

LAKE COUNTY, IL

# 2016 DUCK LAKE SUMMARY REPORT

LAKE COUNTY HEALTH DEPARTMENT

ECOLOGICAL SERVICES



**Duck Lake**

Duck Lake is a 110-acre natural slough pothole lake located near the Village of Fox Lake, Illinois. The northern third of the lake is within Fox Lake village boundaries, with the remainder of the lake in unincorporated Lake County. Duck Lake is at the bottom of the Fish Lake Drain watershed that flows through Fish Lake, Fischer Lake, and Wooster Lake before entering Duck Lake. Water from Duck Lake eventually drains into the Fox River. The lake is privately owned and managed by the Duck Lake Waterway Association for boating, fishing, aesthetics and plant management. A private boat launch is available for the lake residents at Knollwood Park. The primary land uses within Duck Lake’s watershed are single family homes and transportation.

The lake was assessed through many parameters from May-September, 2016. Water clarity was measured by Secchi depth, with the lowest reading in August (0.95 ft) and the deepest was in May (7.80 ft). The average Secchi depth for the season was 3.71 ft, which was deeper than the county median (2.98 ft). Total suspended solids (TSS) concentration (9.2 mg/L) remained nearly identical to the 2006 average (9.1 mg/L). High TSS values are typically correlated with poor water clarity and can be detrimental to many aspects of the lake ecosystem, including the plant and fish communities.

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## DUCK LAKE

### LAKE FACTS

#### Nearest Municipality:

Fox Lake

T45N, R9E, Section 14, 15

#### Elevation:

738 feet

#### Major Watershed:

Fox River

#### Sub-Watershed:

Fish Lake Drain

#### Surface Area:

110.4 Acres

#### Shoreline Length:

7.5 miles

#### Maximum Depth:

9.0 feet

#### Average Depth:

4.5 feet

#### Lake Volume:

496.9 acre-feet

#### Watershed Area:

5334 acres

#### Lake Type:

Glacial

#### Management Entities:

Duck Lake Waterway  
Association

#### Current Uses:

Fishing, boating, swimming,  
and aesthetics.

Nitrogen and phosphorus are the two nutrients that can limit plant and algal growth. The 2016 average epilimnetic total phosphorus concentration in Duck Lake was 0.061 mg/L, which is lower than the county median (0.067 mg/L), and more than a 41% increase from the 2006 concentration (0.061 mg/L). The average total Kjeldahl nitrogen concentration in Duck Lake in 2016 (1.99 mg/L) decreased from 2006 (1.67 mg/L). A total nitrogen to total phosphorus (TN:TP) ratio of 34:1 indicates that phosphorus was the nutrient limiting aquatic plant and algae growth in Duck Lake.

The Illinois Environmental Protection Agency (IEPA) has assessment indices to classify Illinois lakes for their ability to support aquatic life and recreational uses. The guidelines consider several aspects, such as water clarity, phosphorus concentrations (TSIp), and aquatic plant coverage. According to this index, Duck Lake provided Full support of aquatic life and Partial support for recreational activities. The lake also provided Partial overall use. The trophic state of Duck Lake in terms of its phosphorus concentration during 2016 was eutrophic, with a TSIp score of 63.3. In 2006 the TSIp score was lower at 58.3, also eutrophic.

The average conductivity of Duck Lake was 0.7530 mS/cm which is lower than the county median (0.7889 mS/cm). This was a 3.5% decrease from the 2006 average (0.7807 mS/cm). The average Duck Lake chloride concentration in 2016 was 120 mg/L which was lower than the county median of 139 mg/L.

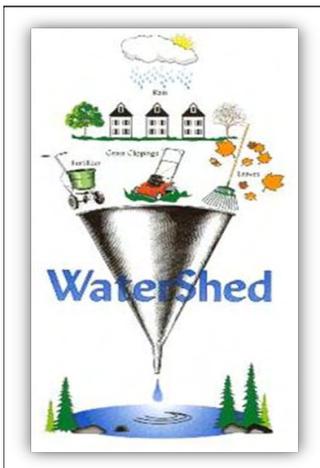
The aquatic plants in the lake help in stabilizing bottom sediment and nutrient uptake. The aquatic plant community was assessed in August when most of the plants are likely to be present. Seventy-three percent of the sites sampled in Duck Lake had aquatic plants present. The aquatic plant community in the lake consisted of 10 species and one macro-algae (Chara) was found in 2016. Coontail (41.3%) was the most dominant species, followed by White Water Lily and Common Bladderwort at 34.1% and 29.4% respectively. Plant diversity decreased by two species between 2006 and 2016, and plant composition changed as well. American Pondweed, Common Bladderwort, Curlyleaf Pondweed, Small Duckweed and Watermeal were found in 2016, but not in 2006. However, Eurasian Water Milfoil, Giant Duckweed, Northern Milfoil, Southern Naiad, and Spiny Naiad were found in 2006 and not in 2016. The changes can probably be attributed to natural annual variation, the timing of sampling and chemical treatment.

Fish stocking by Duck Lake Waterway Association occurred from 2006, 2006, 2009, 2014, and 2016 and included Largemouth Bass, Walleye, and Black Crappie to maintain angling opportunities.

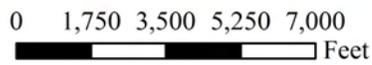
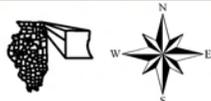
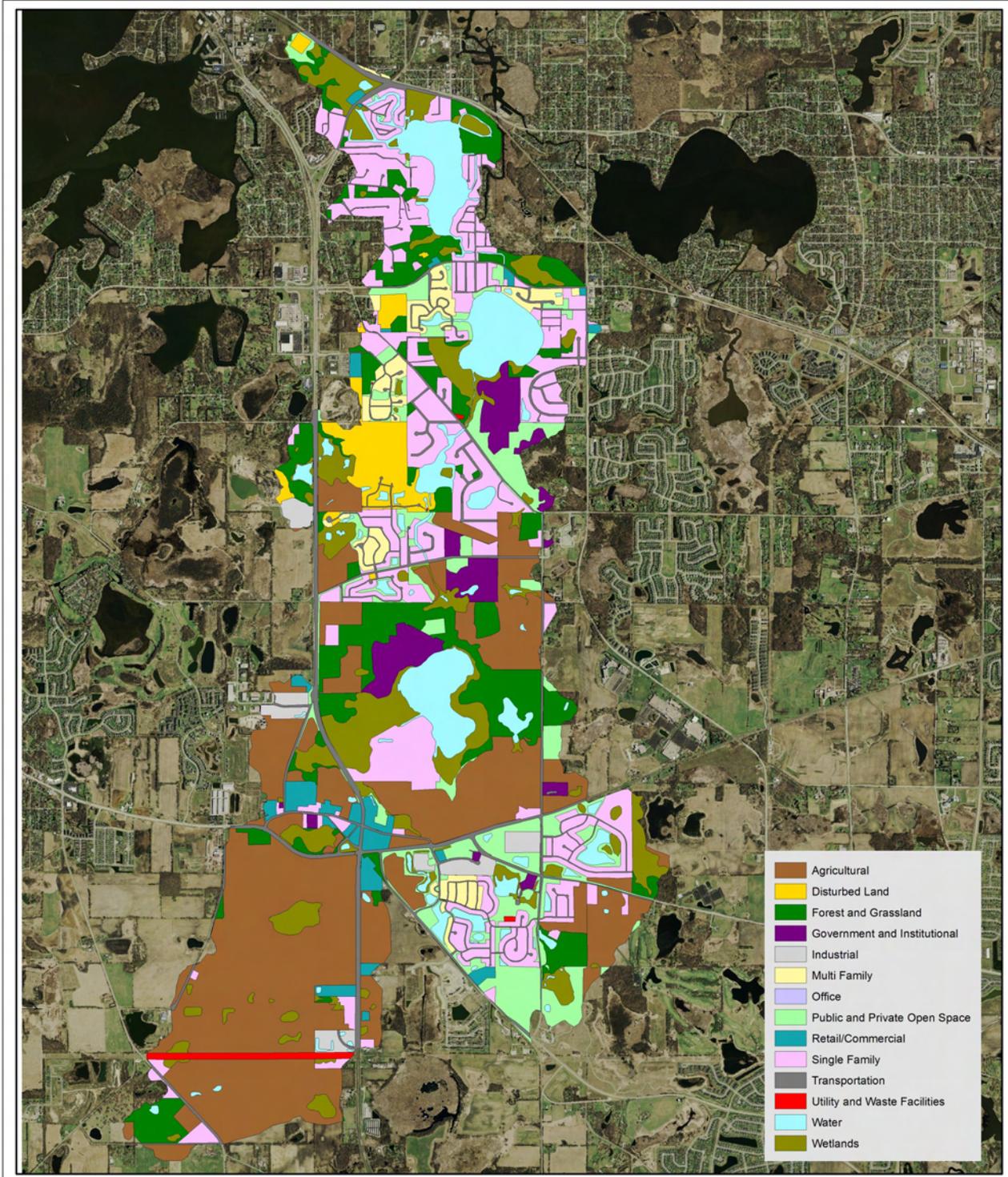
## DUCK LAKE WATERSHED

The Duck Lake is located in the Fish Lake sub basin, within the Fox River watershed. A watershed is a drainage basin where water from rain or snow melt drains into a body of water, such as a river, lake, reservoir, wetland or storm drain. The source of a lake's water supply is very important in determining its water quality and choosing management practices to protect the lake. Duck Lake receives a majority of its water through inlets and runoff from the surrounding area. Fish Lake, Fischer Lake, and Wooster Lake are located upstream of Duck Lake. Water enters Duck Lake from Wooster Lake Drain on the south end of the lake and leaves at the east side, draining into the Squaw Creek and eventually to the Fox River. The retention time, the time it takes for water entering a lake to flow out again was calculated to be approximately 63.18 days.

The Duck Lake watershed is approximately 5334 acres and is comprised mainly of Agricultural (29.0%), Single Family (16.5%) and forest and grassland (10.7%). The major sources of runoff are Single Family (25.3%) and Transportation (25.2%), and Agricultural (7.4%). See Appendix A.



### Duck Lake Land Use 2016



Ecological Services  
Product Number WOS14  
Revised 02/2017

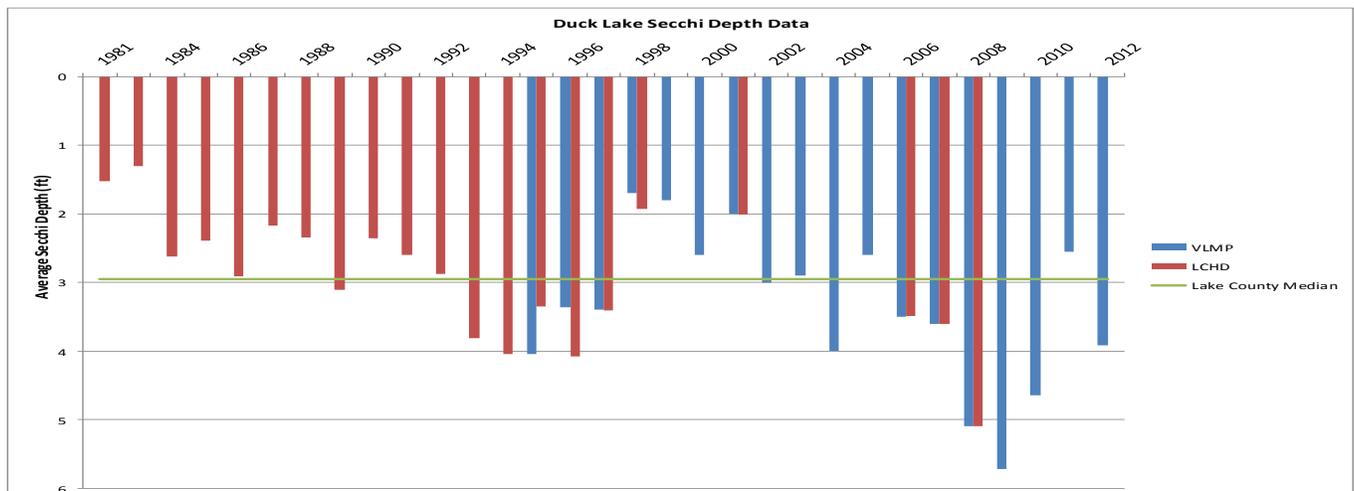
## DUCK LAKE AREA LAND USE

Land Use	Acreage	Runoff Coeff.	Estimated Runoff, acft.	% Total of Estimated Runoff
Agricultural	1545.85	0.05	212.6	7.4
Disturbed Land	141.63	0.05	19.5	0.7
Forest and Grassland	568.15	0.05	78.1	2.7
Government and Institutional	173.30	0.50	238.3	8.3
Industrial	84.28	0.80	185.4	6.5
Multi Family	125.50	0.50	172.6	6.0
Public and Private Open Space	406.61	0.15	167.7	5.8
Retail/Commercial	108.91	0.85	254.6	8.9
Single Family	881.01	0.30	726.8	25.3
Transportation	309.24	0.85	722.8	25.2
Utility and Waste Facilities	28.06	0.30	23.2	0.8
Water	460.69	0.00	0.0	0.0
Wetlands	500.91	0.05	68.9	2.4
<b>TOTAL</b>	<b>5334.14</b>		<b>2870.4</b>	<b>100.0</b>

COMPARISON OF EPILIMNETIC AVERAGES FOR SECCHI DISK TRANSPARENCY, TOTAL SUSPENDED SOLIDS, TOTAL PHOSPHORUS, AND CONDUCTIVITY READINGS IN THE DUCK LAKE WATERSHED

	Fish Lake	Fish Lake	Fish Lake	Fischer Lake	Fischer Lake	Fischer Lake	Wooster Lake	Wooster Lake	Wooster Lake	Wooster Lake	Duck Lake	Duck Lake	Duck Lake
Year	2002	2006	2016	2001	2006	2016	2003	2005	2006	2016	2001	2006	2016
Secchi (feet)	4.02	3.47	3.57	2.72	1.96	2.7	7.83	9.54	7.87	8.74	2.01	3.49	3.71
TSS (mg/L)	11.3	11	12.3	15.4	28.0	16.5	3.4	3.2	5.1	2.5	20.6	9.1	9.2
TP (mg/L)	0.102	0.096	0.073	0.198	0.228	0.138	0.032	0.03	0.043	0.029	0.100	0.043	0.061
Conductivity (ms/cm)	0.6629	0.8688	0.7808	0.6687	0.8524	0.7653	0.6437	0.7100	0.7388	0.7264	0.6071	0.7807	0.753

## WATER CLARITY



## WATER CLARITY

Water clarity is an indicator of water quality related to chemical and physical properties. Measurements taken with a Secchi disk indicate the light penetration into a body of water. Algae, microscopic animals, water color, eroded soil, and resuspension of bottom sediment are factors that interfere with light penetration and reduce water transparency. If light penetration is reduced significantly, macrophyte growth may be decreased which would in turn impact the organisms dependent upon them for food and cover. The 2016 average clarity for Duck Lake was 3.71 feet; this was a 6% increase in the lakes transparency since 2006 of 3.49 feet and the water clarity was above the county median of 2.98 feet. The shallowest Secchi depth for Duck Lake was in August (0.95 ft) and the deepest was in May (7.80 ft). The water clarity began to decrease after the aquatic plants had been chemically treated. Aquatic plants compete with algae for nutrients and stabilize bottom substrate, which in turn improves water clarity. In August the total phosphorus was at its highest concentration at 0.108 mg/L which contribute to the algae bloom.

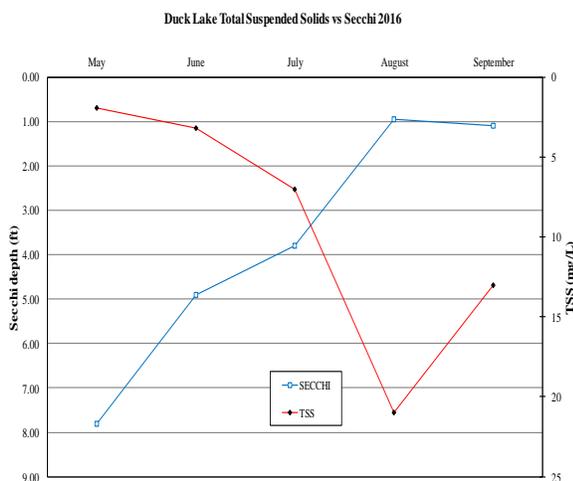
## TOTAL SUSPENDED SOLIDS

Another measure of water clarity is turbidity, which is caused by particles of matter rather than the dissolved organic compounds. Suspended particles dissipate light, which may limit the depth plants can grow. The total suspended solid (TSS) parameter (turbidity) is composed of nonvolatile suspended compounds (NVSS), non-organic clay or sediment materials, and volatile suspended solids (TVS) (algae and other organic matter).

Seasonal Secchi readings changes are affected by algal growth. The absence or low density of algae in early spring usually provides deeper clarity but as the water warms clarity decreases with more algae present in the water. High turbidity caused by sediment or algae can shade out native aquatic plants, resulting in their reduction or disappearance from the littoral zone. This eliminates the benefits provided by plants, such as habitat for many fish species and stabilization of the lake bottom. The 2016 TSS concentrations in Duck Lake averaged 9.2 mg/L which was above the county median of 7.8 mg/L and nearly the same as the 2006 average concentration of 9.1 mg/L. Low TSS values are typically correlated with good water clarity (Secchi disk depth) and can be beneficial to many aspects of the lake ecosystem including the plant and fish communities.

Lakes with NVSS values  $\geq 12$  mg/l could cause impairment for aquatic life in inland lakes. There are internal and external sources of sediment affecting the turbidity in Duck Lake. Internal sources of sediment suspension include wind and wave action along with carp spawning and feeding activity especially along eroded shoreline. Aquatic plants act as a buffer by preventing the resuspension of sediments from affecting the rest of the lake. External sources include sediments that are transported into the lake from culverts and bank erosion. The average calculated nonvolatile suspended solids (NVSS) was 5.51 mg/L. The low NVSS means that means that there is very little amount suspended solids found in the water column. The TVS was at its highest in August (174 mg/L) which coincides with the lowest Secchi reading for the season. Algae bloom was observed at the time the sample was collected. (See Appendix A)

Secchi disk transparency is an indicator overall water quality. In general, the greater the Secchi disk depth, the clearer the water and better the water quality. High TSS values are typically correlated with poor water clarity. Over the past 15 years water clarity in Duck Lake has improved significantly.



<b>TSS</b>
Total Suspended Solids
TSS are particles of algae or sediment suspended in the water column.
<b>TVS</b>
Total Volatile Solids
TVS represents the fraction of total solids that are organic in nature, such as algae cells
<b>NVSS</b>
Non-Volatile Suspended Solids
NVSS represents the non-organic clay and sediments that are suspended in the water column.
<b>TDS</b>
Total Dissolved Solids
TDS are the amount of dissolved substance such as salts or minerals in the water after evaporation.

**WHAT HAS BEEN DONE  
TO REDUCE PHOSPHORUS  
LEVELS IN ILLINOIS**

**July 2010-** The State of Illinois passed a law to reduce the amount of phosphorus content in dishwashing and laundry **detergents.**

**July 2010-** The State of Illinois passed another law restricting the use of lawn fertilizers containing phosphorus by commercial applicators.



SALTS DISSOLVE AND MOVE DOWNHILL OR INTO THE NEAREST STORM DRAIN WITH STORM-WATER AND SNOWMELT RUNOFF TO THE NEAREST LAKE, RIVER OR POND. THEY DO NOT SETTLE OUT; THEY REMAIN IN THE WATER CYCLE VIRTUALLY FOREVER.

## NUTRIENTS

The nutrients organisms need to live or grow are typically taken in from the environment. In a lake the primary nutrients needed for aquatic plant and algal growth are phosphorus and nitrogen. In most lakes, including Duck Lake, phosphorus is the limiting nutrient, which means everything that plants and algae need to grow is available in excess: sunlight, warm temperature, and nitrogen.

Phosphorus has a direct effect on the amount of plant and algal growth in lakes. The 2016 average total phosphorus (TP) epilimnion (near surface sample) concentration in Duck Lake was 0.061 mg/L, this was a 41% increase from the 2006 concentration (0.043 mg/L). Lakes with concentrations exceeding 0.050 mg/L can support high densities of algae and aquatic plants, which can reduce water clarity and dissolved oxygen levels and are considered impaired by the IEPA. Phosphorus originates from a variety of sources, many of which are related to human activities which include: human and animal waste, soil erosion, septic systems, common carp, and runoff from farmland and lawns. Duck Lake's pretreatment TP concentration was 0.022 mg/L was taken on May 19, 2016 the day before aquatic herbicide was applied. The TP concentration increased as plant material decayed and the TP concentration peaked in August at 0.108 mg/L. Nitrogen is the other nutrient critical for algal growth. Total Kjeldahl nitrogen is a measure of organic nitrogen, and is typically bound up in algal and plant cells. The average 2016 TKN for Duck Lake was 1.990 mg/L. If inorganic nitrogen (NO<sub>2</sub>, NO<sub>3</sub>, NH<sub>4</sub>) concentrations exceed 0.3 mg/L in spring, sufficient nitrogen is available to support summer algae blooms. However, low nitrogen levels do not guarantee less algae blooms. Typically lakes are either phosphorus (P) or nitrogen (N) limited. This means one of the nutrients is in short supply and any addition of that nutrient to the lake will result in an increase of plant and/or algal growth. Ratios less than or equal to 10:1 indicate nitrogen is limiting, ratios greater than or equal to 15:1 indicate there are enough of both nutrients to facilitate excess algae or plant growth. The TN:TP ratio for Duck Lake was 34:1, which means that the limiting nutrient for aquatic plants was phosphorus.

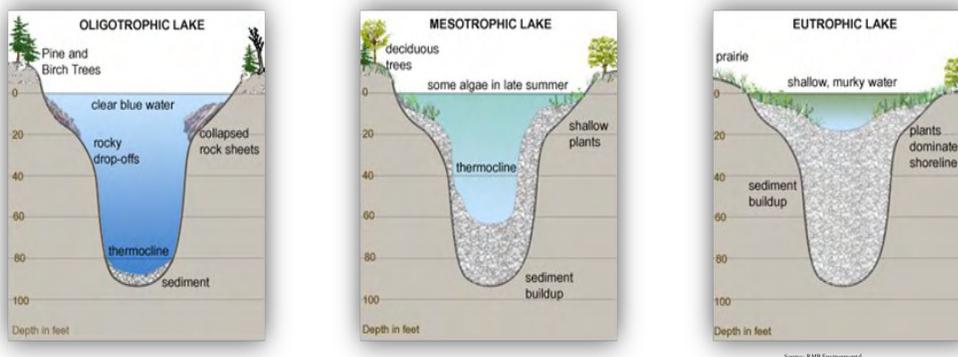
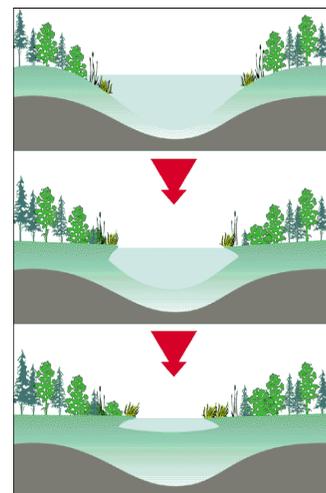
## CONDUCTIVITY AND CHLORIDE

Conductivity is a measure of a water's ability to conduct electricity, measured by the water's ionic activity and content. The higher the concentration of (dissolved) ions the higher the conductivity becomes. Conductivity readings, which are influenced by chloride concentrations, have been increasing throughout the past decade in Lake County. Lakes with residential and/or urban land uses in their watershed often have higher conductivity readings and higher Cl<sup>-</sup> concentrations because of the use of road salts. Storm water run-off from impervious surfaces such as roads and parking lots can deliver high concentrations of Cl<sup>-</sup> to nearby water bodies. Road salt used in the winter road maintenance consists of the following ions: sodium chloride, calcium chloride, potassium chloride, magnesium chloride, or ferrocyanides which are detected when chlorides are analyzed.

The 2017 average conductivity for Duck Lake was 0.7530 mS/cm. This parameter was lower than the county median of 0.7889 mS/cm which is 3% lower than the 2006 value of 0.7807 mS/cm. These values are influenced by the winter road maintenance of Route 12, Big Hollow Road and Rollins, and Route 120 along. The United States Environmental Protection Agency has determined that chloride concentrations higher than 230 mg/L can disrupt aquatic systems and prolonged exposure can harm 10% of aquatic species. Duck Lake's Cl<sup>-</sup> concentration was 120 mg/L which is the same as the 2006 value. Chlorides tend to accumulate within a watershed as these ions do not break down and are not utilized by plants or animals. High chloride concentrations may make it difficult for many of our native species to survive. However, many of our invasive species, such as Eurasian Watermilfoil, Cattail and Common Reed, are tolerant to high chloride concentrations.

## TROPHIC STATE INDEX

Another way to look at phosphorus levels and how they affect lake productivity is to use a Trophic State Index (TSI) based on phosphorus (TSIp). TSIp values are commonly used to classify and compare lake productivity levels (trophic state). A lake's response to additional phosphorus is an accelerated rate of eutrophication. Eutrophication is a natural process where lakes become increasingly enriched with nutrients. Lakes start out with clear water and few aquatic plants and over time become more enriched with nutrients and vegetation until the lake becomes a wetland. This process takes thousands of years to take place. However, human activities on a lake or in the watershed accelerate this process by resulting in rapid soil erosion and heavy phosphorus inputs. This accelerated aging process on a lake is referred to as cultural eutrophication. The TSIp index classifies the lake into one of four categories: oligotrophic (nutrient-poor, biologically unproductive), mesotrophic (intermediate nutrient availability and biological productivity), and eutrophic (nutrient rich, highly productive), or hypereutrophic (extremely nutrient-rich, productive). In 2016, Duck Lake was eutrophic with a TSIp Value of 63.3. Lake Carina and Sterling Lake are tied for 1st out of 175 lakes in Lake County.



“WHEN HUMAN ACTIVITIES ACCELERATE LAKE EUTROPHICATION, IT IS REFERRED TO AS CULTURAL EUTROPHICATION. CULTURAL EUTROPHICATION MAY RESULT FROM SHORELINE EROSION, AGRICULTURAL AND URBAN RUNOFF, WASTEWATER DISCHARGES OR SEPTIC SEEPAGE, AND OTHER NON-POINT SOURCE POLLUTION SOURCES.”

## LAKE LEVEL

Lakes with stable water levels potentially have less shoreline erosion problems. The lake level in Duck Lake was measured from a steel post at the channel entrance next to the beach. The lake level decreased from May to September by 4.68 inches. The highest water level recorded occurred in May (4.09 ft) and the lowest level in August (4.83 ft). The most significant water level fluctuation occurred from May to June with a decrease in the lake level of 8.64 inches. Duck Lakes water level appear to be influenced by rain events. The Fish Lake watershed system contributes to the water level in the lake. In order to accurately monitor water levels it is recommended that a staff gauge be installed and levels measured and recorded frequently (daily or weekly). The data provides lake managers a much better idea of lake level fluctuations relative to rainfall events and can aid in future decisions regarding lake level. Staff gauge is a great tool for measuring water level in lakes, rivers, reservoirs. The data collected can be compiled to help understand the natural fluctuations of the lake. Lakes with fluctuating water levels potentially have poorer water quality and have more shoreline erosion problems.



**EXAMPLE OF A PERMANENT STAFF GAUGE**

2016	Level (ft)	Seasonal Change (ft)	Monthly Change (ft)
May	3.08		
June	3.44	0.36	0.36
July	4.56	1.48	1.12
August	4.75	1.67	0.19
September	3.75	0.67	-1.00

## BATHYMETRIC MAPS

Bathymetric maps are also known as depth contour maps and display the shape and depth of a lake. They are valuable tools for lake managers because they provide information about the surface area and volume of the lake at certain depths.

This information can then be used to determine the volume of lake that goes anoxic, how much of the lake bottom can be inhabited by plants, and is essential in the application of whole-lake herbicide treatments, harvesting activities and alum treatments of your lake. Other common uses for the map include sedimentation control and habitat management. Bathymetric maps are a great tool for identifying fish habitat placement. These structures should be placed shallower than the thermocline.

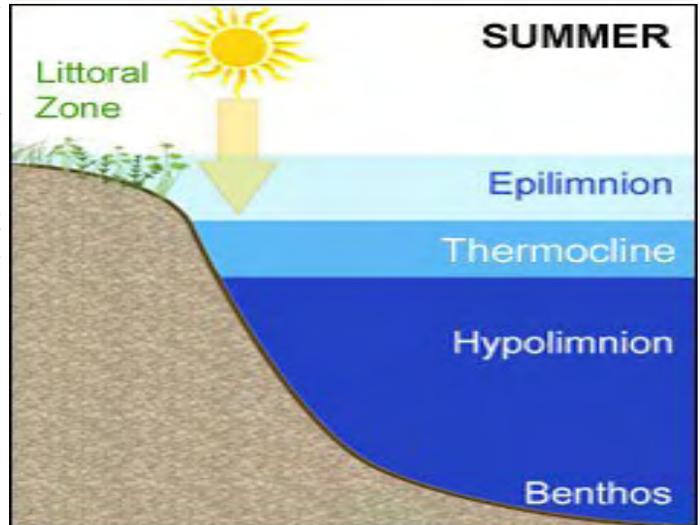
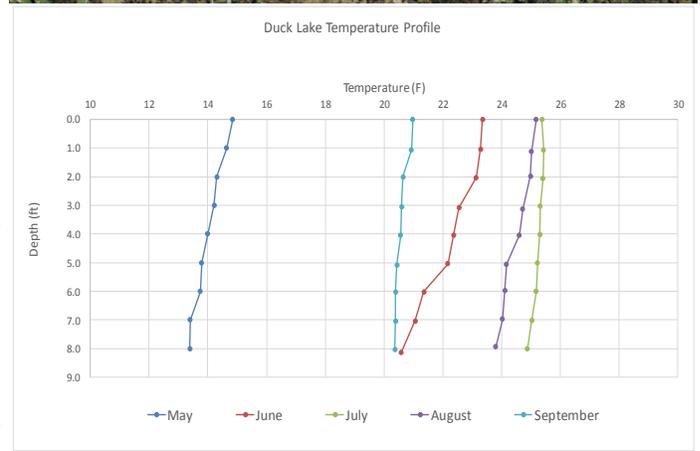
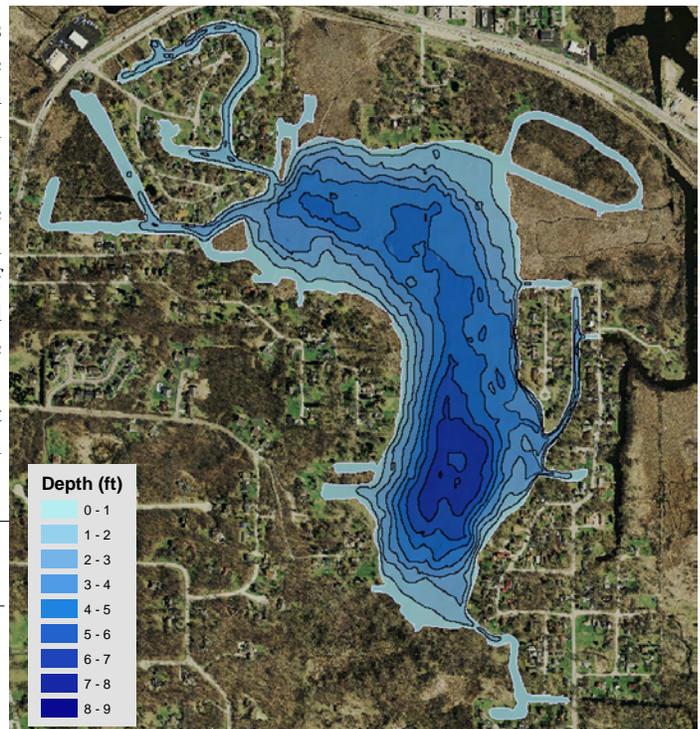
## STRATIFICATION

A lake's water quality and ability to support fish are affected by the extent to which the water mixes. The depth, size, and shape of a lake are the most important factors influencing mixing, but climate, lakeshore topography, inflow from streams and vegetation also play a role. Variations in density caused by different temperatures can prevent warm and cold water from mixing, called stratification.

For example: when lake ice melts in early spring, the temperature and density of lake water will be similar from top to bottom. Since it is uniform throughout the water column, the lake can mix completely recharging the bottom water with oxygen and bringing nutrients up to the surface. Some lakes in summer experience stratification where the lake is dividing into three zones: epilimnion (warm surface layer), thermocline (transition zone between warm and cold water) and hypolimnion (cold bottom water). Stratification traps nutrients released from bottom sediments in the hypolimnion and prevents mixing.

Monthly depth profiles were measured on Duck Lake by measuring water temperature, dissolved oxygen, conductivity, and pH every foot from the lake surface to the lake bottom. The relative thermal resistance to mixing (RTRM) value can be calculated from this data which can tell us if the lake stratifies, how great the stratification is, and what depth it occurs.

Duck Lake was weakly stratified in June at 6 feet. Lakes that are less than 10 feet don't often stratify or can easily be turned over by wind or water flowing through the system. The long and narrow nature of the lake allows for it to be easily mixed by the wind. (See Appendix A)



## BLUE-GREEN ALGAE BLOOM

Algae are important to the freshwater ecosystems, and most species of algae are not harmful. Algae blooms are often caused by blue-green algae, or “cyanobacteria”, which are similar to bacteria in structure but utilize photosynthesis to grow. They have no nucleus and lack the photosynthetic pigments found in algae. They usually are too small to be seen individually, but can form visible colonies that can cover large areas of lakes.

Duck Lake had seasonal algal blooms due to high Total Phosphorus concentrations as a result of the herbicide treatment. Algal blooms may be kept under control by reducing nutrients and sediments entering the lake from the watershed. Blooms can last for an extended period of time, which prevents sunlight from reaching underwater plants and algae that are important to the ecosystem.

Not all blue-green algae produce harmful toxins. The three types of cyanobacteria that are often associated with Harmful Algal Bloom (HAB) are the Anabaena, Aphanizomenon, and Microcystis. The presence of these cyanobacteria does not generally mean that the toxins are present in the water. The presence of toxins can only be verified through a sample analyzed in the lab. Poisoning has caused the death of cows, dogs, and other animals. Most human cases occurred when people swim or ski in affected recreational water bodies during a bloom. If you suspect that you are experiencing symptoms related to exposure to blue-green algae such as stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, or difficulty breathing contact your doctor or the poison control center. For more information or to report a blue-green algae bloom, contact the Lake County Health Department Environmental Services (847) 377-8030.

## SWIMMING BEACH MONITORING

All licensed inland beaches are tested bi-weekly from May to September by the Lake County Health Department’s Ecological Services Department. The water samples are tested for E. coli bacteria, which are found in the intestines of almost all warm-blooded animals. E. coli is used as an indicator organism, meaning that high concentrations of E. coli might suggest the presence of harmful pathogens such as, Salmonella, Giardia, etc. While not all strains of E. coli are the same, certain strains can make humans sick if ingested in high enough concentrations. If water samples come back high for E. coli (>235 E. coli/100 ml), LCHD informs the management body for the bathing beach that the beach is closed and a sign is posted indicating the beach closure. Licensed beaches will also be monitored for blue-green algae and samples may be taken for testing when blooms occur. During the summer of 2016, E. coli counts at Duck Lake Woods Improvement had one sample that exceed the maximum allowable limit when the July 25, 2016 sample registered 1299 FC colonies/100 ml. If you have any questions, feel free to contact the Lake County Health Department at 847-377-8030. How to prevent illness and beach closure:

- If you are sick, do NOT swim.
- Don’t swim when you have diarrhea. You can spread germs in the water.
- Take a shower prior to entering the beach area.
- Children who are not toilet trained should wear tight fitting rubber or plastic pants.
- Pick up garbage around the beach area.
- Avoid swimming during algae blooms.
- Do not ingest the water while swimming.
- Keep pets, ducks and geese out of the beach area.
- Identify sources of pollution (ex: failing septic systems, stagnant standing water near the beaches, creeks and storm drains).

FOR MORE INFORMATION  
ON BLUE-GREEN ALGAE:  
[www.epa.state.il.us/](http://www.epa.state.il.us/)

[water/surface-water/blue-green-algae.html](http://www.epa.state.il.us/water/surface-water/blue-green-algae.html)

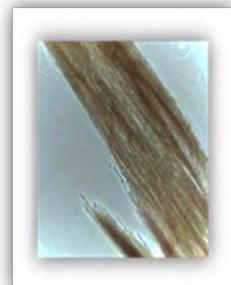
TO REPORT BLUE-GREEN  
ALGAE BLOOM:  
Lake County Health  
Department  
847-377-8030



Anabaena Sp.



Microcystis Sp.



Aphanizomenon Sp.

## SHORELINE EROSION

“VEGETATIVE BUFFER ZONES CAN PLAY A KEY ROLE IN LIMITING NEGATIVE WATER QUALITY IMPACTS FROM DEVELOPED SHORELAND PROPERTY”



SHORELINE BUFFER

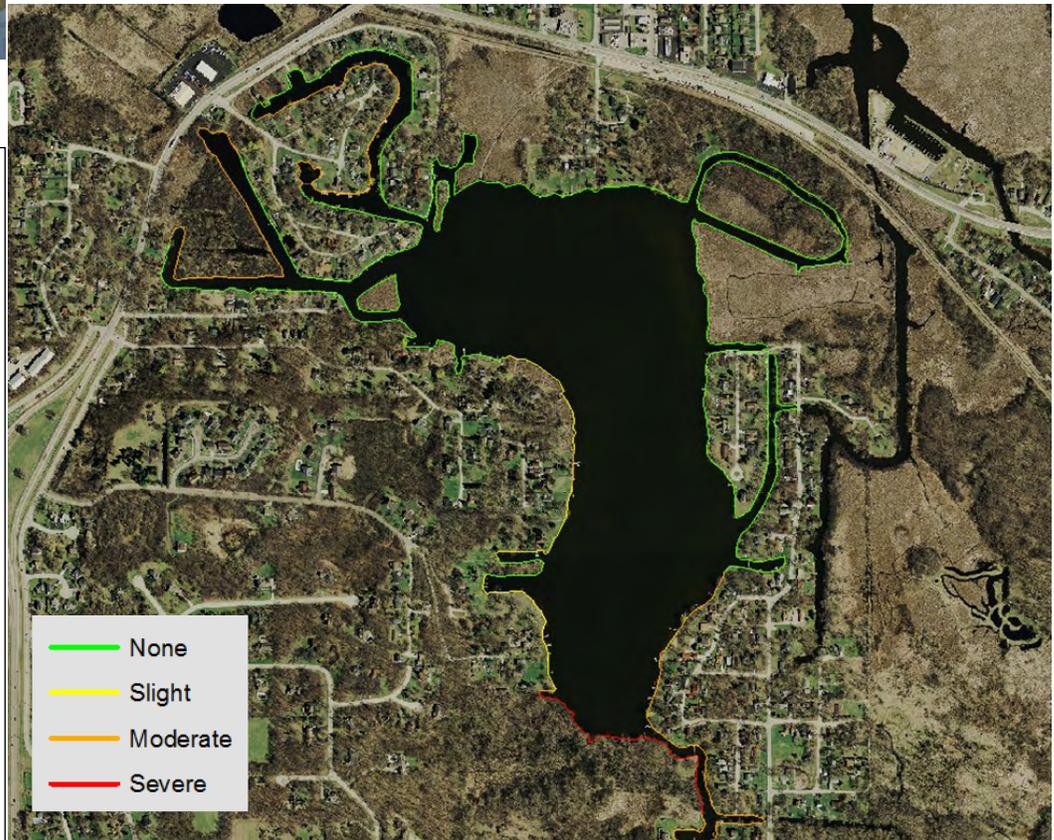
Erosion is a natural process primarily caused by water which results in the loss of material from the shoreline. Disturbed shorelines caused by human activity such as clearing of vegetation and beach rocks, and increasing runoff will accelerate erosion. Rain and melting snow and wave action are the main causes of erosion. Rain can loosen soil and wash it down gradient towards the lake. Creating a native plant buffer helps prevent soil erosion as well as filter out pollutants and unwanted nutrients from entering the lake. Native plants can be planted along the shoreline since plant roots hold the soil particles in place so they are not easily washed away during a rain event, melting snow or wave action. Loose rocks and gravel placed on top of a filter fabric prevents soil from washing away before newly planted seed and vegetation has a chance to grow. Eroded materials cause turbidity, sedimentation, nutrients, and pollutants to enter a lake. Shore line buffer zone planted with native vegetation not only reduces runoff by increasing water infiltration into the ground, it also offers food and habitat for wildlife. Less runoff means less nutrients, sediments and other pollutants entering the lakes and streams. Excess nutrients are the primary cause of algal blooms and increased aquatic plant growth. Once in the lake, sediments, nutrients and pollutants are harder and more expensive to remove.

A shoreline erosion study was assessed for Duck Lake in 2016. The lake was divided into reaches, and the shoreline evaluated for none, slight, moderate and severe erosion based on exposed soil and tree/plant roots, failing infrastructure, undercut banks, and other signs of erosion. Based on the 2016 data, 30% of Duck Lake’s shoreline has some erosion; 17% slight erosion, 11% moderate erosion and 3% had severe erosion. (See Appendix B)

## DUCK LAKE’S 2016 SHORELINE EROSION

INFORMATION ON SHORELINE REGULATION AND PERMITS CAN BE FOUND ON THE ILLINOIS DEPARTMENT OF NATURAL RESOURCES’ WEBSITE.

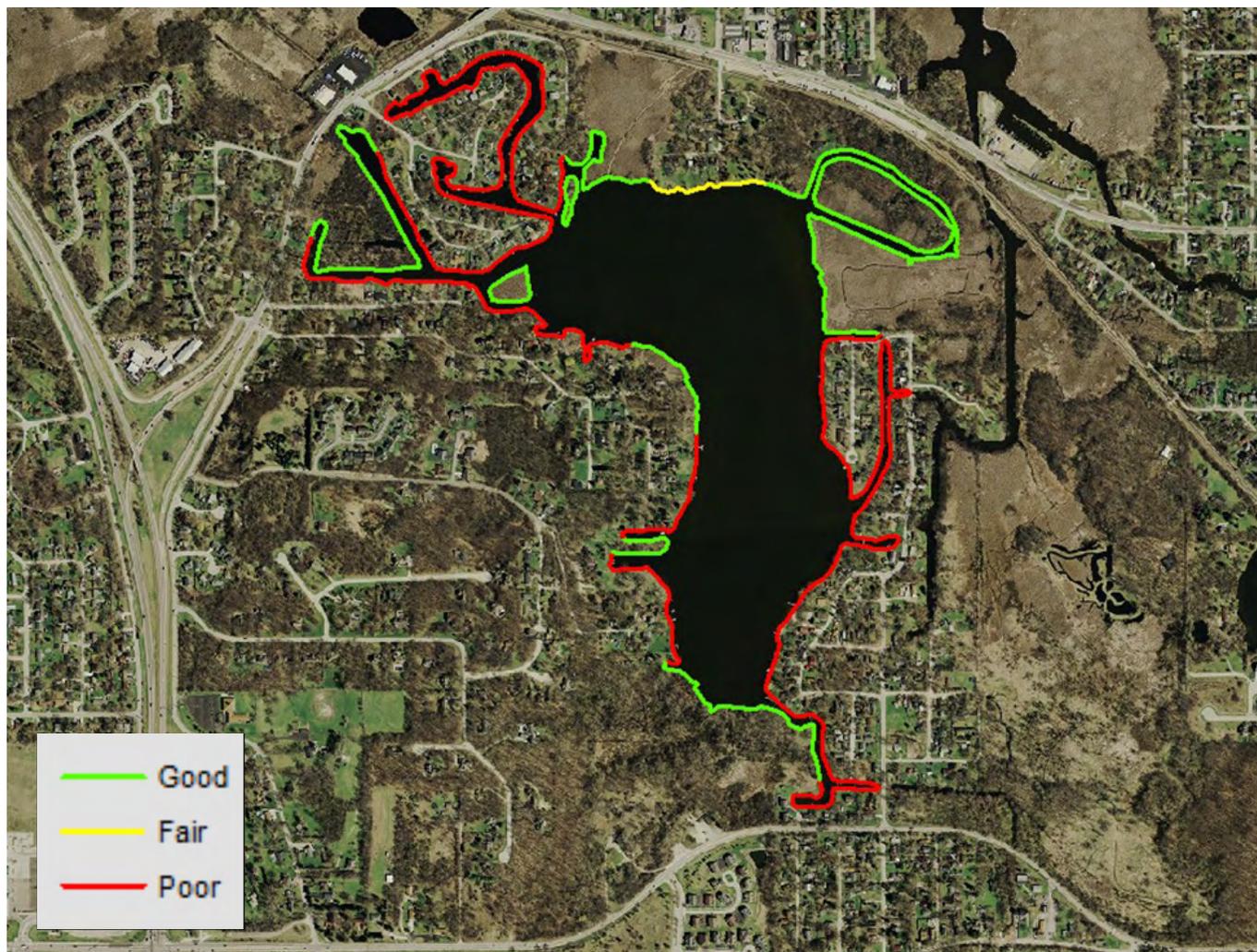
HTTP://WWW.DNR.ILLINOIS.GOV/WATERRESOURCES/DOCUMENTS/3704.PDF



## SHORELAND BUFFER

A shoreland buffer helps stabilize the sediment near the lakes edge which prevents soil erosion. The buffer will also filter out pollutants and unwanted nutrients from entering the lake. Buffer strips should be at least 25 feet wide and can include native wildflowers, native grasses, and native wetland plants. Wider buffers may be needed for areas with a greater slope or additional runoff issues. Areas that are already severely or moderately eroding, a buffer strip of native plants may need to be bolstered for additional stability. Many lakes have re-established buffers or do not mow to lakes edge to allow native grasses to grow. A shoreland buffer condition of Duck Lake was assessed by looking at the land within 25 feet of the lake's edge on aerial images in ArcGIS. Shoreland buffer's were classified into three categories; poor, fair or good based on the amount of unmowed grasses, forbs, tree trunks and shrubs, and impervious surfaces within that 25 foot range. In 2016, Duck Lake had 45% of the shoreline with good buffer, 17% with fair, and 38% with poor buffer. For complete list of shoreline buffer conditions by reach, refer to Appendix B. Identify areas around the lake where of the buffer could be expanded with out impeding shoreline access for home owners and park users. (See Appendix B)

## DUCK LAKE'S 2016 SHORELINE BUFFER ASSESMENT



## FLORISTIC QUALITY INDEX

LAKE COUNTY  
AVERAGE  
FQI = 13.4

DUCK LAKE  
FQI = 18.3

RANK = 40/171

AQUATIC PLANTS  
SPECIES  
OBSERVED = 10

Floristic quality index (FQI) is an assessment tool designed to evaluate the closeness that the flora of an area is to that of undisturbed conditions. It can be used to: 1) identify natural areas, 2) compare the quality of different sites or different locations within a single site, 3) monitor long-term floristic trends, and 4) monitor habitat restoration efforts. Each aquatic plant in a lake is assigned a number between 1 and 10 (10 indicating the plant species most sensitive to disturbance). This is done for every floating and submersed plant species found in the lake. These numbers are averaged and multiplied by the square root of the number of species present to calculate an FQI. A high FQI number indicates that there are a large number of sensitive, high quality plant species present in the lake. Non-native species were counted in the FQI calculations for Lake County lakes. In 2016, Duck Lake had an FQI of 18.3 ranking 40 out of 171 in Lake County. The median FQI of lakes that we have studied from 2000-2016 is 13.4. Cedar Lake is 1st with an FQI of 37.4. (See Appendix B)

In many lakes macrophytes contribute to the aesthetically pleasing appearance of the setting and are enjoyable in their own right. but even more important, they are an essential element in the life systems of most lakes.

### AQUATIC PLANTS: WHERE DO THEY GROW?

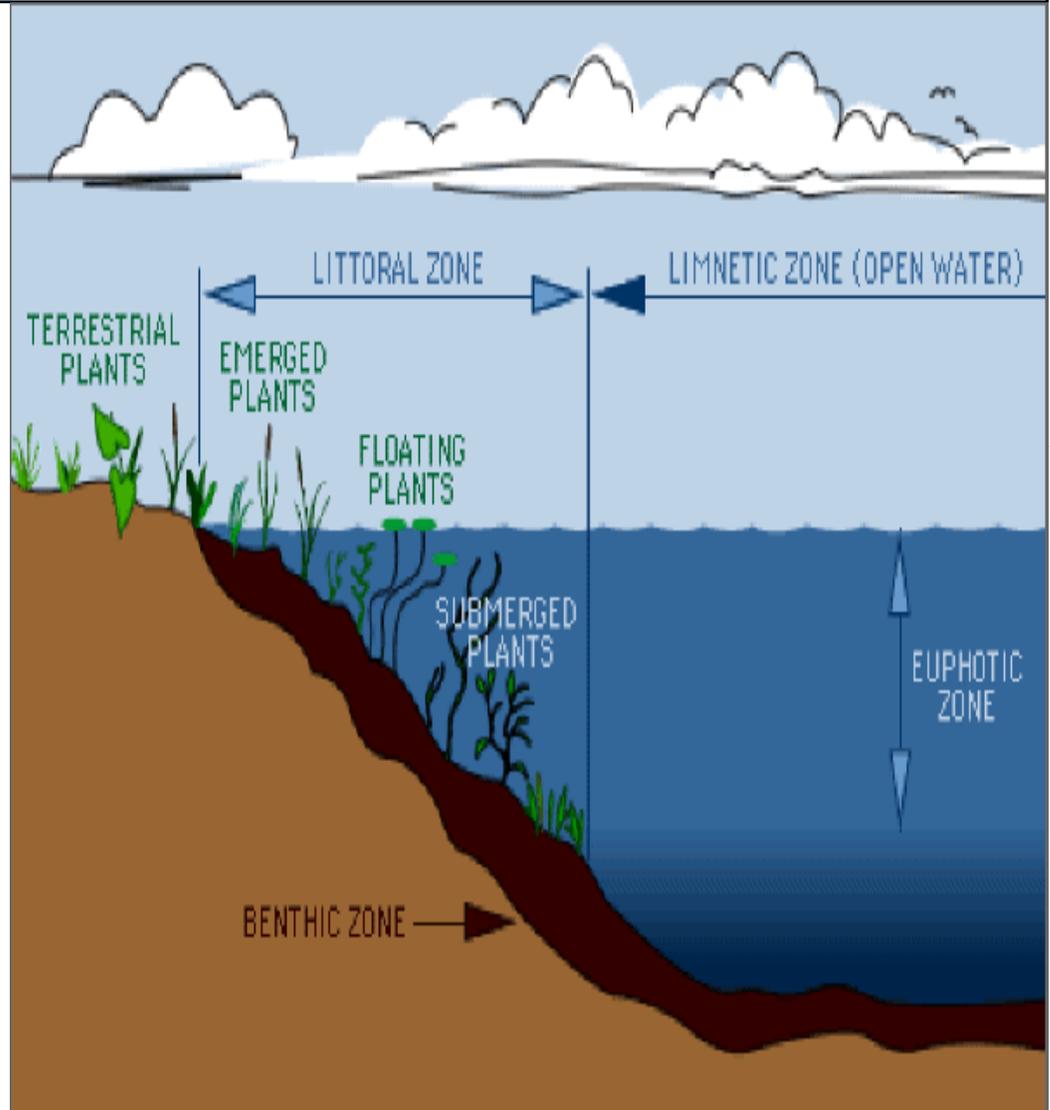
**Littoral Zone**— the area that aquatic plants grow in a lake.

**Algae**— have no true roots, stems, or leaves and range in size from tiny, one-celled organisms to large, multicelled plant-like organisms.

**Submerged Plants**— have stems and leaves that grow entirely underwater, although some may also have floating leaves.

**Floating-leaf Plants**— are often rooted in the lake bottom, but their leaves and flowers flat on the water surface.

**Emergent Plants**— are rooted in the lake bottom, but their leaves and stems extend out of the water.



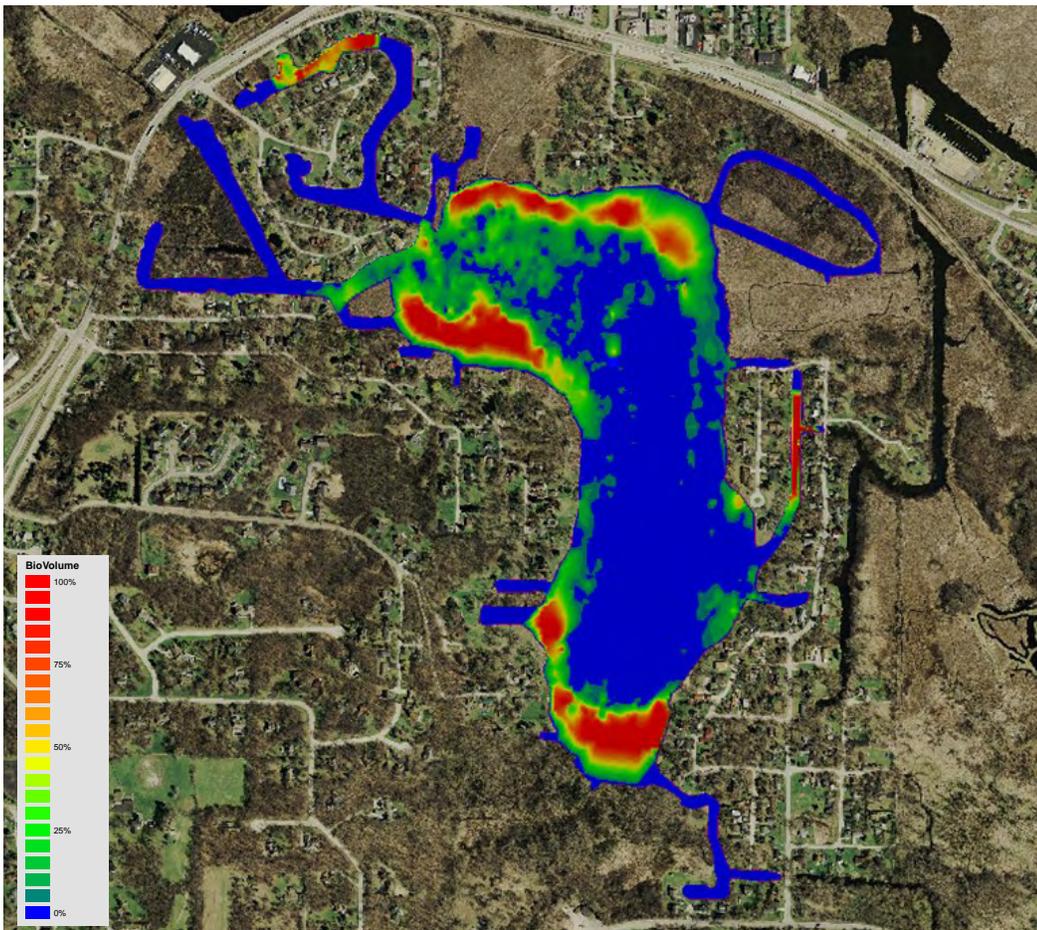
## AQUATIC PLANTS

Aquatic plant mapping survey provides information based on the species, density and distribution of plant communities in a particular lake. An aquatic plant sampling was conducted on Duck Lake on August 2016 when most plants are present. There were 126 points generated based on a computer grid system with points 60 meters apart. Aquatic plants occurred at 92 of the sites (73% total lake coverage) that included 10 aquatic plant species, including 1 exotic invasive species: Curlyleaf Pondweed. The macro algae Chara, was also found during the plant survey. The most commonly occurring aquatic plant species were Watermeal and Coontail at 61.1%, and 41.3% respectively, while White Water Lily (34.1%) Common Bladderwort (29.4), and Small Duckweed (16.7%) were the next abundant species. The extent of plant populations can be influenced by a variety of factors. Water clarity and depth are the major limiting factors in determining the maximum depth at which aquatic plants will grow. When light level in the water column falls below 1% of the surface light level, plants can no longer grow. The extent of the 1% light can be obtained by doubling the Secchi disk reading. The deepest Secchi disk reading for 2016 was 7.80 feet and averaged 3.71 feet during the season. There was enough light penetration though out the lake to allow plants to grow to 7.42 feet. The deepest aquatic plant, Coontail, was found in 7.9 feet of water. Aquatic plants play an important role in the lakes ecosystem by providing habitat for fish and shelter for aquatic organism. Aquatic plants provide oxygen, reduce nutrients such as phosphorus to prevent algae bloom, and stabilize sediment. (See Appendix B)



LCHD Staff identifying plants during sampling.

### AQUATIC PLANT MAP FOR JULY 2016



Rake Density (coverage)	# of Sites	% of Sites
No Plants	34	27
>0-10%	34	27
10-40%	23	18
40-60%	21	17
60-90%	6	5
>90%	8	6
<b>Total Sites with Plants</b>	<b>92</b>	<b>73</b>
<b>Total # of Sites</b>	<b>126</b>	<b>100</b>

### AQUATIC PLANTS

Aquatic plants provide many water quality benefits and play an important role in the lakes ecosystem by providing habitat for fish and shelter for aquatic organism. Plants provide oxygen, reduce nutrients such as phosphorus to prevent algae bloom, and help stabilize sediment. A native plant community tends to be diverse and usually does not impede lake activities such as boating, swimming and fishing.



Chara is an advance form of algae which resemble higher plants. Its easily identified by its musky odor and gritty surface due to mineral deposits on its surface. It filters nutrients out of the water and stabilizes the lake bottom.



Spatterdock



Sago Pondweed



Curlyleaf Pondweed

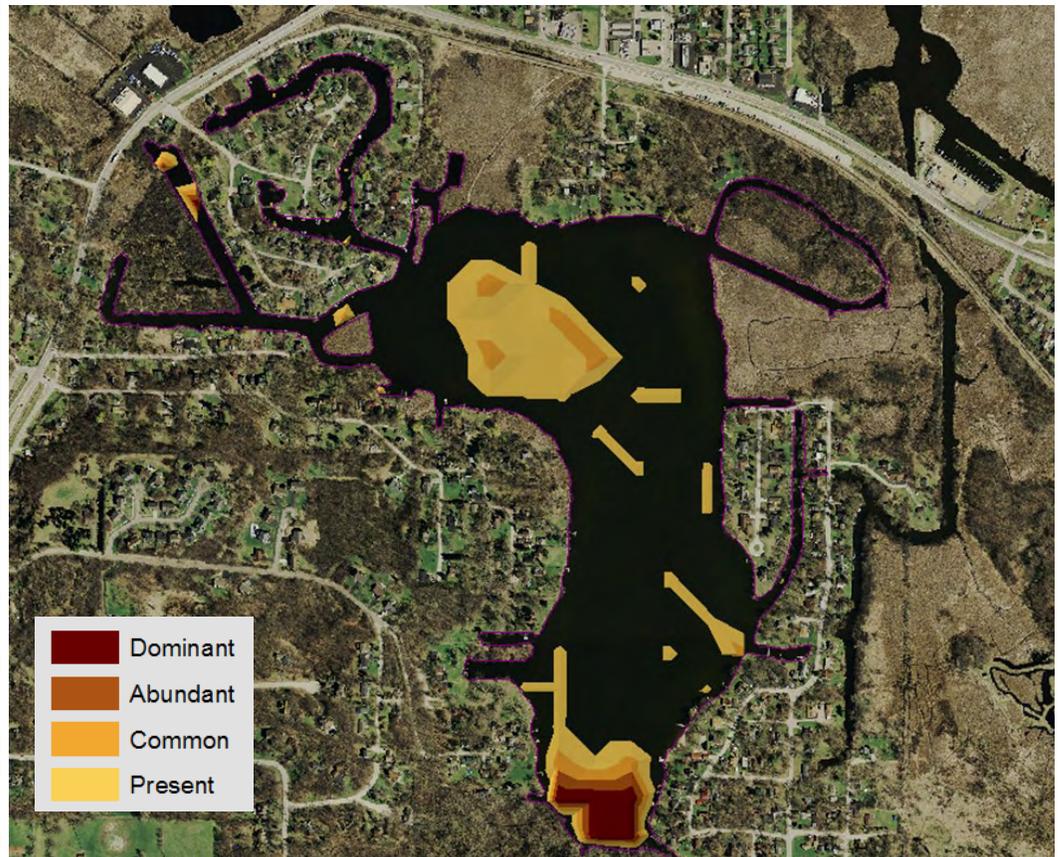
### COMMON AQUATIC PLANTS FOUND IN DUCK LAKE 2016

#### COONTAIL (*Ceratophyllum demersum*)



This perennial plant is a submerged aquatic about 1-3' long. There is more branching of the stems above than below, creating fan-like aggregations of leaves. The stems are up to 1.0 mm. across, light green to nearly white, terete to slightly compressed (flattened), and hairless; they are slender and flexible. The leaves are highly flexible and readily bend. The preference is full sun, shallow water up to 4' deep, and a mucky bottom.

#### JULY 2016 COONTAIL DENSITY AT DUCK LAKE



AQUATIC PLANTS

AMERICAN PONDWEED (*Potamogeton nodosus*)



Paul Skawinski, 2009

American pondweed is a perennial plant that has both floating and a few submerged leaves in an alternate pattern. The floating leaves are elliptical to oval 4 to 7 inches long and to inches wide on long petioles. Submerged leaves are not abundant and are blade-like, somewhat transparent and smaller than floating leaves. Rhizomes are white. Fruits are on spikes that often stand above the water's surface and are brownish to reddish 3 to 2, 1 inches long and 1/8 to 1/4 inches wide.



C) Paul Skawinski, 2009

Elodea

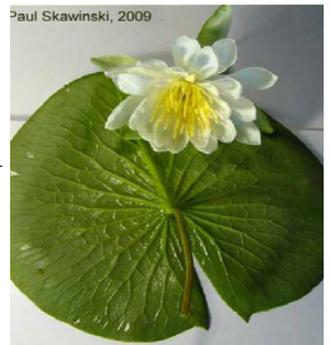


Sago Pondweed

COMMON BLADDERWORT (*Utricularia macrorhiza*)



Common bladderwort is a aquatic carnivorous plant with highly divided, underwater leaf-like stems and numerous small "bladders". The "bladders", from which the common named is derived, are used to capture small aquatic organisms. The flowers, which grow above water, are yellow, two-lipped with a forward facing spur on the lower lip. Leaves finely divided, branching 3-9 times, alternate or sometimes opposite, with tiny hairs on leaflet margins. Bladders are abundant on the leaflets.



Paul Skawinski, 2009

White Water Lily

WATERMEAL (*Wolffia* spp.)



Watermeal is small in size and is a free-floating granular plant. It is the world's smallest flowering plant and resembles small grains of green cornmeal. Watermeal can be mistaken for algae or duckweed. One way to differentiate it from duckweed is that Watermeal lacks roots.

When present, it is usually abundant and often covers the entire surface of the water. Usually it grows in quiet waters with no wave action. Watermeal is also often found mixed in with other duckweed species. Watermeal's tendency to cover entire surfaces of water also reduces the oxygen levels of the water body resulting in oxygen depletion that can kill fish and other organisms.



Small Duckweed

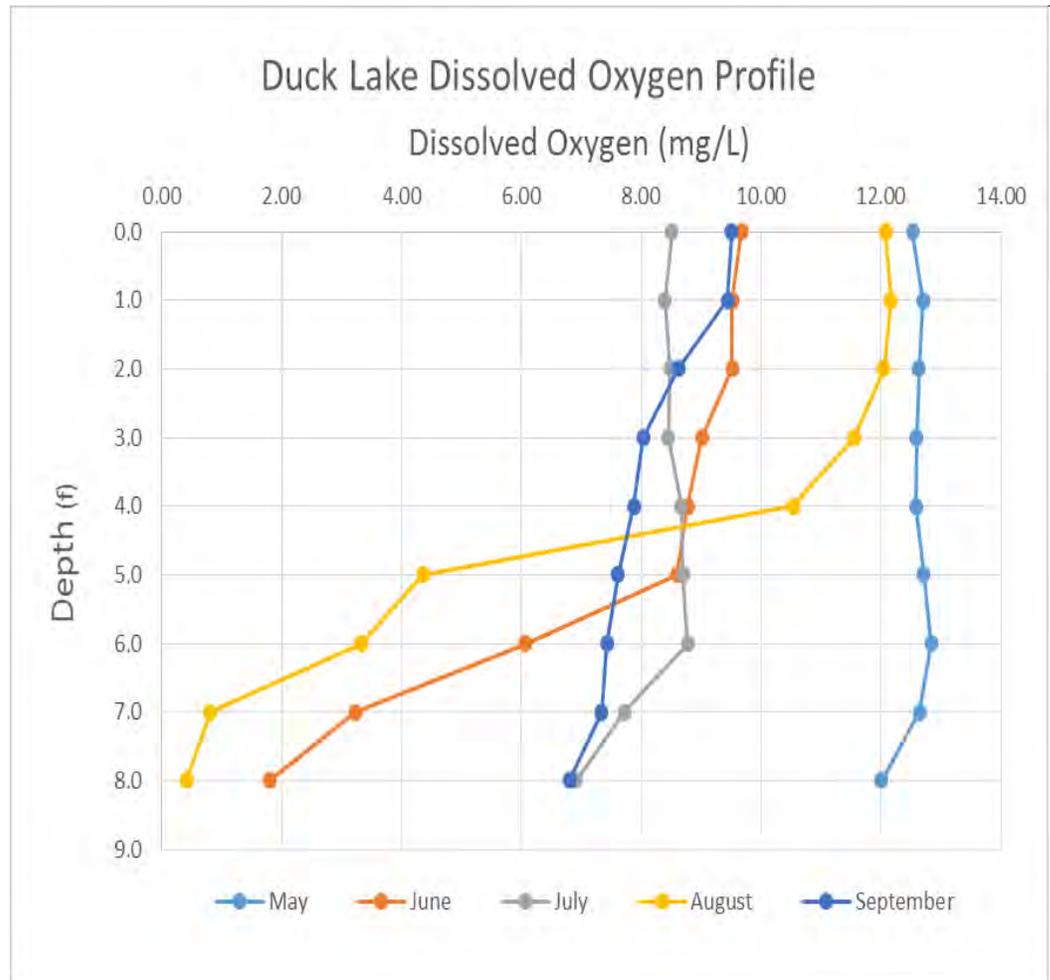
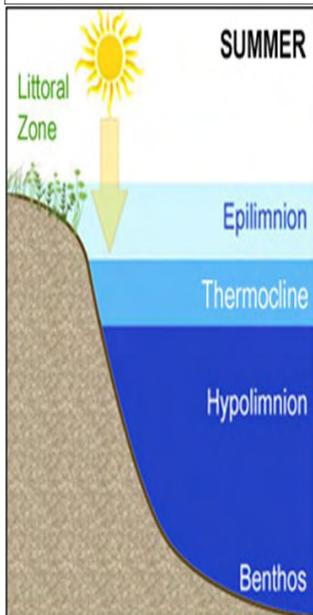
## DISSOLVED OXYGEN

Dissolved oxygen (DO) is a major indicator of water quality and is important for aquatic organisms, algae, macrophytes, and for many chemical reactions to occur that are crucial for lake functions. Dissolved oxygen concentrations can have large variations occurring and are affected by diffusion, aeration, photosynthesis, respiration, and decomposition. Temperature, salinity and pressure changes will also cause DO to fluctuate. Dissolved oxygen will vary both seasonally and by depth throughout the water column in lakes. If dissolved oxygen concentrations drops below levels necessary for sustaining aquatic life (below 5.0 mg/L at 1 foot depth below the lake surface) it becomes a water quality impairment. Low dissolved oxygen primarily is a result of excessive nutrients that stimulate growth of organic matter, such as algae, or the increase of pollutants such as sewage, lawn clippings, and soils that are considered to be “oxygen-demanding”. Low dissolved oxygen levels is also often a factor for fish kills. When many of the plants or algae die at the end of the growing season, their decomposition can significantly reduce DO concentrations. In deeper, thermally stratified lakes, oxygen production is greatest in the upper water layer (epilimnion) where sunlight drives photosynthesis and oxygen consumption is greatest near the bottom of the lake (hypolimnion) where organic matter accumulates and decomposes.

Duck Lakes dissolved oxygen concentrations remained good all year and did not drop below 5.0 mg/L at 1 foot below the lakes surface, which would qualify it as a DO impairment. The lake averaged 10.10 mg/L at 3 feet below the surface from May to September. Anoxic conditions existed in August in the hypolimnion (7-8 ft).

RANGE OF TOLERANCE FOR DISSOLVED OXYGEN IN FISH PARTS PER MILLION (PPM) DISSOLVED OXYGEN	
1	
2	<3.0 PPM too low for fish populations
3	
4	3.0-5.0 PPM 12-24 Hour range of tolerance /stressful conditions
5	
6	>6.0 PPM Supports Spawning
7	
8	>7.0 PPM Supports Growth and Activity
9	
10	>9.0 PPM Supports abundant fish populations

OXYGEN IS VITAL TO THE HEALTH OF AQUATIC HABITATS. PLANTS AND ANIMALS NEED OXYGEN TO SURVIVE. A LOW LEVEL OF OXYGEN IN THE WATER IS A SIGN THAT THE HABITAT IS STRESSED OR POLLUTED.



## AQUATIC PLANTS AND FISH

Fish depend on aquatic plants to provide habitat and forage for food. Most freshwater fish rely on aquatic plants at some point during their life stage. The plant composition and density can play an important role in the nesting, growth, and foraging success of these fish. While many fish require some aquatic vegetation for growth, excessive amounts of aquatic vegetation can negatively impact growth by reducing foraging success. The parameters of an ideal fish habitat can change based on the size and species of fish, the type of lake, structures present in the lake and many other factors. A fish survey can reveal the size distribution and population of the fish in your lake.

### How do plants impact fish?

- ◆ *Plants provide critical structure to aquatic habitats.*
- ◆ *Plants influence growth of fish by enhancing fish diversity, feeding, growth, and reproduction.*
- ◆ *Plants influence spawning. The structure provided by plant beds are important to fish reproduction.*
- ◆ *Plants influence the physical environment. Aquatic plants can change water temperatures and available oxygen in habitats.*

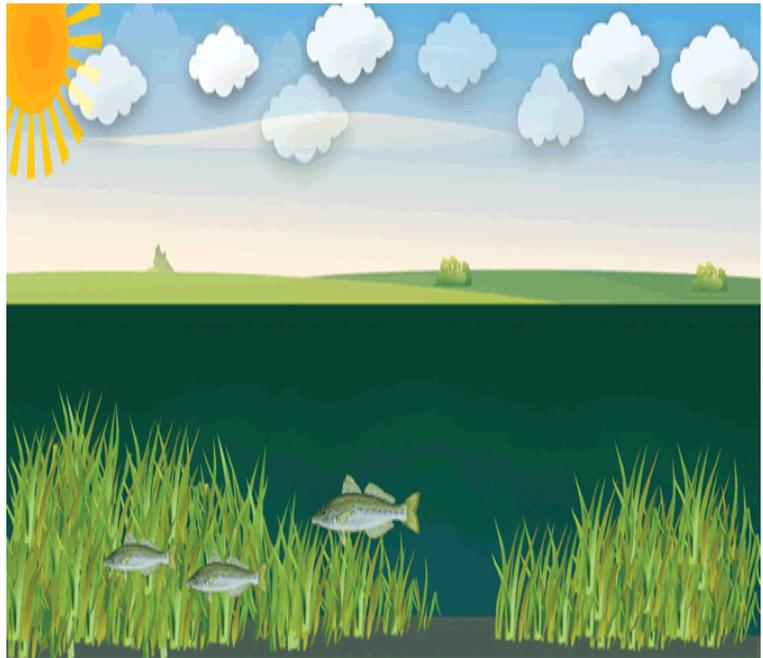


Image <http://agriculture.vic.gov.au/>

Table 1. Common fish and their plant affinity during various life stages and their relationship with plants

Fish	Plant Affinity	Life Stage				Relationship	
		Larvae	Juvenile	Adult	Spawn	Forage	Predator avoidance
<b>Bluegill sunfish</b>	High	X	X	X	X	X	X
<b>Common carp</b>	High	X	X	X	X	X	X
<b>Largemouth bass</b>	High	X	X	X	X	X	X
<b>Musky</b>	High	X	X	X	X	X	X
<b>Northern Pike</b>	High	X	X	X	X	X	X
<b>Black crappie</b>	Moderate		X	X	X	X	X
<b>Smallmouth bass</b>	Moderate		X	X		X	X
<b>Yellow perch</b>	Moderate	X	X			X	X
<b>White crappie</b>	Low		X			X	
<b>Salmon, trout</b>	Low		X				X
<b>Shad</b>	Low	X					
<b>Walleye</b>	Low			X		X	

Table adapted from Gettys, Lynn, William T. Haller and Marc Bellaud. "Biology and Control of Aquatic Plants: A Best Management Practices Handbook". 2009

## PESTICIDE PERMIT REQUIREMENTS FOR PESTICIDE APPLICATION



**Copper Sulfate Application**

Chemical applications for algae is a temporary solution that often requires multiple applications. As the treated algae sink to the bottom to decompose (use oxygen) they release nutrients that the surviving algae uses to rebound.

A pretreatment survey of your lakes aquatic plants is necessary prior to sending out a bid for your lakes survey prior to any vegetation order to assess the success of controls and locate potential treatment areas.

A National Pesticide Discharge Elimination System (NPDES) permit is required when pesticides are applied to, over or near the waters of the State. This permit applies to all public waters that have an outflow to the State waters. A Notice of Intent (NOI) must be filled and submitted electronically to the Illinois Environmental Protection Agency (IEPA) at least 14 days prior to any application of pesticides. In addition to the NPDES, the application of herbicides into waters of the State of Illinois requires a permit by the Illinois Department of Natural Resources (IDNR) per Administrative Code, Part 895. In order to obtain the permit an application needs to be filed with the IDNR requesting a permit for pesticide application, the application can be filled out by the applicant or their representative (which is usually the pesticide consultant).



## AQUATIC HERBICIDES - SONAR (FLURIDONE)

Sonar is a broad spectrum herbicide used to reduce the populations of a variety of submerged, emergent, and floating plants, and shoreline plants. This contact herbicide is absorbed through the leaves and shoots and from the soil through the roots.

Fluridone is a photosynthetic inhibitor, the application blocks the light reactions of photosynthesis where plants convert the energy from sunlight into food. Depending on conditions symptoms of the treatment can be observed 7-10 days after treatment. Leaves will appear pale green, yellow, or yellow-white in color. Plants have been shown to develop resistance to repeated fluridone use, so it is recommended to rotate herbicides with different modes of action when using fluridone as a control. Sonar was applied in Duck Lake on May 20th, 2016 to reduce Eurasian Water Milfoil and Curlyleaf Pondweed (exotic and invasive). There are no restrictions on swimming, eating fish, human or pet/livestock drinking water from treated water bodies.

## REQUEST FOR SERVICE (RFS)

A key to a healthy lake is a well-balanced aquatic plant population. Aquatic plants compete with algae for nutrients and stabilize bottom substrate, which in turn improves water clarity. Putting together a good aquatic plant management plan should not be rushed. The plan should be based on the management goals of the lake and involve usage issues, habitat maintenance/restoration, and limitations of the lake. Schedule treatments as early as possible to prevent treatment of native aquatic plants. Follow up is critical for an aquatic plant management plan to achieve long-term success. A good aquatic plant management plan considers both the short and long-term needs of the lake.

Putting together a good aquatic plant management plan should include a Request for Proposal (RFP). The RFP for aquatic plants ensures lake managers are able simultaneously distribute bids to qualified vendors with type of services, the frequency of needs, budget allocation and the length of the contract terms to get competitive prices.

In order to establish a plant management goal, a pre-treatment survey is necessary to identify the location, density and diversity of the aquatic plants in your lake. Set your goals within your budget and targeting areas that meets recommendations for maintaining the viability of the lake.

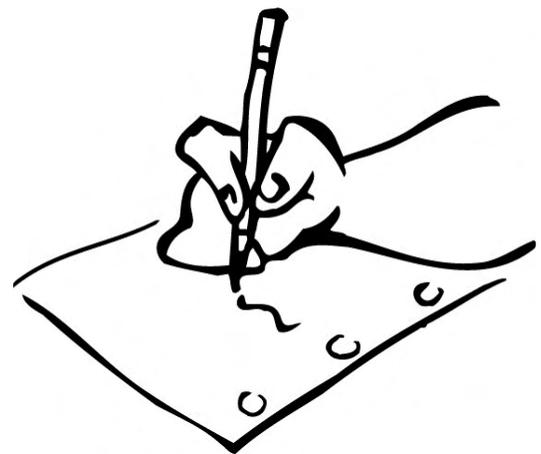
## LAKE MANAGEMENT PLANS

It is recommended that a long term Lake Management Plans be developed to effectively manage lake issues. All stakeholders should participate in the development of the plan and include homeowners, recreational users, lake management associations, park districts, townships or any other entity involved in managing Duck Lake. Lake Management plans should educate the public about specific lake issues, provide a concise assessment of the problem, outline methods and techniques that will be employed to control the problems and clearly define the goals of the program. Mechanisms for monitoring and evaluation should be developed as well and information gathered during these efforts should be used to implement management efforts ( Biology and Control of Aquatic Plants, Gettys et al., 2009)

### What are the steps in creating a Lake Management Plan?

1. **Getting Started:** Identify lake stakeholders and communication pathways
2. **Setting Goals:** Getting the effort organized, identifying problems to be addressed, and agreeing on the goals
3. **Problem Assessment & Analysis:** collecting baseline information to define the past and existing conditions. Synthesize the information, quantifying and comparing the current conditions to desired conditions, researching opportunities and constraints and setting direction to achieve goals.
4. **Alternatives:** List all possible management alternatives and evaluate their strengths, weakness, and general feasibility.
5. **Recommendations:** Prioritize management options, setting objectives and drafting the plan
6. **Project Management:** Management of assets, detailed records of expenses and time
7. **Implementation:** adopting the plan, lining up funding, and scheduling activities for taking action to achieve goals.
8. **Monitor & Modify:** Develop a mechanism for tracking activities and adjusting the plan as it evolves.

**Follow these steps when getting started with writing Lake Management Plans. While each step is necessary, the level of effort and detail for each step will vary depending on the project's goals, size of the lake, and number of stakeholders.**





## ECOLOGICAL SERVICES

Senior Biologist: Mike Adam

madam@lakecountyil.gov

Population Health Services  
500 W. Winchester Road

Phone: 847-377-8030  
Fax: 847-984-5622

**For more information visit us at:**

**[http://www.lakecountyil.gov/  
Health/want/  
BeachLakeInfo.htm](http://www.lakecountyil.gov/Health/want/BeachLakeInfo.htm)**

Protecting the quality of our lakes is an increasing concern of Lake County residents. Each lake is a valuable resource that must be properly managed if it is to be enjoyed by future generations. To assist with this endeavor, Population Health Environmental Services provides technical expertise essential to the management and protection of Lake County surface waters.

Ecological Service's goal is to monitor the quality of the county's surface water in order to:

- Maintain or improve water quality and alleviate nuisance conditions
- Promote healthy and safe lake conditions
- Protect and improve ecological diversity

Services provided are either of a technical or educational nature and are provided by a professional staff of scientists to government agencies (county, township and municipal), lake property owners' associations and private individuals on all bodies of water within Lake County.

## LAKE RECOMMENDATIONS

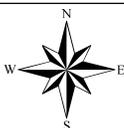
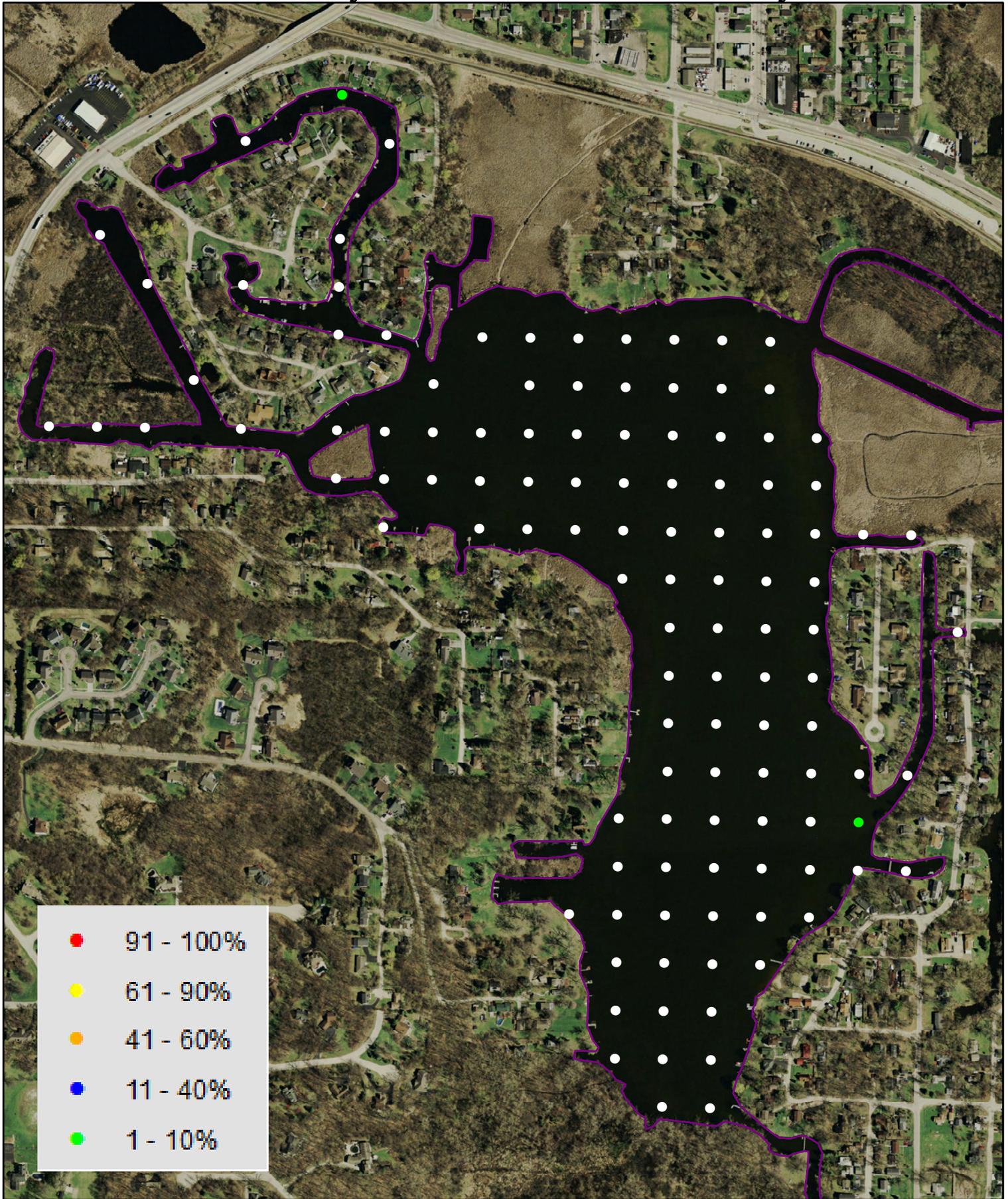
Duck Lake's water quality has seen an increase in Total Phosphorus (TP) concentration since 2006. There was a slight increase in water clarity and a no changes in the chloride levels. There were no Eurasian Watermilfoil observed at the time of the plant sampling. The decrease in aquatic plant density lead to a higher amount of phosphorus which caused a seasonal algae, Watermeal blooms. Duck Lake's management is administered by the Duck Lake Waterway Agency.

**To improve the overall quality of Duck Lake, ES (Ecological Services) has the following recommendations:**

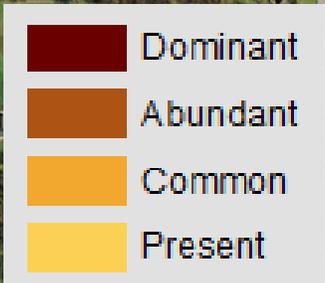
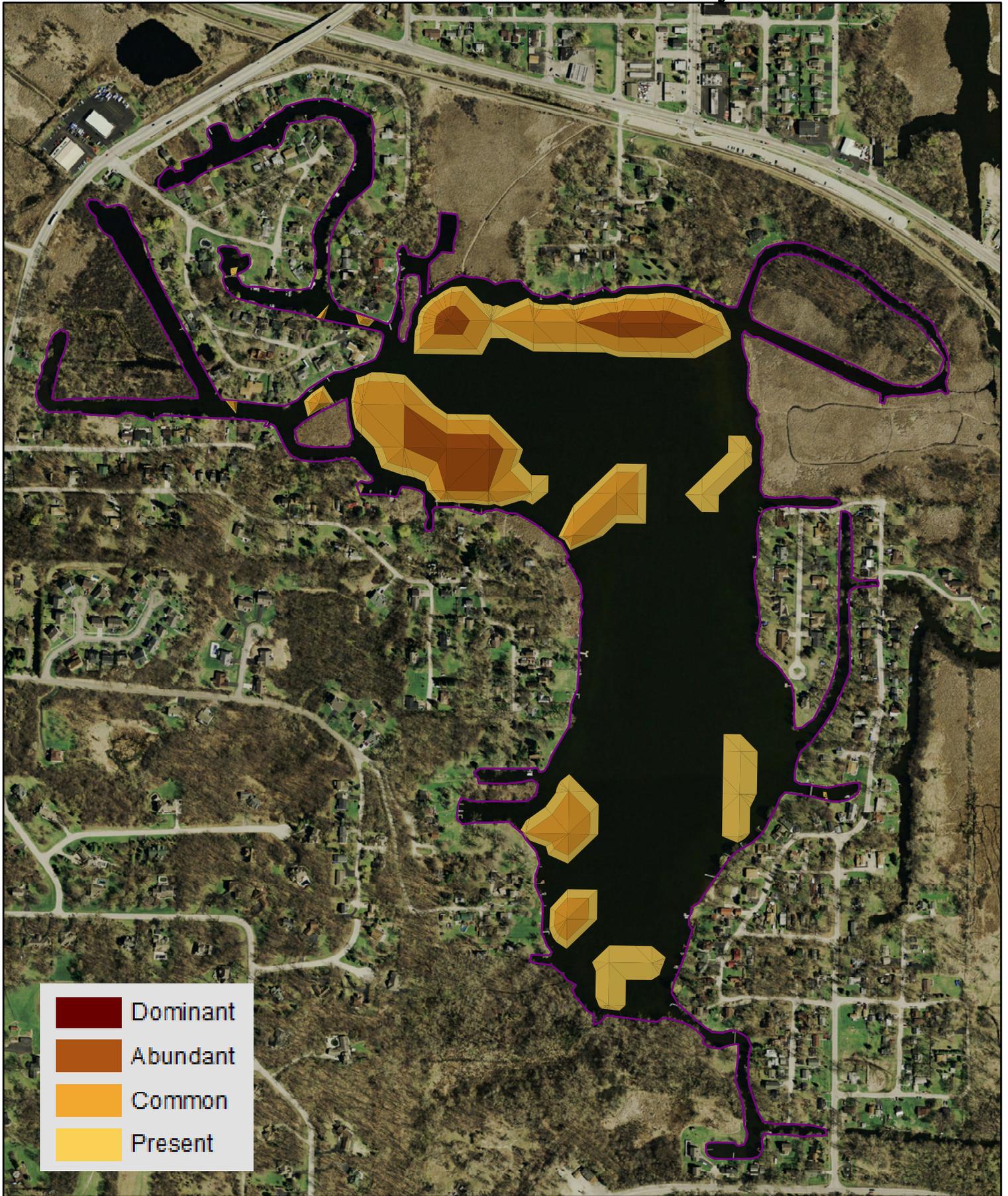
- **Participation in Volunteer Lake Monitoring Program**
- **Install a sign to educate on ways to reduce the spread of Aquatic Invasive Species**
- **Help reduce Cl<sup>-</sup> by supporting wise use of road salt in the watershed**
- **Install a permanent staff gage to monitor lake level fluctuations**
- **Become familiar with the appearance of harmful algal blooms and report any blooms to the LCHD-ES by calling 847-837-8030**
- **Develop an Aquatic Plant Management Plan (APMP) that targets the reduction of invasive species and promotes native plant diversity. Aquatic plant management plans should consider type, timing of pesticide applications, quantity of pesticide used, and protection of native plants**
- **Monitor Eurasian Watermilfoil and Curlyleaf; population. Hand rake or manually remove Eurasian Watermilfoil and Curlyleaf to keep population from expanding**
- **If possible widen plant buffer along the shoreline so its at least 25 feet.**
- **Mitigate shoreline exhibiting erosion**
- **Asses current fish population**

Appendix A:  
Figures

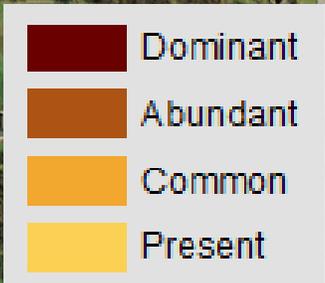
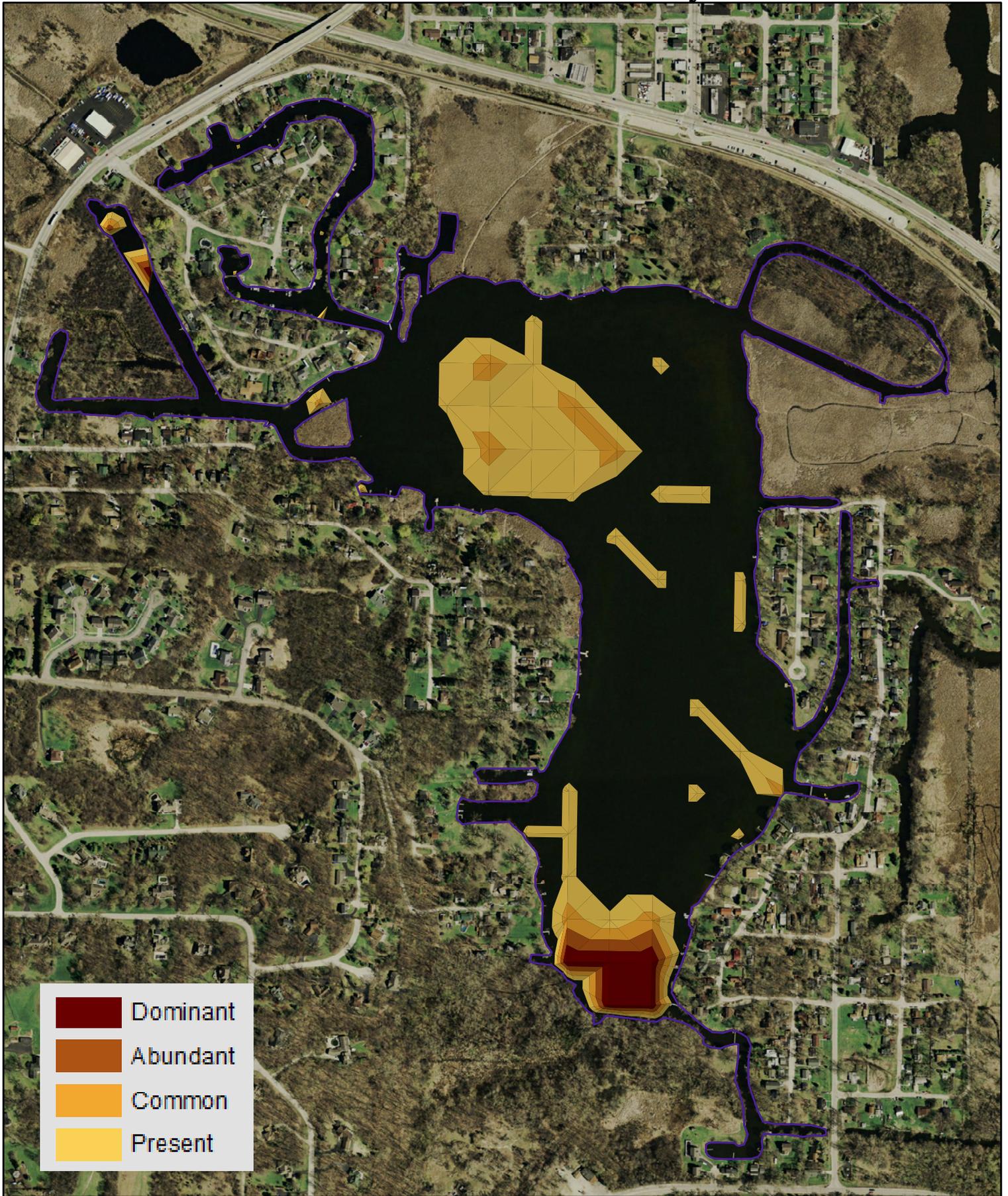
# Duck Lake Curlyleaf Pondweed Rake Density 2016



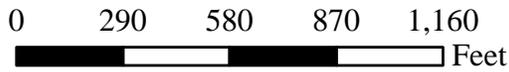
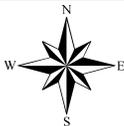
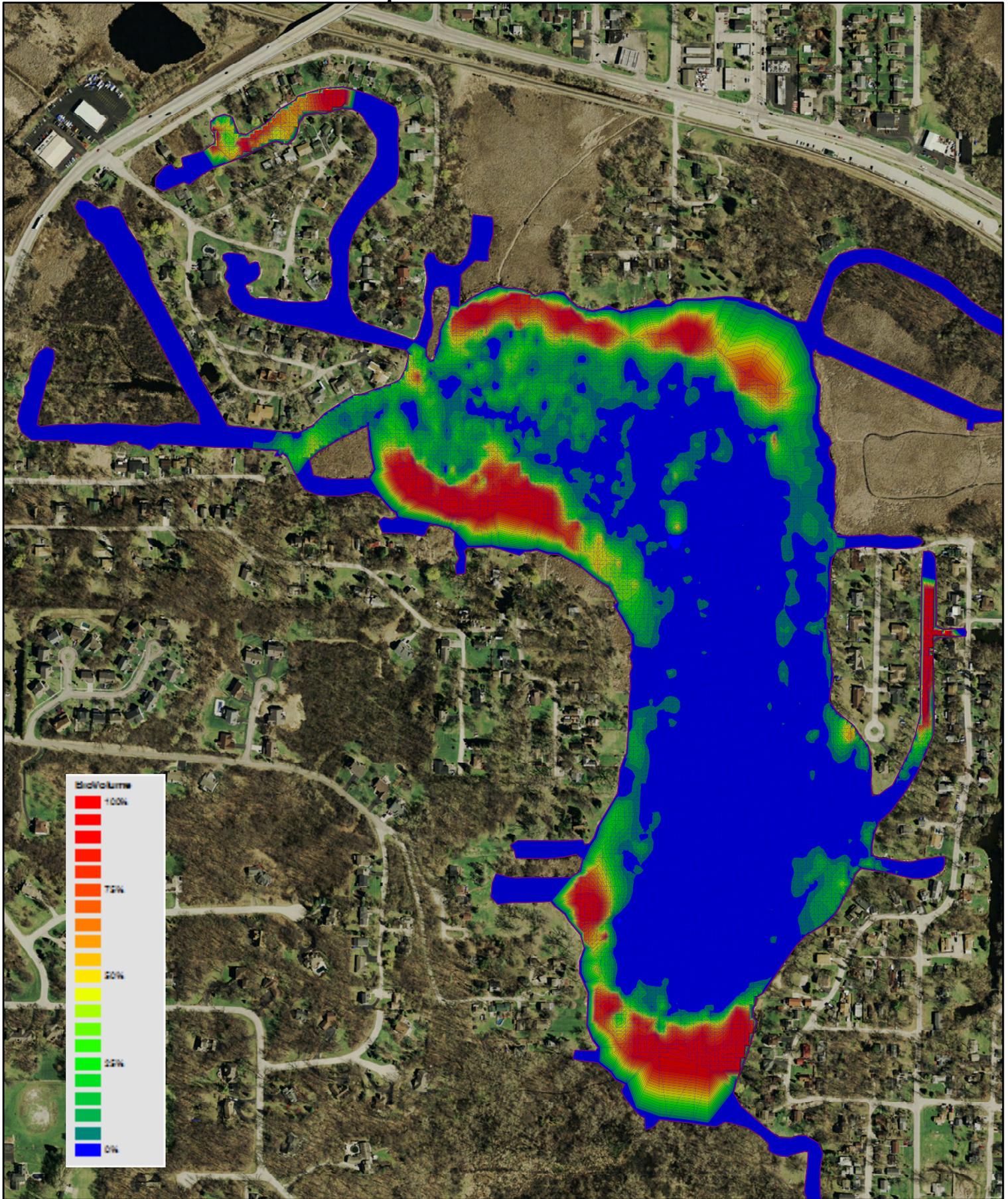
# Duck Lake Bladderwort Rake Density 2016



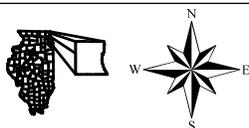
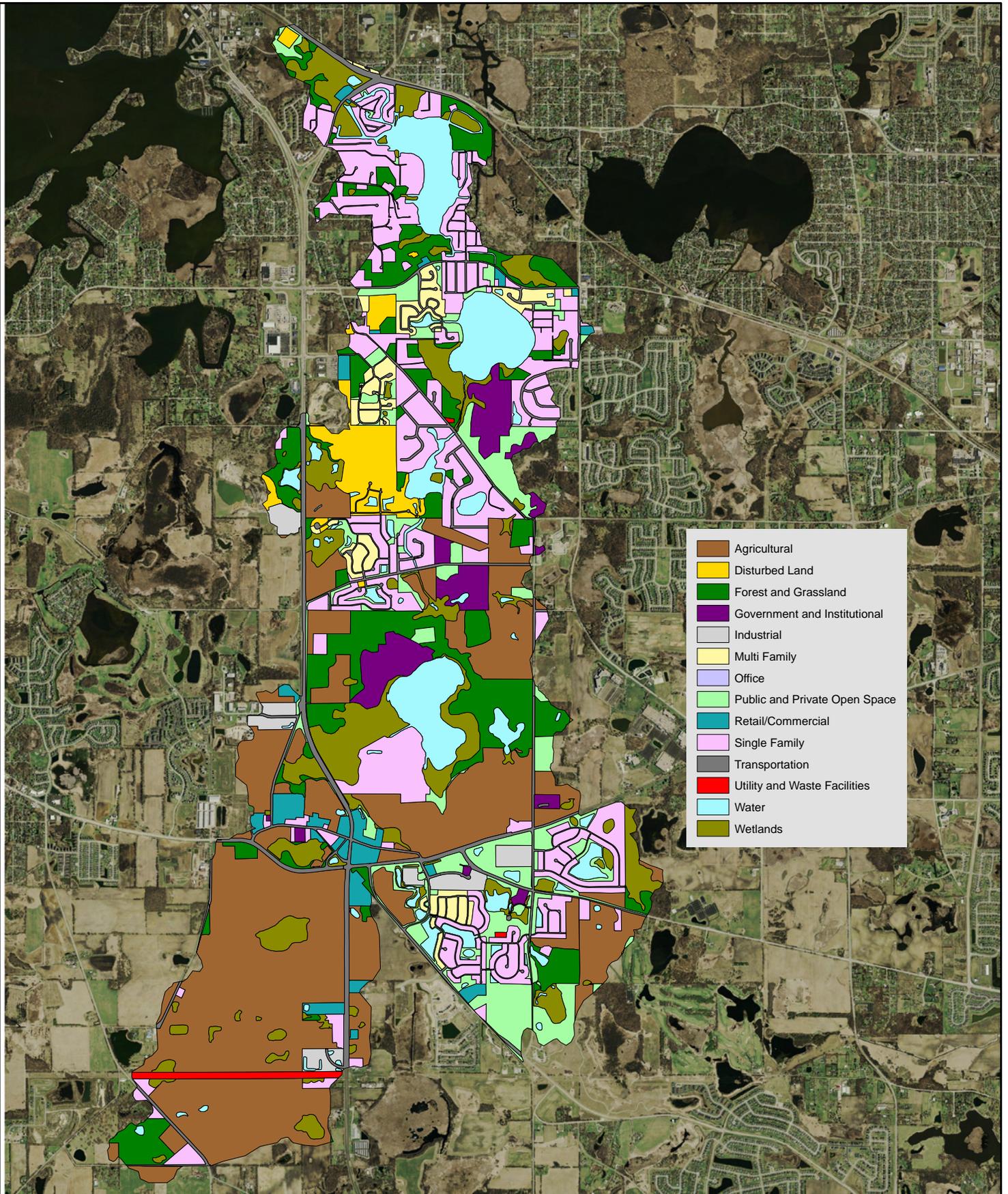
# Duck Lake Coontail Rake Density 2016



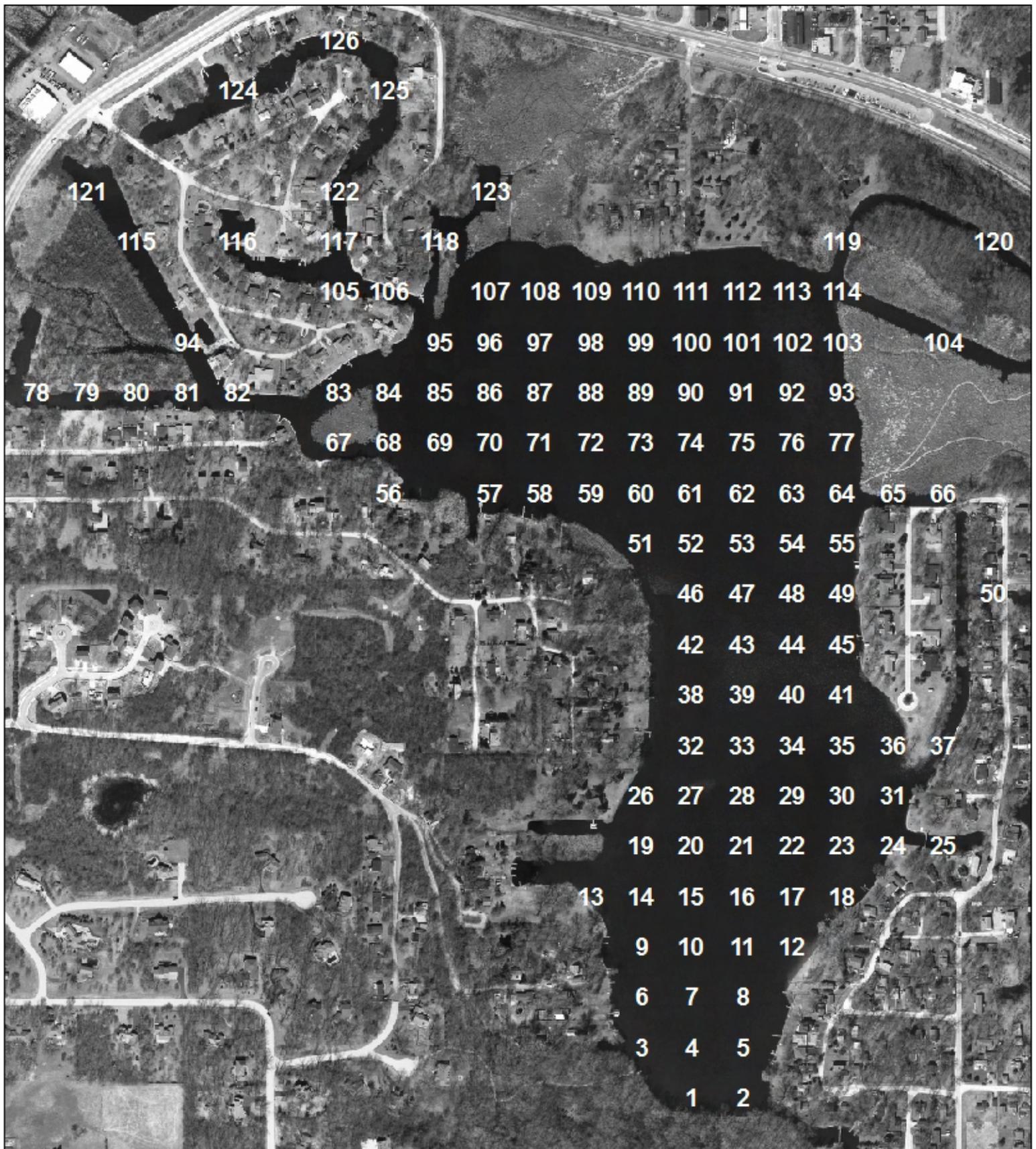
# Duck Lake Aquatic Plant BioVolume 2016



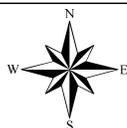
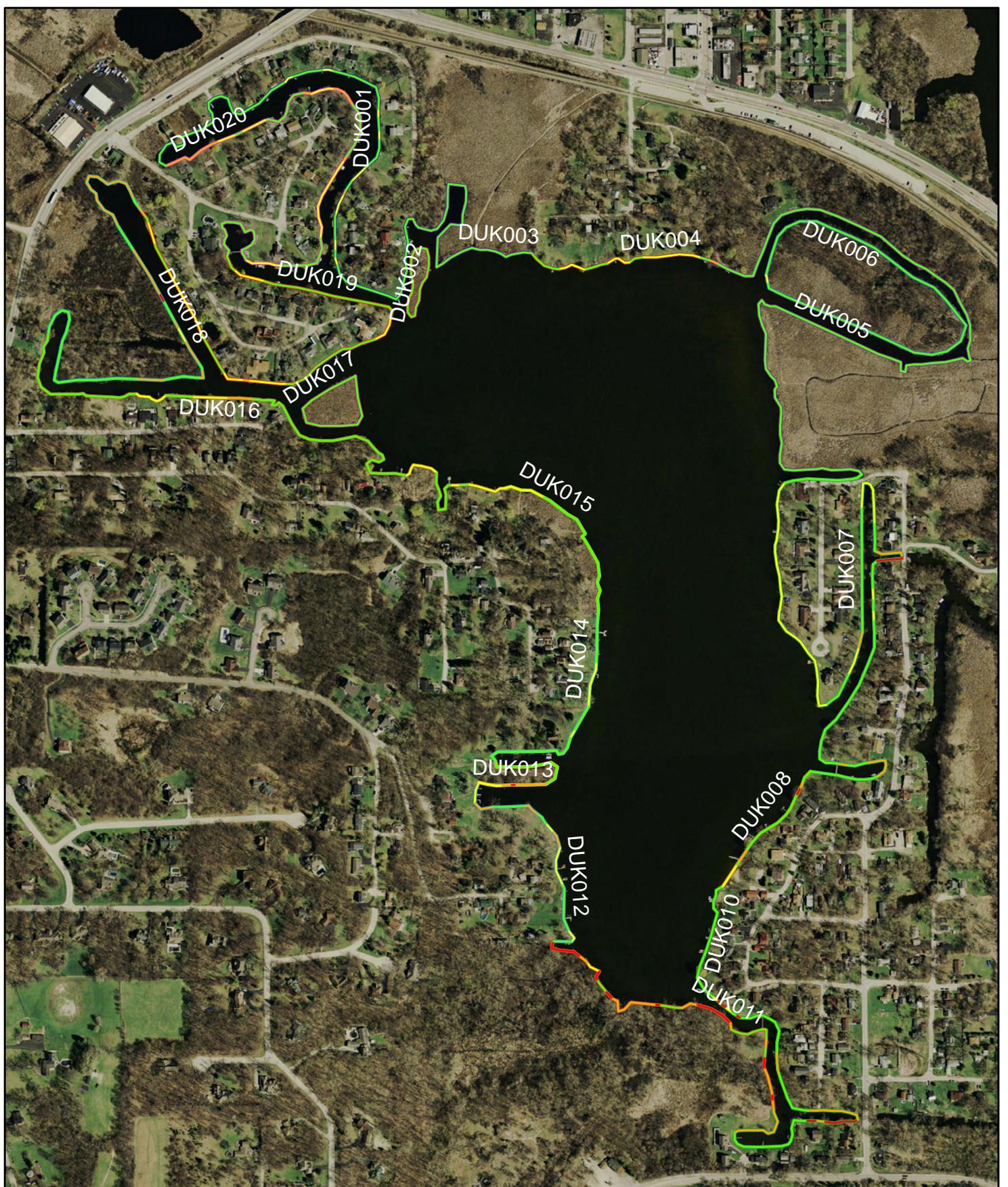
# Duck Lake Land Use 2016



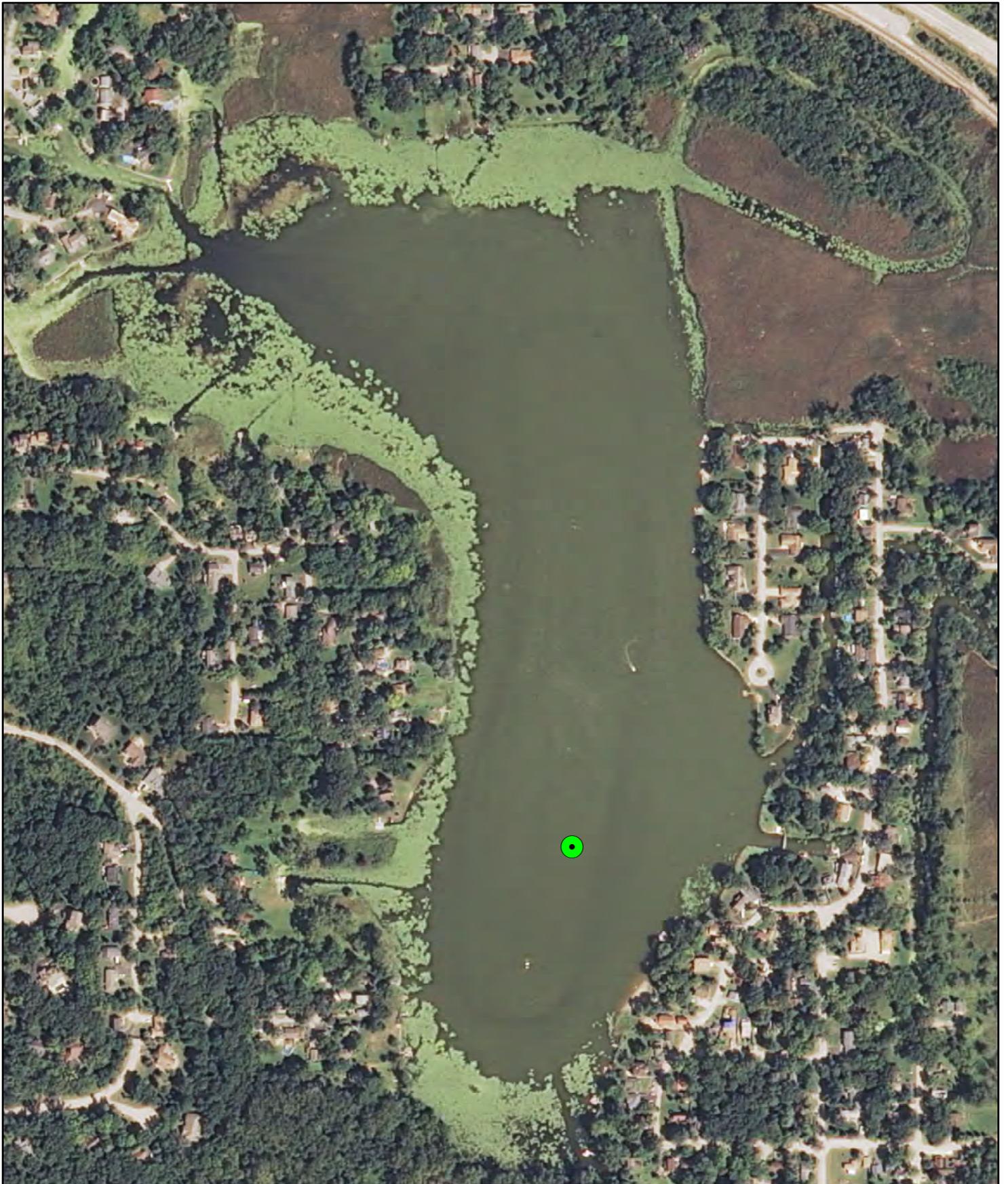
# Duck Lake Plant Grid 2016



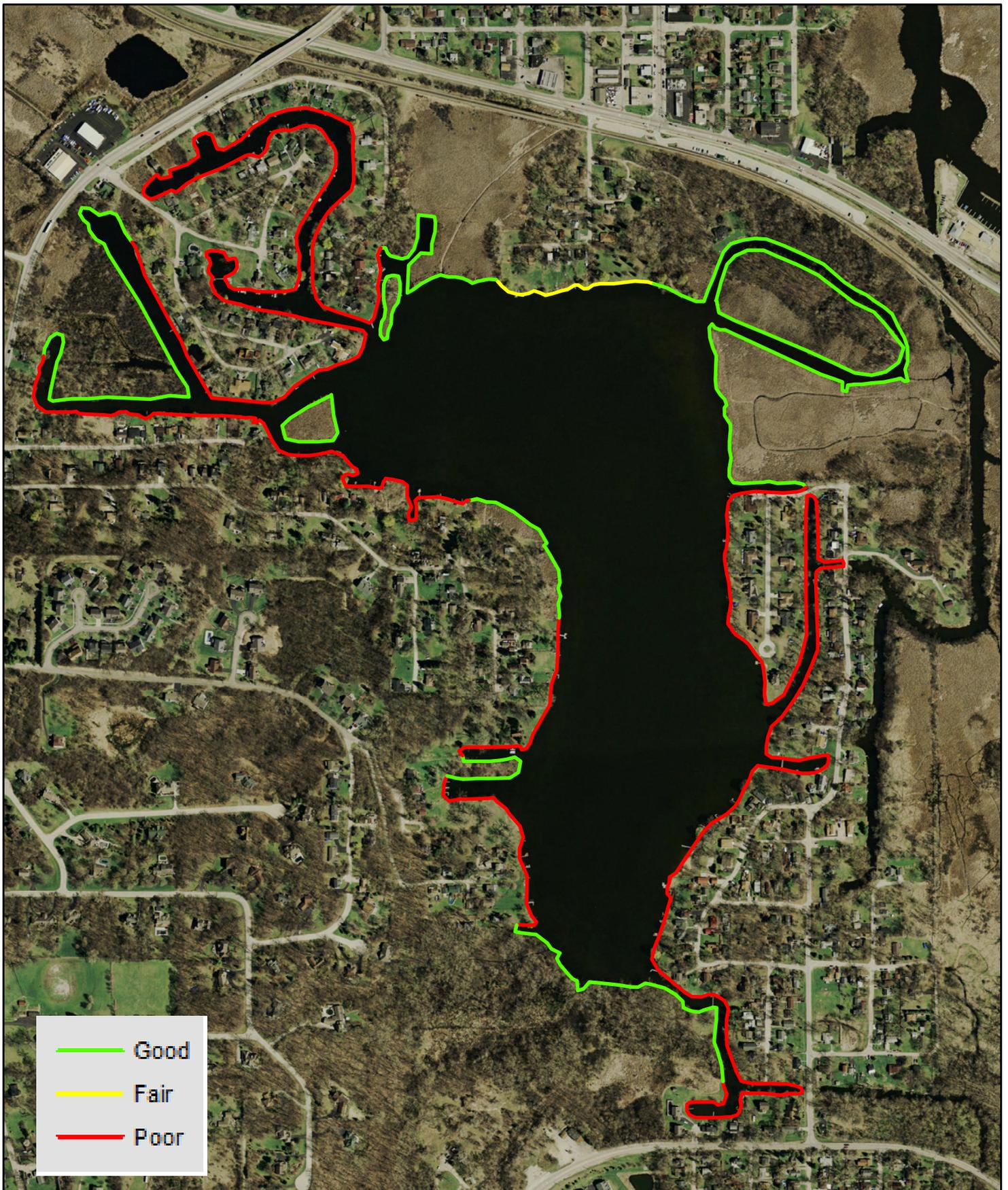
# Duck Lake Shoreline Reaches 2016



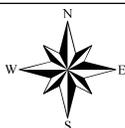
# Duck Lake Sampling Point, 2016



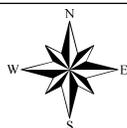
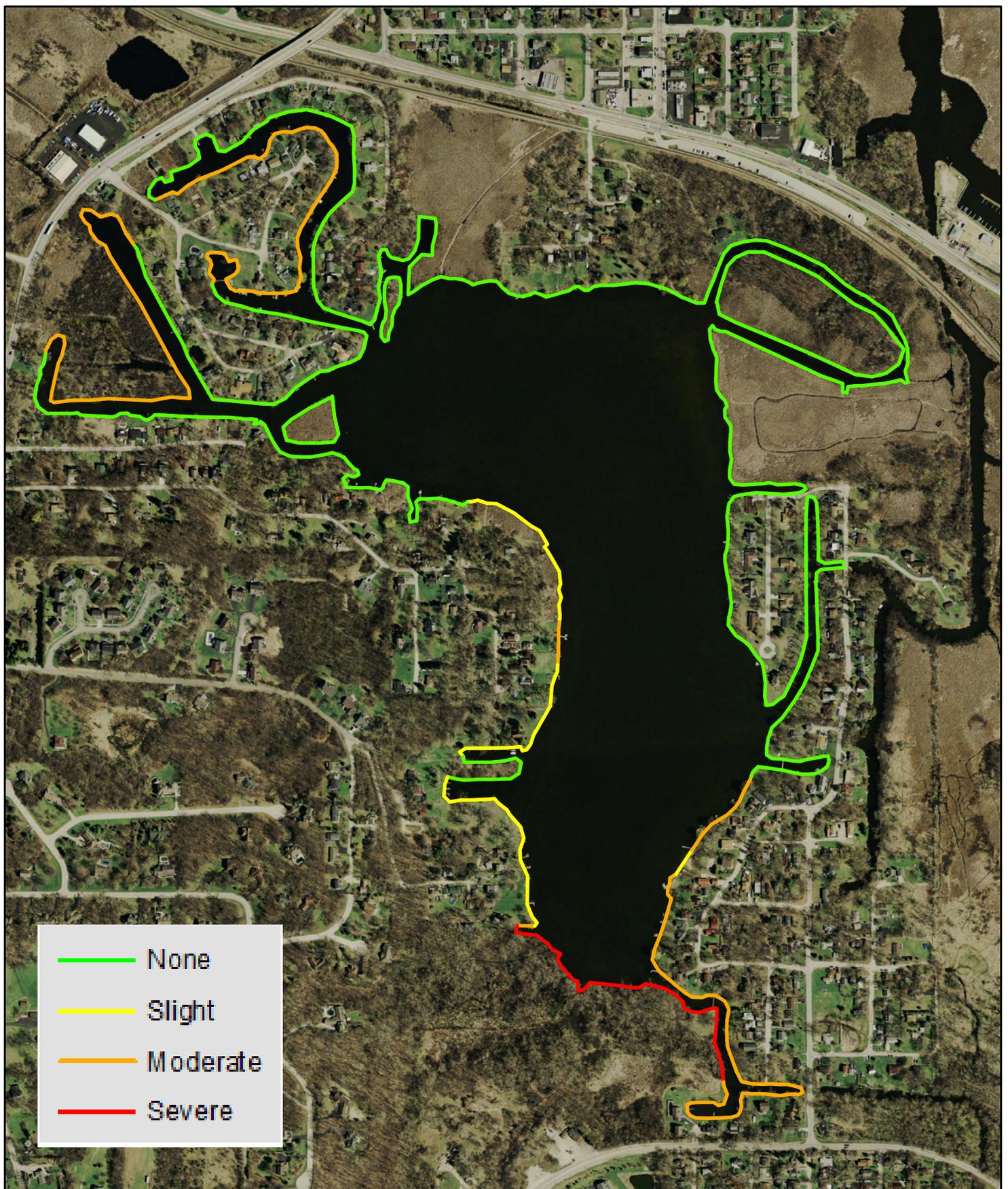
# Duck Lake Shoreline Buffer 2016



— Good  
— Fair  
— Poor



# Duck Lake Shoreline Erosion 2016



Appendix B:  
Tables

## Lake County average Floristic Quality Index (FQI) ranking 2000-2016.

RANK	LAKE NAME	FQI (w/A)	FQI (native)
1	Cedar Lake	37.4	38.9
2	East Loon Lake	34.7	36.1
3	Cranberry Lake	29.7	29.7
4	Deep Lake	29.7	31.2
5	Round Lake Marsh North	29.1	29.9
6	West Loon Lake	27.1	29.5
7	Sullivan Lake	26.9	28.5
8	Bangs Lake	26.2	27.8
9	Little Silver Lake	25.2	26.7
10	Third Lake	25.1	22.5
11	Fourth Lake	24.7	27.1
12	Independence Grove	24.4	26.8
13	Sun Lake	24.3	26.1
14	Redwing Slough	24.0	25.8
15	Schreiber Lake	23.9	24.8
16	Lakewood Marsh	23.8	24.7
17	Sterling Lake	23.6	25.4
18	Deer Lake	23.5	24.4
19	Round Lake	23.5	25.9
20	Pistakee Lake	23.5	25.2
21	Lake Marie	23.5	25.2
22	Lake of the Hollow	23.0	24.8
23	Nippersink Lake (Fox Chain)	22.4	23.2
24	Countryside Glen Lake	21.9	22.8
25	Grass Lake	21.5	22.2
26	Davis Lake	21.4	21.4
27	Timber Lake (North)	20.9	23.4
28	Lake Catherine	20.8	21.8
29	Cross Lake	20.7	18.7
30	ADID 203	20.5	20.5
31	Broberg Marsh	20.5	21.4
32	McGreal Lake	20.2	22.1
33	Fox Lake	20.2	21.2
34	Honey Lake	20.0	20.0
35	Lake Barrington	19.9	21.8
36	Lake Kathryn	19.6	20.7
37	Druce Lake	19.1	21.8
38	Turner Lake	18.6	21.2
39	Salem Lake	18.5	20.2
40	Duck Lake	18.3	19.2
41	Wooster Lake	18.0	20.1
42	Lake Helen	18.0	18.0
43	Old Oak Lake	18.0	19.1
44	Lake Minear	18.0	20.1
45	Potomac Lake	17.8	17.8
46	Lake Zurich	17.7	18.9
47	Redhead Lake	17.7	18.7
48	Long Lake	17.7	15.8
49	Hendrick Lake	17.7	17.7
50	Rollins Savannah 2	17.7	17.7
51	Grandwood Park Lake	17.2	19.0
52	Seven Acre Lake	17.0	15.5
53	Lake Miltmore	16.8	18.7
54	Petite Lake	16.8	18.7
55	Channel Lake	16.8	18.7
56	McDonald Lake 1	16.7	17.7
57	Highland Lake	16.7	18.9
58	Almond Marsh	16.3	17.3

## Lake County average Floristic Quality Index (FQI) ranking 2000-2016.

RANK	LAKE NAME	FQI (w/A)	FQI (native)
59	Owens Lake	16.3	17.3
60	Windward Lake	16.3	17.6
61	Butler Lake	16.1	18.1
62	Grays Lake	16.1	16.1
63	White Lake	16.0	17.0
64	Dunns Lake	15.9	17.0
65	Dog Bone Lake	15.7	15.7
66	Osprey Lake	15.5	17.3
67	Heron Pond	15.1	15.1
68	Ames Pit	15.1	17.6
69	North Churchill Lake	15.0	15.0
70	Hastings Lake	15.0	17.0
71	Forest Lake	14.8	15.9
72	Dog Training Pond	14.7	15.9
73	Summerhill Estates Lake	14.5	15.5
74	Grand Ave Marsh	14.3	16.3
75	Nippersink Lake	14.3	16.3
76	Taylor Lake	14.3	16.3
77	Manning's Slough	14.1	16.3
78	Tower Lake	14.0	14.0
79	Dugdale Lake	14.0	15.1
80	Eagle Lake (S1)	14.0	15.1
81	Crooked Lake	14.0	16.0
82	Spring Lake	14.0	15.2
83	Lake Matthews	13.9	15.5
84	Longview Meadow Lake	13.9	13.9
85	Fischer Lake	13.6	14.7
86	Bishop Lake	13.4	15.0
87	Mary Lee Lake	13.1	15.1
88	Old School Lake	13.1	15.1
89	Lake Tranquility (S1)	12.6	12.6
90	Buffalo Creek Reservoir 1	12.5	11.4
91	Buffalo Creek Reservoir 2	12.5	11.4
92	McDonald Lake 2	12.5	12.5
93	Rollins Savannah 1	12.5	12.5
94	Stone Quarry Lake	12.5	12.5
95	Kemper Lake 1	12.2	13.4
96	Pond-A-Rudy	12.1	12.1
97	Stockholm Lake	12.1	13.5
98	Lake Leo	12.1	14.3
99	Lambs Farm Lake	12.1	14.3
100	Bresen Lake	12.0	13.9
101	Grassy Lake	12.0	12.0
102	Flint Lake Outlet	11.8	13.0
103	Albert Lake	11.5	10.3
104	Rivershire Pond 2	11.5	13.3
105	Hook Lake	11.3	13.4
106	Briarcrest Pond	11.2	12.5
107	Lake Naomi	11.2	12.5
108	Pulaski Pond	11.2	12.5
109	Lake Napa Suwe	11.0	11.0
110	Redwing Marsh	11.0	11.0
111	West Meadow Lake	11.0	11.0
112	Nielsen Pond	10.7	12.0
113	Lake Holloway	10.6	10.6
114	Sylvan Lake	10.6	10.6
115	Echo Lake	10.4	10.4
116	Gages Lake	10.2	12.5

## Lake County average Floristic Quality Index (FQI) ranking 2000-2016.

<b>RANK</b>	<b>LAKE NAME</b>	<b>FQI (w/A)</b>	<b>FQI (native)</b>
117	College Trail Lake	10.0	10.0
118	Valley Lake	9.9	9.9
119	Werhane Lake	9.8	12.0
120	Fish Lake	9.6	10.6
121	Lake Carina	9.5	12.5
122	Columbus Park Lake	9.2	9.2
123	Lake Lakeland Estates	9.2	9.2
124	Waterford Lake	9.2	9.2
125	Bluff Lake	9.1	11.0
126	Lake Fairfield	9.0	10.4
127	Des Plaines Lake	8.6	9.9
128	Antioch Lake	8.5	8.5
129	Loch Lomond	8.5	8.5
130	Lake Fairview	8.5	6.9
131	Timber Lake (South)	8.5	6.9
132	East Meadow Lake	8.5	8.5
133	South Churchill Lake	8.5	8.5
134	Kemper Lake 2	8.5	9.8
135	Lake Christa	8.5	9.8
136	Lake Farmington	8.5	9.8
137	Lucy Lake	8.5	9.8
138	Lake Louise	8.4	8.4
139	Bittersweet Golf Course #13	8.1	8.1
140	Lake Linden	8.0	8.0
141	Sand Lake	8.0	10.4
142	Countryside Lake	7.7	11.5
143	Fairfield Marsh	7.5	8.7
144	Lake Eleanor	7.5	8.7
145	Banana Pond	7.5	9.2
146	Slocum Lake	7.1	5.8
147	Lucky Lake	7.0	7.0
148	North Tower Lake	7.0	7.0
149	Lake Forest Pond	6.9	8.5
150	Ozaukee Lake	6.7	8.7
151	Leisure Lake	6.4	9.0
152	Peterson Pond	6.0	8.5
153	Little Bear Lake	5.8	7.5
154	Deer Lake Meadow Lake	5.2	6.4
155	ADID 127	5.0	5.0
156	Island Lake	5.0	5.0
157	Liberty Lake	5.0	5.0
158	Oak Hills Lake	5.0	5.0
159	Slough Lake	5.0	5.0
160	International Mining and Chemical Lake	5.0	7.1
161	Lochanora Lake	5.0	5.0
162	Diamond Lake	3.7	5.5
163	Lake Charles	3.7	5.5
164	Big Bear Lake	3.5	5.0
165	Sand Pond (IDNR)	3.5	5.0
166	Harvey Lake	3.3	5.0
167	Half Day Pit	2.9	5.0
168	Hidden Lake	0.0	0.0
169	St. Mary's Lake	0.0	0.0
170	Willow Lake	0.0	0.0
171	Woodland Lake	0.0	0.0
	<i>Mean</i>	<b>13.9</b>	<b>14.9</b>
	<i>Median</i>	<b>13.4</b>	<b>14.7</b>

**Lake County average Floristic Quality Index (FQI) ranking 2000-2016.**

Table 1: Duck Lake Shoreline Erosion Condition 2016

Reach	None		Slight		Moderate		Severe		Total	Lateral Recession Rate
	Linear ft.	% Reach								
DUK001	2551.1	86%	386.4	13%	30.9	1%	0.0	0%	2968.4	0.01
DUK002	699.7	100%	0.0	0%	0.0	0%	0.0	0%	699.7	0.01
DUK003	1513.2	100%	0.0	0%	0.0	0%	0.0	0%	1513.2	0.01
DUK004	217.2	29%	524.7	71%	0.0	0%	0.0	0%	741.9	0.02
DUK005	4315.3	99%	42.0	1%	0.0	0%	0.0	0%	4357.3	0.01
DUK006	2240.0	100%	0.0	0%	0.0	0%	0.0	0%	2240.0	0.02
DUK007	2297.1	51%	1655.0	37%	427.4	9%	128.0	3%	4507.5	0.05
DUK008	337.4	72%	0.0	0%	96.2	21%	33.8	7%	467.4	0.03
DUK009	23.1	17%	114.8	83%	0.0	0%	0.0	0%	137.9	0.06
DUK010	1574.3	61%	55.3	2%	673.0	26%	270.6	11%	2573.2	0.16
DUK011	424.7	26%	59.8	4%	596.4	37%	540.7	33%	1621.6	0.04
DUK012	428.7	41%	368.9	35%	248.6	24%	0.0	0%	1046.2	0.05
DUK013	412.8	58%	103.0	14%	180.5	25%	21.2	3%	717.5	0.03
DUK014	576.2	71%	237.5	29%	0.0	0%	0.0	0%	813.7	0.01
DUK015	648.9	77%	197.3	23%	0.0	0%	0.0	0%	846.2	0.01
DUK016	2286.8	75%	667.7	22%	114.8	4%	0.0	0%	3069.3	0.02
DUK017	832.4	100%	0.0	0%	0.0	0%	0.0	0%	832.4	0.02
DUK018	1627.0	57%	67.1	2%	1140.9	40%	44.3	2%	2879.3	0.04
DUK019	1553.2	61%	944.7	37%	49.9	2%	0.0	0%	2547.8	0.02
DUK020	1346.1	51%	834.6	32%	449.4	17%	0.0	0%	2630.1	0.04
Total	25905.2	70%	6258.8	17%	4008.0	11%	1038.6	3%	37210.6	0.03

Table 2: Duck Lake Shoreline Buffer Condition 2016

Reach Code	Good Condition (ft/%)		Fair Condition (ft/%)		Poor Condition (ft/%)		Shoreline Length Assessed (ft)
	ft	%	ft	%	ft	%	
DUK001	290.4	10%	90.0	3%	2617.5	87%	2997.9
DUK002	699.7	100%	0.0	0%	0.0	0%	699.7
DUK003	1371.5	100%	0.0	0%	0.0	0%	1371.5
DUK004	48.0	6%	421.1	52%	334.9	42%	804.0
DUK005	4049.0	100%	0.0	0%	0.0	0%	4049.0
DUK006	2299.6	100%	0.0	0%	0.0	0%	2299.6
DUK007	0.0	0%	821.1	17%	3981.6	83%	4802.7
DUK008	11.7	2%	208.6	40%	305.9	58%	526.2
DUK009	0.0	0%	0.0	0%	137.9	100%	137.9
DUK010	0.0	0%	1185.3	46%	1414.5	54%	2599.7
DUK011	1364.1	84%	0.0	0%	257.5	16%	1621.6
DUK012	0.0	0%	604.6	53%	525.6	47%	1130.2
DUK013	717.6	100%	0.0	0%	0.0	0%	717.6
DUK014	0.0	0%	0.0	0%	1035.3	100%	1035.3
DUK015	846.2	100%	0.0	0%	0.0	0%	846.2
DUK016	1340.3	44%	459.4	15%	1251.4	41%	3051.1
DUK017	807.0	100%	0.0	0%	0.0	0%	807.0
DUK018	2563.4	100%	0.0	0%	0.0	0%	2563.4
DUK019	137.8	5%	84.9	3%	2335.0	91%	2557.7
DUK020	65.8	3%	2554.4	97%	0.0	0%	2620.2
Total	16612.0	45%	6429.4	17%	14197.0	38%	37238.5

**Duck Lake IEPA Ranking**

**TROPHIC STATUS**

Carlson's TSIp                      63.3      Eutrophic

**IMPAIRMENT ASSESSMENTS**

Total Phosphorus                      Yes  
 Total Nitrogen                          None  
 pH    None  
 Low DO                                        None  
 Total Dissolved Solids                  None  
 Total Suspended Solids                  None  
 Aquatic Plants-Native                    Yes  
 Non-Native Aquatic Plants              Yes  
 Non-Native Animals                      Yes

**AQUATIC LIFE USE IMPAIRMENT INDEX**

Mean Trophic State  
 Macrophyte Impairment  
 Sediment Impairment (NVSS)  
 Degree of Use Support

<b>Weighting Criteria</b>	<b>Points</b>	<b>Overall Use Support Points</b>	<b>Degree of Support</b>
63.3	50		
Substantial	15		
Minimal	0		
	<b>65</b>	0	<b>Full</b>

**RECREATION USE IMPAIRMENT INDEX**

Mean Trophic State Index  
 Macrophyte Impairment  
 Sediment Impairment (NVSS)  
 Degree of Use Support

63.3	63.3		
Substantial	15		
Slight	5		
	<b>83.3</b>	1	<b>Partial</b>

**Overall Use Index**

**0.50                      Partial**

Duck Lake 2016 RTRM

Thermal Resistance to Mixing

RVG: Relative Viscosity Gradient

May

Depth ( ft)	Temp	DO	%Sat	RTRM	RVG
0.0	14.85	12.53	123.71	0.0	0
1.0	14.64	12.70	124.84	3.6	17
2.0	14.31	12.63	123.35	5.4	26
3.0	14.21	12.60	122.79	1.8	9
4.0	13.99	12.59	121.89	5.2	26
5.0	13.79	12.71	122.50	3.3	17
6.0	13.74	12.84	123.76	0.0	0
7.0	13.4	12.64	121.02	4.9	26
8.0	13.39	12.01	114.73	1.6	9

June

Depth ( ft)	Temp	DO	%Sat	RTRM	RVG
0.0	23.36	9.67	113.36	0.0	0
1.0	23.29	9.52	111.40	3.0	4
2.0	23.14	9.52	111.19	3.0	4
3.0	22.55	9.01	104.04	17.3	24
4.0	22.37	8.78	100.99	5.7	8
5.0	22.17	8.60	98.55	5.7	8
6.0	21.36	6.07	68.48	22.0	32
7.0	21.06	3.24	36.34	8.2	12
8.0	20.59	1.80	19.99	13.0	20

July

Depth ( ft)	Temp	DO	%Sat	RTRM	RVG
0.0	25.38	8.51	103.55	0.0	0
1.0	25.44	8.39	102.28	-3.2	-4
2.0	25.41	8.48	103.38	0.0	0
3.0	25.32	8.45	102.82	3.2	4
4.0	25.31	8.67	105.50	0.0	0
5.0	25.23	8.70	105.67	3.2	4
6.0	25.19	8.78	106.45	3.2	4
7.0	25.04	7.72	93.43	3.2	4
8.0	24.89	6.91	83.31	6.2	8

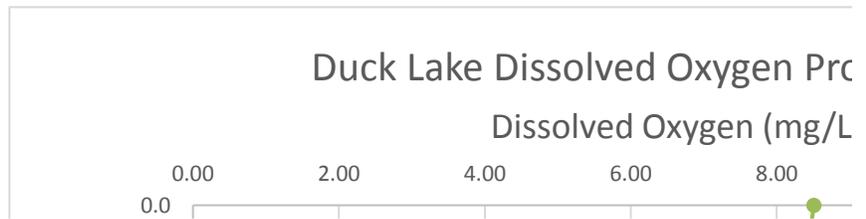
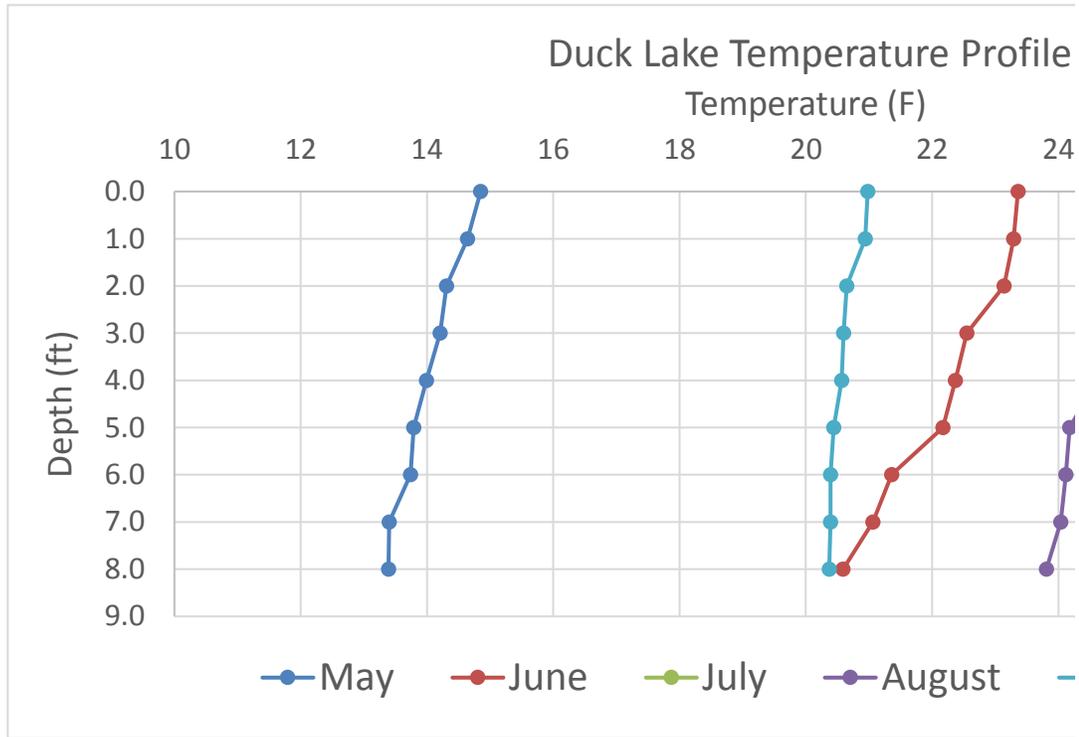
Duck Lake 2016 RTRM

August

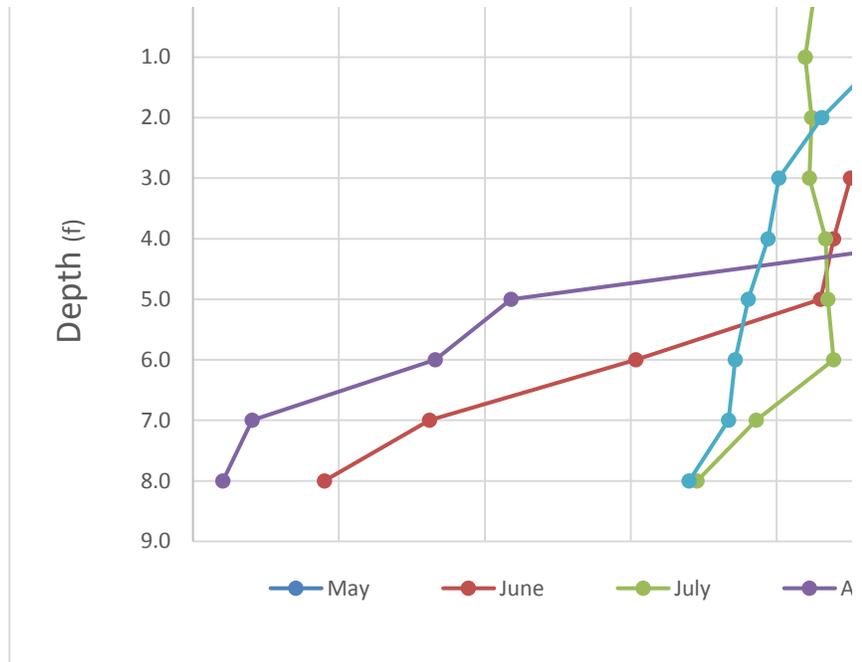
Depth ( ft)	Temp	DO	%Sat	RTRM	RVG
0.0	25.18	12.08	146.46	0.0	0
1.0	25.03	12.17	147.28	3.2	4
2.0	24.99	12.05	145.56	3.1	4
3.0	24.73	11.55	139.00	6.2	8
4.0	24.61	10.53	126.49	3.1	4
5.0	24.18	4.36	51.89	15.5	20
6.0	24.12	3.32	39.51	0.0	0
7.0	24.04	0.81	9.62	3.1	4
8.0	23.81	0.41	4.85	6.0	8

September

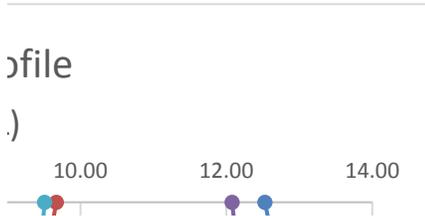
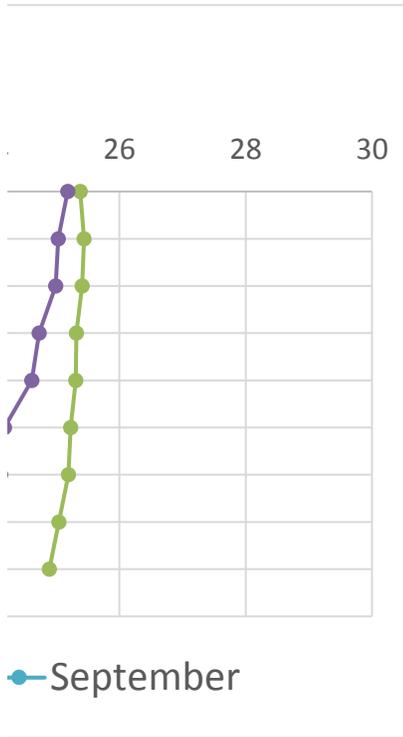
Depth ( ft)	Temp	DO	%Sat	RTRM	RVG
0.0	20.98	9.51	106.46	0.0	0
1.0	20.94	9.44	105.68	0.0	0
2.0	20.65	8.62	95.93	7.8	12
3.0	20.6	8.03	89.19	2.6	4
4.0	20.57	7.88	87.52	0.0	0
5.0	20.44	7.61	84.36	2.6	4
6.0	20.39	7.43	82.20	2.6	4
7.0	20.39	7.34	81.20	0.0	0
8.0	20.37	6.80	75.23	0.0	0



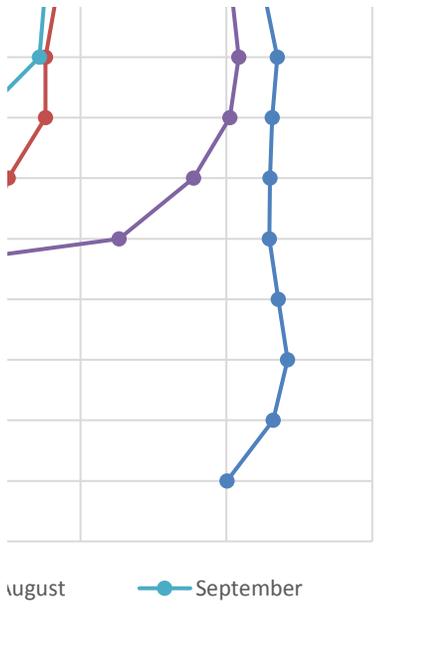
Duck Lake 2016 RTRM



Duck Lake 2016 RTRM



Duck Lake 2016 RTRM



**Duck Lake IEPA Ranking**

**TROPHIC STATUS**

Carlson's TSIp 63.3 Eutrophic

**IMPAIRMENT ASSESSMENTS**

Total Phosphorus Yes  
 Total Nitrogen None  
 pH None  
 Low DO None  
 Total Dissolved Solids None  
 Total Suspended Solids None  
 Aquatic Plants-Native Yes  
 Non-Native Aquatic Plants Yes  
 Non-Native Animals Yes

**AQUATIC LIFE USE IMPAIRMENT INDEX**

Mean Trophic State  
 Macrophyte Impairment  
 Sediment Impairment (NVSS)  
 Degree of Use Support

**RECREATION USE IMPAIRMENT INDEX**

Mean Trophic State Index  
 Macrophyte Impairment  
 Sediment Impairment (NVSS)  
 Degree of Use Support

**Overall Use Index**

<b>Weighting Criteria</b>	<b>Points</b>	<b>Overall Use Support Points</b>	<b>Degree of Support</b>
63.3	50		
Substantial	15		
Minimal	0		
	<b>65</b>	0	<b>Full</b>
63.3	63.3		
Substantial	15		
Slight	5		
	<b>83.3</b>	1	<b>Partial</b>
		<b>0.50</b>	<b>Partial</b>

**Aquatic Plants found at the 126 sampling sites on Duck Lake in August of 2016.  
The maximum depth that plants were found was 7.9 feet.**

Plant Density	American Pondweed	Chara	Common Bladderworth	Coontail	Curlyleaf Pondweed	Elodea
Absent	125	125	89	74	124	123
Present	0	0	14	33	2	1
Common	1	0	17	10	0	2
Abundant	0	1	6	2	0	0
Dominant	0	0	0	7	0	0
% Plant Occurrence	0.8	0.8	29.4	41.3	1.6	2.4

Plant Density	Sago Pondweed	Small Duckweed	Spatterdock	Watermeal	White Water Lily
Absent	125	105	125	49	83
Present	0	13	0	30	18
Common	1	6	0	31	14
Abundant	0	2	1	9	8
Dominant	0	0	0	7	3
% Plant Occurrence	0.8	16.7	0.8	61.1	34.1

**Distribution of rake density across all sampling sites.**

Rake Density (coverage)	# of Sites	% of Sites
No Plants	34	27
>0-10%	34	27
10-40%	23	18
40-60%	21	17
60-90%	6	5
>90%	8	6
Total Sites with Plants	92	73
Total # of Sites	126	100

Duck Lake Water Quality Summary 2016

2016		Epilimnion														
DATE	DEPTH	ALK	TKN	NH <sub>3</sub> -N	NO <sub>2</sub> +NO <sub>3</sub> *	TP	SRP	TDS	Cl <sup>-</sup>	TSS	TS	TVS	SECCHI	COND	pH	DO
19-May	3	199	0.969	0.102	<0.05	0.022	<0.005	416	108	1.9	485	120	7.80	0.7320	8.45	12.60
15-Jun	3	185	1.150	0.136	<0.05	0.039	<0.005	413	114	3.2	477	133	4.90	0.7270	8.12	9.28
14-Jul	3	199	1.340	<0.1	<0.05	0.049	<0.005	432	120	7.0	513	145	3.80	0.7650	8.10	8.45
17-Aug	3	192	3.000	<0.1	<0.05	0.108	0.008	435	130	21.0	547	174	0.95	0.7700	8.64	11.75
14-Sep	3	182	3.490	0.529	<0.05	0.085	0.008	435	126	13.0	530	166	1.10	0.7710	8.28	8.40
<b>Average</b>		191	1.990	0.256 <sup>k</sup>	<0.05	0.061	0.008 <sup>k</sup>	426	120	9.2	510	148	3.71	0.7530	8.32	10.10

2006		Epilimnion														
DATE	DEPTH	ALK	TKN	NH <sub>3</sub> -N	NO <sub>2</sub> +NO <sub>3</sub> *	TP	SRP	TDS	Cl <sup>-</sup>	TSS	TS	TVS	SECCHI	COND	pH	DO
16-May	3	183	1.610	<0.1	<0.05	0.048	<0.005	NA	115	4.1	474	110	5.25	0.7667	8.40	7.97
20-Jun	3	166	1.720	<0.1	<0.05	0.052	<0.005	NA	117	12.0	498	151	3.11	0.7639	8.86	8.78
18-Jul	3	161	1.650	<0.1	<0.05	0.041	<0.005	NA	121	9.4	488	147	3.61	0.7821	8.47	5.72
15-Aug	3	169	1.780	<0.1	<0.05	0.038	<0.005	NA	129	11.0	524	159	2.19	0.8090	8.68	8.61
19-Sep	3	169	1.580	<0.1	<0.05	0.034	<0.005	NA	119	8.8	482	126	3.28	0.7820	8.29	7.96
<b>Average</b>		170	1.668	<0.1	<0.05	0.043	<0.005	NA	120	9.1	493	139	3.49	0.7807	8.54	7.81

2001		Epilimnion														
DATE	DEPTH	ALK	TKN	NH <sub>3</sub> -N	NO <sub>2</sub> -N	TP	SRP	TDS	Cl <sup>-</sup>	TSS	TS	TVS	SECCHI	COND	pH	DO
21-May	3	185	0.729	<0.1	<0.05	0.056	<0.005	378	NA	6.1	393	129	4.63	0.6247	8.27	7.51
19-Jun	3	181	1.630	<0.1	<0.05	0.099	0.006	384	NA	15.0	408	131	2.60	0.6215	7.95	5.74
24-Jul	3	177	3.490	<0.1	<0.05	0.107	0.026	394	NA	26.0	439	141	0.95	0.6224	7.84	4.49
21-Aug	3	151	4.520	<0.1	<0.05	0.129	0.032	390	NA	31.0	428	153	0.72	0.5727	8.08	6.47
18-Sep	3	165	3.770	<0.1	<0.05	0.107	0.034	368	NA	25.0	404	155	1.15	0.5943	7.88	6.79
<b>Average</b>		172	2.828	<0.1	<0.05	0.100	0.025 <sup>k</sup>	383	NA	20.6	414	142	2.01	0.6071	8.00	6.20

Glossary
ALK = Alkalinity, mg/L CaCO <sub>3</sub>
TKN = Total Kjeldahl nitrogen, mg/L
NH <sub>3</sub> -N = Ammonia nitrogen, mg/L
NO <sub>2</sub> +NO <sub>3</sub> -N = Nitrate + Nitrite nitrogen, mg/L
NO <sub>3</sub> -N = Nitrate nitrogen, mg/L
TP = Total phosphorus, mg/L
SRP = Soluble reactive phosphorus, mg/L
Cl <sup>-</sup> = Chloride, mg/L
TDS = Total dissolved solids, mg/L
TSS = Total suspended solids, mg/L
TS = Total solids, mg/L
TVS = Total volatile solids, mg/L
SECCHI = Secchi disk depth, ft.
COND = Conductivity, milliSiemens/cm
DO = Dissolved oxygen, mg/L

k = Denotes that the actual value is known to be less than the value presented.

NA= Not applicable

\* = Prior to 2006 only Nitrate - nitrogen was analyzed

**Lake County Secchi Disk Clarity Ranking, 2000-2016.**

<b>RANK</b>	<b>LAKE NAME</b>	<b>SECCHI AVE</b>	<b>TSI<sub>sd</sub></b>
1	Lake Carina	16.96	36.31
2	Windward Lake	14.28	38.79
3	Sterling Lake	13.84	39.24
4	Cedar Lake	12.55	40.66
5	Druce Lake	12.25	41.00
6	Pulaski Pond	11.69	41.68
7	West Loon Lake	11.55	41.85
8	Lake Zurich	10.40	43.37
9	Independence Grove	10.31	43.49
10	Ames Pit	9.97	43.97
11	Third Lake	9.76	44.28
12	Davis Lake	9.65	44.44
13	Harvey Lake	9.47	44.72
14	Little Silver Lake	9.42	44.79
15	Old School Lake	9.40	44.82
16	Lake Kathryn	9.39	44.84
17	Dugdale Lake	9.22	45.10
18	Dog Training Pond	9.04	45.39
19	Banana Pond	8.85	45.69
20	Deep Lake	8.83	45.72
21	Stone Quarry Lake	8.81	45.76
22	Wooster Lake	8.74	45.87
23	Lake of the Hollow	8.74	45.87
24	Cross Lake	8.18	46.83
25	Bangs Lake	8.02	47.11
26	Briarcrest Pond	8.00	47.15
27	Sand Lake	7.48	48.12
28	Sand Pond (IDNR)	7.42	48.23
29	Timber Lake (North)	7.37	48.33
30	Lake Miltmore	7.35	48.37
31	Lake Leo	7.31	48.45
32	Schreiber Lake	7.25	48.57
33	Nielsen Pond	7.23	48.61
34	Honey Lake	7.17	48.73
35	Lake Minear	7.13	48.81
36	Round Lake	7.01	49.05
37	Highland Lake	6.97	49.14
38	Lake Helen	6.43	50.30
39	Sun Lake	6.33	50.52
40	Lake Barrington	6.12	51.01
41	Cranberry Lake	5.94	51.44
42	Lake Fairfield	5.89	51.56
43	Gages Lake	5.45	52.68
44	Owens Lake	5.30	53.08
45	Valley Lake	5.05	53.78
46	McGreal Lake	5.04	53.81
47	Old Oak Lake	4.85	54.36
48	Waterford Lake	4.70	54.82
49	Lake Linden	4.60	55.13
50	Timber Lake (South)	4.46	55.57
51	Peterson Pond	4.51	55.41

Lake County Secchi Disk Clarity Ranking, 2000-2016.

RANK	LAKE NAME	SECCHI AVE	TSIsd
52	Crooked Lake	4.39	55.79
53	Mary Lee Lake	4.35	55.93
54	Butler Lake	4.35	55.93
55	Crooked Lake	4.28	56.17
56	Deer Lake	4.20	56.45
57	Seven Acre Lake	4.18	56.51
58	Lambs Farm Lake	4.17	56.54
59	Grays Lake	4.08	56.86
60	Lake Naomi	4.05	56.96
61	White Lake	3.96	57.29
62	Hook Lake	3.95	57.32
63	Turner Lake	3.92	57.43
64	Leisure Lake	3.85	57.69
65	Summerhill Estates Lake	3.84	57.73
66	North Tower Lake	3.89	57.74
67	Salem Lake	3.77	58.00
68	Lake Fariview	3.75	58.07
69	Duck Lake	3.71	58.23
70	Countryside Glen Lake	3.64	58.50
71	Fish Lake	3.57	58.78
72	Lochanora	3.52	58.99
73	Taylor Lake	3.52	58.99
74	Hastings Lake	3.52	58.99
75	Bishop Lake	3.47	59.19
76	Lake Lakeland Estates	3.41	59.44
77	Lake Holloway	3.40	59.49
78	Stockholm Lake	3.38	59.57
79	East Loon Lake	3.30	59.92
80	Lucky Lake	3.22	60.27
81	Diamond Lake	3.17	60.50
82	Liberty Lake	3.16	60.54
83	International Mining and Chemical Lake	3.08	60.91
84	Long Lake	3.05	61.05
85	Lake Christa	3.01	61.24
86	Lucy Lake	2.99	61.34
87	Lake Catherine	2.9	61.78
88	St. Mary's Lake	2.79	62.34
89	Channel Lake	2.77	62.44
90	Werhane Lake	2.71	62.76
91	Bresen Lake	2.69	62.86
92	East Meadow Lake	2.61	63.30
93	Buffalo Creek Reservoir 1	2.60	63.35
94	Countryside Lake	2.58	63.46
95	Kemper Lake 1	2.56	63.58
96	Bluff Lake	2.51	63.86
97	Broberg Marsh	2.50	63.92
98	Antioch Lake	2.48	64.03
99	Little Bear Lake	2.38	64.63
100	Island Lake	2.32	65.00
101	Tower Lake	2.31	65.06
102	Buffalo Creek Reservoir 2	2.30	65.12

**Lake County Secchi Disk Clarity Ranking, 2000-2016.**

<b>RANK</b>	<b>LAKE NAME</b>	<b>SECCHI AVE</b>	<b>TSI<sub>sd</sub></b>
103	Woodland Lake	2.28	65.25
104	Rivershire Pond 2	2.23	65.57
105	Lake Charles	2.20	65.76
106	Fischer Lake	2.70	62.81
107	College Trail Lake	2.18	65.89
108	Loch Lomond	2.17	65.96
109	Redhead Lake	2.16	66.03
110	Pistakee Lake	2.15	66.09
111	Echo Lake	2.11	66.36
112	Eagle Lake (S1)	2.10	66.43
113	West Meadow Lake	2.07	66.64
114	Forest Lake	2.04	66.85
115	Grand Ave Marsh	2.03	66.92
116	Columbus Park Lake	2.03	66.92
117	Grassy Lake	2.00	67.14
118	Petite Lake	2	67.14
119	Des Plaines Lake	2.14	66.16
120	Sylvan Lake	1.98	67.28
121	Bittersweet Golf Course #13	1.98	67.28
122	Spring Lake	1.78	68.82
123	Kemper Lake 2	1.77	68.90
124	Fourth Lake	1.77	68.90
125	Nippersink Lake	1.73	69.23
126	Deer Lake Meadow Lake	1.73	69.23
127	Lake Louise	1.68	69.65
128	Willow Lake	1.63	70.09
129	Slough Lake	1.63	70.09
130	Rasmussen Lake	1.62	70.17
131	Lake Farmington	1.62	70.17
132	Half Day Pit	1.60	70.35
133	Lake Marie	1.56	70.72
134	Longview Meadow Lake	1.51	71.19
135	Lake Matthews	1.48	71.48
136	Big Bear Lake	1.32	73.13
137	Fox Lake	1.28	73.57
138	Dunn's Lake	1.22	74.26
139	Lake Eleanor	1.16	74.99
140	McDonald Lake 1	1.13	75.37
141	Lake Napa Suwe	1.06	76.29
142	Rollins Savannah 1	1.05	76.43
143	Osprey Lake	1.03	76.70
144	Manning's Slough	1.00	77.13
145	Rollins Savannah 2	0.95	77.87
146	Dog Bone Lake	0.94	78.02
147	Redwing Marsh	0.88	78.97
148	Flint Lake Outlet	0.83	79.82
149	Fairfield Marsh	0.81	80.17
150	Slocum Lake	0.81	80.17
151	Oak Hills Lake	0.79	80.53
152	Grass Lake	0.78	80.71
153	Lake Nippersink	0.77	80.90

**Lake County Secchi Disk Clarity Ranking, 2000-2016.**

<b>RANK</b>	<b>LAKE NAME</b>	<b>SECCHI AVE</b>	<b>TSIsd</b>
154	South Churchill Lake	0.73	81.67
155	Lake Forest Pond	0.71	82.07
156	ADID 127	0.66	83.12
157	North Churchill Lake	0.61	84.26
158	Hidden Lake	0.56	85.54
159	Ozaukee Lake	0.51	86.84
160	McDonald Lake 2	0.50	87.12

## Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
1	Sterling Lake	0.0110	38.73
2	Lake Carina	0.0110	38.73
3	Independence Grove	0.0130	40.38
4	Cedar Lake	0.0130	41.14
5	Druce Lake	0.0140	42.21
6	Windward Lake	0.0160	44.13
7	Lake Minear	0.0164	44.49
8	Sand Pond (IDNR)	0.0165	44.57
9	West Loon	0.0170	45.00
10	Pulaski Pond	0.0180	45.83
11	Ames Pit	0.0190	46.61
12	Banana Pond	0.0200	47.35
13	Gages Lake	0.0200	47.35
14	Lake Kathryn	0.0200	47.35
15	Highland Lake	0.0202	47.49
16	Lake Miltmore	0.0210	48.05
17	Timber Lake (North)	0.0210	48.05
18	Lake Zurich	0.0210	48.05
19	Cross Lake	0.0216	48.46
20	Dog Training Pond	0.0220	48.72
21	Sun Lake	0.0220	48.72
22	Deep Lake	0.0230	49.36
23	Lake of the Hollow	0.0230	49.36
24	Round Lake	0.0230	49.36
25	Stone Quarry Lake	0.0230	49.36
26	Bangs Lake	0.0260	51.13
27	Lake Leo	0.0260	51.13
28	Lake Barrington	0.0270	51.68
29	Cranberry Lake	0.0270	51.68
30	Dugdale Lake	0.0270	51.68
31	Peterson Pond	0.0270	51.68
32	Little Silver Lake	0.0280	52.20
33	Wooster Lake	0.0290	52.71
34	Lambs Farm Lake	0.0310	53.67
35	Old School Lake	0.0310	53.67
36	Grays Lake	0.0310	53.67
37	Harvey Lake	0.0320	54.13
38	Butler Lake	0.0324	54.31
39	Hendrick Lake	0.0340	55.00
40	Fourth Lake	0.0360	55.82
41	Sullivan Lake	0.0370	56.22
42	Sand Lake	0.0380	56.60
43	Third Lake	0.0384	56.77
44	Diamond Lake	0.0390	56.98
45	East Loon	0.0400	57.34
46	Schreiber Lake	0.0400	57.34
47	Waterford Lake	0.0400	57.34
48	Hook Lake	0.0410	57.70
49	Lake Tranquility (S1)	0.0412	57.77
50	Nielsen Pond	0.0450	59.04
51	Seven Acre Lake	0.0460	59.36

## Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
52	Turner Lake	0.0460	59.36
53	Willow Lake	0.0460	59.36
54	East Meadow Lake	0.0480	59.97
55	Lucky Lake	0.0480	59.97
56	Old Oak Lake	0.0490	60.27
57	College Trail Lake	0.0500	60.56
58	Summerhill Estates Lake	0.0514	60.96
59	Hastings Lake	0.0520	61.13
60	West Meadow Lake	0.0530	61.40
61	Lucy Lake	0.0550	61.94
62	Lake Linden	0.0570	62.45
63	Lake Christa	0.0580	62.70
64	Owens Lake	0.0580	62.70
65	Briarcrest Pond	0.0580	62.70
66	Honey Lake	0.0586	62.85
67	Redhead Lake	0.0608	63.38
68	St. Mary's Lake	0.0608	63.38
69	Duck Lake	0.0610	63.43
70	Lake Lakeland Estates	0.0620	63.66
71	Lake Naomi	0.0620	63.66
72	Lake Catherine	0.0620	63.66
73	Liberty Lake	0.0630	63.89
74	North Tower Lake	0.0630	63.89
75	Werhane Lake	0.0630	63.89
76	Countryside Glen Lake	0.0640	64.12
77	Davis Lake	0.0650	64.34
78	Leisure Lake	0.0650	64.34
79	Channel Lake	0.0680	65.00
80	Buffalo Creek Reservoir 1	0.0680	65.00
81	Mary Lee Lake	0.0680	65.00
82	Little Bear Lake	0.0680	65.00
83	Crooked Lake	0.0710	65.62
84	Timber Lake (South)	0.0720	65.82
85	Lake Helen	0.0720	65.82
86	Grandwood Park Lake	0.0720	65.82
87	ADID 203	0.0730	66.02
88	Fish Lake	0.0730	66.02
89	Broberg Marsh	0.0780	66.97
90	Echo Lake	0.0790	67.16
91	Countryside Lake	0.0800	67.34
92	Lake Nippersink	0.0800	67.34
93	Woodland Lake	0.0800	67.34
94	Redwing Slough	0.0822	67.73
95	Tower Lake	0.0830	67.87
96	Antioch Lake	0.0850	68.21
97	Potomac Lake	0.0850	68.21
98	White Lake	0.0862	68.42
99	Grand Ave Marsh	0.0870	68.55
100	North Churchill Lake	0.0870	68.55
101	McDonald Lake 1	0.0880	68.71
102	Pistakee Lake	0.0880	68.71

## Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
103	Lake Fairview	0.0890	68.88
104	Rivershire Pond 2	0.0900	69.04
105	South Churchill Lake	0.0900	69.04
106	McGreal Lake	0.0910	69.20
107	Lake Charles	0.0930	69.51
108	Deer Lake	0.0940	69.66
109	Eagle Lake (S1)	0.0950	69.82
110	International Mine and Chemical Lake	0.0950	69.82
111	Valley Lake	0.0950	69.82
112	Buffalo Creek Reservoir 2	0.0960	69.97
113	Big Bear Lake	0.0960	69.97
114	Fox Lake	0.1000	70.56
115	Nippersink Lake - LCFP	0.1000	70.56
116	Sylvan Lake	0.1000	70.56
117	Petite Lake	0.1020	70.84
118	Longview Meadow Lake	0.1020	70.84
119	Lake Marie	0.1030	70.98
120	Dunn's Lake	0.1070	71.53
121	Lake Forest Pond	0.1070	71.53
122	Long Lake	0.1070	71.53
123	Grass Lake	0.1090	71.80
124	Des Plaines Lake	0.1090	71.80
125	Spring Lake	0.1100	71.93
126	Kemper 2	0.1100	71.93
127	Bittersweet Golf Course #13	0.1100	71.93
128	Osprey Lake	0.1110	72.06
129	Bluff Lake	0.1120	72.19
130	Middlefork Savannah Outlet 1	0.1120	72.19
131	Lochanora Lake	0.1120	72.19
132	Round Lake Marsh North	0.1130	72.32
133	Deer Lake Meadow Lake	0.1160	72.70
134	Lake Matthews	0.1180	72.94
135	Taylor Lake	0.1180	72.94
136	Island Lake	0.1210	73.31
137	Columbus Park Lake	0.1230	73.54
138	Lake Holloway	0.1320	74.56
139	Fischer Lake	0.1380	75.20
140	Slocum Lake	0.1500	76.40
141	Lakewood Marsh	0.1510	76.50
142	Pond-A-Rudy	0.1510	76.50
143	Forest Lake	0.1540	76.78
144	Bresen Lake	0.1580	77.15
145	Middlefork Savannah Outlet 2	0.1590	77.24
146	Grassy Lake	0.1610	77.42
147	Salem Lake	0.1650	77.78
148	Half Day Pit	0.1690	78.12
149	Lake Louise	0.1810	79.11
150	Lake Eleanor	0.1810	79.11
151	Lake Farmington	0.1850	79.43
152	ADID 127	0.1890	79.74

## Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
153	Lake Napa Suwe	0.1940	80.11
154	Loch Lomond	0.1960	80.26
155	Patski Pond	0.1970	80.33
156	Dog Bone Lake	0.1990	80.48
157	Redwing Marsh	0.2070	81.05
158	Stockholm Lake	0.2082	81.13
159	Bishop Lake	0.2160	81.66
160	Ozaukee Lake	0.2200	81.93
161	Kemper 1	0.2220	82.06
162	Hidden Lake	0.2240	82.19
163	McDonald Lake 2	0.2250	82.25
164	Oak Hills Lake	0.2790	85.35
165	Heron Pond	0.2990	86.35
166	Rollins Savannah 1	0.3070	86.73
167	Fairfield Marsh	0.3260	87.60
168	ADID 182	0.3280	87.69
169	Manning's Slough	0.3820	89.88
170	Slough Lake	0.3860	90.03
171	Rasmussen Lake	0.4860	93.36
172	Albert Lake, Site II, outflow	0.4950	93.62
173	Flint Lake Outlet	0.5000	93.76
174	Rollins Savannah 2	0.5870	96.08
175	Almond Marsh	1.9510	113.40
	<i>Average</i>	<i>0.1113</i>	<i>65.8</i>

Appendix C:  
Methods for Field Data Collection and Laboratory Analyses

## **Water Sampling and Laboratory Analyses**

Two water samples were collected once a month from May through September. Sample locations were at the deepest point in the lake (see sample site map), three feet below the surface, and 3 feet above the bottom. Samples were collected with a horizontal Van Dorn water sampler. Approximately three liters of water were collected for each sample for all lab analyses. After collection, all samples were placed in a cooler with ice until delivered to the Lake County Health Department lab, where they were refrigerated. Analytical methods for the parameters are listed in Table A1. Except nitrate nitrogen, all methods are from the Eighteenth Edition of Standard Methods, (eds. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1992). Methodology for nitrate nitrogen was taken from the 14th edition of Standard Methods. Dissolved oxygen, temperature, conductivity and pH were measured at the deep hole with a Hydrolab DataSonde® 4a. Photosynthetic Active Radiation (PAR) was recorded using a LI-COR® 192 Spherical Sensor attached to the Hydrolab DataSonde® 4a. Readings were taken at the surface and then every two feet until reaching the bottom.

### **Plant Sampling**

In order to randomly sample each lake, mapping software (ArcMap 9.3) overlaid a grid pattern onto an aerial photo of Lake County and placed points 60 or 30 meters apart, depending on lake size. Plants were sampled using a garden rake fitted with hardware cloth. The hardware cloth surrounded the rake tines and is tapered two feet up the handle. A rope was tied to the end of the handle for retrieval. At designated sampling sites, the rake was tossed into the water, and using the attached rope, was dragged across the bottom, toward the boat. After pulling the rake into the boat, plant coverage was assessed for overall abundance. Then plants were individually identified and placed in categories based on coverage. Plants that were not found on the rake but were seen in the immediate vicinity of the boat at the time of sampling were also recorded. Plants difficult to identify in the field were placed in plastic bags and identified with plant keys after returning to the office. The depth of each sampling location was measured either by a hand-held depth meter, or by pushing the rake straight down and measuring the depth along the rope or rake handle. One-foot increments were marked along the rope and rake handle to aid in depth estimation.

### **Plankton Sampling**

Plankton were sampled at the same location as water quality samples. Using the Hydrolab DataSonde® 4a or YSI 6600 Sonde® 1% light level depth (depth where the water light is 1% of the surface irradiance) was determined. A plankton net/tow, with 63µm mesh, was then lowered to the pre-determined 1% light level depth and retrieved vertically. On the way up the water column, plankton were collected within a small cup on the bottom of the tow. The collected sample was then emptied into a pre-labeled brown plastic bottle. The net was rinsed with deionized water into the bottle in order to ensure all the plankton were collected. The sample was then transferred to a graduated cylinder to measure the amount of milliliters (mL) that the sample was. The sample was then returned to the bottle and preserved with Lugol's iodine solution (5 drops/mL). The sample bottle was then closed and stored in a cooler until returning

to the lab, where it was transferred to the refrigerator until enumeration. Enumeration was performed within three months, but ideally within one month, under a microscope. Prior to sub-sample being removed for enumeration, the sample bottle was inverted several times to ensure proper homogenization. An automated pipette was used to retrieve 1 mL of sample, which was then placed in a Sedgewick Rafter slide. This is a microscope slide on which a rectangular chamber has been constructed, measuring 50 mm x 20 mm in area and 1 mm deep. The slide was then placed under the microscope and counted at a 20X magnification (phytoplankton) or 10X magnification (zooplankton). For phytoplankton, twenty fields of view were randomly counted with all species within each field counted. Due to their larger size, zooplankton were counted throughout the entire slide. Through calculations, it was determined how many of each species were in 1 mL of lake water.

Phytoplankton (algae) are free-floating and microscopic and are distinguished from plants because they lack roots, stems and leaves. There are four distinct groups of phytoplankton found in Lake County lakes: blue-greens, greens, diatoms, and dinoflagellates/chrysophytes. Blue-greens are also known as cyanobacteria because they are the only group of bacteria that obtain their energy from photosynthesis like plants. Some of these species can be toxic. Green algae are the closest ancestors of land plants and are the most common group. Diatoms are unique because they are encased in a cell wall made of silica that can be very ornate. Dinoflagellates and chrysophytes are almost always flagellated (able to move by flagella, a whip-like tail) and some can both photosynthesize and consume bacteria for food.

Zooplankton are made up of rotifers and two crustacean groups; the cladocerans and the copepods (broken down further into calanoids and cyclopoids). Rotifers are smaller and most have a crown of cilia (hair-like structure) used for movement and drawing in suspended particles to eat. Crustaceans have jointed appendages and are enclosed in an exoskeleton. Cladocerans, such as the “water flea” *Daphnia* species, are filter-feeding like rotifers, while the copepod group contains both filter-feeders (calanoids and cyclopoids) and raptorial species (cyclopoids).

## **Shoreline Assessment**

### Shoreline Assessment Protocol

Each lake was divided into reaches in ArcGIS based on nearshore landuse. For each reach, a shoreline assessment worksheet was filled out in the field focusing on shoreline conditions (land use, slope, erosion, buffer, etc) that describe the overall reach segment of the lake.

A GPS Trimble unit was used to collect the degree of shoreline erosion along the entire length of the lake. The degree of shoreline erosion was categorically defined as none, slight, moderate, or severe. Below are brief descriptions of each category.

Table 1: Degree of Shoreline Erosion

Category	Description
None	Includes man-made erosion control such as rip-rap and sea wall.
Slight	Minimal or no observable erosion; generally considered stable; no erosion control practices will be recommended with the possible exception of small problem areas noted within an area otherwise designated as "slight". Beaches have been included as "slight" erosion.
Moderate	Recession is characterized by past or recently eroded banks; area may exhibit some exposed roots, fallen vegetation or minor slumping of soil material; erosion control practices may be recommended although the section is not deemed to warrant immediate remedial action.
Severe	Recession is characterized by eroding of exposed soil on nearly vertical banks, exposed roots, fallen vegetation or extensive slumping of bank material, undercutting, washouts or fence posts exhibiting realignment; erosion control practices are recommended and immediate remedial action may be warranted.

Lateral recession rates were calculated on a per reach basis based on the IL EPA stream methodology, defining lateral recession into four main categories (slight, moderate, severe, and very severe). Descriptions of each category are defined in the Table 2.

Table 2: Lateral Recession Rate Categories

Lateral Recession Rate	Description	Description
0.01 – 0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetation overhanging. No exposed tree roots.
0.06 – 0.2	Moderate	Bank mostly bare with some rills and vegetation overhanging.
0.3 – 0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

### Shoreline Buffer Condition

Lakeshore buffer condition was assessed using a qualitative methodology that considered an area up to 25 feet inland from the shoreline for each reach. The assessment was done by viewing high resolution 2014 aerial images in ArcGIS. A 25 foot buffer was chosen based on research that indicates a 25-foot vegetated buffer is the minimum effective width for in-lake habitat maintenance (a 15 foot buffer is the minimum effective width for bank stability). Criteria used for category assignment are shown in table below.

Table 3: Shoreline Buffer Condition Categories

Category	Criteria	Percentage
Good	Unmowed grasses & forbs + tree trunks + shrubs <i>and</i> impervious surfaces	$\geq 70\%$
		$\leq 5\%$
Fair	Unmowed grasses & forbs + tree trunks + shrubs <i>and</i> Impervious surface	$\geq 50\%$ and $< 70\%$
		$\leq 10\%$
Poor	Unmowed grasses & forbs + tree trunks + shrubs <i>and</i> Impervious surface	$< 50\%$
		$\geq 50\%$

### **Wildlife Assessment**

Species of wildlife were noted during visits to each lake. When possible, wildlife was identified to species by sight or sound. However, due to time constraints, collection of quantitative information was not possible. Thus, all data should be considered anecdotal. Some of the species on the list may have only been seen once, or were spotted during their migration through the area.

**Table A1. Analytical methods used for water quality parameters.**

<i>Parameter</i>	<i>Method</i>
Temperature	Hydrolab DataSonde® 4a or YSI 6600 Sonde®
Dissolved oxygen	Hydrolab DataSonde® 4a or YSI 6600 Sonde®
Nitrate and Nitrite nitrogen	USEPA 353.2 rev. 2.0 EPA-600/R-93/100 Detection Limit = 0.05 mg/L
Ammonia nitrogen	SM 18 <sup>th</sup> ed. Electrode method, #4500 NH <sub>3</sub> -F Detection Limit = 0.1 mg/L
Total Kjeldahl nitrogen	SM 18 <sup>th</sup> ed, 4500-N <sub>org</sub> C Semi-Micro Kjeldahl, plus 4500 NH <sub>3</sub> -F Detection Limit = 0.5 mg/L
pH	Hydrolab DataSonde® 4a, or YSI 6600 Sonde® Electrometric method
Total solids	SM 18 <sup>th</sup> ed, Method #2540B
Total suspended solids	SM 18 <sup>th</sup> ed, Method #2540D Detection Limit = 0.5 mg/L
Chloride	SM 18 <sup>th</sup> ed, Method #4500C1-D
Total volatile solids	SM 18 <sup>th</sup> ed, Method #2540E, from total solids
Alkalinity	SM 18 <sup>th</sup> ed, Method #2320B, potentiometric titration curve method
Conductivity	Hydrolab DataSonde® 4a or YSI 6600 Sonde®
Total phosphorus	SM 18 <sup>th</sup> ed, Methods #4500-P B 5 and #4500-P E Detection Limit = 0.01 mg/L
Soluble reactive phosphorus	SM 18 <sup>th</sup> ed, Methods #4500-P B 1 and #4500-P E Detection Limit = 0.005 mg/L
Clarity	Secchi disk
Color	Illinois EPA Volunteer Lake Monitoring Color Chart
Photosynthetic Active Radiation (PAR)	Hydrolab DataSonde® 4a or YSI 6600 Sonde®, LI-COR® 192 Spherical Sensor

**APPENDIX D. INTERPRETING YOUR LAKE'S WATER QUALITY  
DATA**

Lakes possess a unique set of physical and chemical characteristics that will change over time. These in-lake water quality characteristics, or parameters, are used to describe and measure the quality of lakes, and they relate to one another in very distinct ways. As a result, it is virtually impossible to change any one component in or around a lake without affecting several other components, and it is important to understand how these components are linked.

The following pages will discuss the different water quality parameters measured by Lake County Health Department staff, how these parameters relate to each other, and why the measurement of each parameter is important. The median values (the middle number of the data set, where half of the numbers have greater values, and half have lesser values) of data collected from Lake County lakes from 2000-2010 will be used in the following discussion.

### **Temperature and Dissolved Oxygen:**

Water temperature fluctuations will occur in response to changes in air temperatures, and can have dramatic impacts on several parameters in the lake. In the spring and fall, lakes tend to have uniform, well-mixed conditions throughout the water column (surface to the lake bottom). However, during the summer, deeper lakes will separate into distinct water layers. As surface water temperatures increase with increasing air temperatures, a large density difference will form between the heated surface water and colder bottom water. Once this difference is large enough, these two water layers will separate and generally will not mix again until the fall. At this time the lake is thermally stratified. The warm upper water layer is called the *epilimnion*, while the cold bottom water layer is called the *hypolimnion*. In some shallow lakes, stratification and destratification can occur several times during the summer. If this occurs the lake is described as polymictic. Thermal stratification also occurs to a lesser extent during the winter, when warmer bottom water becomes separated from ice-forming water at the surface until mixing occurs during spring ice-out.

Monthly temperature profiles were established on each lake by measuring water temperature every foot (lakes  $\leq$  15 feet deep) or every two feet (lakes  $>$  15 feet deep) from the lake surface to the lake bottom. These profiles are important in understanding the distribution of chemical/biological characteristics and because increasing water temperature and the establishment of thermal stratification have a direct impact on dissolved oxygen (DO) concentrations in the water column. If a lake is shallow and easily mixed by wind, the DO concentration is usually consistent throughout the water column. However, shallow lakes are typically dominated by either plants or algae, and increasing water temperatures during the summer speeds up the rates of photosynthesis and decomposition in surface waters. Many of the plants or algae die at the end of the growing season. Their decomposition results in heavy oxygen consumption and can lead to an oxygen crash. In deeper, thermally stratified lakes, oxygen production is greatest in the top portion of the lake, where sunlight drives photosynthesis, and oxygen consumption is greatest near the bottom of a lake, where sunken organic matter accumulates and decomposes. The oxygen difference between the top and bottom water layers can be dramatic, with plenty of oxygen near the surface, but practically none near the bottom.

The oxygen profiles measured during the water quality study can illustrate if this is occurring. This is important because the absence of oxygen (anoxia) near the lake bottom can have adverse effects in eutrophic lakes resulting in the chemical release of phosphorus from lake sediment and the production of hydrogen sulfide (rotten egg smell) and other gases in the bottom waters. Low oxygen conditions in the upper water of a lake can also be problematic since all aquatic organisms need oxygen to live. Some oxygen may be present in the water, but at too low a concentration to sustain aquatic life. Oxygen is needed by all plants, virtually all algae and for many chemical reactions that are important in lake functioning. Most adult sport-fish such as largemouth bass and bluegill require at least 3 mg/L of DO in the water to survive. However, their offspring require at least 5 mg/L DO as they are more sensitive to DO stress. When DO concentrations drop below 3 mg/L, rough fish such as carp and green sunfish are favored and over time will become the dominant fish species.

External pollution in the form of oxygen-demanding organic matter (i.e., sewage, lawn clippings, soil from shoreline erosion, and agricultural runoff) or nutrients that stimulate the growth of excessive organic matter (i.e., algae and plants) can reduce average DO concentrations in the lake by increasing oxygen consumption. This can have a detrimental impact on the fish community, which may be squeezed into a very small volume of water as a result of high temperatures in the epilimnion and low DO levels in the hypolimnion.

## **Nutrients:**

### *Phosphorus:*

For most Lake County lakes, phosphorus is the nutrient that limits plant and algae growth. This means that any addition of phosphorus to a lake will typically result in algae blooms or high plant densities during the summer. The source of phosphorus to a lake can be external or internal (or both). External sources of phosphorus enter a lake through point (i.e., storm pipes and wastewater discharge) and non-point runoff (i.e., overland water flow). This runoff can pick up large amounts of phosphorus from agricultural fields, septic systems or impervious surfaces before it empties into the lake.

Internal sources of phosphorus originate within the lake and are typically linked to the lake sediment. In lakes with high oxygen levels (oxic), phosphorus can be released from the sediment through plants or sediment resuspension. Plants take up sediment-bound phosphorus through their roots, releasing it in small amounts to the water column throughout their life cycles, and in large amounts once they die and begin to decompose. Sediment resuspension can occur through biological or mechanical means. Bottom-feeding fish, such as common carp and black bullhead can release phosphorus by stirring up bottom sediment during feeding activities and can add phosphorus to a lake through their fecal matter. Sediment resuspension, and subsequent phosphorus release, can also occur via wind/wave action or through the use of artificial aerators, especially in shallow lakes. In lakes that thermally stratify, internal phosphorus release can occur from the sediment through chemical means. Once oxygen is depleted (anoxia) in the hypolimnion, chemical reactions occur in which phosphorus bound to iron complexes in the

sediment becomes soluble and is released into the water column. This phosphorus is trapped in the hypolimnion and is unavailable to algae until fall turnover, and can cause algae blooms once it moves into the sunlit surface water at that time. Accordingly, many of the lakes in Lake County are plagued by dense algae blooms and excessive, exotic plant coverage, which negatively affect DO levels, fish communities and water clarity.

Lakes with an average phosphorus concentration greater than 0.05 mg/L are considered nutrient rich. The median near surface total phosphorus (TP) concentration in Lake County lakes from 2000-2010 was 0.065 mg/L and ranged from a non-detectable minimum of <0.010 mg/L on seven lakes to a maximum of 3.880 mg/L on Albert Lake. The median anoxic TP concentration in Lake County lakes from 2000-2010 was 0.174 mg/L and ranged from a minimum of 0.012 mg/L in Independence Grove Lake to a maximum of 3.800 mg/L in Taylor Lake.

The analysis of phosphorus also included soluble reactive phosphorus (SRP), a dissolved form of phosphorus that is readily available for plant and algae growth. SRP is not discussed in great detail in most of the water quality reports because SRP concentrations vary throughout the season depending on how plants and algae absorb and release it. It gives an indication of how much phosphorus is available for uptake, but, because it does not take all forms of phosphorus into account, it does not indicate how much phosphorus is truly present in the water column. TP is considered a better indicator of a lake's nutrient status because its concentrations remain more stable than soluble reactive phosphorus. However, elevated SRP levels are a strong indicator of nutrient problems in a lake.

#### Nitrogen:

Nitrogen is also an important nutrient for plant and algae growth. Sources of nitrogen to a lake vary widely, ranging from fertilizer and animal wastes, to human waste from sewage treatment plants or failing septic systems, to groundwater, air and rainfall. As a result, it is very difficult to control or reduce nitrogen inputs to a lake. Different forms of nitrogen are present in a lake under different oxic conditions.  $\text{NH}_4^+$  (ammonium) is released from decomposing organic material under anoxic conditions and accumulates in the hypolimnion of thermally stratified lakes. If  $\text{NH}_4^+$  comes into contact with oxygen, it is immediately converted to  $\text{NO}_2^-$  (nitrite) which is then oxidized to  $\text{NO}_3^-$  (nitrate). Therefore, in a thermally stratified lake, levels of  $\text{NH}_4^+$  would only be elevated in the hypolimnion and levels of  $\text{NO}_3^-$  would only be elevated in the epilimnion. Both  $\text{NH}_4^+$  and  $\text{NO}_3^-$  can be used as a nitrogen source by aquatic plants and algae. Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen plus ammonium. Adding the concentrations of TKN and nitrate together gives an indication of the amount of total nitrogen present in the water column. If inorganic nitrogen ( $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{NH}_4^+$ ) concentrations exceed 0.3 mg/L in spring, sufficient nitrogen is available to support summer algae blooms. However, low nitrogen levels do not guarantee limited algae growth the way low phosphorus levels do. Nitrogen gas in the air can dissolve in lake water and blue-green algae can "fix" atmospheric nitrogen, converting it into a usable form. Since other types of algae do not have the ability to do this, nuisance blue-green algae blooms are typically associated with lakes that are nitrogen limited (i.e., have low nitrogen levels).

The ratio of TKN plus nitrate nitrogen to total phosphorus (TN:TP) can indicate whether plant/algae growth in a lake is limited by nitrogen or phosphorus. Ratios of less than 10:1 suggest a system limited by nitrogen, while lakes with ratios greater than 20:1 are limited by phosphorus. It is important to know if a lake is limited by nitrogen or phosphorus because any addition of the limiting nutrient to the lake will, likely, result in algae blooms or an increase in plant density.

### **Solids:**

Although several forms of solids (total solids, total suspended solids, total volatile solids, total dissolved solids) were measured each month by the Lakes Management Staff, total suspended solids (TSS) and total volatile solids (TVS) have the most impact on other variables and on the lake as a whole. TSS are particles of algae or sediment suspended in the water column. High TSS concentrations can result from algae blooms, sediment resuspension, and/or the inflow of turbid water, and are typically associated with low water clarity and high phosphorus concentrations in many lakes in Lake County. Low water clarity and high phosphorus concentrations, in turn, exacerbate the high TSS problem by leading to reduced plant density (which stabilize lake sediment) and increased occurrence of algae blooms. The median TSS value in epilimnetic waters in Lake County was 8.1 mg/L, ranging from below the 0.1 mg/L detection limit to 165 mg/L in Fairfield Marsh.

TVS represents the fraction of total solids that are organic in nature, such as algae cells, tiny pieces of plant material, and/or tiny animals (zooplankton) in the water column. High TVS values indicate that a large portion of the suspended solids may be made up of algae cells. This is important in determining possible sources of phosphorus to a lake. If much of the suspended material in the water column is determined to be resuspended sediment that is releasing phosphorus, this problem would be addressed differently than if the suspended material was made up of algae cells that were releasing phosphorus. The median TVS value was 123.0 mg/L, ranging from 34.0 mg/L in Pulaski Pond to 298.0 mg/L in Fairfield Marsh.

Total dissolved solids (TDS) are the amount of dissolved substances, such as salts or minerals, remaining in water after evaporation. These dissolved solids are discussed in further detail in the *Alkalinity* and *Conductivity* sections of this document. TDS concentrations were measured in Lake County lakes prior to 2004. This practice was discontinued due to the strong correlation of TDS to conductivity and chloride concentrations. Since 2004, chloride concentrations data are collected..

### **Water Clarity:**

Water clarity (transparency) is not a chemical property of lake water, but is often an indicator of a lake's overall water quality. It is affected by a lake's water color, which is a reflection of the amount of total suspended solids and dissolved organic chemicals. Thus, transparency is a

measure of particle concentration and is measured with a Secchi disk. Generally, the lower the clarity or Secchi depth, the poorer the water quality. A decrease in Secchi depth during the summer occurs as the result of an increase in suspended solids (algae or sediment) in the water column. Aquatic plants play an important role in the level of water clarity and can, in turn, be negatively affected by low clarity levels. Plants increase clarity by competing with algae for resources and by stabilizing sediments to prevent sediment resuspension. A lake with a healthy plant community will almost always have higher water clarity than a lake without plants. Additionally, if the plants in a lake are removed (through herbicide treatment or the stocking of grass carp), the lake will probably become dominated by algae and Secchi depth will decrease. This makes it very difficult for plants to become re-established due to the lack of available sunlight and the lake will, most likely, remain turbid. Turbidity will be accelerated if the lake is very shallow and/or common carp are present. Shallow lakes are more susceptible to sediment resuspension through wind/wave action and are more likely to experience clarity problems if plants are not present to stabilize bottom sediment.

Common Carp are prolific fish that feed on invertebrates in the sediment. Their feeding activities stir up bottom sediment and can dramatically decrease water clarity in shallow lakes. As mentioned above, lakes with low water clarity are, generally, considered to have poor water quality. This is because the causes and effects of low clarity negatively impact both plant and fish communities. Fish populations will suffer as water clarity decreases due to a lack of food and decreased ability to successfully hunt for prey. Bluegills are planktivorous fish and feed on invertebrates that inhabit aquatic plants. If low clarity results in the disappearance of plants, this food source will disappear too. Largemouth Bass and Northern Pike are piscivorous fish that feed on other fish and hunt by sight. As the water clarity decreases, these fish species find it more difficult to see and ambush prey and may decline in size as a result. This could eventually lead to an imbalance in the fish community. Phosphorus release from resuspended sediment could increase as water clarity and plant density decrease. This would then result in increased algae blooms, further reducing Secchi depth and aggravating all problems just discussed. The median Secchi depth for Lake County lakes is 2.95 feet. From 2000-2010, both Ozaukee Lake and McDonald Lake #2 had the lowest Secchi depths (0.25 feet) and West Loon Lake had the highest (23.50 feet). As an example of the difference in Secchi depth based on plant coverage, South Churchill Lake, which had no plant coverage and large numbers of Common Carp in 2003 had an average Secchi depth of 0.73 feet (over four times lower than the county average), while Deep Lake, which had a diverse plant community and few carp had an average 2003 Secchi depth of 12.48 feet (almost four times higher than the county average).

Another measure of clarity is the use of a light meter. The light meter measures the amount of light at the surface of the lake and the amount of light at each depth in the water column. The amount of attenuation and absorption (decreases) of light by the water column are major factors controlling temperature and potential photosynthesis. Light intensity at the lake surface varies seasonally and with cloud cover, and decreases with depth. The deeper into the water column light penetrates, the deeper potential plant growth. The maximum depth at which algae and plants can grow underwater is usually at the depth where the amount of light available is reduced

to 0.5%-1% of the amount of light available at the lake surface. This is called the euphotic (sunlit) zone. A general rule of thumb in Lake County is that the 1% light level is about 1 to 3 times the Secchi disk depth.

### **Alkalinity, Conductivity, Chloride, pH:**

#### Alkalinity:

Alkalinity is the measurement of the amount of acid necessary to neutralize carbonate ( $\text{CO}_3^{2-}$ ) and bicarbonate ( $\text{HCO}_3^-$ ) ions in the water, and represents the buffering capacity of a body of water. The alkalinity of lake water depends on the types of minerals in the surrounding soils and in the bedrock. It also depends on how often the lake water comes in contact with these minerals. If a lake gets groundwater from aquifers containing limestone minerals such as calcium carbonate ( $\text{CaCO}_3$ ) or dolomite ( $\text{CaMgCO}_3$ ), alkalinity will be high. The median alkalinity in Lake County lakes (162 mg/L) is considered moderately hard according to the hardness classification scale of Brown, Skougstad and Fishman (1970). Because hard water (alkaline) lakes often have watersheds with fertile soils that add nutrients to the water, they usually produce more fish and aquatic plants than soft water lakes. Since the majority of Lake County lakes have a high alkalinity they are able to buffer the adverse effects of acid rain.

#### Conductivity and Chloride:

Conductivity is the inverse measure of the resistance of lake water to an electric flow. This means that the higher the conductivity, the more easily an electric current is able to flow through water. Since electric currents travel along ions in water, the more chemical ions or dissolved salts a body of water contains, the higher the conductivity will be. Accordingly, conductivity has been correlated to total dissolved solids and chloride ions. The amount of dissolved solids or conductivity of a lake is dependent on the lake and watershed geology, the size of the watershed flowing into the lake, the land uses within that watershed, and evaporation and bacterial activity. Many Lake County lakes have elevated conductivity levels in May, but not during any other month. This was because chloride, in the form of road salt, was washing into the lakes with spring rains, increasing conductivity. Most road salt is sodium chloride, calcium chloride, potassium chloride, magnesium chloride or ferrocyanide salts. Beginning in 2004, chloride concentrations are one of the parameters measured during the lake studies. Increased chloride concentrations may have a negative impact on aquatic organisms. Conductivity changes occur seasonally and with depth. For example, in stratified lakes the conductivity normally increases in the hypolimnion as bacterial decomposition converts organic materials to bicarbonate and carbonate ions depending on the pH of the water. These newly created ions increase the conductivity and total dissolved solids. Over the long term, conductivity is a good indicator of potential watershed or lake problems if an increasing trend is noted over a period of years. It is also important to know the conductivity of the water when fishery assessments are conducted, as electroshocking requires a high enough conductivity to properly stun the fish, but not too high as to cause injury or death.

Since 2004 measurements taken in Lake County lakes have exhibited a trend of increasing salinity measured by chloride concentrations. The median near surface chloride concentration of

Lake County Lakes was 142 mg/L. In 2009, Schreiber Lake had the lowest chloride concentration recorded at 2.7 mg/L. The maximum average chloride measurement was at 2760 mg/L at IMC. It is important to note that salt water is denser than fresh water and so it accumulates in the hypolimnion or near the bottom of the lake, this can impact mixing of bottom waters into surface waters in lakes that experience turnover. This phenomenon could have far reaching impacts to an entire ecosystem within a lake. Further, in studies conducted in Minnesota, chloride concentrations as low as 12 mg/L have been found to impact some species of algae.

#### pH:

pH is the measurement of hydrogen ion ( $H^+$ ) activity in water. The pH of pure water is neutral at 7 and is considered acidic at levels below 7 and basic at levels above 7. Low pH levels of 4-5 are toxic to most aquatic life, while high pH levels (9-10) are not only toxic to aquatic life they may also result in the release of phosphorus from lake sediment. The presence of high plant densities can increase pH levels through photosynthesis, and lakes dominated by a large amount of plants or algae can experience large fluctuations in pH levels from day to night, depending on the rates of photosynthesis and respiration. Few, if any pH problems exist in Lake County lakes. Typically, the flooded gravel mines in the county are more acidic than the glacial lakes as they have less biological activity, but do not usually drop below pH levels of 7. The median near surface pH value of Lake County lakes was 8.37, with a minimum average of 7.07 in Bittersweet #13 Lake and a maximum of 10.40 in Summerhill Estates Lake.

#### **Eutrophication and Trophic State Index:**

The word *eutrophication* comes from a Greek word meaning “well nourished.” This also describes the process in which a lake becomes enriched with nutrients. Over time, this is a lake’s natural aging process, as it slowly fills in with eroded materials from the surrounding watershed and with decaying plants. If no human impacts disturb the watershed or the lake, natural eutrophication can take thousands of years. However, human activities on a lake or in the watershed accelerate this process by resulting in rapid soil erosion and heavy phosphorus inputs. This accelerated aging process on a lake is referred to as cultural eutrophication. The term trophic state refers to the amount of nutrient enrichment within a lake system. *Oligotrophic* lakes are usually deep and clear with low nutrient levels, little plant growth and a limited fishery. *Mesotrophic* lakes are more biologically productive than oligotrophic lakes and have moderate nutrient levels and more plant growth. A lake labeled as *eutrophic* is high in nutrients and can support high plant densities and large fish populations. Water clarity is typically poorer than oligotrophic or mesotrophic lakes and dissolved oxygen problems may be present. A *hypereutrophic* lake has excessive nutrients, resulting in nuisance plant or algae growth. These lakes are often pea-soup green, with poor water clarity. Low dissolved oxygen may also be a problem, with fish kills occurring in shallow, hypereutrophic lakes more often than less enriched lakes. As a result, rough fish (tolerant of low dissolved oxygen levels) dominate the fish community of many hypereutrophic lakes. The categorization of a lake into a certain trophic state should not be viewed as a “good to bad” categorization, as most lake residents rate their

lake based on desired usage. For example, a fisherman would consider a plant-dominated, clear lake to be desirable, while a water-skier might prefer a turbid lake devoid of plants. Most lakes in Lake County are eutrophic or hypereutrophic. This is primarily as a result of cultural eutrophication. However, due to the fertile soil in this area, many lakes (especially man-made) may have started out under eutrophic conditions and will never attain even mesotrophic conditions, regardless of any amount of money put into the management options. This is not an excuse to allow a lake to continue to deteriorate, but may serve as a reality check for lake owners attempting to create unrealistic conditions in their lakes.

The Trophic State Index (TSI) is an index which attaches a score to a lake based on its average total phosphorus concentration, its average Secchi depth (water transparency) and/or its average chlorophyll *a* concentration (which represent algae biomass). It is based on the principle that as phosphorus levels increase, chlorophyll *a* concentrations increase and Secchi depth decreases. The higher the TSI score, the more nutrient-rich a lake is, and once a score is obtained, the lake can then be designated as oligotrophic, mesotrophic or eutrophic. Table 1 (below) illustrates the Trophic State Index using phosphorus concentration and Secchi depth.

**Table 1. Trophic State Index (TSI).**

Trophic State	TSI score	Total Phosphorus (mg/L)	Secchi Depth (feet)
Oligotrophic	<40	≤ 0.012	>13.12
Mesotrophic	≥40<50	>0.012 ≤ 0.024	≥6.56<13.12
Eutrophic	≥50<70	>0.024 ≤ 0.096	≥1.64<6.56
Hypereutrophic	≥70	>0.096	< 1.64