English Lake

Manitowoc County, Wisconsin

Comprehensive Management Plan

May 2012

Sponsored by:

English Lake Protection & Rehabilitation District
WDNR Grant Program

LPL-1365-10, LPL-1366-10, LPL-1391-11

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Onterra LLC
Lake Management Planning

English Lake

Manitowoc County, Wisconsin

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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

English Lake Planning Committee

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Onterra LLC
Lake Management Planning

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1.0 INTRODUCTION

English Lake, Manitowoc County, is a 51-acre seepage lake with a maximum depth of 85 feet (Map 1). This lower eutrophic lake has a relatively small watershed when compared to the size of the lake. English Lake contains 14 native plant species, of which coontail is the most common plant. Two exotic plants (Eurasian water milfoil hybrid and curly-leaf pondweed) are known to exist in English Lake.

Field Survey Notes

Fairly clear water observed during early season surveys. Algae growth accumulated during the summer months, mainly in the form of filamentous algae. Several acres of surface matted EWM growth in late summer.

Photograph 1.0-1 English Lake, Manitowoc County

Lake at a Glance - English Lake

Morphology	
Acreage	51
Maximum Depth (ft)	85
Mean Depth (ft)	36
Shoreline Complexity	0.3
Vegetation	
Curly-leaf Survey Date	April 22, 2010
Comprehensive Survey Date	July 27, 2010
Number of Native Species	13
Threatened/Special Concern Species	None
Exotic Plant Species	Eurasian water milfoil (hybrid), curly-leaf pondweed
Simpson's Diversity	0.78
Average Conservatism	5.0
Water Quality	
Trophic State	Lower eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	Ranges from 7.8 to 9.2
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	3:1

The English Lake District Protection & Rehabilitation District (ELPRD) has sponsored 6 lake management projects since 1991 in an effort to improve and protect the lake. The focus of these projects was related to diagnosing and implementing nutrient control within the English Lake watershed.

In 2006, the Wisconsin Department of Natural Resources (WDNR) Science Services completed a point-intercept macrophyte survey of the lake and did not locate any exotic species. Since this survey, curly-leaf pondweed (CLP) and Eurasian water milfoil (EWM) have both been discovered in English Lake and a subsequent herbicide treatment of CLP has occurred.

After district members observed a massive outbreak of a suspicious-looking plant, Onterra was contracted to complete a survey of the lake for EWM. The August 2009 survey located a relatively heavy infestation of EWM throughout the majority of the lake's littoral zone (Map 6). A short-term EWM control plan (included within the Aquatic Plant Section) was developed that included aggressive herbicide treatments to be conducted during the spring of 2010. As discussed within the Aquatic Plants Section, this treatment was not as effective as hoped for, and a treatment in 2011 was postponed until studies regarding hybrid Eurasian water milfoil could be conducted, and a strategy formulated for 2012 could be formed.

The ELPRD was interested in completing this planning project for three main reasons: 1) to learn the extent of the exotic plants which occur in their lake, 2) to understand their lake ecosystem more fully, and 3) to be eligible to receive additional WDNR grant funds to address AIS and other goals of lake stakeholders. These goals were accomplished during the course of the project, and in fact, much more was learned regarding the lake's water quality and exotic species than what was anticipated.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter.

The highlights of this component are described below in chronological order. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting
On March 19, 2011, a project kick-off meeting was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by ELPRD board members. The attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I
On November 10, 2011, Tim Hoyman and Dan Cibulka of Onterra met with members of the English Lake Planning Committee for nearly 3.5 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including, Eurasian water milfoil treatment results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including water quality and filamentous algae concerns, as well as Eurasian water milfoil management.

Management Plan Review and Adoption Process
In early November, 2011, a written results section was delivered to ELPRD planning committee members for their review prior to the scheduled Planning Meeting. During the planning meeting, several topics regarding the results were discussed, and changes to the results sections of the report modified as needed. On November 25, 2011, a copy of the first draft management plan was sent to the WDNR and ELPRD for review. WDNR comments were received on December 1, 2011 and integrated within the report during April of 2012. A final draft was submitted to the WDNR and ELPRD in May of 2012.

Wrap-Up Meeting

In the fall/winter of 2012, a wrap-up meeting will be held with the ELPRD and general public to discuss the conclusion of the studies that took place on English Lake. This meeting will be timed so that the results of the 2012 Eurasian water milfoil herbicide treatment may be presented upon and discussed.

Stakeholder Survey

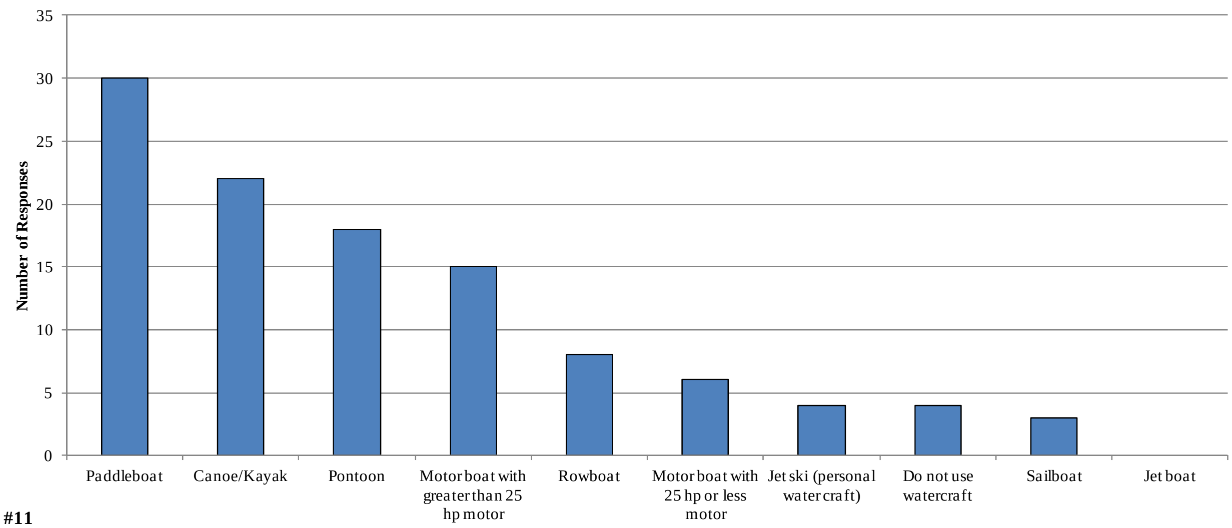
During June 2011, a seven-page, 31-question survey was mailed to 63 riparian property owners in the English Lake watershed. 67 percent of the surveys were returned and those results were entered into a spreadsheet by members of the English Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is summarized below and integrated within the appropriate sections of the management plan as well.

Based upon the results of the stakeholder survey, much was learned about the people that use and care for English Lake. Nearly half of stakeholders (49%) are year-round residents, while 26% describe themselves as seasonal residents and 14% visit on weekends through the year. About 65% of stakeholders have owned their property for over 10 years, and 28% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. The majority of survey respondents indicated that they use either a paddleboat, canoe/kayak, pontoon boat or a combination of these three vessels on English Lake (Question 11). Motor boats with greater than a 25 hp motor were also a popular option. On a relatively small lake such as English Lake, the importance of responsible boating activities is increased. Through the stakeholder survey process and within the written comments of the survey results (Appendix B – written comments) concerns over boating activity were expressed. Several questions were developed by the ELPRD to poll stakeholders on their thoughts regarding this matter. Overall, about 64% of survey respondents indicated that the safety practices of English Lake boaters were “good” or “excellent” (Question 12). Any unsafe boating practices mainly take place on holidays and weekends, coinciding at times when boat traffic is likely at its peak (Question 13). Although it seems that English Lake residents are mainly content with current boating practices, they were split nearly equally when asked if adoption of slow-no-wake hours were needed to improve boater safety (Question 14).

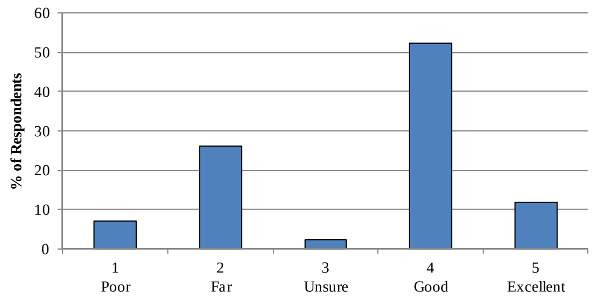
Right now, the primary concerns of the English Lake residents are with the health of the ecosystem, more specifically, perceived water quality degradation, presence of aquatic invasive species, and algae growth within the lake. These issues were ranked as the top three issues that are potentially negatively impacting English Lake (Question 22) and also the top three issues that are of concern to English Lake stakeholders. As a part of this project, studies took place to investigate further the extent of water quality degradation and aquatic invasive species presence in English Lake. These issues, as well as others, are discussed thoroughly within the Results & Discussion portion of this document.

Question 11: What types of watercraft do you currently use on the lake?



#11

Question 12: In general, would you say the safety practices of boaters on English Lake are:



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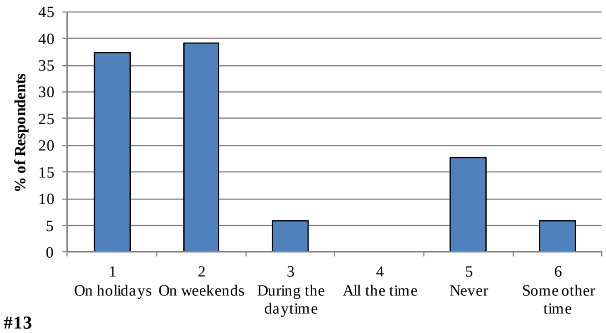
Question 13: When, if at all, are you aware of unsafe boating practices?



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Question 14: Do you believe adoption of slow-no-wake hours are needed to improve boater safety on English Lake?

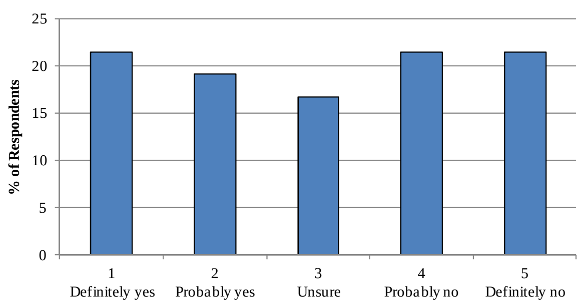

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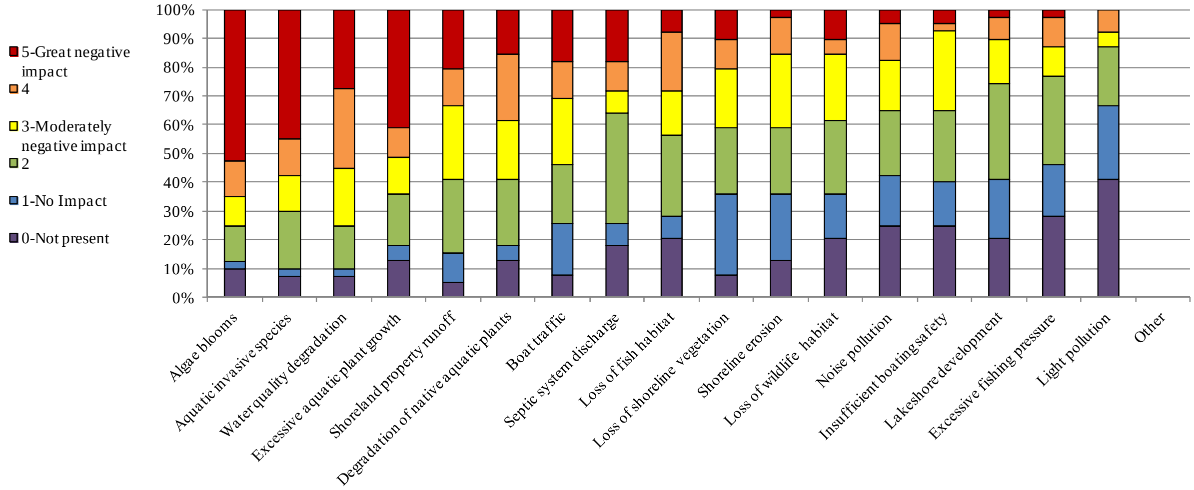
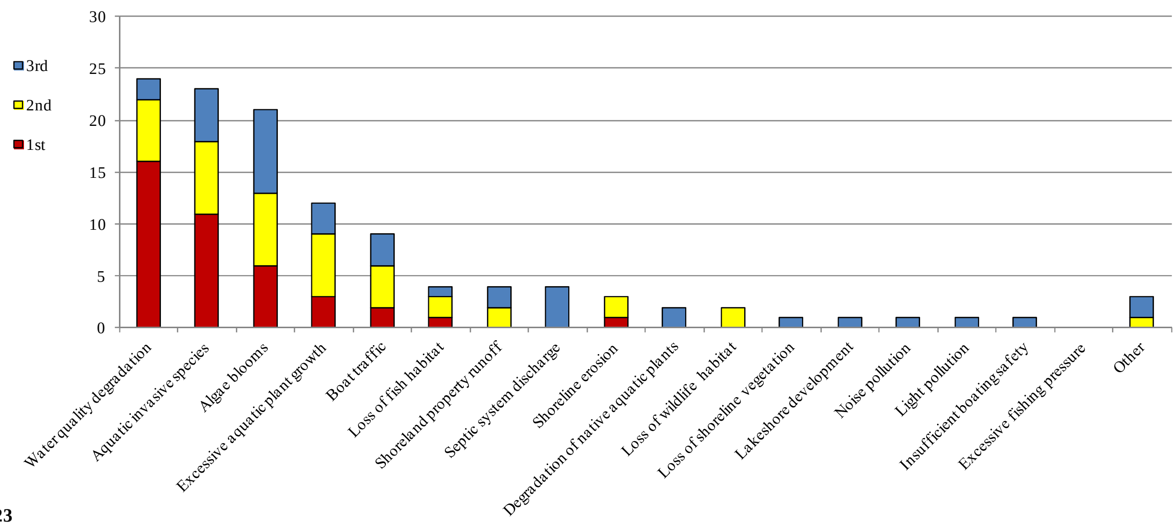
Figure 2.0-1. Select survey responses from the English Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 22: To what level do you believe these factors may be negatively impacting English Lake?



#22

Question 23: Please rank your top three concerns regarding English Lake.



#23

Figure 2.0-2. Select survey responses from the English Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analysis are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on English Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the English Lake's water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-a concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter et al. 1994, Dinius 2007, and Smith et al. 1991).

Trophic State

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the trophic state of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: oligotrophic, mesotrophic, and finally eutrophic. Every lake will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in many Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

Trophic states describe the lake's ability to produce plant matter (production) and include three continuous classifications: Oligotrophic lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. Eutrophic lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. Mesotrophic lakes fall between these two categories.

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a more clear understanding of the lake's trophic state while facilitating clearer long-term tracking. Carlson (1977) presented a trophic state index that gained great acceptance among lake managers.

Limiting Nutrient

The limiting nutrient is the nutrient which is in shortest supply and controls the growth rate of algae and some macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen profiles are created simply by taking readings at different water depths within a lake. Although it is a simple procedure, the completion of several profiles over the course of a year or more provides a great deal of information about the lake. Much of this information relates to whether the lake thermally stratifies or not, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fishkills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

> **Lake stratification** occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epilimnion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Internal Nutrient Loading*In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. months at a time).
- Lakes with hypolimnetic total phosphorus values less than 200 μg/L.

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 μg/L.
- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

Specific to the final bullet-point, during the watershed modeling assessment, the results of the modeled phosphorus loads are used to estimate in-lake phosphorus concentrations. If these estimates are much lower than those actually found in the lake, another source of phosphorus must be responsible for elevating the in-lake concentrations. Normally, two possibilities exist; 1) shoreland septic systems, and 2) internal phosphorus cycling. If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of English Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: shallow (mixed) or deep (stratified). Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or all of the lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

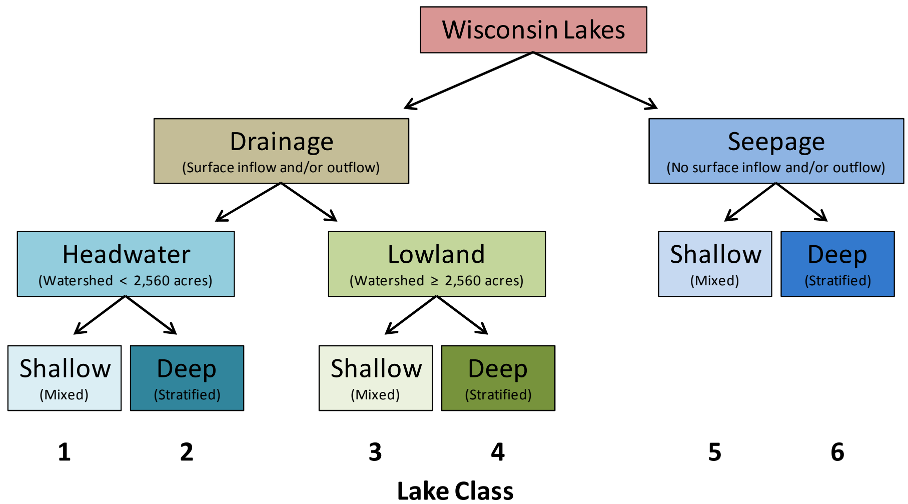


Figure 3.1-1. Wisconsin Lake Classifications. English Lake is classified as a deep (stratified), seepage lake (Class 6). Adapted from WDNR PUB-SS-1044 2008.

Lathrop and Lillie developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). **Ecoregions** are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. English Lake is within the Northern Lakes and Forests ecoregion.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act (WDNR 2009). It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and their experience.

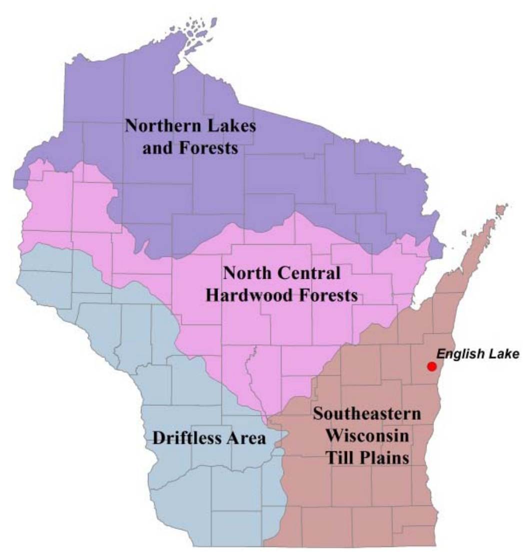


Figure 3.1-2. Location of English Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from English Lake are displayed in Figures 3.1-3 - 3.1-5. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

English Lake Water Quality Analysis

English Lake Long-term Trends

As described above, this long-term trend analysis focuses upon three parameters: total phosphorus, chlorophyll-*a*, and Secchi disk clarity. For English Lake, a moderate amount of historic data exists in the WDNR and EPA databases. With the data available, it is not possible to ascertain whether any trends in surface total phosphorus levels over time are occurring. However, it appears that total phosphorus levels fluctuate annually, and that growing season phosphorus levels are at times much higher than during the summer months (Figure 3.1-3). The reason growing season phosphorus is higher than summer phosphorus in English Lake is discussed in the Internal Nutrient Loading section. Combining all of the available total phosphorus data together and calculating an overall weighted average yields a growing season value that falls into the *Poor* category and a summer value that falls into the *Fair* category, exceeding both the deep seepage lakes state median and the Southeast Wisconsin Till Plains Ecoregion median.

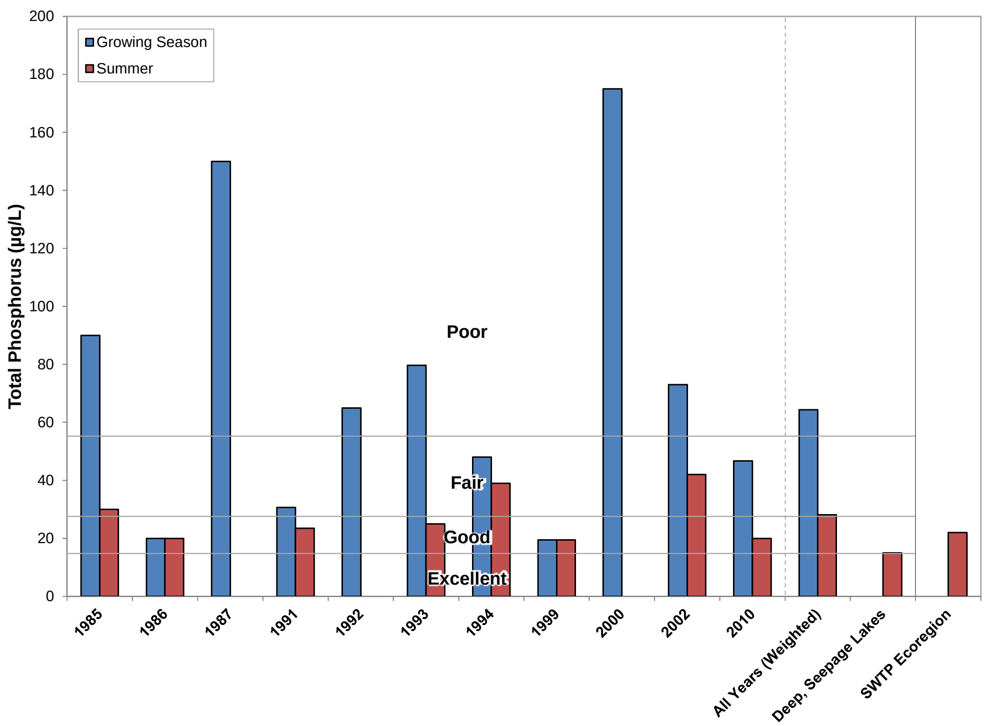


Figure 3.1-3. English Lake, state-wide class 6 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

A moderate amount of historic chlorophyll-*a* data from English Lake exists as well. While enough data are not available to determine if any significant long-term trends are occurring, chlorophyll-*a* values, most notable summer values, have declined over the time period for which data are available (Figure 3.1-4). Like total phosphorus, these values tend to fluctuate on an annual basis and growing season levels are higher than those of just the summer months. In 2010, chlorophyll-*a* values fell into the *Fair* category for the growing season and the *Good* category for the summer months, and correlates with the 2010 total phosphorus values (Figure 3.1-3). Creating a weighted average using all of the available chlorophyll-*a* data indicates that English Lake falls into the *Fair* category for chlorophyll-*a* values, falling above the median for deep seepage lakes and the ecoregion median (Figure 3.1-4).

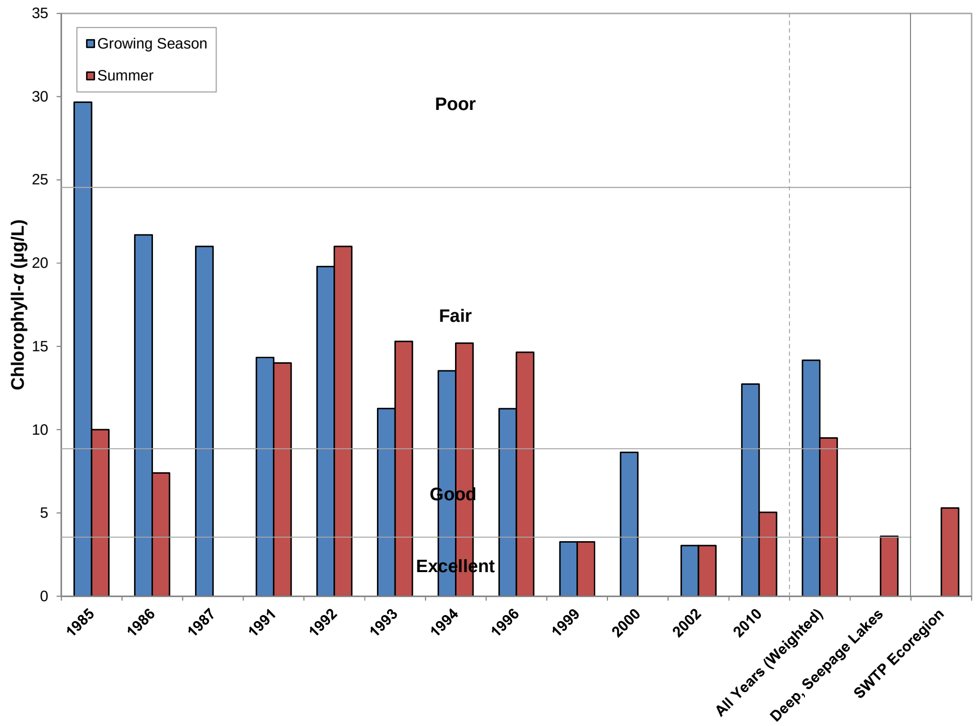


Figure 3.1-4. English Lake, state-wide class 6 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The largest amount of historic water quality data from English Lake exists for Secchi disk transparency. Data are available from 1976, and 1989-2010 collected by English Lake volunteer monitors and professionals including Onterra. Having over 20 years of consecutive water clarity data is very helpful in understanding changes over time. Like the other parameters, the Secchi disk data from English Lake exhibits high annual variability, with years ranging from *Excellent* to *Poor* (Figure 3.1-5). Looking at the data from 1989 to 2010, it appears that water clarity in English Lake fluctuates over five- to six-year periods. These variations are likely due to a number of factors including environmental circumstances (precipitation, temperature, etc.) and also anthropogenic (human caused) factors. In a watershed such as English Lake's watershed, annual changes to the landscape such as crop rotations or winter cover crop plantings will likely change the amount of runoff the lake sees for that year. Couple this with a seasonal weather abnormalities (more or less precipitation, for example) and the opportunity for wide fluctuations exists in the lake. Overall, a weighted average for Secchi disk clarity falls into the *Good* category, below the deep seepage lakes median and above the ecoregion median (Figure 3.1-5).

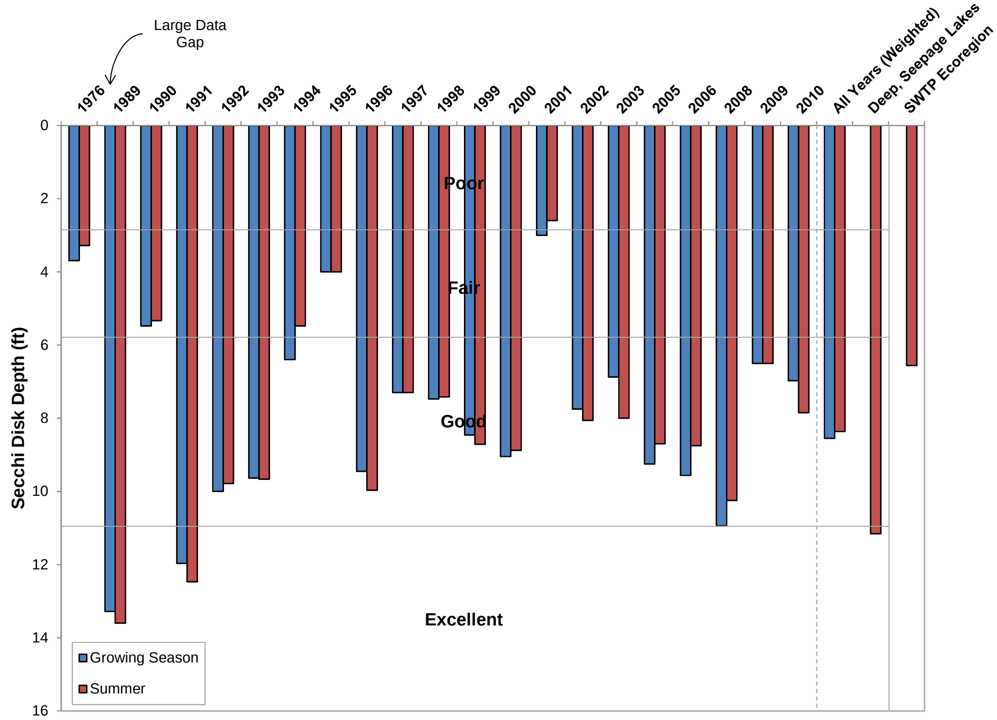


Figure 3.1-5. English Lake, state-wide class 6 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of English Lake

Using midsummer nitrogen and phosphorus concentrations from English Lake, nitrogen:phosphorus ratio of 51:1 was calculated. This finding indicates that English Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

English Lake Trophic State

Figure 3.1-6 contains the trophic state index (TSI) values for English Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to upper eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* WTSI values, it can be concluded that English Lake is in an lower eutrophic state.

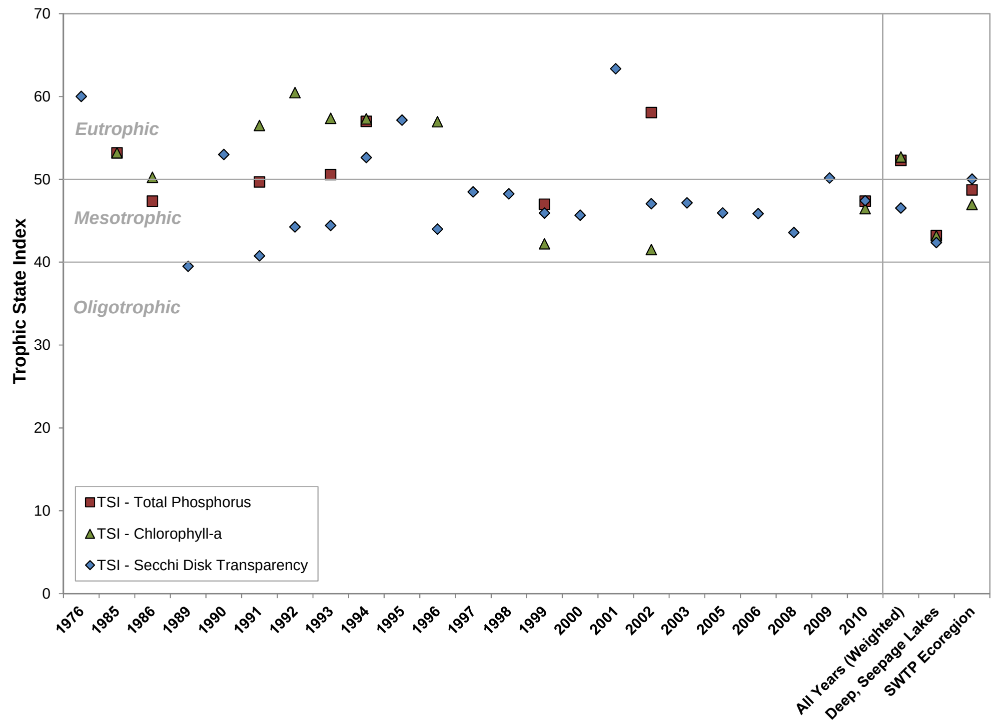


Figure 3.1-6. English Lake, state-wide class 6 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in English Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling event at English Lake during 2010 and 2011. These data are available in Appendix B; while select profiles are displayed in Figure 3.1-7 to represent yearly conditions in the lake.

The profiles indicate that the lake stratifies strongly following spring mixing, and continues to remain stratified until late fall when the lake mixes again. In winter, the lake is inversely stratified, with the warmer (denser) water falling to the lake bottom and the colder (near-frozen) water located near the surface. In the summer and winter months following mixing, an anoxic (little to no oxygen) zone forms in the lower portion of the lake. Through most of the summer, this anoxic zone can be found beginning at 15 to45 feet of depth. Oxygen is depleted due to the decomposition of organic materials, which settle in the lower areas of the lake. Although this process is naturally occurring, it may be accelerated through inputs of additional nutrients. The excess nutrients spur more plant and algae growth, which in turn requires more oxygen to complete the decomposition process. This anoxic zone also plays a role in the release of nutrients from the bottom of the lake.

Internal Nutrient Loading

Watershed modeling based on the area and land cover types within English Lake's watershed predicated a within-lake growing season total phosphorus average of 25.0 µg/L; nearly 22.0 µg/L less than the observed 2010 growing season average of 46.8 µg/L. While this type of modeling is limited when predicting the phosphorus content of seepage lakes, it still servers its purpose to detect abnormalities such as these. This discrepancy between observed and predicted values indicates that there is an unaccounted phosphorus source(s) entering English Lake.

As discussed earlier, in lakes that stratify in the summer and develop a hypolimnion (bottom layer) devoid of oxygen, accumulated sediment phosphorus can be released into this layer and become mixed throughout the entire water column during turnover events fueling algae blooms. Dissolved oxygen/temperature profiles taken on English Lake during the growing season indicate that the lake was stratified throughout, with a developed anoxic hypolimnion beginning at around 15 to 45 feet. The average total phosphorus concentration within the hypolimnion in 2010 was 509 µg/L, well above the 200µg/L internal nutrient loading threshold for candidate lakes.

The Osgood Index is a measure relating a lake's volume to its surface area and is used to determine whether a lake is dimictic or polymictic. Dimictic lakes completely mix or turnover two times per year, once in spring and again in fall, while polymictic lakes have the potential to turn over multiple times per year depending upon wind events. English Lake, being deep with a smaller surface area, has an Osgood Index value of 24, indicating that it is a dimictic system. During the growing season while the lake is stratified, phosphorus is released and is essentially trapped in the hypolimnion where it is unavailable to algae that are growing in the warmer surface waters above. Late in the fall/early winter, the temperature of the epilimnion (upper layer) cools and stratification breaks and the lake turns over. The built-up phosphorus in the hypolimnion is then distributed throughout the entire water column.

The phosphorus delivery from the hypolimnion to the entire water column in the fall does not present immediate problems as algae and aquatic macrophytes are not actively growing at that time. However, a portion of this phosphorus remains in the epilimnion throughout the winter and into spring where it then becomes available to algae and macrophytes that can lead to unwanted algae blooms and nuisance aquatic plant growth. Additionally, phosphorus is released into the anoxic hypolimnion during winter which is then released into the entire water column during spring turnover. In English Lake, for an unknown reason, it is believed that rather than fueling free-floating algae which is measured by chlorophyll-*a*, the excess phosphorus may be fueling the filamentous algae observed growing on the aquatic macrophytes.

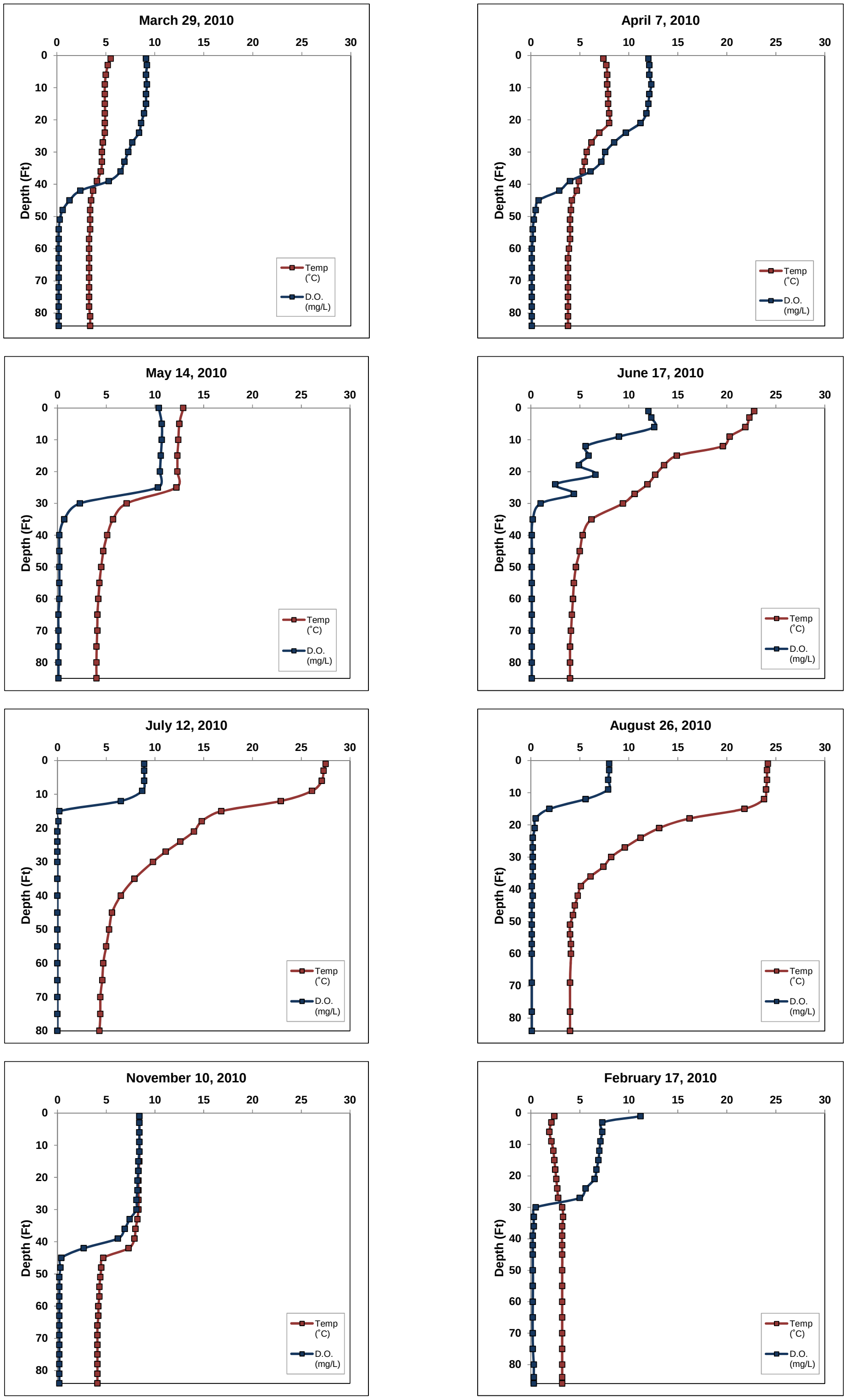


Figure 3.1-7. English Lake dissolved oxygen and temperature profiles.

As seen in Figure 3.1-8, total phosphorus concentrations within the oxygenated epilimnion declined throughout the summer (reason discussed in next section), but rose during mixing events. However, in the anoxic hypolimnion, total phosphorus concentrations rose throughout the open-water season as more and more phosphorus was released from the bottom sediments. Hypolimnetic phosphorus values declined following mixing events as this phosphorus was distributed throughout the entire water column. The impact internal nutrient loading on English Lake and the estimated phosphorus loading will be discussed in the Watershed Section.

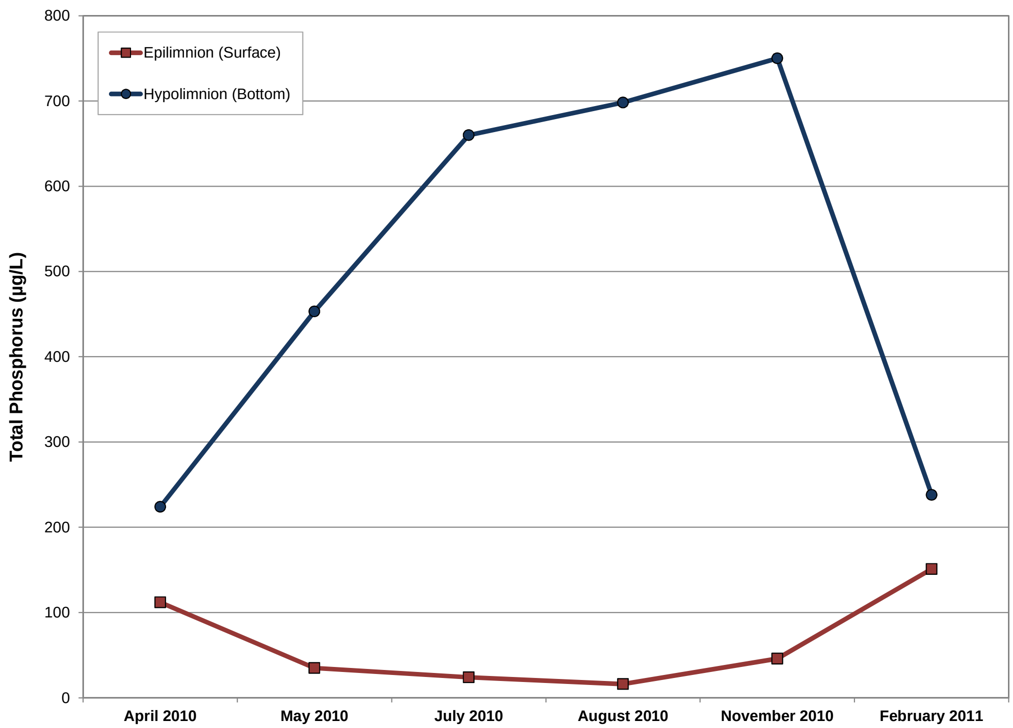


Figure 3.1-8. English Lake 2010-2011 epilimnetic and hypolimnetic total phosphorus concentrations.

Additional Water Quality Data Collected at English Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of English Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Olszyk, 1980). The 2010-2011 pH of surface water in English Lake was found to be alkaline in 2010-2011, with values ranging from 7.8 to 9.2. This higher pH is likely due to a higher concentration of calcium carbonate within the water, or marl.

English Lake, being a seepage lake, receives a portion of its water via groundwater inputs. The groundwater carries high amounts of dissolved minerals, especially calcium carbonate. When calcium carbonate concentrations reach saturation levels, it precipitates and sinks to the bottom. These precipitates absorb phosphorus, pulling phosphorus out of the epilimnion and reducing algae growth. This phenomena is one reason why epilimnetic phosphorus and chlorophyll-*a* values were observed to decline during the summer of 2010 (Figure 3.1-8). This decline is also brought about by sedimentation of algal phosphorus as they cells die and sink to the bottom of the lake.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. As previously discussed, these compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in English Lake was measured at 149.0 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so English Lake's pH values fall within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of English Lake was found to be 35.1 mg/L, placing English Lake in the *high susceptibility* category for zebra mussel establishment if they are ever introduced. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not locate any larval zebra mussels in the 2010 samples. However, English Lake contains optimal conditions for supporting zebra mussels and with its close proximity to Lake Michigan, lake residents should periodically inspect their docks and bottoms of boats for mussels and report any findings to the WDNR or Onterra. Cleaning, removal of water, and inspecting of boats entering and leaving English Lake is especially important for this reason.

3.2 Watershed Assessment

Watershed Modeling

A lake's flushing rate is simply a determination of the time required for the lake's water volume to be completely exchanged. Residence time describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake; 1) the size of the watershed, and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load.

The type of land cover that exists in the watershed determines the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas, minimize infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased phosphorus and pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

In systems with high WS:LA ratios, like those exceeding 10-15:1, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

English Lake's watershed covers approximately 226 acres of land in Manitowoc County (Map 2). The land cover within the lake's watershed is comprised of drain tile A's watershed (59 acres), English Lake's surface (51 acres), row crop agriculture (43 acres), the sedimentation basin's watershed (35 acres), rural residential areas (28 acres), forest (7 acres), and pasture/grasslands (3 acres) respectively (Figure 3.2-1). The majority of drain tile A and the sedimentation basin's watershed are comprised of row crop agriculture, making this land cover type the most prevalent within English Lake's watershed. The watershed to lake area ratio was calculated to be approximately 3:1. As discussed previously, the land cover within the watersheds of lakes with smaller watershed to lake area ratios has a greater influence water quality.

WiLMS was utilized to model the land cover types within the English Lake watershed and quantify nutrient runoff into the waterbody. Modeling using the land cover types and acreages in Figure 3.2-1, the model estimated that approximately 77 pounds of phosphorus is delivered to English Lake from external sources on an annual basis. Based on this information, WiLMS predicted a growing season, in-lake phosphorus concentration of 25 µg/L. However, the sampling conducted in 2010 found the growing season in-lake phosphorus concentration was 46.8 µg/L and a weighted mean of 64.4 µg/L when English Lake's entire dataset is considered. For reasons discussed in the Water Quality Section, this discrepancy between predicted and in-field measurements of phosphorus is believed to be caused by internal nutrient loading. Using WiLMS, it was predicted that 582 lbs of phosphorus are released from bottom sediments in English Lake on an annual basis (Figure 3.3-2). When adding the internal phosphorus loading estimate into the WiLMS model, it predicts a growing season mean of 85 µg/L, nearly 40µg/L higher than what was observed in 2010, but only 21 µg/L higher than the weighted growing season mean. This indicates that only a portion of the phosphorus being released from the bottom is being entrained by surface waters of the lake.

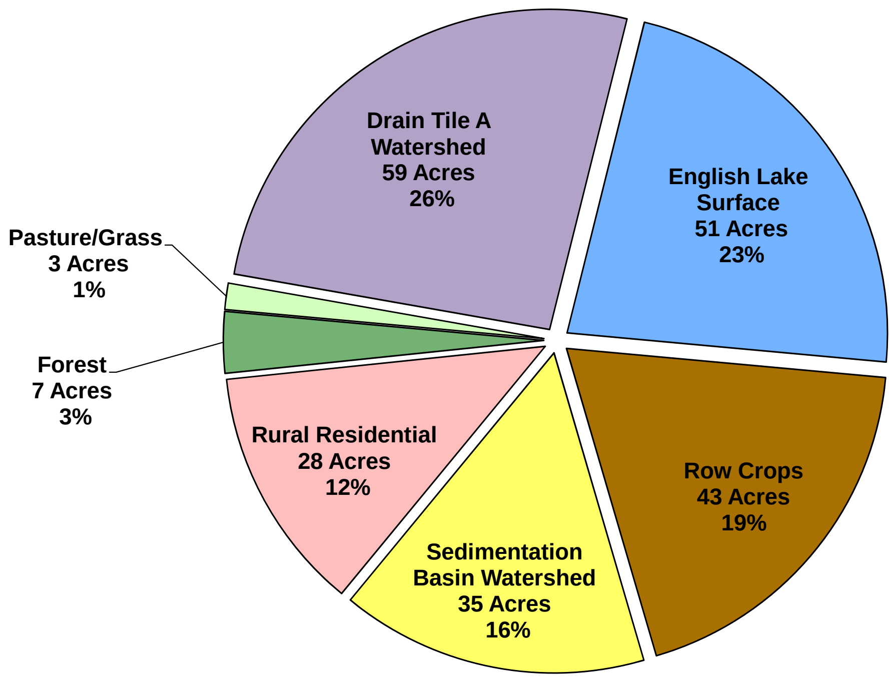


Figure 3.2-1. English Lake watershed land cover types in acres. Based upon the National Land Cover Database (NLCD – Fry et. al 2011)

Using the actual growing season phosphorus (46.8µg/L) from 2010, the WiLMS model was back-calculated to determine how much of the phosphorus from internal nutrient loading would be required to generate this value. Figure 3.2-2 shows that approximately 157 lbs (27%) of phosphorus of the total 582 lbs delivered via internal nutrient loading were available in the epilimnion in 2010. Though only a fraction of the total load from internal nutrient loading, it still is the largest contributor of phosphorus to surface waters in English Lake.

Following internal nutrient loading, row crop agriculture is the second largest contributor of phosphorus to English Lake; delivering approximately 37 lbs of phosphorus to the lake annually. Approximately 13 lbs (2%) of the annual phosphorus load comes from atmospheric deposition of phosphorus directly on the surface of the lake. Annual phosphorus loading from drain tile A and the sedimentation basin watershed (Map 2) were calculated using phosphorus concentrations and flow data collected from studies conducted in 2000 and 2005, and deliver 8 lbs (1%) and 15 lbs (2%) respectively (NES Ecological Services and Onterra, LLC 2000, 2005). Areas of rural residential, forest, and pasture/grass land cover export negligible amounts of phosphorus to the lake annually (Figure 3.2-2).

Regarding external sources of phosphorus loading to English Lake, the greatest concern is large amount of row crop agriculture present within the lake's watershed. To date, the ELPRD has taken great strides towards minimizing external phosphorus sources entering the lake, including the construction of the aforementioned sediment detention basin and re-location of a cattle yard in 1998, and the re-routing of a drain tile that once emptied into the lake. A study conducted in

2000 found that the detention basin was functioning as intended; the basin was retaining nutrients and reducing the amount entering English Lake.

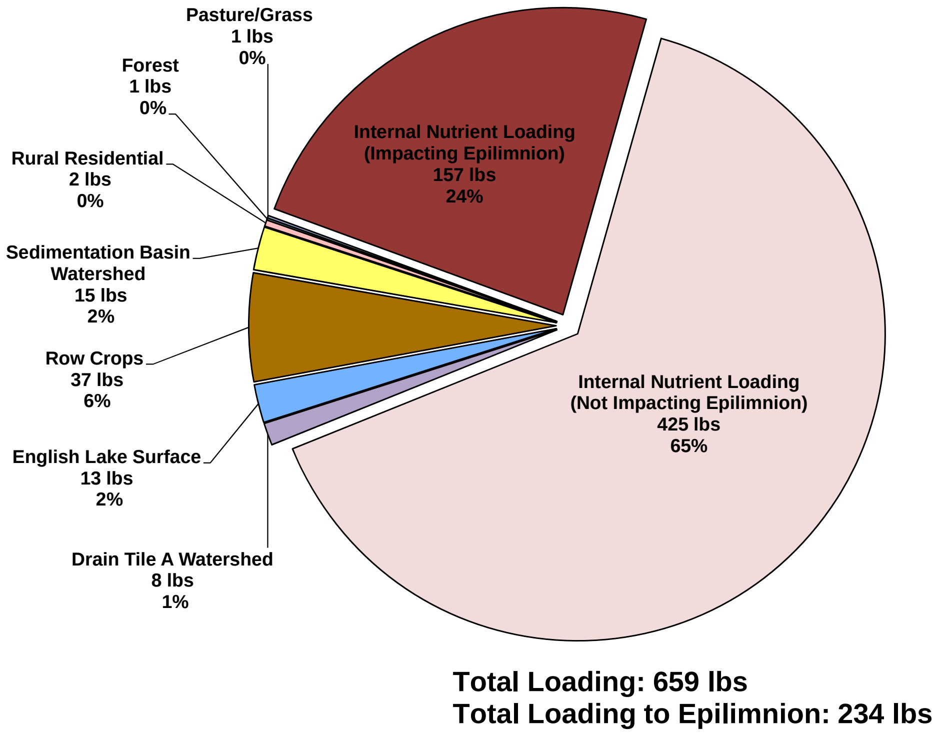


Figure 3.2-2. English Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

At present, the largest and most controllable factor impacting English Lake's water quality is internal nutrient loading. The ELPRD has worked at minimizing external sources of phosphorus over the past 15 years. Even if all of the agricultural land cover within the English Lake watershed could be converted to forest and/or pasture/grass, internal nutrient loading would still continue to impact the lake's water quality. Years of agricultural runoff carrying nutrient-bound sediments have likely lead to the buildup of sediment phosphorus in English Lake.

There are actions that can be taken to reduce this internal source, but their costs can often be substantial. And before control efforts could be initiated, a more in-depth diagnostic/feasibility study specifically attempting to better quantify the amount of phosphorus being delivered to surface waters via internal nutrient loading on English Lake would have to be conducted. This would include a more rigorous sampling regime of epilimnetic and hypolimnetic phosphorus values throughout the year and the collection and analysis of sediment cores to determine phosphorus-release rates. Details surrounding this potential future study and the pros and cons of addressing internal nutrient loading are further discussed in the Summary and Conclusions and Implementation Plan sections.

Shoreline Assessment

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to 35 feet shoreland). When a lake's shoreline is developed, the increased impervious surface, removal of natural vegetation, installation of septic systems, and other human practices can severely increase nutrient loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) affects on the lake is important in maintaining the quality of the lake's water and habitat. Along with this, the immediate shoreland area is often one of the easiest and most beneficial areas to restore.

The intrinsic value of natural shorelines is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. The roots of shoreland plants stabilize the soil, thereby preventing shoreline erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Between the abundant wildlife, the lush vegetation, and the presence of native flowers, shorelands also provide natural scenic beauty and a sense of tranquility for humans.

A lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelines are more stressful on a lake ecosystem, while definite benefits occur from shorelines that are left in their natural state. Figure 3.2-3 displays a diagram of shoreline categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreline has been left in its original state.

Urbanized: This type of shoreline has essentially no natural habitat. Areas that are mowed or unnaturally landscaped to the water's edge and areas that are rip-rapped or include a seawall would be placed in this category.

Developed-Unnatural: This category includes shorelines that have been developed, but only have small remnants of natural habitat yet intact. A property with many trees, but no remaining understory or herbaceous layer would be included within this category. Also, a property that has left a small (less than 30 feet), natural buffer in place, but has urbanized the areas behind the buffer would be included in this category.

Developed-Semi-Natural: This is a developed shoreline that is mostly in a natural state. Developed properties that have left much of the natural habitat in state, but have added gathering areas, small beaches, etc within those natural areas would likely fall into this category. An urbanized shoreline that was restored would likely be included here, also.

Developed-Natural: This category includes shorelines that are developed property, but essentially no modifications to the natural habitat have been made. Developed properties that have maintained the natural habitat and only added a path leading to a single pier would fall into this category.

Natural/Undeveloped: This category includes shorelines in a natural, undisturbed state. No signs of anthropogenic impact can be found on these shorelines. In forested areas, herbaceous, understory, and canopy layers would be intact.

Figure 3.2-3. Shoreline assessment category descriptions.

On English Lake, the development stage of the entire shoreline was surveyed during the fall of 2010, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.2-4.

English Lake has stretches of shoreland that fit four of the five shoreland assessment categories. In all, no areas of natural/undeveloped shoreline and only 0.1 miles of developed-natural shoreline were observed during the survey (Figure 3.2-4). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.7 miles of urbanized and developed–unnatural shoreline were observed. If restoration of the English Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreline lengths around the entire lake.

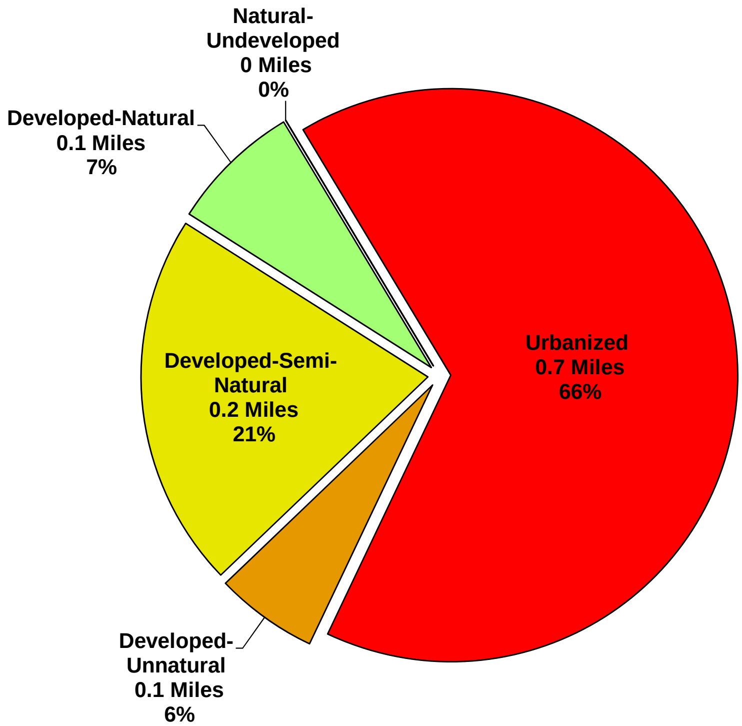


Figure3.2-4. English Lake shoreland categories and total lengths. Based upon a fall 2010 survey. Locations of these categorized shorelands can be found on Map 3.

3.3 Aquatic Plants

Introduction

Although the occasional lake user considers aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, the plants are actually an essential element in a healthy and functioning lake ecosystem. It is very important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No aquatic plant management plan should only contain methods to control plants, they should also contain methods on how to protect and possibly enhance the important plant communities within the lake. Unfortunately, the latter is often neglected and the ecosystem suffers as a result.

Aquatic Plant Management and Protection

Important Note:
Even though most of these techniques are not applicable to English Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake. The techniques applicable to English Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyn godonidella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within those 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Costs

The cost of native, aquatic and shoreland plant restorations is highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:
  - An upland buffer zone measuring 35’ x 100’.
  - An aquatic zone with shallow-water and deep-water areas of 10’ x 100’ each.
  - Site is assumed to need little invasive species removal prior to restoration.
  - Site has a moderate slope.
  - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
  - Plant spacing for the aquatic zone would be 3 feet.
  - Each site would need 100’ of biolog to protect the bank toe and each site would need 100’ of wavebreak and goose netting to protect aquatic plantings.
  - Each site would need 100’ of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
  - There is no hard-armor (rip-rap or seawall) that would need to be removed.
  - The property owner would maintain the site for weed control and watering.

Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreline erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Manual Removal

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized “V” shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width. Please note that the use of powered cutters may require a mechanical harvesting permit to be issued by the WDNR.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Costs

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1,200 to $11,000.

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb *benthic* organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant colonization on top of the screen.

Costs

Material costs range between $.20 and $1.25 per square-foot. Installation cost can vary largely, but may roughly cost $750 to have 1,000 square feet of bottom screen installed. Maintenance costs can also vary, but an estimate for a waterfront lot is about $120 each year.

Advantages	***Disadvantages***
• Immediate and sustainable control. • Long-term costs are low. • Excellent for small areas and around obstructions. • Materials are reusable. • Prevents fragmentation and subsequent spread of plants to other areas.	• Installation may be difficult over dense plant beds and in deep water. • Not species specific. • Disrupts benthic fauna. • May be navigational hazard in shallow water. • Initial costs are high. • Labor intensive due to the seasonal removal and reinstallation requirements. • Does not remove plant biomass from lake. • Not practical in large-scale situations.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Costs

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

Advantages	*Disadvantages*
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian water-milfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant affects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed (*Phragmite saustralis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	***Disadvantages***
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high water mark require herbicides specifically labeled by the United States Environmental Protection Agency.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration exposure times are important considerations for aquatic herbicides.

Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Some herbicides are applied at a high dose with the anticipation that the exposure time will be short. Granular herbicides are usually applied at a lower dose, but the release of the herbicide from the clay carrier is slower and increases the exposure time.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

> <u>Fluridone</u> (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.
>
> <u>Diquat</u> (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.
>
> <u>Endothall</u> (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.
>
> <u>2,4-D</u> (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.
>
> <u>Triclopyr</u>(Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.
>
> <u>Glyphosate</u> (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*). Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.
>
> <u>Imazapyr</u> (Habitat®) Broad spectrum, system herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for

controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments.	• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many herbicides are nonselective. • Most herbicides have a combination of use restrictions that must be followed after their application. • Many herbicides are slow-acting and may require multiple treatments throughout the growing season. • Overuse may lead to plant resistance to herbicides

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Advantages	***Disadvantages***
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Wisconsin has approved the use of two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These beetles were imported from Europe and used as a biological control method for purple loosestrife. Many cooperators, such as county conservation departments or local UW-Extension locations, currently support large beetle rearing operations. Beetles are reared on live purple loosestrife plants growing in kiddy pools surrounded by insect netting. Beetles are collected with aspirators and then released onto the target wild population. For more information on beetle rearing, contact your local UW-Extension location.

In some instances, beetles may be collected from known locations (*cella* insectaries) or purchased through private sellers. Although no permits are required to purchase or release beetles within Wisconsin, application/authorization and release forms are required by the WDNR for tracking and monitoring purposes.

Cost

The cost of beetle release is very inexpensive, and in many cases is free.

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations many lead to long-term control.	• Although considered “safe,” reservations about introducing one non-native species to control another exist. • Long range studies have not been completed on this technique.

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on English Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of English Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

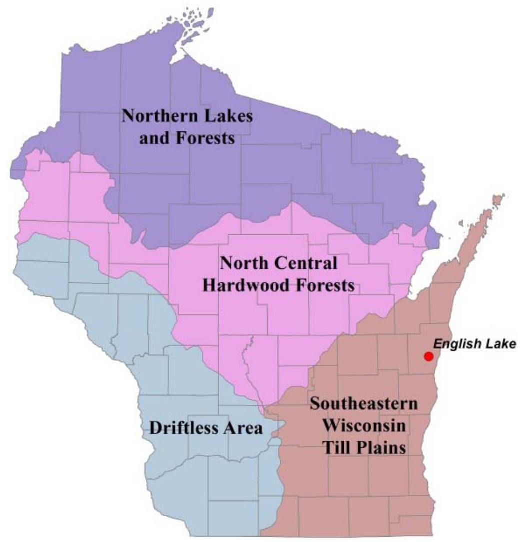


Figure 3.3-1. Location of English Lake within the ecoregions of Wisconsin. After Nichols 1999.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

One factor that influences species diversity is the "development factor" of the shoreline. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreline complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreline complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of English Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.3-1).

> **Ecoregions** are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plan surveys.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-2). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are

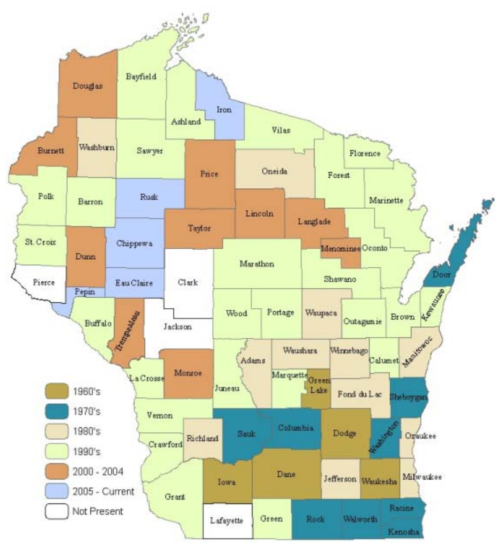


Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly – leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native vegetation. Like Eurasian water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian water milfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

Aquatic Plant Survey Results

As mentioned above, numerous plant surveys were completed as a part of this project. On April 22, 2010, a survey was completed English Lake that focused upon curly-leaf pondweed. Normally, surveys attempting to locate curly-leaf pondweed are conducted in May or June when this plant is near or at peak growth. This survey was conducted in April because it coincided with the whole-lake Eurasian water milfoil pre-treatment survey, and it was believed that because Eurasian water milfoil was already growing at or near the surface in many areas that any curly-leaf pondweed would be visible as well. Although curly-leaf pondweed is known to exist in English Lake, the 2010 survey did not locate any occurrences. A more detailed discussion surrounding curly-leaf pondweed in English Lake can be found in the next section.

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

The whole-lake, aquatic plant point-intercept and aquatic plant community mapping surveys were conducted by Onterra ecologists on English Lake on July 27, 2010. During these surveys, 14 species of aquatic plants were located in English Lake (Table 3.3-1), only one of which is considered to be a non-native, invasive species: Eurasian water milfoil. In fact, upon suspicions that the Eurasian water milfoil may be a hybrid with the native species northern water milfoil, specimens were collected in 2011 and sent in for DNA analysis. Their results determined that the milfoil in English is indeed a hybrid between Eurasian water milfoil and northern water milfoil. However, this report will refer to this milfoil as Eurasian water milfoil. The Eurasian water milfoil population in English Lake and control initiatives will be discussed in detail in the next section.

Using data collected from the 2010 aquatic plant point-intercept survey, approximately 53% of the sampling locations that fell within the littoral zone, or the area of the lake where plants are able to grow, contained fine organic sediment (muck), 42% contained sand, and 5% contained rock (Figure 3.3-3 and Map 10). Like terrestrial plants, aquatic plants prefer the fine, nutrient-rich organic sediments as opposed to nutrient-poor substrates such as sand. However, certain species such as wild celery found in English Lake grow very well in coarser substrates.

Table 3.3-1. Aquatic plant species located on English Lake during July 2010 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)
Emergent	*Sagittaria latifolia*	Common arrowhead	3
	Schoenoplectus acutus	Hardstem bulrush	5
	Schoenoplectus pungens	Three-square rush	5
FL	*Nuphar variegata*	Spatterdock	6
	Nymphaea odorata	White water lily	6
FL/E	*Sparganium eurycarpum*	Common bur-reed	5
Submergent	*Chara sp.*	Muskgrasses	7
	Ceratophyllum demersum	Coontail	3
	Elodea canadensis	Common waterweed	3
	Myriophyllum sibiricum x spicatum	Northern x Eurasian water milfoil (hybrid)	Exotic
	Najas flexilis	Slender naiad	6
	Potamogeton foliosus	Leafy pondweed	6
	Stuckenia pectinata	Sago pondweed	3
	Vallisneria americana	Wild celery	6

FL = Floating Leaf
FL/E = Floating Leaf and Emergent

The littoral zone of English Lake is highly vegetated, with approximately 91% of the point-intercept sampling locations falling within the maximum depth of plant growth (17 feet) containing aquatic vegetation. Map 4 shows that aquatic vegetation, both native and non-native, are distributed throughout the entire littoral area of English Lake. The map also shows that the littoral area is relatively narrow, and the majority of the lake is too deep to support aquatic vegetation. Figure 3.3-4 and that aquatic plant growth is relatively evenly distributed throughout littoral depths, with the highest occurrence of vegetation occurring between 3 and 13 feet.

As discussed in the Water Quality Section, English Lake has relatively high water clarity which allows

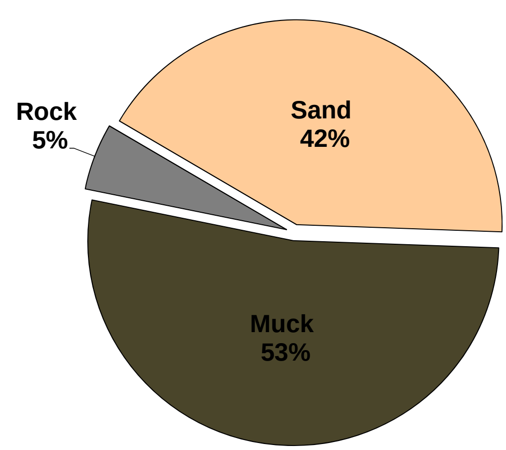


Figure 3.3-3. English Lake proportion of substrate types within littoral areas. Created using data from 2010 aquatic plant point-intercept survey.

sunlight to penetrate to deeper depths and support aquatic plant growth. In a 2006 Wisconsin Department of Natural Resources (WNDR) point-intercept survey on English Lake, they observed aquatic vegetation growing to a maximum depth of 22 feet. The increased depth of aquatic plant growth in 2006 was likely due to higher water clarity during that year; the 2006 growing season average Secchi disk transparency for 2006 was nearly 10 feet, 3 feet higher than what was observed in 2010.

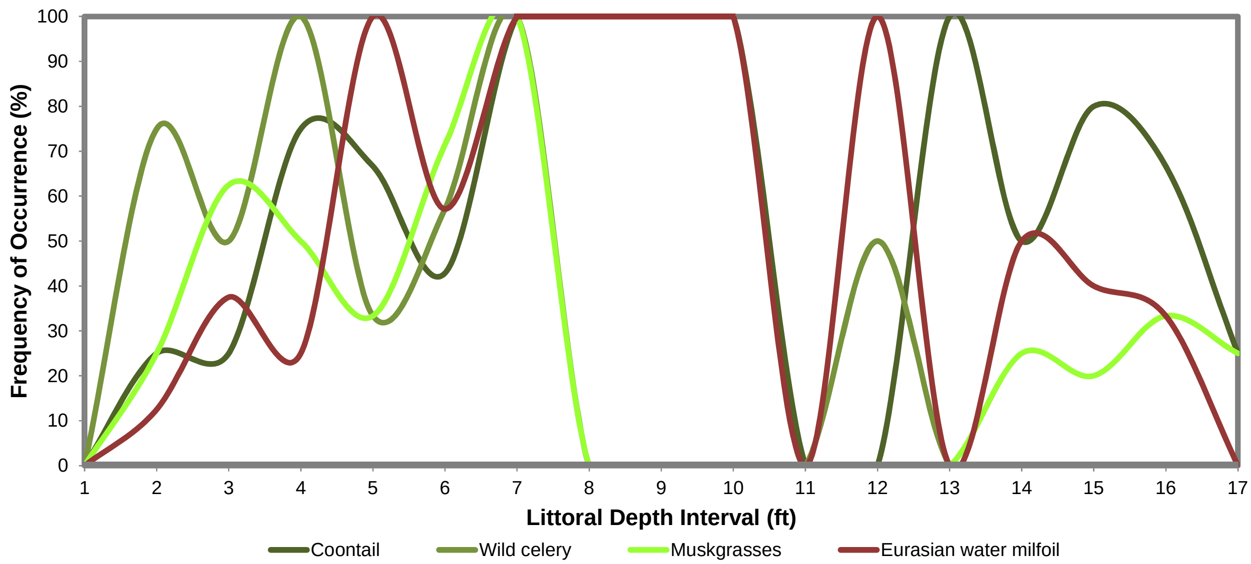


Figure 3.3-4 English Lake 2010 frequency of occurrence of English Lake aquatic plants by depth. Created using data from 2010 aquatic plant point-intercept survey.

Coontail, wild celery, and muskgrasses were the three-most frequently encountered native aquatic plant species during the 2010 aquatic plant point-intercept survey respectively (Figure 3.3-4). Coontail, arguably the most common aquatic plant species in Wisconsin, has bushy whorls of leaves that resemble a raccoon's tail. Lacking roots, this species obtains the majority of its nutrients directly from the water and can grow prolifically in nutrient-rich water, often attaining nuisance levels and forming dense mats at the surface. Also able to tolerate low-light conditions, coontail is usually one of the most dominant species found in eutrophic lakes. The dense foliage of coontail provides excellent habitat for aquatic invertebrates and fish, especially in deeper water where other native aquatic plants cannot grow. While coontail was the most frequently encountered species in English Lake in 2010, the majority was found growing well below the surface between 7 and 10 feet (Figure 3.3-4). Onterra ecologists did not observe any coontail growth in 2010 that would be classified as *nuisance*: interfering with navigation or recreational activities.

Wild celery, also known as tape or eel grass, was the second-most common native species encountered during the 2010 point-intercept survey on English Lake and was most abundant between 2 and 7 feet (Figure 3.3-4). Like coontail, wild celery is tolerant of low-light conditions, and its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruit, tubers, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife.

The third-most common native aquatic plant encountered in English Lake during the 2010 point-intercept survey were muskgrasses (Figure 3.3-5). These plants resemble other submersed vascular aquatic plants but in fact are a group of macroalgae. Several species of muskgrasses occur in Wisconsin, though this study did not identify this group to the species level. As their name suggests, muskgrasses exude a strong, skunk-like odor. They are usually found in lakes with higher alkalinity and can be found growing in sandy or mucky substrates. Muskgrasses often grow in large beds providing both structural habitat and sources of food for both aquatic and terrestrial organisms.

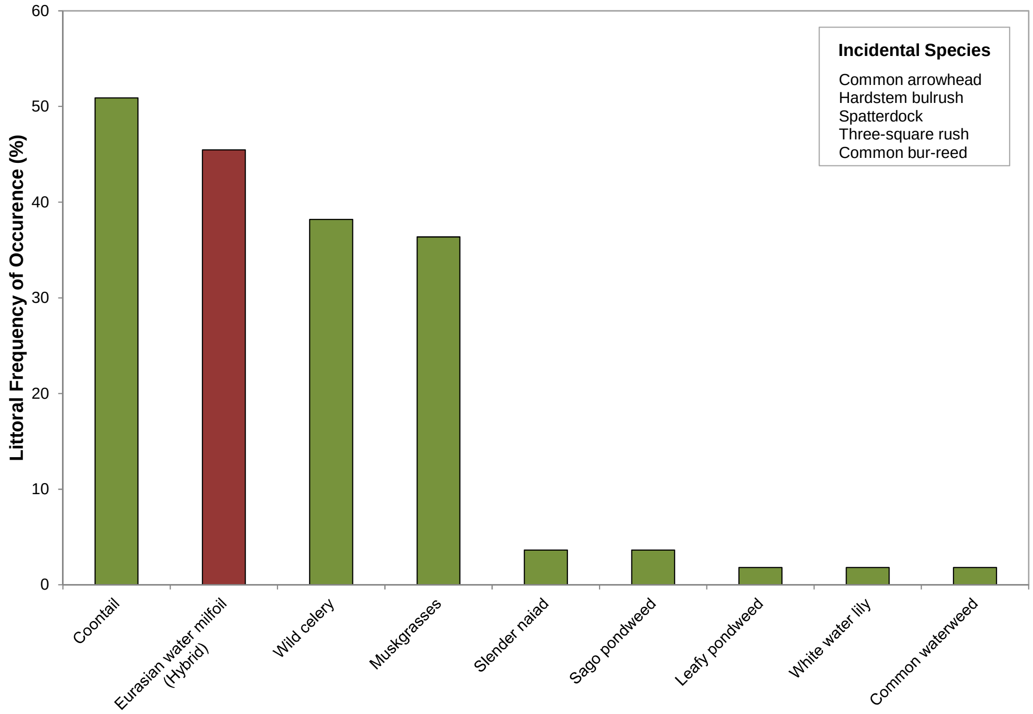


Figure 3.3-5 English Lake aquatic plant littoral occurrence analysis. Created using data from 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

While no native aquatic plant species were observed growing at levels which would interfere with navigation and recreational activities during the summer of 2010, the non-native Eurasian water milfoil was observed growing at or near the surface throughout most of the shallower half of the lake's littoral zone, and this growth is certainly a hindrance to lake users. In a stakeholder survey sent out to English Lake property owners, 75% of respondents indicated that aquatic plant growth often or always negatively impacts their enjoyment of the lake (Appendix B, Question # 24).

Eurasian water milfoil was the second-most frequently encountered aquatic plant during the 2010 point-intercept survey (Figure 3.3-5). Though high, its occurrence declined by almost half from when the point-intercept survey was conducted in the spring of 2010 prior to a whole-lake herbicide treatment; the results of which will be discussed in detail in the next section. In addition impeding human activities on the lake and degrading aesthetics, the excessive growth of Eurasian water milfoil is likely having an adverse impact on the native plant community by displacing valuable native species and decreasing species diversity.

To calculate species diversity and the Floristic Quality Analysis, only those species that were recorded on the rake during the point-intercept survey are used and incidental species are not included. During the point-intercept survey, 8 native aquatic plant species recorded on the rake, which falls below the Southeast Till Plains Ecoregion median as well as the Wisconsin State median (Figure 3.3-6). Because of this low species richness, one might assume that species diversity is also low. As discussed earlier, species diversity is influenced by both the native aquatic plant species richness and how evenly those species are distributed within the community. Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. A plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish and other wildlife with diverse structural habitat and various sources of food.

Using the data collected from the 2010 point-intercept survey, the diversity of English Lake's plant community was found to be relatively low, with a Simpson's Diversity value of 0.78. In other words, if two individual plants were randomly sampled from English Lake's plant community, there would be a 78% probability that the two individuals would be of different species. The lower species diversity in English Lake can be attributed to a plant community that is dominated by a small number of species: mainly coontail, Eurasian water milfoil, wild celery, and muskgrasses. Data collected from the WDNR point-intercept survey in 2006, prior to the discovery of Eurasian water milfoil, indicates that the diversity of the plant community was nearly the same, with a value of 0.79. The fact that species diversity was low prior to the establishment of Eurasian water milfoil may be one of the factors why Eurasian water milfoil was able to colonize the majority of the lake's littoral zone in such a short period of time.

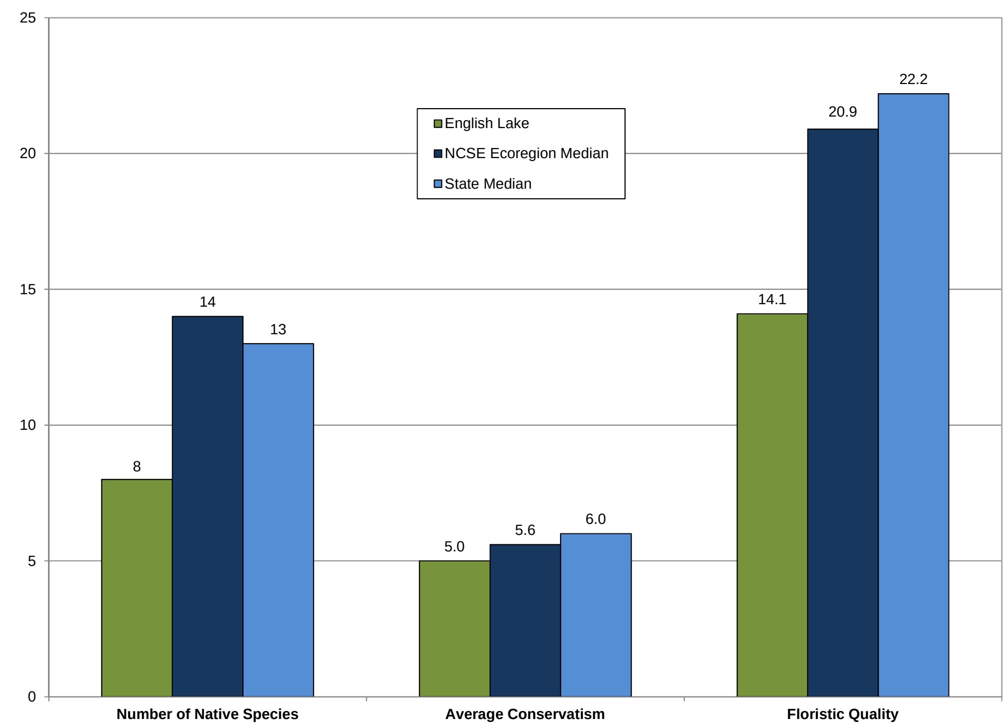


Figure 3.3-6. English Lake Floristic Quality Assessment. Created using data from 2010 aquatic plant point-intercept survey. Analysis following Nichols (1999).

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at almost 47% of the sampling locations, its relative frequency of occurrence is approximately 34% (Figure 3.3-7). Explained another way, if 100 plants were randomly sampled from English Lake 34 of them would be coontail.

Figure 3.3-7 indicates that coontail, Eurasian water milfoil, wild celery, and muskgrasses comprise approximately 93% of English Lake's plant community, illustrating the low species diversity. The average conservatism value (5.0) of English Lake's plant community falls below both the ecoregion and state medians, indicating that the plant community is of lesser quality than other lakes in the region and state (Figure 3.3-6). This also indicates that English Lake's plant community is indicative of a disturbed system, likely due to a combination of water quality and the presence of Eurasian water milfoil. Combining English Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a low value of 14.1 (equation shown below); well below the ecoregion and state medians (Figure 3.3-6).

$$\text{FQI} = \text{Average Coefficient of Conservatism (5.0)} * \sqrt{\text{Number of Native Species (8)}}$$
$$\text{FQI} = 14.1$$

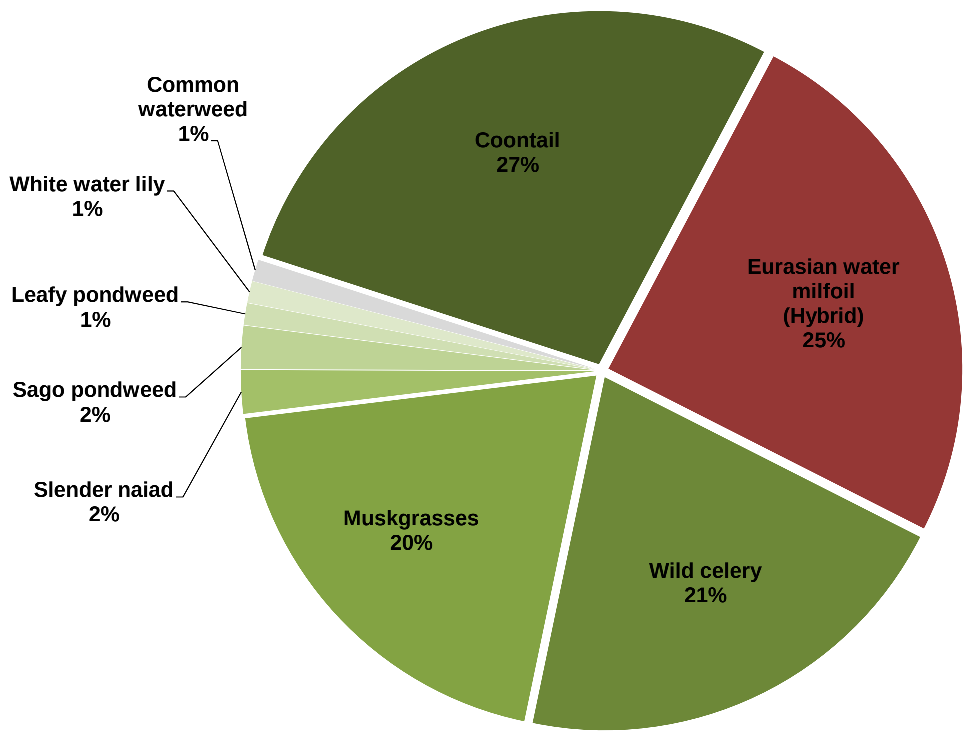


Figure 3.3-7 English Lake aquatic plant relative occurrence analysis. Created using data from 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

Despite having a relatively low quality submersed aquatic plant community, English Lake contains numerous occurrences of floating-leaf and emergent aquatic plant communities (Map 5). Six species of emergent and floating-leaf aquatic plants were located during the 2010 surveys. The 2010 community map indicates that approximately 1.4 acres (3%) of the 51-acre lake contains these types of plant communities. These communities provide valuable habitat to wildlife and stabilize lake substrate and shoreline areas by dampening wave action from wind and watercraft.

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities. A replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within English Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to the undeveloped shorelines in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Exotic Plants in English Lake

Curly-leaf Pondweed

Curly-leaf pondweed was first discovered in English Lake in 2007, and consisted of two small colonies; one growing along the northwestern shoreline and the other on the eastern shoreline. Despite efforts to hand-remove the curly-leaf pondweed, it continued to spread. In 2008, the ELPRD successfully applied for a permit to chemically treat approximately 0.19 acres of curly-leaf pondweed with granular Aquathol (Super K). This treatment was likely successful as no curly-leaf pondweed was observed in English Lake during the 2010 curly-leaf pondweed survey. While no curly-leaf pondweed was observed in 2010, it is not believed that this invasive plant has been eradicated from the lake, but rather exists at a level which is difficult to detect. In 2011, property owners indicated that they had observed some curly-leaf pondweed growing in the northwestern portion of the lake. It was not until 2012 that Onterra was led to a very small clump of curly-leaf pondweed, growing along the northwest side of the lake. As the Implementation Plan describes, watchful eyes are necessary to monitor the growth and potential spread of this plant throughout the lake.

Eurasian water milfoil (Hybrid)

Introduction

Eurasian water milfoil (EWM) was first discovered in English Lake in 2009 by district members who described a "massive outbreak" of a suspicious looking plant. Onterra was contracted that year to complete a survey for EWM, and discovered a dense infestation of the plant throughout the majority (13 acres) of the lake's littoral zone (Map 6). Water clarity is quite good in English Lake, and EWM can be found growing out to 18 feet of water.

A treatment strategy was devised for English Lake in 2010 using a liquid formulation of 2,4-D. Although applied directly to areas of EWM, this herbicide quickly diffuses through the system and reaches an equilibrium concentration within the entire volume of the lake. Typically the dose of this herbicide is determined such that when it reaches equilibrium, it is at a sufficient level to impact the EWM population. However, English Lake contains a relatively narrow ring of EWM surrounding a large area of deep water which means there is a large volume of water in English Lake when compared to that of the treatment area. If the herbicide dilutes into the entire volume of the lake, even if applied at the maximum application rate (4.0 ppm), 2,4-D concentrations may not be sufficient to impact EWM (Table 3.3-2).

While emerging data appears clear that liquid 2,4-D mixes horizontally within the lake, little information exists regarding if 2,4-D vertically mixes into deep areas of the lake during stratification. After discussions between Onterra and John Skogerboe from the US Army Corps of Engineers (USACE), it was hypothesized that if the lake was thermally stratified, the 2,4-D would dissipate throughout the upper zone of the lake (epilimnion), but not into the deeper water zones of the lake (metalimnion and hypolimnion).

Based upon historical temperature profile data from English Lake, it was anticipated that the lake would be stratified at this time of the year around 20 to 30 feet. Table 3.3-2 shows that at the traditional application rate of 2.0 ppm, the anticipated 2,4-D concentrations within the epilimnion would likely be between 0.158 ppm and 0.218 ppm (30 feet and 20 feet, respectively).

Table 3.3-2. Calculated residual concentrations dependent on depth of stratification at various application rates over treatment areas.

	2.0 ppm	4.0 ppm
Stratify at 15 feet	0.278	0.556
Stratify at 20 feet	0.218	0.436
Stratify at 25 feet	0.182	0.364
Stratify at 30 feet	0.158	0.315
Mix throughout lake	0.091	0.181

On April 22, 2010, Onterra staff visited English Lake to survey the proposed treatment area and refine their boundaries as deemed appropriate. It was observed during the spring pretreatment survey that the extents of treatment areas were still accurate, and the proposed areas were kept as is for the final treatment map (Map 7).

Herbicide applications were conducted by Bonestroo, Inc (now Stantec) on May 17, 2010. On the application date, the applicator reported that the surface water temperature was 61°F and the winds were 5-10 mph. A temperature and dissolved oxygen profile collected by an ELPRD volunteer that same day confirmed the surface temperature and showed that the lake stratified at a depth of 25 to 30 feet (Figure 3.3-7).

2010 Treatment Monitoring

The goal of herbicide treatments is to maximize target species (EWM) mortality while minimizing impacts to valuable native aquatic plant species. Monitoring herbicide treatments and defining their success incorporates both quantitative and qualitative methods. As the name suggests, quantitative monitoring involves comparing number data (or quantities) such as plant frequency of occurrence before and after the control strategy is implemented. Qualitative monitoring is completed by comparing slightly more subjective data such as EWM colony density ratings before and after the treatments.

On English Lake, quantitative evaluation was made through the collection of point-intercept data at a whole lake level, since it was known that the herbicide would disperse throughout the entire lake. English Lake was visited during the spring before the treatment (May 2010) and again during August to conduct whole-lake point intercept surveys to quantitatively monitor the 2010 treatment. During the May pretreatment survey, only EWM occurrence was documented whereas the presence of both native and non-native occurrence was collected during the summer post treatment survey. The WDNR conducted a whole-lake point-intercept survey on the lake in 2006 and is the only source of native pretreatment data.

Quantitatively, a treatment is deemed to be successful if the EWM frequency following the treatments is statistically reduced by at least 50%. Further, a noticeable decrease in rake fullness ratings within the fullness categories of 2 and 3 should be observed and preferable, there would be no rake tows exhibiting a fullness of 2 or 3 during the post treatment surveys.

Spatial data reflecting EWM locations were collected using a sub-meter Global Positioning System (GPS) during the late summers of 2009 and 2010, when this plant is assumed to be at its peak biomass or growth stage. Comparisons of these surveys are used to qualitatively evaluate the 2010 herbicide treatment on English Lake. Qualitatively, a successful treatment on a particular site would include a reduction of EWM density as demonstrated by a decrease in density rating (e.g. highly dominant to dominant). In terms of a treatment as a whole, at least 75% of the acreage treated that year would decrease by one level of density as described above for an individual site.

Many actions are taken to reduce the chance for herbicide to impact native aquatic species, including the determination of the herbicide type and concentration along with the time of year that the herbicide is applied. While 2,4-D is thought to be selective towards broad-leaf (dicot) species at traditional concentrations and exposure times, emerging data from the WDNR and USACE suggests that some narrow-leaf (monocot) species may also be impacted by this herbicide. For this reason, it is important to monitor treatments to not only understand the impacts upon EWM, but also to determine the response from the native plant community.

2010 Treatment Results

Photo 3.3-1. Surface-matted Eurasian water milfoil. Flowers stem upward from a dense colony in front of an English Lake residence, August 2010**.**

In 2009, four treatment areas totaling 13 acres were mapped within the littoral zone of English Lake (Map 6). With the exception of site B-10, the treatment areas consisted of segments that ranged from densities of highly scattered to surface matted. At the beginning of the summer, lake residents were quite pleased with the initial treatment results and could hardly find any EWM within the lake when looking from the surface. But as the summer progressed, the presumably injured EWM rebounded and during the late-summer post treatment survey, was erect in the water column.

When comparing the EWM within these treatment areas between 2009 to 2010, it is apparent that no treatment area, nor individual delineated segment within a treatment area, experienced a reduction in density (Maps 7 and 8). The majority of the delineated segments remained the same density category as in 2009, with several segments increasing in density. As can be observed in Photograph 3.3-1, EWM within the northeast part of English Lake that was highly dominant in August 2009 increased in density to surface matting in early September 2010. These qualitative results do not meet the qualitative success criteria (75% reduction) for the 2010 treatment.

During the 2010 spring point-intercept pretreatment survey, EWM was located at 96% of the locations (Table 3.3-3) that were less than the maximum depth of EWM growth (16 feet). Following the treatment during the last week of July 2010, EWM was located in approximately 53% of point-intercept locations less than 16 feet (49% within maximum depth of plant growth, Table 3.3-3). The statistically valid 44.9% reduction in EWM occurrence was close, but did not meet the predetermined lake-wide quantitative success criteria (50% reduction in occurrence).

Table 3.3-3.Statistical analysis of Eurasian water milfoil occurrence within whole-lake point-intercept surveys. Created using data from spring and summer 2010 surveys.

2010 Spring FOO	2010 Summer FOO	% Change	Chi-square Analysis	
			Direction	p-value
96.0	52.9	-44.9	▼	0.000

2010 Spring N = 50, 2010 Summer N= 51; FOO = Frequency of Occurrence

A rake fullness rating of 1-3 was used to determine the abundance of EWM at each point-intercept location. Please note that EWM typically increases in biomass throughout the growing season. Figure 3.3-8 displays the lake-wide proportions of EWM rake fullness ratings from the pre- and post treatment surveys. The figure indicates that the while the number of point-intercept locations containing EWM decreased, over half of the remaining EWM was determined to have rake fullness ratings of greater than 1.

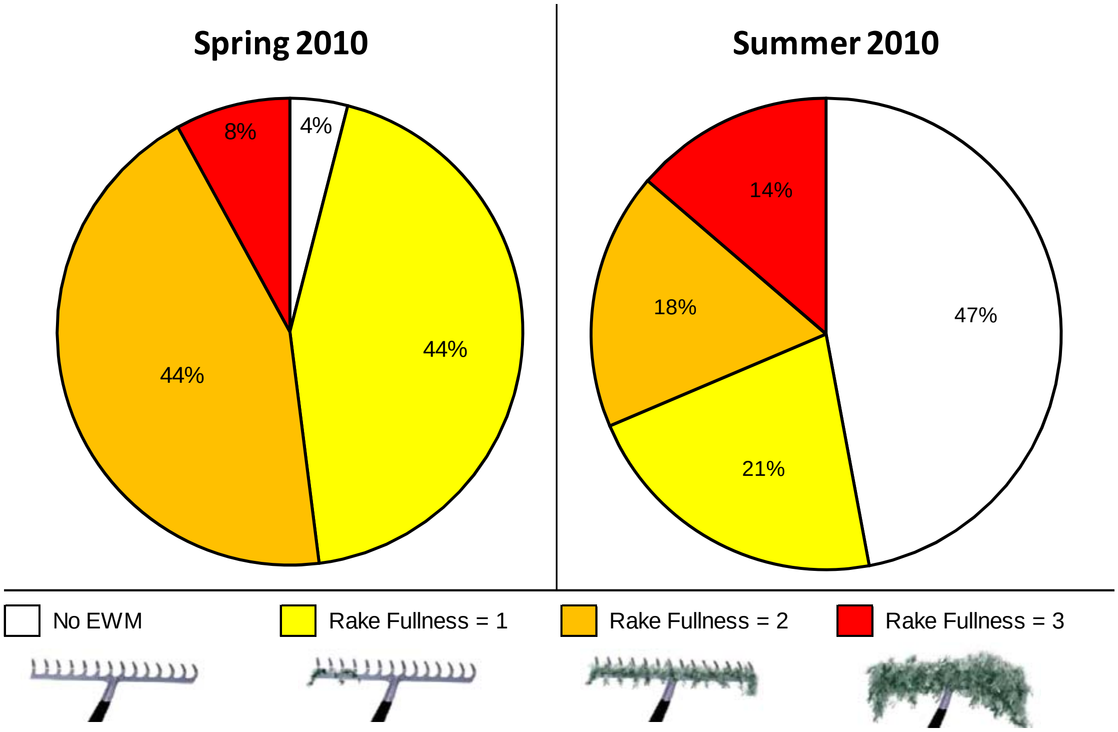


Figure 3.3-8. Lake-wide proportions of EWM rake fullness ratings from point-intercept sampling locations. Created using data from spring 2010 pre-treatment survey and summer 2010 post treatment survey.

It is important to reiterate that comparing the 2006 and 2010 summer point-intercept datasets will allow for an understanding of the changes in the plant community during that time period; however, the changes may not be solely a result of the 2010 control measure. As Table 3.3-4 shows, EWM was not located during the 2006 survey and changes in the native plant community may be a result of the incredible increase in occurrence of EWM during that time frame. Only leafy pondweed experienced a statistically valid reduction between 2006 and 2010 (Table 3.3-4). Two native species, coontail and muskgrasses, experienced a statistical increase in their frequency of occurrence between the two surveys.

Leafy pondweed, a monocot species, was not thought to be particularly susceptible to dicot-selective herbicides. However, emerging data gathered from lakes in 2010 from lakes with similar large-scale liquid treatments suggests that some non-dicot species of plants may be prone to decline after treatment. As stated previously, English Lake was one many lake selected for herbicide residual monitoring. Water sampling was led by the Engineer Research and Development Center, a division of the USACE, and collected by an English Lake volunteer and Onterra ecologists from sites located both within and outside of herbicide application areas (Map 7).

Table 3.3-4. Statistical comparison of aquatic plant frequency data, 2006-2010. Comparisons are made using 2006 WDNR and 2010 Onterra summer point-intercept surveys.

	Scientific Name	Common Name	2006 FOO	2010 FOO	Percent Change	Direction	Chi-square Analysis Significance	Chi-square Analysis p-value
D	Myriophyllum spicatum	Eurasian water milfoil	0	49.1	-	▲	Yes	0.000
D	Ceratophyllum demersum	Coontail	32.4	50.9	57.2	▲	Yes	0.036
ND	Chara sp.	Muskgrasses	19.7	36.4	84.4	▲	Yes	0.037
ND	Potamogeton foliosus	Leafy pondweed	15.5	1.8	-88.3	▼	Yes	0.010
ND	Vallisneria americana	Wild celery	35.2	38.2	8.4	▲	No	0.731
ND	Elodea canadensis	Common waterweed	9.9	1.8	-81.6	▼	No	0.066

2006 N = 71, 2010 N = 55; D = Dicots, ND = Non-dicots, FOO = Frequency of Occurrence

▲ or ▼ = Significant Change (Chi-square; α = 0.05)

▲ or ▼ = Insignificant Change (Chi-square; α = 0.05)

As indicated on Figure 3.3-9, the epilimnion of English Lake likely extended to 25 feet deep at the time of the treatment on May 17. If 2,4-D mixed throughout the entire epilimnion, the calculated concentration would be approximately 0.182 ppm (Table 3.3-2). However, the mean lake concentration was approximately 0.277 ppm the day after treatment. To assess vertical mixing of 2,4-D, herbicide residual samples were collected at the deepest part of the lake at depths of 5, 15, 25, 35, and 55 feet. At this location, herbicide residuals were not found above the detection limit except at 5 feet deep (Appendix F, Figure 4). This likely indicates that 2,4-D may not have completely mixed throughout the epilimnion. Perhaps coincidentally, the mean lake concentration at 1 day after treatment (0.277 ppm) is alarmingly similar to the calculated concentration if 2,4-D only mixed within the volume of water that was less than 15 feet deep. Appendix A contains the USACE draft report with more detail regarding the residual sampling study on English Lake.

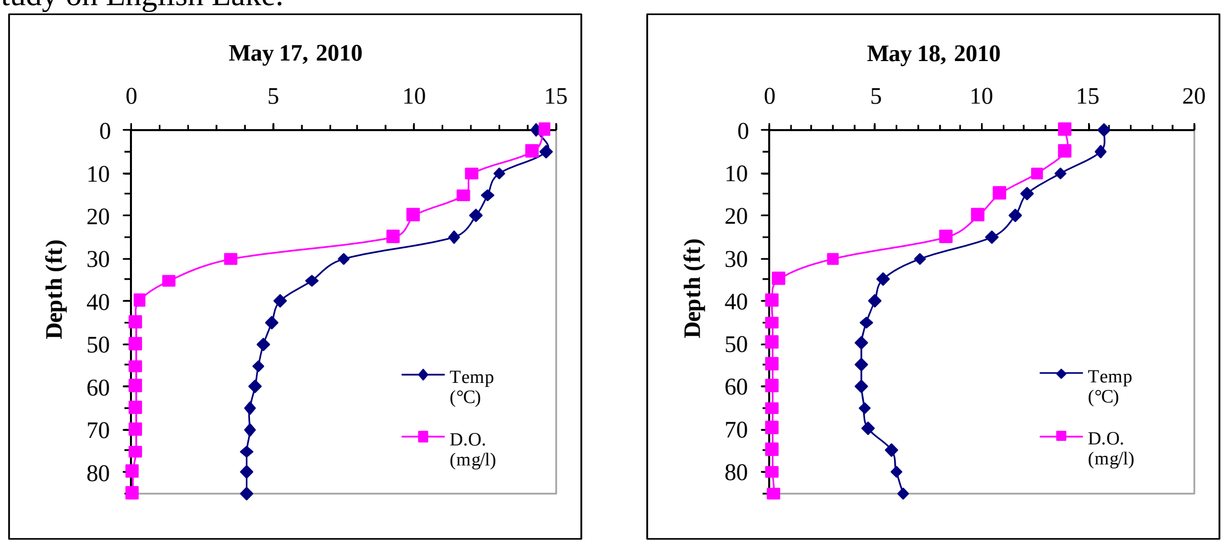


Figure 3.3-9. English Lake dissolved oxygen and temperature profiles. Data collected by ELPRD volunteers.

Published data states that to achieve "good control" (60 to 75% reduction) of EWM, an application concentration of 0.5 ppm with an exposure time of 72 hours is needed. One day after the treatment, concentrations were already below this level (0.277 ppm). Sixteen days after the treatment, concentrations were found to be about 0.300 ppm lake wide. While published data currently does not exist about the exposure time required to get control at lower doses, sustaining these concentrations for more than 16 days should have been more effective based upon results collected on other Wisconsin lakes during 2009 and 2010.

As indicated within the USACE report, there are a number of factors that may have contributed to the lack of control observed, including water pH, filamentous algae, and genetics. A profile collected on May 26, 2010 shows that pH levels ranged from 9.2 at the surface to 8.2 at 25 feet. Ester formulations such as Navigate are known to be less effective at pH levels greater than 8.0. However, the herbicide used (DMA IV) is an amine formulation and as indicated by a similar product's fact sheet (Sculpin G), "amine formulation not affected by high pH water."

At the time of the treatment, the EWM was also observed to be covered with filamentous algae. That information was provided to the herbicide applicator and they suggested that an algaecide may contribute to a more effective treatment. Most algaecides are copper-based and some concerns exist about the use of metals in lakes. Because it is unknown if filamentous algae truly has the ability to affect treatment efficacy, an algaecide was not used in conjunction with the 2010 2,4-D treatment. It is unclear what affect filamentous algae have on the uptake of 2,4-D by EWM. While some have stated that the algae forms a barrier around the EWM plant that limits the amount of 2,4-D taken in by the plant, this may not be true as the plant must be actively interfacing with the water or it would not be able to respire or photosynthesize.

2011 Eurasian water milfoil monitoring

No herbicide treatment was conducted in 2011, and on August 12, 2011, a repeat of the whole-lake aquatic plant point-intercept survey was conducted by Onterra ecologists to assess any possible effects on Eurasian water milfoil and native aquatic plant populations one year following the 2010 herbicide treatment. This survey revealed that the littoral occurrence Eurasian water milfoil remained unchanged since the summer 2010 survey (Table 3.3-5). The only native aquatic plant species to show a statistically valid decline in 2011 were the muskgrasses (Table 3.3-5). These plants, a group of macroalgae, are not thought to be sensitive to dicot-selective herbicides, and the reason for their decline is believed to be annual climatic variations. Overall, this survey further illustrates the ineffectiveness of the 2010 whole-lake treatment. The Eurasian water milfoil in English Lake was also mapped in August 2011, and shows that the lake-ward extents remain the same as its growth is depth-limited, but the density increased in many areas (Map 9).

Table 3.3-5. Statistical comparison of aquatic plant frequency data, 2010-2011. Comparisons are made using 2010 and 2011 Onterra summer point-intercept surveys.

	Scientific Name	Common Name	Summer 2010 FOO	Summer 2011 FOO	Percent Change	Direction	Chi-square Analysis	
							Significance	p-value
Dicots	Myriophyllum spicatum	Eurasian water milfoil	45.5	45.5	0.0	-	No	1.000
Dicots	Ceratophyllum demersum	Coontail	50.9	57.6	13.1	▲	No	0.463
Dicots	Nuphar variegata	Spatterdock	0.0	1.5	100.0	▲	No	0.359
Dicots	Nymphaea odorata	White water lily	1.8	1.5	-16.7	▼	No	0.896
Non-dicots	Chara sp.	Muskgrasses	36.4	7.6	-79.2	▼	Yes	0.000
Non-dicots	Vallisneria americana	Wild celery	38.2	39.4	3.2	▲	No	0.892
Non-dicots	Najas flexilis	Slender naiad	3.6	6.1	66.7	▲	No	0.541
Non-dicots	Stuckenia pectinata	Sago pondweed	3.6	7.6	108.3	▲	No	0.355
Non-dicots	Elodea canadensis	Common waterweed	1.8	1.5	-16.7	▼	No	0.896
Non-dicots	Potamogeton foliosus	Leafy pondweed	1.8	6.1	233.3	▲	No	0.243
Non-dicots	Nitella sp.	Stoneworts	0.0	1.5	100.0	▲	No	0.359

FOO = Frequency of Occurrence
Summer 2010 FOO N = 55; Summer 2011 FOO N = 66
▲ or ▼ = Significant Change (Chi-square; α = 0.05)
▲ or ▼ = Insignificant Change (Chi-square; α = 0.05)

Future Treatment Strategy

While it was known that eradication of Eurasian water milfoil from English Lake was highly unlikely, those involved, including the district, USACE, Onterra, and the applicator, were anticipating greater EWM impacts from the 2010 treatment. The 2010 EWM treatment on English Lake was not successful at reducing EWM density and colony size within the lake. The qualitative success criterion was not met; however the criterion for quantitative success was nearly met (45% vs. a goal of 50%). Because EWM colonization in English Lake is almost solely limited by water depth, the size of many of the EWM colonies remained the same as observed in 2009. The 2010 treatment strategy of 13 acres (Map 7) has also been increased to address some colonial expansion within the lake (Map 8).

Although the 2010 EWM treatment on English Lake did not satisfy expectations, a large amount of information was gathered that will be a benefit not only to English Lake, but to all lakes that employ large-scale 2,4-D treatments. While it was suspected that 2,4-D would only mix vertically within the epilimnion, this was the first time it was documented. In 2010 on English Lake, it appears that that 2,4-D did not mix throughout the entire epilimnion, but only within the top 15 feet or so. This is likely a result of density differences within thin this stratified layer. A greater understanding of this issue could only be known if a significant increase in sampling intensity occurs, both temporally and within the water column. Some logistical issues and scheduling conflicts were encountered regarding the volunteer residual sample collection in 2010.

Determining a treatment strategy for English Lake in 2011 was perplexing. From knowledge gained on similar waterbodies around Wisconsin, the herbicide concentrations observed on English Lake in 2010 should have contributed to better EWM control. As discussed above, factors such as pH, filamentous algae, and EWM genetics may have contributed to the lack of efficacy observed in 2010. Because it is not known which factor(s) are to blame, it was decided that a treatment in 2011 would not be completed until the herbicide resistance testing was completed by SePRO and the USACE.

In winter of 2012, discussions began concerning a spring 2012 treatment for Eurasian water milfoil; specifically, treatment strategies involving herbicide types and concentrations were discussed. English Lake's pH was found to be above 8.0 and therefore using ester 2,4-D formulations (Navigate) is not recommended. Amine 2,4-D formulations are not thought to be affected by high water pH, but discussions are currently being conducted by WDNR and USACE researchers. One option for English Lake would be to conduct a similar whole-lake treatment using triclopyr. Similar to 2,4-D, triclopyr is an auxin-mimic herbicide that may be a more effective in alkaline systems. While this herbicide is used extensively in Minnesota, its past use in Wisconsin has been quite limited. Therefore, more information concerning the use of Triclopyr was needed.

In an effort to determine why the 2010 herbicide treatment did not reach the level of Eurasian water milfoil control that was expected, Onterra ecologists collected approximately 600 live strands of milfoil from English Lake as well as Frog Lake (Florence County, WI) in August of 2011 and sent them to SePRO and the USACE for herbicide resistance testing. Cultures of these plants were grown, and then experimental groups were exposed to varying concentrations of either 2,4-D amine or triclopyr. While the results are still preliminary at the time of this writing, the overall conclusion of the study is that hybrid Eurasian water milfoil from both English and Frog Lakes appeared to be less responsive to both 2,4-D and triclopyr herbicides.

Due to the uncertainty surrounding triclopyr use within the field (as opposed to a laboratory environment), and the knowledge that higher rates of 2,4-D were more effective in SePRO's laboratory studies, a conclusion was made by WDNR personnel, USACE, English Lake stakeholders, and Onterra to move forward in 2012 with a higher dose of 2,4-D than was applied to English Lake in 2010. Within an AIS Established Population Control (EPC) grant written on February 1, 2012, cost coverage for triclopyr or a 2,4-D/triclopyr blend was included as an option for 2013 and 2014. The AISEPC grant includes discussion on dosing options for triclopyr, should the ELPRD decide to pursue this option. However, this option will only be presented if the 2012 2,4-D treatment fails to meet expectations.

3.4 English Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2010).

Table 3.4-1. Gamefish present in the English Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Green Sunfish	*Lepomis cyanellus*	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4-35cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pikes, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Walleye	*Sander vitreus*	18	Mid April - Early May	Rocky, wave-washed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent vegetation	Small fish, aquatic invertebrates

English Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the 3rd ranked important or enjoyable activity on English Lake (Question #16). Approximately 55% of these same respondents believed that the quality of fishing on the lake was either very poor or poor (Question #9); and approximately 60% believe that the quality of fishing has gotten worse since they have obtained their property (Question #10).

Table 3.4-1 shows the popular game fish that are present in the system. Management actions that have taken place and will likely continue on English Lake according to this plan include herbicide applications to control Eurasian water milfoil. These applications should occur in early spring when the water temperatures are below 60-65°F. It is important to understand the effect the chemical has on the spawning environment which would be to remove the submergent plants that are actively growing at these low water temperatures. Yellow perch is a species that could potentially be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species.

English Lake Fish Stocking and Management

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults.

Bass have not been stocked by the WDNR in English Lake since 1978. Walleye have been steadily stocked in the lake to enhance their otherwise low population. Table 3.4-2 displays the walleye stocking record for English Lake. It is believed by WDNR biologists that this species, along with northern pike, will always be present in English Lake in low numbers because the spawning habitat is limited.

A WDNR 2006 survey report (attaches as Appendix F) details the history of this lake's fishery as well as a recent analysis of the fish community. The composition of this fish community has changed much within the past 70 years. In the 1940's, fisheries surveys revealed that walleye were the dominant gamefish in the lake, and bluegill were the dominant panfish. Surveys conducted in the late 1950's showed that northern pike and bass had replaced walleyes as the most prevalent gamefish species in the lake, and yellow perch had successfully replaced bluegill as the top panfish. In the 1960's, walleye were prevalent again, as were small yellow perch. In the 1970's black crappies were the dominant species, and black bullhead were present in large numbers as well. Removal efforts took place to thin the populations of these two species. Despite removing over 57,000 crappies from the lake during this time, this fish remained the dominant panfish species in the 1980's and 1990's.

A 2006 WDNR survey turned up nine species of fish within the lake. Largemouth bass was found to be the most common gamefish, and bluegill the most common panfish. Because of the lake's limited spawning habitat for other species, English Lake is managed by the WDNR as a bass and bluegill lake. The water quality of the lake favors these two species as well.

Currently, no special fishing regulations exist on English Lake. State-wide regulations are however applicable. Harvests of bass and walleye are limited to 5 fish per day, while 25 panfish may be kept in a day. Because English Lake is located south of U.S. Hwy 10 and thus within the southern management zone for northern pike, 2 fish of this species may be kept in a single day. Size restrictions include a 14 inch limit on bass species, a 15 inch limit on walleye and a 26 inch limit on northern pike.

Table 3.4-2. Walleye stocking data available from the WDNR from 1972 to 2010 (WDNR 2010).

Year	Age Class	# Stocked	Avg. Length (inches)
1975	Fingerling	2,500	5
1977	Fingerling	5,000	3
1978	Fingerling	5,000	3
1982	Fingerling	2,500	3
1984	Fingerling	2,500	3
1985	Fingerling	2,500	4
1987	Fingerling	7,500	7
1989	Fry	2,244	3
1992	Fingerling	4,393	3
1994	Fingerling	1,332	2.5
1995	Fingerling	1,287	2.8
1997	Large fingerling	1,275	3
1999	Small fingerling	5,100	2
2001	Small fingerling	5,100	2
2003	Small fingerling	5,095	2
2005	Small fingerling	2,530	1
2009	Small fingerling	1,765	2

English Lake Substrate Type

According to the point-intercept survey conducted by Onterra in summer 2010, 53% of the substrate sampled in the littoral zone on English Lake was muck, with 42% being classified as sand and 6% classified as rock (Map 10). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three objectives;

1) Collect baseline data to increase the general understanding of the English Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil.
3) Collect sociological information from English Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the English Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Overall, the studies that were completed on lake indicate that it has been disturbed by human influences. The Watershed Section discusses the relatively minimal impact that the watershed has on English Lake. The reason that the primarily agricultural watershed minimally impacts English Lake is due to the management practices implemented by the ELPRD over the past 15 years. However, regardless of these actions the nutrient and algal content of the water is still higher than the median for similar lakes within the state and ecoregion. The Water Quality Section goes on to discuss the impact of internal loading on the lake. Currently, it is believed that approximately 157 lbs of phosphorus are contributed to the surface waters of English Lake via internal loading each year, while only 77 lbs are derived from external (outside of the lake) sources. The recycling of nutrients from the bottom sediments of English Lake are likely the primary factor creating the less than desirable water quality within the lake.

While the nutrient input from internal loading is controllable, a more in-depth understanding is needed to accurately assess this situation and determine the feasibility of treatment options. Specifically, three components of the lake's phosphorus budget should be looked at more closely:

1. A more rigorous sampling of waters from the epilimnion and hypolimnion is needed to determine phosphorus concentrations throughout the year. This would lead to a better understanding of how much hypolimnetic phosphorus is actually being added to the epilimnion, where algae and macrophytes can utilize it.
2. Collection and analysis of sediment cores from various locations throughout the lake would help determine the rate at which phosphorus is released from the sediment and if an alum treatment were to be completed, what dose should be utilized.
3. An updated study determining the amount of phosphorus that is exiting the sedimentation basin on the lake's east side. If the phosphorus entering the sedimentation basin was also determined, the efficiency of the sedimentation at removing the nutrient from runoff waters before entering the lake could be recalculated and compared with conclusions drawn in the 2000 study report.

Following the completion of these studies, the ELPRD would be able to investigate options for control, such as an alum treatment.

Alum (aluminum sulfate, $AL_2(SO4)_3$) is a nontoxic material commonly used in water treatment plants to clarify drinking water. Treatment consists of a chemical application to the surface waters of the lake. The alum targets what is called Redox-P, or phosphorus that is susceptible to being released from the sediment into overlaying waters during times of anoxia (conditions of no dissolved oxygen). When the alum contacts the lake water, it forms a precipitate called a floc. This floc binds with Redox-P to form a compound which is insoluble in water, thus, it can no longer be utilized by algae or plants. As this floc settles towards the lake bottom, it removes some phosphorus from the water column, but upon reaching the sediments forms a “phosphorus barrier” by combining with phosphorus as it is released from the sediments.

While studies to determine the feasibility of an alum treatment on English Lake are applicable in the future, the primary matter at hand for the ELPRD is the dense Eurasian water milfoil infestation that has largely taken over the lake. In 2010, Eurasian water milfoil was mapped throughout most of the littoral zone of the lake. In fact, the data collected during the 2010 point-intercept survey shows that Eurasian water milfoil is the second most common species found in the lake. Analysis of recent aquatic plant survey data show that the native plant community in English Lake is indicative of a disturbed system, with a low number of native species, low average coefficient of conservatism, low diversity, and low overall floristic quality. The presence of Eurasian water milfoil has undoubtedly contributed towards this low quality plant community. “Invasive” plants are defined as such because of their ability to out-compete native species and gain control of the available habitat. Continued presence of very dense Eurasian water milfoil communities may result in loss of additional native aquatic plant species abundance, and thus lower the quality of the overall plant community.

Although the treatment strategy enacted in 2010 achieved less than desirable results when considering control of Eurasian water milfoil, much was learned during this treatment. Researchers with the WDNR and the USACE, as well as Onterra ecologists, herbicide applicators and ELPRD volunteers collaborated on a groundbreaking study in which much was learned regarding the mixing of herbicide within the water column of English Lake. As discussed in the Eurasian water milfoil portion of the plant section, further investigation into additional perplexing factors, such as water pH and hybrid Eurasian water milfoil resistance to herbicides were conducted during fall/winter of 2011/2012 which will aid in future treatment strategies on English Lake as well as other lakes in the state of Wisconsin that are battling large-scale Eurasian water milfoil infestations. In 2012, a strategy involving higher doses of 2,4-D herbicide was enacted in hopes of effectively combating this resilient plant.

In the Implementation Plan that follows, goals developed by the English Lake Planning Committee are presented to address issues and concerns dealing with English Lake. These goals were written to be realistic and implementable for English Lake stakeholders to conduct, and will guide management actions aiming to improve the ecosystem of English Lake.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the ELPRD Planning Committee and ecologist/planners from Onterra. It represents the path the ELPRD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the English Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Control Eurasian Water Milfoil within English Lake While Preventing Introduction of Other AIS.

Management Action: Herbicide treatments and monitoring of Eurasian water milfoil (3 years).
Timeframe: Begin 2012
Facilitator: ELPRD Board of Commissioners
Funding Possibility: AIS Established Population Control Grant
Description: In 2009, 2010 and 2011, Eurasian water milfoil was mapped throughout much of the littoral zone around English Lake (Map 4). While many questions were answered following the herbicide treatment that took place in 2010, more questions were raised as to why the efficacy of the treatment was not as expected. Studies being conducted by SePro and the USACE have shed light upon some of these questions and point the ELPRD in a direction of an answer to their Eurasian water milfoil problem.

During winter of 2012, discussions were held between Onterra, the WDNR, SePRO, the USACE and English Lake stakeholders considering a course of action for combating Eurasian water milfoil in English Lake. Using information gained from the 2010 treatment study and current studies being conducted as it becomes available, the ELPRD elected to conduct a whole lake 2012 treatment with liquid 2,4-D at a dose higher than what was used in 2010, which was 2.0 ppm over the treatment areas. In 2012, approximately 3.75 ppm a.e. liquid 2,4-D was applied to the 13.2 acre area of lake containing this species (Map 9). This will result in a calculated whole-lake epilimnetic concentration of 0.347 ppm a.e., since at the time of treatment the lake was found to stratify at 26 feet.

The higher dose of 2,4-D was justified through several ways; 1) little effects to the native plant community were observed following the 2010 treatments, and 2) preliminary results from studies conducted by SePRO show that the hybrid Eurasian water milfoil from English Lake is more resistant to herbicides than pure Eurasian water milfoil strains. As with the 2010 treatment, volunteers from the ELPRD will be trained in collecting water samples from the lake after treatment so that an understanding of the herbicide concentration and longevity may be understood. These samples will be collected surrounding the 2012-2014 treatments following protocols developed by the USACE. Members of the

ELPRD would collect samples at various locations within the lake at different locations and time-periods following the treatment. Properly preserved samples will then be sent to the USACE for laboratory analysis.

Action Steps:

1. The ELPRD prepares an AIS-EPC grant to fund treatment activities and monitoring by the February 1st 2012 deadline using most expensive treatment scenario listed above within grant budget. At the time of this writing, this grant application has been funded.
2. Retain consultant to map aquatic invasive species occurrences and oversee 2012 Eurasian water milfoil treatments and monitoring.
3. In 2013, 2014 & 2015 open water seasons, control strategy will be based upon professional findings.
4. District, with help from an herbicide applicator if applicable, obtains the proper permits to implement management action.
    a. WDNR Plant Management and Protection Program: www.dnr.state.wi.us/lakes/plants
    b. The UW Extension Lake List is a great resource for locating an herbicide applicator: www.uwsp.edu/cnr/uwexlakes/lakelist/businessSearch.asp
5. District updates management plan to reflect changes in control strategy

Management Action: Continue Clean Boats Clean Waters watercraft inspections at English Lake public access location.

Timeframe: Start 2012

Facilitator: ELPRD Board of Commissioners

Description: English Lake is a popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasives from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasives that originated in English Lake. The goal would be to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of its spread.

Often, it is difficult for lake groups to recruit and maintain a volunteer base to oversee Clean Boats Clean Waters (CBCW) inspections throughout the summer months. Recruitment outside of the ELPRD may be necessary in order to have sufficient coverage of the English Lake public access. Education efforts outside of the lake community help to not only raise awareness about the threat of AIS, but also potentially recruit new volunteers to participate in activities such as CBCW.

Members of the ELPRD, as well as other volunteers, will need to be trained on CBCW protocols in order to participate in public boat landing inspections. Fully understanding the importance of CBCW inspections, paid watercraft inspectors may be sought to ensure monitoring occurs at the public boat landing. These paid inspectors may be purchased alone or in conjunction with volunteers through the

ELPRD or in the community. To meet requirements set forth by the AIS-EPP grant the ELPRD will likely submit in February 2012, 200 hours of CBCW time must be logged at the English Lake public access point.

Action Steps:

1. Members of ELPRD periodically attend CBCW training session through the WDNR or Manitowoc County Lakes Association (Tom Ward – 920.588.0047) to update their skills to current standards.
2. Training of additional volunteers completed by those previously trained.
3. Begin inspections during high-risk weekends
4. Report results to WDNR and ELPRD
5. Promote enlistment and training of new of volunteers to keep program fresh.

Management Action: Initiate volunteer-based monitoring of aquatic invasive species.
Timeframe: Start 2012
Facilitator: ELPRD volunteers
Description: In 2007, a sample of what was believed to be curly-leaf pondweed was pulled from English Lake and sent to the WDNR. Mary Gansberg positively identified the plant as curly-leaf pondweed, and a subsequent chemical treatment occurred. During Onterra's 2010 and 2011 surveys on English Lake, no occurrences of curly-leaf pondweed were found. Later on, in spring of 2012, Carol Entringer of the ELPRD found a small clump of curly-leaf pondweed within the lake and alerted this discovery to Onterra staff. Carol led Onterra staff to the location, and GPS coordinates were taken. One of several observed plants were pulled from the sediment and sent into the University of Wisconsin - Stevens Point Herbarium to be vouchered.

In lakes with small amounts of AIS, early detection of pioneer colonies is crucial in combating the plants spread throughout the lake. This is often the only chance lake residents have to hope to contain a very small infestations, let along possibly eradicate the AIS. Using trained volunteers is a feasible method to monitor for the occurrence of these unwanted species. The keys to success are proper training and persistence by the lake group.

Following a training session by the WDNR, UW-Extension or Manitowoc County Lakes Association, volunteers would monitor Eurasian water milfoil and curly-leaf pondweed occurrences within the lake. Initial training would include identification of Eurasian water milfoil and curly-leaf pondweed as well as native look-a-likes and expand to proper use of GPS for recording aquatic plant occurrences, note taking, and transfer of spatial data. If this form of training is not available through the organizations listed above, the ELPRD may seek professional training on these tasks. Please note that until the Eurasian water milfoil population is brought under control, these volunteer efforts would focus primarily on curly-leaf pondweed as Eurasian water milfoil would be tracked through professional monitoring during treatments.

Action Steps:

1. Volunteers from ELPRD attend training session conducted by WDNR, UW-Extension or Manitowoc County Lakes Association.
2. Trained volunteers recruit and train additional district members.
3. Complete lake surveys following protocols.
4. Report results to WDNR and ELPRD.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation and expansion of current effort.

Facilitator: English Lake Protection & Rehabilitation District, specifically Dave Pfeffer and Scott Molepske

Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason as of why the trend is developing.

The Citizens Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers trained by the WDNR as a part of the CLMN program begin by collecting Secchi disk transparency data for at least one year, then if the WDNR has availability in the program, the volunteer may enter into the *advanced program* and collect water chemistry data including chlorophyll-a, and total phosphorus. Currently, a volunteer collects Secchi disk clarity data on English Lake, and has been doing so for some time. The ELPRD should seek to enter the advanced water chemistry program so that nutrients and algal content may be documented over time as well as Secchi disk clarity. Note: as a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

Action Steps:

Please see description above

Management Action: Complete study to determine feasibility of completing an alum treatment on English Lake to control internal nutrient loading.

Timeframe: Begin 2013/2014

Facilitator: ELPRD Board of Directors

Description: As the Water Quality and Watershed Sections discuss, there is likely a significant amount of internal nutrient loading that occurs within English Lake. WiLMS modeling and general water quality analyses were able to show that this significant loading does occur, however, the exact extent of loading can only be determined by a more in-depth study. This study would involve extensive hypolimnetic and epilimnetic water quality sampling, as well as quantifying the phosphorus release rates from sediment cores extracted from the English Lake bottom. Further modeling with this information would be able to provide answers as to exactly how much phosphorus is being released from the English Lake sediments, as well as what measures of control might be enacted and what their efficacy may be.

In order to enact this diagnostic/feasibility study, the ELPRD can apply for financial assistance through the State of Wisconsin in the form of a Lake Management Planning Grant. This grant would provide financial assistance for the intensive water quality monitoring, analyses, and research needed to determine the extent of internal nutrient loading in the lake. Furthermore, this project would determine if a corrective measure such as an alum treatment would be a feasible and cost-effective action.

The ELPRD acknowledges that there are more pertinent issues at hand (i.e. the Eurasian water milfoil infestation) and that this should be addressed first. Once a strategy is developed and a measurable decrease in Eurasian water milfoil is achieved, the district may devote its time and efforts towards this new study. This would likely not occur until 2013 or 2014.

Action Steps:

1. See above.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to English Lake.

Timeframe: Begin 2012

Facilitator: ELPRD Board of Directors or appointed committee/individual.

Description: As the watershed section discusses, the English Lake watershed is in an acceptable condition due to the efforts of the ELPRD; however, watershed inputs still need to be focused upon, especially in terms of the lake's shoreland properties. These sources include shoreland areas that are maintained in an unnatural manner and impervious surfaces.

On April 14th, 2009, Governor Doyle signed the "Clean Lakes" bill (enacted as 2009 Wisconsin Act 9) which prohibits the use of lawn fertilizers containing phosphorus starting in April 2010. Phosphorus containing fertilizers were identified as a major contributor to decreasing water quality conditions in lakes, fueling plant growth. While this law also bans the display and sale of phosphorus containing fertilizers, educating lake stakeholders about the regulations and their purpose is important to ensure compliance.

To reduce these negative impacts, the ELPRD will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include newsletter articles and guest speakers at ELPRD meetings. Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts. Shoreland restoration activities have already taken place at a residence along English Lake, so using a live example of this action may spur further interest in this area of lake enhancement.

The results of the 2010 shoreline assessment survey may be used to prioritize areas along the lakeshore that are in need of enhancement.

Action Steps:

1. Recruit facilitator.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Manitowoc County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for ELPRD meetings.

Management Goal 3: Increase English Lake Protection & Rehabilitation District's Capacity to Communicate Information with Lake Stakeholders

Management Action: Develop district website
Timeframe: Begin summer 2012
Facilitator: Planning Committee to form Education Committee
Description: The ELPRD is motivated to create a website for the district where information, such as this management plan, Eurasian water milfoil treatments, or special events, could be posted along with fostering unity amongst district members. The website will be constructed in an easy-to-use format to ensure stakeholders of all levels of computer literacy will have access to the information posted.
Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. Facilitators gather appropriate information relating to website development and event organization.

Management Action: Develop district newsletter
Timeframe: Begin summer 2012
Facilitator: Planning Committee to form Education Committee
Description: Because some English Lake stakeholders may not utilize the Internet for information, or lack proficiency in computer use, the ELPRD has discussed creating a newsletter to keep stakeholders informed of activities concerning English Lake. This newsletter may be circulated on an interval determined by the Education Committee. In addition to providing information regarding events and updates, it may be used as an educational tool.

Example Educational Topics:

- Specific topics brought forth in other management actions
- Aquatic invasive species monitoring updates
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreland restoration and protection
- Septic system maintenance

- Fishing Rules

Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. Facilitators gather appropriate information relating to newsletter content and event organization.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in English Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll a	●		●		●		●		●			
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●	●	●	●	●	●	●	●	●	●	●
Calcium	●											

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 5.

Watershed Analysis

The watershed analysis began with an accurate delineation of English Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on English Lake during an April 22, 2010 field visit. Because incidental reports of curl-leaf pondweed were received from English Lake residents, the survey was conducted at this time to prepare for a possible 2010 treatment if necessary. Visual inspections were completed throughout the lake by completing a meander survey by boat. No occurrences of curly-leaf pondweed were documented during this survey.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on English Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in "Appendix D" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used to complete this study on July 27, 2010. A point spacing of 30 meters was used resulting in approximately 211 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within English Lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium. A set of samples was also provided to the English Lake Protection & Rehabilitation District.

Eurasian Water Milfoil Treatment Monitoring

The methodology used to monitor the 2010 herbicide treatments is included within the results section under the heading: Treatment Monitoring.

7.0 LITERATURE CITED

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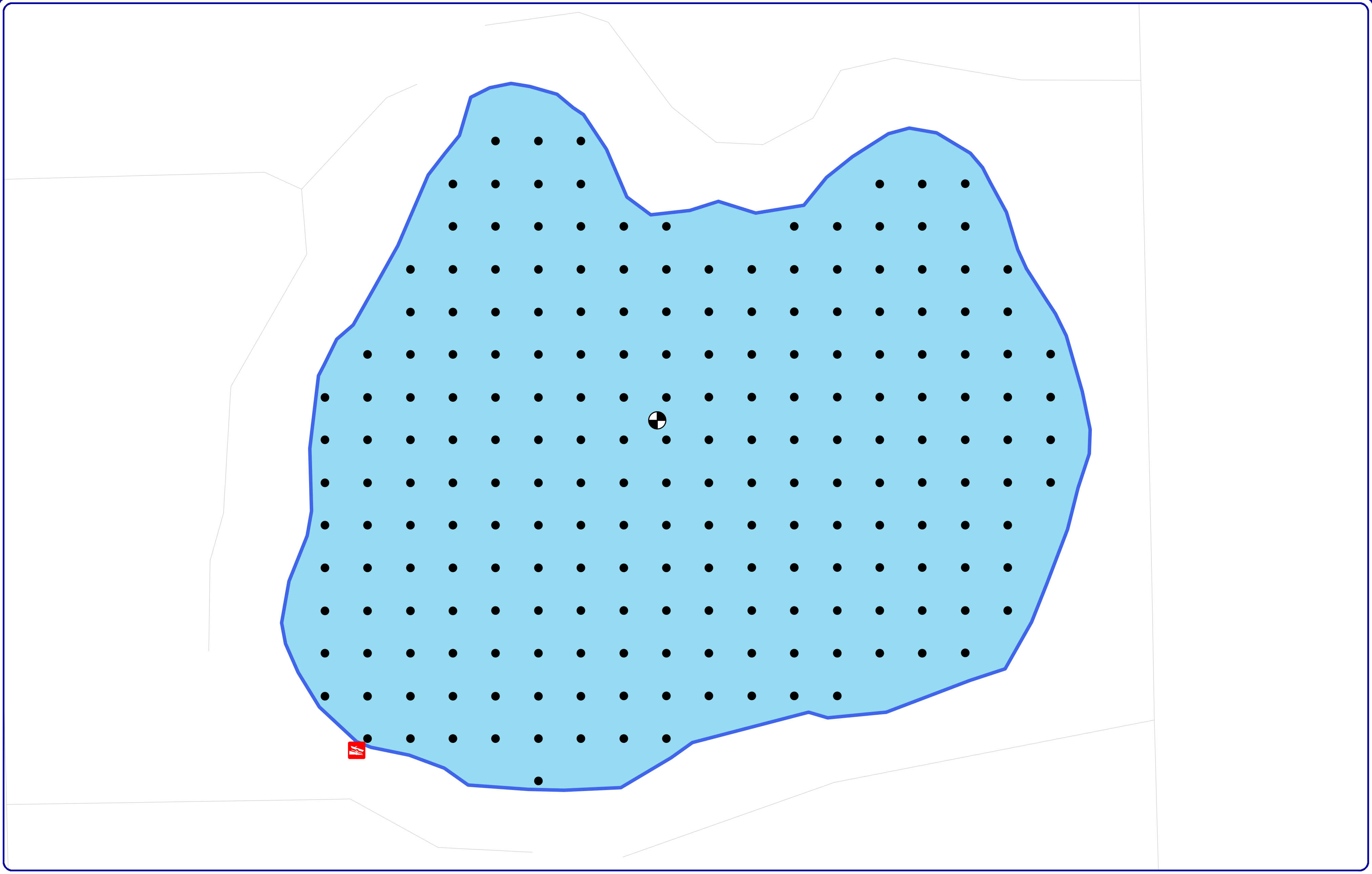

N
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300
Feet

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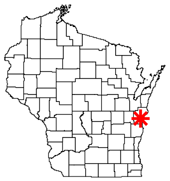
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads & Hydro: WDNR
Map date: October 14, 2011
Filename: Map1_English_location.mxd



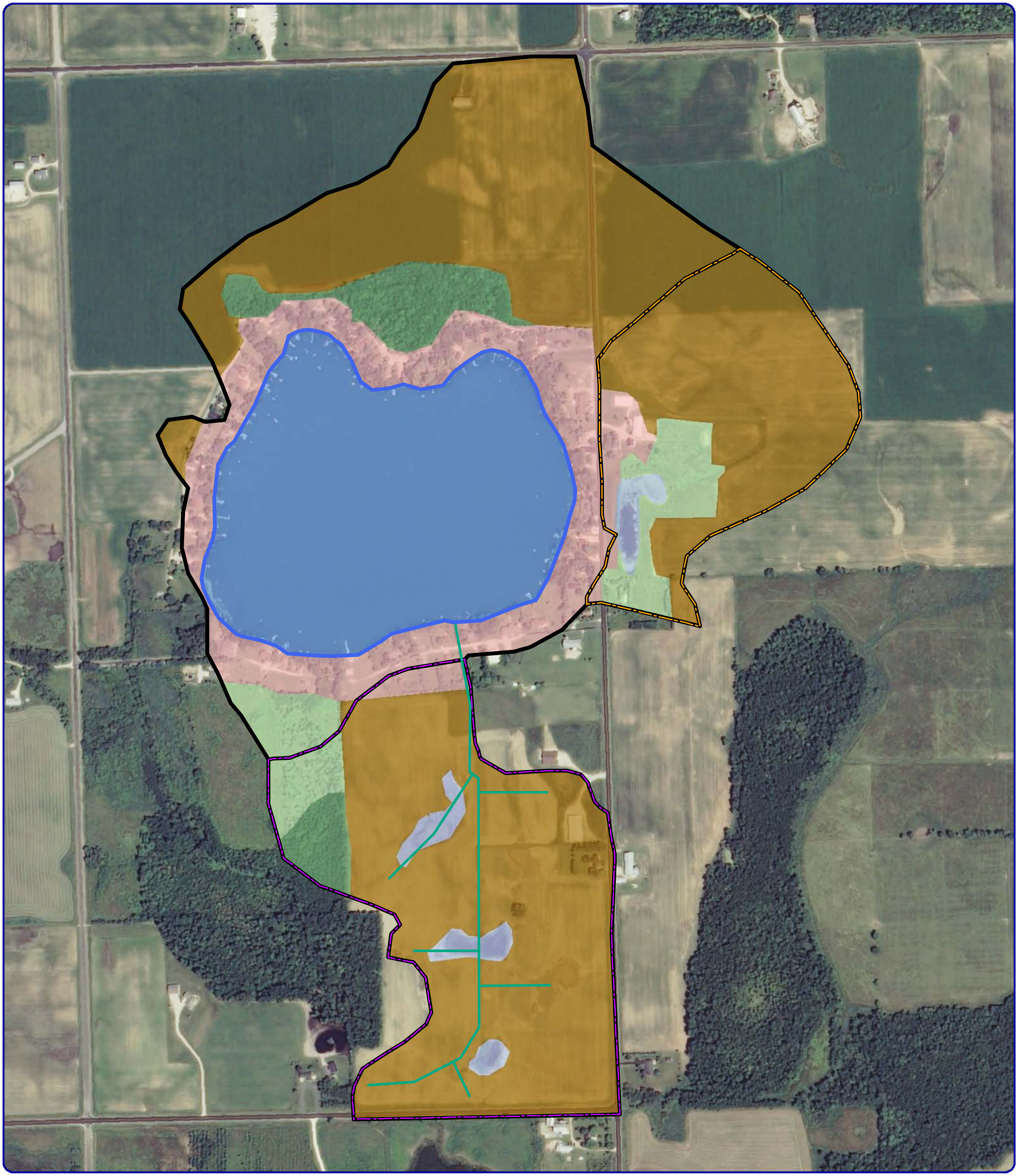
Project Location in Wisconsin

Legend

- English Lake ~56 acres
  WDNR Definition
- Point-Intercept Survey Location
  30-meter spacing, 211 total points
- Public Access
- Water Quality Sampling Location

Map 1
English Lake
Manitowoc County, Wisconsin

Project Location
& Lake Boundaries



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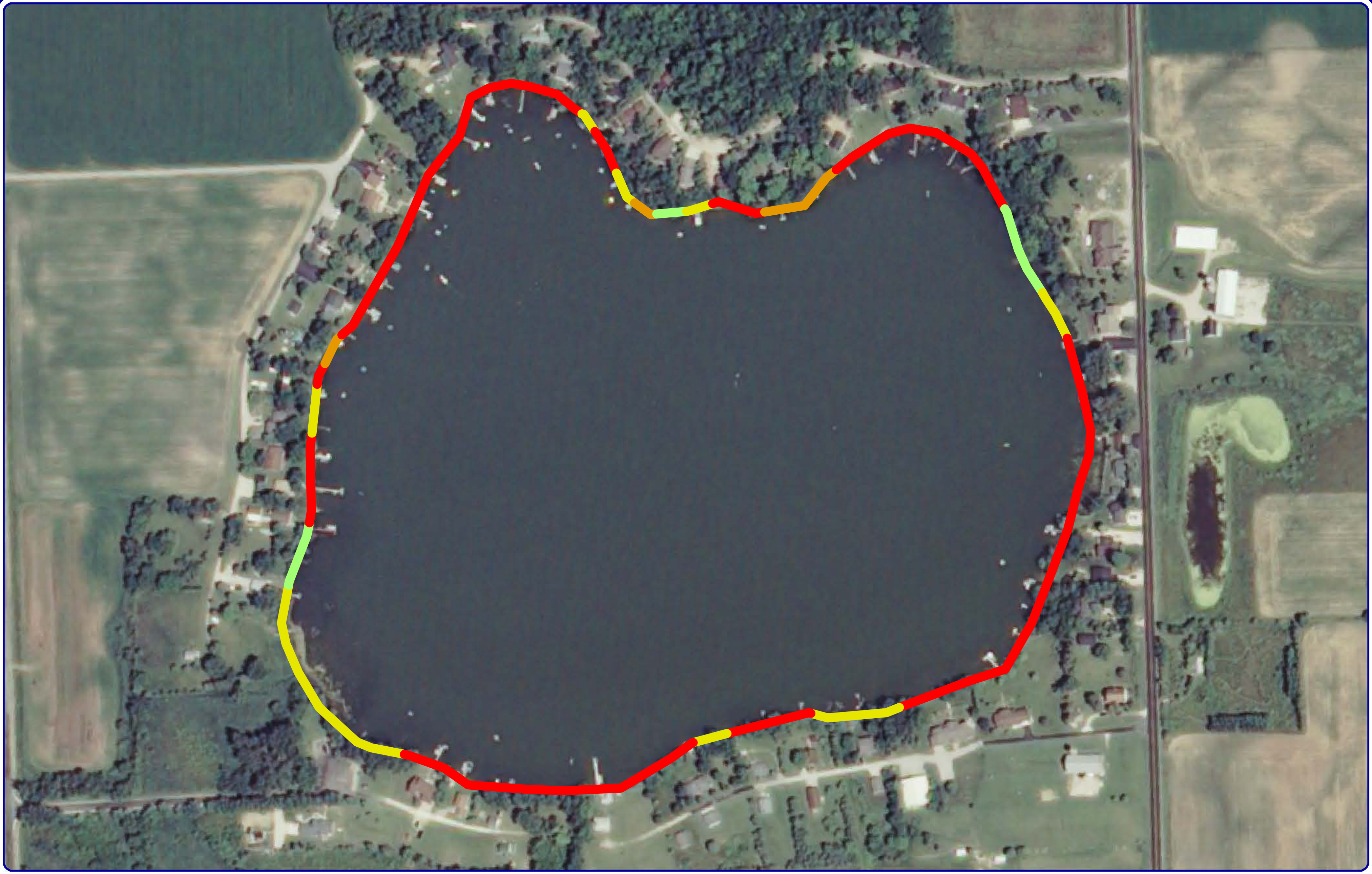
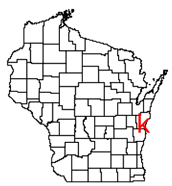
Sources:
Land Cover: NLCD 2006
Hydro: WDNR
Orthophotography: NAIP, 2008
Map Date: October 17, 2011
Filename: Map2_English_Watersehd.mxd

Map 2
English Lake
Manitowoc County, Wisconsin

Watershed and Land Cover Types





Project Location in Wisconsin

Legend

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

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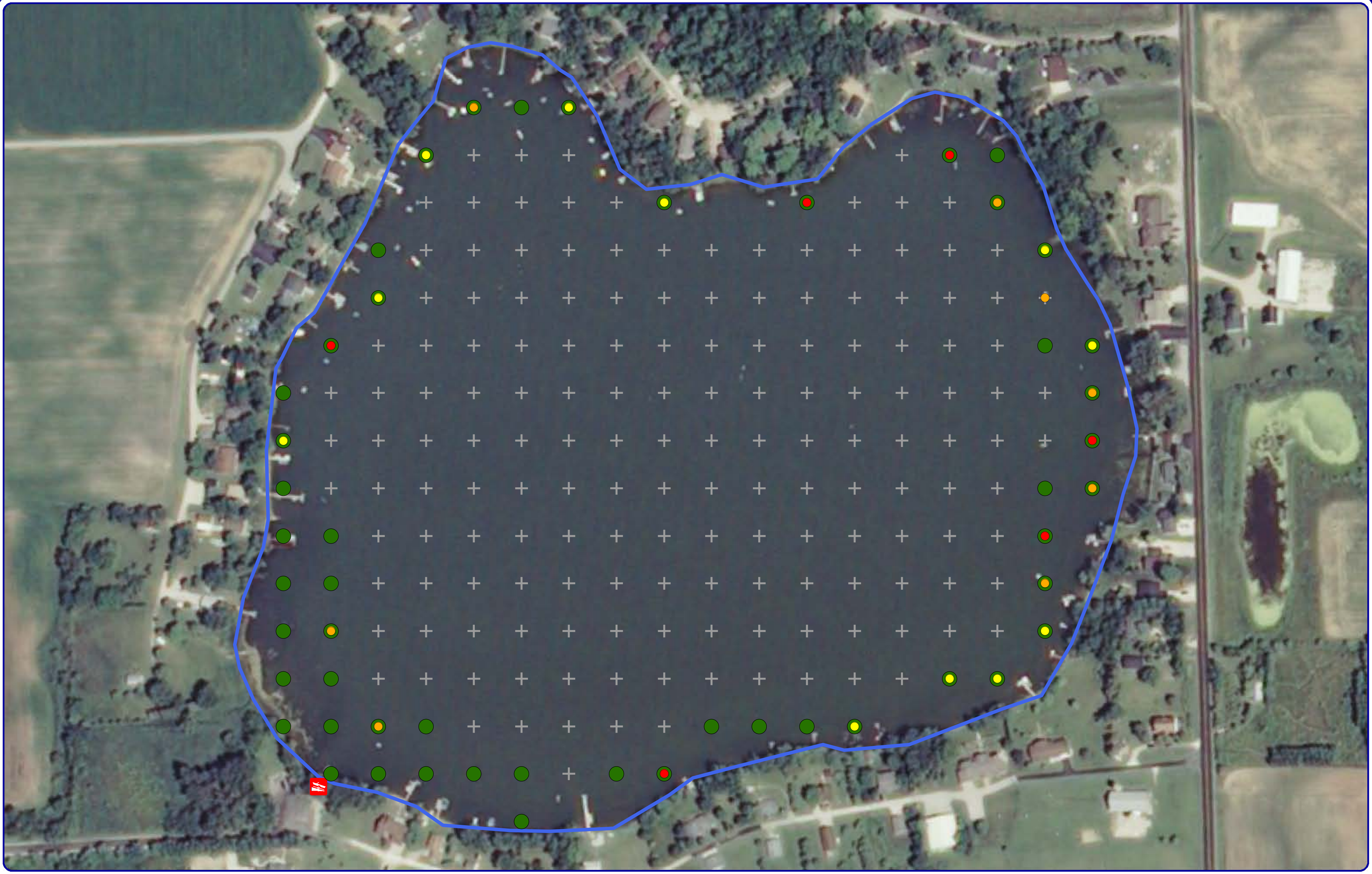
Sources:
Orthophotography: NAIP, 2008
Shoreline Assessment: Onterra, 2010
Map date: October 14, 2011
Filename: Map3_English_2010SAmxd

Map 3
English Lake
Manitowoc County, Wisconsin

2010 Shoreline Condition



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270
Feet

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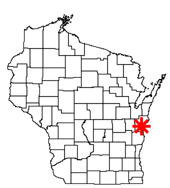
Sources:
Hydro: WDNR
Aquatic Plant Survey: Onterra, 2010
Orthophotography: NAIP, 2008
Map Date: October 19, 2011
Filename: Map4_English_2010_Veg_Locations.mxd



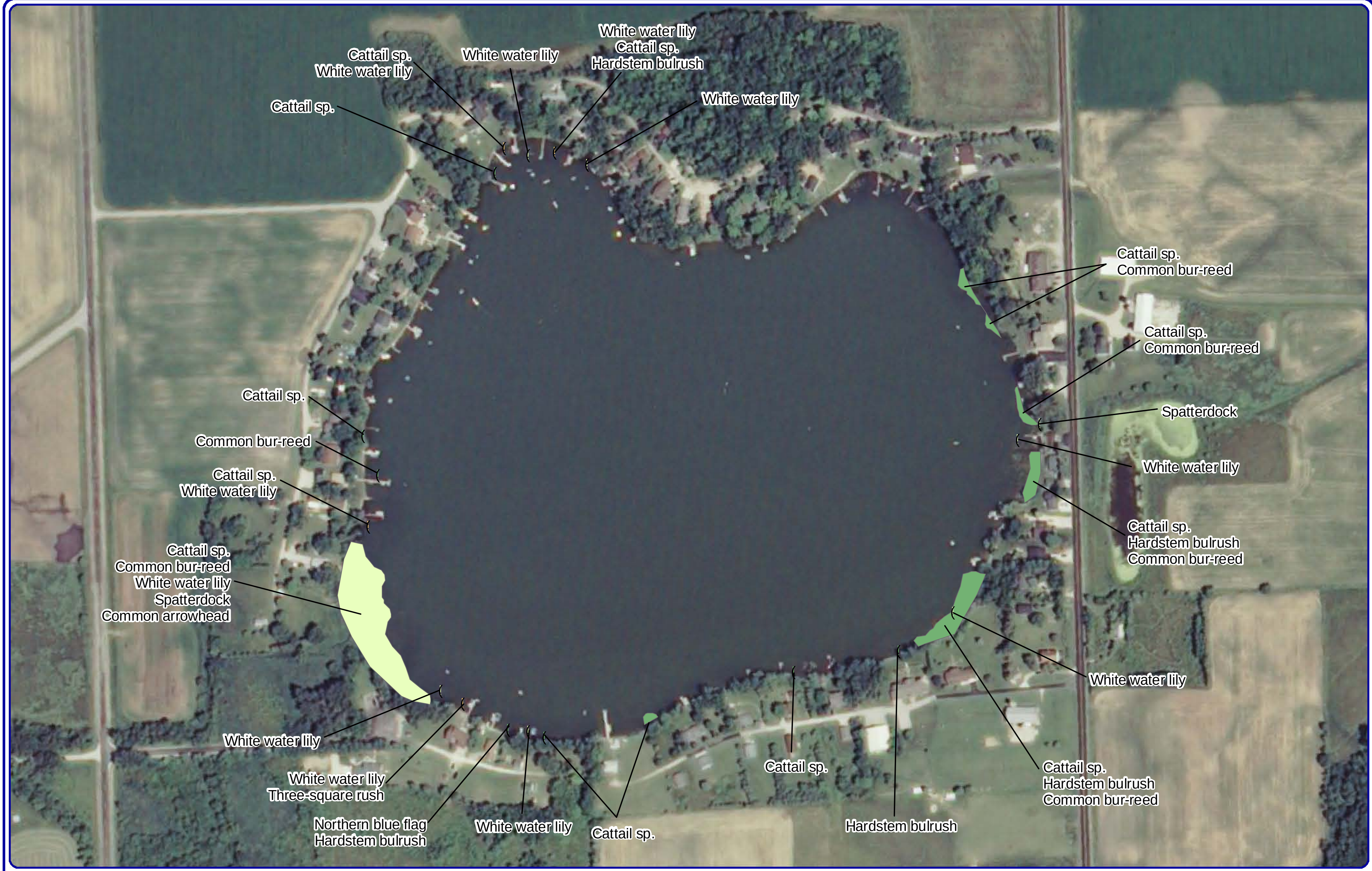
Project Location in Wisconsin

Legend

Point-intercept Sampling Locations

+ No Vegetation
Native Vegetation
EWM Rake-fullness = 1
EWM Rake-fullness = 2
EWM Rake-fullness = 3

Map 4
English Lake
Manitowoc County, Wisconsin
2010 Aquatic Plant Distribution



350

Feet

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Sources:
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2008
Map date: March 29, 2011
Filename: Map5_English_Comm10.mxd

Project Location in Wisconsin

Legend

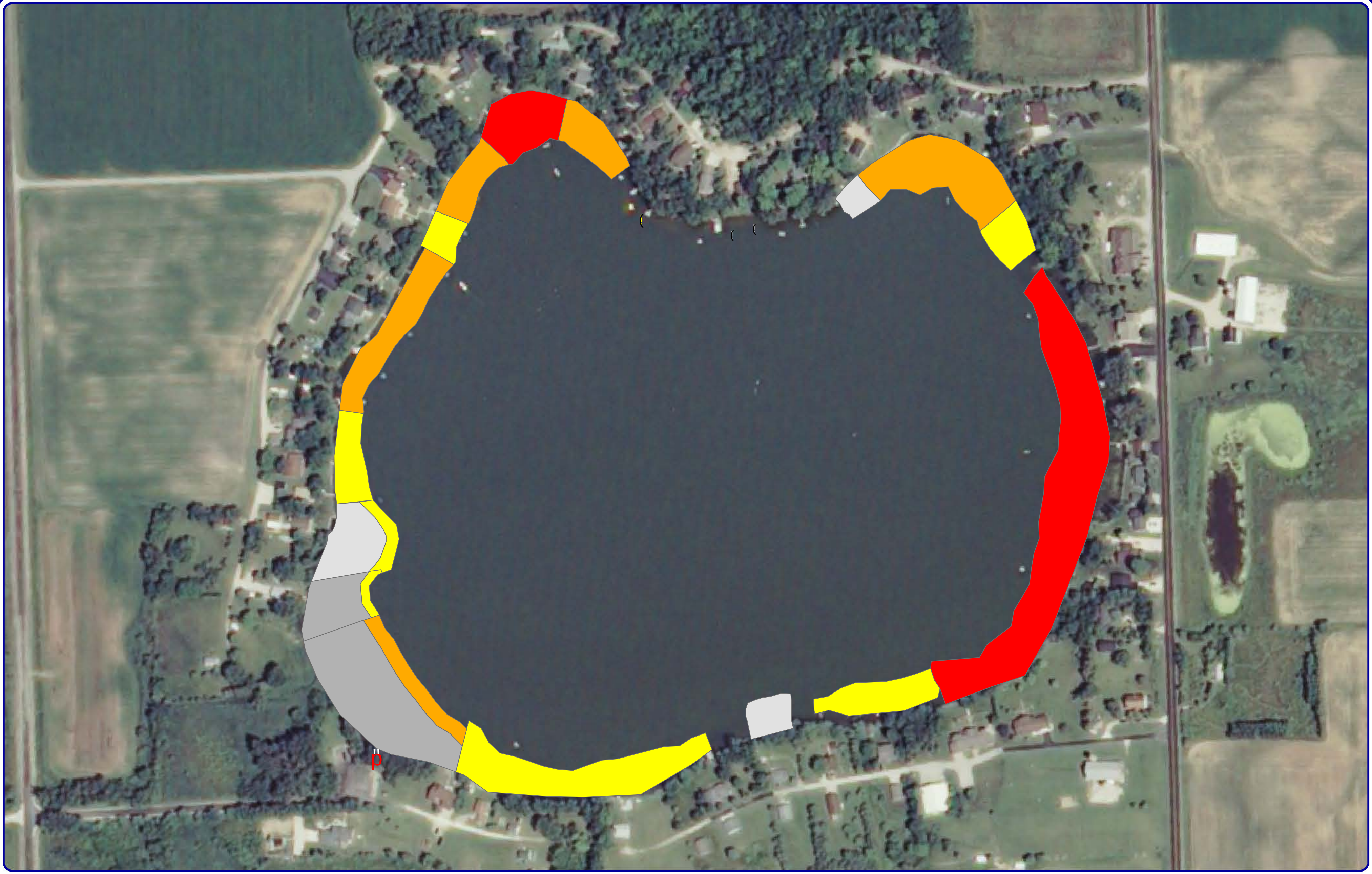
Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 5

English Lake
Manitowoc County, Wisconsin

Aquatic Plant Communities



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Feet

Legend

p Public Access

EWM Survey Results (Aug 2009)

(Single or Few Plants

(Clumps of Plants

EWM Survey Results (Aug 2009)

- Highly Scattered (0.8 acres)
- Scattered (1.7 acres)
- Dominant (2.4 acres)
- Highly Dominant (2.5 acres)
- Surface Matting (3.0 acres)

Project Location in Wisconsin

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Sources:
Orthophotography: NAIP, 2008
Aquatic Plants: Onterra, 2009
Map Date: October 14, 2011
File Name: Map6_English_EWM_PB2009.mxd

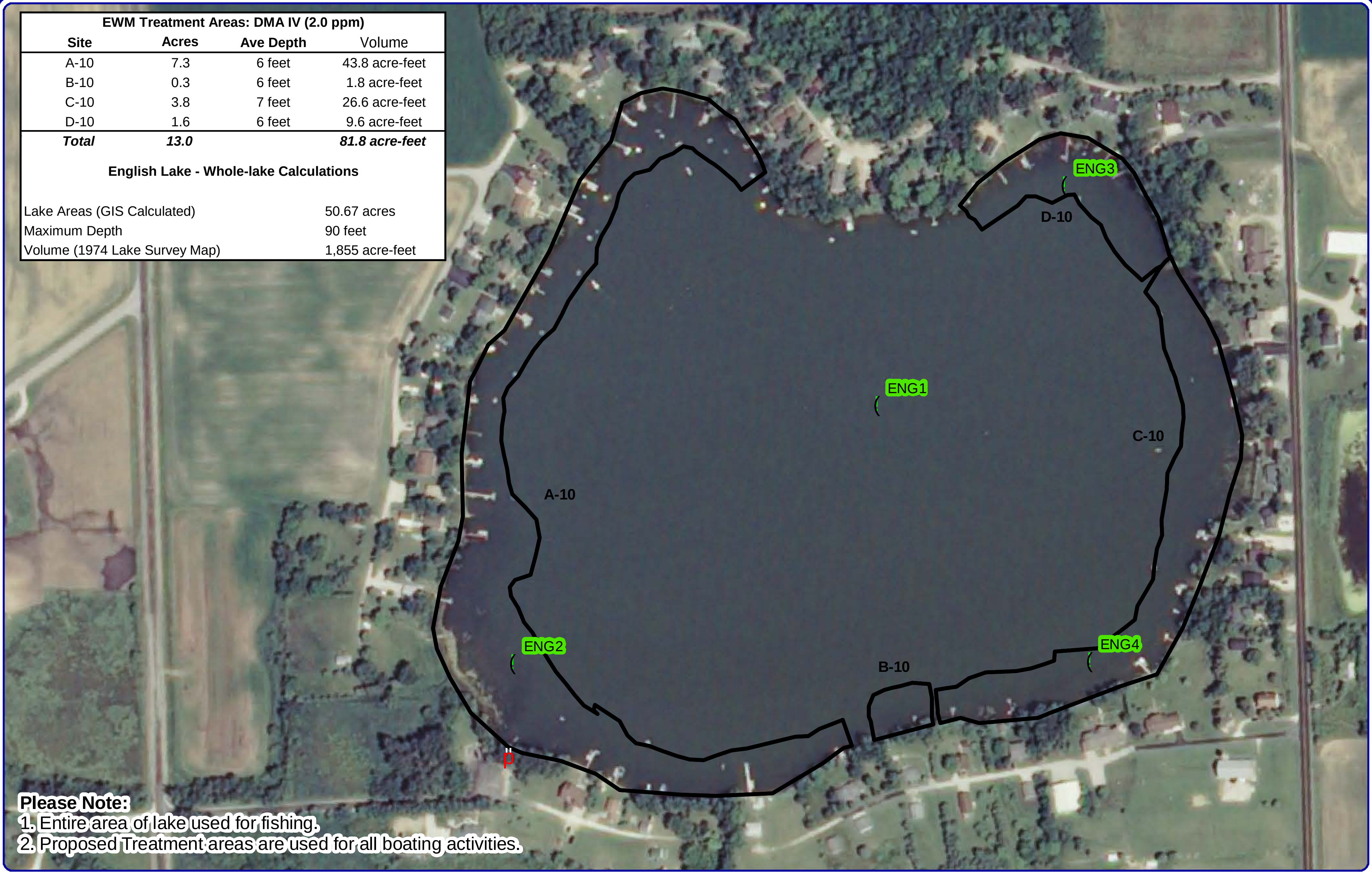
Map 6
English Lake
Manitowoc County, Wisconsin

2009 EWM Survey Results

EWM Treatment Areas: DMA IV (2.0 ppm)			
Site	Acres	Ave Depth	Volume
A-10	7.3	6 feet	43.8 acre-feet
B-10	0.3	6 feet	1.8 acre-feet
C-10	3.8	7 feet	26.6 acre-feet
D-10	1.6	6 feet	9.6 acre-feet
Total	***13.0***		***81.8 acre-feet***

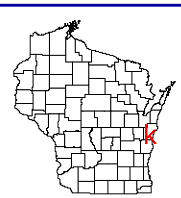
English Lake - Whole-lake Calculations

Lake Areas (GIS Calculated)	50.67 acres
Maximum Depth	90 feet
Volume (1974 Lake Survey Map)	1,855 acre-feet



Please Note:
1. Entire area of lake used for fishing.
2. Proposed Treatment areas are used for all boating activities.

300
Feet



Project Location in Wisconsin

Legend

2010 Final EWM Treatment Area

Residual Sample Location

Map 7
English Lake
Manitowoc County, Wisconsin
2010 Final EWM Treatment Areas

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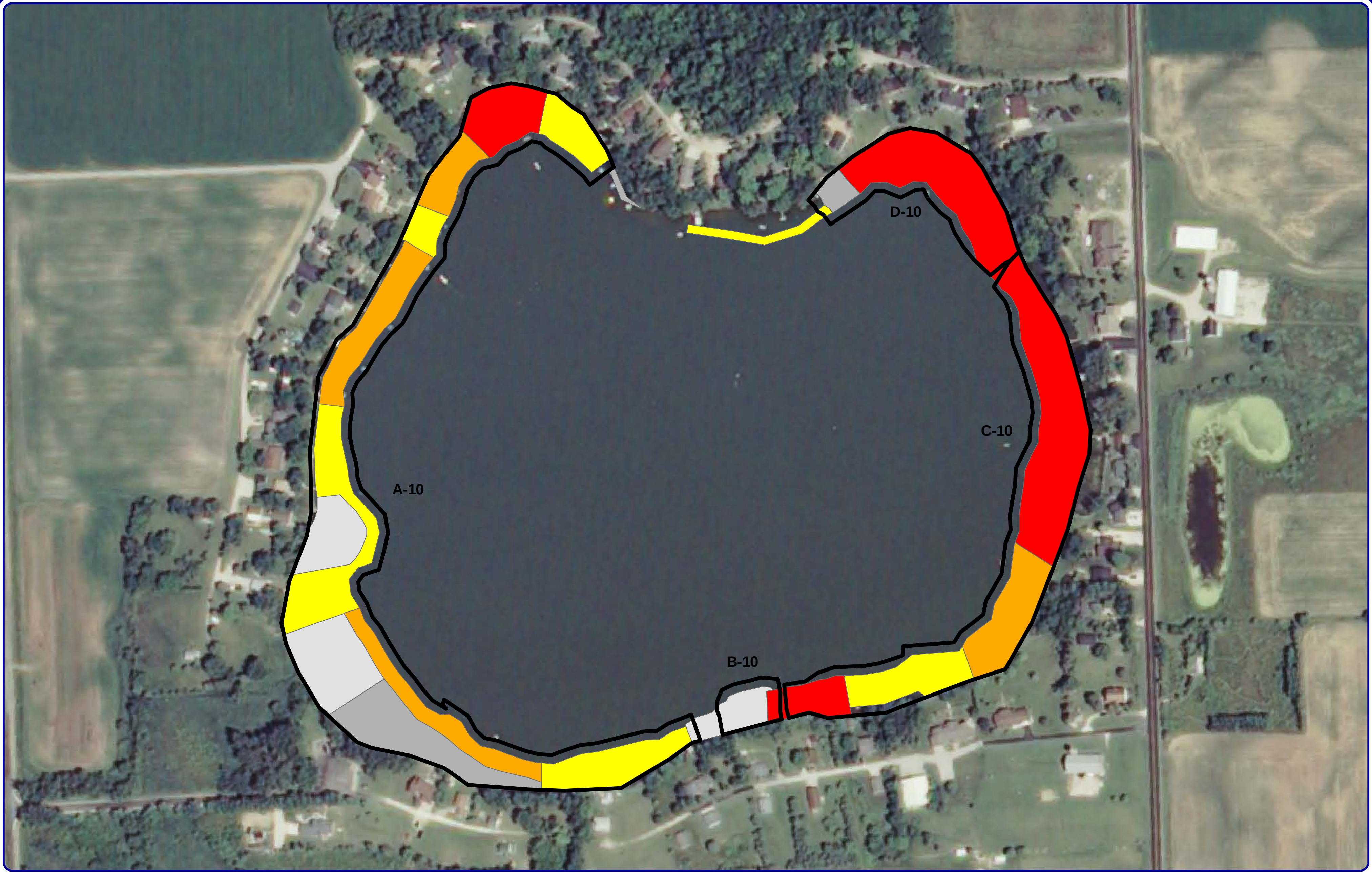
Sources:
Orthophotography: NAIP, 2008
Map Date: April 23, 2010
File Name: Map7_English_T2010EWM_Perm1.mxd



300
Feet

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Sources:
Orthophotography: NAIP, 2008
Aquatic Plants: Onterra, 2010
Map Date: October 8, 2010
File Name: Map8_English_EWM_PB_Sept10.mxd

Project Location in Wisconsin

Eurasian water milfoil ***September 2010***

- Highly Scattered (1.5 acres)
- Scattered (1.0 acres)
- Dominant (2.7 acres)
- Highly Dominant (2.1 acres)
- Surface Matting (3.8 acres)

2010 Final EWM Treatment Area

Map 8
English Lake
Manitowoc County, Wisconsin

2010 EWM Survey Results

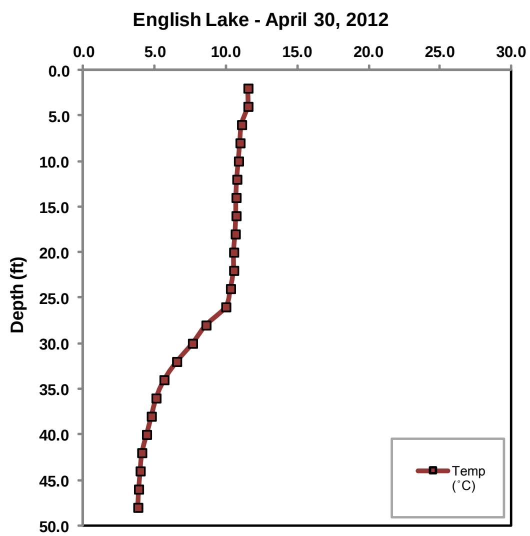
2012 Final EWM Treatment Areas - Liquid 2,4-D

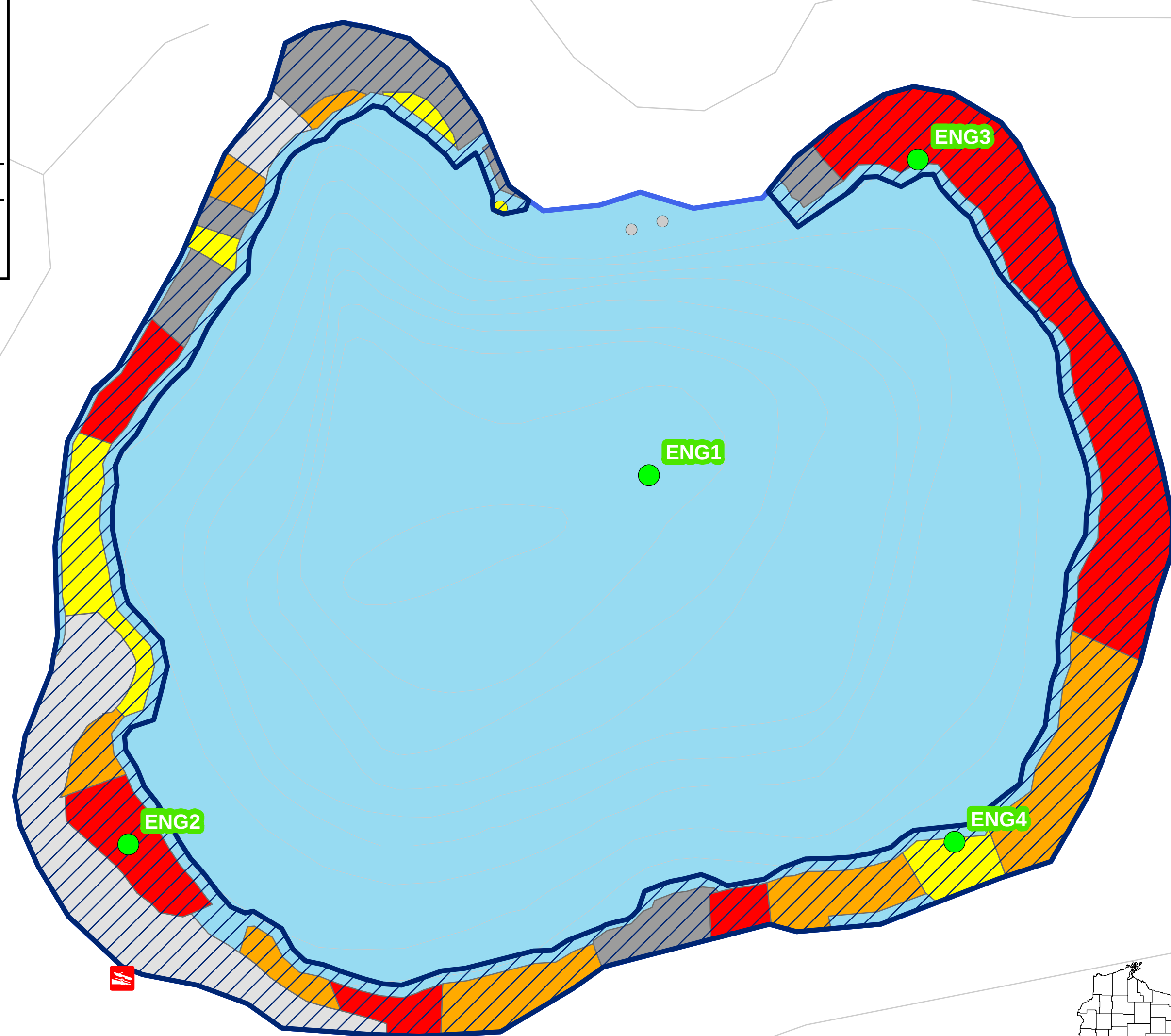
Application Area Dose: 3.75 ppm ae

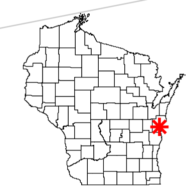
Calculated Epilimnion Concentration (26 ft): 0.347 ppm ae

Application Area Acres	Ave. Depth* (feet)	Volume (ac-ft)
13.2	6.5	85.8

** Back Caluclated from GIS-based Volume Calculations*







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Legend

EWM Survey Results (Aug 2011)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

2012 EWM Treatment

- Final EWM Application Area
- Chemical Concentration Sampling Location

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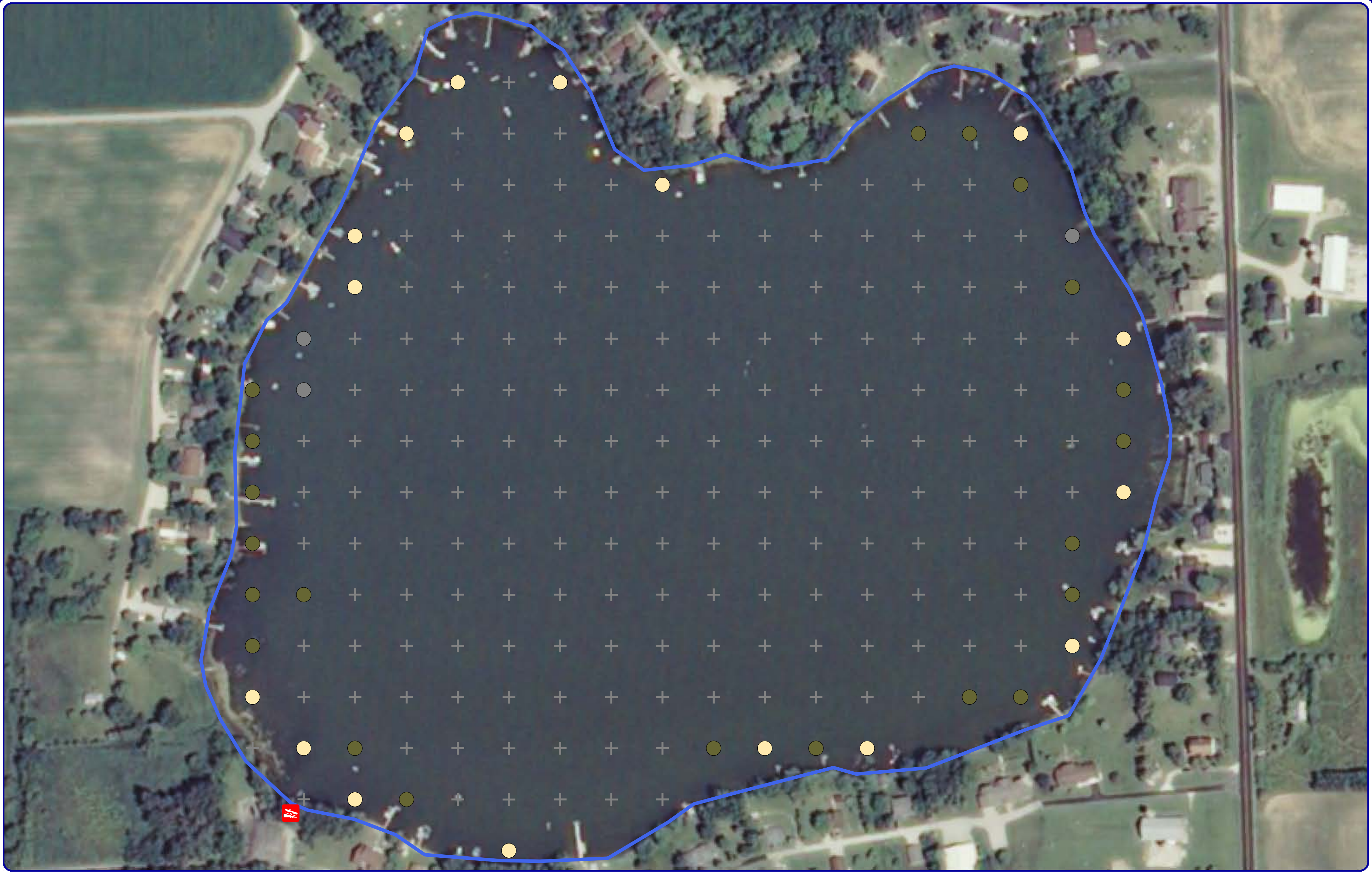
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2011-12
Map Date: April 30, 2012
File Name: Map9_English_PB2011_T2012.mxd

Map 9

English Lake

Manitowoc County, Wisconsin

2011 EWM Survey Results & 2012 Final Treatment Areas



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Feet

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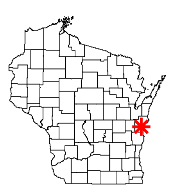
Sources:
Hydro: WDNR
Aquatic Plant Survey: Onterra, 2010
Orthophotography: NAIP, 2008
Map Date: October 19, 2011
Filename: Map10_English_2010_Sediment.mxd



Project Location in Wisconsin

Legend

Point-intercept Sampling Locations

- No Data *(Too Deep)*
- Muck
- Rock
- Sand

Map 10
English Lake
Manitowoc County, Wisconsin
Littoral Substrate Types