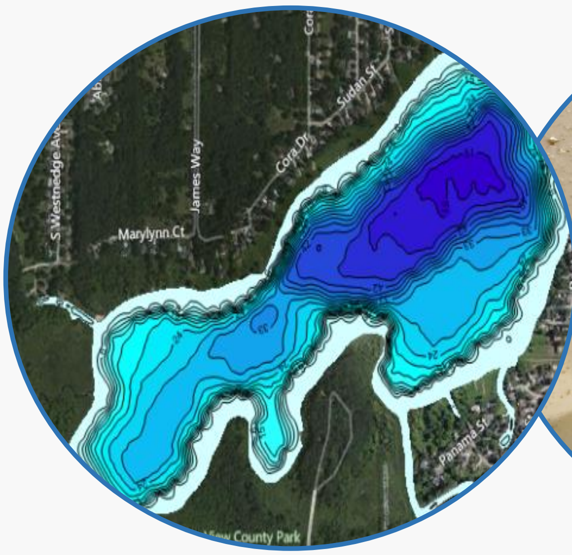
Gourdneck Lake Management Plan & Study
Kalamazoo County, Michigan



Provided for the Gourdneck Lake Association Members & Stakeholders

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Gourdneck Lake Management Plan & Study

May, 2014

1.0 EXECUTIVE SUMMARY

Gourdneck Lake, comprising 220 acres, is of natural glacial origin with nearly 4.5 miles of shoreline and a fetch of 1.1 miles which allows for the production of sizeable waves during high-wind events. Based on the current study, Gourdneck Lake contains a good native aquatic plant biodiversity (22 native species) but the exotic submersed macrophyte Eurasian Watermilfoil (*Myriophyllum spicatum* L.; EWM) growth threatens the biodiversity of the submersed native aquatic macrophyte communities, may threaten navigation and recreational activities, and also may harbor bacteria and other nuisance algae that are not beneficial to the lake's ecosystem. Additionally, 3 other invasives were found in and around the lake and include Curly-leaf Pondweed, Purple Loosestrife, and *Phragmites*, and were all very low in abundance.

Gourdneck Lake's overall water quality was measured as good with moderate to low nutrients such as phosphorus and nitrogen and high water clarity. The pH and alkalinity of the lake indicate that it is a soft water system. The lake has a large watershed and receives its water from precipitation, inlets, and springs. The large size of the immediate watershed may compromise water quality. Additionally, the primary soils around the lake are mucks that are prone to saturation and ponding and thus runoff management is critical.

The lake contains 24 different species of fish and thus contains a very high biodiversity of lake fish.

Restorative Lake Sciences, LLC recommends that spot-treatments using systemic aquatic herbicides for milfoil and contact herbicides for nuisance native aquatic plants be used for aquatic plant management. The quantity of organic matter in the lake sediments is highly variable among sampling sites and thus the use of aeration to biodegrade muck would yield differential results among these locations. Gourdneck Lake is a good candidate for whole-lake aeration with bio augmentation (microbes and enzyme addition) for the primary purpose of destratification of the lake water which would increase dissolved oxygen throughout the lake.

It is also recommended that the riparians around Gourdneck Lake implement Best Management Practices (BMP's) to reduce the potential nutrient and sediment loads transported into the lake.

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 riparians with a better understanding of the forthcoming lake management recommendations for Gourdneck 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. **Gourdneck Lake is categorized as a drainage lake since it receives water from an inlet and contains an outlet. It also has springs that contribute water at the north and east shores.**

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). **Gourdneck Lake contains 24 different species of fish which represents a highly diverse fishery.**

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 GOURDNECK LAKE PHYSICAL & WATERSHED CHARACTERISTICS

3.1 The Gourdneck Lake Basin

Gourdneck Lake is located in Section 3 of Schoolcraft Township (T4S, R11W) in Kalamazoo County, Michigan. The lake has a surface area of approximately 220 acres (Michigan Department of Natural Resources, 2001; Figure 1) and is classified as a meso-eutrophic aquatic ecosystem with two deep basins and a small-sized littoral (shallow) zone. Gourdneck Lake has a mean (average) depth of 22 feet and maximum depth of 52 feet and contains two inlets at the west end of the lake that empty from the Sugarloaf Lakes and from Hogsett Lake and an outlet which empties at the south end of the lake to Sunset Lake via Gourdneck Creek. There are also some springs present near shore along the north and east shores. The lake bottom consists primarily of marl (calcium carbonate which is common in hard waters) and also of muck, fibrous peat, sand, pulpy peat, and gravel. Gourdneck Lake has a lake perimeter of approximately 4.5 miles (Michigan Department of Natural Resources, 1999).

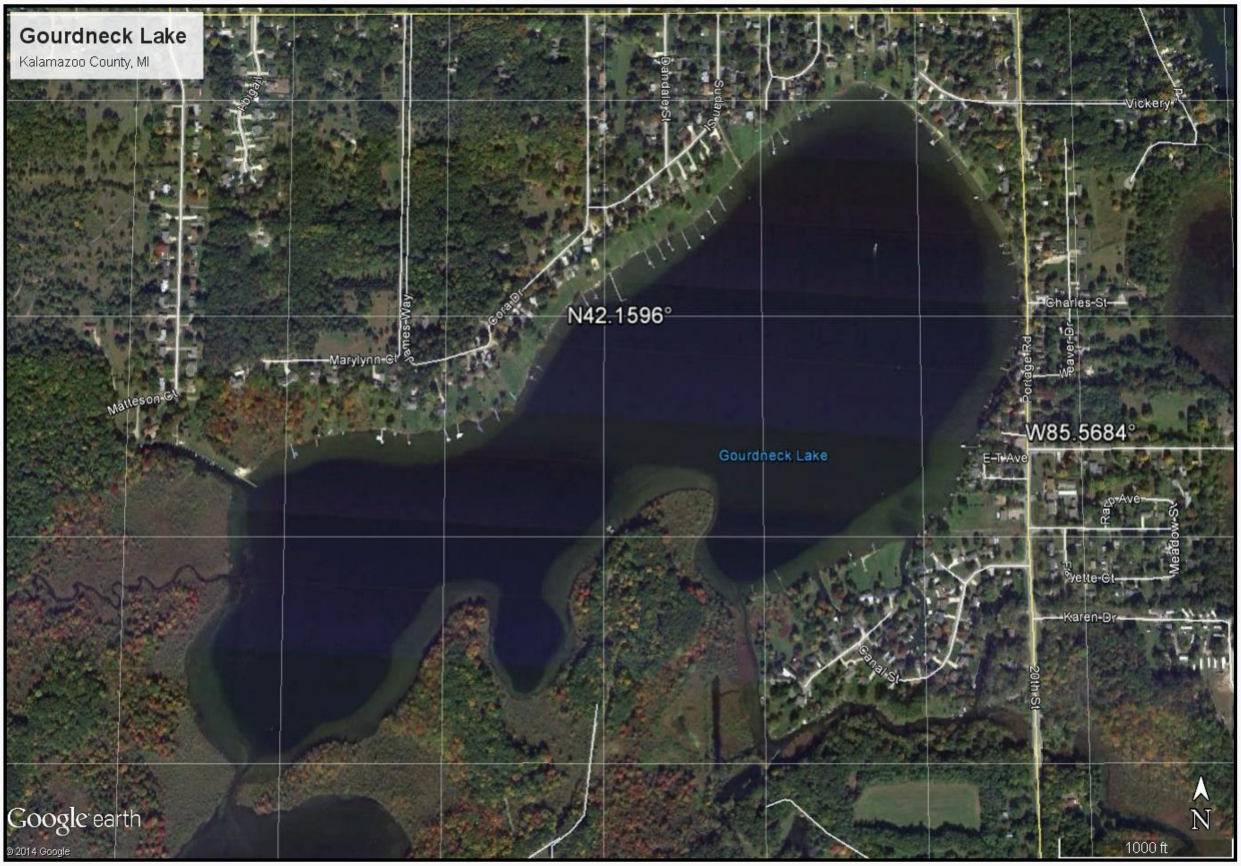


Figure 1. Gourdneck Lake, Schoolcraft Township, Kalamazoo County, Michigan.

3.2 Gourdneck Lake Extended and Immediate Watershed

Gourdneck Lake is located within the Portage River sub watershed which is approximately 125,539 acres (approximately 196 mi^2) in area and includes portions of Kalamazoo and St. Joseph counties, (Michigan Department of Environmental Quality, 2008). The Portage River Watershed is a sub watershed of the St. Joseph River Watershed which drains 4,685 mi^2 from 15 counties, including Berrien, Branch, Calhoun, Cass, Hillsdale, Kalamazoo, St. Joseph, and Van Buren in the state of Michigan, and De Kalb, Elkhart, Kosciusko, Lagrange, Noble, St. Joseph, and Steuben in the state of Indiana. The majority of the extended watershed is agricultural, with 25-50% remaining forested.

Gourdneck Lake's **immediate watershed** consists of the area around the lake which directly drains to the lake and measures **approximately 5,197 acres** (8.1 mi^2) in size (Figure 2). The moderate amount of development around the lake reduces pollutant runoff during rain events due to less impervious cover. Additionally, the wetlands near the west end of the lake assist with the filtration of nutrients that exit the land to the lake during heavy rain events. Furthermore, the **immediate watershed is approximately 23.4 times larger than the size of Gourdneck Lake**, which indicates the presence of a **large immediate watershed**. Large watersheds are often associated with more abundant nutrients that can compromise water quality and lead to accelerated algae and aquatic plant growth.

The Gourdneck State Game Area located is located along a portion of the west shore of the lake, whereas the north and eastern regions of the shoreline are developed by the City of Portage.

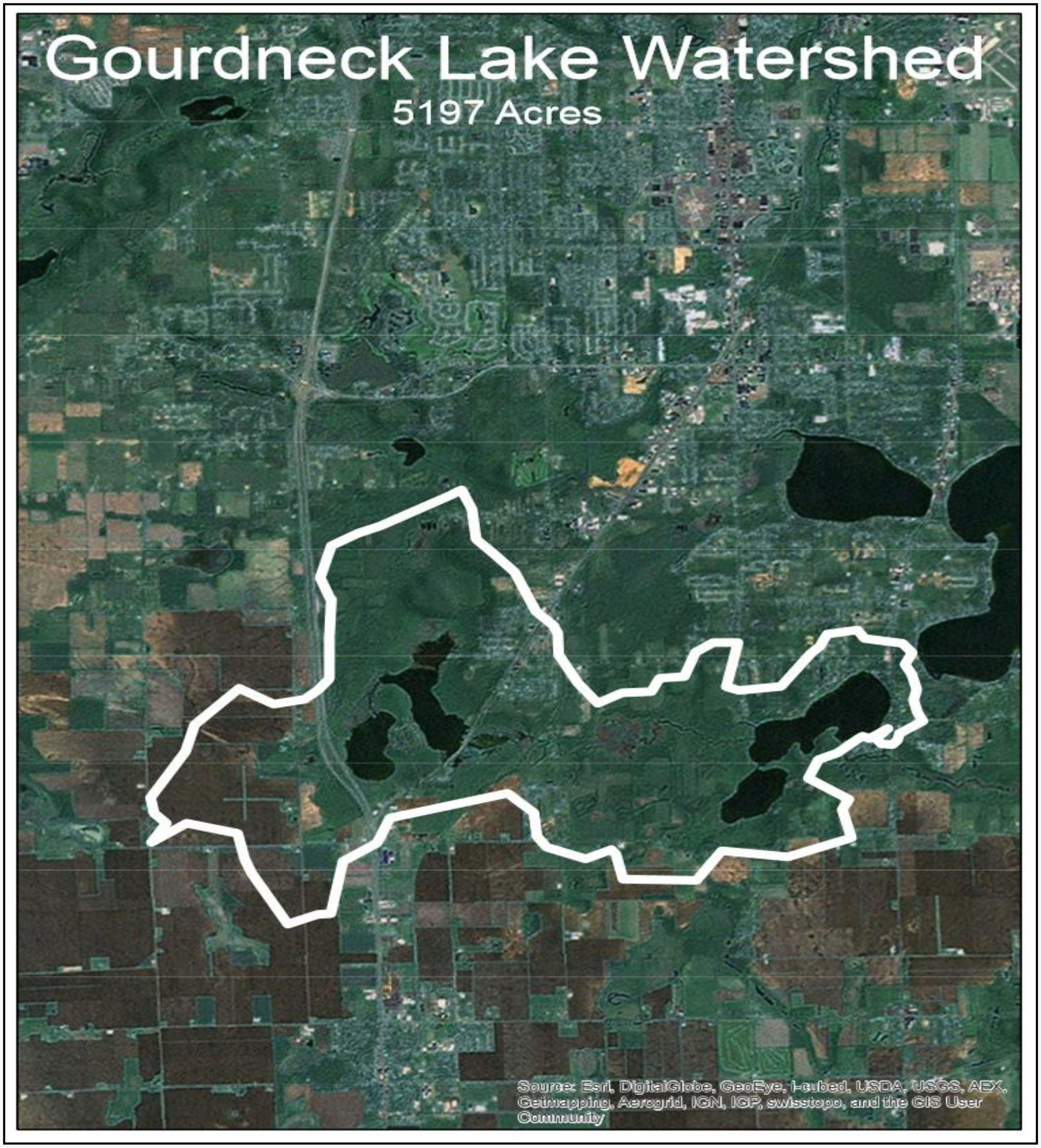


Figure 2. Gourdneck Lake Immediate Watershed boundary.

3.3 Gourdneck Lake Shoreline Soils

There are 3 major soil series types immediately surrounding Gourdneck 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 Gourdneck Lake. **Major characteristics of the dominant soil types directly surrounding the Gourdneck Lake shoreline are listed in Table 1 below.**

USDA-NRCS Soil Series	***Gourdneck Lake Location***	***Prominent Soil Type Characteristics***
Houghton Muck (0-1% slopes); Hn	north, west, south shores	poorly drained soils; prone to ponding
Oshtemo Sandy Loam (1-6% slopes);OsB	east shore	very deep well drained soils; low slope
Oshtemo Sandy Loam (6-12% slopes);OsC	south shore	very deep well drained soils; high slope

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

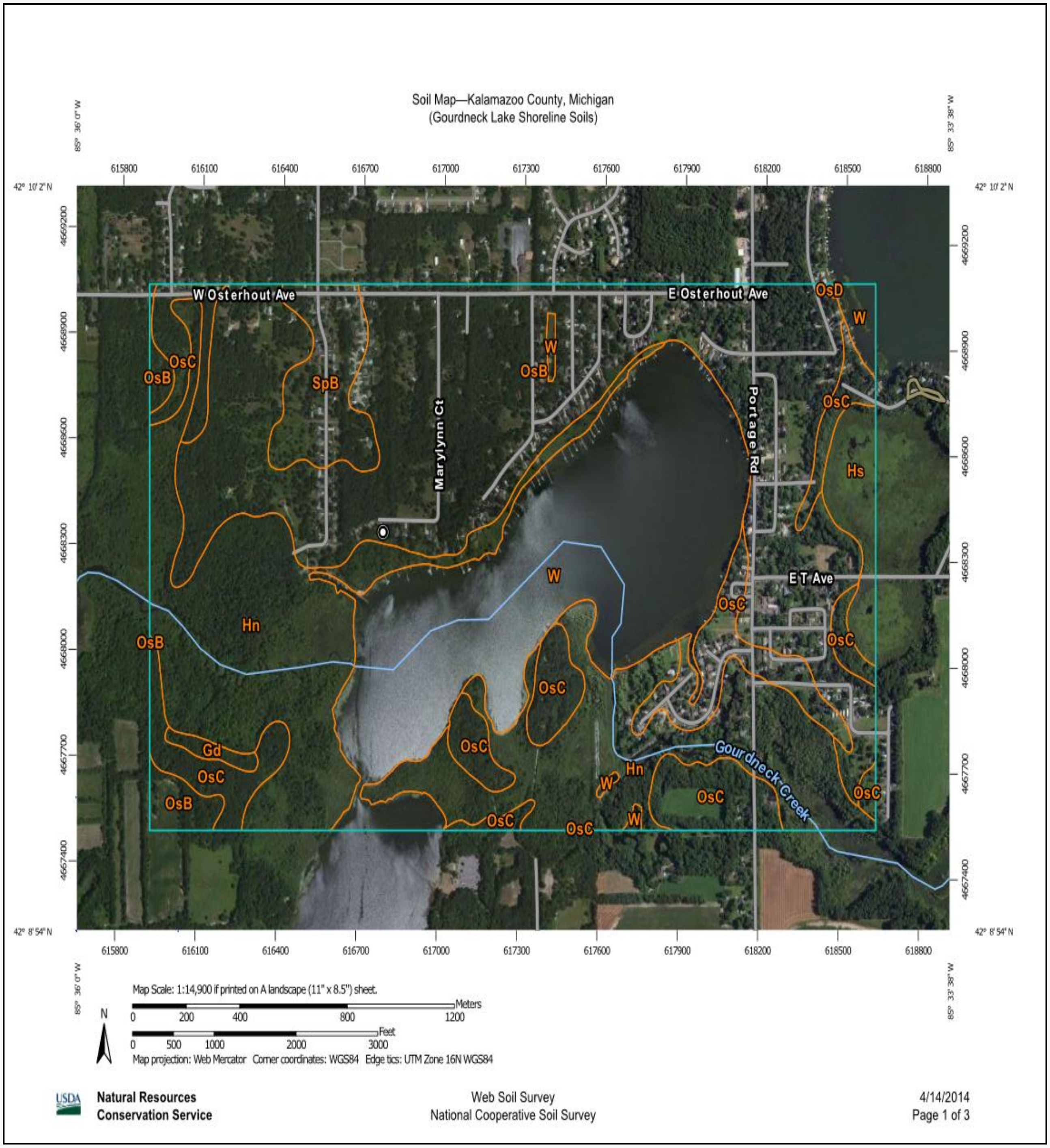


Figure 3. NRCS-USDA soils map for Gourdneck Lake shoreline soils (1999 data).

The majority of the lake is immediately surrounded by mucky soils that are 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. Sandy soils are however vulnerable to septic tank effluent since the drain field discharge can enter the sands and eventually migrate to the water table into the lake.

However, in areas around the lake where the slopes are greater than 6% (the south shore), surface runoff may be a factor, transporting sediments and nutrients to the lake. 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. Tips on this are offered in section 5.2 of this report.

Many of the shoreline protection structures around the lake consisted of tall emergent grasses that help stabilize soils and prevent erosion. However, there were some metal and concrete seawall structures that may absorb wave energy and minimize shoreline recession but do not provide wildlife benefits of natural shoreline vegetation. A “natural” shoreline is always encouraged for optimal lake health.

4.0 GOURDNECK 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**. **Gourdneck Lake is classified as meso-eutrophic.**

Lake Trophic Status	***Total Phosphorus (μg L^{-1})***	***Chlorophyll-a (μg 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, conductivity, turbidity and total dissolved solids, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, sediment percentage of 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, water samples from the 2 lake deep basins and sediment samples from 7 locations around the lake were collected in November, 2013 and/or late-April of 2014. The results are discussed below and are presented in Tables 3-7. A map showing the sampling locations for all water quality samples is shown below in Figure 4 on page 28.

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 7.3 – 9.8 mg L^{-1}, with concentrations lower at depth and at the bottom of deep basin 2. A value above 5.0 mg L^{-1} is preferred by the warm water fishery.** 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. **Historical review of legacy data collected by the MDEQ in 1996 revealed that Gourdneck Lake quickly loses dissolved oxygen below a depth of 25 feet during warm summer months. 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 November, 2013 and April, 2014 water temperatures of Gourdneck Lake demonstrated the lack of a thermocline (a transition zone of change in water temperature from top to bottom) between the surface and depth at both deep basins. Historical review of legacy data collected by the MDEQ in 1996 revealed that Gourdneck Lake experiences a temperature difference of 10°C from surface to bottom during summer months. A thermocline exists around 27 feet during late summer.**

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 Gourdneck Lake ranged from 416-430 mS cm^{-1}, which was moderately high for an inland lake. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Gourdneck 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 & Suspended Solids

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, 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 Gourdneck Lake was favorably low and ranged from 0.3 – 2.8 NTU's during the sampling events.** The lake bottom is comprised of soft sediments therefore is easily moved from water turbulence and wave action. 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) is 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 mean TDS for the deep basins was favorably low between 69-75 mg L^{-1}.**

Total Suspended Solids

Total suspended solids (TSS) refers to a measure of the amount of particulate (organic and inorganic) that exists in the water column. An increase in TSS is related to elevated turbidity since the particles reduce water transparency and cause murkiness.

All TSS values for the deep basins were less than < 10 mg L^{-1} which was favorably low and indicates clear water.

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 Gourdneck Lake water ranged from 8.3 – 8.5 S.U. during the sampling events. From a water quality perspective, Gourdneck Lake is considered slightly basic or "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 Gourdneck Lake is considered "elevated" (> 150 mg L^{-1} of $CaCO_3$), and indicates that the water is alkaline**. Total alkalinity in the deep basins ranged from 178-190 mg L^{-1} of $CaCO_3$ during the sampling events. This value indicates a moderately high alkalinity which means that Gourdneck Lake is a "hardwater" system.** 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 auto analyzer. **TP concentrations ranged from 0.010-0.022 mg L^{-1} These numbers indicate a low to moderately nutrient-rich lake but are low relative to most lakes of the same size and depth. The numbers were also lower in April than in November.**

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. **Gourdneck Lake contained consistent values for TKN (< 0.50 – 0.58 mg L^{-1}). Thus, the N:P ratio in Gourdneck Lake is 29 which indicates a P-deficient system. P-deficient lakes are highly vulnerable to increased runoff inputs of phosphorus.**

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 Gourdneck 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 5.6 µg L^{-1} and deep basin 2 had a value of 6.1 µg L^{-1} during the fall of 2013. These values are moderate for an inland lake of similar size and depth.** 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 Gourdneck Lake were analyzed under a compound brightfield microscope. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Ulothrix* sp., *Rhizoclonium* sp., *Haematococcus* sp., *Gleocystis* sp., *Pandorina* sp., *Protococcus* sp., *Zygnema* sp., *Spirogyra* sp., *Ankistrodesmus* sp., *Dictyosphaerium* sp., *Chroococcus* sp., *Rivularia* sp., *Cryptomonas* sp., *Synechococcus* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Gleocapsa* sp. and *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Cymbella* sp., *Navicula* sp., *Cyclotella* sp., *Tabellaria* sp., *Melosira* sp., *Fragilaria* sp., *Nitzschia* sp., *Synedra* sp., *Asterionella* 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. These algae indicate a tendency towards green algae and diatoms which are good indicators of a healthy and productive lake.

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 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 transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. **The Secchi transparency of Gourdneck Lake averaged 12.5 feet over the two deep basins during the sampling events, which was collected during calm wind conditions. This is another indicator of clear water.** 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 Gourdneck Lake ranged between 26.1 mV and 76.2 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. Gourdneck 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 a laboratory for analysis of sediment total phosphorus and percentage of organic matter. **Percentage of OM ranged from 5.5%-73%, which indicates highly variable sediments that contribute nutrients to rooted aquatic vegetation.** In contrast, sediments collected from similar depths in White Lake (Kalamazoo County, Michigan) had mean organic matter values of < 0.8% (Jermalowicz-Jones, MS thesis, *unpublished data*). 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 Gourdneck Lake originates from glacial deposits and decayed 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	50.3	9.8	8.3	422	0.3	76.7	< 0.50	178	0.022
25	48.2	8.1	8.4	426	0.7	54.2	< 0.50	180	0.018
50	44.6	7.3	8.4	430	2.4	26.1	0.50	190	0.020

Table 3. Gourdneck Lake water quality parameter data collected in deep basin 2 (November, 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	50.1	9.4	8.4	421	0.4	67.1	< 0.50	188	0.016
15	49.4	8.0	8.4	416	0.8	58.4	< 0.50	190	0.019
30	45.2	8.0	8.3	423	2.6	36.9	< 0.50	190	0.021

Table 4. Gourdneck Lake water quality parameter data collected in deep basin 1 (November, 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	45.4	8.9	8.4	427	0.6	76.2	0.54	185	0.011
25	45.1	9.1	8.5	430	0.9	66.8	0.58	188	0.015
50	45.0	9.1	8.4	430	2.4	56.1	0.50	190	0.010

Table 5. Gourdneck Lake water quality parameter data collected in deep basin 2 (April, 2014).

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	45.1	8.8	8.4	427	0.4	60.1	0.50	186	0.014
15	44.7	9.1	8.5	427	1.4	53.7	0.57	183	0.010
30	44.8	8.9	8.5	430	2.8	47.9	0.55	190	0.010

Table 6. Gourdneck Lake water quality parameter data collected in deep basin 1 (April, 2014).

Sample Location	***% Organic Matter***
3	73
4	5.9
5	29
6	33
7	9.5
8	5.5
9	7.8

Table 7. Gourdneck Lake organic matter sediment data collected from 7 sites around the lake (April, 2014).


Gourdneck Lake
Kalamazoo County, MI
Legend
Water Quality Sample Site
001
002
003
004
005
006
007
008
009
Gourdneck Lake
N42.1596°
W85.5684°
Matteson Ct
Marylynn Ct
James Way
Cora Dr
Abigail
Dandale St
Sudan St
Portage Rd
20th St
E T Ave
Weaver Dr
Charles St
Karen Dr
Meadow St
Vickery
Canal St
Google earth
© 2014 Google
1000 ft
N

4.2 Gourdneck 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 Gourdneck 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*; EWM; 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. EWM 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. EWM 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, EWM can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

Some individual plants of EWM were found at depths of approximately 13 feet; however**, the majority of the growth was located at depths between 5-10 feet.** EWM growth is thus capable of growing in nearly all depths of the littoral zone of Gourdneck Lake, where light is adequate due to the high water transparency. **The results of a detailed aquatic vegetation assessment site (AVAS) survey of Gourdneck Lake on November 1, 2013 demonstrated that approximately 17.4 acres of pure EWM infested the lake. In addition, Gourdneck Lake contained the invasive submersed Curly-leaf Pondweed (Figure 6) in a few areas along with the invasive emergent Purple Loosestrife (Figure 7) and *Phragmites* (Figure 8). All of these species should be managed. Fortunately, there were only a few plants of Curly-leaf Pondweed and a few individual plants of the Purple Loosestrife and Phragmites. Specifically, sampling location points 20, 46, and 74 contain *Phragmites* and sampling location points 34, 73, 76, and 81-83 contain Purple Loosestrife. Figure 32 shows the general distribution of the EWM which was scattered among the littoral zone and shoreline of Gourdneck Lake.**

The survey conducted on Gourdneck Lake utilized the methods as defined by the Michigan Department of Environmental Quality (MDEQ). The Aquatic Vegetation Assessment Site (AVAS) Survey method was developed by the MDEQ to assess the presence and relative abundance of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of Michigan lakes. With this survey method, the littoral zone areas of the lake are divided into lakeshore sections approximately 100 - 300 feet in length. 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. A whole-lake BioBase® scan of all aquatic vegetation and updated depth contour map can be found on pages 35 and 36, respectively. A full list of all species and their relative abundance is listed in Appendix A.

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

Figure 6. Curly-leaf Pondweed ©RLS, 2006

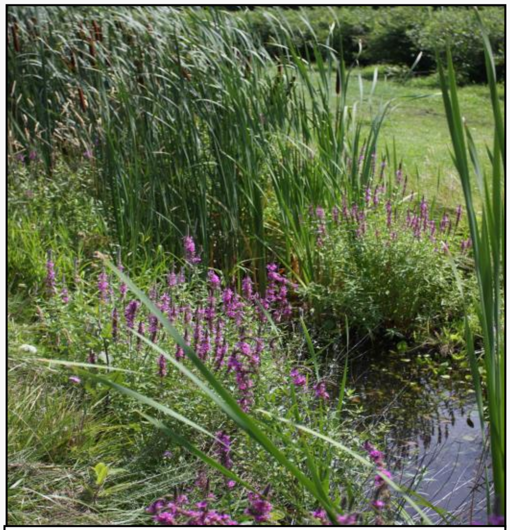
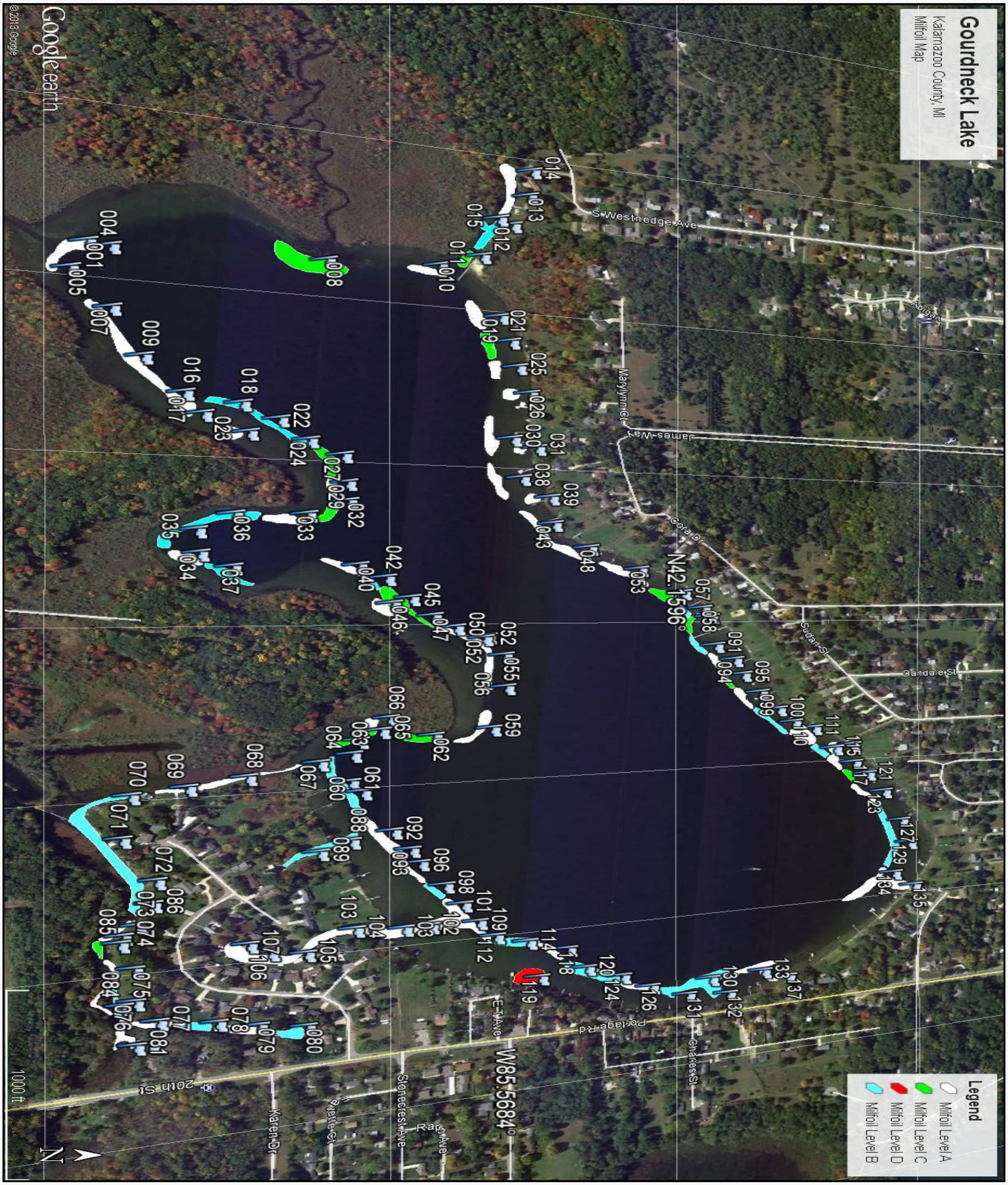


Figure 7. Purple Loosestrife ©RLS, 2006

Figure 8. Phragmites. ©RLS, 2009


Gourdneck Lake
Kalamazoo County, MI
Milfoil Map
Legend
Milfoil Level A
Milfoil Level C
Milfoil Level D
Milfoil Level B
N42.1596°
W85.5684°
1000 ft
Google earth

4.2.2 Gourdneck Lake Native Aquatic Macrophytes

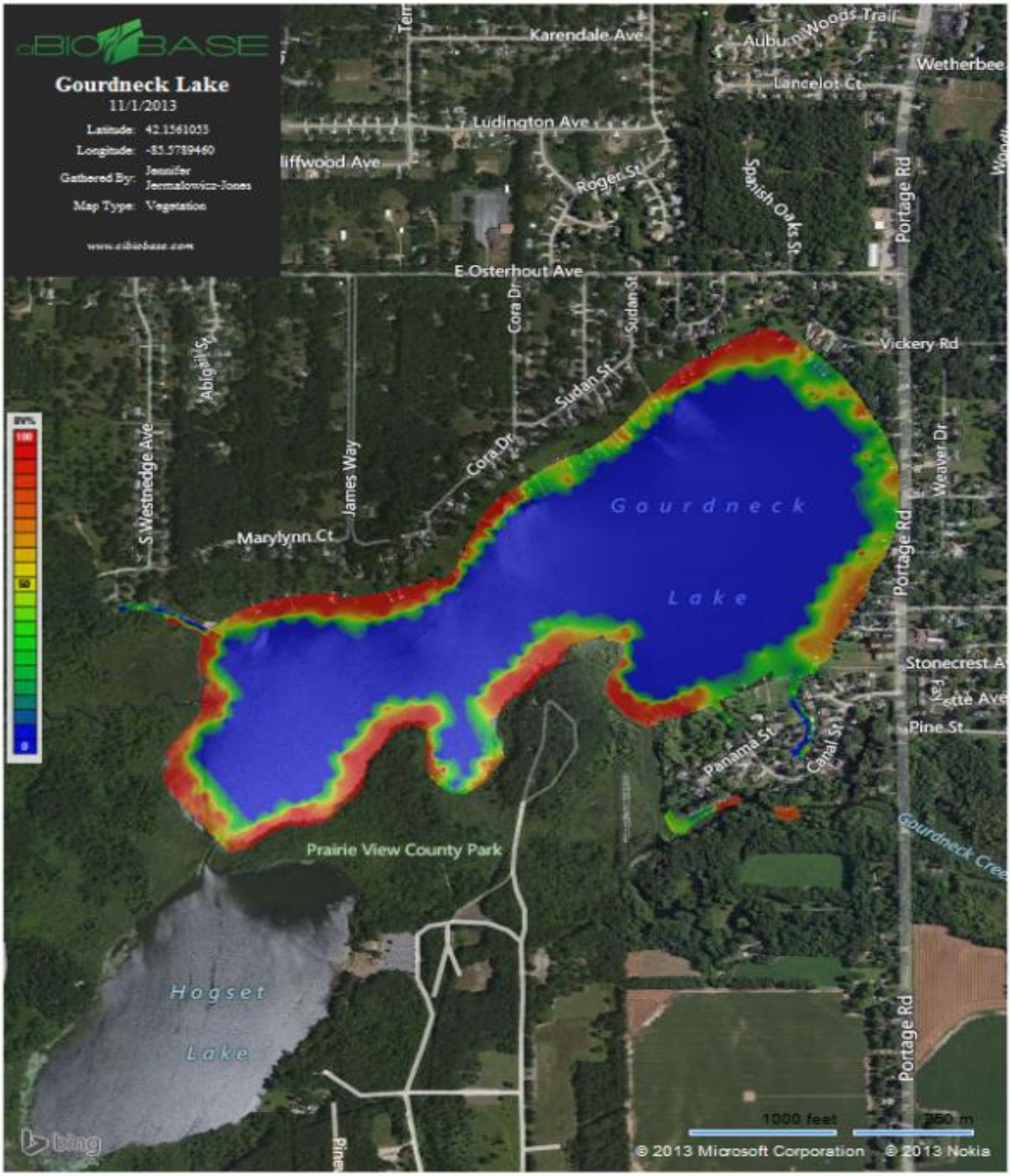
There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (Pondweeds) and the Haloragaceae (Milfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) 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.
Gourdneck Lake contained 13 native submersed, 2 floating-leaved, and 7 emergent aquatic plant species, for a total of 22 native aquatic macrophyte species which represents a good biodiversity (Table 8). Photos of these species can be found in figures 12-27 on pages 37-39. Two **floating-leaved plants** (White Waterlily) and Duckweed were found and typically grows near wetlands and protected areas of lakes. This is likely due to enriched sediments and shallower water depth with reduced wave energy that facilitates the growth of aquatic plants with floating-leaved morphological forms. Additionally, the plant 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. **The dominant native aquatic plants in the lake included the macroalga Chara and the Pondweeds such as Illinois Pondweed.** Both are capable of forming dense stands that can interfere with navigation and recreation activities but are also important fish forage habitat.

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.

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. Of particular interest was the discovery of a rarer emergent plant, Wild Rice (*Zizania aquatica*) which houses seeds that are a great nutritional benefit to waterfowl and other wildlife.

Native Aquatic Plant Species	***Aquatic Plant Common Name***	***Abundance in/around Gourdneck Lake***	***Aquatic Plant Growth Habit***
Chara vulgaris	Muskgrass	42.7	Submersed, Rooted
Potamogeton pectinatus	Thin-leaf Pondweed	0.4	Submersed, Rooted
Potamogeton zosteriformis	Flat-stem Pondweed	1.5	Submersed, Rooted
Potamogeton gramineus	Variable-leaf Pondweed	2.2	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	23.9	Submersed, Rooted
Potamogeton natans	Floating-leaf Pondweed	2.2	Submersed, Rooted
Vallisneria americana	Wild Celery	5.4	Submersed, Rooted
Ceratophyllum demersum	Coontail	1.6	Submersed, Non-Rooted
Elodea canadensis	Common Elodea	2.7	Submersed, Rooted
Myriophyllum sibiricum	Northern Watermilfoil	2.2	Submersed, Rooted
Utricularia vulgaris	Common Bladderwort	4.2	Submersed, Non-Rooted
Najas guadalupensis	Southern Naiad	1.1	Submersed, Rooted
Najas flexilis	Slender Naiad	1.6	Submersed, Rooted
Nymphaea odorata	White Waterlily	1.6	Floating-Leaved, Rooted
Lemna minor	Duckweed	0.5	Floating-Leaved, Non-Rooted
Typha latifolia	Cattails	1.9	Emergent
Pontedaria cordata	Pickerelweed	0.4	Emergent
Scirpus acutus	Bulrushes	1.0	Emergent
Decodon verticillatus	Swamp Loosestrife	0.4	Emergent
Zizania aquatica	Wild Rice	0.1	Emergent
Eleocharis sp.	Spikerush	4.0	Emergent
Iris pseudacorus	Yellow Flag Iris	0.1	Emergent

Table 8. Gourdneck Lake native aquatic plants (November 2013).


ciBIOBASE
Gourdneck Lake
11/1/2013
Latitude: 42.1561053
Longitude: -85.5789460
Gathered By: Jennifer Jermalowicz-Jones
Map Type: Vegetation
www.cibiobase.com
Gourdneck Lake
Hogset Lake
Prairie View County Park
Karendale Ave
Ludington Ave
E Osterhout Ave
Portage Rd
Vickery Rd
Cora Dr
Sudan St
James Way
Marylynn Ct
S Westnedge Ave
Roger St
Spanish Oaks St
Panama St
Canal St
Stonecrest
Pine St
Weaver Dr
Lancelot Ct
1000 feet
250 m
© 2013 Microsoft Corporation © 2013 Nokia

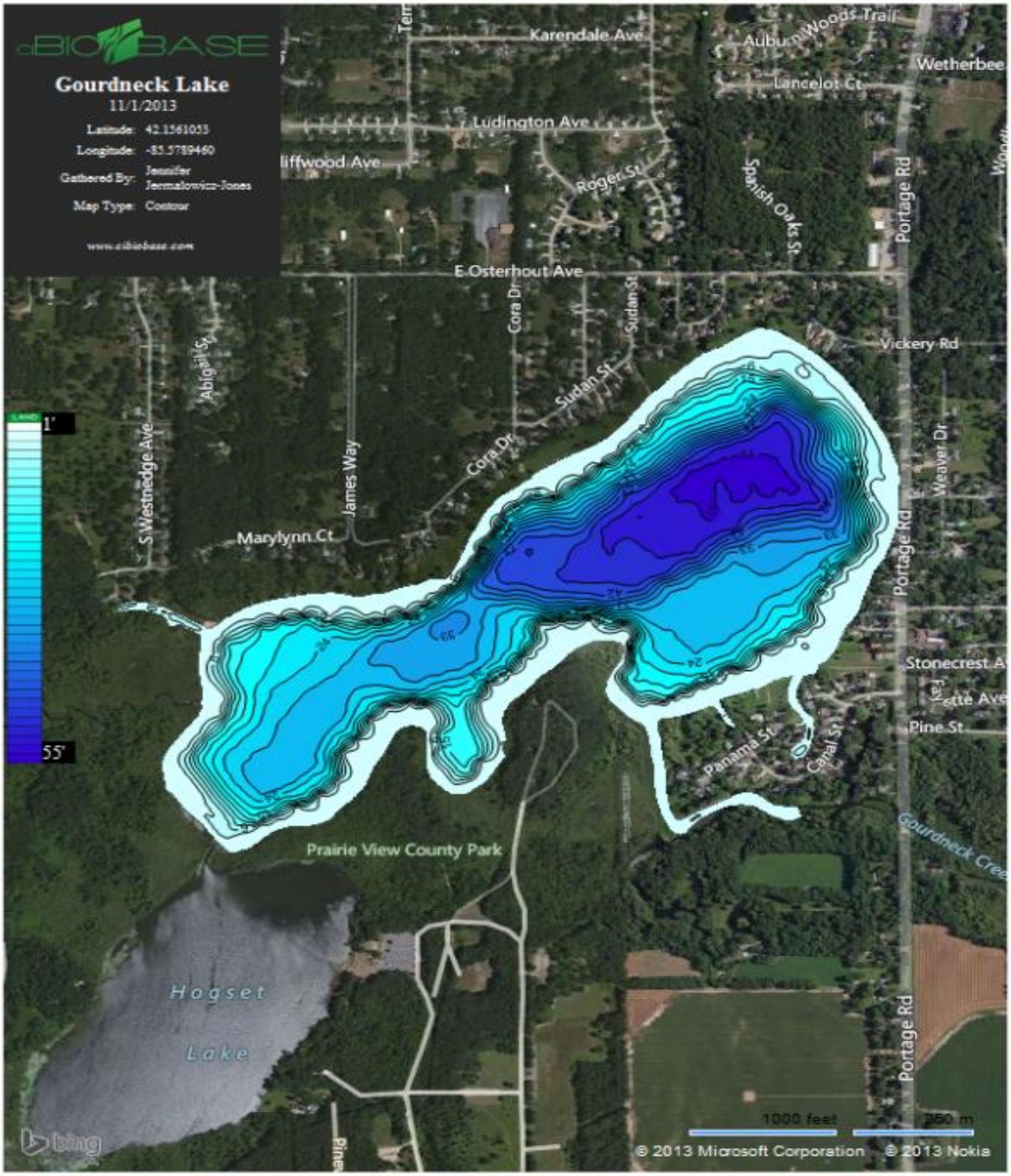

Gourdneck Lake
11/1/2013
Latitude: 42.1561035
Longitude: -85.5789460
Gathered By: Jennifer Jermalowicz-Jones
Map Type: Contour
www.cibiobase.com
1'
55'
Karendale Ave
Ludington Ave
Roger St
Spanish Oaks St
Portage Rd
Wetherbee
Lancelot Ct
E Osterhout Ave
Cora Dr
Sudan St
Vickery Rd
Abigail St
S Westnedge Ave
James Way
Marylynn Ct
Weaver Dr
Stonecrest A
Pine St
Panama St
Canal St
Gourdneck Cree
Prairie View County Park
Hogset
Lake
1000 feet
250 m
© 2013 Microsoft Corporation © 2013 Nokia

Figure 12. Chara (Muskgrass)

Figure 13. Thin-leaf Pondweed ©RLS, 2006

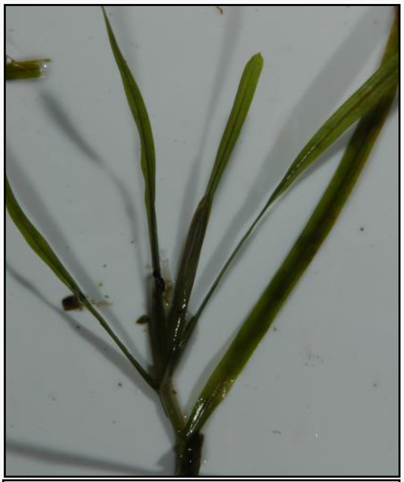


Figure 14. Flat-stem Pondweed ©RLS, 2006

Figure 15. Variable-leaf Pondweed ©RLS, 2006

Figure 16. Southern Naiad ©RLS, 2006

Figure 17. Illinois Pondweed ©RLS, 2006

Figure 18. Wild Celery ©RLS, 2006

Figure 19. Northern Watermilfoil ©RLS, 2006

Figure 20. Coontail ©RLS, 2006

Figure 21. Elodea ©RLS, 2006

Figure 22. Slender Naiad ©RLS, 2006

Figure 23. White Waterlily ©RLS, 2006

Figure 24. Wild Rice ©RLS, 2006

Figure 25. Beak Rush ©RLS, 2006

Figure 26. Cattails ©RLS, 2006

Figure 27. Bulrushes ©RLS, 2006

5.0 GOURDNECK LAKE MANAGEMENT IMPROVEMENT METHODS

Improvement strategies, including the management of exotic aquatic plants, control of beach and shoreline erosion, and protection from nutrient loading from external sources, are available for the various problematic issues facing Gourdneck Lake. The increase in developmental pressures and use of the aquatic ecosystem necessitates the implementation of inland lake management practices to preserve and maintain balance within the Gourdneck Lake watershed. 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 lakefront 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).

5.1 Chemical Herbicide and 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 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 35% of a lake. Thus, the use of either of these systemic herbicides is recommended for the control of milfoil in Gourdneck 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**. A whole-lake treatment of fluridone is not recommended for Gourdneck Lake since it contains a low amount of native vegetation and milfoil relative to its size and may be better controlled with spot-treatments using Triclopyr near shore and 2,4-D offshore.**

Algae treatments with 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 green algae in the water of Gourdneck Lake denotes that algal**

treatments may not be needed. All products are applied to the lake in a specialized treatment boat similar to the one in Figure 28.

Figure 28. An airboat used to apply aquatic herbicides.

5.2 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 29). 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 Gourdneck Lake is not recommended. It may be used in future years if the milfoil is eradicated and natural removal of nuisance pondweeds is desired.**

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.

Figure 29. A mechanical harvester.

5.3 Diver Assisted Suction Harvesting (DASH)

Suction harvesting via a Diver Assisted Suction Harvesting (DASH) boat (Figure 30) 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.**

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

5.4 Biological Control

The use of the aquatic weevil, *Euhrychiopsis lecontei* (Figure 31) 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 suitable candidates for the milfoil weevil. 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 scattered distribution of milfoil in Gourdneck Lake and the need for a fast-acting solution to remove the increasing biomass, stocking of weevils is not recommended.**

Figure 31. The milfoil weevil (*Euhrychiopsis lecontei*). Photo from R. Newman used with permission.

5.5 Laminar Flow Aeration and Bioaugmentation

Laminar flow aeration systems (Figure 32) 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 and algae management in eutrophic ecosystems (Restorative Lake Sciences, LLC 2009-present). 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 bio augmentation 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 bio augmentation. 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 detailed study by Restorative Lake Sciences (2009-present) of Indian Lake (Van Buren County, Michigan) during 2010 also indicated a significant reduction of organic sediments in bioaugmented/aerated regions, as well as a decline in the relative proportion of blue-green algae and the presence of the rooted, submersed, exotic aquatic plant, Eurasian Watermilfoil (*Myriophyllum spicatum*). A study by Turcotte et *al*. (1988) analyzed the impacts of bio augmentation on the growth of EWM 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 EWM 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 EWM 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 Restorative Lake Sciences).

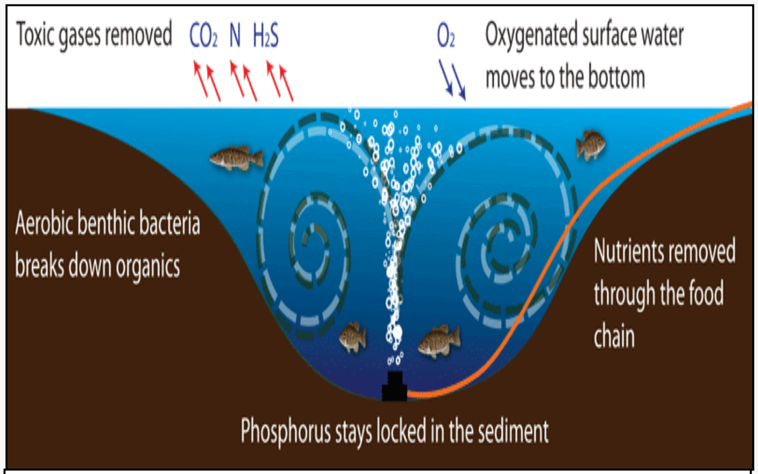


Figure 31. A diagram showing the laminar flow aeration mechanisms. ©Restorative Lake Sciences

6.0 GOURDNECK LAKE CONCLUSIONS & FURTHER RECOMMENDATIONS

The **urgent control of the Eurasian Watermilfoil infestation throughout Gourdneck Lake** is essential for the long-term preservation of the native aquatic plant communities. Furthermore, the **selected methods for the control of it should also protect native aquatic plant species through targeted control.** Gourdneck Lake possesses a very robust fishery, with many species of native aquatic plants that help to support the associated fishery through housing macro invertebrates (fish food) and providing habitat and shelter in the lake. The preferred aquatic plant management method(s) must also satisfy the needs of lake residents, by enhancing recreational activities such as boating (navigation) and fishing, increasing the safety of swimming, and protecting the property values of surrounding homes. Thus, management options must complement the socio-economic climate that influences both riparians and individual components of the Gourdneck Lake ecosystem. Every lake management plan should offer solutions that are ecologically sound, practical, and economically feasible. Improvements can be implemented though an SAD currently established through Schoolcraft Township pursuant to provisions of P.A. 188 of 1954. The objective of an SAD is to provide an equitable way to disperse costs for lake-wide improvement project(s). The SAD is typically chosen based on established criteria that define "units of benefit" that each individual property derives from the proposed improvements.

6.1 Further Recommendations: Integrated Management

Integrated management combines the use of chemical, biological, mechanical, aeration, or other methods to control aquatic plant growth and protect the lake health. Integrated management is becoming increasingly common since aquatic ecosystems are multi-dimensional and have different vegetation communities in certain lake areas and thus may show variable responses to specific treatments. **The recommended use of systemic chemical herbicides for the EWM and contact herbicides for nuisance native aquatic plant growth present within the lake and the recommended use of aeration for reduction of sediment organic muck and oxygenation of the lake and the use of other watershed management methods (i.e., BMP's for the reduction of external nutrient inputs to the lake), are indicative of an integrated management plan.**

Furthermore, a professional limnologist/aquatic botanist from RLS should perform regular GPS-guided whole-lake surveys each spring and fall to monitor the growth and distribution of EWM, and 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 Gourdneck 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 herbicide applicator or other lake contractors 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 meetings with the Gourdneck Lake riparians. An educational newsletter should be devised and circulated to riparians that contains educational tips for residents to recognize and prevent the transfer of invasive species to the lake and watershed management methods.

6.2 Gourdneck Lake Watershed Management

In addition to the proposed treatment of Eurasian Watermilfoil around and within Gourdneck 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 soils map),
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 size to reduce wave energy and thus erosion potential,
4) Avoiding the use of retaining walls and encouraging the growth of dense shrubs or rip-rap to control erosion,
5) Maintenance of drainfields and/or sewers and runoff is critical in areas with Houghton Muck soils which are prone to ponding during heavy rain events,
6) Using only native genotype plants (those native to Gourdneck 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, and

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

6.2.1 Gourdneck 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 Gourdneck 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. The November survey noted that the majority of the riparian shorelines contained natural vegetation, or were currently being mowed and sanded. 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 those residences 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 Gourdneck Lake. The emergent aquatic plant, *Scirpus* sp. (Bulrushes) or Cattails offer satisfactory stabilization of shoreline sediments and assists in the minimization of sediment release into the lake.

6.2.2 Gourdneck Lake Nutrient Source Control

Additional inputs of phosphorus or nitrogen to the lake are likely to create additional algal and aquatic plant growth. Accordingly, it is recommended that the following procedures to protect the water quality of Gourdneck 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.

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) Annually inspect septic tank systems and be sure to clean as needed and maintain the viability of the drain field since this area drains into the groundwater which enters the lake.

6.3 Invasive Aquatic 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 transfer of exotic species to Gourdneck Lake is awareness and education.

6.3.1 Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) 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 have a nearly microscopic larval 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).

The recommended prevention protocols for introduction of zebra mussels includes steam-washing all boats, boat trailers, jet-skis, and floaters prior to placing them into Gourdneck Lake. 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. Fishing poles, lures, and other equipment used in other lakes (and especially the Great Lakes) should also be thoroughly steam-washed before use in Gourdneck Lake. Additionally, all solid construction materials (if recycled from other lakes) must also be steam-washed.

7.0 PROJECT FINANCING

It is highly recommended that the residents around Gourdneck Lake adopt the lake water quality and aquatic vegetation guidelines suggested in this management plan. To protect the biodiversity of native aquatic plants within Gourdneck Lake, aquatic herbicides should be minimized and used primarily for exotic species or on nuisance native aquatic plants. Additionally, an integrated management approach involving the use of other lake improvement strategies (i.e. nutrient-reducing BMP’s and shoreline erosion reduction methods and possibly aeration) for water quality improvement is recommended for the management of nuisance rooted aquatic plant growth and improvement of water quality in Gourdneck Lake.

7.1 Cost Estimates for Gourdneck Lake Improvements

The proposed integrated management program for the control of EWM and lake improvement of Gourdneck Lake would begin during the 2015 season. A separate SAD may be needed to implement a laminar flow aeration system if desired due to a measureable increase in cost in addition to the weed control program. A breakdown of costs associated with Gourdneck Lake improvements is presented in Table 9. 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 Gourdneck Lake Improvement Item	Estimated 2015 Cost	Estimated 2016 Cost[4]	Estimated 2017-2019 Cost[5]
Herbicides for *EWM*[1] for 18 acres@ $500 per acre; $800 MDEQ permit fee;	$9,000	$6,750	$6,750
Note: Control of nuisance natives with contact herbicides @$300 per acre for 20 acres	$6,000	$6,000	$6,000
Professional Services (limnologist surveys, oversight, processing, education, newsletter)[2]	$5,500	$5,500	$6,000
Contingency[3]	$2,050	$1,825	$1,875
Total Annual Estimated Cost	$22,550	$20,075	$20,625
Approx. Riparian Cost[6]	$322	$286	$295

Table 7. Gourdneck Lake proposed lake improvement program costs (2015-2019).

[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 of a high-quality, scientific newsletter, and attendance at up to 4 Gourdneck Lake Improvement 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 2016-2019 based on 75% of the herbicide treatment costs for 2015. Note: Herbicide unit costs given for 2015-2019 may change due to cost of living adjustments for the contractor services and/or products.

[5] Costs of the proposed program for years 2015-2019 are estimates only and may change based on the distribution and/or abundance of EWM and costs of products and contractor services.

[6]Cost estimates per riparian based on 70 lakefront properties.

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APPENDIX A

GOURDNECK LAKE AQUATIC VEGETATION SURVEY AVAS SURVEY TABLE

LAKE NAME- GOURDNECK LAKE **COUNTY- KALAMAZOO** **SURVEY DATE: November 1, 2013**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: JLJ, GLJ

		Total number of AVAS's 137 for each Density Catagory				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil	59	35	15	2	59	350	600	160	1169	137	8.5	1	Eurasian milfoil
2	Curly leaf pondweed	2	1	1		2	10	40	0	52	137	0.4	2	Curly leaf pondweed
3	Chara	2	9	2	71	2	90	80	5680	5852	137	42.7	3	Chara
4	Thinleaf pondweed	4	9	14	6	4	90	560	480	1134	137	8.3	4	Thinleaf pondweed
5	Flatstem pondweed	2	4	2	1	2	40	80	80	202	137	1.5	5	Flatstem pondweed
6	Robbins pondweed					0	0	0	0	0	137	0.0	6	Robbins pondweed
7	Variable pondweed	4	2	1	3	4	20	40	240	304	137	2.2	7	Variable pondweed
8	Whitestem pondweed					0	0	0	0	0	137	0.0	8	Whitestem pondweed
9	Richardsons pondweed					0	0	0	0	0	137	0.0	9	Richardsons pondweed
10	Illinois pondweed	12	22	34	21	12	220	1360	1680	3272	137	23.9	10	Illinois pondweed
11	Large leaf pondweed					0	0	0	0	0	137	0.0	11	Large leaf pondweed
12	American pondweed					0	0	0	0	0	137	0.0	12	American pondweed
13	Floating leaf pondweed	4	2	5	1	4	20	200	80	304	137	2.2	13	Floating leaf pondweed
14	Water stargrass					0	0	0	0	0	137	0.0	14	Water stargrass
15	Wild Celery	3	1	4	7	3	10	160	560	733	137	5.4	15	Wild Celery
16	Sagittaria					0	0	0	0	0	137	0.0	16	Sagittaria
17	Northern milfoil	3	2	5	1	3	20	200	80	303	137	2.2	17	Northern milfoil
18	Whorled Watermilfoil					0	0	0	0	0	137	0.0	18	Whorled Watermilfoil
19	Variable leaved Milfoil					0	0	0	0	0	137	0.0	19	Variable leaved Milfoil
20	Coontail	3	6	2	1	3	60	80	80	223	137	1.6	20	Coontail
21	Elodea	11	4	2	3	11	40	80	240	371	137	2.7	21	Elodea
22	Bladderwort-Large	12	4	1	6	12	40	40	480	572	137	4.2	22	Bladderwort-Large
23	Bladderwort-mini					0	0	0	0	0	137	0.0	23	Bladderwort-mini
24	Buttercup					0	0	0	0	0	137	0.0	24	Buttercup
25	Southern Naiad	6	2	1	1	6	20	40	80	146	137	1.1	25	Southern Naiad
26	Brittle naiad					0	0	0	0	0	137	0.0	26	Brittle naiad
27	Spikerush	15	2	7	4	15	20	280	320	635	137	4.6	27	Spikerush
28	Slender Naiad	3	6	2	1	3	60	80	80	223	137	1.6	28	Slender Naiad
29						0	0	0	0	0	137	0.0	29	
30	White Waterlily	6	9	3		6	90	120	0	216	137	1.6	30	White Waterlily
31	Yellow Waterlily					0	0	0	0	0	137	0.0	31	Yellow Waterlily
32	Brasenia					0	0	0	0	0	137	0.0	32	Brasenia
33	Lemna minor	4	2	1		4	20	40	0	64	137	0.5	33	Lemna minor
34						0	0	0	0	0	137	0.0	34	
35	Watermeal					0	0	0	0	0	137	0.0	35	Watermeal
36	Arrowhead	2	1			2	10	0	0	12	137	0.1	36	Arrowhead
37	Pickerelweed	7	1	1		7	10	40	0	57	137	0.4	37	Pickerelweed
38	Arrow Arum					0	0	0	0	0	137	0.0	38	Arrow Arum
39	Cattails	7	1	2	2	7	10	80	160	257	137	1.9	39	Cattails
40	Bulrushes	7	5	2		7	50	80	0	137	137	1.0	40	Bulrushes
41	Wild Rice	2	2			2	20	0	0	22	137	0.2	41	Wild Rice
42	Swamp Loosestrife	2	5			2	50	0	0	52	137	0.4	42	Swamp Loosestrife
43	Purple Loosestrife	1	2	1		1	20	40	0	61	137	0.4	43	Purple Loosestrife
44	Yellow Iris	2	1			2	10	0	0	12	137	0.1	44	Yellow Iris
45	Phragmites	2	1			2	10	0	0	12	137	0.1	45	Phragmites
												119.7		