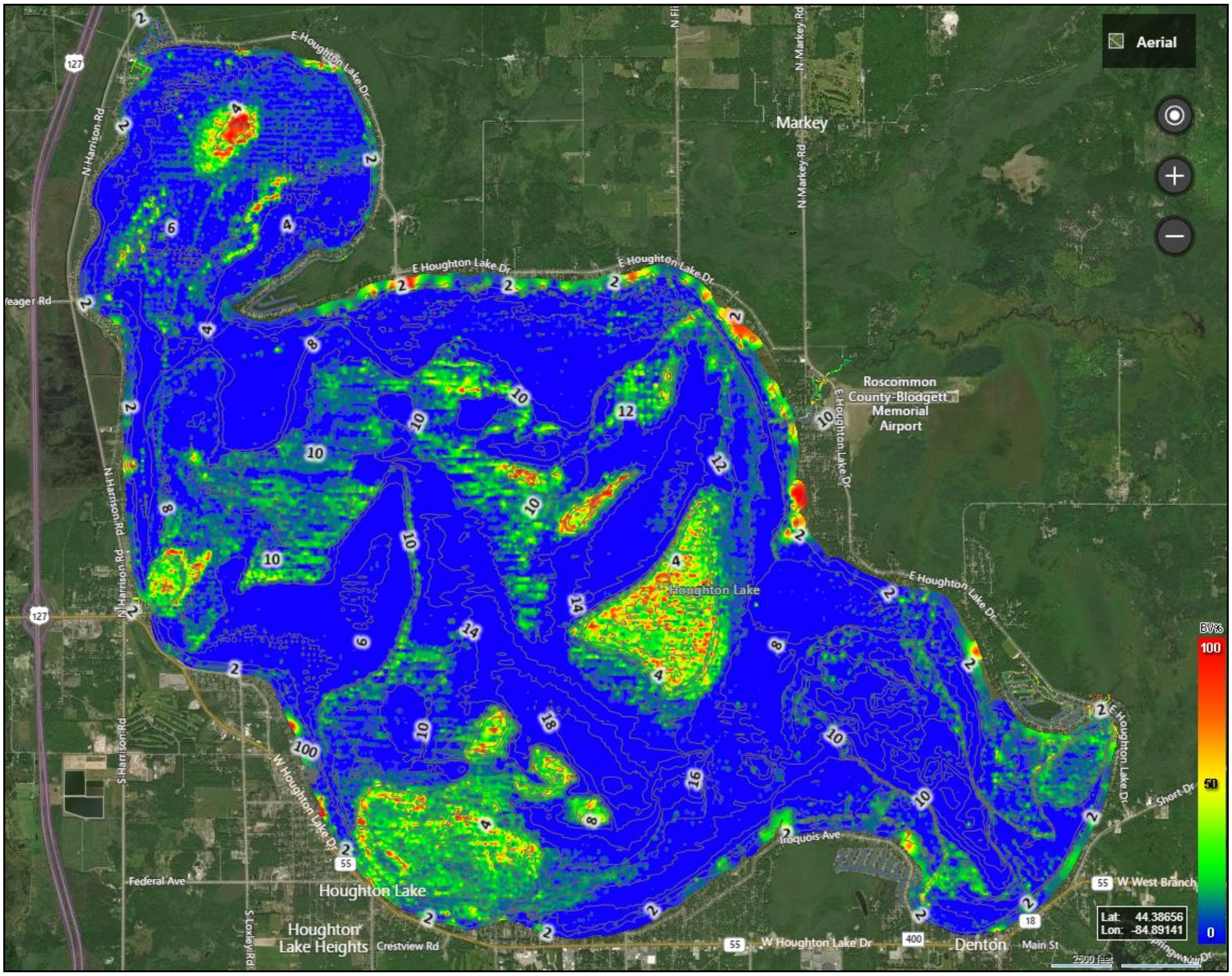

Figure 10. Aquatic vegetation biovolume scan and map of Houghton Lake in June/July, 2021 (RLS). NOTE: The blue color represents no vegetation present (previously this was displayed as blue and will be in the future); Red color represents tall, high-growing aquatic plants; Green color represents low-growing vegetation on the lake bottom such as Chara.

Status of Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (Figure 11) present in Houghton Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. The 2021 surveys revealed that a total of approximately 1,105 acres of milfoil were found throughout the entire lake and necessitated treatment. These areas were treated beginning on June 16, 2021 and ending August 31, 2021. Treatments were conducted by PLM with oversight by RLS. Figures 12-30 display areas of critical treatment areas in 2021. A summary table off all treatments and associated costs is shown below in Table 14. Table 15 below shows the history to date on the amounts of contact and systemic herbicides used in Houghton Lake for milfoil treatments and in some canals the use of contacts for extremely dense vegetation.

Table 14. Aquatic herbicide treatment summary of all areas treated and dates, products used, and associated costs.

Date	Products/Locations Used	# Acres	Cost
2-23-2021	2021 EGLE Permit Fee	NA	$1,500
6-15-2021	Flumioxazin treatment-canals 200 ppb	16	$8,240
	Flumioxazin/Diquat canals 100 ppb	16	$5,840
	Algae Treatment SeClear (Canals)	1	$212.50
6-16-2021	EWM-Inside Middle Grounds w/ Ren 3(4 gal/acre) + diquat (0.5 gal/acre)	400	$150,200
	EWM-Outer Rim Middle Ground w/Ren 3 (5 gal/acre) + diquat (0.5 gal/acre)	100	$45,350
6-24-2021	Flumioxazin treatment-canals 200 ppb	2.25	$1,158.75
	Flumioxazin treatment canals-100 ppb/diquat	7.5	2,737.50
7-8-2021	Phoslock treatment of McKinley Canal #5	0.5	$6,250
	Treatment of canals-diquat	1.0	$230
	Flumioxazin treatment of canals-200 ppb	2.5	$1,287.50
	Harvesting of BeBee and Porath Canals	1.0	$2,500
7-14-2021	EWM North and East Bay Treatment-Sculpin G @$240 lbs./acre	50	$28,500
	Brad and Chris Canal Algae treatment w/Se Clear	3.25	$406.25
8-2-2021	Phoslock treatment of McKinley #5 Canal	0.5	$6,250
8-24-2021	EWM SW Main Lake w/ Sculpin G #240 lbs./acre	65	$37,050
	Lyman's Resort Canal-flumioxazin treatment 200 ppb	0.75	$386.25
8-31-2021	SW EWM treatment w/ Ren 3 @5 gal/acre + diquat (0.5 gal/acre)	490	$222,215
9-16-2021	Houghton Lake Heights Marina flumioxazin treatment (200 ppb)	1.5	$772.50
			$521,086.25

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Figure 11. Eurasian Watermilfoil with seed head and lateral branches.

Figure 12. SW Bay Treatment Areas

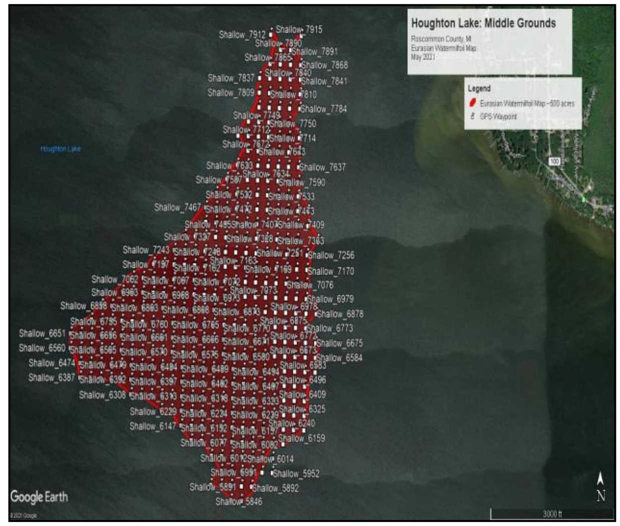

Figure 13. Middle Grounds Treatment Areas

Figure 14. North Bay Treatment Areas

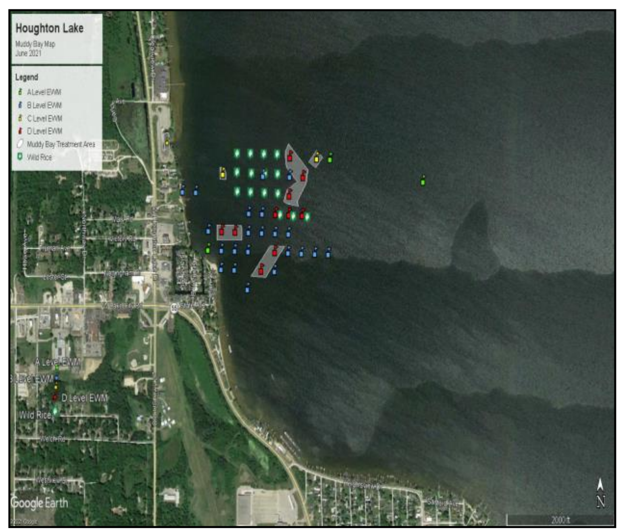

Figure 15. Muddy Bay Treatment Areas

Figure 16. East Bay Treatment Areas

Figure 17. Beebe Canal Treatment Areas

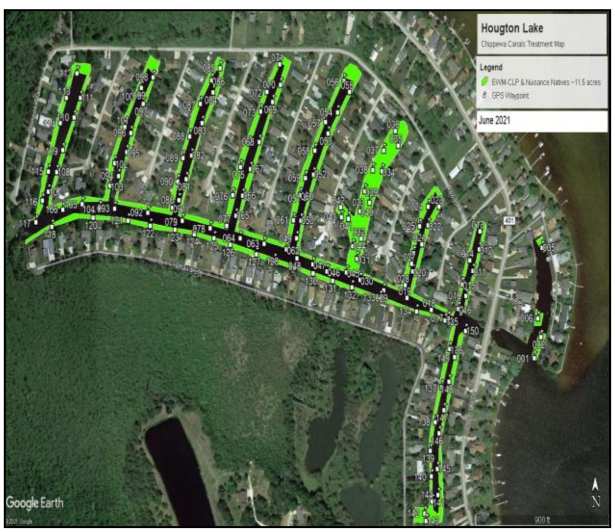

Figure 18. Chippewa Canal Treatment Areas

Figure 19. Long Point Canal Treatment Areas

Figure 20. Fox Canal Treatment Areas

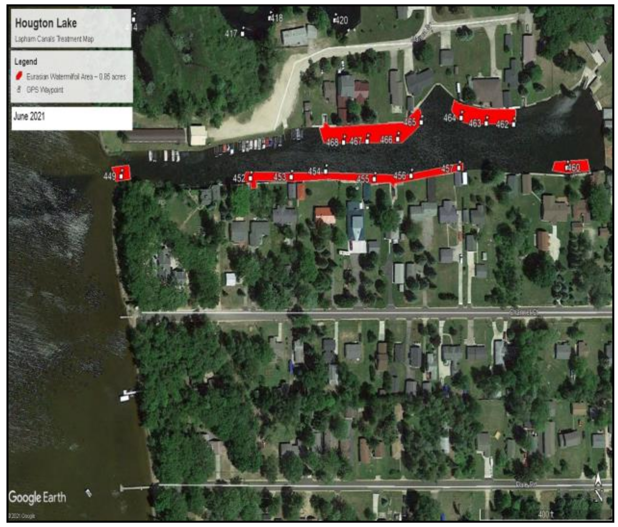

Figure 21. Lapham Canal Treatment Areas

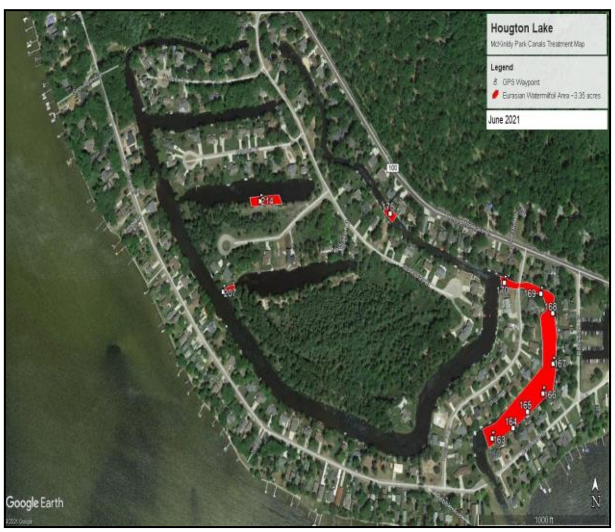

Figure 22. McKinley Canal Treatment Areas

Figure 23. Siebert Canal Treatment Areas

Figure 24. Cut River Treatment Areas

Figure 25. Church Canal Treatment Areas

Figure 26. Muskegon River Treatment Areas

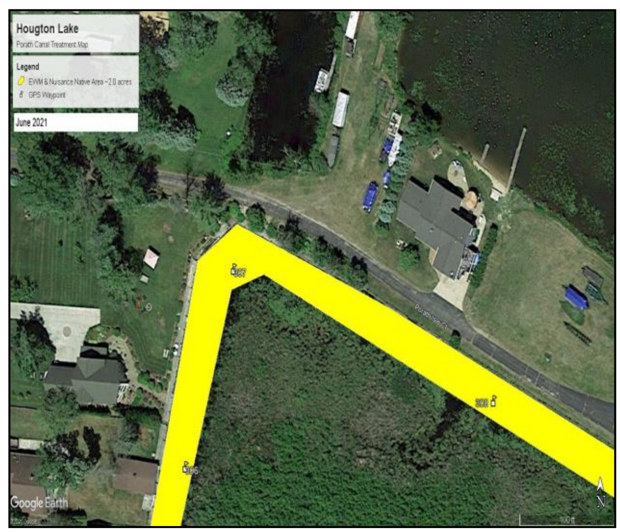

Figure 27. Porath Canal Treatment Areas

Figure 28. Birchcrest Canal Treatment Areas

Figure 29. Cains Canal Treatment Areas

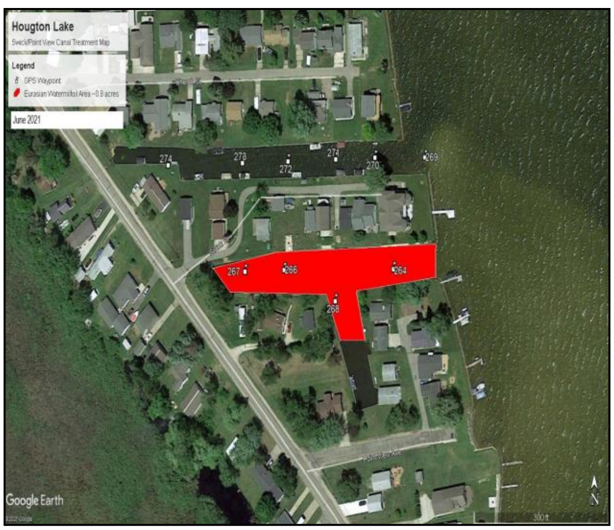

Figure 30. Swick Canal Treatment Areas

Table 15. Houghton Lake invasive aquatic plant treatment history to date (2002-2021). Note: This includes treatments in all canals and 2021 required rigorous treatment of some canals with algaecides and contacts to address dense algae along with EWM. Note: In 2021, Phoslock was also used in the McKinley Canal system to reduce blue-green algae.

Year	# Acres Sonar	# Acres Contacts	# Acres Systemics	# Acres Harvested	# Milfoil Weevils Stocked
2002	20,044	17	--	--	--
2003	--	--	32	--	--
2004	--	--	44	81	5,000
2005	--	50	395	84	28,000
2006	--	59	444	105	--
2007	--	106	660	--	30,000
2008	--	20	1,310	35	--
2009	--	40	1,751	--	--
2010	--	39	558	--	--
2011	--	42	1,747	--	--
2012	--	84	1,237	--	--
2013	--	49	1,902	--	--
2014	--	51	1,054	--	--
2015	--	65	600	--	--
2016	--	450	499	--	--
2017	--	0.3	434	8.75	--
2018	--	16.7	875	8.75	--
2019	--	13.9	734	--	--
2020	--	110	351	--	--
2021	--	53	1,105	1.0	--

Section

4

Houghton Lake Sediment Aquatic Macroinvertebrates

RLS scientists collected sediment macroinvertebrate communities from the North Bay, Central Basin, and South Bay on October 26, 2021 so they may be compared to earlier sample data and also determine the existing biodiversity of taxa that contribute to the ecological balance of Houghton Lake. Tables 16-18 list all of the aquatic macroinvertebrates found during the sampling.

A previous study on the Houghton Lake macroinvertebrate community determined that the total number of macroinvertebrate taxa declined from 19 in 1973 to 9 by 1995-1996. The October 2021 samples demonstrated 11 different taxa in the lake sediments and this number is likely to fluctuate among seasons due to changes in environmental and climatic conditions. Thus, future preservation is important since these organisms support the lake food chain and fishery. In 2021, the Central Basin had the highest macroinvertebrate count followed by the North Basin. Taxa found in the samples included:

1. Pond snails
2. Mayfly larvae
3. Sow bugs
4. Wheel snails
5. Dragonfly larvae
6. Midge larvae
7. Caddisfly larvae
8. Flatworms
9. Crane fly larvae
10. Damselfly larvae
11. Predaceous water beetles

A macro found Houghton Lake in 2021.

Table 16. Houghton Lake sediment macroinvertebrate sampling data from the North Bay (October 26, 2021).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	4	Crane fly larvae
		Ephemeroptera	Ephemerillidae	2	Mayfly larvae
		Planaria	Planariidae	2	Flatworms
		Diptera	Chironomidae	23	Midge larvae
		Gastropoda	Physidae	1	Pond snails
		Coleoptera	Dytiscidae	1	Predaceous water beetle
		Gastropoda	Planorbidae	10	Wheel Snails
			Total	**43**	
Sample 2	**Grab**	**Order**	**Family/Genus**	**Number**	**Common Name**
		Gastropoda	Physidae	9	Pond snails
		Ephemeroptera	Ephemerillidae	2	Mayfly larvae
		Isopoda	Asellidae	8	Sow bugs
		Diptera	Tipulidae	2	Crane fly larvae
		Gastropoda	Planorbidae	15	Wheel snail
		Odonata	Calopterygidae	1	Damselfly larvae
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	16	Midge larvae
			Total	**55**	

Table 17. Houghton Lake sediment macroinvertebrate sampling data from the Central Basin (October 26, 2021).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	6	Crane fly larvae
		Ephemeroptera	Ephemerillidae	4	Mayfly larvae
		Isopoda	Asellidae	6	Sow bugs
		Planaria	Planariidae	1	Flatworms
		Diptera	Chironomidae	18	Midge larvae
		Gastropoda	Physidae	6	Pond snails
		Gastropoda		14	Wheel Snails
			Total	**55**	
Sample 2	**Grab**				
		Gastropoda	Physidae	8	Pond snails
		Ephemeroptera	Ephemerillidae	2	Mayfly larvae
		Diptera	Tipulidae	2	Crane fly larvae
		Isopoda	Asellidae	7	Sow bugs
		Gastropoda	Planorbidae	9	Wheel snail
		Odonata	Calopterygidae	4	Damselfly larvae
		Planaria	Planariidae	1	Flatworm
		Diptera	Chironomidae	15	Midge larvae
			Total	**48**	

Table 18. Houghton Lake sediment macroinvertebrate sampling data from the South Basin (October 26, 2021).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	3	Crane fly larvae
		Gastropoda		14	Wheel Snails
		Ephemeroptera	Ephemerillidae	1	Mayfly larvae
		Diptera	Chironomidae	13	Midge larvae
		Gastropoda	Physidae	6	Pond snails
		Trichoptera	Phryganeidae	1	Caddis fly larvae
		Isopoda	Asellidae	11	Sow Bugs
			Total	**49**	
Sample 2	**Grab**				
		Gastropoda	Physidae	6	Pond snails
		Ephemeroptera	Ephemerillidae	1	Mayfly larvae
		Gastropoda	Planorbidae	11	Wheel snail
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	13	Midge larvae
			Total	**33**	

Section

5

Wild Rice Restoration and 2021 Update:

RLS accompanied Dr. Scott Herron from Ferris State University on September 22, 2020 to a 50-acre area of Muddy Bay to complete the initial planting of Wild Rice in that region. Conditions in the Muddy Bay region were ideal for Wild Rice with shallow depths and highly organic bottom substrate. A total of 108 geo-referenced GPS points were recorded and randomly selected from within the 50-acre area for data recording (Figure 20). A total of 22 bags of Wild Rice were carefully hand-tossed into the water and the seeds made fast contact with the lake bottom. A follow-up survey of this seeded area occurred on May 17, 2021 to carefully monitor the efficacy of the Wild Rice planting. Table 19 below displays the data collected which includes the presence of 7 native submersed aquatic plants in addition to the emergent Wild Rice. Wild Rice was the most dominant aquatic plant present, occupying around 98.8 % of the sampling sites. This was a very successful germination, and it will be re-surveyed in 2022 to determine if more seeding is needed.

Figures 21-24 demonstrate some of the project highlights to date.

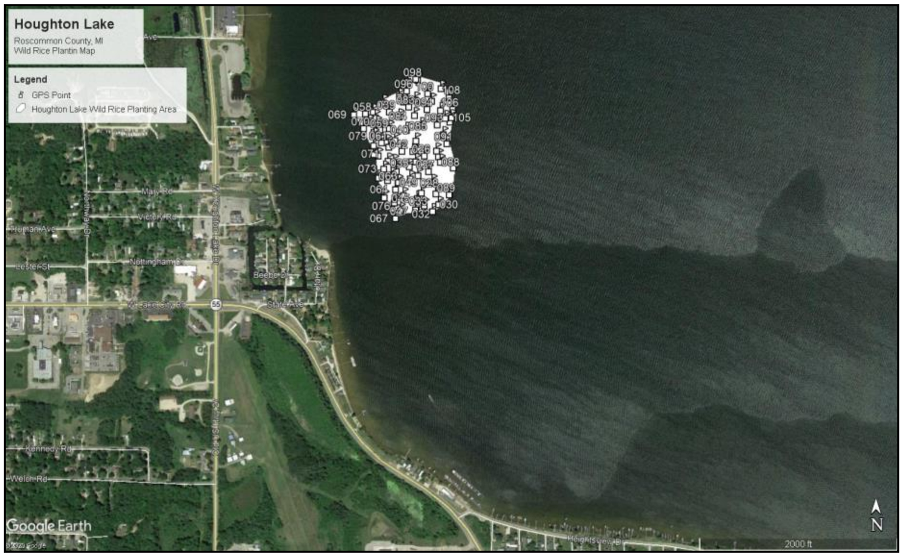

Figure 31. Wild Rice Planting and sampling locations in Muddy Bay (September, 2020).

Figure 32. Wild Rice being collected for the Houghton Lake replanting project (September, 2020).

Figure 33. Wild Rice bags used to retain the rice prior to Planting (September, 2020).

Figure 34. Blessing of the rice prior to planting (September, 2020).

Figure 35. Wild Rice (Manoomin) seed (September, 2020).

Table 19. Aquatic vegetation survey data for the Wild Rice seeded area of Muddy Bay on May 17, 2021.

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found (% of N=80 sites)
Muskgrass	*Chara vulgaris*	2	2	0	0	5.0
Curly-leaf Pondweed	*Potamogeton crispus*	21	19	9	0	61.3
Flat-stem Pondweed	*Potamogeton zosteriformis*	1	0	0	0	1.3
White-stem Pondweed	*Potamogeton praelongus*	1	0	0	0	1.3
Illinois Pondweed	*Potamogeton illinoensis*	12	17	0	0	36.3
Common Waterweed	*Elodea canadensis*	3	1	0	0	5.0
Southern Naiad	*Najas guadalupensis*	0	1	0	0	1.3
Wild Rice	*Zizania palustris*	4	48	27	0	98.8

Figure 36. Photo of Wild Rice establishment prior to emergence (May 17, 2021).

Section

6

Management Recommendations for 2022-2026

RLS has recommended the following management activities for 2022-2026 as critical components for a continuing lake improvement (management) program. The primary and secondary goals of these management activities are shown below in Table 20.

1. Whole-lake Aquatic Vegetation Surveys & Scans:

Continued aquatic vegetation surveys are needed to determine the precise locations of Eurasian Watermilfoil (EWM) Curly-leaf Pondweed (CLP), Starry Stonewort, or other problematic invasives in or around Houghton Lake and in the canals as in past years. These surveys should include a whole lake inventory in late June-early July 2022-2026 and partial surveys post-treatment as needed. The canals and Middle Grounds as well as the Southwest regions of the lake may require earlier surveys beginning in mid to late May, depending on climatic conditions. Scientists from RLS will be present to oversee all aquatic herbicide treatments in 2022 as in previous years. Treatment results will then be compared with previous years in the 2022 annual lake report.

2. Aquatic Herbicide Treatments for Invasive Species in the Main Lake and Canals:

Due to the relative scarcity of native aquatic vegetation in Houghton Lake, the treatment of these species with aquatic herbicides is not recommended and re-colonization of the lake by these species is a major goal for the current Houghton Lake management plan. The plan for 2022-2026 includes the use of high doses of systemic aquatic herbicides (such as triclopyr nearshore and 2, 4-D or ProcellaCOR® offshore) for the milfoil that may be present. Doses will be dependent upon the permit requirements as well as the size and density of the weed beds. Lower doses are used in the sensitive Middle Grounds area and in any areas where RLS finds Wild Rice during the whole-lake survey. Additionally, RLS will continue to individually evaluate previously treated ProcellaCOR® treatment areas and any new areas that may be added with that product.

Thus far, the ProcellaCOR® product has proven to be a very effective herbicide for controlling the density and relative abundance of EWM without reducing favorable native aquatic plant species. Use of it may be alternated with other products to allow for reduced probability of tolerance.

3. Phoslock Treatment of Select Canals:

The presence of toxic blue-green algal blooms is a threat to the health of some canals and pets that may drink from them. RLS recommended and evaluated the innovative product Phoslock® on the McKinley Canal System in 2021. Overall, the product showed significant reductions in blue-green algal concentrations. More treatment may be recommended in 2022 and beyond and RLS will continue to evaluate all canals that may need this treatment.

4. Benthic Barriers and Weed Rollers:

Both of these technologies are simple to install and may be used in nearshore areas to reduce and/or prevent germination of submersed aquatic vegetation in beach areas and around docks. They act to reduce germination of all aquatic plants and lead to a local area free of most aquatic vegetation. Benthic barriers may come in various sizes between 100-400 feet in length. They are anchored to the lake bottom to avoid becoming a navigation hazard. The implementation of a benthic barrier mat requires a minor permit from EGLE which can cost around $50-$100. The cost of the barriers varies among vendors but can range from $100-$1,000 per mat. Benthic barrier mats can be purchased online at: www.lakemat.com or www.lakebottomblanket.com. The efficacy of benthic barrier mats has been studied by Laitala et *al.* (2012) who report a minimum of 75% reduction in invasive milfoil in the treatment areas. Lastly, benthic barrier mats should not be placed in areas where fishery spawning habitat is present and/or spawning activity is occurring.

Weed Rollers are electrical devices which utilize a rolling arm that rolls along the lake bottom in small areas (usually not more than 50 feet) and pulverizes the lake bottom to reduce germination of any aquatic vegetation in that area. They can be purchased online at: www.crary.com/marine or at: www.lakegroomer.net.

5. Mechanical Harvesting in Select Areas:

The use of a mechanical harvesting machine may continue to be needed for problem areas with extremely dense aquatic vegetation such as the Beebe Canal or other canals. This method is often preferred when the quantity of biomass is so large that contact herbicides may cause an unacceptable decline in dissolved oxygen in the water column upon rapid decay. This may not be needed every year but will be evaluated on an as-needed basis. Permission is obtained from John Hanes with the Wastewater Treatment Authority to dump on their property. The exact location is the facility off of Knapp and Old HW27 on the SW end of Houghton Lake.

6. Wild Rice Re-colonization:

One of the objectives in the current Houghton Lake management plan was to re-colonize the North Bay with a healthy, viable population of Wild Rice (*Zizania aquatica*). Previous presentations from Dr. Scott Herron from Ferris State University recommended that Muddy Bay would also be a favorable area for planting. RLS worked with Dr. Herron on the restoration of Wild Rice in Muddy Bay in 2020 evaluations in 2021 showed great success with germination. RLS is actively working on a scientific publication/peer-reviewed paper with Dr. Herron on this project as it contributes to lake restoration efforts and will share with the community and HLIB when completed.

7. Boat Washing Stations:

RLS has recommended installation of boat washing stations at all points of entry to reduce the presence of invasive species into and out of Houghton Lake. Although this equipment is not patrolled regularly, it is of benefit if it is available for use. The HLIB and HLA are working together to determine the average use of each station and plans to promote increased use over time. This technology in an important tool for reducing herbicide treatment costs in the future.

8. Water Quality & Macroinvertebrate Monitoring:

Water quality parameters from the lake will also be monitored and graphed with historical data annually to observe long-term trends. In addition, water quality from the canals and tributaries will also be sampled. RLS will use that data to make any necessary recommendations for additional BMPs (best management practices) if needed.

The data collected to date have provided RLS and the HLIB with assurance that the lake is in overall good health. Sediment macroinvertebrates are good indicators of lake health and regular assessments allow for determination of lake health over time.

9. Educational Outreach for Houghton Lake:

RLS continues to assist the HLIB with an educational strategy to assist the Houghton Lake community with learning how to preserve and protect Houghton Lake. In 2019-2021, an educational ad campaign was released with the assistance of Spectrum® which was broadcast on local channels. RLS received feedback from many residents that the campaign was effective at raising awareness. RLS will continue to assist the HLIB with other educational opportunities with a community-wide workshop highly recommended for 2023 and 2025.

Table 20. Primary and Secondary Management Goals and Activities for each year of the 2022-2026 Houghton Lake Improvement Program.

Lake Management Activity	Primary Goal	Secondary Goal	Best Locations to Use
Aquatic herbicide treatment of hybrid milfoil	To reduce areas where the milfoil is prominent	To prevent dense areas from spreading in the lake	Main lake & canals
Aquatic Herbicide treatment of Starry Stonewort	To reduce areas where it is dense	To prevent plant from carpeting lake bottom	Main lake & canals
Mechanical Harvesting	Reduce dense areas in problem canals	Reduce DO depletion in canals	Canals
Benthic Barriers/Weed Rollers	To prevent germination of nuisance weeds in beach areas or canals	To reduce dependency on chemicals in nearshore areas	Beach areas, canals
Wild Rice Cultivation	To allow for new growth of Wild Rice in previously colonized areas	To increase biodiversity of native aquatic vegetation	Middle Grounds, North Bay, Muddy Bay
Phoslock® of canals	To reduce presence of blue-green blooms in problem canals	To reduce nutrients that exacerbate blue-green blooms	Canals (especially MKP-5 canal system)
Lake Vegetation Surveys/Scans	To determine % cover by invasives and use as data tool for management	To compare year to year reductions in invasive vegetation areas	Main lake, canals
Boat Washing Stations	To clean boats of invasives before entering the lake	To educate boaters on the proper cleaning of boats and on invasives	All points of access as funding becomes available
Water Quality Lake & Tributary Monitoring	To troubleshoot areas that have poor water quality	To compare trend in water quality parameters with time	Main Lake, canals, tributaries
Macroinvertebrate Sampling	To determine changes in community structure as food source annually	To determine if herbicides have an impact on populations	Areas consistently sampled annually in main lake
Educational Outreach	To educate riparians and lake users on current lake health	To promote citizen lake protection	Proposed workshops in 2023 and 2025

Proposed Cost Estimates for Houghton Lake Improvements

The proposed aquatic vegetation management program for the improvements of Houghton Lake would begin during the 2022 season and continue through 2026. This proposed scope is similar to the scope recommended during the first feasibility evaluation in 2017 but includes funding of boat washing stations and Wild Rice restoration.

The reduction in acres of watermilfoil and Starry Stonewort would likely follow in 2022 and beyond and thus that portion of the annual budget may be spared, and a surplus may continue in future years. The line items including the contact herbicides and permit fees will likely exist annually due to the temporary nature of contact herbicides on overly dense aquatic plants in canals that are not in need of harvesting.

A breakdown of estimated costs associated with the various necessary treatments in Houghton Lake is presented in Table 21. It should be noted that proposed costs are estimates and may change in response to changes in environmental conditions (i.e., increases in aquatic plant growth or distribution, or changes in herbicide costs or other market costs). The annual project costs were calculated with current costs along with a 15% per year contingency as required by PA 451. Additionally, the annual assessment is estimated by dividing the estimated total annual costs by 4,568 units of benefits as previously determined for the SAD. The HLIB must adopt an annual budget for each year of the program.

Table 21. Proposed Houghton Lake improvement costs for the five year program.

Proposed Houghton Lake Management Improvement Item	*Estimated 2022 Cost*	*Estimated 2023 Cost*	*Estimated 2024-2026 Cost*
Herbicides for Hybrid Watermilfoil and Starry Stonewort and/or DASH Boat removal of invasives, Permit Fees	$550,000	$550,000	$580,000
Professional Limnologist Services (limnologist surveys, sampling, contractor oversight, education)	$70,000	$70,000	$75,000
Attorney Fees	$2,500	$2,500	$2,500
Assessment Roll Mgmt	$4,000	$4,000	$4,000
Board Audit	$3,400	$3,400	$3,400
Conferences	$1,000	$1,000	$1,000
Insurance	$2,600	$2,600	$2,600
Memberships	$200	$200	$200
Printing/Publishing	$4,000	$4,000	$4,000
Board Secretary	$4,200	$4,200	$4,200
Board Treasurer	$3,000	$3,000	$3,000
Office Supplies & Rent	$2,100	$2,100	$2,100
Publications/Postage	$3,250	$3,250	$3,250
Refunds	$500	$500	$500
Travel Expenses	$250	$250	$250
Boat Washing Support	$20,000	$20,000	$20,000

TV/Radio	$12,000	$12,000	$12,000
Wild Rice Restoration	$10,000	$10,000	$10,000
Contingency (15%)	$104,970	$104,970	$110,220
TOTAL ANNUAL ESTIMATED COST	$796,950	$796,950	$837,200
APPROX. ANNUAL COST PER UNIT OF BENEFIT	$174.46	$174.46	$183.27

Economic Impact Report on the local tax structure and the effects on local government:

The Houghton Lake Improvement Board ("Board") is considering a proposed five (5) year assessment period that would extend from 2022 through 2026. The proposed assessment for 2022 would be up to $200.00 per one (1.0) unit of assessment, with the amounts for the successive years (2023 through 2026) to be determined each year, but not to exceed $200.00 per one (1.0) unit of assessment per year. Non-commercial backlot (Tier 2) parcels would be assessed at fifty percent (50%) of that amount at $100 (i.e., 0.5 unit of assessment) and commercial property would be assessed according to Table 22 below, along with other property classifications. The annual assessed amounts would be placed on the late season tax bill for each benefited parcel.

The Board develops its own budget, hires a consultant to survey and oversee projects, and an herbicide applicator to address identified problems. The Board meets approximately 5-7 times each year to administer the program and has an elected Chair, Vice-Chair, Treasurer and Secretary. The Board was formed under Part 309 (Inland Lake Improvements) of Act 451 of 1994 (the Natural Resources and Environmental Protection Act) ("Act"). The Board's makeup was established in the Act.

Four Townships (Lake, Roscommon, Markey, and Denton) surround Houghton Lake. Archives are located at the Roscommon Township hall. The HLIB writing checks on behalf of the Board and obtains an annual audit of the HLIB along with securing of proper insurance. All Townships also host meetings of the Board.

Each municipality does its own assessing. There are no anticipated additional assessment costs due to the Board's activities.

The economic impacts on the four (4) municipalities is very limited in scope and would be considered nominal. The benefit derived from the Board's actions is a much improved lake with significant increase in navigability, fewer invasive weeds, increased biodiversity, better water quality and enhanced fisheries, and protection of property values and municipal tax base. This results in a lake with sustainable property values, increased tourism, and economic conditions that support the tax base.

Table 22. Houghton Lake Improvement Board assessment criteria for the proposed 2022-2026 improvement program.

Parcel Type	Unit of Benefit	Category	2022-2026 assessment amount
Waterfront Residential	1.0 unit	1MF1	$200
Waterfront Canal/River	1.0 unit	1MF2	$200
Back Lot Residential	0.5 units	1MF5	$100
Waterfront Condominium/ Association Complexes	1.0 unit per condominium unit or dwelling unit	1MF3	$200
Back Lot Condominium/Association Complexes	0.5 units per condominium unit or dwelling unit	1MF3	$100
Commercial Waterfront	2.0 units	1MF4	$400
Commercial Back Lot	1.0 Unit	1MF6	$200
Marinas	2.0 Units (base assessment for 20 slips or less) + 1.0 unit for each additional 20 boat slips	1MF3	$400 Plus $200 for each additional 20 boat slips
Waterfront Hotels/Cabins/Mobile Homes/Apartments	2.0 units (base assessment for 10 units or less), + 1.0 unit for each additional 10 rental rooms/units	1MF3	$400 Plus $200 for each additional 10 rental room/units
Back Lot Hotels/Cabins/Mobile Homes/ Apartments	1.0 Unit (base assessment for 10 or less units) + 0.5 units for each additional 10 rental rooms/units	1MF3	$200 Plus $100 for each additional 10 rental room/units
Waterfront Campgrounds	2.0 units (base assessment for 20 sites or less) + 1.0 unit for each 20 additional sites.	1MF3	$400 Plus $200 for each additional sites
Back Lot Campgrounds	1.0 Unit (base assessment for 20 sites or less) + 0.5 units for each 20 additional sites.	1MF3	$200 Plus $100 for each additional 20 sites
Boat Storage Facilities	2.0 Units		$400

(less than 10 acres)		1MF3	
Boat Storage Facilities (More than 10 acres)	4.0 Units	1MF3	$800
Golf Courses (9-hole)	1.0 Unit	1MF6	$200
Golf Courses (18- hole)	2.0 Units	1MF6	$400