Dewey Lake Management Plan & Recommendations
Cass County, Michigan

Provided for the:
Dewey Lake Property Owners Association
(Amended July 6, 2017)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES II

LIST OF TABLES

LIST OF APPENDICES

NAME	APPENDIX

Dewey Lake Management Plan & Study

Amended July, 2017

1.0 EXECUTIVE SUMMARY

Dewey Lake, comprising **225.9 acres**, is of glacial origin with nearly **3.5 miles of shoreline** and a fetch of 0.84 miles which allows for the production of sizeable waves during high-wind events. Based on the current study, Dewey Lake contains a fair amount of submersed native aquatic plant biodiversity but the **11.6 acres of exotic submersed macrophyte Eurasian Watermilfoil** (*Myriophyllum spicatum* L.) growth threatens the biodiversity of the submersed native aquatic macrophyte communities, threatens navigation and recreational activities, and also may harbor bacteria and other nuisance algae that are not beneficial to the lake's ecosystem.

The **overall water quality of Dewey Lake was measured as good to fair with moderate nutrients such as phosphorus and nitrogen and moderate water clarity.** The pH and alkalinity of the lake indicate that it is a "softwater" lake. The majority of the vegetation in the lake receives nutrients from the sediments as the primary growth source since there is a strong presence of rooted aquatic plants.

Restorative Lake Sciences, LLC recommends that **spot-treatments with highly selective systemic aquatic herbicides be used to treat the exotic milfoil within the lake and that strong contact herbicides be used to control the nuisance native aquatic plants. The implementation of laminar flow aeration with bioaugmentation** would reduce the release of phosphorus from the lake bottom during stratified periods (summer) which would help improve water clarity and reduce algae and increase dissolved oxygen. Muck would also decrease but the response of the milfoil by the system is uncertain.
In addition, it is recommended that the Association implement **Best Management Practices (BMP's) to reduce the nutrient and sediment loads being transported into the lake from land areas with high slope.**

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 Dewey 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. **Dewey Lake may be categorized as a seepage lake as it receives water supplies from wetlands and surface water from precipitation and also from bottom springs.**

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 stormwater 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 DEWEY LAKE PHYSICAL AND WATERSHED CHARACTERISTICS

3.1 The Dewey Lake Basin

Dewey Lake is located in Sections 4, 5, 8, and 9 of Silver Creek Township (T.5S, R.16W) in Cass County, Michigan. The lake has a **surface area of approximately 226 acres** (Michigan Department of Natural Resources, 2001; Figure 1) and is classified as a meso-eutrophic aquatic ecosystem with two deep basins of 54 feet and 20 feet deep and a large-sized littoral (shallow) zone**. Dewey Lake has a maximum depth of 54 feet and lacks inflow from rivers or tributaries.** The **lake bottom consists of fibrous and pulpy peat in the deep basins and sand gravel in the shallow areas.** Dewey Lake has a lake **perimeter of approximately 3.5 miles** (Michigan Department of Natural Resources, 1999).

Figure 1. Dewey Lake, Silver Creek Township, Cass County, Michigan.

3.2 Dewey Lake Extended and Immediate Watershed

Dewey Lake is located within the **St. Joseph River watershed** which is approximately 2,998,400 acres (approximately 4,685 mi^2) in area and **includes portions of 15 counties**, including Berrien, Branch, Calhoun, Cass, Hillsdale, Kalamazoo, St. Joseph and Van Buren County in Michigan, and De Kalb, Elkhart, Kosciusko, Lagrange, Noble, St. Joseph, and Steuben Counties in Indiana (http://www.stjoeriver.net). This extended watershed consists of agricultural lands, with more than 50% of the riparian habitat being agricultural or urban, and 25-50% as forested area.

Dewey Lake's immediate watershed consists of the area around the lake which directly drains to the lake and **measures approximately 2,276 acres** (3.56 mi^2) in size (Figure 2). The low amount of development around the lake greatly reduces pollutant runoff during rain events due to less impervious cover. However, the presence of abundant agricultural fields around the west and south shores may contribute nutrients to the lake hydrologically; however, surface runoff from the farms into the lake would be limited by the presence of forested buffers around most of the lake. Wetlands at the south and east of the lake contribute water to the lake via hydrologic inputs and via runoff when fully saturated. The **immediate watershed is approximately 10 times larger than the size of Dewey Lake**, which indicates the presence of **a moderately-sized immediate watershed**.

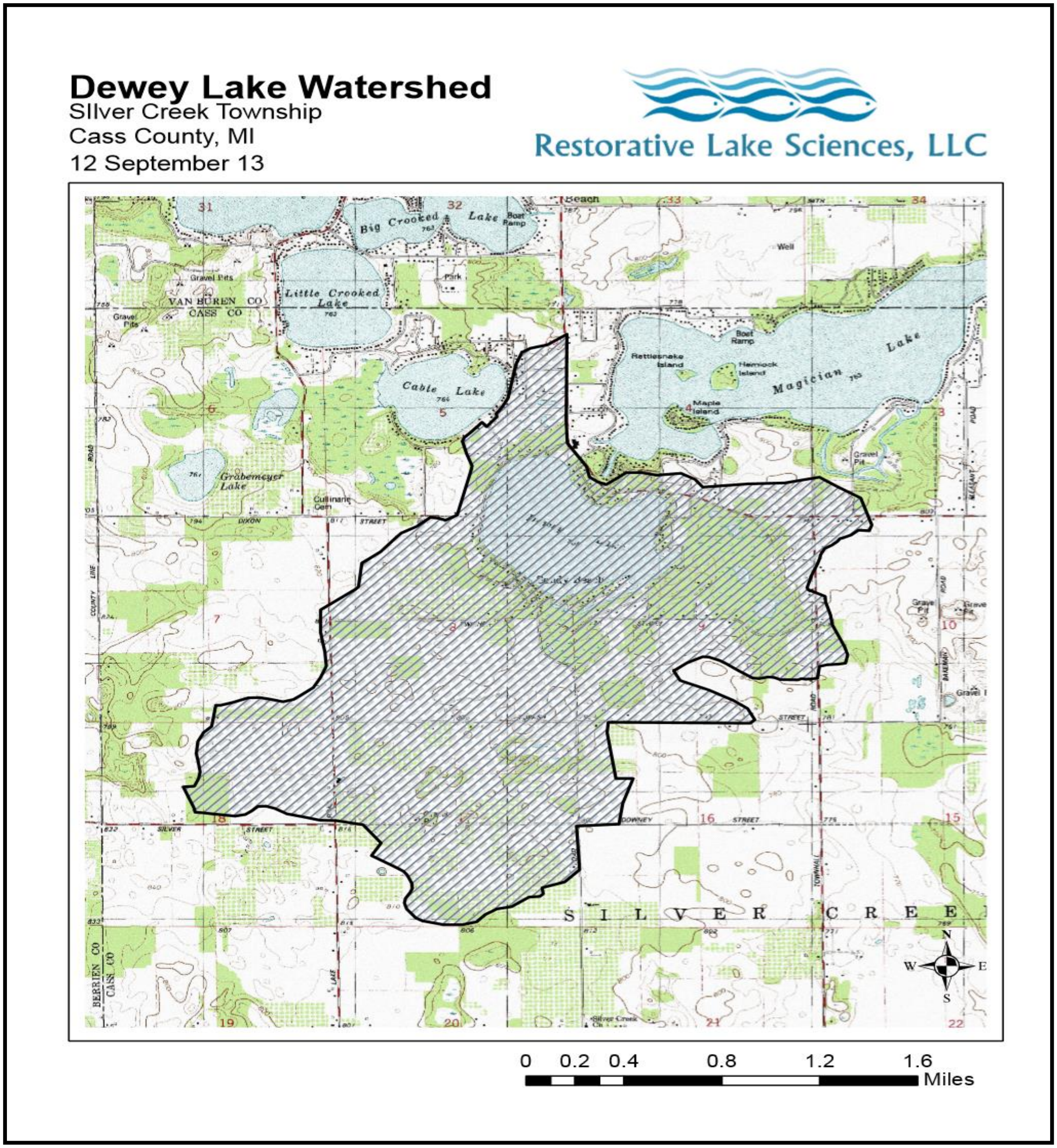

Figure 2. The Dewey Lake Immediate Watershed Boundary.

3.3 Dewey Lake Shoreline Soils

There are 5 major soil series immediately surrounding Dewey 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 Dewey Lake. Major characteristics of the dominant soil types directly surrounding the Dewey Lake shoreline are listed in Table 1 below.

USDA-NRCS Soil Series	***Dewey Lake Location***	***Prominent Soil Type Characteristics***
Oshtemo Sandy Loam (2-6% slope);4B	West shoreline	Deep, well-drained soils; Low runoff potential
Ohstemo Sandy Loam (6-12% slope);4C	Southwest/East shoreline	Deep, well-drained soils; Moderate to rapid permeability
Spinks-Oshtemo Complex (2-6% slope);41B	South shoreline	Deep, well-drained soils; Low runoff potential
Udipsamments & Udorthents, Nearly level;42	North/South shoreline	Excessively drained soils; Very low runoff potential
Spinks-Oshtemo Complex; (6-12% slope);41B	South shoreline	Deep, well drained sands; Low runoff potential
Gilford Sandy Loam;36	Southeast shoreline	Very deep; Poorly drained soils; High water table

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

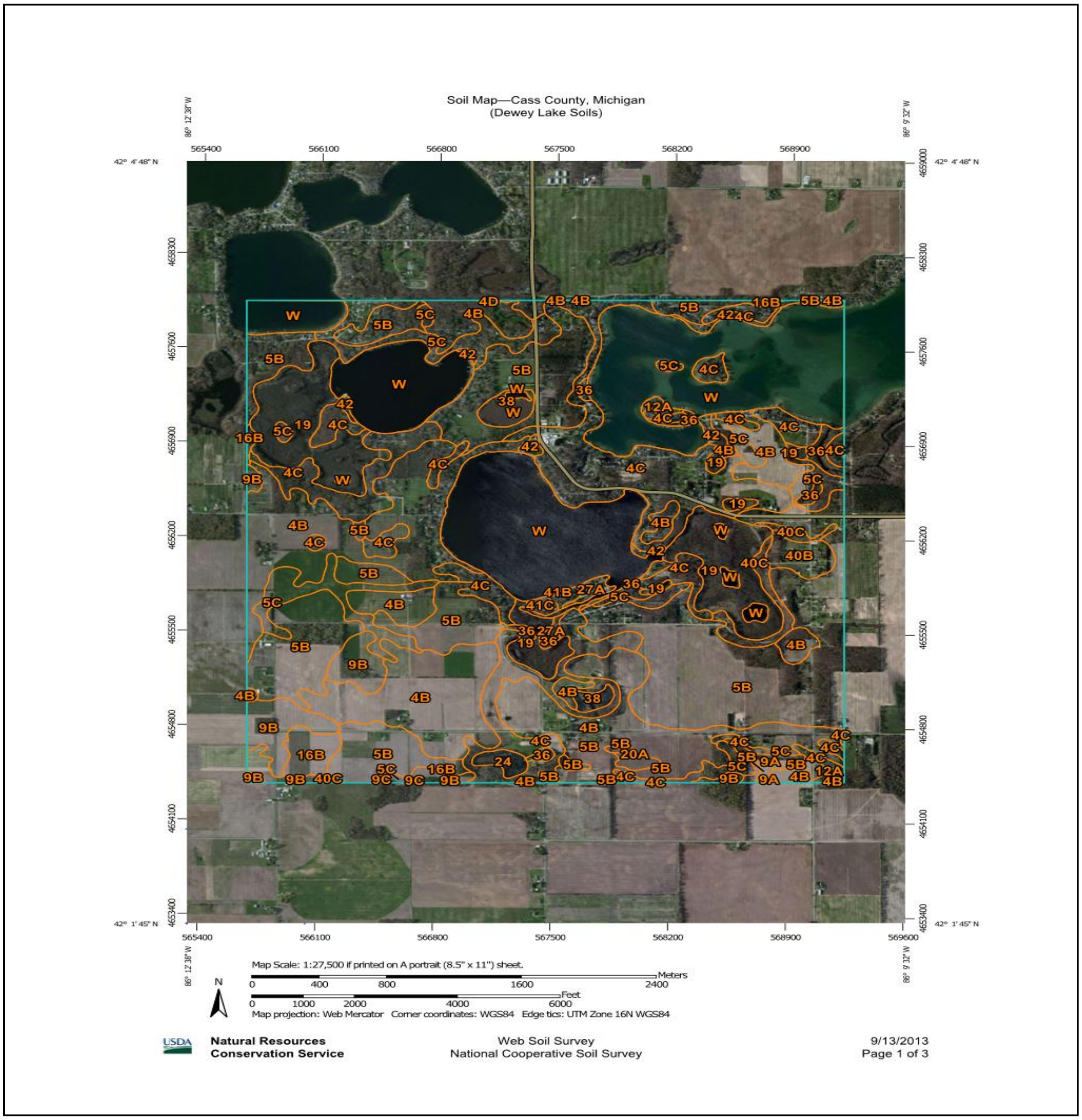

Figure 3. NRCS-USDA soils map for Dewey Lake shoreline soils (1999 data).

There are **5 major classes of soils found around the Dewey Lake shoreline: the Oshtemo Sandy Loams, the Spinks-Oshtemo Complex, Udipsamments and Udorthents, and Gilford Sandy Loams. The Oshtemo Sandy Loams** are very deep soils that are **well-drained** and have rapid permeability. They are also low risk for runoff into nearby waterways. The **Spinks-Oshtemo Complex** consists of very deep soils that are **well-drained** and have moderate to rapid permeability. The majority of the lake is immediately surrounded by these soils that are not prone to saturation or ponding. 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 **Adrian, Napoleon, and Houghton Mucks** are found just beyond the shoreline of Dewey Lake near the adjacent wetlands. These soils contain high concentrations of moist organic substrates that are very poorly drained and have highly variable permeability, resulting in the accumulation of water on the soil surface (ponding). Additionally, the **Gilford Sandy Loams** located at the southeast corner of the lake are very poorly drained and have a high water table which means that the water is not far below the ground level and can result in ponding during heavy rainfall.

However, in areas around the lake where the slopes are greater than 6% (the north, south, and east shores), surface runoff may be a factor, transporting sediments and nutrients to the lake. This is especially true in unvegetated 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 and construction of septic systems close to the lake should be followed.

4.0 DEWEY 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) 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**. **Dewey Lake is classified as meso-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 2 lake deep basins and analyzed them in the laboratory for analysis. Additionally, 2 sediment samples were collected at those sites and analyzed for sediment % organic matter. The results are discussed below and are presented in Tables 3-4. A map showing the sampling locations for all water quality samples is shown below in Figure 4.

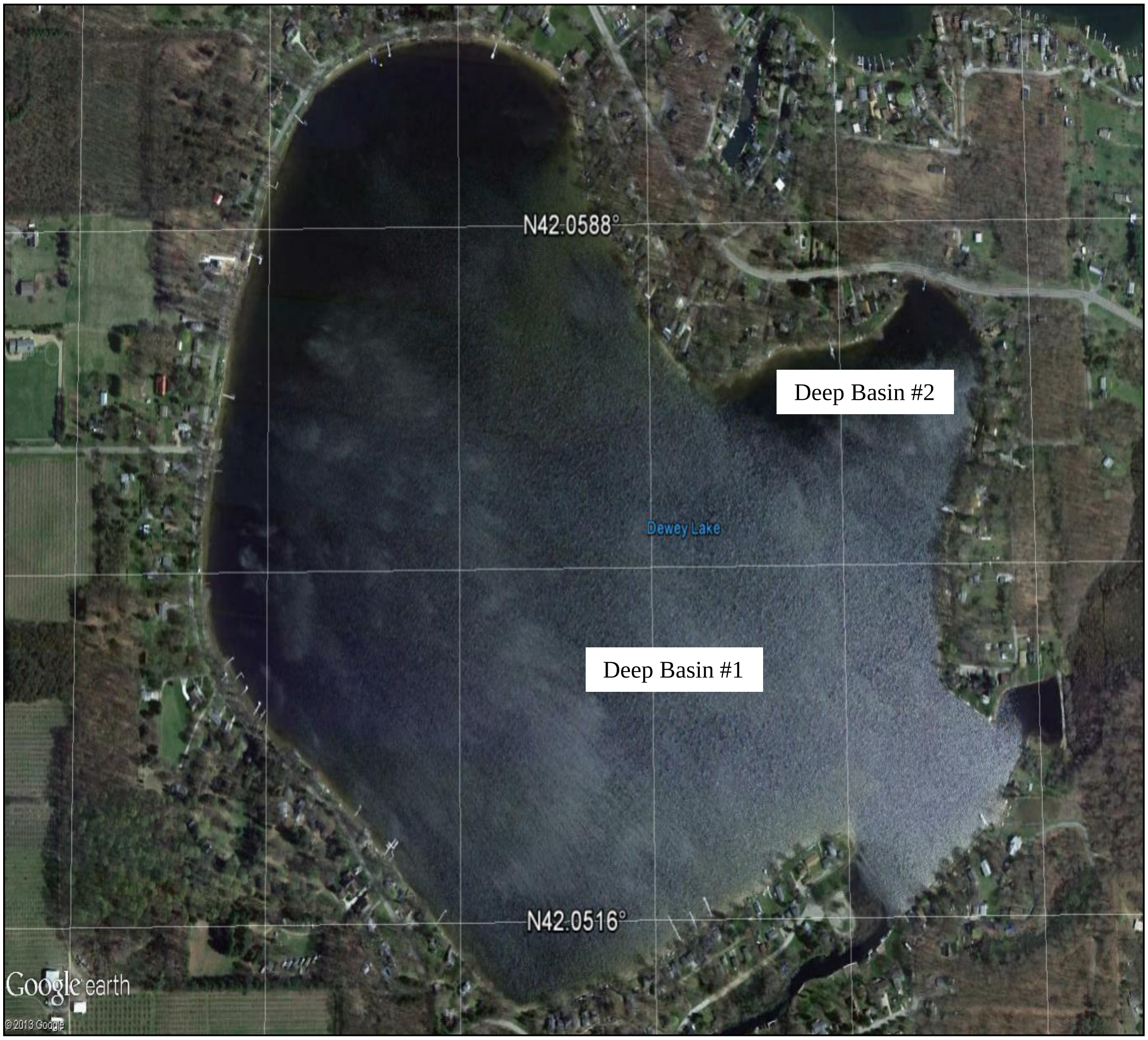

Figure 4. Locations for water quality sampling of the 2 deep basins in Dewey Lake (September, 2013).

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 2.4–8.8 mg L^{-1}, with concentrations of dissolved oxygen higher at the shallower deep basin, especially at the bottom. During the summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. A decline in the dissolved oxygen concentrations to near zero may result in an increase in the release rates of phosphorus (P) from lake bottom sediments.

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 early September water temperatures of Dewey Lake demonstrated a slight thermocline (a transition zone of change in water temperature from top to bottom) between the surface and 20 feet and an additional one at a depth of 54 feet. On the day of sampling, water temperatures ranged between 82.9ºF (at the surface) and 61.1ºF (at the bottom) of the deepest basin.

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 Dewey Lake were variable among depths at the deep basins and ranged from 46.9-69.1 mS cm^{-1}. These values are very low for an inland lake and mean that the lake water does not contain many salts or dissolved metals. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Dewey 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.

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, stormwater 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 Dewey Lake is quite low and ranged from 0.4-1.1 NTU's during the sampling event.** The lake bottom is predominately silt and mineral which is high in bulk density and does not remain suspended in the water column for long which reduces turbidity and enhances water clarity. 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 22-30 mg L^{-1} for the deep basins which is favorably low for an inland lake.**

4.1.5 pH

pH is the measure of acidity or basicity of water. 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). pH is measured with a pH electrode and pH-meter in Standard Units (S.U). **The pH of Dewey Lake water ranged from 7.4 – 8.1 during the sampling event, with lower values recorded on the lake bottom. This range of pH is neutral to slightly alkaline on the pH scale.**

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 Dewey Lake is considered "elevated" (> 150 mg L^{-1} of $CaCO_3$), and indicates that the water is highly alkaline**. Total alkalinity in the deep basins ranged from 27-30 mg L^{-1} of $CaCO_3$ during the sampling event. These values indicate a "soft water lake".** 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 0.20 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 autoanalyzer. TP values ranged from 0.024 mg L^{-1} at the surface to 0.038 mg L^{-1} at the bottom. For a lake this deep, these values are quite low even though they fall within the meso-eutrophic range.

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. 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. **Dewey Lake contains highly variable values for TKN (0.50 – 0.96 mg L^{-1}), with the highest value at the bottom of the deepest basin.**

4.1.9 *Chlorophyll-a and Algae*

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 Dewey 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* concentration in deep basin 1 was 6.2 µg L^{-1}, which was a eutrophic value, and deep basin 2 had a value of 7.9 µg L^{-1}, which was also eutrophic.** 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 basins of Dewey Lake were analyzed under a compound brightfield microscope. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Haematococcus* sp., *Gleocystis* sp., *Ulothrix* sp., *Rhizoclonium* sp., *Closterium* sp., *Cladophora* sp., *Pandorina* sp., *Protococcus* sp., *Botryococcus* sp., *Synechococcus* sp., *Zygnema* sp., *Ankistrodesmus* sp., *Dictyosphaerium* sp., *Chroococcus* sp., *Cryptomonas* sp., *Spirogyra* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Gleocapsa* sp.; the Bascillariophyta (diatoms): *Cymbella* sp., *Navicula* sp., *Fragilaria* sp., *Nitzschia* sp., *Synedra* sp., *Asterionella* sp., *Cyclotella* sp., *Tabellaria* sp., *Melosira* sp.,and *Opehora* sp. The aforementioned species indicate a 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 Dewey Lake are rich in the Chlorophyta (green algae) and diatoms, which are indicators of productive but healthy waters.

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 Dewey Lake averaged 10.0 feet over the two deep basins during the sampling event, which was 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.

4.1.11 Oxidative Reduction Potential

The oxidation-reduction potential (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 Eh 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 (ORP) values for Dewey Lake ranged between 22.9 mV and 98.4 mV throughout the depths of the deep basins**, and thus were within a normal range for inland Michigan lakes.

4.1.12 Sediment % Organic Matter

Organic matter (OM) contains a high amount of carbon that 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 allochthonus 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. Dewey Lake bottom sediment samples were collected at the sampling locations with the use of an Ekman hand dredge. The upper horizons of the sediment were kept intact for accurate evaluation of organic matter content in the upper layers. Samples were placed on ice and taken to the laboratory for analysis of sediment total phosphorus and percentage of organic matter. **Percentage of OM ranged from 33-39% at the bottom of the deep basins. The values indicate moderately low organic sediments that may contain a high mineral component.** 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 ferment 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. Much of the organic matter present in Dewey Lake originates from the surrounding wetlands that can deliver high soil loads to the lake during rain events or from decomposition of submersed aquatic vegetation.

Depth ft	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	82.6	8.6	8.1	69.1	0.4	98.3	< 0.50	30	0.024
25	70.3	4.8	7.8	63.1	0.6	77.6	0.54	29	0.028
50	61.1	2.4	7.4	57.5	1.1	22.9	0.96	27	0.038

Table 3. Dewey Lake water quality parameter data collected in deep basin 1 (September, 2013).

Depth ft	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	82.9	8.8	8.1	65.5	0.6	98.4	0.55	29	0.024
8	78.3	7.3	7.8	65.0	0.8	76.1	0.50	30	0.032
17	74.6	6.0	7.4	46.9	1.0	45.9	0.95	27	0.038

Table 4. Dewey Lake water quality parameter data collected in deep basin 2 (September, 2013).

4.2 Dewey 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. 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). 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 Dewey 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 5) 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. *M. spicatum* 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. ***M. spicatum*** **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, *M. spicatum* can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

Exotic aquatic plant species found in and around Dewey Lake are shown in Table 5. Some individual plants of *M. spicatum* were found at depths of approximately 12 feet; however, the **majority of the growth was located at depths of 5-10 feet.** *M. spicatum* growth is thus capable of growing in nearly all depths of the littoral zone of Dewey Lake, where light is adequate due to the moderate water transparency. *M. spicatum* growth in Dewey Lake is quite robust, with wide, thick stems, capable of producing dense surface canopies. **The results of a detailed aquatic vegetation assessment site (AVAS) survey of Dewey Lake in September, 2013 demonstrated that approximately 11.6 acres of pure *M. spicatum*** (determined through genetic analysis on June 18, 2013 by GVSU AWRI to be of Eurasian and not hybrid biotype) **infested the lake. Figure 7 shows the general distribution of the *M. spicatum* which was scattered among the littoral zone and shoreline of Dewey Lake.** The species of aquatic macrophytes present and relative abundance of each macrophyte are recorded and then the amount of cover in the littoral zone is calculated. In addition, Purple Loosestrife (Figure 6) was found in a few areas around the lake.

Figure 5. Eurasian Watermilfoil stems and seed head. ©RLS, 2006

Figure 6. Purple Loosestrife ©RLS, 2006

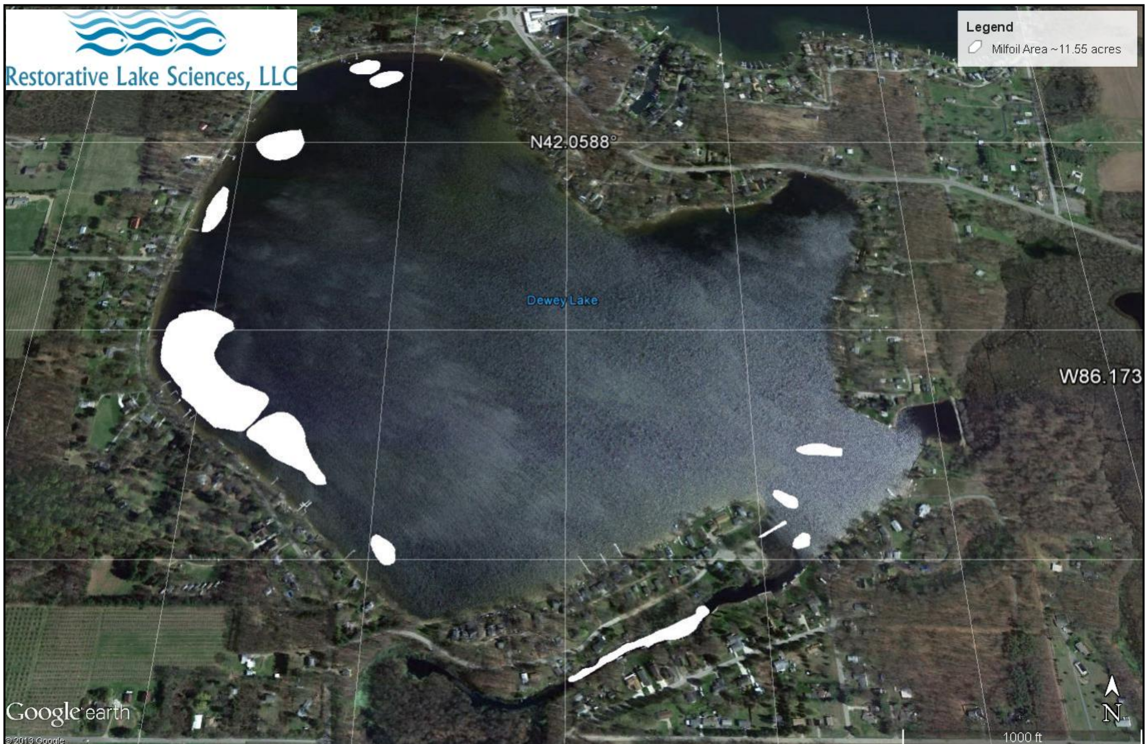

Figure 7. Locations of Eurasian Watermilfoil in Dewey Lake (September, 2013)

Exotic Aquatic Plant Species	*Common Name*	*Growth Habit*	*Abundance in or around Dewey Lake*
Myriophyllum spicatum	Eurasian Watermilfoil	Submersed; Rooted	Sparse
Lythrum salicaria	Purple Loosestrife	Emergent	Sparse

Table 5. Dewey Lake exotic aquatic plant species (September, 2013).

4.2.2 Dewey 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.
Dewey Lake contained 11 native submersed, 6 floating-leaved, and 4 emergent aquatic plant species, for a total of 21 native aquatic macrophyte species (Table 6). A map showing the locations of nuisance native aquatic plants is shown in Figure 8. **Photos of all native aquatic plants are shown below in Figures 9-29.** 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 Pondweeds and Wild Celery. The Pondweeds grow tall in the water column and serve as excellent fish cover. In dense quantities, they can be a nuisance for swimming and boating and can be controlled with selective herbicide management. **Wild Celery** was also abundant in many areas and grows via seed, underground runners (stolons) and also through tuber reproduction. It can become a nuisance due to the high density and ability to create impairments for swimming and boating.

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 **six 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, and ***Brasenia schreberi* (Watershield)** which appears like small "footballs" on stalks that are covered with mucilage on the underside of the leaf. Also present were the small **Duckweed (*Lemna minor*)** and **Watermeal (*Wolffia* sp.)** which float on the lake surface. One small specimen of **Water Pennywort (*Hydrocotyle* sp.)** was found. The **emergent plants, such as *Typha latifolia* (Cattails), and**

***Scirpus acutus* (Bulrushes)** are critical for shoreline stabilization as well as for wildlife and fish spawning habitat. The presence of Purple Loosestrife around the Dewey Lake shoreline is an imminent threat to the emergent macrophyte populations, which could be displaced if left untreated or removed.

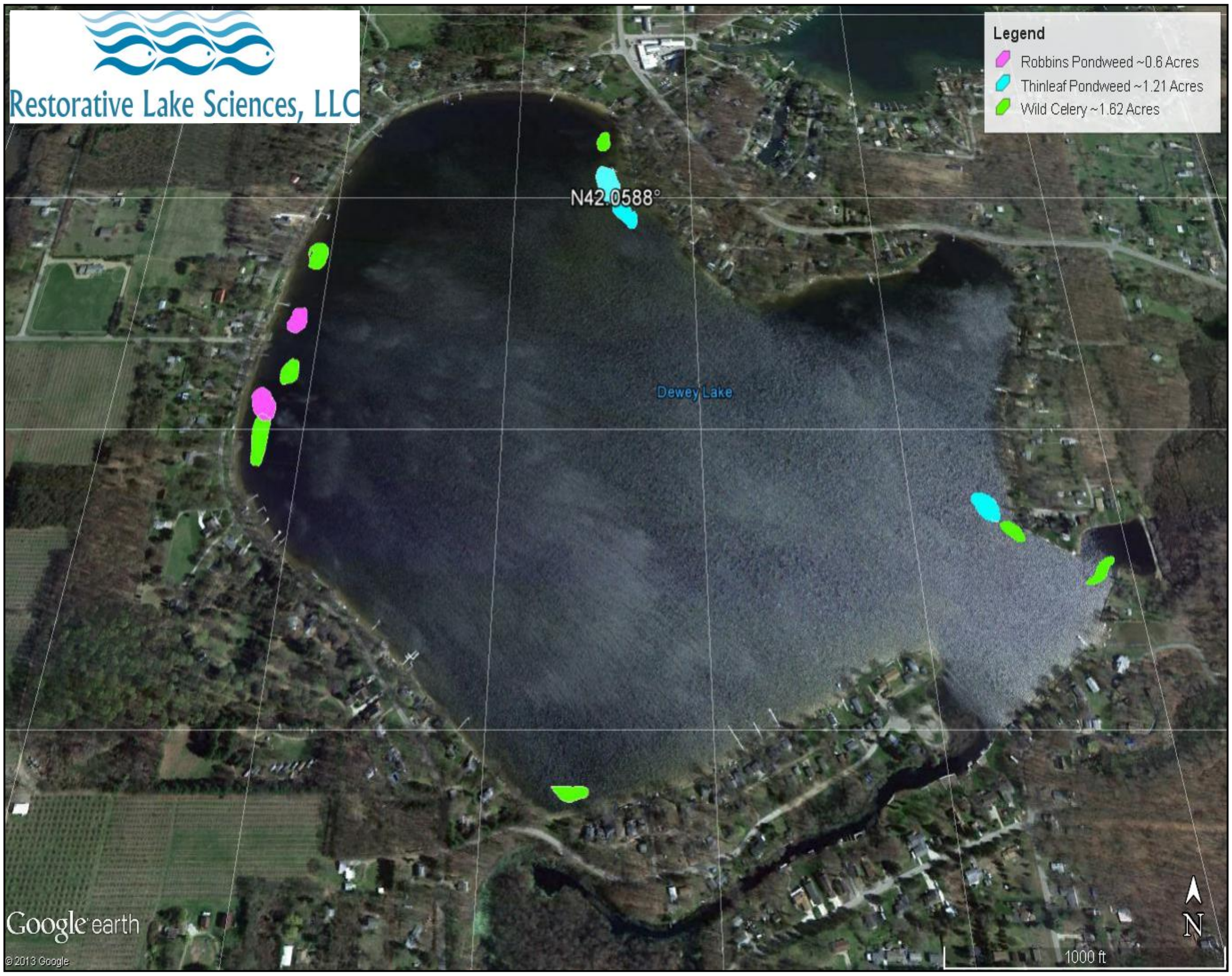

Figure 8. Distribution of nuisance native aquatic plants in Dewey Lake (September, 2013).

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***Abundance in/around Dewey Lake***	***Aquatic Plant Growth Habit***
Chara vulgaris	Muskgrass	0.5	Submersed, Rooted
Potamogeton pectinatus	Thin-leaf Pondweed	3.0	Submersed, Rooted
Potamogeton robbinsii	Fern-leaf Pondweed	2.4	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	0.5	Submersed, Rooted
Potamogeton gramineus	Variable-leaf Pondweed	2.8	Submersed, Rooted
Potamogeton praelongus	White-stem Pondweed	0.1	Submersed, Rooted
Potamogeton natans	Floating-leaf Pondweed	0.1	Submersed, Rooted
Potamogeton pusillus	Small-leaf Pondweed	0.1	Submersed, Rooted
Vallisneria americana	Wild Celery	6.5	Submersed, Rooted
Ceratophyllum demersum	Coontail	0.3	Submersed, Non-Rooted
Najas guadalupensis	Southern Naiad	0.1	Submersed, Rooted
Nymphaea odorata	White Waterlily	0.7	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	1.9	Floating-Leaved, Rooted
Brasenia schreberi	Watershield	0.1	Floating-Leaved, Rooted
Hydrocotyle sp.	Water Pennywort	0.1	Floating-Leaved, Rooted
Lemna minor	Duckweed	0.2	Floating-Leaved, Non-Rooted
Azolla sp.	Watermeal	0.1	Floating-Leaved, Non-Rooted
Typha latifolia	Cattails	0.1	Emergent
Scirpus acutus	Bulrushes	0.1	Emergent
Pontedaria cordata	Pickerelweed	0.1	Emergent
Decodon verticillatus	Swamp Loosestrife	0.1	Emergent

Table 6. Dewey Lake native aquatic plants (September, 2013).

Figure 9. Chara (Muskgrass)

Figure 10. Thin-leaf Pondweed

Figure 11. Fern-leaf Pondweed ©RLS, 2006

Figure 12. Large-leaf Pondweed ©RLS, 2006

Figure 13. Variable-leaf Pondweed ©RLS, 2006

Figure 14. White-stem Pondweed ©RLS, 2006

Figure 15. Floating-leaf Pondweed

Figure 16. Small-leaf Pondweed ©RLS, 2006

Figure 17. Wild Celery ©RLS, 2006

Figure 18. Coontail ©RLS, 2006

Figure 19. Southern Naiad ©RLS, 2006

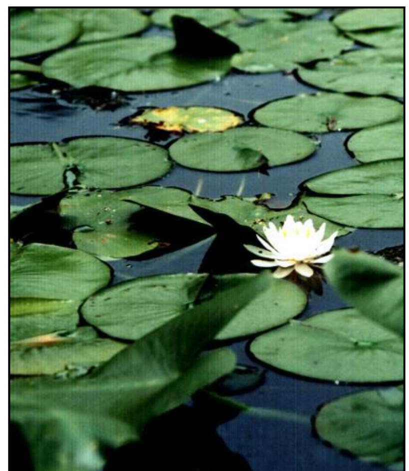

Figure 20. White Waterlily ©RLS, 2006

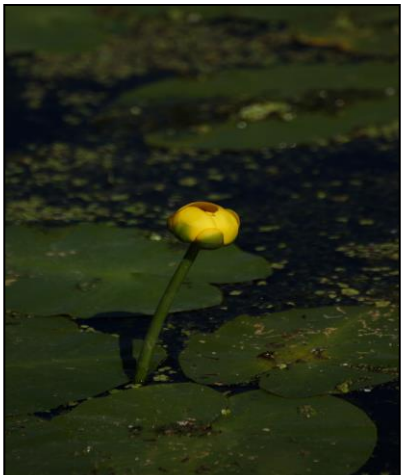

Figure 21. White Waterlily ©RLS, 2006

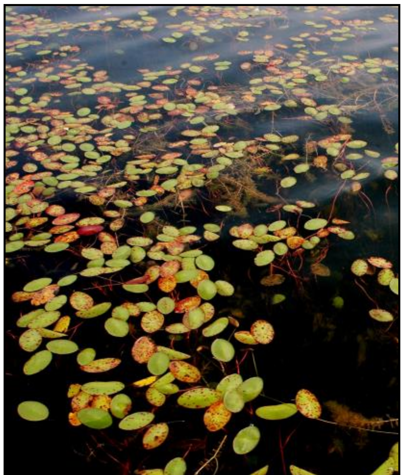

Figure 22. Watershield ©RLS, 2006

Figure 23. Water Pennywort

Figure 24. Duckweed

Figure 25. Watermeal

Figure 26. Cattails ©RLS, 2006

Figure 27. Bulrushes ©RLS, 2006

Figure 28. Pickerelweed ©RLS, 2006

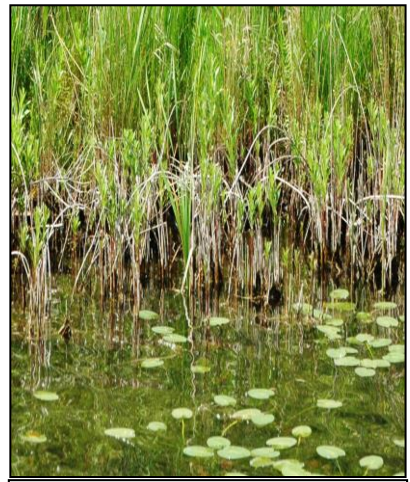

Figure 29. Swamp Loosestrife ©RLS, 2006

5.0 AQUATIC PLANT MANAGEMENT OPTIONS FOR DEWEY LAKE

5.1 Dewey 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 Dewey 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, floating-leaved and emergent aquatic plants is necessary in nutrient-enriched aquatic ecosystems 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. Implementation of more growth of favorable native aquatic plants (especially the low-growing pondweeds) in Dewey Lake to provide for a healthier lake is recommended. However, exotic aquatic plant species should be managed with solutions that will yield long-term results.

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. **Contact and systemic aquatic herbicides are the two primary categories used in aquatic systems.**

Contact herbicides such as diquat and hydrothol 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.

Systemic herbicides such as 2, 4-D and Triclopyr are the two primary systemic herbicides used to treat milfoil that grows in less than 25% of a 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**. Future whole-lake treatments of fluridone may be used in Dewey Lake to control the milfoil if the plant occupies more than 25% of the littoral zone. It currently colonizes around 11 acres of the littoral zone and thus spot-treatments of systemic herbicides are recommended. Granular Triclopyr could be used in near shore areas with shallow well (< 30 feet deep) restrictions and 2, 4-D offshore.**

Algae treatments through the use of algaecides should be limited to filamentous algal blooms and efforts should be taken to reduce the nutrient loads that encourage algal blooms that may require treatments. **The current low abundance of dense green algae in the water of Dewey Lake indicates that algal treatments may not be needed and would not last long due to the moderate water column nutrients.**

5.1.2 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 30). 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 threat of milfoil fragmentation, the use of mechanical harvesting for the removal of the milfoil in Dewey Lake is not recommended. Once the milfoil has been successfully reduced with herbicides, then harvesting could be used to remove dense native aquatic vegetation.**

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 (as is the case with Dewey Lake).

Figure 30. A mechanical harvester

5.1.3 Diver Assisted Suction Harvesting (DASH)

Suction harvesting via a Diver Assisted Suction Harvesting (DASH) boat (Figure 31) 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 31. A DASH boat for hand-removal of milfoil or other nuisance vegetation. ©Restorative Lake Sciences, LLC

5.1.4 Biological Control

The use of the aquatic weevil, *Euhrychiopsis lecontei* (Figure 32) to control Eurasian Watermilfoil has been implemented in a few lakes in Michigan. The use of the weevil for bio-control is both inundative and classical (Harley and Forno, 1992). The inundative approach refers to the application of weevils at a higher density than the existing population to damage milfoil. The classical approach refers to the use of a host-specific herbivore (weevil) to damage the target plant (milfoil). The weevil naturally exists in many of our lakes; however, the lack of adequate populations in many lakes requires that they be implanted or stocked for successful control of milfoil. The weevil feeds almost entirely on milfoil and will leave native aquatic species unharmed if adequate amounts of milfoil are present. The weevil burrows into the stems of milfoil and damages the vascular tissue, thereby reducing the plant's ability to store carbohydrates (Newman et *al*. 1996). Eventually, the stems lose buoyancy and the plant decomposes on the lake bottom.

Recent research has shown that the weevils require a substantial amount of aquatic plant biomass for successful control of milfoil. In addition, the weevils require adequate over-wintering habitat since they overwinter within shoreline vegetation. Lakes with sparse milfoil distribution are not ideal candidates for the milfoil weevil.

Recent peer-reviewed scientific research by Newman and Biesboer (2000) demonstrated that the requirements for weevil stocking density to obtain adequate control of milfoil may be as high as 150-300 weevils per square meter. It is important to note that this number refers to a "stocking density", which implies the number of weevils that should be stocked in a stocking area for ultimate population growth. It does not mean that each acre within the lake must have this density stocked to obtain the desired result. **Given the high cost and low measured efficacy in many lakes, stocking of this weevil in Dewey Lake is not recommended.**

Figure 32. The milfoil weevil (*Euhrychiopsis lecontei*). Photo from R. Newman used with permission.

5.1.5 Laminar Flow Aeration and Bioaugmentation

Laminar flow aeration systems (Figure 30) 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.

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.

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 *M. spicatum* 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 *M*. *spicatum* 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 *M. spicatum* 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 Dewey 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.

Due to the **low quantity of organic matter in Dewey Lake, the reduction of sediment muck would be slow. However, if the lake bottom continues to experience low dissolved oxygen levels during stratified periods, then aeration may be useful for that purpose. Aeration and bio augmentation have also been successfully used to reduce nuisance algal blooms.** The response of the submersed aquatic vegetation varies among sites and thus cannot be determined for Dewey Lake. The use of both spot-treatment of herbicides and the aeration may be beneficial for treatment of the weeds and improvement of water quality.

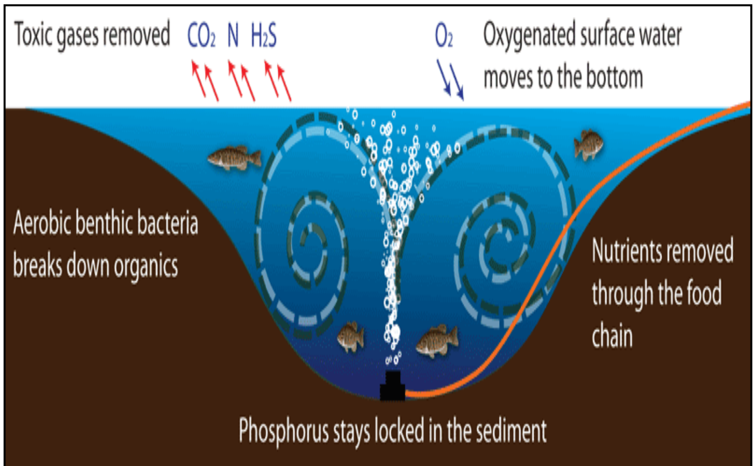

Figure 33. A diagram showing the laminar flow aeration mechanisms. ©Restorative Lake Sciences, LLC

5.2 Dewey Lake Watershed Management

In addition to the proposed treatment of Eurasian Watermilfoil and Purple Loosestrife in and around Dewey 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%)
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 <u>native</u> genotype plants (those native to Dewey 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 Dewey 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 Dewey 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%. The September survey noted that the majority of the shoreline contained natural vegetation which is favorable but growth of tall emergent plants around the shoreline is encouraged. 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 Dewey Lake. The emergent aquatic plant, *Scirpus* sp. (Bulrushes) present in Dewey Lake offers satisfactory stabilization of shoreline sediments and assists in the minimization of sediment release into the lake.

5.2.2 Dewey 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 Dewey 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.

6.0 DEWEY LAKE PROJECT CONCLUSIONS & RECOMMENDATIONS

The **urgent control of the Eurasian Watermilfoil and Purple Loosestrife infestations in and around Dewey Lake** is essential for the long-term preservation of the native aquatic plant communities. The **use of systemic aquatic herbicides for species-specific control of these plants is preferred** over other methods at this time for reasons described above with each method. Mechanical harvesting could be used in future years once the milfoil is controlled and not a threat to fragmentation. Also, the use of laminar flow aeration with bio augmentation to improve dissolved oxygen levels at depth and reduce algae may be considered. 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 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 soil loading to the lake.

Furthermore, a professional limnologist/aquatic botanist should perform regular GPS-guided whole-lake surveys each spring and late summer/early fall to monitor the growth and distribution of all invasives prior to and after treatments to determine treatment efficacy. Furthermore, continuous monitoring of the lake for potential influxes of other exotic aquatic plant genera (i.e. *Hydrilla*) that could also significantly disrupt the ecological stability of Dewey Lake is critical. 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 lake management education.

6.1 Cost Estimates for Dewey Lake Improvements

The proposed integrated management program for the control of Eurasian Watermilfoil and Purple Loosestrife and lake improvement of Dewey Lake would begin during the 2017-2018 season. A breakdown of estimated costs associated with Dewey Lake improvements is presented in Table 7. 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 Improvement Item For Dewey Lake	***Estimated 2018 Cost***	***Estimated 2019-2022 Cost[4]***
Herbicides (systemic) for *M. spicatum*[1] for up to 20 acres@ $600 per acre (note: reduced for 2019-2021)	$12,000	$7,000
Herbicide treatment of nuisance pondweeds and invasive Curly-leaf Pondweed for up to 18 acres @$250 per acre	$4,500	$4,500
Professional Services (limnologist surveys, oversight, processing, education, newsletter)[2]	$5,000	$5,000
Contingency[3]	$2,150	$1,815
TOTAL ANNUAL ESTIMATED COST	$23,650	$18,150

Table 7. Dewey Lake proposed budget for management program (2018-2022).

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

[2] Professional services includes two annual GPS-guided, Point-Intercept aquatic vegetation grid 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. Attendance at annual meeting and water quality monitoring of lake.

[3] Contingency is 10% of the total project cost, to assure that extra funds are available for unexpected expenses or ones that do not fall into a budget category above (mainly association administrative costs).

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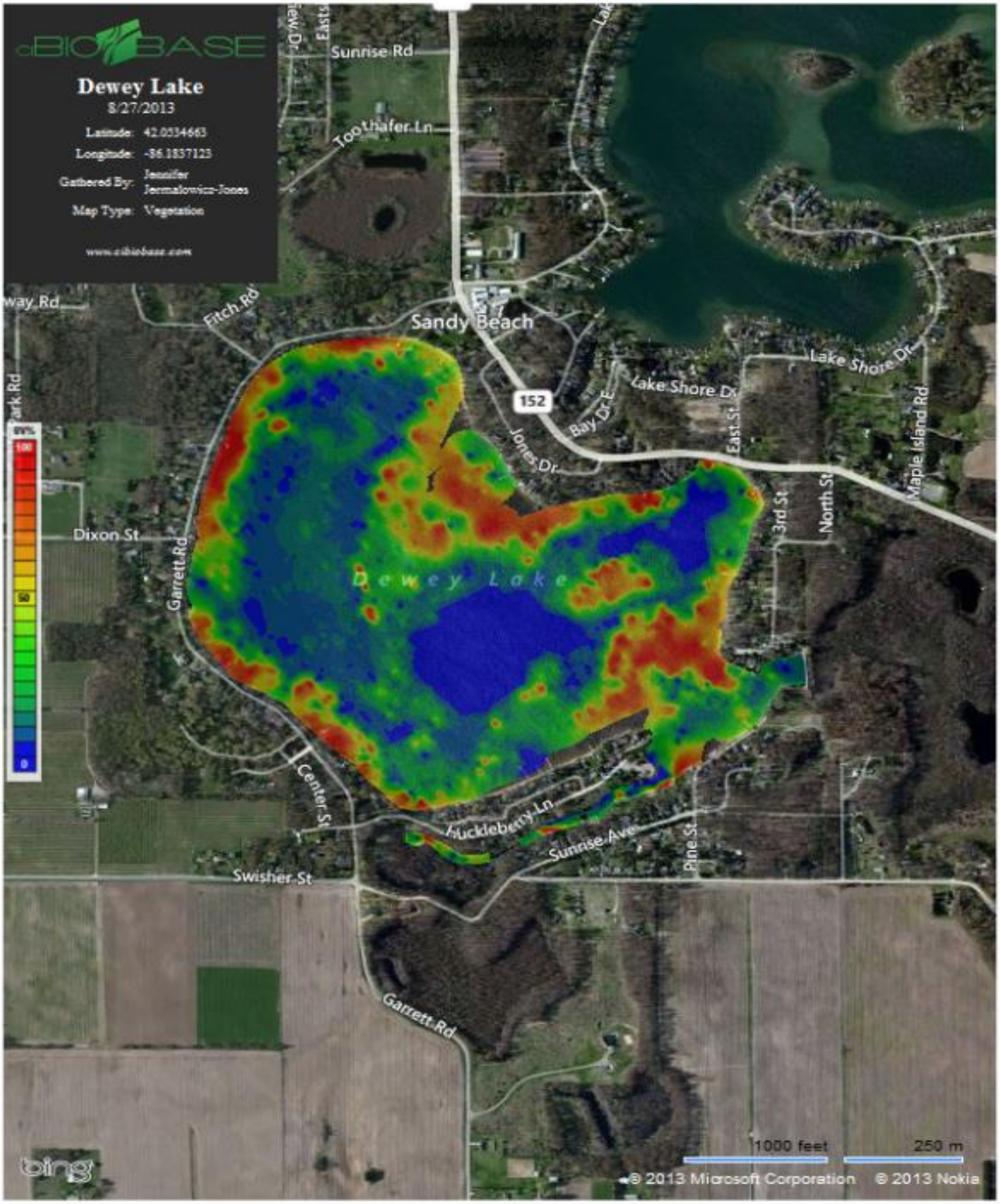
APPENDIX A:
BIOBASE AQUATIC VEGETATION SCAN OF DEWEY LAKE


Dewey Lake
8/27/2013
Latitude: 42.0534663
Longitude: -86.1837123
Gathered By: Jennifer Jermalowicz-Jones
Map Type: Vegetation
Sunrise Rd
Toothafer Ln
Fitch Rd
Sandy Beach
152
Lake Shore Dr
Jones Dr
Bay Dr E
East St
3rd St
North St
Maple Island Rd
Dixon St
Garrett Rd
Dewey Lake
Center St
Huckleberry Ln
Sunrise Ave
Pine St
Swisher St
Garrett Rd
100
50
0
1000 feet
250 m
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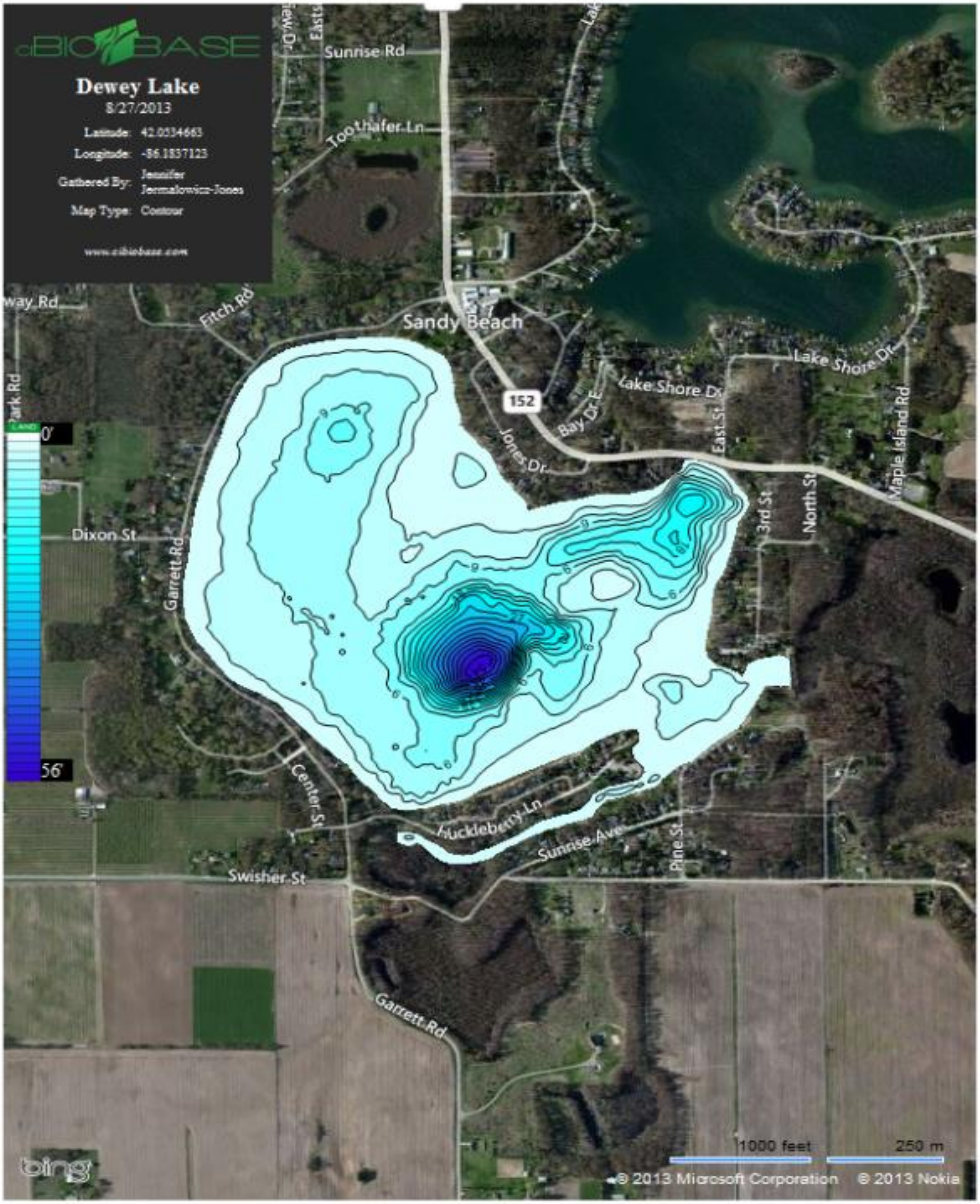
APPENDIX B
BIOBASE DEPTH CONTOUR MAP OF DEWEY LAKE



Dewey Lake
8/27/2013
Latitude: 42.0334663
Longitude: -86.1837123
Gathered By: Jennifer Jermalowicz-Jones
Map Type: Contour
www.cibiobase.com
0'
56'
Sunrise Rd
Toothafer Ln
Fitch Rd
Sandy Beach
Lake Shore Dr
152
Bay Dr E
Jones Dr
East St
3rd St
North St
Maple Island Rd
Dixon St
Garrett Rd
Center St
Huckleberry Ln
Sunrise Ave
Pine St
Swisher St
Garrett Rd
1000 feet
250 m
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