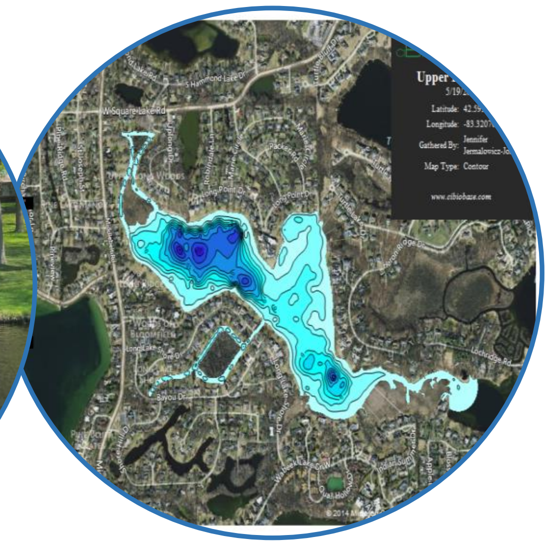
Upper Long Lake 4-Year Lake Management Plan
Oakland County, Michigan



Provided for: Upper Long Lake Management Committee

Prepared by: Restorative Lake Sciences
Jennifer L. Jermalowicz-Jones, PhD Candidate
Water Resources Director
18406 West Spring Lake Road
Spring Lake, Michigan 49456
www.restorativelakesciences.com

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September, 2014

1.0 EXECUTIVE SUMMARY

Upper Long Lake, comprising **121 acres**, is of glacial origin with nearly **3.2 miles of shoreline** and a mean **(average) depth of 9.7 feet and a maximum depth of 27.0 feet.** Based on the current study, Upper Long Lake contains a very high abundance of the **exotic submersed macrophyte hybrid Eurasian Watermilfoil** (*Myriophyllum sibiricum var. spicatum* L.). In previous years, this plant has been of great concern since it outcompetes favorable native biodiversity of aquatic vegetation and causes significant impairments in navigational and recreational activities. In addition, the plant possesses such high biomass that upon decay, it consumes large quantities of the limited dissolved oxygen (DO) from the Upper Long Lake water column. This decay also contributes to the accumulation of organic muck on the lake bottom that further increases the Biochemical Oxygen Demand (BOD) of the lake ecosystem. A high BOD means that the lake microbial (bacterial) community must work extra hard to reduce the organic material which reduces oxygen in the process. The lake loses DO sharply beyond a depth of 10 feet in mid to late summer. The decay of this organic material under low DO conditions is very slow and leads to more muck accumulation. **An urgent increase in the whole lake DO is needed and thus a whole-lake aeration system with supplemental aerobic bacteria is recommended. Prior to implementation of such as system, the use of the systemic herbicide Triclopyr is recommended in the spring of 2015 to reduce the hybrid milfoil growth. Fluridone (Sonar®) is not recommended due to the high frequency of it being used in the past and possible accumulative tolerance by the milfoil plants that could render the treatment ineffective.**

Laminar flow aeration has proven multiple benefits on over a dozen of lakes in Michigan. These benefits have included the increase of dissolved oxygen throughout the water column, decline in sediment muck depth and organic matter, reduction of water column nutrients, reduction of milfoil and some other nuisance species such as Sago Pondweed in some lakes, increase in beneficial algae such as diatoms (which supports a better fishery), increase in water clarity, and decrease in toxic blue-green algae and other forms of nuisance algae (planktonic, filamentous).

In addition to the milfoil, 4 other exotic aquatic plant species were noted and include Curly-Leaf Pondweed, Starry Stonewort, Purple Loosestrife, and Phragmites. Except for Phragmites, these species are not at nuisance levels, they must be managed to prevent further population increases.

Upper Long Lake contains 25 native aquatic plant species which represents a very diverse aquatic ecosystem and thus management of milfoil and other invasives or nuisance-level weed growth is critical.

The **overall water quality of Upper Long Lake was measured as fair with moderate nutrients such as phosphorus and nitrogen and moderate water clarity but low dissolved oxygen.** The pH and alkalinity of the lake indicate that it is a moderately alkaline lake.

Mechanical harvesting may also be used in 2015 to remove nuisance native vegetation if the systemic herbicide treatment of the milfoil is successful and milfoil fragmentation is not a threat. Due to the fact that milfoil has been extensively harvested in Upper Long Lake over the years and fragmentation has allowed the acreage to increase, thus necessitating more harvesting, our recommendation is to temporarily cease harvesting operations until the milfoil has been effectively reduced. If a successful systemic herbicide treatment of the lake is conducted on the milfoil in 2015, then harvesting may be conducted around 6-8 weeks post-treatment, to allow the plants to adequately uptake the herbicide product and the dying biomass to be removed. In future years of the program, harvesting may be used to reduce nuisance native aquatic vegetation growth. The current non-chemical approach for controlling Phragmites is working satisfactorily and should be continued to control and/or eradicate them.

A reduction in herbicide treatment area is projected for ongoing years of the program if no other invasives enter the Upper Long Lake ecosystem. Additionally, the management of exotic shoreline Purple Loosestrife is recommended via hand-removal, biological control, or the use of systemic triclopyr.

It is also recommended that the Upper Long Lake community implement **Best Management Practices (BMP's) to reduce the nutrient and sediment loads being transported into the lake from areas with high slope (> 6% slope) and in areas with mucky soils that are prone to ponding during heavy rainfall events.**

2.0 LAKE ECOLOGY BACKGROUND INFORMATION

2.1 Introductory Concepts

Limnology is a multi-disciplinary field which involves the study of the biological, chemical, and physical properties of freshwater ecosystems. A basic knowledge of these processes is necessary to understand the complexities involved and how management techniques are applicable to current lake issues. The following terms will provide the reader with a more thorough understanding of the forthcoming lake management recommendations for Upper Long Lake.

2.1.1 Lake Hydrology

Aquatic ecosystems include rivers, streams, ponds, lakes, and the Laurentian Great Lakes. There are thousands of lakes in the state of Michigan and each possesses unique ecological functions and socio-economic contributions (O'Neil and Soulliere 2006). In general, lakes are divided into four categories:

- Seepage Lakes,
- Drainage Lakes,
- Spring-Fed Lakes, and
- Drained Lakes.

Some lakes (seepage lakes) contain closed basins and lack inlets and outlets, relying solely on precipitation or groundwater for a water source. **Seepage lakes** generally have small watersheds with long hydraulic retention times which render them sensitive to pollutants. Drainage lakes receive significant water quantities from tributaries and rivers. Drainage lakes contain at least one inlet and an outlet and generally are confined within larger watersheds with shorter hydraulic retention times. As a result, they are less susceptible to pollution. Spring-fed lakes rarely contain an inlet but always have an outlet with considerable flow. The majority of water in this lake type originates from groundwater and is associated with a short hydraulic retention time. Drained lakes are similar to seepage lakes, yet rarely contain an inlet and have a low-flow outlet. The groundwater and seepage from surrounding wetlands supply the majority of water to this lake type and the hydraulic retention times are rather high, making these lakes relatively more vulnerable to pollutants. The water quality of a lake may thus be influenced by the quality of both groundwater and precipitation, along with other internal and external physical, chemical, and biological processes. **Upper Long Lake may be categorized as a drainage lake since it has two inlets at the south end of the "shores" subdivision canal from an unnamed lake and the other at the northwest corner to the "woods" canal from Hammond Lake and an outlet at the east end of the lake. Additionally, the lake also receives water from wetlands and runoff.**

2.1.2 Biodiversity and Habitat Health

A healthy aquatic ecosystem possesses a variety and abundance of niches (environmental habitats) available for all of its inhabitants. The distribution and abundance of preferable habitat depends on limiting man's influence from man and development, while preserving sensitive or rare habitats. As a result of this, **undisturbed or protected areas generally contain a greater number of biological species and are considered more diverse.** A highly diverse aquatic ecosystem is preferred over one with less diversity because it allows a particular ecosystem to possess a greater number of functions and contribute to both the intrinsic and socio-economic values of the lake. Healthy lakes have a greater biodiversity of aquatic macroinvertebrates, aquatic macrophytes (plants), fishes, phytoplankton, and may possess a plentiful yet beneficial benthic microbial community (Wetzel, 2001).

2.1.3 Watersheds and Land Use

A **watershed** is defined as an area of land that drains to a common point and is influenced by both surface water and groundwater resources that are often impacted by land use activities. In general, larger watersheds possess more opportunities for pollutants to enter the eco-system, altering the water quality and ecological communities. In addition, watersheds that contain abundant development and industrial sites are more vulnerable to water quality degradation since from pollution which may negatively affect both surface and ground water. Since many inland lakes in Michigan are relatively small in size (i.e. less than 300 acres), they are inherently vulnerable to nutrient and pollutant inputs, due to the reduced water volumes and small surface areas. As a result, the living (biotic) components of the smaller lakes (i.e. fishery, aquatic plants, macro-invertebrates, benthic organisms, etc.) are highly sensitive to changes in water quality from watershed influences**. Land use activities** have a dramatic impact on the quality of surface waters and groundwater.

In addition, the **topography of the land** surrounding a lake may make it vulnerable to nutrient inputs and consequential loading over time. Topography and the morphometry of a lake dictate the ultimate fate and transport of pollutants and nutrients entering the lake. **Surface runoff** from the steep slopes surrounding a lake will enter a lake more readily than runoff from land surfaces at or near the same grade as the lake. In addition, lakes with steep drop-offs may act as collection basins for the substances that are transported to the lake from the land.

Land use activities, such as residential land use, industrial land use, agricultural land use, water supply land use, wastewater treatment land use, and storm water management, can influence the watershed of a particular lake. All land uses contribute to the water quality of the lake through the influx of **pollutants from non-point sources or from point sources. Non-point sources** are often diffuse and arise when climatic events carry pollutants from the land into the lake. **Point-source pollutants** are discharged from a pipe or input device and empty directly into a lake or watercourse.

Residential land use activities involve the use of lawn fertilizers on lakefront lawns, the utilization of septic tank systems for treatment of residential sewage, the construction of impervious (impermeable, hard-surfaced) surfaces on lands within the watershed, the burning of leaves near the lakeshore, the dumping of leaves or other pollutants into storm drains, and removal of vegetation from the land and near the water. In addition to residential land use activities, agricultural practices by vegetable crop and cattle farmers may contribute nutrient loads to lakes and streams. Industrial land use activities may include possible contamination of groundwater through discharges of chemical pollutants.

3.0 UPPER LONG LAKE PHYSICAL AND WATERSHED CHARACTERISTICS

3.1 The Upper Long Lake Basin

Upper Long Lake is located in Section 7 of Bloomfield Township (T.2N, R.10E) and in Section 12 of West Bloomfield Township (T.2N, R.9E) in Oakland County, Michigan. The lake has a **surface area of approximately 121 acres** (Water Quality Investigators, 2004; Figure 1) and is classified as a **eutrophic (nutrient-enriched)** aquatic ecosystem with three distinct deep basins. The lake contains a large-sized littoral (shallow) zone**.**

Upper Long Lake contains a **volume of approximately 1,174 acre-feet of water** and has a **mean depth of 9.7 feet and a maximum depth of 27 feet.** The maximum depth was confirmed by RLS scientists in 2014 with the use of a bottom-scanning GPS system that created a modernized depth contour bathymetric map (Appendix B).

In addition to the depth contour map, a map of soft versus hard bottom was also created (Appendix C). The bottom hardness map shows that **the majority of the lake bottom contains soft deposits of organic content and small areas of hard sand and gravel bottom.** Upper Long Lake contains an inlet at the southwest end of the “shores” subdivision canal from an unnamed lake. Hammond Lake overflows to the northwestern “woods” subdivision canal. Upper Long Lake also receives water from wetlands at the northeast end and southeast end from Wabeek Lake. An outlet is located at the east end of the lake. The outlet drains to Lower Long Lake and to Forest Lake and empties at the Rouge River before discharging into the Detroit River.

Upper Long Lake has a lake **perimeter of approximately 3.2 miles** (Restorative Lake Sciences, 2014).

Figure 1. Upper Long Lake, Bloomfield and West Bloomfield Townships, Oakland County, Michigan.

3.2 Upper Long Lake Extended and Immediate Watershed and Land Use Summary

A watershed is defined as a region surrounding a lake that contributes water and nutrients to a waterbody through drainage sources. Watershed size differs greatly among lakes and also significantly impacts lake water quality. Large watersheds with high development, numerous impervious or paved surfaces, abundant storm water drain inputs, and surrounding agricultural lands, have the potential to contribute significant nutrient and pollution loads to aquatic ecosystems.

Upper Long Lake is located within the **Rouge River extended watershed** (HUC 04090004) and measures approximately 466 mi^2 in area. It encompasses 3 counties including Oakland, Wayne, and Washtenaw. The watershed is characterized by highly variable terrain, land use, and soil types which means that sustainable land use practices must consider site-specific conditions.

Watershed land use categorizes the many activities and land types that occur within the watershed and often include: residential development, commercial development, agriculture, forested land, open space, and wetlands.

Upper Long Lake's immediate watershed consists of the area around the lake which directly drains to the lake and **measures approximately 900 acres** (1.4 mi^2) in size (Figure 2).

There are however, many areas around the lake with significant slopes. These areas are prone to erosion especially in areas with non-vegetated sands. The **immediate watershed is approximately 7.4 times larger than the size of Upper Long Lake**, which indicates the presence of **a large-sized immediate watershed**.

Figure 2. Immediate Watershed draining into Upper Long Lake, Oakland County, Michigan (Restorative Lake Sciences, 2014)

3.3 Upper Long Lake Shoreline Soils

There are **10 major soil types immediately surrounding Upper Long Lake** which may impact the water quality of the lake and may dictate the particular land use activities within the area. Figure 3 (created with data from the United States Department of Agriculture and Natural Resources Conservation Service, 1999) demonstrates the precise soil types and locations around Upper Long Lake. Major characteristics of the dominant soil types directly surrounding the Upper Long Lake shoreline are discussed below. The locations of each soil type are listed in Table 1 below.

USDA-NRCS Soil Series	***Upper Long Lake Location***
60D-Urban Land-Marlette Complex 15-25% slopes	NW corner and NW near canals
60C-Urban Land-Marlette Complex 8-15% slopes	NW shore, north-central shore
60B-Urban Land-Marlette Complex 0-8% slopes	SW shore
10C-Marlette Sandy Loam 6-12% slopes	SW shore, south shore
61A-Urban Land Capac Complex 0-3% slopes	South-central shore
69-Thomas Muck	SE corner
11B-Capac Sandy Loam 0-4% slopes	SE corner
27-Houghton Muck	SE shore, NE corner
14C-Oakville Fine Sand 6-18% slopes	NE shore
18B-Fox Sandy Loam 1-6% slopes	NE corner

Table 1. Upper Long Lake Shoreline Soil Types (USDA-NRCS, 1999).

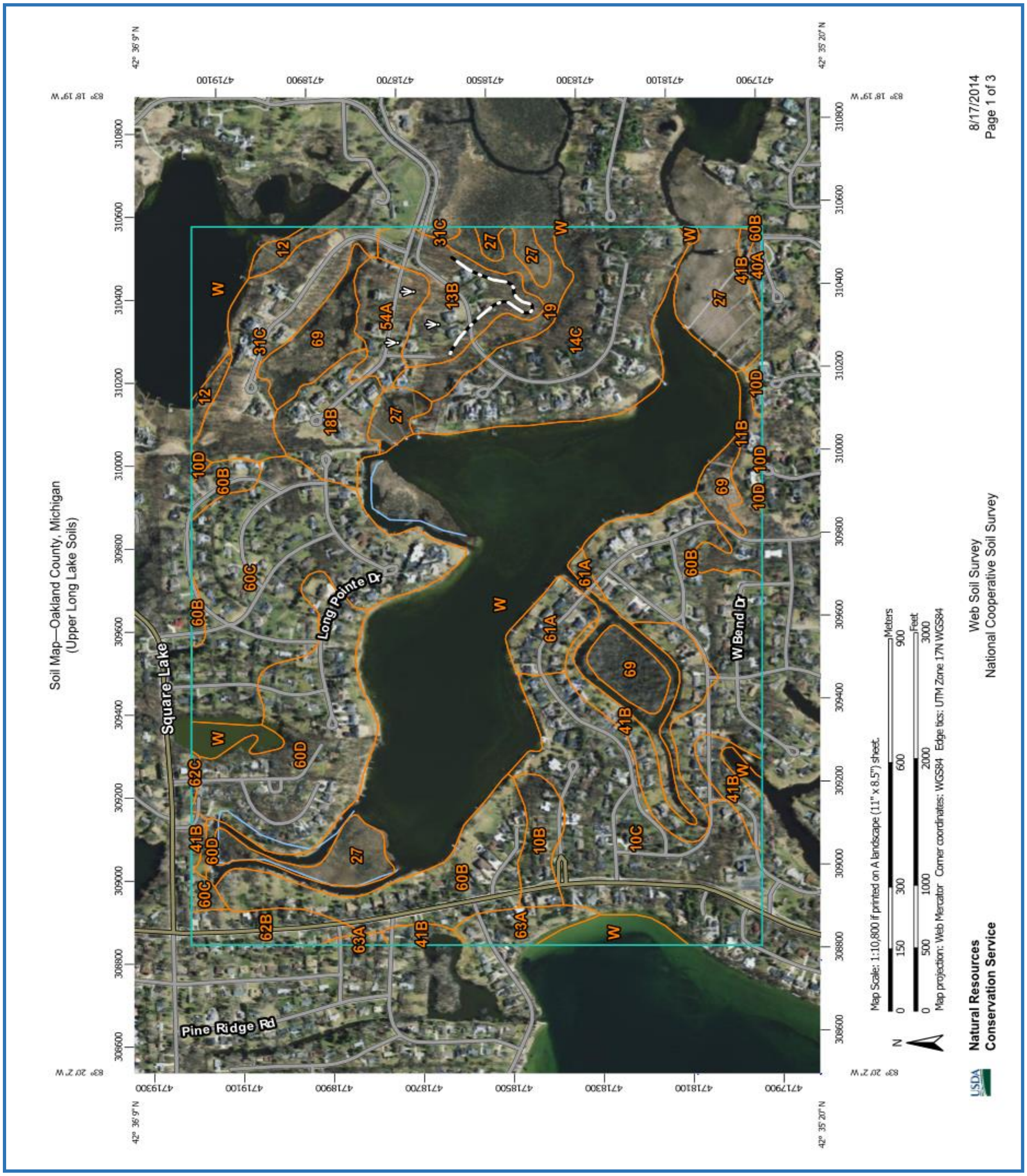

Figure 3. NRCS-USDA soils map for Upper Long Lake shoreline soils (1999 data).

The majority of the soils around Upper Long Lake are moderately well-drained sands with low to high slopes. There are 4 areas around the immediate shoreline that contains ponded or mucky soils that may be problematic for septic systems or runoff during heavy rainfall. These areas consist of Houghton Mucks which are located at the northwest, northeast, and southeast corners of the lake and also Thomas Mucks that are located at the southwest corner of the lake. Ponding occurs when water cannot permeate the soil and accumulates on the ground surface which then may runoff into nearby waterways and carry nutrients and sediments into the water. Excessive ponding of such soils may lead to flooding of some low-lying shoreline areas, resulting in nutrients entering the lake via surface runoff since these soils do not promote adequate drainage or filtration of nutrients**. The mucks located on the wetland islands may become ponded during extended rainfall and the wetlands can serve as a source of nutrients to the lake. When the soils of the wetland are not saturated, the wetland can serve as a sink for nutrients.**

Most of the lake is surrounded by sandy loams that are deep soils and are moderately **well-drained** and have adequate permeability. However, in areas around the lake where the **slopes are greater than 6% (the majority of the lake shoreline), surface runoff** may be a factor, transporting sediments and nutrients to the lake. This is especially true in non-vegetated areas where soils can be directly transported to the lake from the uplands via runoff. Accordingly, every effort to implement low impact development (LID) techniques for construction of pervious surfaces close to the lake should be followed.

4.0 UPPER LONG LAKE WATER QUALITY

Water quality is highly variable among Michigan's inland lakes, although some characteristics are common among particular lake classification types. The water quality of each lake is affected by both land use practices and climatic events. Climatic factors (i.e. spring runoff, heavy rainfall) may alter water quality in the short term; whereas, anthropogenic (man-induced) factors (i.e. shoreline development, lawn fertilizer use, use of septic systems, etc.) alter water quality over longer time periods. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 2). Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as **eutrophic**; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as **oligotrophic**. Lakes that fall in between these two categories are classified as **mesotrophic**. **Upper Long Lake is classified as eutrophic.**

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. Lake Trophic Status Classification Table (MDNR)

4.1 Water Quality Parameters

Parameters such as, but not limited to, dissolved oxygen, water temperature, oxidative reduction potential, conductivity, turbidity and total dissolved solids, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, sediment % organic matter, chlorophyll-*a*, algal species, and Secchi transparency, respond to changes in water quality and consequently serve as indicators of change. During the study, RLS collected water samples from select locations within the lake deep basin and inlets and analyzed them in the laboratory for analysis. **The deep basin results are discussed below and are presented in Tables 3 and 4. A map showing the sampling locations for all water quality samples is shown below in Figure 4. All water samples and readings were collected on May 19, 2014 with the use of a Van Dorn horizontal water sampler and Hanna® multi-meter probe with parameter electrodes, respectively.**
A total of 10 sediment samples were collected in the lake and analyzed for sediment organic matter percentage and sediment total phosphorus and total nitrogen (Table 5).

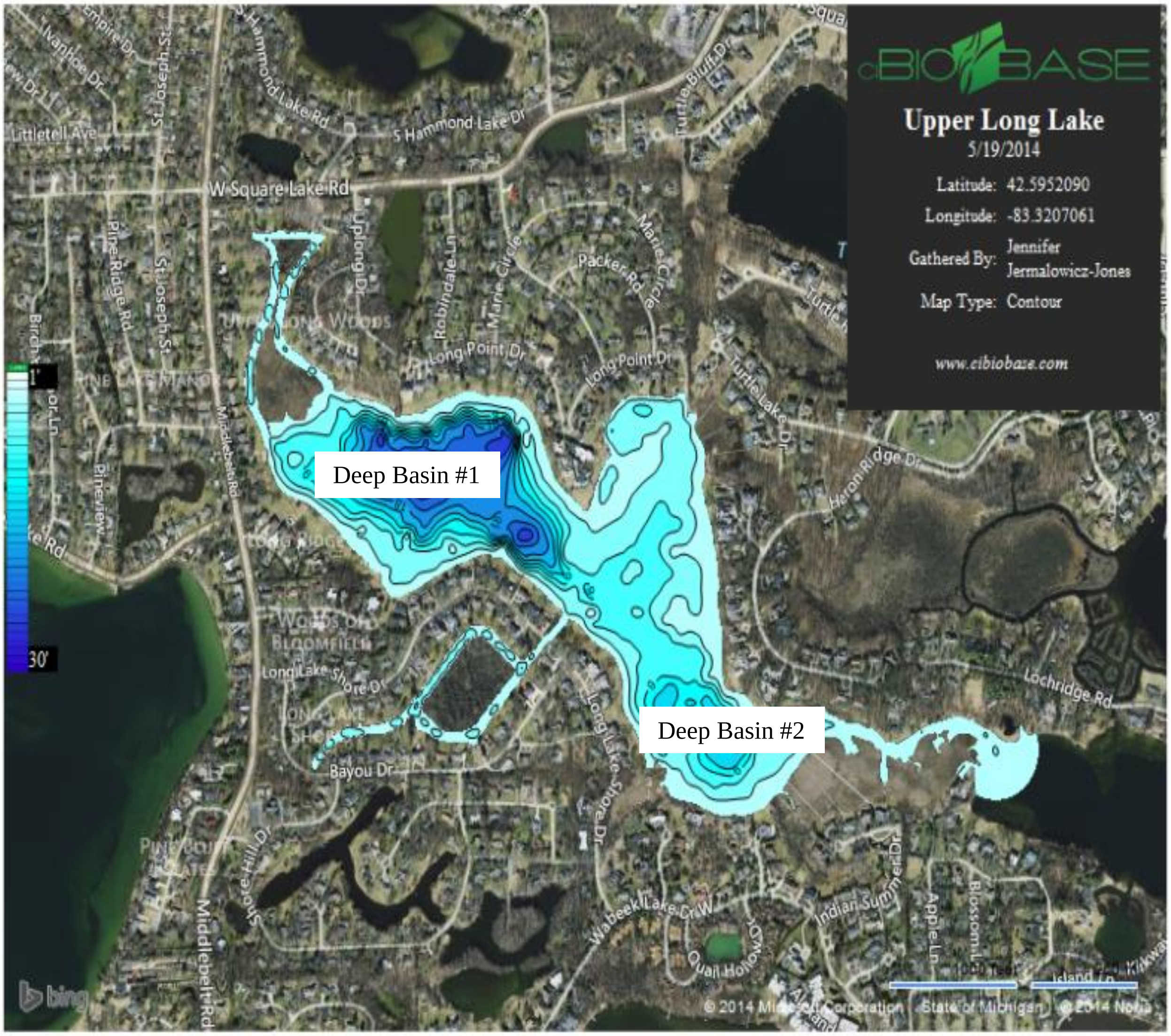

Figure 4. Locations for water quality sampling of the deep basins in Upper Long Lake (May, 2014).

4.1.1 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 is measured in milligrams per liter (mg L^{-1}) with the use of a dissolved oxygen meter and/or through the use of Winkler titration methods. **Dissolved oxygen concentrations ranged between 9.2–5.1 mg L^{-1}, with concentrations of dissolved oxygen higher at the surface and lower at the bottom. DO concentrations have been historically lower in mid to late summer, often declining to near 0 mg L^{-1} beyond a depth of 10 feet (Water Quality Investigators 1999-2003; Metzer, 1993).** Although the deep basin is only 27 feet deep at the maximum depth, the lake exhibits significant stratification and variation in DO measurements. The bottom of the lake produces a high Biochemical Oxygen Demand (BOD) due to microbial activity attempting to break down high quantities of organic plant matter, which reduces DO in the water column.

4.1.2 Water Temperature

A lake's water temperature varies within and among seasons, and is nearly uniform with depth under the winter ice cover because lake mixing is reduced when waters are not exposed to the wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover". In general, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature is measured in degrees Celsius (ºC) or degrees Fahrenheit (ºF) with the use of a submersible thermometer. The **mid-May water temperatures of Upper Long Lake demonstrated a slight thermocline (transition zone of change in water temperature from top to bottom).** On the day of sampling, **water temperatures ranged between 70.5ºF (at the surface) and 60.8ºF (at the bottom) of the deep basins.**

4.1.3 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 with water temperature and the amount of dissolved minerals and salts in a lake. Conductivity is measured in micro ohms per centimeter (µmho cm^{-1}) with the use of a conductivity probe and meter.

Conductivity values for Upper Long Lake were consistent among the deep basins and ranged from 661-702 mS cm^{-1}. These values are quite high for an inland lake and mean that the lake water contains ample dissolved metals and ions such as calcium, potassium, magnesium, sodium, chlorides, sulfate, and carbonate. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Upper Long Lake over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading.
Historical values of between 600-727 mS cm^{-1} (Metzer, 1993; Holler, 1974-2003) have been reported. Elevated conductivity values over 800 mS cm^{-1} can negatively impact aquatic life.

4.1.4 Turbidity & Total Dissolved 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 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 is measured in Nephelometric Turbidity Units (NTU's) with the use of a turbimeter. 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 Upper Long Lake is quite low and ranged from 0.9-3.7 NTU's during the sampling event.** The lake bottom is predominately organic which is low in bulk density and will be suspended in the water column for on windy days which may temporarily increase turbidity. On the day of sampling, the winds were calm and turbidity was low except near the lake bottom where res-suspension of sediments often occur. Spring values would likely be higher due to increased watershed inputs from spring runoff and/or from increased algal blooms in the water column from resultant runoff contributions.

Total Dissolved Solids

Total dissolved solids (TDS) are the 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. Total dissolved solids are often measured with the use of a calibrated meter in mg L^{-1}. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. **The TDS ranged from 475-489 mg L^{-1} for the deep basins which is high for an inland lake and correlates with the measured high conductivity.**

4.1.5 pH

pH is the measure of acidity or basicity of water. pH is measured with a pH electrode and pH-meter in Standard Units (S.U). The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. 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). **The pH of Upper Long Lake water ranged from 8.2 – 8.3 S.U. during the sampling event. This range of pH is neutral to alkaline on the pH scale. Historical pH values ranged from 7.9-8.4 S.U.**

4.1.6 Total Alkalinity

Total alkalinity is the measure of the pH-buffering capacity of lake water. 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 is measured in milligrams per liter of $CaCO_3$ through an acid titration method. The total alkalinity of Upper Long Lake is considered "elevated" (> 120 mg L^{-1} of $CaCO_3$), and indicates that the water is slightly alkaline. **Total alkalinity in the deep basins ranged from 133-142 mg L^{-1} of $CaCO_3$ during the sampling event. Historical values ranged from 119-178 mg L^{-1}, which represents a wide range of values.** 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.

4.1.7 Total 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. Lakes which contain greater than 0.020 mg L^{-1} of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to the higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Total phosphorus is measured in micrograms per liter (µg L^{-1}) with the use of a chemical auto analyzer. **TP concentrations ranged from 0.032-0.042 mg L^{-1}. These values indicate that the lake is relatively uniform in moderate TP levels but still contains adequate nutrients to support algae and aquatic plant growth. Given the significant density of submersed rooted aquatic vegetation, the plants likely derive most of their phosphorus from the lake sediments rather than the water column. Alternatively, planktonic algae and Chara obtain most of their nutrients from the water column as dissolved, bio-available phosphorus.**

4.1.8 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), 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 groundwater 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. With reference to nitrogen, 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. **Upper Long Lake contains moderate values for TKN at all depths (0.550-0.750 mg L^{-1}), which is normal for an inland lake of similar size and demonstrates that the lake is phosphorus limited. Thus, any additional inputs of phosphorus would lead to increased aquatic plant and algae growth. Given the mean TP concentration of 0.038 mg L^{-1} and the mean TKN concentration of 0.638 mg L^{-1}, the N:P for Upper Long Lake water is 16.8 which means that the lake is phosphorus-limited.**

4.1.9 Chlorophyll-a, Algae, and Zooplankton

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-*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^{-1} are found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* is measured in micrograms per liter (µg L^{-1}) with the use of an acetone extraction method and a spectrometer. The chlorophyll-*a* concentrations in Upper Long Lake were determined by collecting a composite sample of the algae throughout the water column at each of the two deep basin sites from just above the lake bottom to the lake surface. **The chlorophyll-*a* concentrations in the deep basins ranged from 7.4-9.6 µg L^{-1}, which indicates a fair amount of planktonic algae throughout the water column.** It is likely that these values are higher in the spring after spring runoff or in late summer when water temperatures increase and lead to the growth of algae in the water column (planktonic form) or on the surface (filamentous form).

Algal genera from a composite water sample collected over the deep basin of Upper Long Lake were analyzed under a compound brightfield microscope. Genera are listed here in the order of most abundant to least abundant. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Haematococcus* sp., *Ulothrix* sp., *Pandorina* sp., *Rhizoclonium* sp., *Gleocystis* sp., *Scenedesmus* sp., *Botryococcus* sp., *Pediastrum* sp., *Spirogyra* sp., *Euglena* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Anabaena* sp., and *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Cymbella* sp., *Navicula* sp., *Fragilaria* sp., *Synedra* sp., and *Tabellaria* sp. The aforementioned species indicate a moderately diverse algal flora and represent a relatively balanced freshwater ecosystem, capable of supporting a strong zooplankton community in favorable water quality conditions. **The waters of Upper Long Lake are rich in the Chlorophyta (green algae) but contain less diatoms. If the DO levels of the lake were increased, diatoms may increase and be beneficial for a healthy fishery.**

A zooplankton tow using a pelagic plankton net with collection jar was conducted by RLS scientists on July 19, 2014. Plankton sub-samples (in 1 ml aliquots) were analyzed under a Meiji dissection scope with the use of a Bogorov counting chamber. The most abundant zooplankton genera included copepods such as *Diaptomus* sp. and *Diaphanasoma* sp. (approximately 55 organisms per 1 ml aliquot) Also present but in lower quantities was *Daphnia* (approximately 10 organisms per 1 ml aliquot), *Mesocyclops* (approximately 3 organisms per 1 ml aliquot), *Ceriodaphnia*, *Bosmina*, and *Epischura* general (approximately 2 organisms per 1 ml aliquot). Although zebra mussel veligers are likely present in the water, they were not detected in the plankton tow samples.

4.1.10 Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk. Secchi disk transparency is measured in feet (ft.) or meters (m) by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk. Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. The Secchi transparency of Upper Long Lake deep basins in mid-May was around 9.5 feet. Measurements were collected during calm wind conditions. This transparency is adequate 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 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.** Historical Secchi measurements ranged from a low of 2.5 feet to a maximum of 15.5 feet (CLMP data, 2002 report). Additional data collected by Stephen George from April 25-August 31, 2014 demonstrate a mean of 8.7 feet.

4.1.11 Oxidative Reduction Potential

The oxidation-reduction potential (ORP or E_h) of lake water describes the effectiveness of certain atoms to serve as potential oxidizers and indicates the degree of reductants present within the water. In general, the E_h level (measured in millivolts) decreases in anoxic (low oxygen) waters. Low E_h values are therefore indicative of reducing environments where sulfates (if present in the lake water) may be reduced to hydrogen sulfide (H_2S). Decomposition by microorganisms in the hypolimnion may also cause the E_h value to decline with depth during periods of thermal stratification. **The E_h values for the Upper Long Lake ranged from 119.4-23.1 mV from the surface to the bottom.** The high variability could be due to numerous factors such as degree of microbial activity near the sediment-water interface, quantity of phytoplankton in the water, or mixing of the lake water. These values are normal for an inland lake and the values almost always demonstrate considerable variability, especially among depths and in stratified lakes.

4.1.12 Sediment Organic Matter and Phosphorus

Organic matter (OM) contains a high amount of carbon which is derived from biota such as decayed plant and animal matter. Detritus is the term for all dead organic matter which is different than living organic and inorganic matter. OM may be autochthonous or allochthonous in nature where it originates from within the system or external to the system, respectively. Sediment OM is measured with the ASTM D2974 Method and is usually expressed in a percentage (%) of total bulk volume. Many factors affect the degradation of organic matter including basin size, water temperature, thermal stratification, dissolved oxygen concentrations, particle size, and quantity and type of organic matter present. There are two major biochemical pathways for the reduction of organic matter to forms which may be purged as waste. First, the conversion of carbohydrates and lipids via hydrolysis are converted to simple sugars or fatty acids and then fermented to alcohol, CO_2, or CH_4. Second, proteins may be proteolyzed to amino acids, deaminated to NH_3+, nitrified to NO_2- or NO_3-, and denitrified to N_2 gas. Sediment ammonia nitrogen is thus converted to nitrate and eventually nitrogen gas which are both forms that are unusable by rooted aquatic plants and this may explain reductions in some nuisance-level weed infestations. Bacteria are the major factor in the degradation of organic matter in sediments (Fenchel and Blackburn, 1979).

Wang et *al*. (2008) showed that although organic matter in sediments may restrict the release of soluble reactive phosphorus (SRP) to overlying waters, the fraction of dissolved organic phosphorus (DOP) is readily released by organic matter under anoxic conditions. Thus, reduction of the organic matter layer may reduce the total nutrient pool available for release in eutrophic lake systems. The concentrations of phosphorus in both sediments and the water column fluctuate seasonally in lakes with reported increases occurring during the summer (Clay and Wilhm, 1979).
Laing (1978) demonstrated an annual loss of 49-82 cm (19-32 inches) of organic sediment in a study of nine lakes which received aeration and bioaugmentation. It was further concluded that this sediment reduction was not due to redistribution of sediments since samples were collected outside of the aeration "crater" that is usually formed.

Sediment total phosphorus (TP) is a measure of the amount of phosphorus present in the lake sediment. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. **The TP concentrations in lake sediments are often up to several times higher than those in the water column since phosphorus tends to adsorb onto sediment particles and sediments thus act as a "sink" or reservoir of nutrients.** TP concentrations are usually higher at increased depths due to higher release rates of phosphorus from lake sediments under low oxygen (anoxic) conditions. Sediment TP is measured in milligrams per kilogram (mg kg^{-1}) with EPA Method 6010B. **Lake sediments were collected in Upper Long Lake on July 9, 2014 by RLS scientists with the use of an Ekman dredge. The data are presented in Table 5.**

The **organic content ranged from 17-56% organic matter which is highly variable. The majority of the low organic samples were collected near shore in sandy areas around the east lobe of the lake and high organic samples were collected in offshore areas throughout the entire lake. The sediment content of total phosphorus and nitrogen varied among sampling sites but contain enough of both nutrients to support dense rooted aquatic vegetation growth. A map showing the relative hard versus soft bottom areas in Upper Long Lake is shown below in Figure 5.**

Depth ft.	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	64.0	9.2	8.3	687	0.9	0.750	138	0.035
13	61.7	7.0	8.3	690	1.7	0.600	133	0.039
27	54.9	5.1	8.3	661	3.7	0.580	142	0.042

Table 3. Upper Long Lake water quality parameter data collected in deep basin #1 (May, 2014).

Depth ft.	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	64.9	9.2	8.3	701	1.0	0.650	133	0.032
10	62.6	6.9	8.3	702	1.6	0.550	136	0.038
22	56.8	5.8	8.2	702	2.8	0.700	140	0.040

Table 4. Upper Long Lake water quality parameter data collected in the deep basin #2 (May, 2014).

Sample Location	*Sediment Organic Matter %*	*Sediment Total Phosphorus (mg/kg)*	*Sediment Total Nitrogen (mg/kg)*
1	21	490	11,000
2	17	450	9,800
3	34	880	15,000
4	35	780	18,000
5	56	28	26,000
6	20	460	11,000
7	17	220	6,500
8	40	810	15,000
9	18	490	7,100
10	19	520	8,400

Table 5. Upper Long Lake sediment data collected in July, 2014.

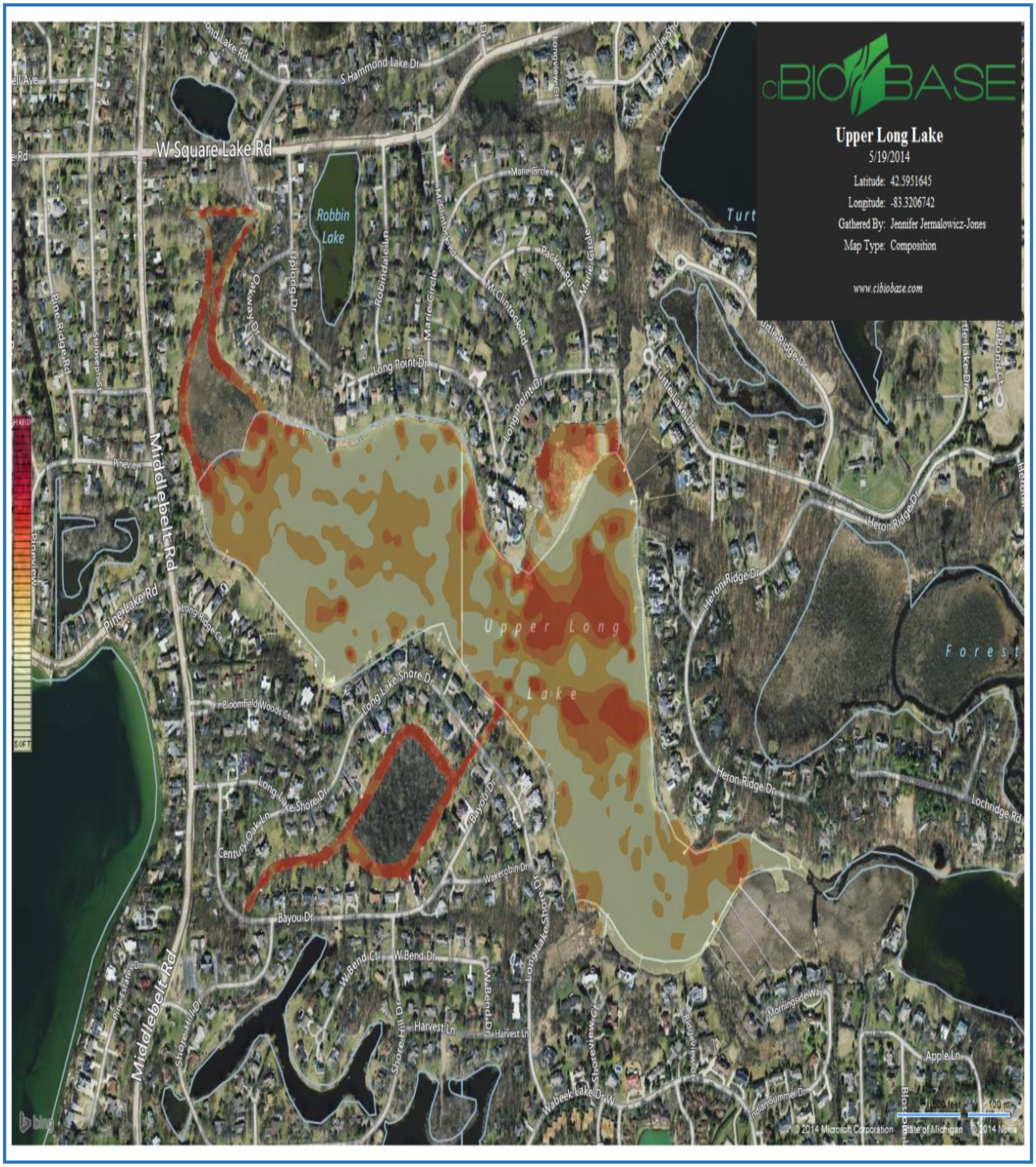

Figure 5. Bioacoustic map showing hard (red) versus soft (grey) bottom in Upper Long Lake (RLS, 2014)

4.2 Upper Long Lake Aquatic Vegetation Communities

Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as suitable habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients such as phosphorus and nitrogen upon decay. In addition, decaying aquatic plants contribute organic matter to lake sediments which further supports healthy growth of successive aquatic plant communities that are necessary for a balanced aquatic ecosystem. **An overabundance of aquatic vegetation may cause organic matter to accumulate on the lake bottom faster than it can break down. The use of mechanical harvesting to remove excess biomass does decrease the amount of organic matter that falls to the bottom; however, timing of harvesting is critical since aquatic plants grow very quickly (within weeks) and not all of the biomass is removed (typically just the upper few feet).** Aquatic plants generally consist of rooted submersed, free-floating submersed, floating-leaved, and emergent growth forms. The emergent growth form (i.e. Cattails, Native Loosestrife) is critical for the diversity of insects onshore and for the health of nearby wetlands. Submersed aquatic plants can be rooted in the lake sediment (i.e. Milfoils, Pondweeds), or free-floating in the water column (i.e. Coontail). Nonetheless, there is evidence that the diversity of submersed aquatic macrophytes can greatly influence the diversity of macroinvertebrates associated with aquatic plants of different structural morphologies (Parsons and Matthews, 1995). Therefore, it is possible that declines in the biodiversity and abundance of submersed aquatic plant species and associated macroinvertebrates, could negatively impact the fisheries of inland lakes. Alternatively, the overabundance of aquatic vegetation can compromise recreational activities, aesthetics, and property values.

4.2.1 Upper Long Lake Exotic Aquatic Macrophytes

Exotic aquatic plants (macrophytes) are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem. **Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 6) is an exotic aquatic macrophyte** first documented in the United States in the 1880's (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was first found in the 1940's. Eurasian Watermilfoil has since spread to thousands of inland lakes in various states through the use of boats and trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. **Eurasian Watermilfoil is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation within lakes (Madsen et *al*. 1991), and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et *al*. 1979).** Additionally, Eurasian Watermilfoil can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

The Eurasian Watermilfoil in Upper Long Lake has been treated in 2000 with fluridone (Sonar®). Laboratory analyses conducted on Upper Long Lake milfoil samples by the GVSU AWRI laboratory in July, 2014 revealed that the majority of the milfoil in the lake is the hybrid form Myriophyllum spicatum x Myriophyllum sibiricum. This combination had shown resistance to fluridone on many lakes and thus a different systemic herbicide is recommended for 2015 to reduce the milfoil. This approach is discussed in the aquatic herbicide section under lake management methods. The lake currently contains approximately 39 acres of hybrid milfoil. Due to the moderate water clarity of Upper Long Lake, Eurasian Watermilfoil growth is capable of growing in nearly all depths of the littoral zone of Upper Long Lake where light is adequate. The littoral zone of Upper Long Lake occupies nearly 68% of the total lake surface area which is approximately 82.3 acres.

Curly-leaf Pondweed (*Potamogeton crispus*; Figure 7) is an exotic, submersed, rooted aquatic plant that was introduced into the United States in 1807 but was abundant by the early 1900's. It is easily distinguished from other native pondweeds by its wavy leaf margins. It grows early in the spring and as a result may prevent other favorable native aquatic species from germinating. The plant reproduces by the formation of fruiting structures called turions. The plant does not reproduce by fragmentation as milfoil does; however, the turions may be deposited in the lake sediment and germinate in following seasons. Fortunately, the plant naturally declines around mid-July in most lakes and thus is not likely to be prolific throughout an entire growing season. Curly-leaf Pondweed is a pioneering aquatic plant species and specializes in colonizing disturbed habitats. It is highly invasive in aquatic ecosystems with low biodiversity and unique sediment characteristics.

Starry stonewort (*Nitellopsis obtusa*; Figure 8) is an invasive macro alga that has invaded many inland lakes of Michigan and was originally discovered in the St. Lawrence River. **Approximately 3 acres of this invasive alga was found in Upper Long Lake.** The "leaves" appear as long, smooth, angular branches of differing lengths. The alga has been observed in dense beds at depths beyond several meters and can grow to heights in excess of a few meters. It prefers clear alkaline waters and has been shown to cause significant declines in water quality and fishery spawning habitat. Management options for the plant are provided in the management recommendations section of the report.

Purple Loosestrife (*Lythrum salicaria*; Figure 9) is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas and was found along nearly 2 acres of shoreline of Upper Long Lake. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as Cattails (*Typha latifolia*) or native Swamp Loosestrife (*Decodon verticillatus*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity. **The presence of Purple Loosestrife around the Upper Long Lake shoreline is an imminent threat to the emergent macrophyte populations, which could be displaced if left untreated or removed.** Lake residents should be educated about its invasiveness and threat to the health of the Upper Long Lake ecosystem. The plant was located at the following locations on the Upper Long Lake map and should be removed promptly (i.e. by hand pulling or using a shovel to remove the roots and then discarding the plant into the garbage) if it is discovered to avoid further infestation. If the plant is not promptly removed by hand, it could dominate in wetland areas and require larger-scale systemic herbicide treatments.

In addition to milfoil, Upper Long Lake contained 20 sites or approximately 1 acre of the emergent Giant Common Reed (*Phragmites australis*; Figure 10), which should be promptly removed before mitigation efforts become too costly. *Phragmites* is an imminent threat to the surface area of Upper Long Lake since it may grow submersed in water depths of ≥ 2 meters (Herrick and Wolf, 2005), thereby drying up wetland habitat and reducing lake surface area. In addition, large, dense stands of *Phragmites* accumulate sediments, reduce habitat variability, and impede natural water flow (Wang et al., 2006). **Dense stands of Phragmites were noted along the outlet to Lower Long Lake and should be addressed there to reduce spread back into Upper Long Lake.**

Figure 11 shows the general distribution of the hybrid Eurasian Watermilfoil which was scattered among the littoral zone of Upper Long Lake in May of 2014. Figure 12 shows the general distribution of the 11.5 acres of Curly-leaf Pondweed which was scattered among the littoral zone of Upper Long Lake in May of 2014. Figure 13 shows the general distribution of the Starry Stonewort which was scattered among the littoral zone of Upper Long Lake in May of 2014. Figure 14 shows the distribution of the exotic emergents Purple Loosestrife and Phragmites. Table 6 below shows all exotic aquatic plant species in Upper Long Lake as of May, 2014.

Figure 6. Eurasian Watermilfoil (©RLS, 2006).

Figure 7. Curly-leaf Pondweed (©RLS, 2006).

Figure 8. Starry Stonewort (USGS photo).

Figure 9. Purple Loosestrife (©RLS, 2006).

Figure 10. Phragmites. (©RLS, 2006).

Figure 11. Distribution of Eurasian Watermilfoil in Upper Long Lake (May, 2014).

Figure 12. Distribution of Curly-leaf Pondweed around Upper Long Lake, Oakland County, MI. (May, 2014).

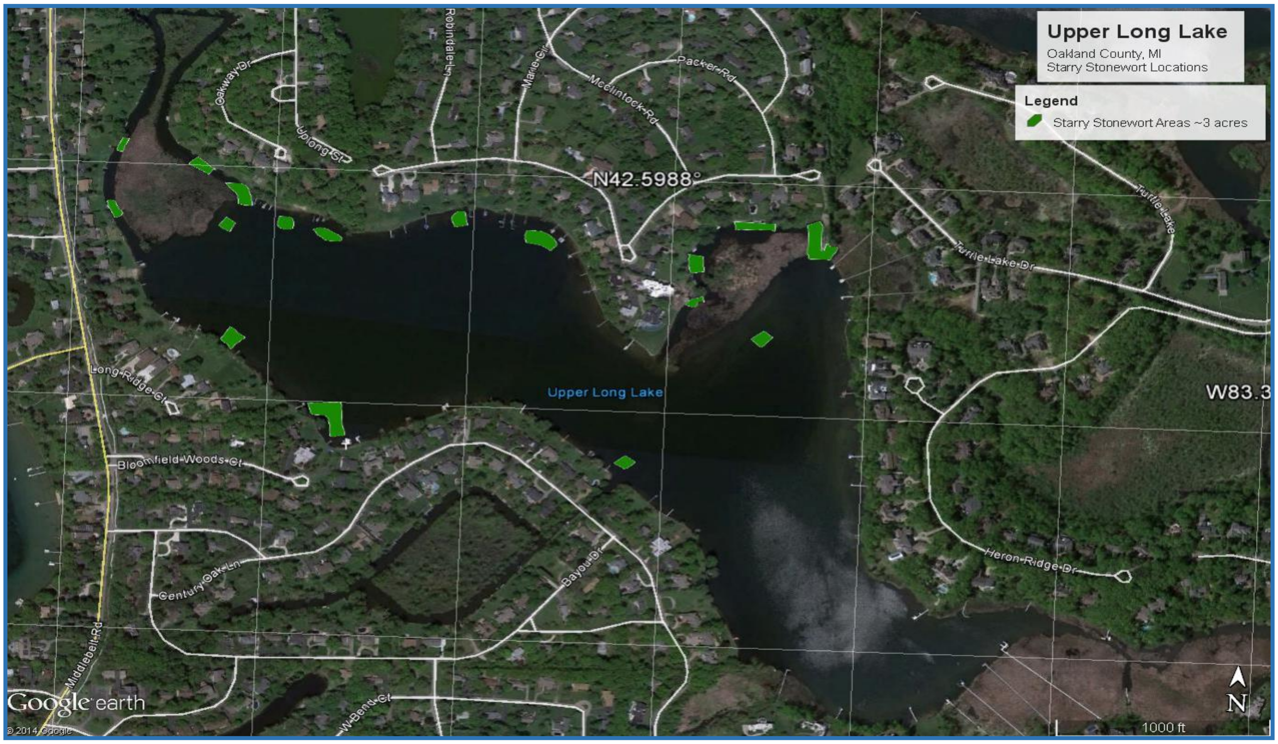

Figure 13. Distribution of Starry Stonewort in Upper Long Lake, Oakland County, MI. (May, 2014).

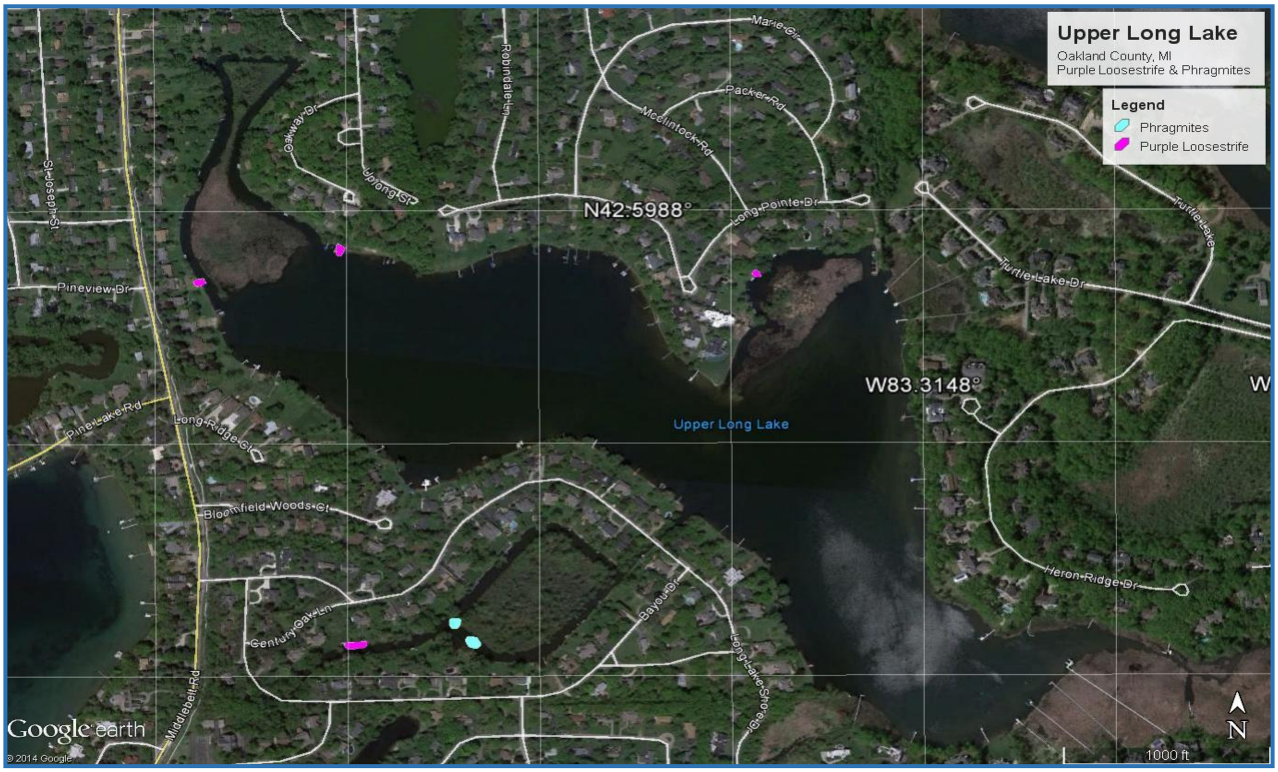

Figure 14. Map showing the distribution of emergent invasive Purple Loosestrife and Phragmites around Upper Long Lake, Oakland County, MI (May, 2014).

Exotic Aquatic Plant Species	***Common Name***	***Growth Habit***	***Abundance in or around Upper Long Lake***
Myriophyllum spicatum	Eurasian Watermilfoil	Submersed; Rooted	Common/Dense
Nitellopsis obtusa	Starry Stonewort	Submersed; Rooted	Sparse
Potamogeton crispus	Curly-leaf Pondweed	Submersed; Rooted	Sparse
Lythrum salicaria	Purple Loosestrife	Emergent	Sparse
Giant Common Reed	Phragmites australis	Emergent	Sparse

Table 6. Upper Long Lake exotic aquatic plant species (May, 2014).

4.2.2 Upper Long Lake Native Aquatic Macrophytes

There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (Pondweeds) and the Haloragaceae (Milfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) such as phosphorus, and in sites with high water transparency. The diversity of native aquatic plants is essential for the balance of aquatic ecosystems, because each plant harbors different macroinvertebrate communities and varies in fish habitat structure.

Upper Long Lake contained 17 native submersed, 2 floating-leaved, and 4 emergent aquatic plant species, for a total of 23 native aquatic macrophyte species (Table 7). The majority of the emergent macrophytes may be found along the shoreline of the lake. Additionally, the majority of the floating-leaved macrophyte species can be found near the shoreline. This is likely due to enriched sediments and shallower water depth with reduced wave energy, which facilitates the growth of aquatic plants with various morphological forms.

The dominant aquatic plants in the main part of the lake included the macro alga Chara (*Chara vulgaris*) and the rootless plant, Coontail (*Ceratophyllum demersum*). Chara carpets the lake bottom and is responsible for stabilizing sediments which increases water clarity. Additionally, Chara serves as excellent fish spawning habitat. Coontail, derives all of its nutrition from the lake water which is high enough in nutrient to support a strong population of coontail. The plant may drift through the water column or rest on the lake bottom. IT may become a nuisance since it can clog boat propellers and be obstructive to swimmers.

The relative abundance of rooted aquatic plants (relative to non-rooted plants) in the lake suggests that the lake sediments are the primary source of nutrients (relative to the water column), since these plants obtain most of their nutrition from the sediments. There were also **two floating-leaved macrophyte species, *Nymphaea odorata* (White-Waterlily)**, which is critical for housing macroinvertebrates and should be protected and preserved in non-recreational areas to serve as food sources for the fishery and wildlife around the lake, and ***Nuphar variegata* (Yellow-Waterlily)**, which harbors seeds that are eaten by waterfowl. The **emergent plants, such as *Typha* sp. (Cattails), and *Scirpus acutus* (Bulrushes)** are critical for shoreline stabilization as well as for wildlife and fish spawning habitat.

Figure 15 shows the relative biovolume of all aquatic vegetation in Upper Long Lake. Biovolume is a measure of the height in the water column that each plant occupies. As the map demonstrates, Upper Long Lake contains a high quantity of aquatic vegetation with high biovolume and thus the need for intensive lake management techniques. **Photos of all native aquatic plant species are shown in Figures 16-38.**

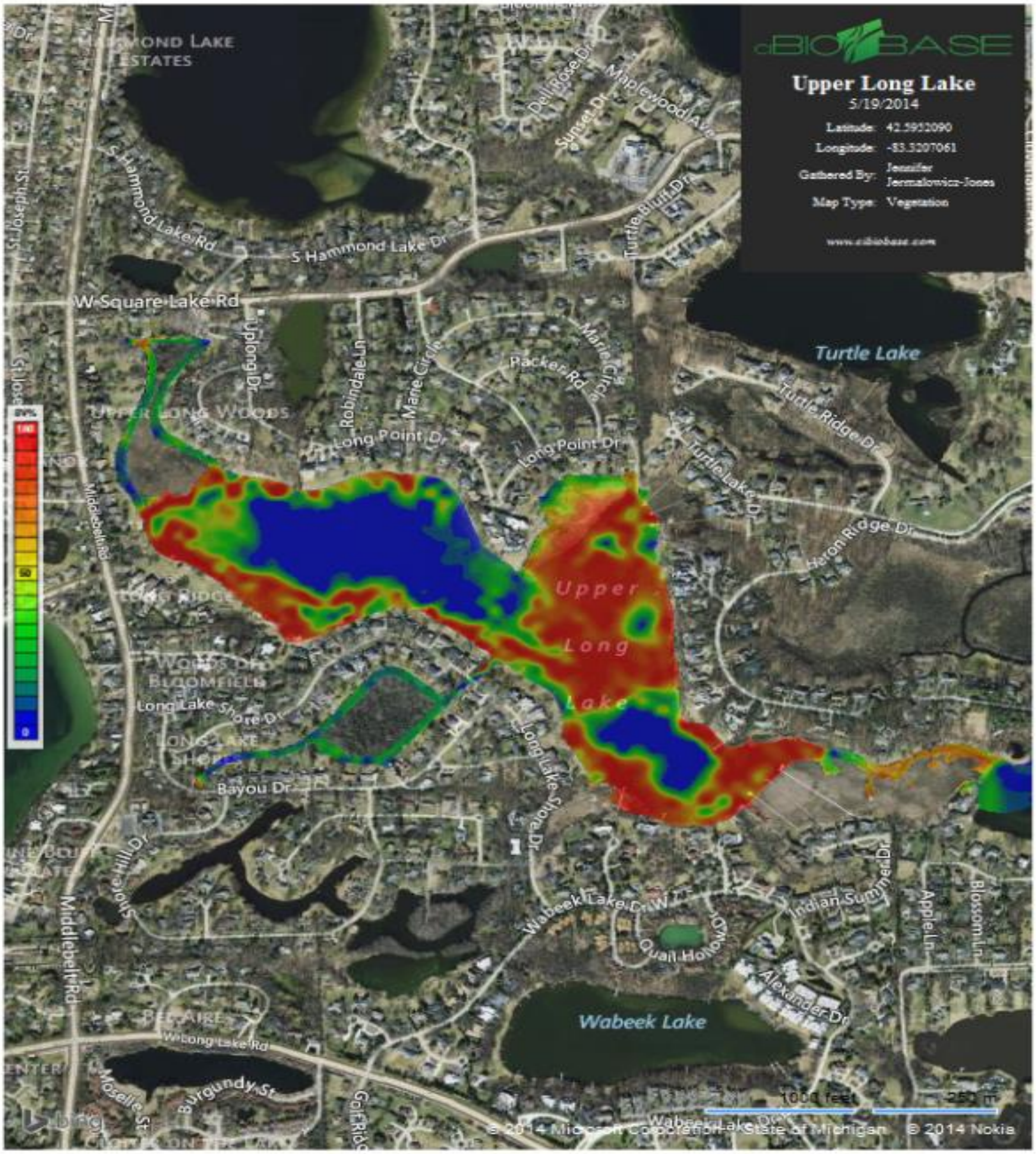

Figure 15. A biovolume map showing relative heights in the water column of all aquatic vegetation in Upper Long Lake. (May, 2014). Note: Dark red and orange colors denote milfoil, whereas green and yellow colors show lower-growing plants and blue denotes no vegetation.

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***Abundance in/around Upper Long Lake***	***Aquatic Plant Growth Habit***
Chara vulgaris	Muskgrass	37.9	Submersed, Rooted
Potamogeton pectinatus	Thin-leaf Pondweed	0.6	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	0.3	Submersed, Rooted
Potamogeton zosteriformis	Flat-stem Pondweed	0.1	Submersed, Rooted
Potamogeton gramineus	Variable-leaf Pondweed	6.8	Submersed, Rooted
Potamogeton americanus	American Pondweed	5.8	Submersed, Rooted
Potamogeton natans	Floating-leaf Pondweed	0.1	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	8.2	Submersed, Rooted
Myriophyllum sibiricum	Northern Watermilfoil	0.1	Submersed, Rooted
Myriophyllum verticillatum	Whorled Watermilfoil	1.6	Submersed, Rooted
Zosterella dubia	Water star grass	0.1	Submersed, Rooted
Elodea canadensis	Common Waterweed	12.5	Submersed, Rooted
Ceratophyllum demersum	Coontail	25.5	Submersed, Non-Rooted
Utricularia vulgaris	Bladderwort	13.1	Submersed, Non-Rooted
Ranunculus sp.	Buttercup	1.3	Submersed, Non-Rooted
Najas guadalupensis	Southern Naiad	0.1	Submersed, Rooted
Scirpus subterminalis	Submersed Bulrush	0.7	Submersed, Rooted
Nymphaea odorata	White Waterlily	0.4	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	0.4	Floating-Leaved, Rooted
Typha latifolia	Cattails	6.7	Emergent
Scirpus acutus	Bulrushes	0.2	Emergent
Sagittaria sp.	Arrowhead	0.1	Emergent
Decodon verticillatus	Swamp Loosestrife	0.1	Emergent
Polygonum amphibium	Water Smartweed	1.1	Emergent

Table 7. Upper Long Lake native aquatic plants (May, 2014). Relative abundance displayed as a percentage.

Figure 16. Chara (Muskgrass)

Figure 17. Thin-leaf Pondweed ©RLS, 2009

Figure 18. Large-leaf Pondweed ©RLS, 2006

Figure 19. Variable-leaf Pondweed ©RLS, 2006

Figure 20. American Pondweed ©RLS, 2006

Figure 21. Flat-stem Pondweed ©RLS, 2006

Figure 22. Floating-leaf Pondweed

Figure 23. Submersed rush

Figure 24. Illinois Pondweed ©RLS, 2006

Figure 25. Northern Watermilfoil ©RLS, 2006

Figure 26. Elodea ©RLS, 2006

Figure 27. Bladderwort ©RLS, 2006

Figure 28. Coontail ©RLS, 2007

Figure 29. Buttercup

Figure 30. Whorled Watermilfoil ©RLS, 2009

Figure 31. Southern Naiad ©RLS, 2006

Figure 32. Water Smartweed ©RLS, 2006

Figure 33. Arrowhead ©RLS, 2006

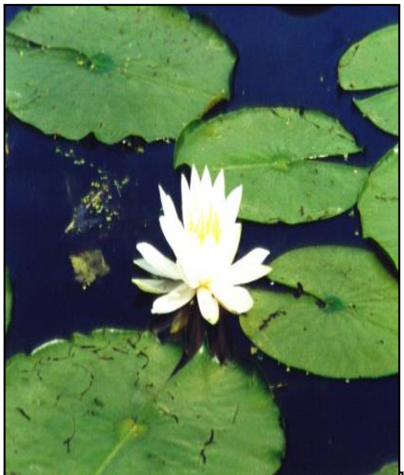

Figure 34. White Waterlily ©RLS, 2006

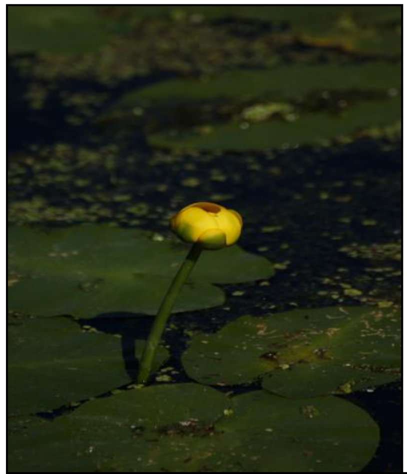

Figure 35. Yellow Waterlily ©RLS, 2006

Figure 36. Bulrushes ©RLS, 2006

Figure 37. Cattails ©RLS, 2006

Figure 38. Swamp Loosestrife ©RLS, 2006

5.0 AQUATIC PLANT MANAGEMENT OPTIONS FOR UPPER LONG LAKE

5.1 Upper Long Lake Aquatic Plant Management

Improvement strategies, including the management of exotic aquatic plants, control of land and shoreline erosion, and further nutrient loading from external sources, are available for the various problematic issues facing Upper Long Lake. The lake management components involve both within-lake (basin) and around-lake (watershed) solutions to protect and restore complex aquatic ecosystems. **The goals of a Lake Management Plan (LMP) are to increase water quality, favorable wildlife habitat, aquatic plant and animal biodiversity, recreational use, and protect property values.** Regardless of the management goals, all management decisions must be site-specific and should consider the socio-economic, scientific, and environmental components of the LMP (Madsen 1997).

The management of submersed hybrid watermilfoil and other invasive aquatic plants is necessary in Upper Long Lake due to accelerated growth and distribution. **Management options** should be **environmentally and ecologically sound and financially feasible**. Options for control of aquatic plants are limited yet are capable of achieving strong results when used properly. However, exotic aquatic plant species and nuisance-level native aquatic vegetation should be managed with solutions that will yield long-term results. Various methods and their application to the management of nuisance aquatic vegetation in Upper Long Lake are discussed below.

5.1.1 Chemical Herbicide Applications

The use of aquatic chemical herbicides is regulated by the MDEQ under Part 33 (Aquatic Nuisance) of the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, and requires a permit. The permit contains a list of approved herbicides for a particular body of water, as well as dosage rates, treatment areas, and water use restrictions. Furthermore, each aquatic herbicide has been rigorously tested by the Environmental Protection Agency (EPA) and the United States Department of Agricultural and Rural Development (MDARD). Before any one product can be used in or on public trust waters, it must be proven safe for aquatic life and with low probability of any impacts on human health. It is then up to individual states, such as the Michigan Department of Environmental Quality (MDEQ) to set dosage rates allowed in the state for each aquatic herbicide. Rigorous follow-up treatment surveys are also required to assure that no harmful effects are observed on unintended targets such as wildlife.

Contact and systemic aquatic herbicides are the two primary categories used in aquatic systems. Contact herbicides such as **diquat, hydrothol, glyphosate, and flumioxazin** cause damage to leaf and stem structures; whereas systemic herbicides are assimilated by the plant roots and are lethal to the entire plant. Wherever possible, it is preferred to use a systemic herbicide for longer-lasting aquatic plant control. There are often restrictions with usage of some systemic herbicides around shoreline areas that contain shallow drinking wells. **In Upper Long Lake, the use of contact herbicides is recommended for the control of**

approximately 3 acres of nuisance Starry Stonewort growth, 11.5 acres of nuisance Curly-leaf Pondweed growth, 2 acres of Purple Loosestrife growth and 1 acre of Phragmites growth. Unfortunately, there are not systemic herbicides to treat these types of aquatic vegetation.

Systemic herbicides such as 2, 4-D and triclopyr are the two primary systemic herbicides used to treat milfoil that does not cover an entire lake. Fluridone (trade name, SONAR®) is a systemic whole-lake

herbicide treatment that is applied to the entire lake volume in the spring and is used for extensive infestations. The objective of a fluridone treatment is to selectively control the growth of milfoil in order to allow other native aquatic plants to germinate and create a more diverse aquatic plant community**. Given the high probability of hybrid milfoil resistance to fluridone, the use of another effective systemic herbicide such as granular or liquid Triclopyr is recommended. This herbicide was used very successfully on many lakes with hybrid watermilfoil, including local Lake Angelus. Triclopyr must be used in near shore areas with shallow well (< 30 feet deep) restrictions. Also, the use of granular 2,4-D in offshore area may be considered. The objective is to reduce the biomass of milfoil and rely on spot-treatments with significantly less herbicide once the population is under control.**

Additional information on the aquatic herbicide uses and procedures is available in Appendix B.

5.1.2 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 39). The mechanical harvester collects numerous loads of aquatic plants as they are cut near the lake bottom. The plants are off-loaded onto a conveyor and then into a dump truck. Harvested plants are then taken to an offsite landfill or farm where they can be used as fertilizer. Mechanical harvesting is preferred over chemical herbicides when primarily native aquatic plants exist, or when excessive amounts of plant biomass need to be removed. Mechanical harvesting is usually not recommended for the removal of Eurasian Watermilfoil since the plant may fragment when cut and re-grow on the lake bottom. **Due to the fact that milfoil has been extensively harvested in Upper Long Lake over the years and fragmentation has allowed the acreage to increase, thus necessitating more harvesting, our recommendation is to temporarily cease harvesting operations until the milfoil has been effectively reduced. In future years of the program, harvesting may be used to reduce nuisance native aquatic vegetation growth.**

Mechanical harvesting does not require a permit from the Michigan Department of Environmental Quality (MDEQ); however, some counties require a launch site use permit from the Michigan Department of Natural Resources (MDNR) if a public access site is present.

On Upper Long Lake, there are three sites that could possibly be used for harvesting. The first is currently being used as the harvest site with two ramps and sufficient room to not only accommodate harvesting but also allow residents to use the open ramp. The second site is in the same subdivision and is currently used as a marina, swim beach, and playground. The third is located in the "woods" canal and is currently used to launch and retrieve the harvesters. Sites two and three would require extensive expense to create a site capable of harvesting and a significant change from its current use. Some of the sites are shown in Figures 40-41. This is an issue that should be discussed among the lake board and the subdivisions involved to determine acceptable long-term locations for future years.

Figure 39. A mechanical harvester

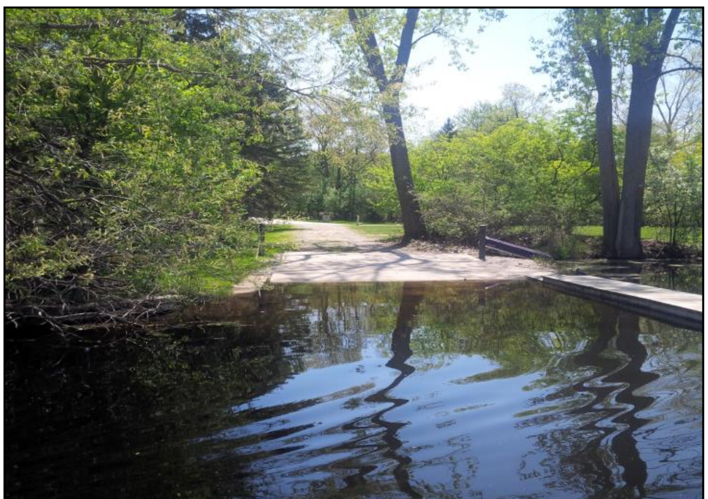

Figure 40. A possible harvesting transfer site near the northwest end of Upper Long Lake

Figure 41. A possible harvesting transfer site near the northwest end of Upper Long Lake

5.1.3 Diver Assisted Suction Harvesting (DASH)

Suction harvesting via a Diver Assisted Suction Harvesting (DASH) boat (Figure 42) involves hand removal of individual plants by a SCUBA diver in selected areas of lake bottom with the use of a hand-operated suction hose. Samples are dewatered on land or removed via fabric bags to an offsite location**. This method is generally recommended for small (less than 1 acre) spot removal of vegetation since it is costly on a large scale. It may be used in the future to remove small remaining areas of milfoil after large-scale initial treatments have been successful or is useful on dense lily pad growth.**

Furthermore, this activity may cause re-suspension of sediments (Nayar et *al*., 2007) which may lead to increased turbidity and reduced clarity of the water. This method is a sustainable option for removal of plant beds in beach areas and areas where herbicide treatments may be restricted. The process requires a permit from the MDEQ.

Figure 42. A DASH boat for hand-removal of milfoil or other nuisance vegetation. ©Restorative Lake Sciences, LLC

5.1.4 Dredging

Dredging is a lake management option used to remove accumulated lake sediments to increase accessibility for navigation and recreational activities. Dredging activities in Upper Long Lake would remove sediments in shallow areas, along with some dense aquatic vegetation. Selection of a particular dredging method and CDF should consider the environmental, economical, and technical aspects involved. Dredging is regulated pursuant to provisions of Part 301 (Inland Lakes and Streams) of the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, and requires a joint permit through both the Michigan Department of Environmental Quality (MDEQ) and the U.S. Army Corps of Engineers (USACE).
The two major types of dredging include hydraulic and mechanical. A mechanical dredge usually utilizes a backhoe and requires that the disposal site be adjacent to the lake. In contrast, a hydraulic dredge removes

sediments in an aqueous slurry and the wetted sediments are transported through a hose to a confined disposal facility (CDF). The CDF must be chosen to maximize retention of solids and accommodate large quantities of water from the dewatering of sediments. It is imperative that hydraulic dredges have adequate pumping pressure which can be achieved by dredging in waters greater than 3 foot of depth. Dredge spoils cannot be emptied into wetland habitats; therefore a large upland area is needed for lakes that are surrounded by wetland habitats. In addition, proposed sediment for removal must be tested for metal contaminants before being stored in a CDF. If the sediment is not contaminated, it could be used for habitat restoration, landfill cover, agriculture, strip mine reclamation, or in other industrial or construction uses (U.S. EPA/USACE 2004).

Funding for dredging projects is usually limited and thus a Special Assessment District (SAD) may need to be established to fund the project. If an SAD is formed, then approval of the project would require a public hearing. A dredging Feasibility Study would also need to be conducted prior to the start of the project to determine the amount of sediment to be dredged and the associated removal and management oversight costs. The State of Michigan Department of Environmental Quality (MDEQ) has established threshold effects and probable effects concentrations for arsenic levels in sediments. The threshold effects concentration is at 9.79 mg/kg of dry weight and the probable effects concentration is as 33.0 mg/kg of dry weight.

Two canals were dredged in Upper Long Lake in 2007 and 2009 and demonstrated initial declines in all aquatic vegetation forms; however, within two years, the aquatic plants returned to prior growth conditions. Thus, dredging is not recommended as a solution for aquatic plant management.

5.1.5 Laminar Flow Aeration and Bioaugmentation

Laminar flow aeration systems (Figure 43) are retrofitted to a particular site and account for variables such as water depth and volume, contours, water flow rates, and thickness and composition of lake sediment. The systems are designed to completely mix the surrounding waters and evenly distribute dissolved oxygen throughout the lake sediments for efficient microbial utilization.

A laminar flow aeration system utilizes diffusers which are powered by onshore air compressors. The diffusers are connected via extensive self-sinking airlines which help to purge the lake sediment pore water of gases such as benthic carbon dioxide (CO_2) and hydrogen sulfide (H_2S), which is a primary nutrient necessary aquatic plant photosynthetic growth and productivity and is also a byproduct of microbial metabolism. In addition to the placement of the diffuser units, the concomitant use of bacteria and enzymatic treatments to facilitate the microbial breakdown of organic sedimentary constituents is also used as a component of the treatment. Beutel (2006) found that lake oxygenation eliminates release of NH_3+ from sediments through oxygenation of the sediment-water interface. Allen

(2009) demonstrated that NH_3+ oxidation in aerated sediments was significantly higher than that of control mesocosms with a relative mean of 2.6 ± 0.80 mg N g dry wt day^{-1} for aerated mesocosms and 0.48 ± 0.20 mg N g dry wt day^{-1} in controls. Although this is a relatively new area of research, recent case studies have shown promise on the positive impacts of laminar flow aeration systems on aquatic ecosystem management with respect to **organic matter degradation and resultant increase in water depth, and rooted aquatic plant management in eutrophic ecosystems** (Jermalowicz-Jones, 2010; 2011). Toetz (1981) found evidence of a decline in *Microcystis* algae (a toxin-producing blue-green algae) in Arbuckle Lake in Oklahoma. Other studies (Weiss and Breedlove, 1973; Malueg et *al.*, 1973) have also shown declines in overall algal biomass (planktonic and filamentous).

Conversely, a study by Engstrom and Wright (2002) found no significant differences between aerated and non-aerated lakes with respect to reduction in organic sediments. This study was however limited to one sediment core per lake and given the high degree of heterogeneous sediments in inland lakes may not have accurately represented the conditions present throughout much of the lake bottom. The philosophy and science behind the laminar flow aeration system is to reduce the organic matter layer in the sediment so that a significant amount of nutrient is removed from the sediments and excessive sediments are reduced to yield a greater water depth. There is still a pool of sedimentary phosphorus that is bound to the sediments and not released into the water column since anoxic conditions are no longer present.

Benefits and Limitations of Laminar Flow Aeration

In addition to the reduction in toxic blue-green algae (such as *Microcystis* sp.) as described by Toetz (1981), aeration and bioaugmentation in combination have been shown to exhibit other benefits for the improvements of water bodies. Laing (1978) showed that a range of 49-82 cm of organic sediment was removed annually in a study of nine lakes which received aeration and bioaugmentation. It was further concluded that this sediment reduction was not due to re-distribution of sediments since samples were collected outside of the aeration "crater" that is usually formed. A study by Turcotte et *al*. (1988) analyzed the impacts of bioaugmentation on the growth of Eurasian Watermilfoil and found that during two four-month studies, the growth and re-generation of this plant was reduced significantly with little change in external nutrient loading. Currently, it is unknown whether the reduction of organic matter for rooting medium or the availability of nutrients for sustained growth is the critical growth limitation factor and these possibilities are being researched. A reduction of Eurasian Watermilfoil is desirable for protection of native plant biodiversity, recreation, water quality, and reduction of nutrients such as nitrogen and phosphorus upon decay (Ogwada et *al*., 1984).

Furthermore, bacteria are the major factor in the degradation of organic matter in sediments (Fenchel and Blackburn, 1979) so the concomitant addition of microbes to lake sediments will accelerate that process. A reduction in sediment organic matter would likely decrease Eurasian Watermilfoil growth as well as increase water depth and reduce the toxicity of ammonia nitrogen to overlying waters. A study by Verma and Dixit (2006) evaluated aeration systems in Lower Lake, Bhopal, India, and found that the aeration increased overall dissolved oxygen, and reduced biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliform counts.

The Laminar Flow Aeration system has some limitations including the inability to break down mineral sediments, the requirement of a constant Phase I electrical energy source to power the units and possible unpredictable response by various species of rooted aquatic plants (currently being researched by RLS).

Design of the Laminar Flow Aeration System

The design of a laminar flow system would be retrofitted to the entire basin of Upper Long Lake. The system has several components which consist of in-water components such as micro-porous ceramic diffusers, self-sinking airline, and bacteria and enzyme treatments which consist of C-Flo® bacteria for sediment nutrient reduction, and Clean and Clear® Enzymes as a catalyst for muck reduction. On-land components consist of locally-sourced sheds and rotary claw compressor(s) along with cooling fans and ventilation. Once the system has been installed, the MDEQ has instituted a required minimum sampling protocol to monitor the efficacy of the system for the intended purposes as determined by stakeholders. A custom-engineered design to completely mix the waters in Upper Long Lake is shown below in Figure 44. Note: This design is for the main lake basin and separate designs would be needed for each canal given the unique bathymetries of each site.

Due to the **high quantity of organic matter in many offshore areas of Upper Long Lake, the reduction of sediment muck is likely. In addition, there is an intense need for oxygen in the lake water column, especially during mid to late summer when the lake is stratified.** The response of the submersed aquatic vegetation varies among sites and thus cannot be determined. The use of both spot-treatment of herbicides and aeration may be beneficial for treatment of the weeds and improvement of water quality.

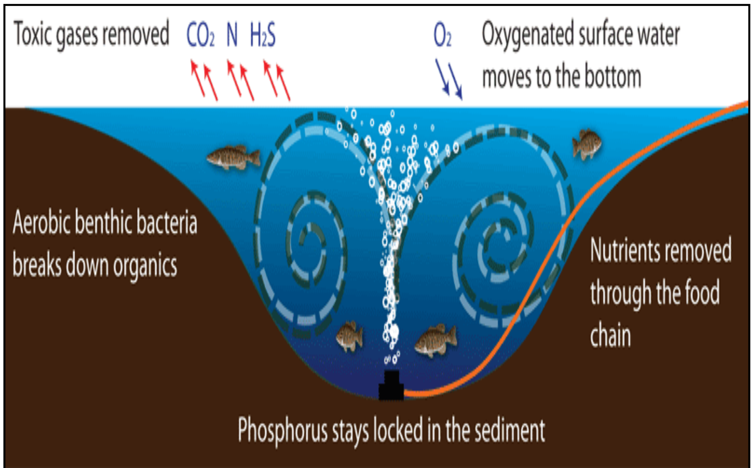

Figure 43. A diagram showing the laminar flow aeration mechanisms. ©Restorative Lake Sciences, LLC

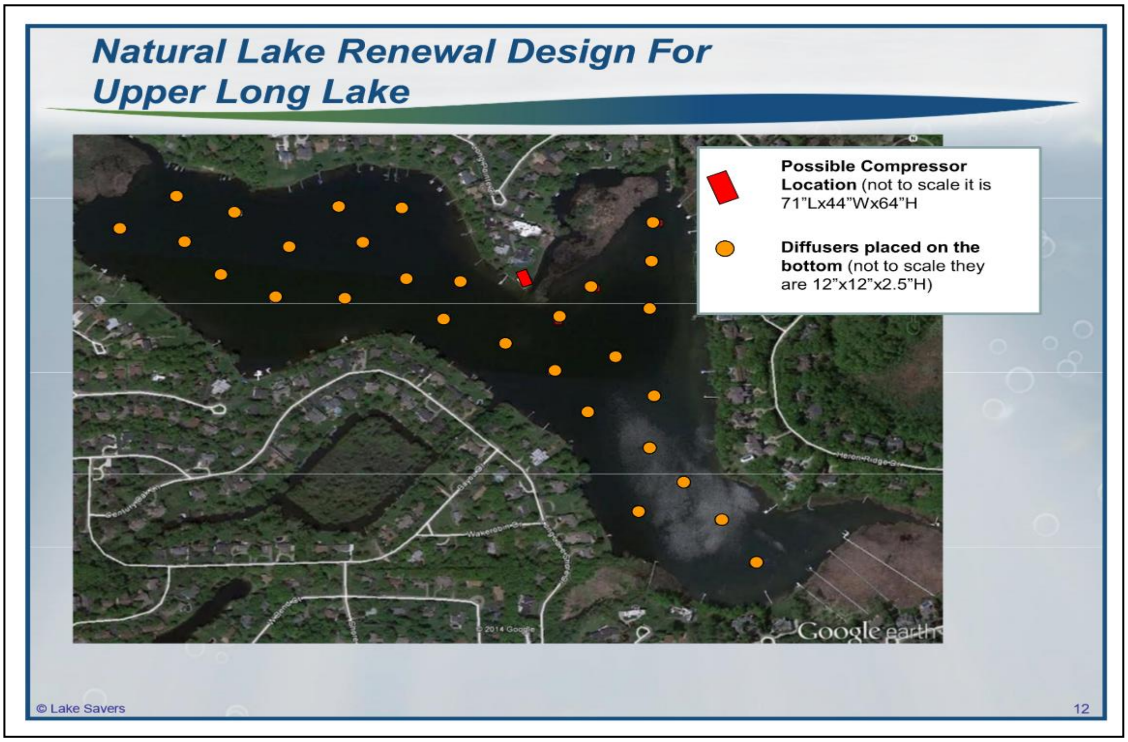

Figure 44. Custom-engineered design for a whole-lake aeration system for Upper Long Lake, Oakland County, MI (©Lake Savers, LLC, 2014).

The aeration components would include a single C1202 inversion system with variable frequency drive technology, outdoor sound-insulated protective enclosures, 20 micro-porous ceramic diffusers, 34,000 feet of self-sinking aeration, fittings. Bioaugmentation would consist of approximately 65 pounds of Clean and Clear® enzyme formula, 65 pounds of C-Flo® bacteria, and 150 pounds of Nutrisorb® bacteria for muck reduction.

5.2 Upper Long Lake Watershed Management

In addition to the proposed treatment of Eurasian Watermilfoil in Upper Long Lake, it is recommended that Best Management Practices (BMP's) be implemented to improve the lake's water quality. The guidebook, Lakescaping for Wildlife and Water Quality (Henderson et *al*. 1998) provides the following guidelines:

1) Maintenance of brush cover on lands with steep slopes (those > 6%; see above soil table)
2) Development of a vegetation buffer zone 25-30 feet from the land-water interface with approximately 60-80% of the shoreline bordered with vegetation
3) Limiting boat traffic and boat size to reduce wave energy and thus erosion potential
4) Encouraging the growth of dense shrubs or emergent shoreline vegetation to control erosion
5) Using only native genotype plants (those native to Upper Long Lake or the region) around the lake since they are most likely to establish and thrive than those not acclimated to growing in the area soils

The book may be ordered online at: http://web2.msue.msu.edu/bulletins/mainsearch.cfm.

5.2.1 Upper Long Lake Erosion and Sediment Control

The construction of impervious surfaces (i.e. paved roads and walkways, houses) should be minimized and kept at least 100 feet from the lakefront shoreline to reduce surface runoff potential. In addition, any wetland areas around Upper Long Lake should be preserved to act as a filter of nutrients from the land and to provide valuable wildlife habitat. Construction practices near the lakeshore should minimize the chances for erosion and sedimentation by keeping land areas adjacent to the water stabilized with rock, vegetation, or wood retaining walls. This is especially critical in areas that contain land slopes greater than 6%. Erosion of sand into the water may lead to increased turbidity and nutrient loading to the lake. Seawalls should consist of rip-rap (stone, rock), rather than metal, due to the fact that rip-rap offers a more favorable habitat for lakeshore organisms, which are critical to the ecological balance of the lake ecosystem. Rip-rap should be installed in front of areas where metal seawalls are currently in use. The rip-rap should extend into the water to create a presence of microhabitats for enhanced biodiversity of the aquatic organisms within Upper Long Lake. The emergent aquatic plant, *Scirpus* sp. (Bulrushes) present around Upper Long Lake offers satisfactory stabilization of shoreline sediments and assists in the minimization of sediment release into the lake. This plant should be encouraged to grow around the shoreline.

5.2.2 Upper Long Lake Nutrient Source Control

Based on the high ratio of nitrogen to phosphorus (i.e. N: P > 15), any additional inputs of phosphorus to the lake are likely to create additional algal and aquatic plant growth. Accordingly, RLS recommends the following procedures to protect the water quality of Upper Long Lake:

1) Avoid the use of lawn fertilizers that contain phosphorus (P). P is the main nutrient required for aquatic plant and algae growth, and plants grow in excess when P is abundant. When possible, water lawns with lake water that usually contains adequate P for successful lawn growth. If you must fertilize your lawn, assure that the middle number on the bag of fertilizer reads "0" to denote the absence of P. If possible, also use low N in the fertilizer or use lake water.
2) Preserve riparian vegetation buffers around lake (such as those that consist of Cattails, Bulrushes, and Swamp Loosestrife), since they act as a filter to catch nutrients and pollutants that occur on land and may run off into the lake. As an additional bonus, Canadian geese (*Branta canadensis*) usually do not prefer lakefront lawns with dense riparian vegetation because they are concerned about the potential of hidden predators within the vegetation.
3) Do not burn leaves near the lake shoreline since the ash is a high source of P. The ash is lightweight and may become airborne and land in the water eventually becoming dissolved and utilized by aquatic vegetation and algae.
4) Assure that all areas that drain into the lake from the surrounding land are vegetated and that no fertilizers are used in areas with saturated soils (see soil table above).
5) For long-term health of the lake, installation of sewers in those subdivisions that have septic systems within the watershed and especially in subdivisions along the shoreline of Upper Long Lake.

5.3 Upper Long Lake Invasive Species Prevention

An exotic species is a non-native species that does not originate from a particular location. When international commerce and travel became prevalent, many of these species were transported to areas of the world where they did not originate. Due to their small size, insects, plants, animals, and aquatic organisms may escape detection and be unknowingly transferred to unintended habitats. The first ingredient to successful prevention of unwanted transfers of exotic species to Upper Long Lake is awareness and education. The exotic species of concern have been listed in this report. **Other exotic species on the move should be introduced to the riparians around Upper Long Lake through the use of an educational newsletter which would be distributed in the spring or early summer of each season.**

5.3.1 Zebra Mussels and Asian Clams

Zebra mussels (*Dreissena polymorpha*; Figure 45) were first discovered in Lake St. Clair in 1988 (Herbert et al. 1989) and likely arrived in ballast water or on shipping vessels from Europe (McMahon 1996). They are easily transferred to other lakes because they inherit a larval (nearly microscopic) stage where they can easily avoid detection. The mussels then grow into the adult (shelled) form and attach to substrates (i.e. boats, rafts, docks, pipes, aquatic plants, and lake bottom sediments) with the use of byssal threads. The fecundity (reproductive rate) of female zebra mussels is high, with as many as 40,000 eggs laid per reproductive cycle and up to 1,000,000 in a single spawning season (Mackie and Schlosser 1996). Although the mussels only live 2-3 years, they are capable of great harm to aquatic environments. In particular, they have shown selective grazing capabilities by feeding on the preferred zooplankton food source (green algae) and expulsion of the non-preferred blue green algae (cyanobacteria). Additionally, they may decrease the abundance of beneficial diatoms in aquatic ecosystems (Holland 1993). Such declines in favorable algae, can decrease zooplankton populations and ultimately the biomass of planktivorous fish populations. Zebra mussels are viewed by some as beneficial to lakes due to their filtration capabilities and subsequent contributions to increased water clarity. However, such water clarity may allow other photosynthetic aquatic plants to grow to nuisance levels (Skubinna et al. 1995). Zebra mussels were also noted throughout Upper Long Lake and thus these guidelines should be followed to reduce future invasions.

The Asian Clam (*Corbicula fluminea*; Figure 46) is native to southern and eastern Asia, Australia, and Africa, but was first noted in North America in the 1920's (Counts 1986**). It was found in several areas of Upper Long Lake and there is not an existing treatment protocol.** The bivalve is usually less than 3 cm in size, colonizes lake sediments, and feeds on organic matter. It has the ability to cross and self-fertilize which creates a high reproduction rate and colonization density of greater than 1000 m^2 (McMahon and Williams 1986) under some environmental conditions. Fortunately, the adult clams may

only live for up to three years and are not likely to persist long if water quality conditions are less than ideal (i.e., low dissolved oxygen levels). Reproduction generally occurs when the water temperature is around 15°C (59°F), with more than one annual brood in the late spring and fall. **Like Zebra Mussels, the Asian Clam, may also result in blue-green algae blooms because they compete with native clams for food by filtering favorable green algae from the water (along with the benthic organic matter) and this results in a disproportionate quantity of blue-green algae in the water column relative to green algae which results in a "bloom".** Such declines in favorable algae can decrease zooplankton populations and ultimately the biomass of planktivorous fish populations (i.e. fish that feed on favorable zooplankton) which includes most warm-water and cool-water fish species.

The recommended prevention protocols for introduction of zebra mussels and Asian clams includes steam-washing all boats, boat trailers, jet-skis, and floaters prior to placing them into Upper Long Lake. Fishing poles, lures, and other equipment used in other lakes (and especially the Great Lakes) should also be thoroughly steam-washed before use in Upper Long Lake. Additionally, all solid construction materials (if recycled from other lakes) must also be steam-washed. Boat transom wells must always be steam-washed and emptied prior to entry into the lake. Excessive waterfowl should also be discouraged from the lake since they are a natural transportation vector of the microscopic zebra mussel larvae or mature adults.

Figure 45. Photo of a zebra mussel colony, USGS

Figure 46. Asian Clam

5.3.2 Invasive Aquatic Plants

In addition to Eurasian watermilfoil (*M. spicatum*), many other invasive aquatic plant species are being introduced into waters of the North Temperate Zone. The majority of exotic aquatic plants do not depend on high water column nutrients for growth, as they are well-adapted to using sunlight and minimal nutrients for successful growth. These species have similar detrimental impacts to lakes in that they decrease the quantity and abundance of native aquatic plants and associated macroinvertebrates and consequently alter the lake fishery. Such species include *Hydrilla verticillata* (Figure 47) and *Trapa natans* (Water Chestnut; Figure 48). *Hydrilla* was introduced to waters of the United States from Asia in

1960 (Blackburn et al. 1969) and is a highly problematic submersed, rooted, aquatic plant in tropical waters. Recently, *Hydrilla* was found in Lake Manitou (Indiana, USA) and the lake public access sites were immediately quarantined in an effort to eradicate it. *Hydrilla* retains many physiologically distinct reproductive strategies which allow it to colonize vast areas of water and to considerable depths, including fragmentation, tuber and turion formation, and seed production. Currently, the methods of control for *Hydrilla* include the use of chemical herbicides, rigorous mechanical harvesting, and Grass Carp (*Ctenopharyngodon idella* Val.), with some biological controls currently being researched. However, use of the Grass Carp in Michigan is currently not permitted by the Michigan Department of Natural Resources (MDNR).

Water Chestnut (*Trapa natans*) is a non-native, annual, submersed, rooted aquatic plant that was introduced into the United States in the 1870's yet may be found primarily in the northeastern states. The stems of this aquatic plant can reach lengths of 12-15 feet, while the floating leaves form a rosette on the lake surface. Seeds are produced in May and are extremely thick and hardy and may last for up to 12 years in the lake sediment. If stepped on, the seed pods may even cause deep puncture wounds to those on the lake. Methods of control involve the use of mechanical removal and chemical herbicides. Biological controls are not yet available for the control of this aquatic plant.

Figure 47. Hydrilla

Figure 48. Water Chestnut

6.0 UPPER LONG LAKE PROJECT CONCLUSIONS & RECOMMENDATIONS

The **urgent control of the invasive hybrid Eurasian Watermilfoil with systemic Triclopyr and 2,4-D and, Curly-leaf Pondweed, Starry Stonewort, Purple Loosestrife, and Phragmites with contact herbicides in and around Upper Long Lake** is essential for the long-term preservation of the favorable (non-nuisance) native aquatic plant communities in the lake. The **use of aquatic herbicides for species-specific control of these plants is preferred** over other methods at this time due to a high fragmentation risk and need to urgently decrease the invasive populations to protect the lake ecosystem.

The Purple Loosestrife around the shoreline may either be hand-pulled and discarded or treated with the systemic herbicide, triclopyr. Alternatively, *Galerucella* beetles can be used to naturally destroy flowering portions of the plant and reduce spread. **Phragmites has been successfully controlled in many areas due to swift management actions by riparians for the past three years. The dense stands at the east end of the lake (into Lower Long Lake) must be addressed since they are a threat to spreading into Upper Long Lake if not managed.** These plants can be treated with contact herbicides and hand-swiped with herbicides and/or burned or hand removed.

Also, the use of laminar flow aeration with bio augmentation to increase the dissolved oxygen in the lake and reduce sediment muck is recommended for immediate implementation (spring, 2015) to reduce further damage to the lake ecosystem. The Freshwater Physician's report (1974) emphasized that the sediments in Upper Long Lake are the main source of problems for the lake. These sediments will continue to release phosphorus into the water column if there is a lack of dissolved oxygen at the lake bottom which continues to occur. It is possible to select a portion of the lake, including the canals as test areas or for a pilot project.

However, the results in the canals would likely be very different from the main lake due to obvious differences in water depth, sediment depths, water volume, etc. Both areas would experience reductions in muck and improvements to water quality.

Additional improvements would include the assurance that all areas around the lake are vegetated at all times so that runoff from the steep land slopes (>6%, see soils map earlier in report) into the lake water is reduced. If the lake water becomes turbid during a rain event all efforts to determine the entry point of the turbidity should be executed to reduce sediment loading to the lake. **The conductivity of the lake water is very high and efforts to reduce chlorides from septic system leachate and storm water should be pursued.**

6.1 Recommendations for Upper Long Lake Improvements

Every lake management plan should offer solutions that are ecologically sound, practical, and economically feasible. Project funds as recommended should come from the existing Special Assessment District. If additional funds are needed, public hearings of practicability and assessment roll may be necessary. The SAD should include all riparian properties around Upper Long Lake and back lot properties with deeded or dedicated access. The community is encouraged to continue to participate in regular water quality sampling of Upper Long Lake through the Cooperative Lakes Monitoring Program (CLMP) with the Michigan Lake and Streams Association (MLSA) and Michigan Department of Environmental Quality (MDEQ). Such monitoring is continuously recommended to assess the nutrient status of the lake both prior to lake improvements and for years after to reassess water quality improvements from implemented management techniques. The Association may also create an educational program for riparians to reduce nutrient loads to the lake.

Furthermore, a professional limnologist/aquatic botanist should perform regular GPS-guided whole-lake surveys each spring and fall to monitor the growth and distribution of all invasives and all aquatic plants continuously monitor the lake for potential influxes of other exotic aquatic plant genera (i.e. *Hydrilla*) that could also significantly disrupt the ecological stability of Upper Long Lake. The lake manager should oversee all management activities and would be responsible for the creation of aquatic plant management survey maps, direction of the harvester or herbicide applicator to target-specific areas of aquatic vegetation for removal, implementation of watershed best management practices, administrative duties such as the processing of contractor invoices, and the education of lakefront owners through an educational newsletter and through attending committee meetings. The educational newsletter should contain educational tips for residents to recognize and prevent the transfer of invasive species to the lake and watershed management methods.

6.1.1 Cost Estimates for Upper Long Lake Improvements

The proposed integrated management treatment program for the continued control of the invasives and aeration of Upper Long Lake would begin during the spring of 2015 and continue through 2018. A breakdown of costs associated with the recommended Upper Long Lake improvements is presented in Table 8. 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).

Proposed Upper Long Lake Improvement Item	Estimated 2015 Cost	Estimated 2016 Cost[4]	Estimated 2017-2018 Cost[5]
Systemic herbicides for Eurasian Watermilfoil[1] for 39 acres@ $515 per acre; $800 MDEQ permit fee	$20,085	$15,064	$15,064
Contact herbicides for Curly-leaf Pondweed, Starry Stonewort, Purple Loosestrife, Phragmites	$5,790	$5,790	$4,343
Note: Additional costs were provided to the Association and Board for review.			

Table 8. Upper Long Lake proposed lake improvement program costs (2015-2018).

[1] Herbicide treatment scope may change annually due to changes in the distribution and/or abundance of aquatic plants.

[2] Professional services includes two annual GPS-guided, aquatic vegetation surveys, pre and post-treatment surveys for aquatic plant control methods, oversight and management of the aquatic plant control program, processing of all invoices from contractors and others billing for services related to the improvement program, education of local riparians through the development and publication of a high-quality, scientific newsletter, and attendance at up to 3 regularly scheduled board meetings.

[3] Contingency is 10% of the total project cost, to assure that extra funds are available for unexpected expenses. Note: Contingency may be advised and/or needed for future treatment years. Contingency funds may also be used for other water quality improvements and watershed management.

[4] Cost estimates for 2016 based on 75% of the herbicide treatment costs for 2015. Note: herbicide unit costs given for 2016 may change in 2017 and beyond due to cost of living adjustments for the contractor services and/or products.

[5] Costs of the proposed program for years 2017-2018 are estimates only and may change based on the distribution and/or abundance of invasive or nuisance pondweed and costs of products and contractor services.

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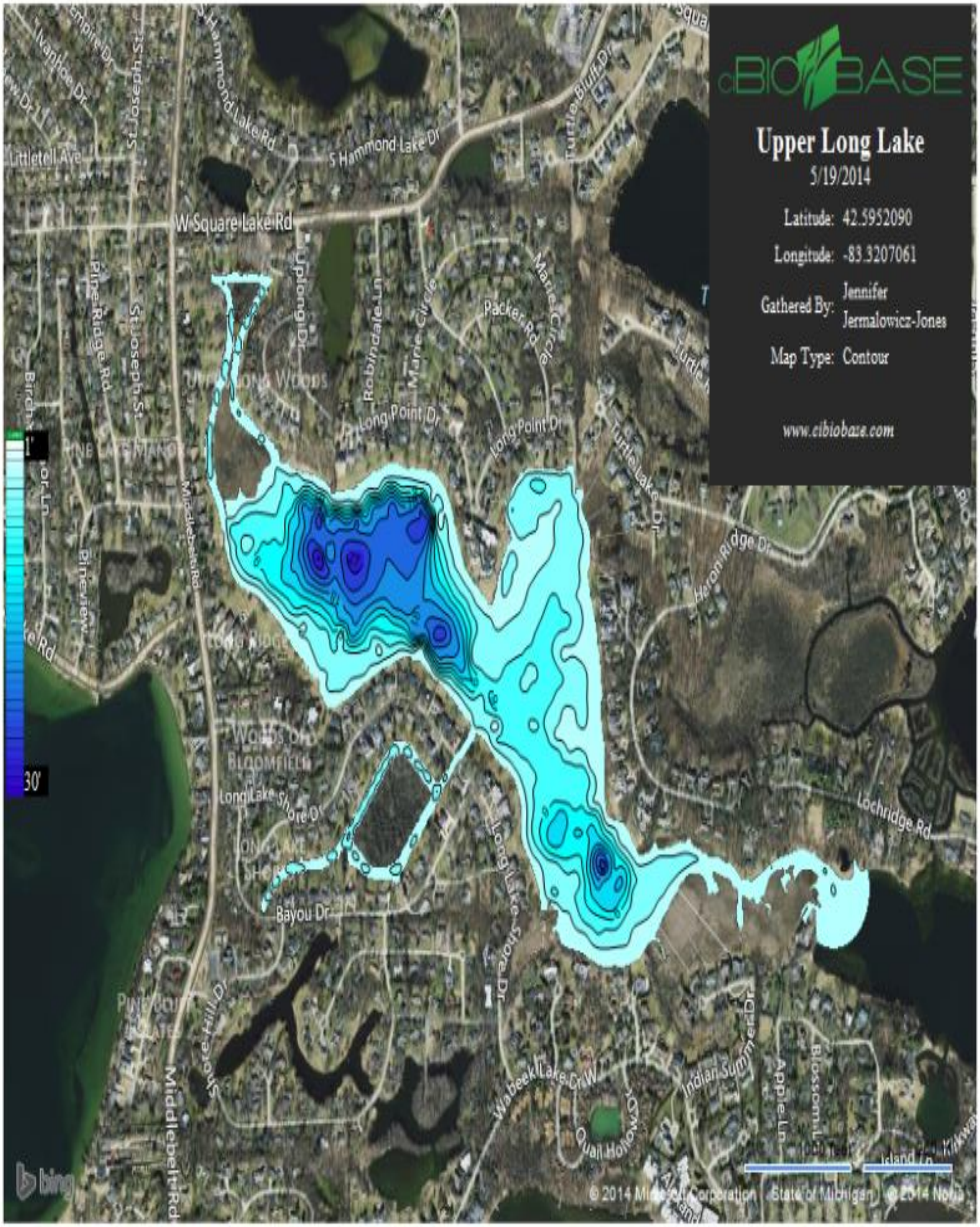
APPENDIX A:
BIOBASE MODERN DEPTH CONTOUR MAP OF UPPER LONG LAKE



ciBIOBASE
Upper Long Lake
5/19/2014
Latitude: 42.5952090
Longitude: -83.3207061
Gathered By: Jennifer Jermalowicz-Jones
Map Type: Contour
www.cibiobase.com
1'
30'
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APPENDIX B:
FREQUENTLY ASKED QUESTIONS ABOUT AQUATIC HERBICIDES

1) **What is this notice I received and what does it tell me?**
Answer: It is required by the state of Michigan Department of Environmental Quality (MDEQ) for the herbicide applicator under contract to send first class notices to all riparians on the lake prior to any lake treatments. These notices must specify the types of herbicides that may be used (not necessarily that they will be used but may depending on conditions), the dosages, and the watering, swimming, and possible fishing restrictions. To find all required info please visit the MDEQ website at:
http://www.michigan.gov/deq/0,1607,7-135-3313_3681_3710---,00.html

2) **Why are we poisoning our lakes with chemicals!?**
Answer: It is unfortunate that we need to use herbicides for some invasive aquatic plant species or other nuisance native species. However, if these plants are not controlled through some means, they will take over most inland lakes and leave the lake in a useless state. Such overgrowth may also threaten the ecological balance of a lake and also lead to reductions in use and property values. Until more tools are available, we are limited to herbicides, mechanical removal, or aeration for some types of plants. The link given above in Question #1 has many PDF files that discuss the registration process and how herbicides can be safe if used as labelled. Also, the link below to the EPA website discusses herbicides in even more detail:
http://www.epa.gov/caddis/ssr_herb_int.html

3) **Will the herbicides kill my garden plants?**
Answer: Individual herbicides have their own restrictions for use in watering of plants. If there is concern about herbicide residues being high in the lake water, lab testing can be conducted to see if watering restrictions can be lifted. It has been the experience of most lake managers that most residues are low within 2 weeks of treatment.

4) **Why are postings required on the day of treatment? Also, why do they sometimes staple them to trees?**
Answer: The posting of all treatment areas is required on or just before the day of treatment. Treatment cannot occur without these signs near treatment areas. The signs are usually bright yellow and are 8.5” x 11”. On the postings is information such as the date of treatment, lake treatment permit number, contact information, exact pesticides that are being used in that area, and use restrictions. Posters may be attached to trees, posts, decks, docks, and other visible locations around the shoreline. The postings are usually placed within 100 feet of one another and may stay in place until removed or weathered.

5) **Other than the MDEQ website reference above and the US EPA website also referenced above, what other websites contain herbicide information?**
   Answer: The Aquatic Ecosystem Restoration Foundation is a great source of information on why waterways should be managed and how. The link to their website is:
   http://www.aquatics.org/herbicides.html