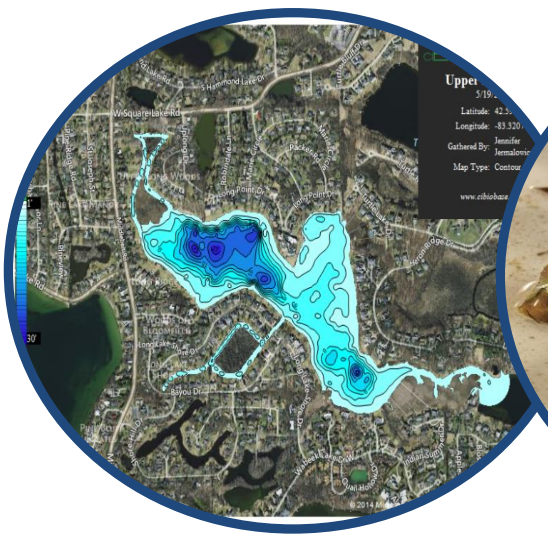
Upper Long Lake "State of the Lake" (2017) Report & 2018 Management Recommendations



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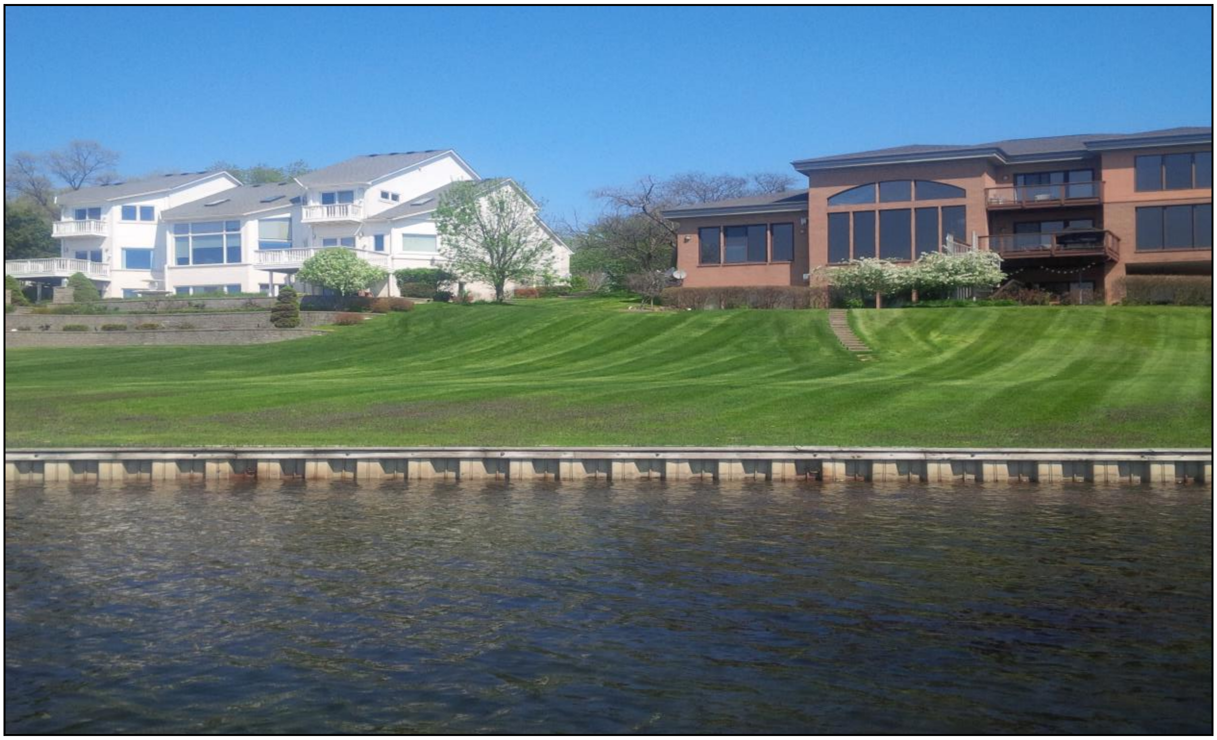

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Section 1

Upper Long Lake "State of the Lake" Summary

The following information is a summary of key lake findings collected during the 2017 season.

The overall condition of Upper Long Lake is ranked in the top 45% of developed lakes of similar size in the state of Michigan. The water clarity is between 6 feet at the lowest and just under 14.5 feet at the highest (as was observed in 2017). Much of this clarity is due to filtration of the water by Zebra Mussels that have expanded in the lake. These mussels have a cyclic population dynamic and will increase and decline from year to year which will cause differences in clarity. Increased runoff from storms and rains can also reduce water clarity.

Upper Long Lake has enough nutrients (phosphorus and nitrogen) to support some algae and submersed aquatic plant growth. Invasive species such as Eurasian Watermilfoil (EWM), Curly-leaf Pondweed (CLP), and Starry Stonewort are able to grow in moderate nutrient waters and thus are a challenge to the Upper Long Lake ecosystem. A mechanical harvesting program has been implemented on the lake to reduce the dense stands of milfoil and is executed throughout the growing season.

Protection of the 24 native aquatic plant species is paramount for the health of the lake fishery and these plants should not be managed unless they are a nuisance to lakefront property owners and possess navigational and recreational hazards.

The lake did not experience depletion of dissolved oxygen with depth during late May sampling as it had not stratified yet but did by late September of 2017. Conductivity and total dissolved solids are very high and are of concern since both can stress aquatic life. The nutrients were low to moderate in spring but increase in mid to late summer due to release of nutrients under low oxygen concentrations. Additionally, the storm water issue needs to be addressed in the near future to reduce the solids and increased conductivity in the lake which can impair water quality.

Section

2

Upper Long Lake Water Quality Data (2017)

Water Quality Parameters Measured

There are hundreds of water quality parameters one can measure on an inland lake but several are the most critical indicators of lake health. These parameters include water temperature (measured in °F), dissolved oxygen (measured in mg/L also known as ppm), pH (measured in standard units-SU), conductivity (measured in micro-Siemens per centimeter-µS/cm), total dissolved solids (mg/L), secchi transparency (feet), total phosphorus and ortho-phosphorus (both in µg/L also known as ppb), chlorophyll-*a* (in µg/L), and algal species composition. Water quality is measured in the 3 deep basins of Upper Long Lake in spring and/or late summer of each year. Table 1 below demonstrates how lakes are classified based on key parameters. Upper Long Lake would be considered mesotrophic (relatively productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation growth but has fair to good water clarity and moderate algal growth. General water quality classification criteria are defined in Table 1. 2017 water quality data for Upper Long Lake is shown below in Tables 2-7.

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**

Table 2. Upper Long Lake water quality parameter data collected in deep basin #1 (May 11, 2017).

Depth ft.	*Water Temp ºC*	*DO mg/L*	*pH S.U.*	*Cond. µS/cm*	*TDS mg/L*	*Ortho-P mg/L*	*TSS mg/L*	*Total Phos. mg/L*
0	15.9	8.5	8.4	452	120	< 0.010	< 10	0.012
14	15.7	8.4	8.4	425	117	< 0.010	< 10	0.018
28	13.5	6.2	8.0	420	110	< 0.010	< 10	0.013

Table 3. Upper Long Lake water quality parameter data collected in the deep basin #2 (May 11, 2017).

Depth ft.	*Water Temp ºC*	*DO mg/L*	*pH S.U.*	*Cond. µS/cm*	*TDS mg/L*	*Ortho-P mg/L*	*TSS mg/L*	*Total Phos. mg/L*
0	15.8	8.3	8.4	420	121	< 0.010	< 10	<0.010
14	15.1	8.0	8.3	438	117	< 0.010	< 10	0.011
28	14.0	7.0	8.3	439	110	< 0.010	< 10	0.016

Table 4. Upper Long Lake water quality parameter data collected in the deep basin #3 (May 11, 2017).

Depth ft.	*Water Temp ºC*	*DO mg/L*	*pH S.U.*	*Cond. µS/cm*	*TDS mg/L*	*Ortho-P mg/L*	*TSS mg/L*	*Total Phos. mg/L*
0	15.9	8.1	8.4	450	122	< 0.010	< 10	0.013
8	15.1	7.9	8.4	440	117	< 0.010	< 10	0.013
16	14.3	6.5	8.1	420	116	< 0.010	22	0.037

Table 5. Upper Long Lake water quality parameter data collected in deep basin #1 (September 28, 2017).

Depth ft.	*Water Temp ºC*	*DO mg/L*	*pH S.U.*	*Cond. µS/cm*	*TDS mg/L*	*Ortho-P mg/L*	*TSS mg/L*	*Total Phos. mg/L*	*TKN mg/L*
0	22.4	7.9	8.5	695	298	< 0.010	< 10	0.018	0.7
14	22.2	7.2	8.7	695	272	< 0.010	< 10	0.015	0.7
28	19.9	3.1	8.6	691	293	< 0.010	< 10	0.027	0.7

Table 6. Upper Long Lake water quality parameter data collected in deep basin #2 (September 28, 2017).

Depth ft.	*Water Temp ºC*	*DO mg/L*	*pH S.U.*	*Cond. µS/cm*	*TDS mg/L*	*Ortho-P mg/L*	*TSS mg/L*	*Total Phos. mg/L*	*TKN mg/L*
0	23.1	7.7	8.8	689	300	< 0.010	< 10	0.019	0.8
14	23.0	7.6	8.7	690	294	< 0.010	< 10	0.011	0.9
28	19.3	1.5	8.6	682	281	< 0.010	< 10	0.029	0.9

Table 7. Upper Long Lake water quality parameter data collected in deep basin #3 (September 28, 2017).

Depth ft.	*Water Temp ºC*	*DO mg/L*	*pH S.U.*	*Cond. µS/cm*	*TDS mg/L*	*Ortho-P mg/L*	*TSS mg/L*	*Total Phos. mg/L*	*TKN mg/L*
0	23.1	7.4	8.7	688	286	< 0.010	< 10	0.013	1.0
8	22.9	6.7	8.6	687	284	< 0.010	< 10	0.017	0.8
16	18.9	0.8	8.5	684	296	< 0.010	62	0.047	2.4

Water Clarity (Transparency) Data

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Upper Long Lake is adequate to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake. Since 2010, the water clarity has been higher than 6.0 feet and approaching 15.0 feet (data provided by Stephen George and RLS) due to filtration by Zebra Mussels. On May 11, 2017, the Secchi transparency was approximately 13.0 feet and on September 28, 2017, the Secchi transparency was around 14.5 feet. Secchi transparency is variable and depends on the amount 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; measured in mg/L) is correlated with water clarity and shows an increase as clarity decreases. The turbidity in Upper Long Lake has been quite low at less than 2.0 NTU's during each year sampled. The exception in 2017 was lake water sampled from the deep basin south which had elevated TSS readings in 2017 along with a turbidity value of 10.5 NTU's. This could either be due to re-suspension of sediments from the lake bottom or from storm water inputs in that region of the lake.

Total Phosphorus and 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 (which are present at the bottom of Upper Long Lake beginning in mid-summer). Phosphorus may also be released from sediments as pH increases. TP concentrations on May 11, 2017 ranged from <0.010-0.037 mg L^{-1} from top to bottom with the highest concentration recorded at the bottom of deep basin #3 (south). The TP concentrations on September 28, 2017 ranged from 0.013-0.047 mg L^{-1} from top to bottom which is higher than in May and also was highest at the bottom of deep basin #3 (south).

Ortho-phosphorus refers to the fraction of phosphorus that is bioavailable to aquatic life. Ortho-phosphorus concentrations on both May 11, 2017 and September 28, 2017 were all < 0.010 mg L^{-1} which is low and means that most of the TP present in the lake water column is not in the bioavailable form.

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). Upper Long Lake is considered "slightly basic" on the pH scale. The pH of Upper Long Lake on May 11, 2017 ranged from 8.0-8.4 S.U. which is ideal for an inland lake. The pH of the lake on September 28, 2017 ranged from 8.5-8.8 S.U. which is higher than in May due to increased photosynthesis of the lake vegetation which increases pH throughout the season.

Conductivity

Conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. The conductivity values for Upper Long Lake on May 11, 2017 were moderately high and ranged from 420-452 µS/cm. The conductivity values for the lake on September 28, 2017 ranged from 682-695 µS/cm. This means that increased storm water contributions that occur later in the season may also result in higher specific conductivity measurements. Severe water quality impairments do not occur until values exceed 800 µS/cm and are toxic to aquatic life around 1,000 µS/cm.

Total Dissolved and Suspended Solids

Total dissolved solids (TDS) refers to the amount of solids that are dissolved in the water column whereas Total suspended solids (TSS) refers to the amount of solids that are suspended in the water column. The TSS samples collected on May 11, 2017 ranged from < 10-22 mg/L which is good and low with the exception of the bottom sample at deep basin #3 (south). The TSS samples collected on September 28, 2017 ranged from < 10-62 mg/L which is also favorable except again for the bottom of deep basin #3 (south). Both the TDS and conductivity are of significant concern since they negatively impact the water quality of the lake. Storm water should be considered in future lake management endeavors.

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 chlorophyll-*a* concentrations in the 3 deep basins on May 11, 2017 ranged from 0-1.60 µg/L, which is favorable and means that algae was not overabundant in the water column. The chlorophyll-*a* concentrations in the 3 deep basins on September 28, 2017 ranged from 0-2.14 µg/L, which is also favorable but slightly higher than in May.

The algal genera were determined from composite water samples collected over the deep basin of Upper Long Lake in 2017 were analyzed with a compound bright field microscope. The genera present included the Chlorophyta (green algae): *Scenedesmus* sp., *Chlorella* sp., *Cladophora* sp., *Haematococcus* sp., *Mougeotia* sp., *Gleocystis* sp., *Pandorina* sp., *Radiococcus* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae): *Oscillatoria* sp., the Bascillariophyta (diatoms*): Synedra* sp., *Navicula* sp., *Fragilaria* sp., *Cymbella* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of alga with an abundance of diatoms that are indicative of great water quality.

Section

3

Aquatic Vegetation Data (2017)

Status of Native Aquatic Vegetation in Upper Long Lake

The native aquatic vegetation present in Upper Long Lake is essential for the overall health of the lake and the support of the lake fishery. The most recent surveys on May 11, 2017 and September 28, 2017 utilized 302 sampling points evenly spaced across the entire lake. The May 11, 2017 survey determined that there were a total of 21 native aquatic plant species in Upper Long Lake. These included 10 submersed species, 3 floating-leaved species, and 8 emergent species. The September 28, 2017 survey determined that there were a total of 24 species with 13 submersed, 3 floating-leaved, and 8 emergent aquatic plant species. This indicates a high biodiversity of aquatic vegetation in Upper Long Lake. In addition, it also demonstrates that not all native aquatic plant species are present by May 11, 2017. Thus, a vegetation survey is also needed later in the season. It is also obvious how much the current milfoil infestation has reduced the relative abundance of all native aquatic plant species.

The most common native aquatic plant species included the macro alga, Chara, which is light green, grows low to the lake bottom, and has a strong, skunky odor. Also common was Wild Celery, which has long, green, ribbon-like leaves and usually does not emerge high into the water column until late summer. The most common floating-leaved plant was Yellow Waterlily and the most common emergent plant was the Cattail.

Lists of all native aquatic plant species found in Upper Long Lake in May and September of 2017 are shown below in Tables 8 and 9.

Table 8. Upper Long Lake Native Aquatic Plant Species (May 11, 2017).

Native Aquatic Plant Species Name	*Aquatic Plant Common Name*	*Abundance in/around Upper Long Lake*	*Aquatic Plant Growth Habit*
Chara vulgaris	Muskgrass	2.8	Submersed, Rooted
Potamogeton pectinatus	Thin-leaf Pondweed	0.3	Submersed, Rooted
Potamogeton zosteriformis	Flat-stem Pondweed	0.0*	Submersed, Rooted
Potamogeton natans	Floating-leaf Pondweed	0.0*	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	0.0*	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	0.0*	Submersed, Rooted
Myriophyllum sibiricum	Northern Watermilfoil	0.1	Submersed, Rooted
Elodea canadensis	Common Waterweed	0.2	Submersed, Rooted
Ceratophyllum demersum	Coontail	0.0*	Submersed, Non-Rooted
Utricularia vulgaris	Bladderwort	0.0*	Submersed, Rooted
Najas guadalupensis	Southern Naiad	0.0*	Submersed, Rooted
Nymphaea odorata	White Waterlily	0.0*	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	0.0*	Floating-Leaved, Rooted
Lemna minor	Duckweed	0.0*	Floating-Leaved, Non-Rooted
Typha latifolia	Cattails	0.9	Emergent
Scirpus acutus	Bulrushes	0.0*	Emergent
Sagittaria sp.	Arrowhead	0.0*	Emergent
Decodon verticillatus	Swamp Loosestrife	0.0*	Emergent
Pontedaria cordata	Pickerelweed	0.0*	Emergent
Iris sp.	Iris	0.0*	Emergent
Arrow arum	Arrowhead	0.0*	Emergent
Eleocharis sp.	Spikerush	0.0*	Emergent

Table 8. Upper Long Lake Native Aquatic Plant Species (September 28, 2017).

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***Abundance in/around Upper Long Lake***	***Aquatic Plant Growth Habit***
Chara vulgaris	Muskgrass	6.1	Submersed, Rooted
Potamogeton pectinatus	Thin-leaf Pondweed	1.9	Submersed, Rooted
Potamogeton zosteriformis	Flat-stem Pondweed	0.7	Submersed, Rooted
Potamogeton natans	Floating-leaf Pondweed	0.4	Submersed, Rooted
Potamogeton gramineus	Variable-leaf Pondweed	0.3	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	0.6	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	0.5	Submersed, Rooted
Myriophyllum sibiricum	Northern Watermilfoil	0.2	Submersed, Rooted
Elodea canadensis	Common Waterweed	1.4	Submersed, Rooted
Ceratophyllum demersum	Coontail	0.2	Submersed, Non-Rooted
Vallisneria americana	Wild Celery	6.2	Submersed, Rooted
Utricularia vulgaris	Bladderwort	0.6	Submersed, Rooted
Najas guadalupensis	Southern Naiad	0.1	Submersed, Rooted
Nymphaea odorata	White Waterlily	0.2	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	0.2	Floating-Leaved, Rooted
Lemna minor	Duckweed	1.0	Floating-Leaved, Non-Rooted
Typha latifolia	Cattails	1.1	Emergent
Scirpus acutus	Bulrushes	0.3	Emergent
Sagittaria sp.	Arrowhead	0.2	Emergent
Decodon verticillatus	Swamp Loosestrife	0.1	Emergent
Pontedaria cordata	Pickerelweed	0.1	Emergent
Iris sp.	Iris	0.2	Emergent
Arrow arum	Arrowhead	0.2	Emergent
Eleocharis sp.	Spikerush	0.1	Emergent

Status of Invasive (Exotic) Aquatic Plant Species in Upper Long Lake:

The amount of Eurasian Watermilfoil and other invasives present in Upper Long Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. Images of the four invasive aquatic plant species found in and around Upper Long Lake are shown below in Figures 1-4. Although the emergent invasives are not common, the milfoil and Curly-leaf Pondweed are abundant each spring and both overlap in their distribution. Fortunately, both can be easily harvested since they often grow together. The Starry Stonewort may need chelated copper and contact herbicides or aeration to be effectively controlled if it spreads further into the lake. If not controlled, this plant can form dense hummocks on the lake bottom that may reach to the surface and create substantial navigation and recreational challenges.

Figure 1. Eurasian Watermilfoil (©RLS, 2006).

Figure 2. Curly-leaf Pondweed (©RLS, 2006).

Figure 3. Starry Stonewort (USGS photo).

Figure 4. Purple Loosestrife (©RLS, 2006).

Mechanical Harvesting of Milfoil in Upper Long Lake (2015-2017):

Throughout the past, a mechanical harvesting operation has been conducted on Upper Long Lake as an alternative to the use of aquatic herbicides. This method would require multiple harvests each season throughout the lake to reduce the dense stands of milfoil that grow very quickly and threaten recreational activities and the native aquatic plant biodiversity. Harvesting areas also include along the shoreline and in the canals. After harvesting operations are complete (i.e. September of each year), the native aquatic plant biodiversity begins to improve as is evidenced in the native aquatic plant tables above. The maps below (Figures 5-7) show the distribution of milfoil and the areas harvested in the past three years. Each spring, RLS surveys the lake for these locations and releases a harvesting map to the harvesting contractors. A post-harvest inventory is conducted later in the season to determine which native aquatic plants have rebounded and how the harvest has lasted relative to milfoil re-growth.

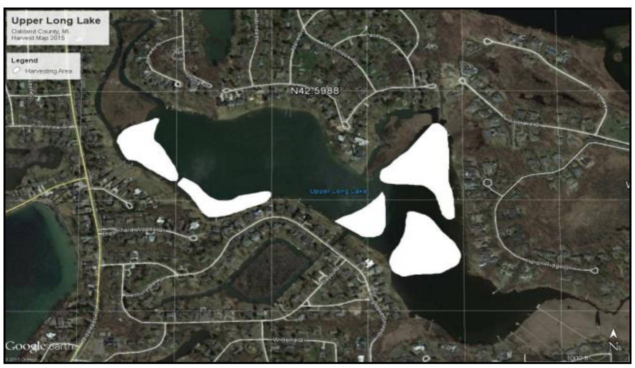

Figure 5. 2015 Harvesting Areas

Figure 6. 2016 Harvesting Areas

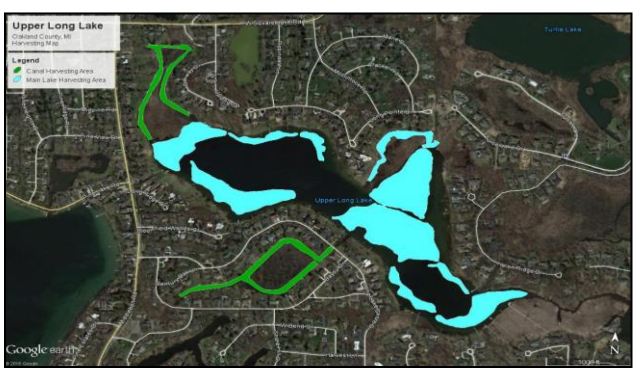

Figure 7. 2017 Harvesting Areas

Section

4

Management Recommendations for 2018

Continuous aquatic vegetation surveys are needed to determine the precise locations of EWM, Starry Stonewort, or other problematic invasives in and around Upper Long Lake. These surveys should occur in late-May to early-June and again post-harvest in 2018.

Due to the relative scarcity of many native aquatic vegetation in Upper Long Lake, the treatment of these species with aquatic herbicides is not recommended (one exception is the overgrowth of weeds in a few select areas of the canals if desired but these areas can also be harvested as in the past). The plan for 2018 includes the use of mechanical harvesting to remove excessive milfoil biomass.

RLS has collected multiple water quality parameters for further sampling of lake water quality. This testing, as in recent years, will also be conducted in 2018 and includes two sampling events with the following parameters: water temperature, dissolved oxygen as a profile through the water column, pH, conductivity, turbidity, total dissolved and suspended solids, ortho-phosphorus and phosphorus, secchi transparency, chlorophyll-a, and algal community composition. Based on the data above, there is some concern regarding storm water as the water quality at the bottom of the south deep basin #3 has shown increased phosphorus and solids. The conductivity of the lake also increases with increased storm events. RLS recommends a closer look into the storm water issue for the long-term protection of the lake.

Laminar flow aeration is still recommended but there have been some issues with securing compressor sites and increased costs associated with the program. RLS will provide any updated information in the Upper Long Lake Improvement Feasibility Study Report as it becomes available.

In conclusion, Upper Long Lake is a relatively healthy lake with very good aquatic plant biodiversity (but low relative abundance), good water clarity, moderate to high nutrients, and a healthy lake fishery. Management of the EWM, Starry Stonewort, and protection of the water quality are paramount for the long-term health of the lake.

Section

5

Glossary of Scientific Terms

1) Biodiversity- The relative abundance or amount of unique and different biological life forms found in a given aquatic ecosystem. A more diverse ecosystem will have many different life forms such as species.

2) $CaCO_3$- The molecular acronym for calcium carbonate; also referred to as "marl" or mineral sediment content.

3) Eutrophic- Meaning "nutrient-rich" refers to a lake condition that consists of high nutrients in the water column, low water clarity, and an over-abundance of algae and aquatic plants.

4) Mesotrophic- Meaning "moderate nutrients" refers to a lake with a moderate quantity of nutrients that allows the lake to have some eutrophic qualities while still having some nutrient-poor characteristics

5) Macrophyte- Meaning large plant or in this case a non-microscopic aquatic plant that can be easily seen with the naked eye.

6) Oligotrophic- Meaning "low in nutrients or nutrient-poor" refers to a lake with minimal nutrients to allow for only scarce growth of aquatic plant and algae life. Also associated with very clear waters.

7) Sedimentary Deposits- refers to the type of lake bottom sediments that are present. In some lakes, gravel and sand are prevalent. In others, organic muck, peat, and silt are more common.