Gresham Chain of Lakes

Vilas County, Wisconsin

Comprehensive Management Plan

May 2009

Sponsored by:

Gresham Lakes Association

LPL-1156-07, LPL-1157-07, LPL-1158-07, & LPL-1159-07

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Onterra LLC
Lake Management Planning

Gresham Chain of Lakes

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Acknowledgements

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

Gresham Lakes Association Planning Committee

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Ms. Karen Christopherson
Mr. Rich Larson
Mr. Don Osborn
Ms. Cathy Snyder
Mr. Tom Sommerfeld
Mr. Charlie Spencer
Mr. Don Suominen
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Vilas County Land & Water Conservation Dept.

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Wisconsin Dept. of Natural Resources

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INTRODUCTION

The Gresham Chain of Lakes, Vilas County (Map 1), comprises three lakes (Upper, Middle, and Lower Gresham Lakes) with a surface area of nearly 570 acres. Water from this headwater drainage system ultimately leads to the Manitowish Waters Chain of Lakes.

Eurasian water milfoil was discovered in Upper Gresham Lake over five years ago and has been treated sporadically with 2,4-D providing minimal control of the exotic species. Volunteers from the lake have tracked the infestation and as a result understand the potential problems associated with the species and its control. Surveys conducted by Wisconsin Department of Natural Resources (WDNR) research confirmed the existence of Eurasian water milfoil in Upper Gresham during the summer of 2005, but did not find the exotic plant in Middle Gresham during the summer of 2006. Subsequent surveys completed by Onterra during the summer of 2007 found two small occurrences of Eurasian water milfoil within Middle Gresham Lake. Informal surveys completed by the Gresham Lakes Association (GLA) had not located Eurasian water milfoil in Lower Gresham Lake.

While dealing with the Eurasian water milfoil problem on Upper Gresham Lake, the GLA has realized that managing an exotic infestation is only a small portion of managing a lake, or in this case, a chain of lakes. They understand that because of the intricate links between the three lakes, that it is most appropriate to study and manage the chain as a whole. As a result of this understanding, the GLA and its partner, the Town of Boulder Junction, elected to complete a comprehensive management plan for the Gresham Lakes Chain. This is despite the fact that only an aquatic plant management plan would have been needed for Upper Gresham Lake to continue control efforts on the lake's Eurasian water milfoil infestation.

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 August 4, 2007 the GLA held their annual meeting of which an important part was to inform association members and other interested parties about the lake management planning project the association was undertaking. During the meeting, Eddie Heath, an aquatic ecologist with Onterra, presented information about lake eutrophication, native and non-native aquatic plants, the importance of lake management planning, and the goals and components of the Gresham Lakes management planning project. Eddie also discussed the Eurasian water milfoil treatments that were completed on Upper Gresham Lake during that spring.

Stakeholder Survey

During March 2008, a five-page, 28-question survey was mailed to 145 riparian property owners in the Gresham Lakes watershed. Fifty-one percent of the surveys were returned and those results were entered into a spreadsheet by members of the Gresham Lakes 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 integrated within the appropriate sections of the management plan.

Planning Committee Meeting I

On April 4, 2008, Tim Hoyman of Onterra met with eight members of the Gresham Lakes Planning Committee for nearly 3 hours. 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 nuisance levels of aquatic plants, and low water levels, beaver dam management, and the proposed expansion of the state-owned campground.

Planning Committee Meeting II

On May 3, 2008, Tim Hoyman met with nine members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Gresham Lakes management plan.

Project Wrap-up Meeting

On August 2, 2008, the Gresham Lakes Association held a special meeting regarding the completion of the Gresham Lakes Management Planning Project. During the meeting, Tim Hoyman presented the results of the many studies that had been completed on the lake since 2007. He also answered many questions about the lake and how it should be managed. The 2008 EWM Treatment Monitoring Project and the Implementation Plan for the Gresham Chain of Lakes were also presented and discussed.

RESULTS & DISCUSSION

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, not all chemical attributes collected may have a direct bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, 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 ecology 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.

Comparisons with Other Datasets

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 similar lakes in the area. In this document, a portion of the water quality information collected in the Gresham Lakes are compared to other lakes in the region and state (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 Gresham Chain 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).

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Vilas County lakes are included within the study's Northeast Region (Figure 1) and are among 242 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from the Gresham Chain are displayed in Figures 2-10. Please note that the data in these graphs represent values collected only during the summer months (June-August) from the deepest location in each of the Gresham Lakes (Map 1). 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 (see discussion under Internal Nutrient Loading on page 9). Surface samples in the Gresham Lakes were collected at a depth of 3 feet.

Figure 1. Location of Gresham Chain of Lakes within the regions utilized by Lillie and Mason (1983).

Apparent Water Quality Index

Water quality, like beauty, is often in the eye of the beholder. A person from southern Wisconsin that has never seen a northern lake may consider the water quality of their lake to be good if the bottom is visible in 4 feet of water. On the other hand, a person accustomed to seeing the bottom in 18 feet of water may be alarmed at the clarity found in the southern lake.

Lillie and Mason (1983) used the extensive data they compiled to create the *Apparent Water Quality Index* (WQI). They divided the phosphorus, chlorophyll-*a*, and clarity data of the state's lakes into ranked categories and assigned each a "quality" label from "Excellent" to "Very Poor". The categories were created based upon natural divisions in the dataset and upon their experience. As a result, using the WQI as an assessment tool is very much like comparing a particular lake's values to values from many other lakes in the state. However, the use of terms like, "Poor", "Fair", and "Good" bring about a better understanding of the results than just comparing averages or other statistical values between lakes. The WQI values corresponding to the phosphorus, chlorophyll-*a*, and Secchi disk values for Gresham Lakes are displayed on Figures 2-4.

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. 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.

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.

Carlson (1977) presented a trophic state index that gained great acceptance among lake managers. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-*a*, and total phosphorus values of a relatively small set of Minnesota Lakes, researchers from Wisconsin (Lillie et. al. 1993), developed a new set of relationships and equations based upon the data compiled in Lillie & Mason (1983). This resulted in the Wisconsin Trophic State Index (WTSI), which is essentially a TSI calibrated for Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers.

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.

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The *epiliminion* 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.

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.

*Temperature and dissolved oxygen profiles were not collected as a part of this project. The explanation provided under this heading is strictly for the information of the reader.

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.

*Lack of temperature/dissolved oxygen profiles and hypolimnetic phosphorus data prevents these analyses from being performed. The explanation provided under this heading is strictly for the information of the reader.

Gresham Lakes Water Quality Analysis

Gresham Lakes Long-term Trends

Unfortunately, there is not a great deal of water quality data available for assessing long-term trends within the Gresham Chain as a whole. Upper Gresham Lake, thanks to the efforts of its citizen lake monitor, Mr. Don Osborn, has the largest dataset and includes consistent water clarity data back to the early 1990’s (Figure 8). However, consistent water chemistry data for Upper Gresham Lake only occurs from 2000 to present (Appendix C). The datasets for Middle and Lower Gresham Lakes are much more limited with very sparse water clarity data and even less water chemistry data (Appendix C). Obviously this lack of information severely limits the conclusions that can be drawn about the water quality of the Gresham Chain. It also demonstrates the importance of continuing the water quality monitoring that has been occurring on Upper Gresham for the past 8 years and has just began as a part of this project in 2007 on Middle and Lower Gresham.

Recent total phosphorus concentrations collected on all three lakes (Figures 2-4) are considered to be good and are less than average values found in other lakes in the region and state. Further examination of the total phosphorus data from Upper Gresham Lake indicates no definite trend in greater or lesser concentrations of phosphorus occurring over the course of the dataset. Like in all lakes, fluctuations occur as a result of many variables, of which the most important is probably amount of precipitation.

Chlorophyll-*a* concentrations for the Gresham Lakes are displayed in Figures 5-7 and much like the phosphorus data are very limited temporally, but recent data indicate that the values are good and below averages for the state and region. In fact, the 2007 concentrations for Middle Gresham Lake are considered very good. The historic data from Upper Gresham Lake does not show a trend in the chlorophyll-*a* concentrations over the years, but there is a definite increase in these values that correspond with the higher total phosphorus concentrations that occurred in 2005 and 2006 (Figure 2).

Figures 8-10 contain water clarity data for the three Gresham Lakes. These data indicate that the water clarity of the lakes range from good to very good and again are better than clarity values from lakes in the region and the state. Nearly two decades of clarity data exists for Upper Gresham Lake (Figure 8) and those values indicate that the lake's water quality has been relatively stable over that timeframe. Again, the most influential cause of the fluctuation likely relates to precipitation and the varying amounts of phosphorus being transported to the lake from its watershed. Examination of the limited water clarity datasets from Middle and Lower Gresham Lake also lead to the conclusion that those lakes are also stable over the timeframe for which the data exists.

Limiting Plant Nutrient of the Gresham Lakes

Table 1 contains nitrogen to phosphorus ratios calculated using data from three different timeframes. All of these values are well over the threshold of 15:1 indicating that the lakes are strongly phosphorus limited.

Table 1. Nitrogen to phosphorus ratios for Gresham Lakes based upon parameter concentrations from different timeframes of 2007 dataset.

Dataset	Upper Gresham Lake	Middle Gresham Lake	Lower Gresham Lake
Mid Summer	28:1	47:1	29:1
Avg. Growing Season	25:1	33:1	31:1
Avg. Summer	43:1	43:1	30:1

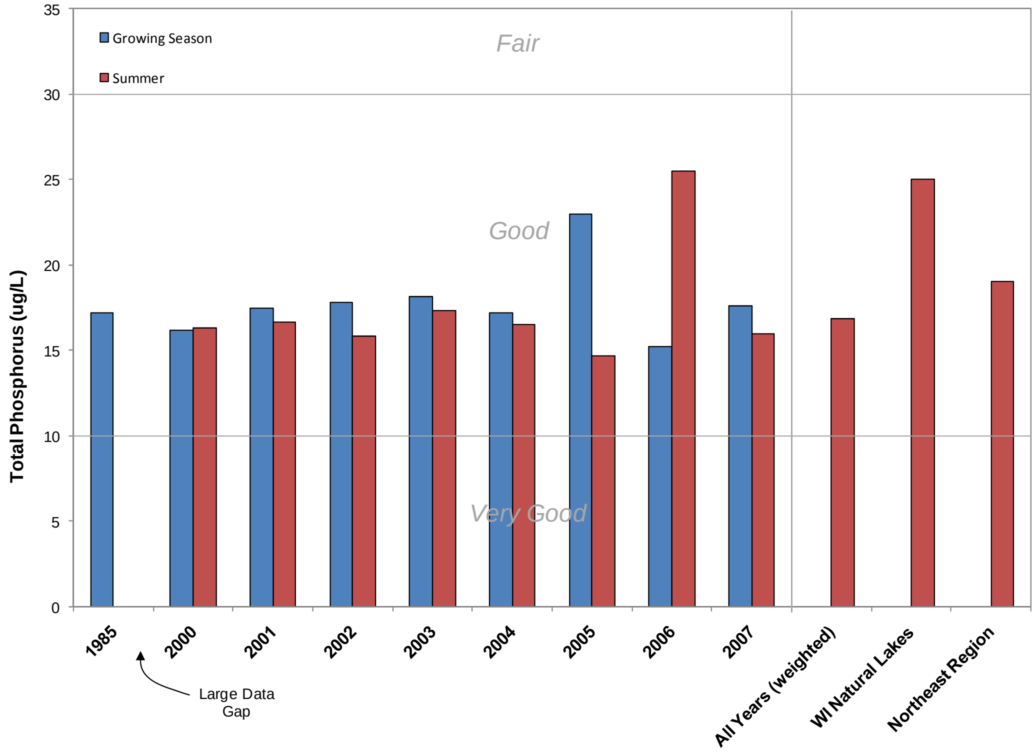

Figure 2. Upper Gresham Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

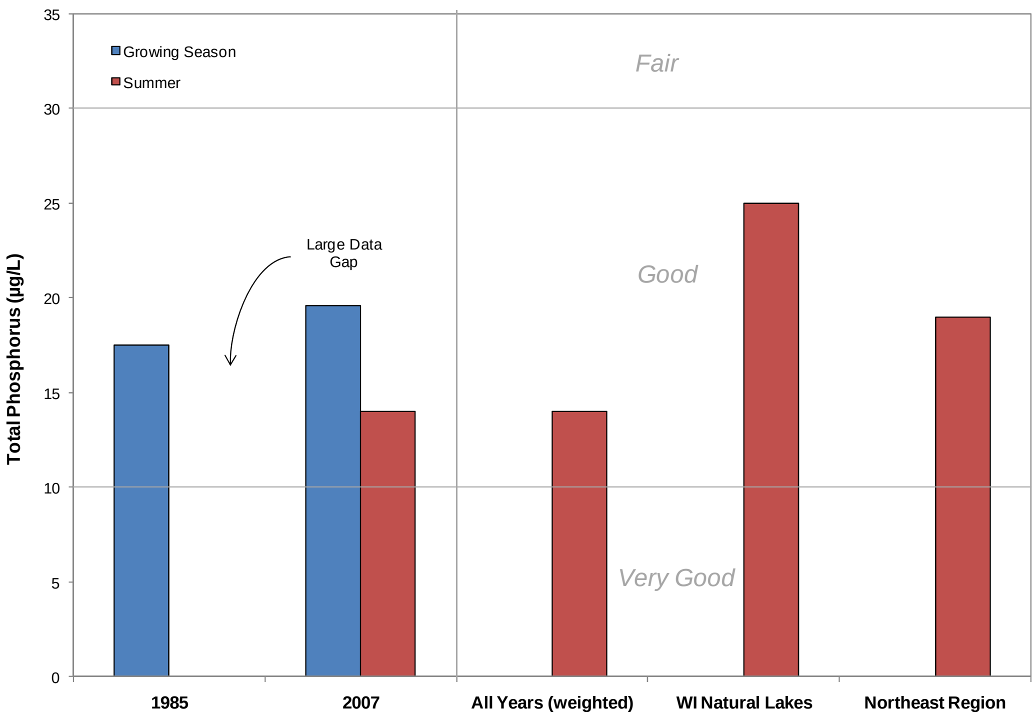

Figure 3. Middle Gresham Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

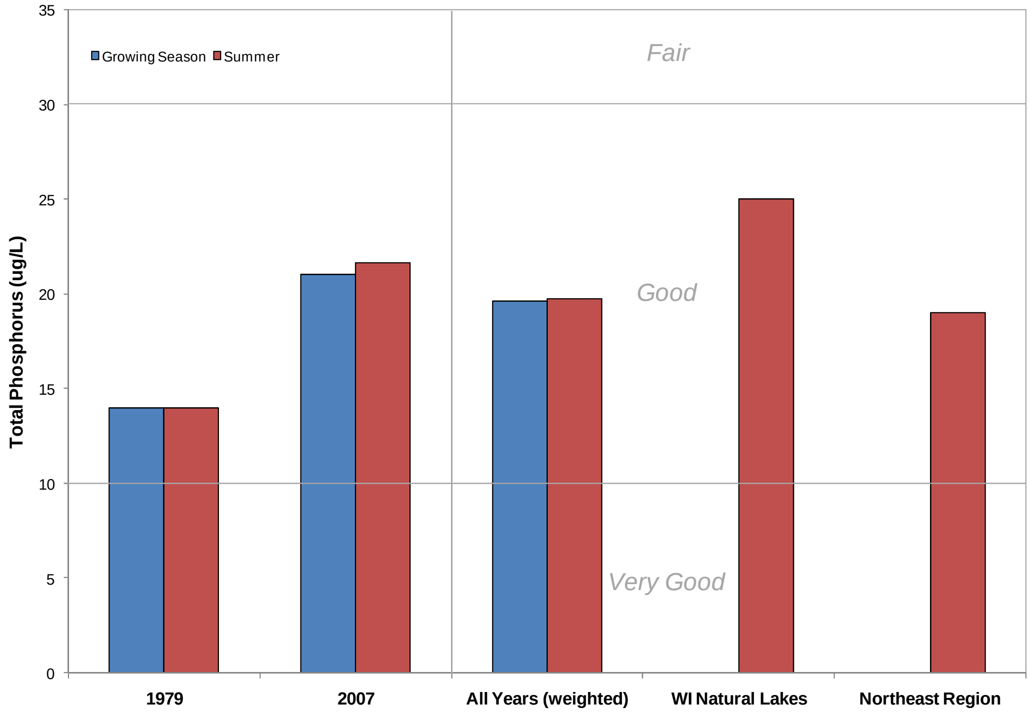

Figure 4. Lower Gresham Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

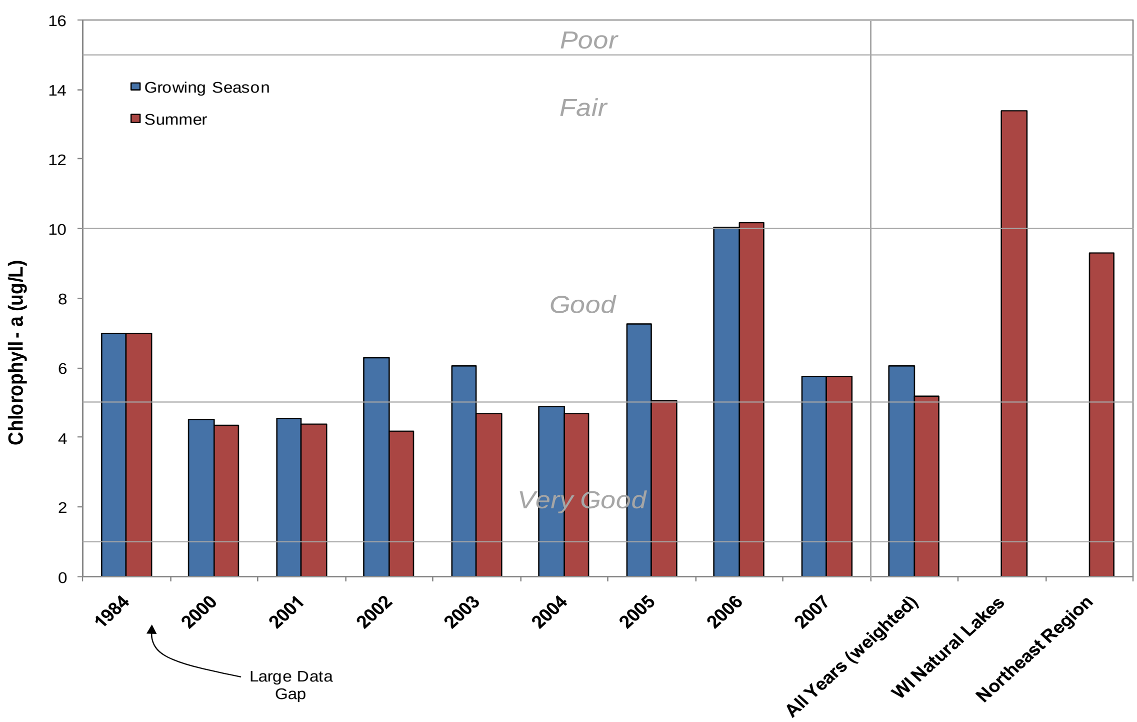

Figure 5. Upper Gresham Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

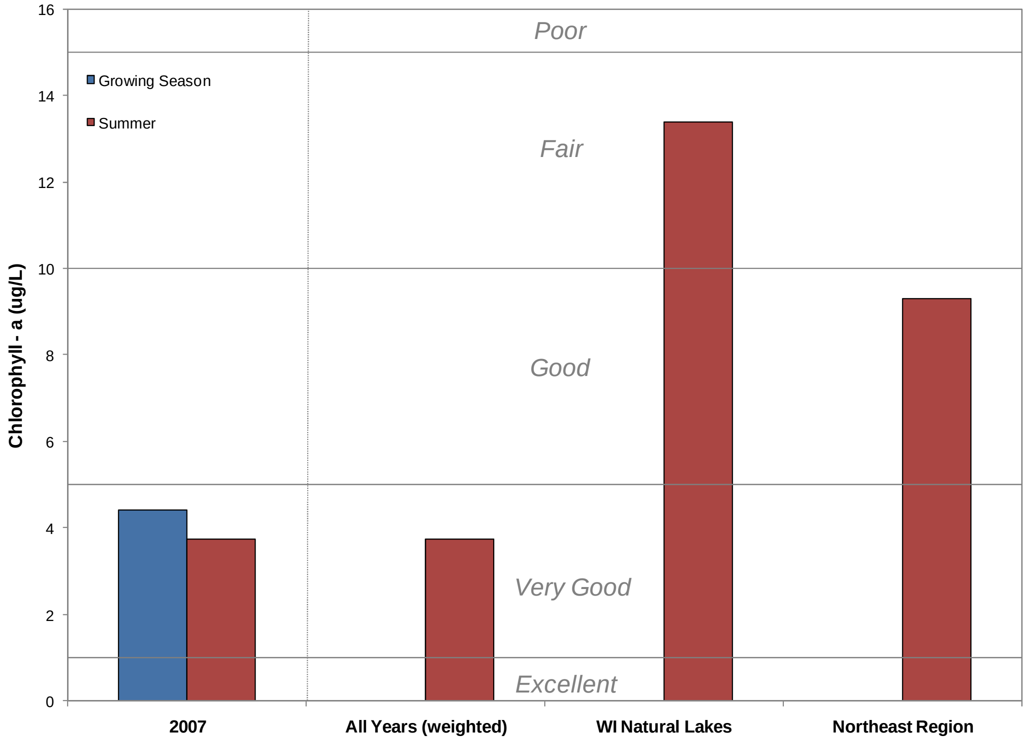

Figure 6. Middle Gresham Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

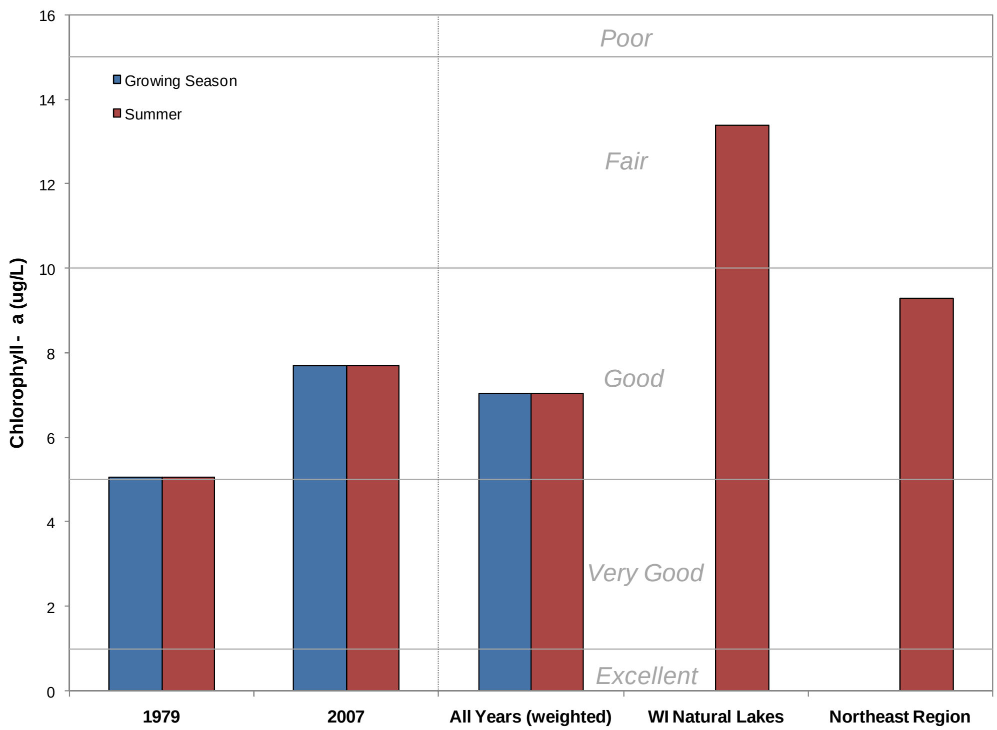

Figure 7. Lower Gresham Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

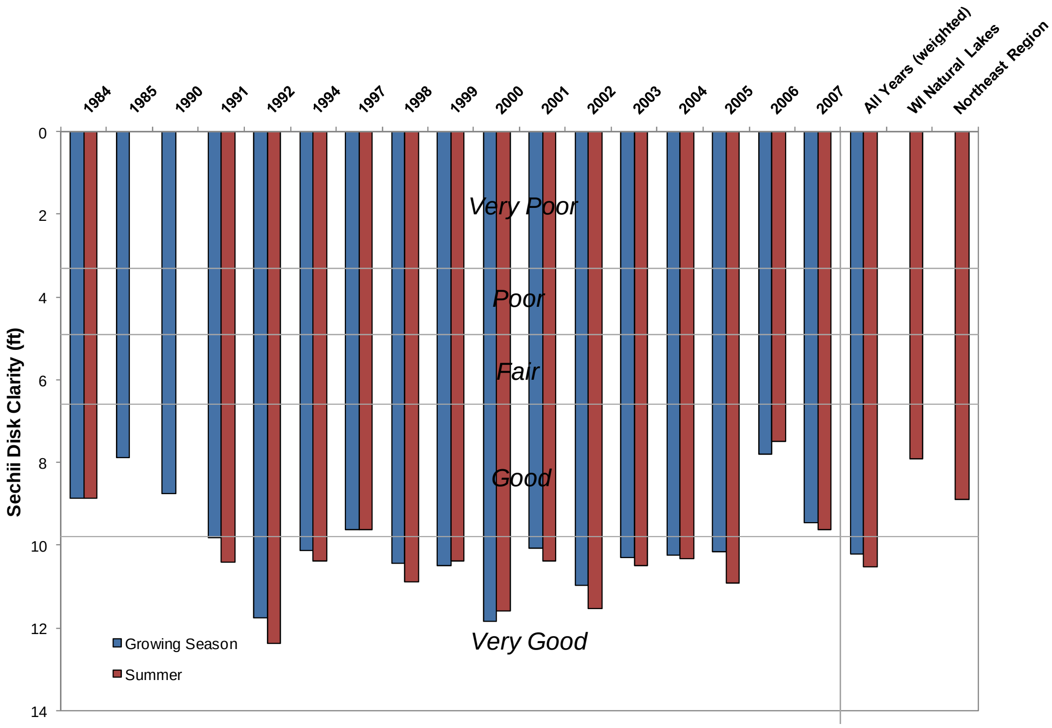

Figure 8. Upper Gresham Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

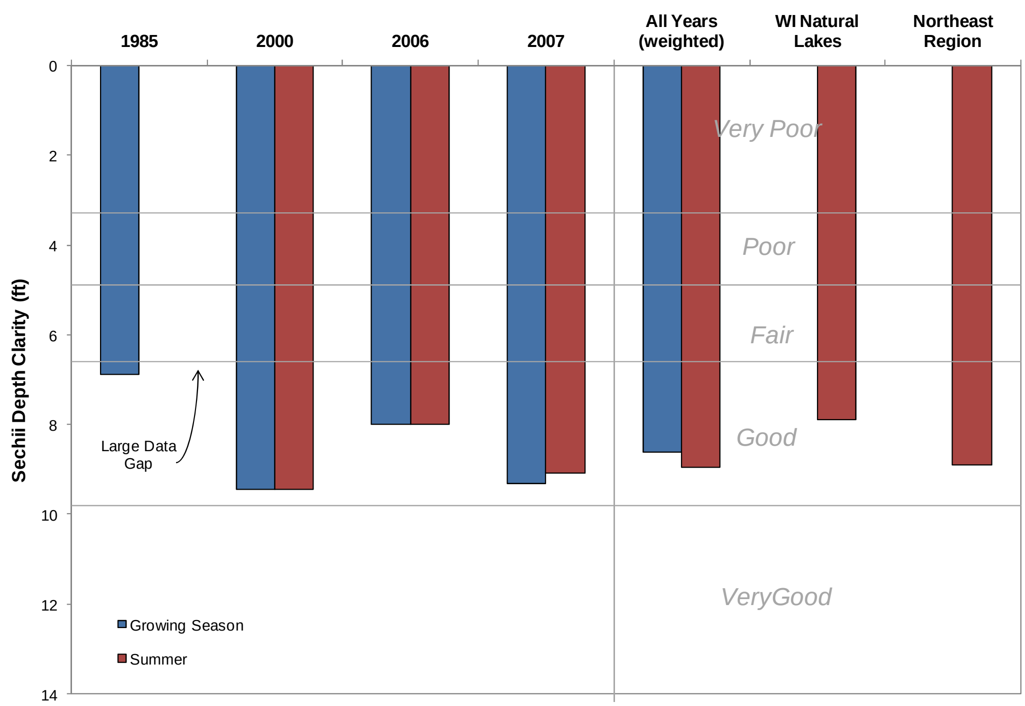

Figure 9. Middle Gresham Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

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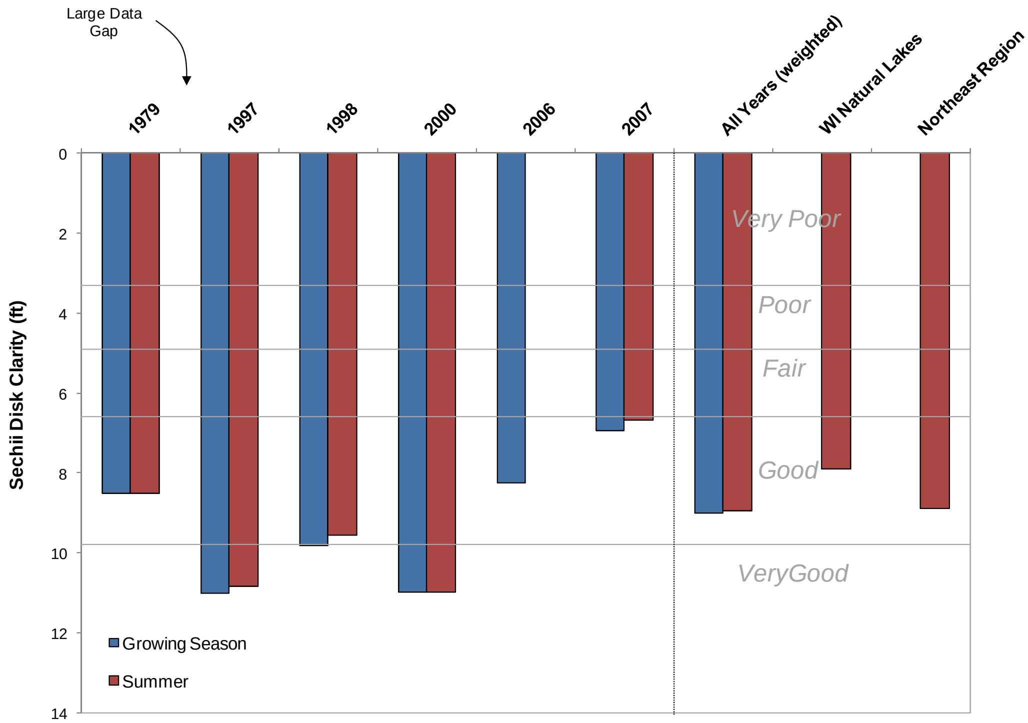

Figure 10. Lower Gresham Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Gresham Lakes Trophic State

Figures 11-13 contain the WTSI values for the Gresham Lakes. Upper Gresham Lake, having the most extensive dataset also has the most extensive collection of WTSI values. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to lower 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 Upper Gresham is in an upper mesotrophic state.

Very little data is available for Middle and Lower Gresham Lakes (Figures 12 and 13). However, according to the 2007 data, Middle Gresham is considered to be upper mesotrophic while Lower Gresham is considered lower eutrophic.

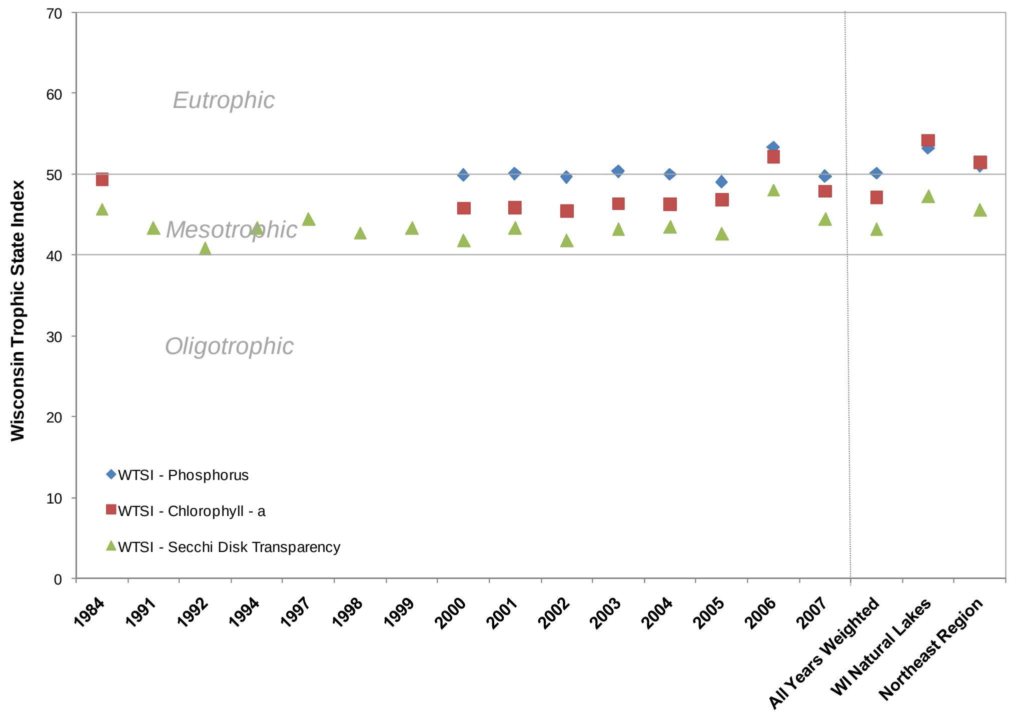

Figure 11. Upper Gresham Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

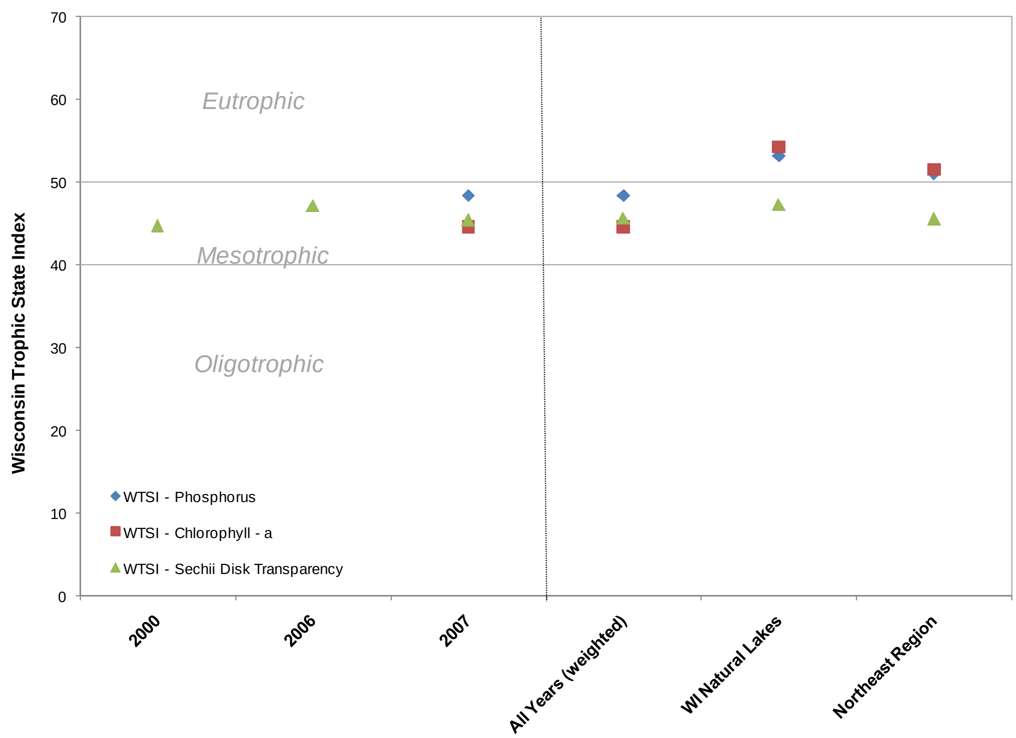

Figure 12. Middle Gresham Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

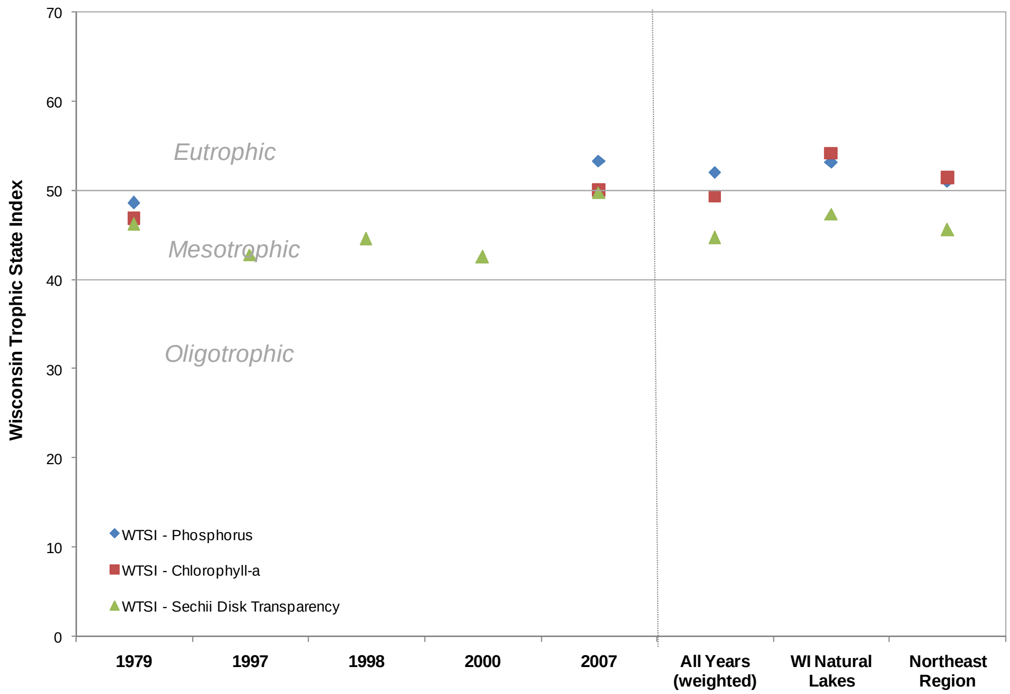

Figure 13. Lower Gresham Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Additional Water Quality Data Collected on the Gresham Chain of Lakes

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 the Gresham Chain of Lakes 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 (Shaw et al. 2004). The pH of surface water in Upper Gresham Lake, Middle Gresham Lake, and Lower Gresham Lake was 7.5, 8.0, and 8.4 respectively. All of these pH values fall within the normal range for Wisconsin Lakes.

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. 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 Upper Gresham Lake, Middle Gresham Lake, and Lower Gresham Lake was 45.3, 39.6, and 35.4 (mg/L as $CaCO_3$) respectively, indicating that these lakes have a substantial capacity to resist fluctuations in pH and have low sensitivity 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 the Gresham Chain of Lakes 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 Upper Gresham Lake and Middle Gresham Lake was found to be 14.0 and 12.1 mg/L, falling into the low susceptibility category for zebra mussel establishment. Plankton tows were completed by Onterra staff during the summer of 2007 and these samples were processed by the WDNR for larval zebra mussels. Their analysis returned a negative result for the presence of these exotic species.

Watershed Assessment

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 will be lessened. 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 can be 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 useful 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.

Modeling the watersheds of a chain of lakes presents certain challenges that require special procedures to accurately assess each lakes' hydrographic and phosphorus load information. The most prominent challenge is accounting for the affects of upstream lakes on the phosphorus load of lakes further down the chain. In the case of the Gresham Chain of Lakes, Upper Gresham Lake is at the headwater, so its tributaries do not flow through other lakes before reaching its basin. However, much of the watershed that feeds Middle Gresham Lake must flow through Upper Gresham first. Lower Gresham Lake of course shares a large portion of its watershed with Middle and Upper Gresham, so much of its watershed load flows through the two lakes before reaching its basin.

As the water moves through one lake to another, a portion of the phosphorus load is utilized within the upstream lake through biological process, and as those plants and animals die, the phosphorus settles to the bottom. Further, some of the phosphorus load entering the upstream lake sorbs (attaches) to sediment particles and sinks to the bottom or is precipitated out of the water column by marl or iron. In the end, this means that the upstream lake acts as a large settling basin or retention pond for the downstream lake and only allows a portion of the phosphorus entering it to pass through to the next lake via its outlet. To account for this process in the load modeling of downstream lakes, the upstream lake's outlet is treated as a point-source that contributes to the downstream lake's annual phosphorus load. The upstream lake's contribution is calculated by multiplying the lake's outlet discharge by the lake's average annual water phosphorus concentration. This yields a phosphorus load and water volume that can be added to the downstream lake along with the other watershed information within WiLMS.

As described above, watershed land cover is a primary component in determining the amount of phosphorus loaded to a lake on an annual basis. Map 2 contains the watershed boundary and land cover types of the Gresham Lakes, while Figures 14-16 display the parsing of land cover types within each of the lakes' subwatersheds. These charts also display the acreage of watershed that flows through upstream lakes before entering Middle Gresham (Figure 15) and Lower Gresham (Figure 16).

Upper Gresham Lake's subwatershed contains approximately 1,858 acres of land, yielding a watershed to lake area ratio (WS:LA) of 4.5:1 (Table 2). Tying this relatively small WS:LA to the fact that nearly 70% of the lake's watershed is forested leads to an understanding as to why Upper Gresham Lake has good water quality. Input of the watershed land cover data within WiLMS produced a loading estimate of 228 lbs of phosphorus annually (Figure 17 and Appendix D), which is very low and further supports the lake's good water quality. Interestingly, over 40% of the lake's annual phosphorus load enters the lake through atmospheric fallout, which is just a bit lower than the load contributed by forest areas.

Table 2. Subwatershed area, lake surface area, watershed to lake area ratios (WS:LA), and residence times of the Gresham Lakes. Subwatershed acreages include lake surface areas. When calculating WS:LA ratio, the watershed value is less the lake surface acreage.

Lake	Watershed Area (acres)	Lake Area (acres)	WS:LA	Residence Time (yr)
Upper Gresham Lake	1,858	336	4.5:1	2.55
Middle Gresham Lake	2,538	53	46.9:1	0.16
Lower Gresham Lake	4,035	149	26.1:1	0.21

Middle Gresham Lake is the second lake in the chain and as a result has a much larger watershed than Upper Gresham. Combining its large watershed with its small surface area results in a relatively high WS:LA of nearly 47:1 (Table 2). This indicates that watershed runoff plays a major role in the lake's water quality. However, the combination of these three factors leads to the lake's good water quality despite its high WS:LA;

1. The land cover types within the watershed export minimal amounts of phosphorus (Figure 18). Approximately 73% of Middle Gresham Lake's watershed is shared with Upper Gresham's watershed, which as stated above is in excellent land cover. The remaining land that flows directly to Middle Gresham Lake is also in great shape as the majority of it is forested (Figure 15).
2. A major portion of the water entering Middle Gresham Lake is "treated" by Upper Gresham Lake first. As discussed above, upstream lakes act as sedimentation basins for downstream lakes and essentially treat the water as it flows through on its way downstream. Upper Gresham Lake's annual phosphorus load is approximately 228 lbs.; however, the Upper Gresham Lake contribution to Middle Gresham Lake's annual load of 141 lbs. is roughly 71 lbs (Appendix D). This means that Upper Gresham Lake removes about 157 lbs of phosphorus from the water it provides Middle Gresham Lake.
3. Middle Gresham Lake's small volume (424 acre-feet) combined with its large watershed produces a high flushing rate (low residence time). Middle Gresham's water is replaced roughly every 58 days. This low residence time essentially means that many of the nutrients that enter Middle Gresham Lake are flushed out before they are utilized by the lake's organisms or before they settle out.

Lower Gresham Lake being the last lake in the chain, of course has the largest watershed at 4,035 acres. Combining that with the lake's surface area yields a WS:LA of a little over 26:1

(Table 2). As with Middle Gresham Lake, this is a relatively high ratio. Also like Middle Gresham Lake, Lower Gresham's water quality is moderated by its watershed cover types, its low residence time (77 days), and to a lesser extent, the treatment effect of an upstream lake.

Over 60% of the land that flows to Lower Gresham Lake flows through Middle Gresham Lake first and the remaining drainage area, as with the other lakes in the chain, is primarily forested (Figure 16). WiLMS estimates that approximately 292 lbs. of phosphorus is delivered to Lower Gresham Lake from its watershed every year (Appendix D). Of that amount, approximately 46% arrives from Middle Gresham Lake and the remaining amount arrives via the direct watershed (Figure 19).

Middle Gresham Lake's high flushing rate minimizes its treatment effects as water flows through it on its way to Lower Gresham Lake. As stated above, Middle Gresham's annual phosphorus load is approximately 141 lbs./year and its outlet load feeding to Lower Gresham is approximately 133 lbs./year (Figure 19). This means that Middle Gresham Lake is only removing less than 10 lbs of phosphorus from the water it contributes to Lower Gresham Lake annually.

Overall, the watershed of the Gresham Chain of Lakes is currently in excellent condition and contributes very little phosphorus to the chain lakes. That being said, the importance of the immediate shoreland's contributions on the chain's water quality comes to the forefront because any unnecessary phosphorus inputs would be considered negligible. In other words, even a small amount of phosphorus being added to one of the lakes as the result of shoreland development, lawn fertilization, or an increase in impervious surface area would likely have some impact on that lake's water quality. Therefore, shoreland properties must be managed correctly and responsibly to minimize their impact on the chain.

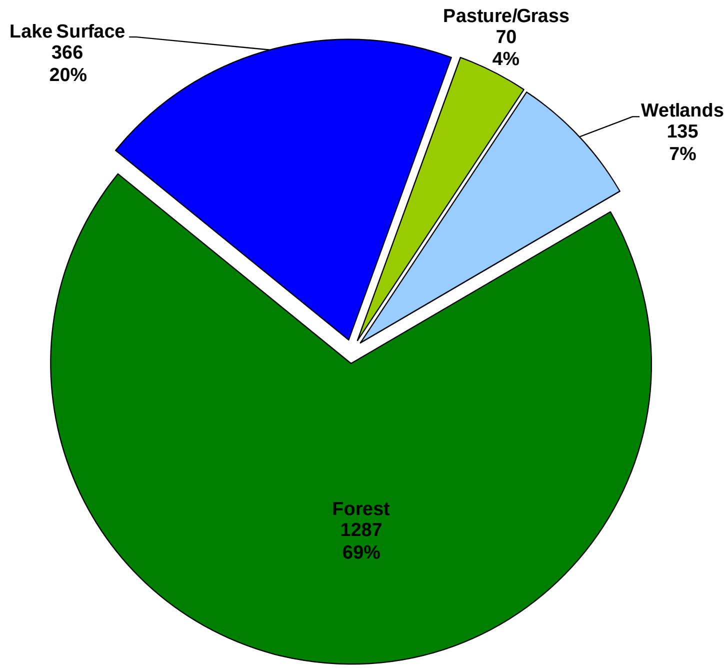

Figure 14. Upper Gresham Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

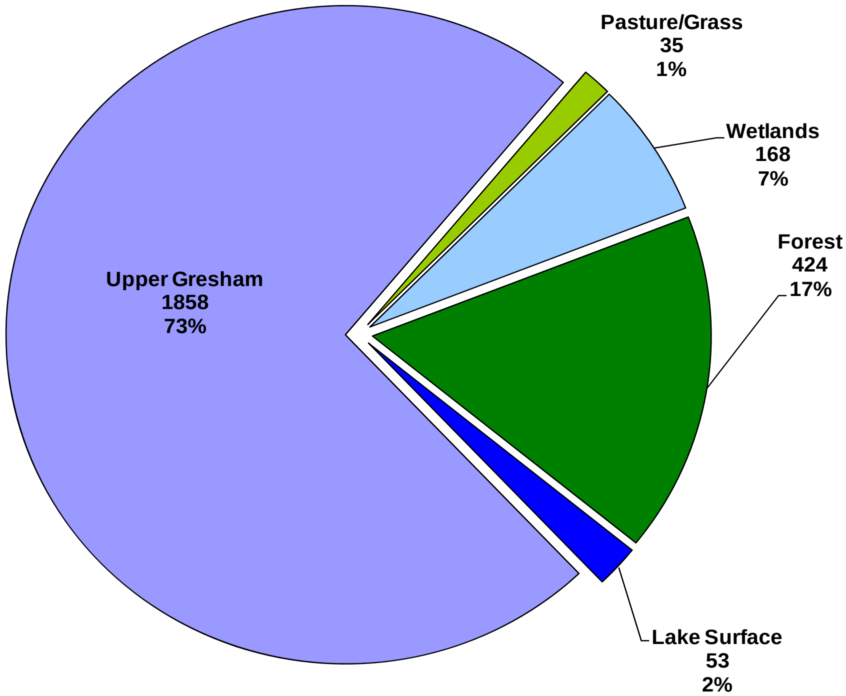

Figure 15. Middle Gresham Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR 1998).

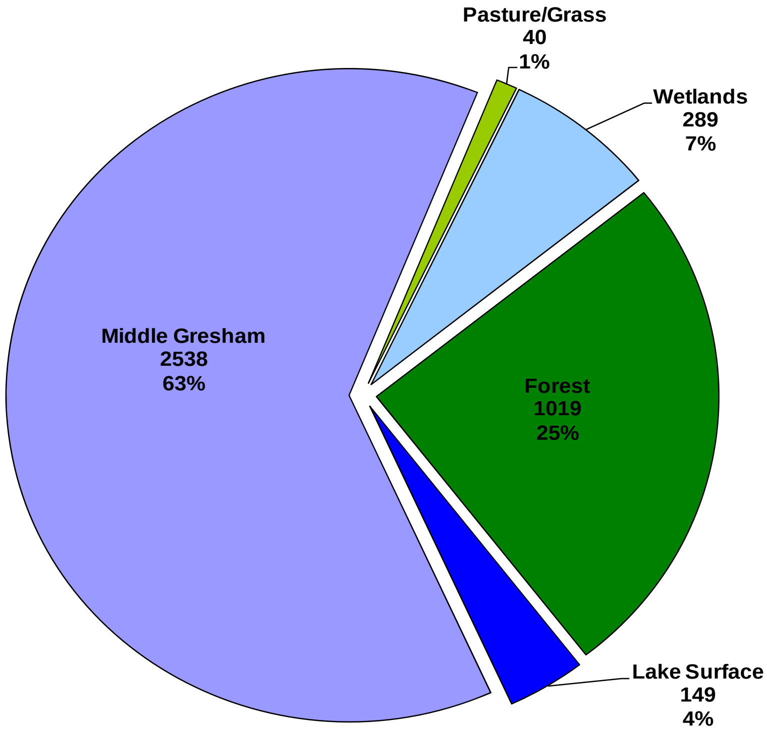

Figure 16. Lower Gresham Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR 1998).

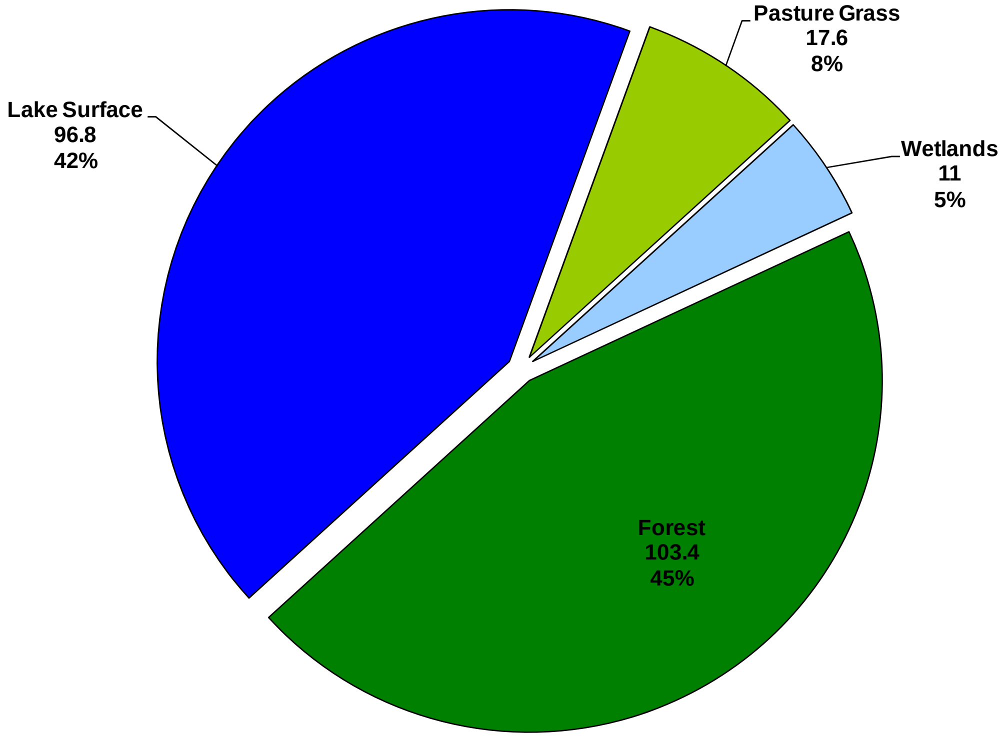

Figure 17. Upper Gresham Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

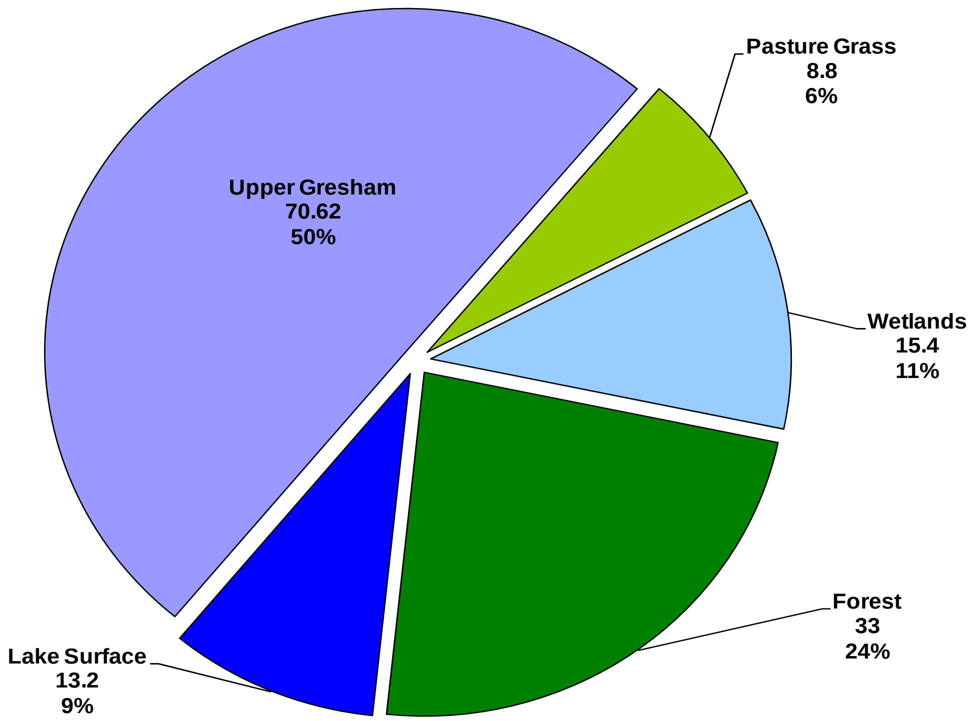

Figure 18. Middle Gresham Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

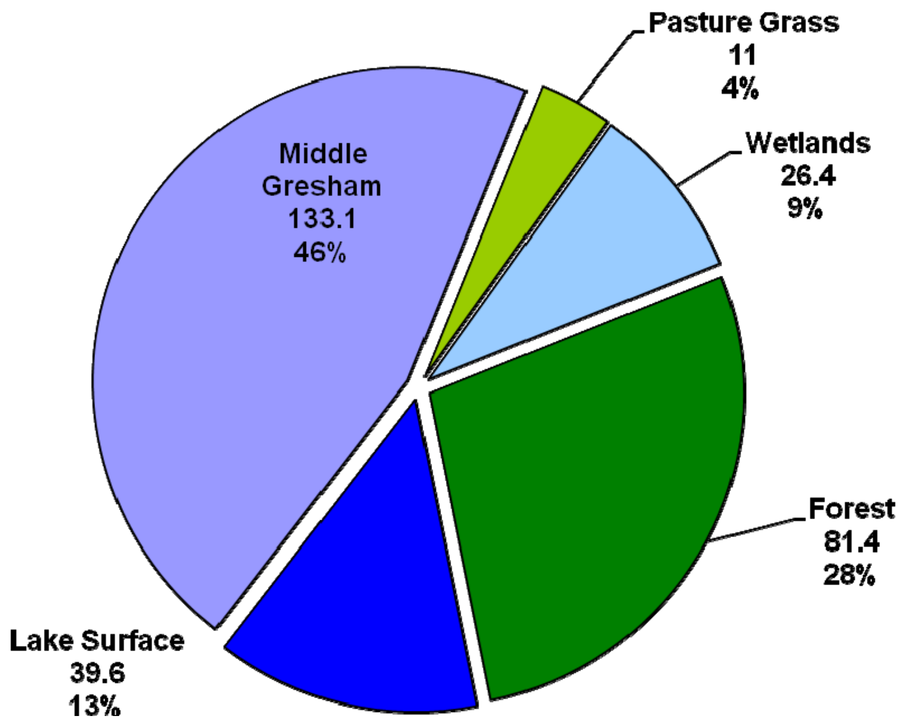

Figure 19. Lower Gresham Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Beavers inhabit the streams the flow into and between the Gresham Lakes and as a part of their normal habits, they build dams and lodges within the steam beds. The existence of the dams alters water flows and lake levels, both upstream and downstream of the dam. The beaver activity has caused a certain level of controversy within the chain. Although it was not originally within the scope of the planning project, this subject is elaborated on within the Summary and Conclusions Section.

Gresham Chain of Lakes Fishery

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 and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) WDNR 2007 & GLIFWC 2007).

Based on data collected from the stakeholder survey (Appendix B, Question #7), fishing was the activity most often ranked first as the most important or enjoyable on the Gresham Chain. Almost 65% of these same respondents believed that the quality of fishing on the Gresham Chain has remained the same since they have obtained their property (Appendix B, Question #10).

Table 3 shows the popular game fish that are present in the system. Management actions that have taken place and will likely continue on the Gresham Chain according to this plan include herbicide applications to control EWM. These applications occur in May when the water temperatures are below 60°F. It is important to understand the effect the chemical has on the spawning environment which would be to remove broad-leaf (dicot) submergent plants that are actively growing at these low water temperatures. Yellow perch and Muskellunge are a couple of species that could be affected by early season herbicide applications.

Table 3. Gamefish present in the Gresham Lakes with corresponding biological information (Becker, 1983).

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
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
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskellunges, small mammals, shore birds, frogs
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Smallmouth Bass	*Micropterus dolomieu*	13	Mid May - June	Nests more common on North and West shorelines, over gravel	Small fish including other bass, crayfish, insects (aq. and ter)
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent vegetation	Small fish, aquatic 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

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 20). The Gresham Chain falls within the ceded territory based on the Treaty of 1837. This allows for a regulated spear fishery by Native Americans on specified systems. The spear harvest is regulated by having the six Wisconsin Chippewa Tribes declaring a tribal quota based on a percent of the estimated safe harvest each year by March 15th. The tribal declaration will influence the daily bag limits for hook-and-line anglers, possibly reducing it to zero if 100% of the safe harvest is declared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

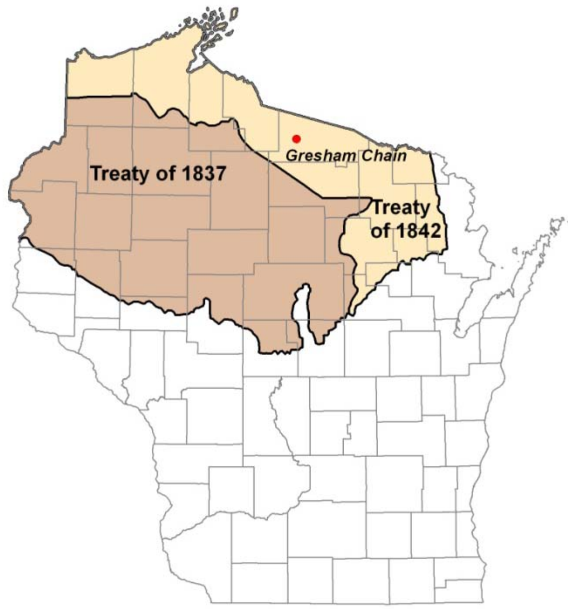

Figure 20. Location of the Gresham Chain within the Native American Ceded Territory (GLIFWC 2007). This map was digitized by Onterra; therefore it is a representation and not legally binding.

In 2007, the estimated safe harvest for Upper Gresham Lake was set at 47 walleye, a relatively low number of fish for the region. This is largely because the lake's walleye population almost exclusively consists of a stocked population. Tribal declaration is usually set at 50-80% of the estimated safe harvest for a given lake. Upper Gresham Lake was not declared as a spear harvest lake in 2007 and has not been harvested in the past. A combination of a low estimated safe harvest for walleye and the availability to spear other lakes in the region with higher estimated safe harvest have likely contributed to Upper Gresham Lake not being declared as a spear harvest lake.

Walleye is a prized game fish in northern Wisconsin and can be found in the Gresham Chain. As stated above, the Gresham Chain is located within ceded territory and special fisheries regulations may occur if the lake receives tribal declaration. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which would explain the more restrictive bag or length limits for the chain.

On the Gresham Chain, there is a 15 inch length limit on walleye. A fisheries survey in 2002 indicated that walleye abundances on Upper Gresham Lake were moderate (1.5 per acre) for a stocked walleye population. Largemouth bass populations were estimated to be at 5.4 per acre (WDNR 2002).

The Gresham Chain of Lakes is also known for its muskellunge population. Tables 4-6 show that all the lakes heavily rely on stocking as a source of their muskellunge population. All three lakes are considered Category 2 muskellunge lakes, whereas stocking is needed to augment natural reproduction. Lower Gresham Lake is a Class B muskellunge lake which means that while the lake provides good fishing potential, the success and catch rates are less than in prime waters. Upper and Middle Gresham Lakes are Class A2 lakes which are known for providing the most consistent angling action and have the potential to produce trophy sized fish.

According to the point-intercept survey conducted by the Wisconsin Department of Natural Resources and Onterra, most of the substrate sampled in the littoral zone on the Gresham Chain of Lakes was muck, although Upper Gresham Lake had more than 20% less than the other two lakes (see table below and Maps 3-5). 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. Muskellunge is one species that does not provide parental care to its eggs. Muskellunge 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 they do not get buried in sediment and suffocate. 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.

Lake	% Muck	% Sand	%Rock	Survey Date	Surveyor
Upper Gresham	72.6	20.8	6.6	August 10-11, 2005	WDNR
Middle Gresham	95.9	1.4	2.7	July 27-28, 2007	WDNR
Lower Gresham	98.3	1.7	0	June 15, 2007	Onterra

Table 4. Fish stocking data available from the WDNR from 1972 to 2006 for Upper Gresham Lake (WDNR 2007).

Year	Species	Age Class	# Fish Stocked	Ave Fish Length (in)
1972	Walleye	Fingerling	9,000	3.00
1974	Walleye	Fingerling	15,000	3.00
1975	Muskellunge	Fingerling	400	9.00
1975	Walleye	Fingerling	15,000	3.00
1976	Walleye	Fingerling	15,000	3.00
1977	Muskellunge	Fingerling	700	7.00
1977	Walleye	Fingerling	17,000	3.00
1979	Muskellunge	Fingerling	350	11.00
1980	Walleye	Fingerling	10,000	2.50
1981	Muskellunge	Fingerling	400	12.00
1984	Walleye	Fingerling	19,080	2.00
1985	Muskellunge	Fingerling	700	11.00
1986	Walleye	Fingerling	19,000	3.00
1987	Muskellunge	Fingerling	2,100	12.00
1988	Walleye	Fingerling	19,000	5.00
1989	Muskellunge	Fingerling	338	5.00
1990	Walleye	Fingerling	18,900	3.00
1991	Muskellunge	Fingerling	100	11.00
1991	Walleye	Fingerling	9,072	3.00
1992	Muskellunge	Fingerling	100	11.00
1992	Walleye	Fingerling	9,312	2.00
1993	Muskellunge	Fingerling	300	11.00

Table 4 *Con't.* Fish stocking data available from the WDNR from 1972 to 2006 for Upper Gresham Lake (WDNR 2007).

Year	Species	Age Class	# Fish Stocked	Ave Fish Length (in)
1994	Walleye	Fingerling	17,919	2.30
1995	Muskellunge	Fingerling	300	11.30
1996	Walleye	Fingerling	18,054	1.80
1997	Muskellunge	Large Fingerling	150	9.90
1998	Walleye	Small Fingerling	36,000	1.50
1999	Muskellunge	Large Fingerling	152	10.50
2000	Walleye	Small Fingerling	18,203	3.10
2001	Muskellunge	Large Fingerling	366	10.20
2002	Walleye	Small Fingerling	18,300	1.70
2003	Muskellunge	Large Fingerling	366	9.90
2004	Walleye	Small Fingerling	18,290	1.30
2005	Muskellunge	Large Fingerling	382	10.60
2006	Walleye	Small Fingerling	13,062	1.80

Table 5. Fish stocking data available from the WDNR from 1972 to 2006 for Middle Gresham Lake (WDNR 2007).

Year	Species	Age Class	# Fish Stocked	Ave Fish Length (in)
1974	Muskellunge	Fingerling	100	11.00
1977	Muskellunge	Fingerling	150	9.00
1979	Muskellunge	Fingerling	50	11.00

Table 6. Fish stocking data available from the WDNR from 1972 to 2006 for Lower Gresham Lake (WDNR 2007).

Year	Species	Age Class	# Fish Stocked	Ave Fish Length (in)
1972	Walleye	Fingerling	4,125	3.00
1973	Muskellunge	Fingerling	900	10.00
1975	Muskellunge	Fingerling	200	11.00
1975	Walleye	Fingerling	5,000	3.00
1977	Muskellunge	Fingerling	400	9.00
1979	Muskellunge	Fingerling	150	11.00
1980	Walleye	Fingerling	4,000	3.00
1981	Muskellunge	Fingerling	176	12.00
1982	Walleye	Fingerling	7,000	3.00
1983	Muskellunge	Fingerling	300	10.00
1985	Walleye	Fingerling	7,000	2.00
1990	Muskellunge	Fingerling	300	9.00
1991	Muskellunge	Fingerling	150	11.00
1992	Muskellunge	Fingerling	150	10.00
1993	Muskellunge	Fingerling	300	11.00
1995	Muskellunge	Fingerling	300	11.30
1997	Muskellunge	Large Fingerling	150	9.90
1999	Muskellunge	Large Fingerling	150	12.10
2001	Muskellunge	Large Fingerling	74	12.20

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 affects 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 numbers of predator fish and 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

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 (*Ctenopharyngodon idella*) 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.

Important Note:
Even though most of these techniques are not applicable to the Gresham Chain of Lakes, 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 the Gresham Lakes are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

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 that length. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR. 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.

Cost

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

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 resuspension 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.

Disadvantages

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.

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.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1200 to $11,000.

Advantages

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.

Disadvantages

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 harvest remaining plants
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.

Cost

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 are about $120 each year.

Advantages

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.

Disadvantages

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.

Cost

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.

Advantages

Inexpensive if outlet structure exists.
May control populations of certain species, like Eurasian water-milfoil for up to two years.
Allows some loose sediments to consolidate.
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.

Disadvantages

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 (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).
Permitting process requires an environmental assessment that may take months to prepare.
Unselective.

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

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.

Disadvantages

Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.
Multiple treatments may be required during the growing season because lower portions of the plant and root systems are left intact.
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.
Larger harvesters are not easily maneuverable in shallow water or near docks and piers.
Bottom sediments may be resuspended 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.

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

Fluridone (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.

Glyphosate (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 permited for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic orgainsims.

Diquat (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.

Endothal (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothal (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.

2,4-D (Navigate®, Aqua-Kleen®, 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 apply.

Advantages

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.

Disadvantages

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.

Cost

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

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 waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*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 not 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 EWM. Wisconsin is also using two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These biocontrol insects are not covered here because purple loosestrife is predominantly a wetland species.

Advantages

Milfoil weevils occur naturally in Wisconsin.
This is likely an environmentally safe alternative for controlling Eurasian water-milfoil.

Disadvantages

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.

Cost

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

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 the Gresham Lakes; 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 the Gresham Lakes, 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, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. 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.

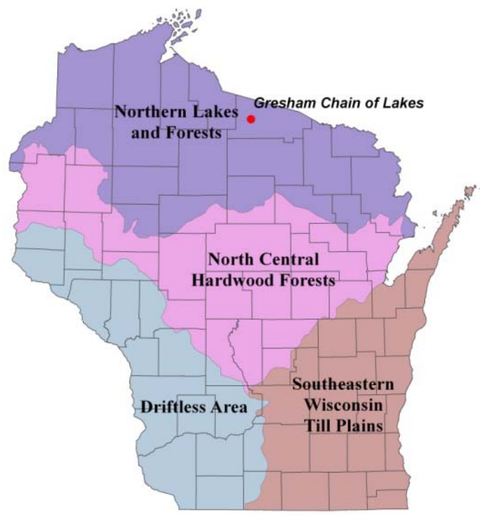

Figure 21. Location of the Gresham Chain within the ecoregions of Wisconsin. After Nichols 1999.

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.

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 each of the Gresham Lakes will be compared to lakes in the same ecoregion and in the state (Figure 21).

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.

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 22). 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 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,

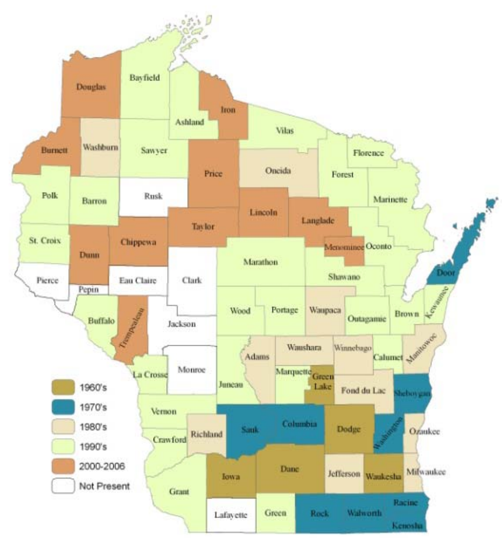

Figure 22. Spread of Eurasian water milfoil within WI counties. WDNR Data 2006 mapped by Onterra.

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. In June 2007, a survey was completed on all three lakes that focus upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed. It is believed that this aquatic invasive species either does not occur in the Gresham Chain or exists at an undetectable level.

Point-intercept surveys were conducted by Wisconsin Department of Natural Resources (WDNR) research in 2005 on Upper Gresham Lake and 2006 on Middle Gresham Lake. The point intercept survey was conducted on Lower Gresham Lake in August 2007 by Onterra. Additional surveys were completed by Onterra on all three lakes to create the aquatic plant community maps (Maps 6-8) during August 2007.

During the point-intercept and aquatic plant mapping surveys, 57 species of plants were located on the chain (Table 7), two are considered non-native species: Eurasian water milfoil and giant reed (also known as common reed). Because of its frequency within the lake, Eurasian water milfoil will be discussed in depth in a separate section.

At this time, giant reed exists in only a few locations on Upper Gresham Lake (Map 9). Regardless of its frequency at this time, this species presents risks to the native emergent plant communities common on the lake because it is capable of taking over vast tracks of wetlands and lake shorelines.

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.

It is important to note that much discussion occurs amongst experts on the invasive nature of common reed. Currently as many as 15 strains of this plant are found to occur, of which at least one may be native to North America. With only slight morphological differences, understanding whether the plant is a native strain requires molecular analysis. At this point, all occurrences of common reed that occur along developed (disturbed) shorelines should be considered invasive unless analysis states otherwise.

Table 7. Aquatic plant species located on the Gresham Chain of Lakes during 2005-2007 surveys.

Life Form	Common Name	Scientific Name	Upper Gresham	Middle Gresham	Lower Gresham	Coefficient of Conservatism (c)
Emergent	Water arum	*Calla palustris*			I	9
	Lake sedge	*Carex lacustris*	I	I		6
	Three-way sedge	*Dulichium arundinaceum*	I	I	I	9
	Creeping spikerush	*Eleocharis palustris*	I	I	X	6
	Brown-fruited rush	*Juncus pelocarpus*	X		X	8
	Giant reed	*Phragmites australis*	I			Exotic
	Pickerelweed	*Pontederia cordata*	I	X	X	9
	Common arrowhead	*Sagittaria latifolia*	I		X	3
	Hardstem bulrush	*Schoenoplectus acutus*	I	I	I	5
	Softstem bulrush	*Schoenoplectus tabernaemontani*	I		X	4
	Narrow-leaved cattail	*Typha angustifolia*	I			1
	Broad-leaved cattail	*Typha latifolia*	I	I	X	1
FL	Watershield	*Brasenia schreberi*	X	X	X	7
	Spatterdock	*Nuphar variegata*	X	X	X	6
	White water lily	*Nymphaea odorata*	X	X	X	6
	Water smartweed	*Polygonum amphibium*	I		I	5
FL/E	Eastern bur-reed	*Sparganium americanum*		X		8
	Narrow-leaf bur-reed	*Sparganium angustifolium*	X			9
	Short-stemmed bur-reed	*Sparganium emersum*	I	I	X	8
	Common bur-reed	*Sparganium eurycarpum*			I	5
	Floating-leaf bur-reed	*Sparganium fluctuans*		X		10
Submergent	Coontail	*Ceratophyllum demersum*	X	X	X	3
	Muskgrasses	*Chara sp.*	X	X		7
	Common waterweed	*Elodea canadensis*	X	X	X	3
	Pipewort	*Eriocaulon aquaticum*	X			9
	Water stargrass	*Heteranthera dubia*	X	X	I	6
	Quillqort sp.	*Isoetes sp.*	X			8
	Water lobelia	*Lobelia dortmanna*	X			10
	Water marigold	*Megalodonta beckii*	X	X	X	8
	Northern water milfoil	*Myriophyllum sibiricum*	X	X	X	7
	Eurasian water milfoil	*Myriophyllum spicatum*	X			Exotic
	Dwarf water milfoil	*Myriophyllum tenellum*	X			10
	Slender naiad	*Najas flexilis*	X	X	I	6
	Stoneworts	*Nitella sp.*	X	X	X	7
	Alpine pondweed	*Potamogeton alpinus*		X		9
	Large-leaf pondweed	*Potamogeton amplifolius*	X	X	X	7
	Fries' pondweed	*Potamogeton friesii*	X	X		8
	Variable pondweed	*Potamogeton gramineus*	X	X		7
	Floating-leaf pondweed	*Potamogeton natans*	X	X	X	5
	White-stem pondweed	*Potamogeton praelongus*	X		X	8
	Small pondweed	*Potamogeton pusillus*	X	X	I	7
	Clasping-leaf pondweed	*Potamogeton richardsonii*	X	X	X	5
	Fern pondweed	*Potamogeton robbinsii*	X	X	X	8
	Stiff pondweed	*Potamogeton strictifolius*	X	X		8
	Flat-stem pondweed	*Potamogeton zosteriformis*	X	X	X	6
	Creeping spearwort	*Ranunculus flammula*	X			9
	Sago pondweed	*Stuckenia pectinata*	X			3
	Flat-leaf bladderwort	*Utricularia intermedia*		X		9
	Small bladderwort	*Utricularia minor*		X		10
	Common bladderwort	*Utricularia vulgaris*	X	X		7
FF	Lesser duckweed	*Lemna minor*			I	5
	Forked duckweed	*Lemna trisulca*		X	X	6
	Greater duckweed	*Spirodela polyrrhiza*			I	5
SE	Needle spikerush	*Eleocharis acicularis*	X	X	I	5
	Sagitaria sp.	*Sagitaria sp. (rosette)*	X	X	X	3
	Grass-leaved arrowhead	*Sagittaria graminea*	I	I	X	9

Life Forms: FL = Floating Leaf, FL/E = Floating Leaf and Emergent, FF = Free Floating, and S/E = Submergent and Emergent
X = Present, I = Incidental Occurrence

Although non-native aquatic plant species are documented within the lake, when compared to the native species, the non-native frequencies of occurrence are quite low. At this time, it is believed that Lower Gresham Lake does not contain any non-native aquatic plant species. As Figures 23-25 indicate, fern pondweed and common water weed are the most dominant plants within the Gresham Chain. The dominance of the native plant community over that of the exotics is good news for the lake and is an indication of the lake's overall good health in terms of its plant community. An additional positive indicator is the species diversity index for the lakes (Simpson's). Upper Gresham (0.92) and Middle Gresham (0.89) have a high diversity plant community while the diversity index for Lower Gresham's plant community (0.82) shows that the lake has an uneven distribution (relative frequency) of plant species throughout the lake. Figure 25 clearly shows that the lake is dominated by fern pondweed, flat stem pondweed, coontail, and common waterweed.

Floristic Quality Assessment is also a strong indicator of the health of the Gresham Chain of Lake's aquatic plant community (see equation below). The native species richness of all three lakes is much higher than the median value for the Northern Lakes and Forests – Natural Lakes ecoregion and that of the state (Figure 26). While all three lakes exhibit average coefficient of conservatism values at or above the state medians, all but Middle Gresham Lake's value are below the ecoregion median. These data show that while many species exist within the chain, many are indicative of a disturbed system. This is not surprising due to the high amount of recreation that occurs on Upper and Lower Gresham Lakes. Respondents of the stakeholder survey indicate that motor boating on Upper and Lower Gresham Lakes are among their top three enjoyable activities on the lake (Appendix B, Question #7). Only one respondent from Middle Gresham ranked motor boating as one of their top three enjoyable activities on the lake.

	Average Coefficient of Conservatism	* √ Number of Native Species	= Floristic Quality
Upper Gresham	6.3	44	42.1
Middle Gresham	6.7	38	41.0
Lower Gresham	6.0	36	36.0

The plant community mapping was completed in August 2007 (Maps 6-8). These maps depict the many areas throughout the Gresham Chain where diverse floating-leaf and emergent communities can be found. Middle Gresham is somewhat unique from the other two lakes because it is also contains a few large communities of mixed floating leaf and submergent plants (Map 7). All of these communities provide valuable fish and wildlife habitat important to the ecosystem both inside and outside of the lakes.

Plant Community	**Upper Gresham**	**Middle Gresham**	**Lower Gresham**
Emergent	1.4	1.5	0.0
Floating-leaf	0.5	8.9	0.6
Mixed Floating-leaf and Emergent	21.7	26.9	5.0
Mixed Floating-leaf & Submergent	0.0	10.9	0.0
Total	**23.6**	**48.2**	**5.6**

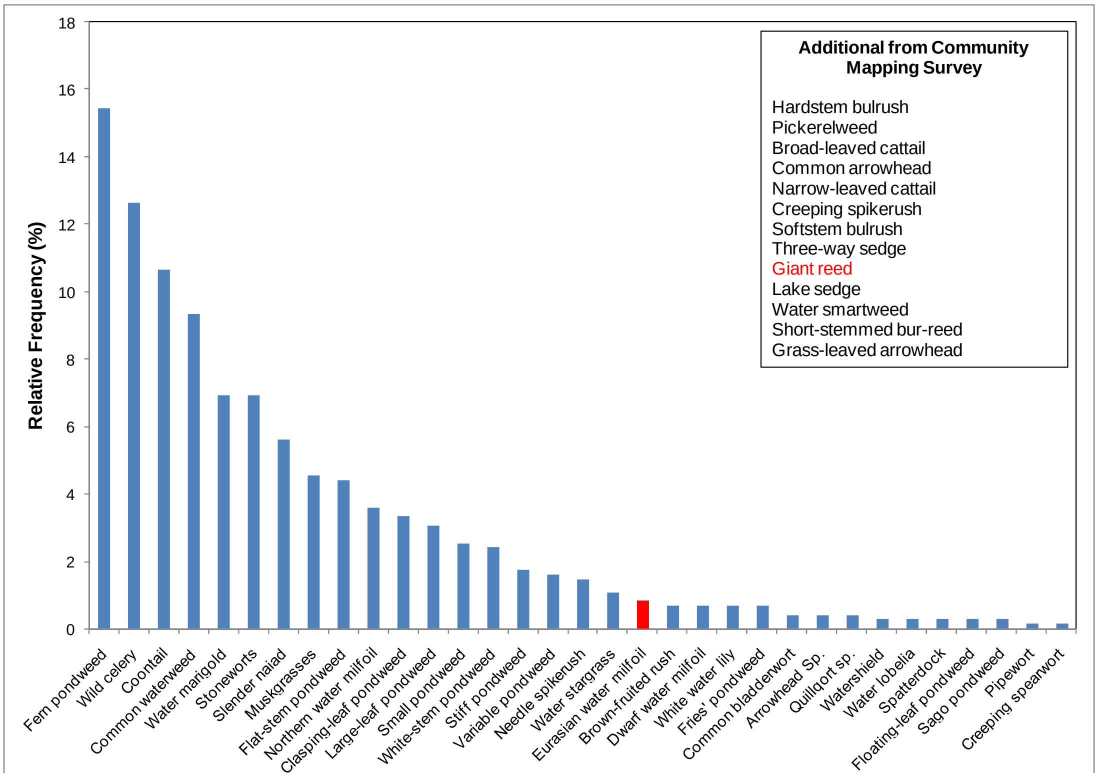

Figure 23 Upper Gresham Lake aquatic plant occurrence analysis of 2005 and 2007 survey data Exotic species indicated with red.

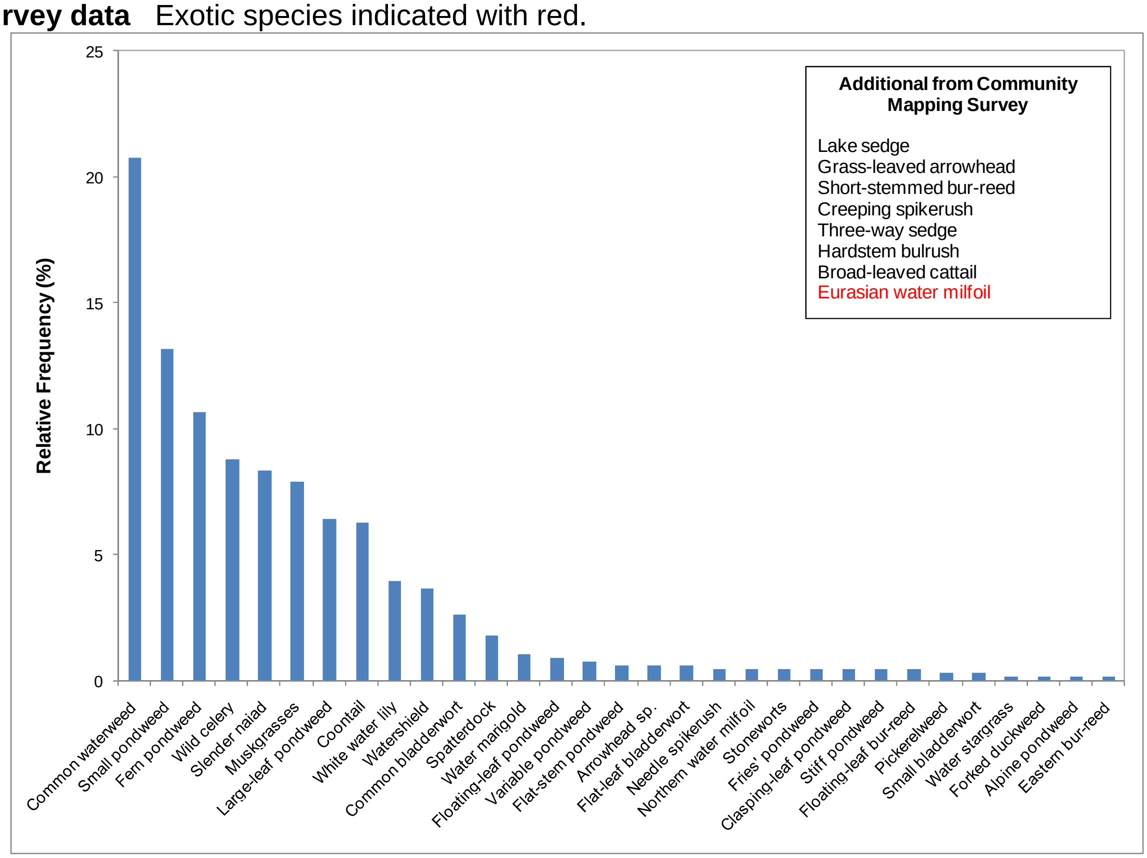

Figure 24 Middle Gresham Lake aquatic plant occurrence analysis of 2006 and 2007 survey data Exotic species indicated with red.

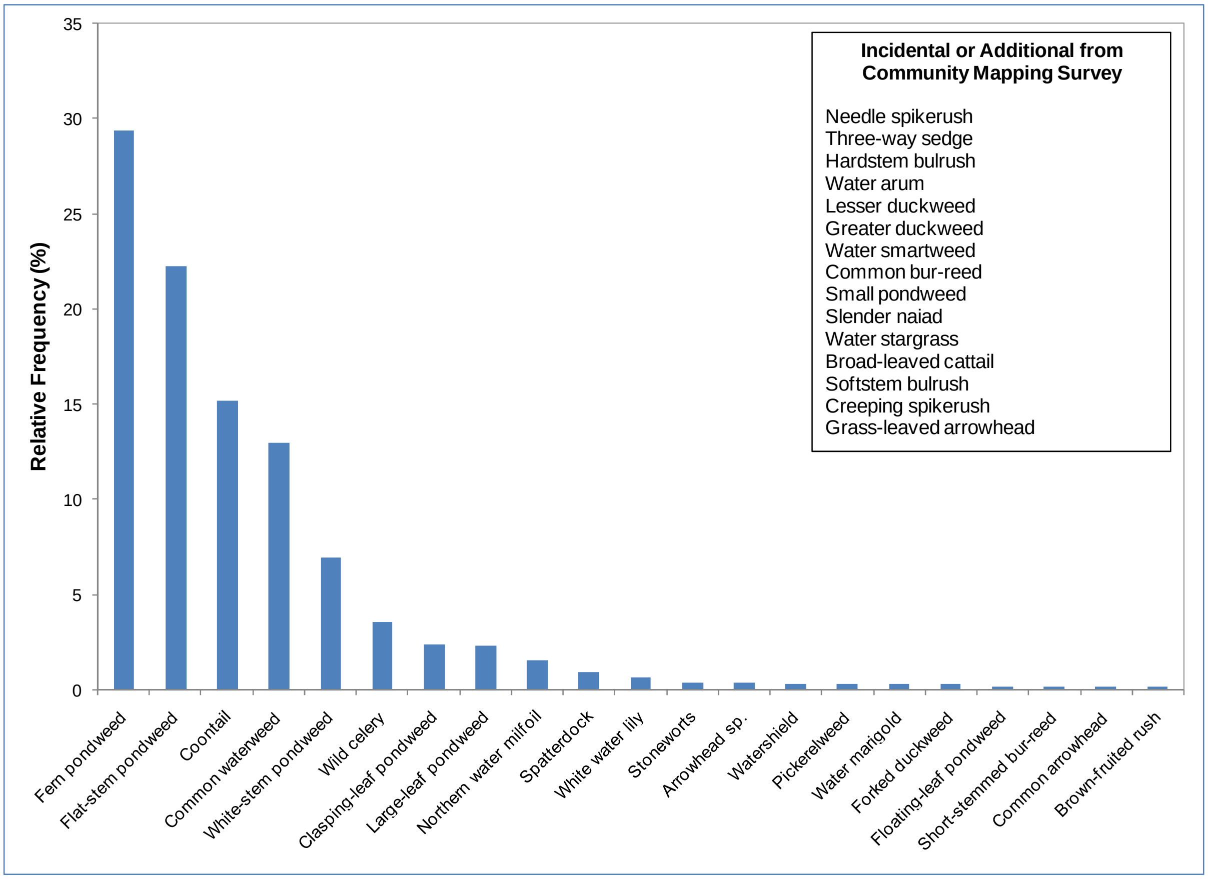

Figure 25 Lower Gresham Lake aquatic plant occurrence analysis of 2007 survey data Exotic species indicated with red.

A combination of two factors are likely the primary contributors to the Gresham Chain's exceptional plant community; 1) a large diversity of lake habitats, including steep, rocky ledges in Upper Gresham Lake, wetland areas in Middle Gresham, and shallow, mucky areas in Lower Gresham and 2) fluctuating water levels on an annual and seasonal basis. Natural, undisturbed wetlands normally hold diverse plant communities. Especially on Middle and Lower Gresham Lakes, fluctuating water levels contribute by allowing the emergent and to some extent, the floating-leaf species, to grow prolifically around the lake (Maps 7 & 8). Although these areas are very important to the lake's health, they can, in some occasions reach abundant levels and impact recreational enjoyment of the lake. Extremely low water levels in 2007 caused native submergent aquatic plants to reach the surface on Middle Gresham Lake (Photo 1).

Photo 1. Abundant levels of native aquatic plants on Middle Gresham Lake, 2007.

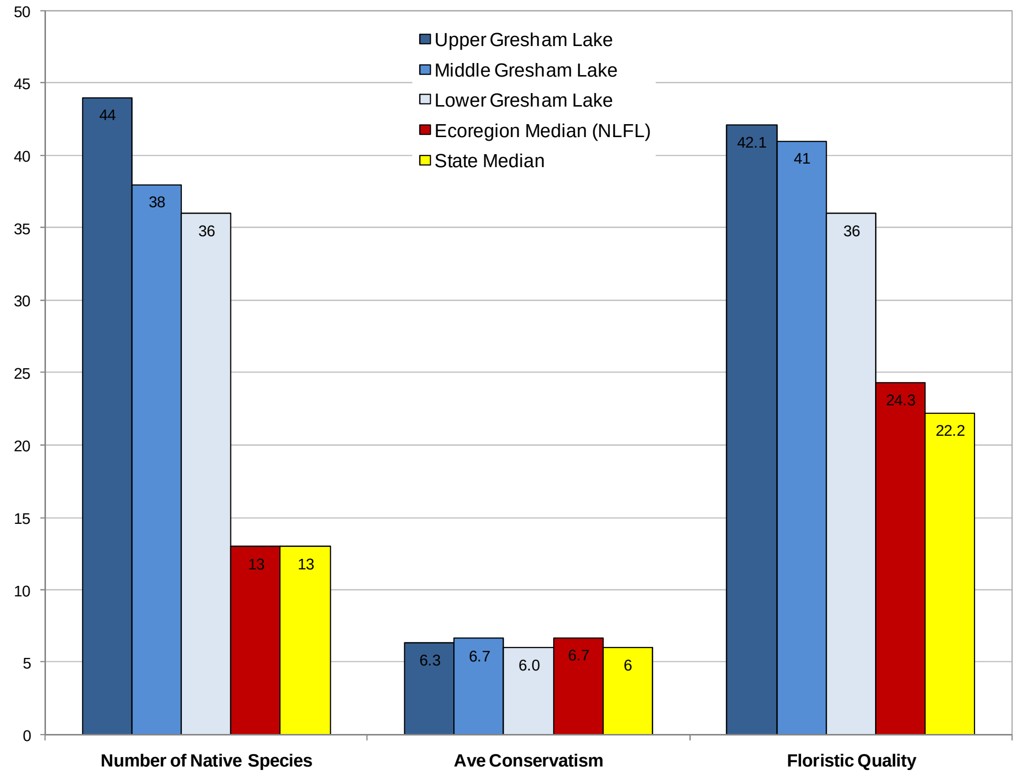

Figure 26. Floristic Quality Assessment using data from aquatic plant surveys. Analysis following Nichols (1999).

As a part of this project, the 2007 herbicide treatment of Eurasian water milfoil was monitored according to current WDNR protocols (April 2007) to provide analysis of treatment efficacy and to satisfy the chemical application permit issued by the WDNR. The following text was modified from the treatment report detailing the 2007 treatment.

2007 Treatment Report

Coordinating with Rich Larson of the Gresham Lakes Association (GLA), Eurasian water milfoil focus areas were digitized and these areas served as a preliminary treatment area of approximately 8.8 acres (Map 10) that was used to obtain a conditional chemical application permit from the WDNR. It is important to note that the original Eurasian water milfoil focus areas were created based on Rich's recollection of the colony's position and size and not with the aid of existing GPS data. During May, these areas were surveyed to produce accurate delineations of the colonies and ultimately to refine the treatment areas. Eurasian water milfoil was located in all of the focus areas and using a sub-meter GPS datacollector, the colonies were accurately mapped. After adding a 20-foot buffer on the mapped colonies, a treatment strategy of 7.9 acres was developed to encompass these locations (Map 11, 12). These areas were recommended to be treated with 2,4-D at 100 pounds/acre. We provided the necessary data to the applicator, Schmidt's Aquatic Plant Control (SAPC), and an application of Navigate (2,4-D) was completed on May 15, 2007 at 100 lbs/acre. The winds were calm and the water temperature was 14.4°C (58°F). To aid in our understanding of the treatment, the applicator provided the approximate application path which is generated by his onboard Global Positioning System (GPS) (Map 11).

Treatment Monitoring

Determining the success or failure of chemical treatments on Eurasian water milfoil is often a difficult task because the criteria used in determining success or failure is ambiguous. Most people involved with Eurasian water milfoil management, whether professionals or laypersons, understand that the eradication of Eurasian water milfoil from a lake, or even a specific area of a lake, is nearly, if not totally, impossible. Most understand that achieving control is the best criteria for success. During the surveys reported on here, two different methods of evaluation were used to understand the level of control that was achieved by the chemical treatment. A qualitative assessment was determined for each treatment site by comparing detailed notes of pre- and post treatment observations and spatial data were collected with the GPS technology described above. A quantitative assessment of the treatment was also made by collecting data at 42 point-intercept sample locations before and after the treatment (Appendix F). At these locations, Eurasian water milfoil presence and rake fullness was documented as well as water depth and substrate type. Native plant abundances were also determined at each plot during the pre- and post treatment surveys; however, these data are only lightly discussed here because comparisons between early spring samples and summer samples are not valid due to the lifecycles of these species.

Pretreatment Survey – May 9-10, 2007

The purpose of this survey was to refine the treatment areas used in the conditional permit to more accurately and effectively coordinate the control method. The conditions on both days were excellent for viewing the Eurasian water milfoil with only a slight breeze and almost full sun. Because of Rich Larson’s experience on Upper Gresham Lake, his aid was solicited to better understand the location, size, and density of the Eurasian water milfoil on the lake compared to his late summer 2006 observations.

Site A A small, relatively dense patch of Eurasian water milfoil was located just to the east of a shallow hump. No sub-sampling occurred at this treatment site.

Site B Only a few Eurasian water milfoil plants were located at this location, but Rich conveyed that more Eurasian water milfoil was present at this location in 2006. No sub-sampling occurred at this treatment site.

Site C This large area was chemically treated in previous years. Scattered locations of dense Eurasian water milfoil were located in this site ranging from 4-8 feet of water depth. 50% of the 20 point-intercept sample locations contained Eurasian water milfoil before the treatment.

Site D Many clumps of Eurasian water milfoil were located in this site growing in 6-9 feet of water. No sub-sampling occurred at this treatment site.

Site E This treatment area was comprised of a few isolated clumps of Eurasian water milfoil. Only 2 of the 10 (20%) point-intercept locations contained Eurasian water milfoil previous to the treatment

Sites F, G, H, I, J, & K Eurasian water milfoil was scattered along this northern shore between the 6-10 foot contours (Map 11). The treatment areas were placed around clumps of plants with only isolated plants occurring outside of the constructed treatment areas. Because of their small size, not all lent themselves well to replicable sub-sampling treatment monitoring. Of these treatment sites, sub-sampling techniques were only applied to Site G where 3 out of 4 locations contained Eurasian water milfoil (Table 8).

Site L This deep water site contained relatively dense occurrences of Eurasian water milfoil. The extents of this colony were verified using the aid of a submersed underwater camera. Also, Onterra ecologists scuba dove the area to gain further understanding of the colony (substrate type, native plants, water depth, etc.). 62.5% of the 8 point-intercept locations contained Eurasian water milfoil.

Site M One clump of Eurasian water milfoil was discovered in this location. No sub-sampling occurred at this location.

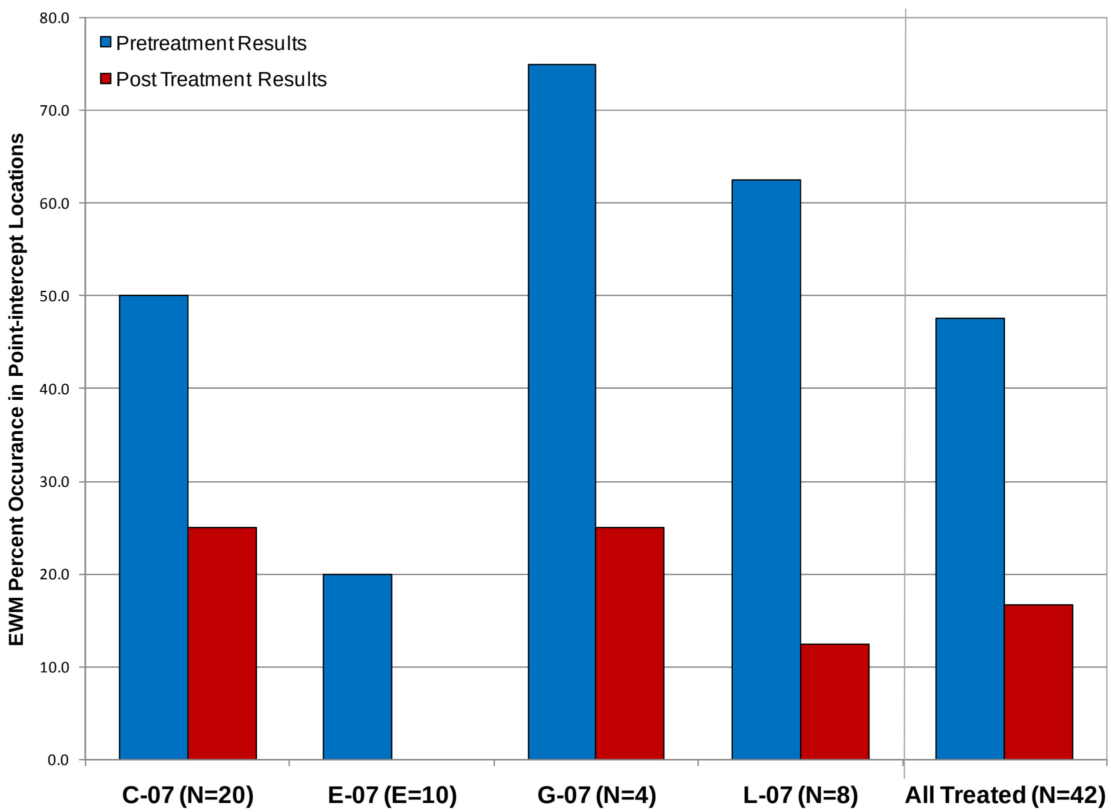

Figure 27. Eurasian water milfoil Percent Occurrence in Point-intercept Locations.

Post Treatment Survey – August 13, 2007

During this survey, all treatment areas were visited to determine the efficacy of the chemical application. All point-intercept sample locations were re-visited and data were collected in the same manner as during the pretreatment survey. A peak-biomass Eurasian water milfoil survey was also conducted during these field visits to help coordinate Eurasian water milfoil management in 2008. Please note that an attempt was made to keep treatment site names as consistent as possible between 2007 and 2008 (Maps 11, 12). However, each site differs between years both by size and location.

Site A-07 Eurasian water milfoil was located within this treatment site and it appeared largely the same as during the pretreatment site visit. One 25 foot colony along with another large clump of Eurasian water milfoil was located in this area and was considered a primary treatment area for 2008 (Map 12).

Site B-07 No Eurasian water milfoil was located within this treatment site during the August 2007 visit.

Site C-07 A few Eurasian water milfoil colonies were located and mapped within Site C, one of which was relatively dense (Map 12). These two sites were recommended for treatment in 2008 (Sites C-08 and N-08).

Site D-07 This treatment site was located on the western edge of a 5-7 foot shelf located in the southwestern basin of Upper Gresham Lake (Map 11). The post treatment field visit mapped numerous occurrences of small and large Eurasian water milfoil colonies growing along the margins of this shelf. Eurasian water milfoil was mapped within D-07, consisting of the northern part of a large colony (Map 12, Site D-08) and other large clumps.

Site E-07 Only one large Eurasian water milfoil clump was located within this treatment site after the treatment. However, 2 large, dense Eurasian water milfoil colonies were located off the lakeward edge of this treatment site (Map 12, Site E). None of the 10 sub-sample locations contained Eurasian water milfoil after the treatment (Table 8).

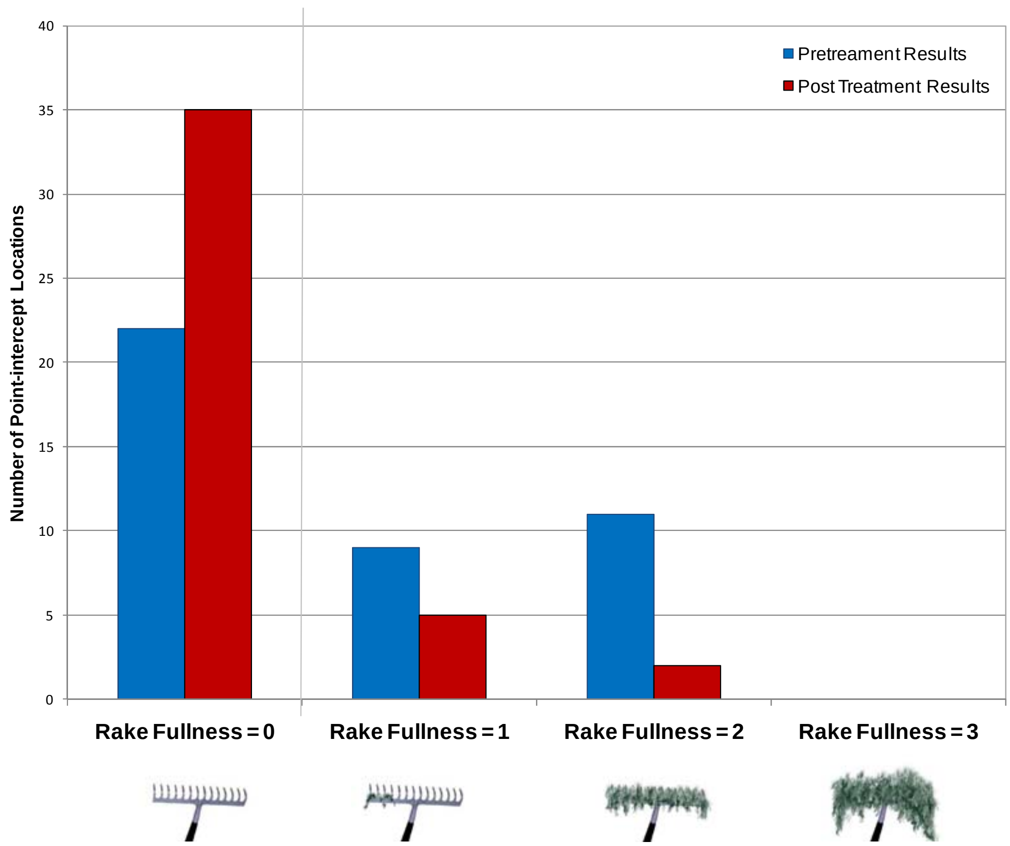

Figure 28. Eurasian water milfoil Rake Fullness Distribution.

Sites F, G, H, I, J, & K-07 Much Eurasian water milfoil was discovered along the northern shore of Upper Gresham Lake and in some locations it was canopied and flowering at the surface (Map 12, Sites F-08 and I-08). Eurasian water milfoil was located in every one of the 2007 treatment areas. The 4 point-intercept locations only yielded 1 Eurasian water milfoil occurrence (Table 8). Multiple treatment areas were recommended for treatment in 2008 (Map 12).

Site L-07 This Eurasian water milfoil colony was re-mapped and found to be almost exactly the same size. However, the Eurasian water milfoil appeared less dense and very little Eurasian water milfoil was tall enough to reach the surface of the water. 12.5% of the 8 point-intercept locations contained Eurasian water milfoil after the treatment (Table 8).

Site M-07 A few Eurasian water milfoil occurrences were located within and around this treatment site. Based on the amount of Eurasian water milfoil located in other areas of the lake, no treatment in 2008 was recommended in this area.

Conclusions and recommendations

Before the treatment, 47.6% of the point-intercept locations contained Eurasian water milfoil and 16.7% contained Eurasian water milfoil after the treatment (Figure 27). However, almost half of these locations are contained within Site C-07, a site that had been treated previous to 2007 A rake fullness rating of 1-3 was used to determine abundance of the Eurasian water milfoil at each location. Figure 28 displays the number of point-intercept locations exhibiting each of the rake fullness ratings. The figure shows that of the 17 locations that contained Eurasian water milfoil before the treatment, 58% had a rake fullness rating of 2. These data suggest a relatively heavy density of Eurasian water milfoil plants within the treatment areas. 71% of the Eurasian water milfoil located during the post treatment survey had a rake fullness rating of 1, showing a reduction in density.

Because of the lifecycle of native plants, they should be at very low biomass (or not even started growing yet) during the spring survey. However, it is important to understand the effects of the dicot-specific herbicide on some of the broad-leafed natives. Table 8 shows that coontail and northern water milfoil were not adversely affected by the treatment. All native monocots that were located in the pretreatment survey increased in occurrence after the treatment. Water marigold, a native dicot, was observed during the post treatment survey and not during the pre-treatment survey.

Table 8. Percent occurrence of native dicots from the point-intercept survey.

	% Occurrence	
Species	**Pretreatment Results**	**Post Treatment Results**
Coontail	31.0	31.0
Northern water milfoil	7.1	12.5

Based on the quantitative survey, a reduction in the quantity and density of Eurasian water milfoil was documented which suggests that a moderate level of control was observed on Upper Gresham Lake. However, using a small number of sub-sample points does not grant a high level of statistical significance. Also, some locations were too small to use sub-sampling techniques so the quantitative results can truly only be extrapolated to the 4 sites that contained sub-sampling locations. Based on the results of the peak-biomass survey, Eurasian water milfoil was not observed to be controlled on a lake-wide level (Map 12). Evaluating treatment success in Upper Gresham Lake is difficult without peak-biomass survey data from 2006 to compare with the 2007 findings. Based on numerous conversations from members of the GLA, Eurasian water milfoil occurrence and density in 2007 exceeded that of previous years. It was our recommendation that all areas be treated in 2008 at 150 lbs/acre. Working on many lakes in this region, we have noticed that several factors lead to ineffective treatments: depth of plants, density of plants, and size of treatment area. In many of the 2008 proposed treatment areas, the plants are found in 7-12 feet of water and are relatively dense. Also, many of the treatment areas are a half acre or less which makes them vulnerable to the edge effects of dilution and chemical drift which decrease the concentration of herbicide needed for an effective treatment in the small area for which it is intended. One method of reducing these effects would be to increase the buffer placed on the Eurasian water milfoil colony to create a larger treatment area. At this time, this technique is not recommended for Upper Gresham Lake due to the amount of sensitive native plants that may be affected.

2008 Pretreatment Survey – May 8, 2008

A survey conducted previous to the 2008 treatment was used to refine areas based on the most available data on the locations of Eurasian water milfoil within Upper Gresham Lake. The majority of treatment areas were found to be adequate during this survey, but some additional acreage was added to J-08 and D-08 (Map 13). Consistent with the conclusions made from the 2007 treatment report, all areas were recommended to be treated at 150 lbs/acre.

Also on this date, Middle Gresham Lake was visited. In 2007, Onterra located a few Eurasian water milfoil plants near the inlet from Upper Gresham Lake (Map 14) and removed the plant, roots and all, with a rake. While it is hoped that the entire plants were removed, continued monitoring of these location will need to continue as to monitor these and additional plants that may enter the lake from Upper Gresham Lake.

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 Gresham Chain of Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within the chain of lakes with a primary focus on Eurasian water milfoil in Upper Gresham Lake.
3) Collect sociological information from Gresham Lakes watershed inhabitants regarding their use of the chain and their thoughts pertaining to the past and current condition of the lakes and their management.

The three objectives were fulfilled during the project and have led to a good understanding of the Gresham Chain of Lakes 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 the chain indicate that they are healthy in terms of their watershed and water quality. With the exception of two exotic species found in two of the lakes, the aquatic plant communities are also believed to be healthy.

Although the three Gresham Chain lakes share much of the same watershed, the affect that the watershed has on each lake is quite different. The common factor between all of the lakes is that the watershed is comprised mostly of forested areas that export a minimal amount of phosphorus to the lakes and their tributaries. The real differences in the impact the watershed has on each of the lakes relates to the size of the drainage basin feeding that particular lake relative to the surface area of that lake. Upper Gresham Lake is the largest lake in the chain and has the smallest watershed. Middle and Lower Gresham are smaller lakes and each has a much larger watershed draining to it; therefore, their watersheds have greater impact on each lake's water quality.

An important aspect of the Gresham Lakes watershed is the immediate watershed, or near-shore watershed that surrounds each lake as these are the areas where development and other human activities can have the most dramatic impact on the lake. Land development often leads to destruction of native shoreland plant communities which leads to increased erosion and loss of valuable habitat. These impacts along with increased impervious surfaces within the immediate watershed as brought about by construction of rooftops and driveways mean increased levels of sediment and phosphorus loading to the lake.

When this management plan is updated, the association should include a shoreland assessment component that would lead to a better understanding of which areas of the shoreland are likely impacting the lakes the greatest. Those properties could then be targeted for shoreland restoration projects as a part of the updated plan's implementation.

The water quality of each of the Gresham Lakes is considered to be good to very good when compared to other lakes in the region and in the state. However, that determination is made with very little water quality data. Upper Gresham Lake has the most historic data, yet it only spans back to 2000. Middle and Lower Gresham Lake have basically no historic data. Obviously, the lack of past water quality information makes long-term trend analysis impossible, hampering a full understanding the of the Gresham Lakes ecosystem.

The aquatic plant surveys completed by the WDNR and Onterra between 2005 and 2007 discovered 55 aquatic native species within the Gresham Chain. Two non-native species were also located in limited occurrences. Each of these non-native species is addressed in the implementation plan that follows this section. Overall, the studies indicate that the aquatic plant communities are outstanding, which points at the general good health of the system. The Middle and Upper Gresham Lake communities were found to be highly diverse. Lower Gresham Lake's diversity is not great mostly because the plant community is limited by the dominance of two plant species; however, Lower Gresham Lake is the only lake in the chain believed not to contain exotic species.

Both Lower and Middle Gresham Lake have an abundance of native aquatic plants. In fact, both lakes may contain levels of native plants in limited areas that may, in some situations, impact the ability of riparian property owners in accessing open water from their shoreland. While alternatives exist that will provide access to the lake, they need to be used sparingly because there overuse can open areas up to easy infestation by exotic plants by removing the native competitors.

A large portion of the Upper Gresham Lakes shoreline is owned by the State of Wisconsin, and a portion of that land serves as a popular campground. The campground adds a great deal of recreational use to the lake, including boating, fishing, skiing, and jet skiing. The state's plans for expanding the campground to include more sites has raised concerns among Gresham Lakes stakeholders (Appendix B, Question #13), and rightfully so as that increase in sites will also lead to an increase in recreational use of the lake. The increase in use also means an increased risk in the chain of lakes being exposed to AIS infestation. The WDNR needs to listen to the concerns of the GLA and weigh the public benefit that will be gained by expanding the campground with the increased risk of the chain being exposed to additional AIS.

The GLA has also expressed concerned about illegal destruction of beaver dams within the Gresham Lakes watershed. For many years, members of the Gresham Lakes Association have managed beavers within the watershed through permitted trapping. In recent years an individual or group of individuals have taken it upon themselves to completely destroy beaver dams, an illegal act on public and private lands. Members of the GLA have contacted the WDNR about these activities and have not received the help they desire. The WDNR needs to discuss the issue with the Gresham Lakes stakeholders and come to a resolution that supports the statutes of the State of Wisconsin.

Overall, the biggest concern among Gresham Chain stakeholders is aquatic invasive species (Appendix B, Question #s 18 and 19). Obviously, Eurasian water milfoil would be of the most concern as it currently occurs in the two most upstream lakes. At this time, the most feasible alternative for controlling the Eurasian water milfoil and preventing it from negatively impacting that lakes quality native plant habitat is the use of herbicide application. In Middle Gresham Lake, continued monitoring and hand-harvesting is the preferred path to maintain control over the plant's infrequent occurrence. Herbicide control is the preferred method in Upper Gresham because it will bring the exotic under control in the most cost-effective and environmentally-sound manner. Further, this is considered an acceptable method by Gresham Lakes stakeholders

(Appendix B, Question #22). Other common control alternatives are infeasible and/or impractical for use in Upper Gresham Lake. Water level drawdown is infeasible because a dam does not exist on the lake; therefore, pumping would be required. Harvesting would accelerate the Eurasian water milfoil's spread through fragmentation. Milfoil weevils are still unproven and quite costly. Currently, there is too much Eurasian water milfoil to be controlled by hand-harvesting, but in the future, this may be an appropriate technique to use in conjunction with herbicide application.

IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Gresham Lakes Association Planning Committee and ecologist/planners from Onterra. It represents the path the GLA 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 Gresham Chain of Lakes 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: Maintain Current Water Quality Conditions

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

Timeframe: Continuation of current effort.

Facilitator: Board of Directors

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. The lack of this type of historical information hampered the water quality analysis during this project. Early discovery of negative trends may lead to the reason as of why the trend is developing. Volunteers from the Gresham Lakes association have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizen Lake Monitoring Program. At this time, a volunteer from each lake has been trained to collect the samples and enter the data into the WDNR database. Stability will be added to the program by selecting an individual from the lake association to coordinate the chain's volunteer efforts and to recruit additional volunteers to keep the program fresh.

Action Steps:

1. Board of Directors recruits volunteer coordinator from association.
2. Coordinator directs water quality monitoring program efforts and volunteers.
3. Volunteers collect data and coordinator/volunteers report results to WDNR and to association members during annual meeting.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to Gresham Lakes.

Timeframe: Begin 2008

Facilitator: Planning Committee to recruit volunteer or form Education Committee

Description: As the watershed section discusses, the Gresham Lakes watershed is in good condition; however, watershed inputs still need to be focused upon, especially in terms of the chain's shoreland properties. These sources include faulty septic systems, the use of phosphorus-containing fertilizers, shoreland areas that are maintained in an unnatural manner, and impervious surfaces. To reduce these impacts, the GLA will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include news letter articles and guest speakers at association 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.

Action Steps:

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

Management Goal 2: Control Aquatic Invasive Species within Gresham Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Upper Gresham Lake public access.

Timeframe: Continue current effort

Facilitator: Planning Committee

Description: The GLA will be initiating watercraft inspections at the Upper Gresham Lake boat landing during the summer of 2008 as a part of the Education, Prevention & Planning AIS Grant they received during the February 2008 grant cycle. Upper Gresham Lake is a popular destination by recreationists and anglers, making the system vulnerable to new infestations of exotic species. Although the system already contains aquatic invasive species, it is still important to minimize the chance of new infestations of aquatic invasive species to be introduced to the lake and ensure that the Gresham Chain is not the source of aquatic invasive species for other waterbodies.

1. Members of association attend Clean Boats Clean Waters training session during spring or summer 2008
2. Training of additional volunteers completed by those trained during 2008.
3. Begin inspections during high-risk weekends
4. Report results to WDNR and GLA.
5. Promote enlistment and training of new volunteers to keep program fresh.

Management Action: Reduce occurrence of giant reed on Upper Gresham Lake shorelands.

Timeframe: Begin summer 2008

Facilitator: Planning Committee

Description: Giant reed, an invasive species was found in two locations of Upper Gresham Lake shoreland. At this time, infestation levels are still low enough that cutting and chemical application efforts will likely keep this invasive species under control; therefore, this method will be utilized initially during the program.

Information sources, such as the WDNR, UW-Extension, and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC, www.glifwc.org) will be used to properly identify giant reed and provide guidance on the proper time to treat the plants. All Wisconsin statutes will be adhered to during these management efforts.

Important aspects of this management action will be the monitoring and record keeping that will occur in association with the control efforts. These records will include maps indicating infested areas and associated documentation regarding the actions that were used to control the areas, the timing of those actions, and the results of the actions. These maps and records will be used to track and document the successfulness of the program and to keep the WDNR and GLA updated.

Action Steps:

1. Recruit members to begin monitoring and control efforts
2. Group completes surveys to verify infested areas
3. Initiate applicable control methods
4. Monitor results and reapply control as necessary
5. Keep WDNR and GLA informed regarding program results

Management Action: Control Eurasian water milfoil infestation on Upper Gresham Lake.
Timeframe: Initiate 2008
Facilitator: Planning Committee with professional help as needed
Description: As described in the Aquatic Plant section and elaborated upon within the Summary and Conclusions, Upper Gresham Lake is believed to currently contain approximately 15 acres of Eurasian water milfoil. At this time, the most feasible method of control is herbicide applications, specifically, early-spring treatments with 2,4-D. The responsible use of this technique is well supported by Gresham Chain stakeholders as indicated by over 78% of stakeholder survey respondents indicating that they are moderately to highly supportive of an herbicide control program (Question 22). Past treatments have met with only limited control being achieved. It is believed better control will result from the increased dosage rate called for in the 2008 treatment plan.

The objective of this management action is not to eradicate Eurasian water milfoil from Upper Gresham Lake, as that would be impossible. The objective is to bring Eurasian water milfoil down to more easily controlled levels. In other words, the goal is to reduce the amount of Eurasian water milfoil in Upper Gresham Lake to levels that would only require spot treatments to keep the exotic under control. To complete this objective efficiently, a cyclic series of steps is used to plan and implement the treatment strategies. The series includes:

1. A lakewide assessment of Eurasian water milfoil completed while the plant is at peak biomass (July or August).
2. Creation of treatment strategy for the following spring.
3. Verification and refinement of treatment plan immediately before treatments are implemented.
4. Completion of treatments.
5. Assessment of treatment results (summer after treatment).

Once Step 5 is completed, the process would begin again that same summer with the completion of a peak biomass survey. The survey results would then be used to create the next spring's treatment strategy.

Obviously, monitoring is a key aspect of the cycle, both to create the treatment strategy and monitor its effectiveness. The monitoring would also facilitate the "tuning" or refinement of the treatment strategy as the control project proceeds. It must be remembered, that this portion of the management plan (control plan) would be intended to span approximately 3-7 years before it would need to be updated to account for changes within the ecosystem. The ability to tune the treatment strategies is important because it allows for the most effective results to be achieved within the plan's life span.

Two types of monitoring would be completed to determine treatment effectiveness; 1) quantitative monitoring using WDNR protocols, and 2) qualitative monitoring using observations at individual treatment sites and on a treatment wide basis. Results of both of these monitoring strategies would be used to create the subsequent treatment strategies. The quantitative strategies include sampling plants, both Eurasian water milfoil and native species, at predetermined locations (points) within treatment areas, while the qualitative monitoring includes the determination of Eurasian water milfoil abundance based upon a continuum of density. The density continuum ranges from non-detectable levels of Eurasian water milfoil to what is considered a monoculture where Eurasian water milfoil is essentially the only plant that exists in the area. Both monitoring types would be completed before and after the treatments (pretreatment surveys and post treatment surveys). Comparing the monitoring results from the pretreatment and post treatment surveys would determine the effectiveness of the treatment on a site-by-site basis and on a treatment wide basis. Finally, a lakewide plant survey (point-intercept survey) would be completed after this management action is completed (3 to 7 years) to determine the effectiveness of the intense control program.

Success Criteria

Determining the effectiveness of the treatment program is impossible unless specific success criteria (goals) are set before beginning the program. For this control program, the criteria would be evaluated at three levels

1. Treatment area (site specific)
2. Annual treatment (treatment wide)
3. Control program

Treatment Area

Qualitatively, a successful treatment on a particular site would include a reduction of Eurasian water milfoil density as demonstrated by a decrease in density rating.

Quantitatively, a successful treatment on a specific-site level would include a significant reduction in Eurasian water milfoil frequency following the treatments as exhibited by at least a 50% decrease in Eurasian water milfoil frequency from the pre- and post treatment point-intercept sub-sampling. In other words, if the Eurasian water milfoil frequency of occurrence before the treatment was 40%, the post treatment frequency would need to be 20% or lower for the treatment to be considered a success for that particular site. Further, there would be a noticeable decrease in rake fullness ratings within the fullness categories of 2 and 3.

Annual Treatment

Qualitatively, success would be achieved annually when 75% of the treatment areas are reduced by a density rating (as described above).

Similar to the site specific evaluation, annual treatment success would be observed when a 50% decrease in Eurasian water milfoil frequency from the sub-sampling occurs. Preferably, there would be no rake tows completed during the post treatment surveys exhibiting a fullness of 2 or 3.

Control Program

At the end of the project, it is hoped that no Eurasian water milfoil colonies would exist over *density=1*. Ecological function of a particular area is thought to be greatly reduced when Eurasian water milfoil becomes the dominant plant which corresponds to a *density=1* rating.

The control program would be quantitatively evaluated by recompleting the whole-lake point-intercept survey at the end of the project and observing a reduction in frequency of Eurasian water milfoil.

Control Program Specifics

This control program is anticipated to span four treatment years. Although it is very difficult, if not impossible, to accurately estimate how many acres of Eurasian water milfoil will need to be treated for some number of years in the future, it is obviously needed for budgeting purposes. Based upon the Eurasian water milfoil surveys completed in recent years and the results of recent treatments, a conservative estimate of treatment acreages is listed below. It is conservative in anticipation of some areas requiring treatment for multiple years to reduce densities as discussed in the success criteria.

Project Year	Treatment Year	Estimated Acreage
2009	1	20
2010	2	15
2011	3	10
2012	4	8

Project Funding Assistance

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund this control program and other elements of this management plan. Specifically, funds would be applied for under the Established Infestation Control Project classification.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the cyclic series of steps discussed above.
2. Apply for a WDNR Established Infestation Control Grant based on developed project design.
3. Initiate control plan
4. Revisit control plan in 4 years
5. Update management plan to reflect changes in control needs and those of the lake ecosystem

Management Action: Coordinate annual volunteer monitoring of Aquatic Invasive Species
Timeframe: Start 2008
Facilitator: Planning Committee
Description: In lakes without Eurasian water milfoil, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. Even in lakes where these plants occur, monitoring for new colonies is essential to successful control. Although the intensity of Eurasian water milfoil in Upper Gresham Lake requires professionally conducted surveys, Middle and Lower Gresham Lakes are believed to have very low or no occurrences of Eurasian water milfoil within them.

Volunteers from the GLA will monitor Eurasian water milfoil and other aquatic invasive species within the Gresham Chain using training provided by the WDNR, Vilas County, UW-Extension, and/or other qualified professionals. Training will include identification of target species and native look-a-likes, proper use of GPS for recording aquatic plant occurrences, note taking, and transfer of data to agency or other professional lake managers. In the end, the ultimate objective is to have a group of volunteers prepared to carry on a portion of the Eurasian water milfoil control program, including the herbicide treatments on Gresham Lake and the periodic manual removal of Eurasian water milfoil on Middle Gresham Lake. This action will also meld well with the control of giant reed as described above.

Action Steps:

Please see description above.

Management Goal 3: Maintain recreational access to Gresham Lakes for shoreland property owners

Management Action: **Support reasonable and responsible actions by shoreland property owners to gain navigational access to open water areas of Gresham Lakes.**
Timeframe: Begin 2008
Facilitator: Board of Directors

Description: The GLA supports reasonable and environmentally sound actions to facilitate access to open water areas of Gresham Lakes by shoreland property owners. These actions may include the chemical treatment of nuisance levels of native aquatic plants in order to restore watercraft access to open water areas of the Gresham Chain. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area required to permit the access. These actions do not include areas that can be controlled through manual removal such as swimming areas and areas around piers and boatlifts. Individual property owners are solely responsible for the financial burden of the control and for documenting the need for nuisance control as described in Aquatic Plant Management Strategy Northern Region WDNR (Summer 2007). This guidance document clearly states that no individual permits will be issued. If documentation of impairment exists, this plan must be amended to specifically delineate the areas requiring control and a permit must be obtained by the association.

Three possibilities exist to maintain access to open water from the impacted riparian properties: 1) contract to have the plants removed manually, 2) contract to have the plants cut and removed through mechanical harvesting, and 3)apply herbicides to kill the plants. With any of these options, the ecology of the area must be seriously considered. Loss of native plants in any area of a lake is unfortunate because they are the foundation of the lake ecosystem. Further, in a lake such as Middle Gresham Lake where invasive plant species are known to exist but have not yet established themselves, the destruction of native plant stands may cause a disturbance that would allow for easier non-native establishment.

At this time it is unknown if a contractor exists that is able to manually remove the plants in feasible manner that would create navigation lanes to open water from the shoreland properties. Local landscaping companies may fill this niche as more lakes seek this service. It is also unknown if mechanical harvesting is possible in these area due to shallow water and lack of an improved boat landing on the lake. However, both of these techniques would be preferable over chemical treatments; therefore, those options will be exhausted before herbicide applications are used.

Regardless of the technique used, their impact on the native plant community will be minimized by removing only as much native habitat as necessary in order gain access to open water. No more than a 30-foot wide navigation lane will be cleared in any area and the shortest route possible will be used.

The GLA understands that the property owner may be required to offset the impacts to the native plant community caused by the aquatic plant control by meeting shoreland restoration requirements. Essentially, if the property owner is going impact existing native plant habitat, they may need to restore native habitat on their property to mitigate what is lost as a result of the aquatic plant control they are completing. Before control of native aquatic plant species occur on the lake, a defined plan of management would need to be developed to serve as an amendment to the current lake management plan.

Action Steps:

1. Individual property owners document impairment, either on their own or by hiring a professional as described in the Aquatic Plant Management Strategy Northern Region WDNR
2. The property owner provides the materials to the WDNR and the association for review.
3. The association requests a site visit by the WDNR to verify impairment.
4. The association updates the current management plan to further define the management objective and associated actions (mechanical harvesting or herbicide application) needed to augment the impairment.
5. Association obtains a permit to implement management action after WDNR verifies impairment and approves the update to the management plan.

METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in the Gresham Chain of Lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on Upper Gresham, Middle Gresham, and Lower Gresham that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network protocols and occurred once in spring and winter and three times during the summer. All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (SLOH). The parameters measured, sample collection timing, designated collector, and cost coverage are contained in table below. Secchi disk transparency was also included during each visit.

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

The diamond shape indicates samples collected as a part of the Citizen Lake Monitoring Network and the circle indicates samples collected under the proposed project funding. The winter samples were collected by Onterra. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle.

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Upper, Middle, and Lower Gresham Lakes on June 19-20, 2007 during field visits, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on the system to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in "Appendix C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2005) was used to complete this study.

	Point-intercept Resolution	Number of Points	Survey Dates	Surveyor
Upper Gresham	50-meter	583	August 10-11, 2005	WDNR
Middle Gresham	37-meter	278	July 27-28, 2007	WDNR
Lower Gresham	48-meter	257	June 15, 2007	Onterra

Community Mapping

During the species inventory work, the aquatic vegetation community types within each 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 each of the lakes.

2007 Treatment Monitoring

The methodology used to monitor the 2007 herbicide treatments is included within the results section under the heading: *Treatment Monitoring.*

Watershed Analysis

The watershed analysis began with an accurate delineation of the Gresham Chain of 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 Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) 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).

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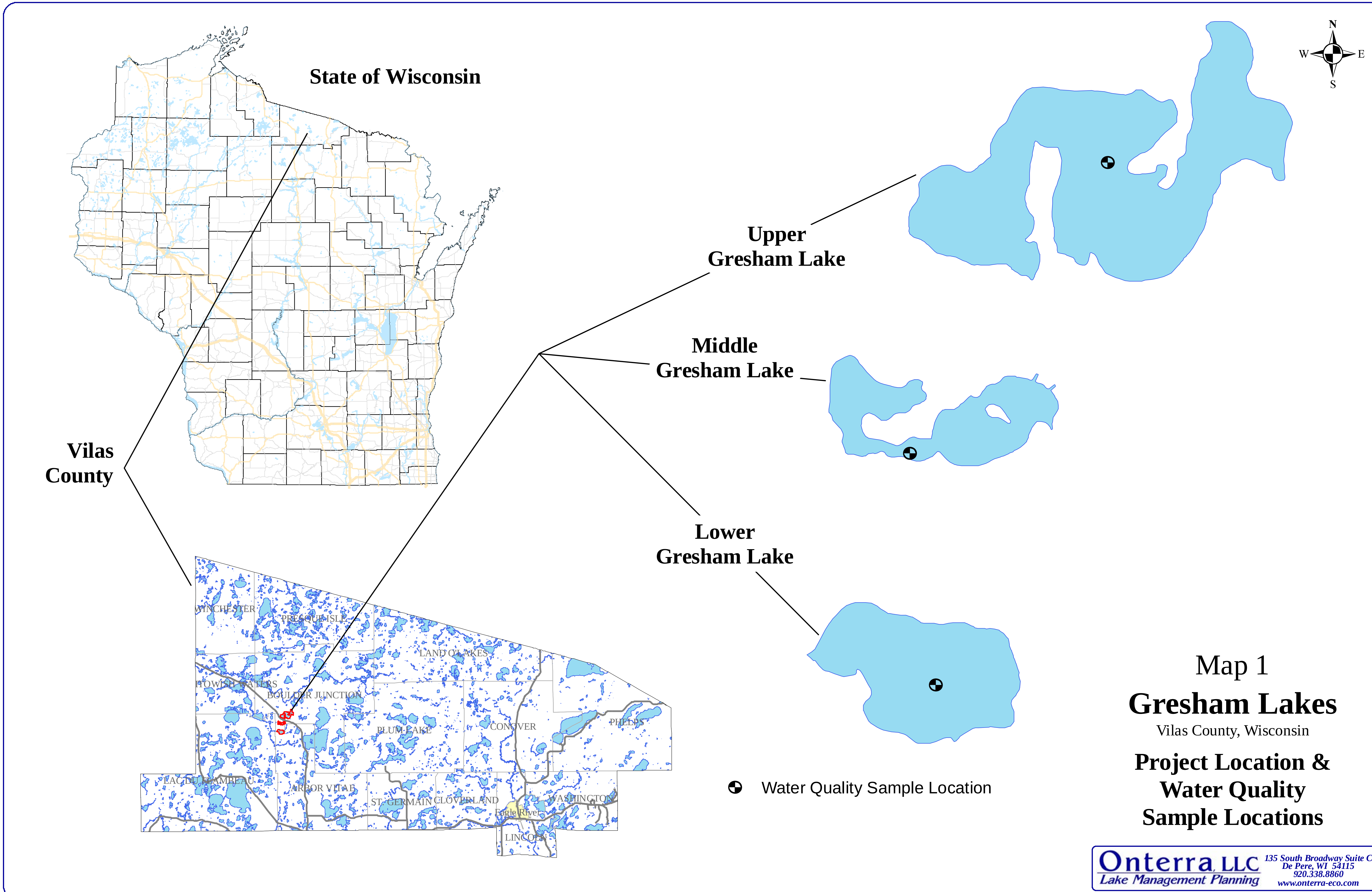
State of Wisconsin
Vilas County
WINCHESTER
PRESQUE ISLE
LAND O' LAKES
MANITOWISH WATERS
BOULDER JUNCTION
PLUM LAKE
CONOVER
PHELPS
LAC DU FLAMBEAU
ARBOR VITAE
ST. GERMAIN
CLOVERLAND
WASHINGTON
Eagle River
LINCOLN
Upper Gresham Lake
Middle Gresham Lake
Lower Gresham Lake
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W
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S
Water Quality Sample Location
Map 1
Gresham Lakes
Vilas County, Wisconsin
Project Location & Water Quality Sample Locations
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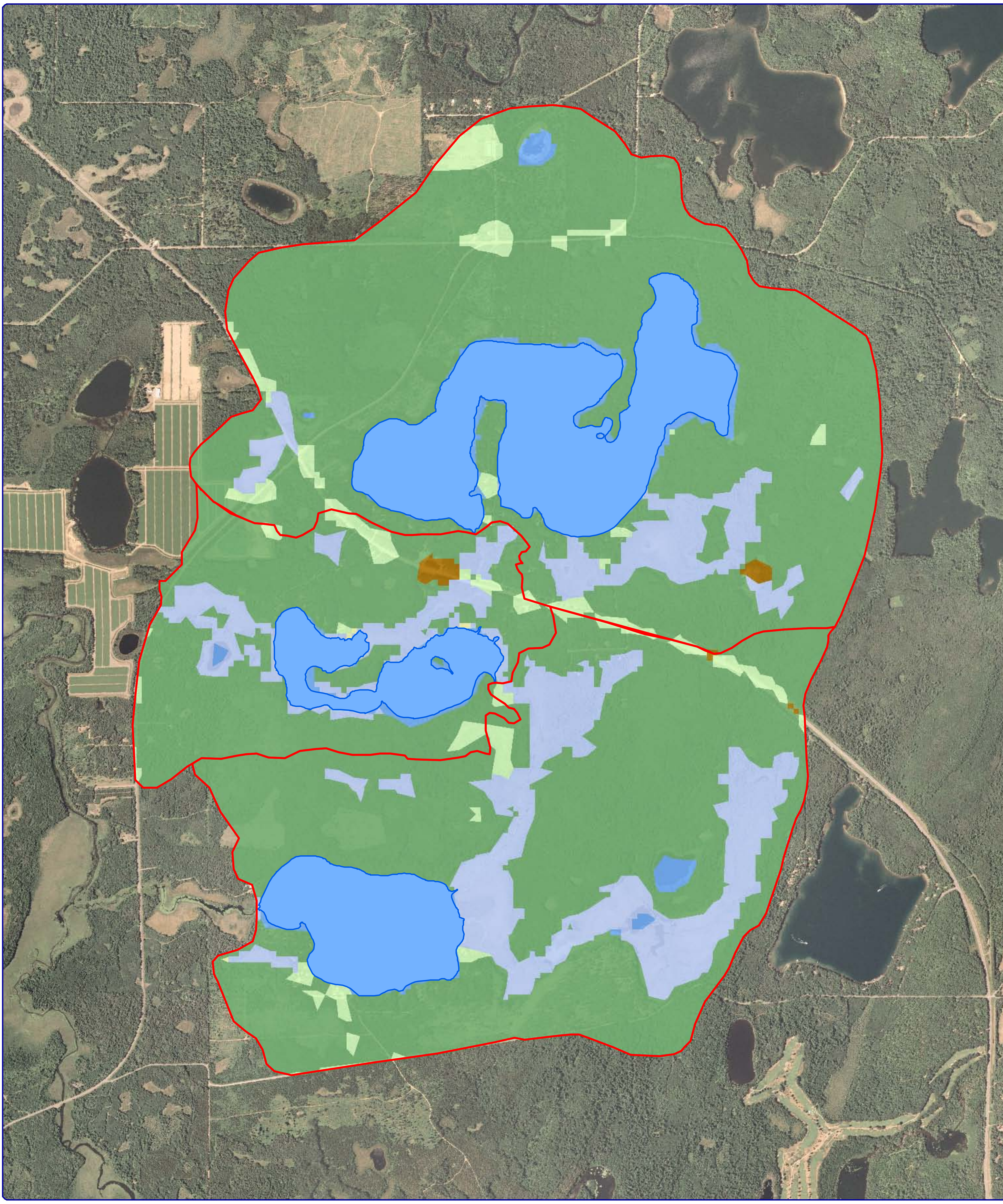

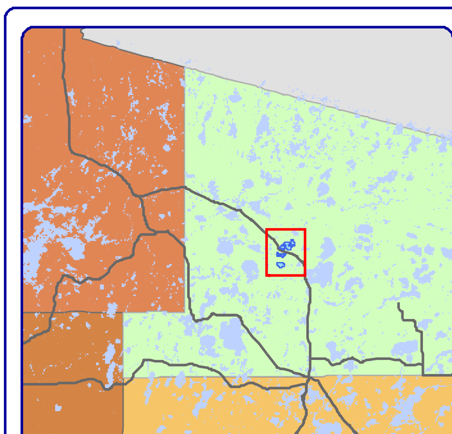

Extent of large map shown in red.

Sources:
Watershed: WDNR & Onterra
Landcover: WISCLAND
Roads & Hydro: WDNR
Orthophotography: NAIP, 2005
Map Date: May 20, 2008

Legend

Watershed Boundary

Land Cover Types

Row Crop
Pasture/Grass
Forest
Open Water
Wetland

N
W E
S

1,800
Feet

Map 2

Gresham Lakes

Vilas County, Wisconsin

Watershed and Land Cover Types

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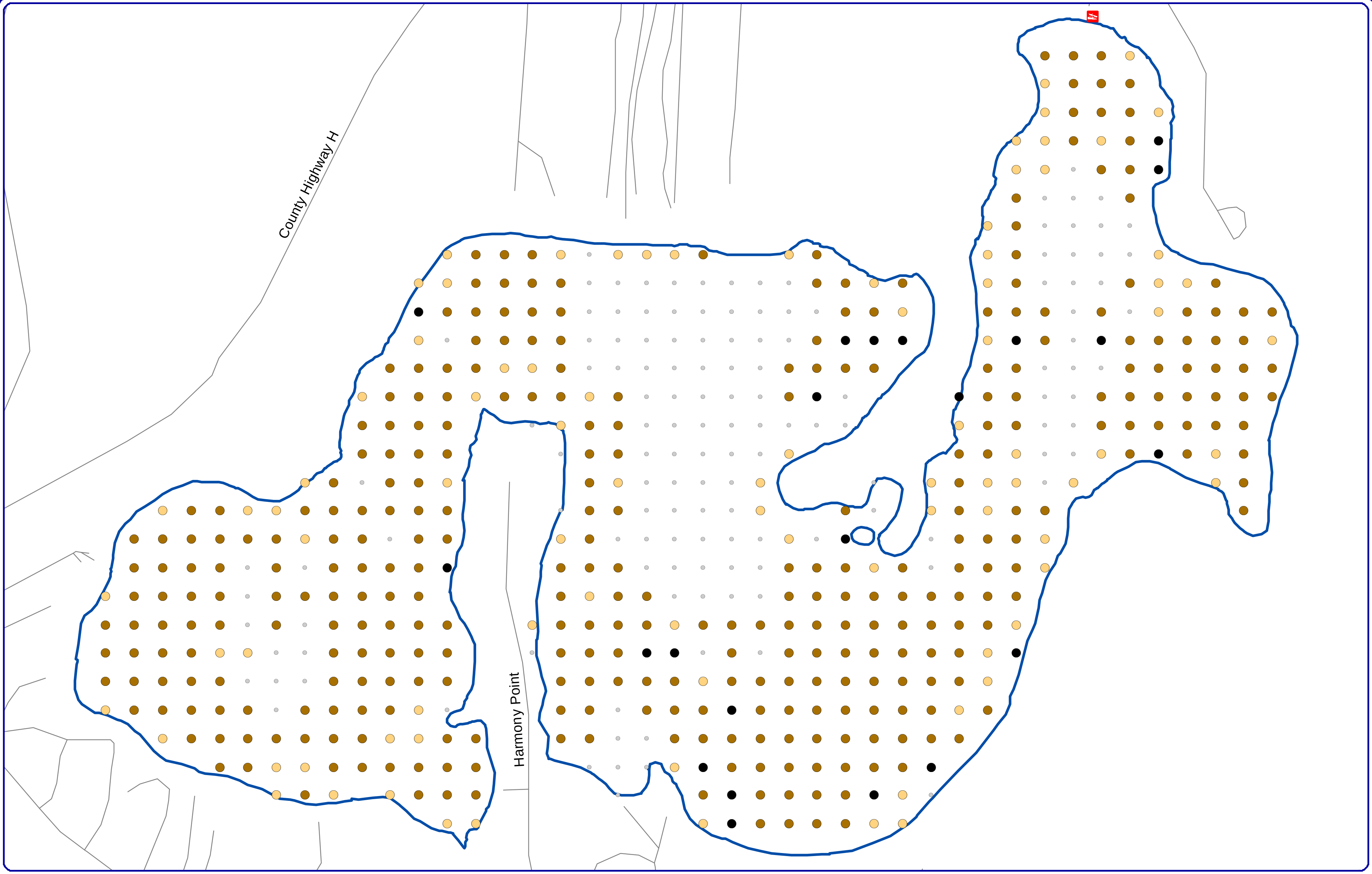

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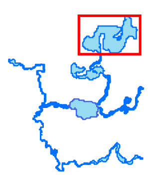
Sources:
Roads & Hydro: WDNR
Point-Intercept Locations: WDNR ISS
Map date: March 10, 2009



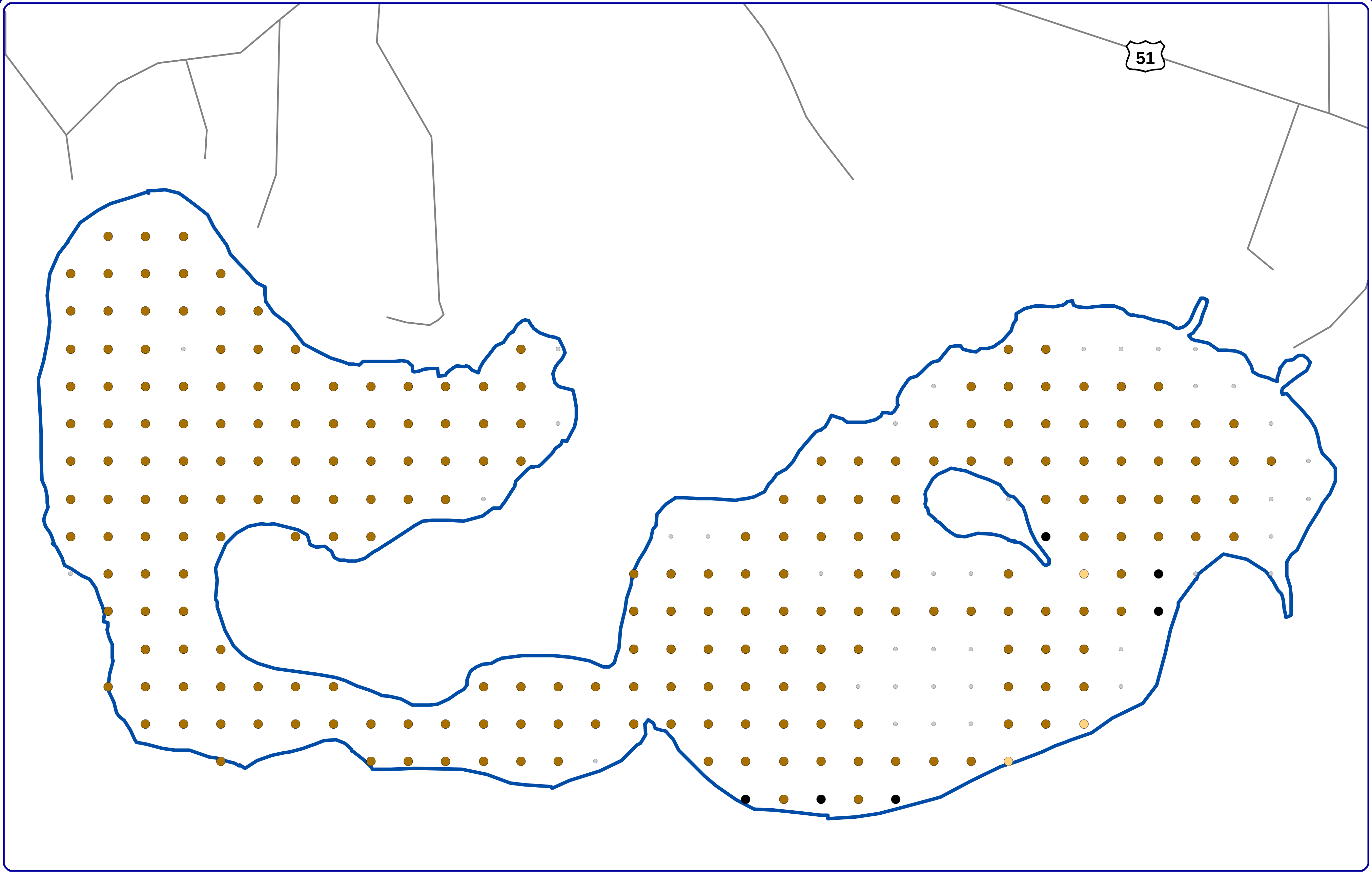
Extent of large map shown in red.

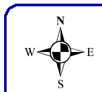
Legend
Substrate
- Muck
- Rock
- Sand
- Too Deep or No Data

Map 3

Upper Gresham Lake
Vilas County, Wisconsin

2008 P-I Survey: Substrate





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Feet

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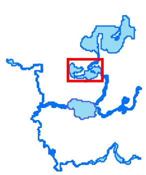
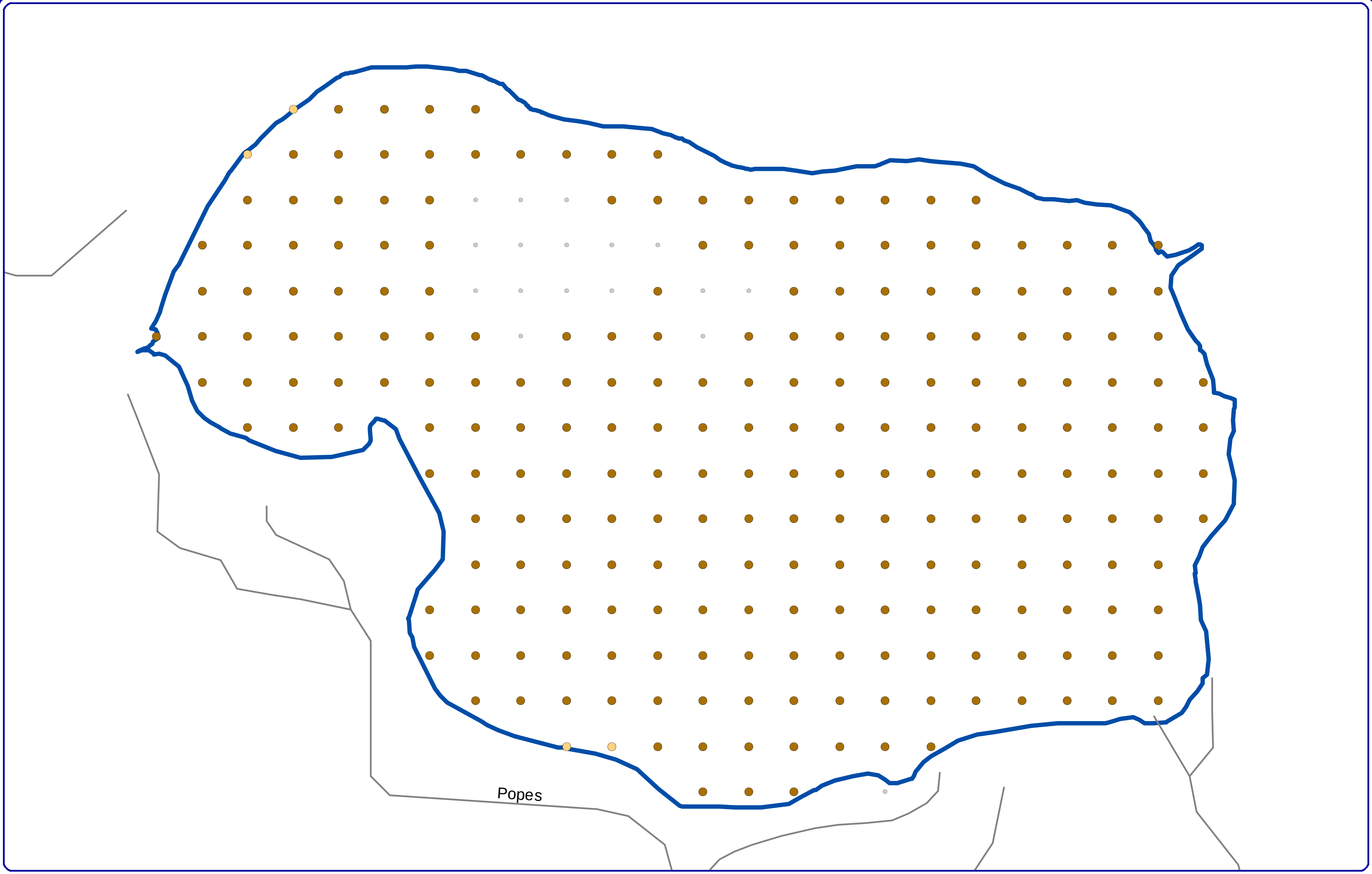
Sources:
Roads & Hydro: WDNR
Point-Intercept Locations: WDNR ISS
Map date: March 3, 2009


Extent of large map shown in red.

Legend
Substrate
- Muck
- Rock
- Sand
- Too Deep or No Data

Map 4
Middle Gresham Lake
Vilas County, Wisconsin
2008 P-I Survey: Substrate



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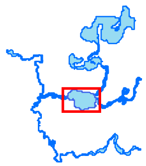
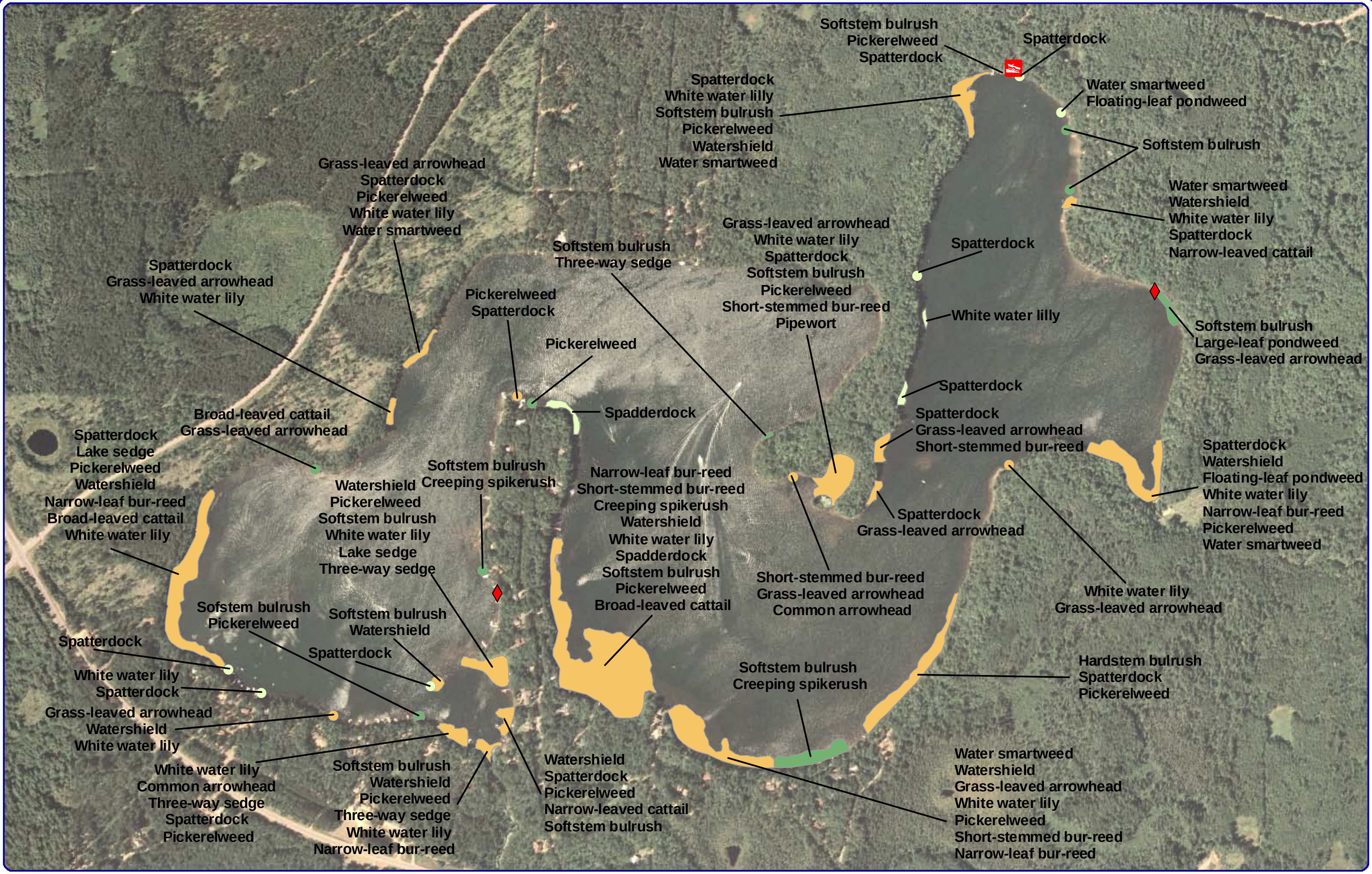
Sources:
Roads & Hydro: WDNR
Point-Intercept Locations: WDNR ISS
Map date: March 3, 2009



Extent of large map shown in red.

Legend
Substrate
- Muck
- Rock ***(not found)***
- Sand
- Too Deep or No Data

Map 5
Lower Gresham Lake
Vilas County, Wisconsin
2008 P-I Survey: Substrate



N W E S

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Feet

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Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2007
Orthophotography: NAIP, 2005
Map date: May 27, 2008

Extent of large map shown in red.

Legend

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

Exotic Plant Communities
- Giant Reed ***Note: Eurasian Water Milfoil displayed on separate map***

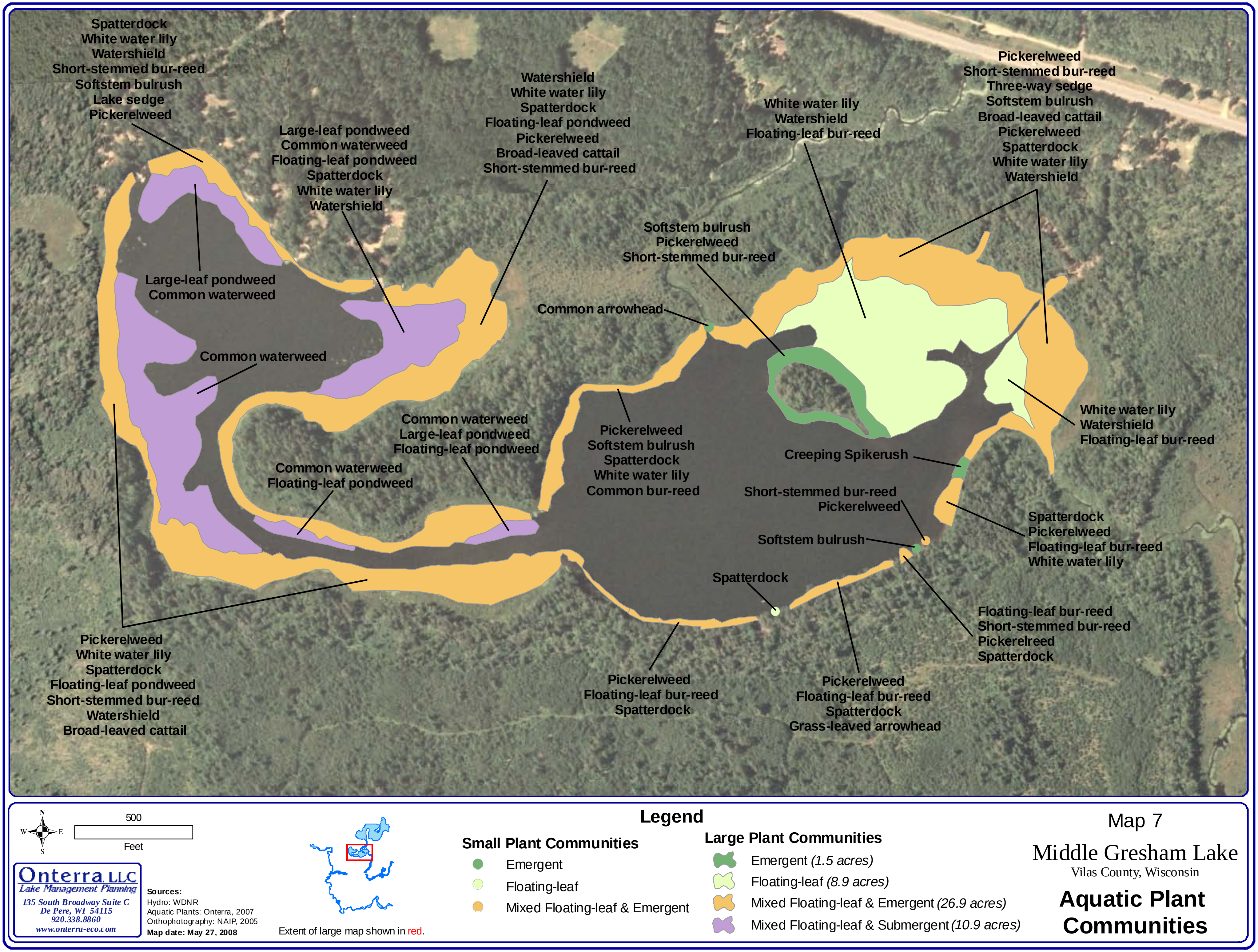
Large Plant Communities
- Emergent *(1.4 acres)*
- Floating-leaf *(0.5 acres)*
- Mixed Floating-leaf & Emergent *(21.7 acres)*

Map 6

Upper Gresham Lake

Vilas County, Wisconsin

Aquatic Plant Communities


Spatterdock
White water lily
Watershield
Short-stemmed bur-reed
Softstem bulrush
Lake sedge
Pickerelweed
Large-leaf pondweed
Common waterweed
Floating-leaf pondweed
Spatterdock
White water lily
Watershield
Watershield
White water lily
Spatterdock
Floating-leaf pondweed
Pickerelweed
Broad-leaved cattail
Short-stemmed bur-reed
White water lily
Watershield
Floating-leaf bur-reed
Pickerelweed
Short-stemmed bur-reed
Three-way sedge
Softstem bulrush
Broad-leaved cattail
Pickerelweed
Spatterdock
White water lily
Watershield
Softstem bulrush
Pickerelweed
Short-stemmed bur-reed
Large-leaf pondweed
Common waterweed
Common arrowhead
Common waterweed
White water lily
Watershield
Floating-leaf bur-reed
Common waterweed
Large-leaf pondweed
Floating-leaf pondweed
Pickerelweed
Softstem bulrush
Spatterdock
White water lily
Common bur-reed
Creeping Spikerush
Common waterweed
Floating-leaf pondweed
Short-stemmed bur-reed
Pickerelweed
Spatterdock
Pickerelweed
Floating-leaf bur-reed
White water lily
Softstem bulrush
Spatterdock
Floating-leaf bur-reed
Short-stemmed bur-reed
Pickerelreed
Spatterdock
Pickerelweed
White water lily
Spatterdock
Floating-leaf pondweed
Short-stemmed bur-reed
Watershield
Broad-leaved cattail
Pickerelweed
Floating-leaf bur-reed
Spatterdock
Pickerelweed
Floating-leaf bur-reed
Spatterdock
Grass-leaved arrowhead
N
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500
Feet
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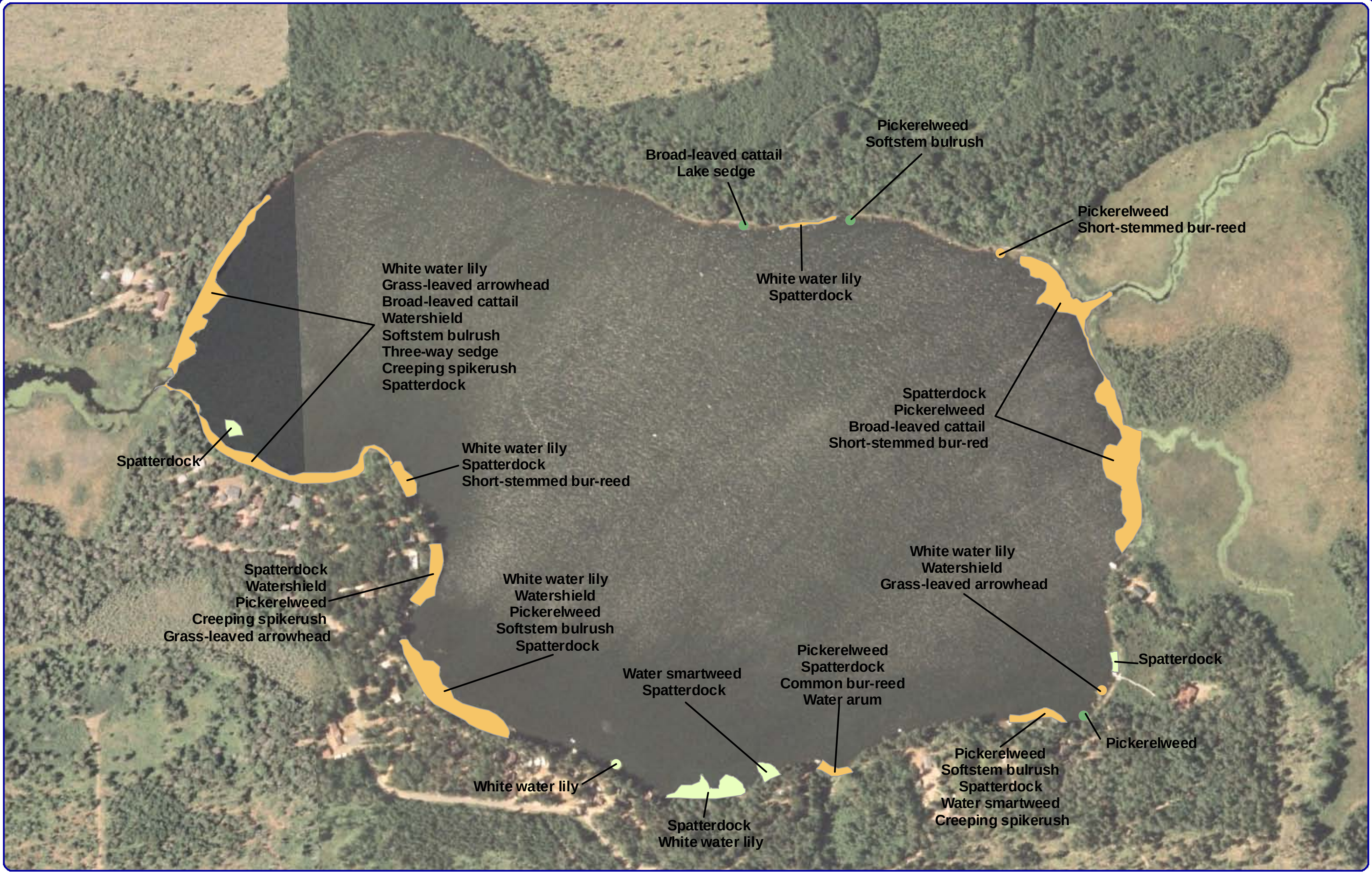
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2007
Orthophotography: NAIP, 2005
Map date: May 27, 2008
Extent of large map shown in red.
Legend
Small Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Large Plant Communities
Emergent (1.5 acres)
Floating-leaf (8.9 acres)
Mixed Floating-leaf & Emergent (26.9 acres)
Mixed Floating-leaf & Submergent (10.9 acres)
Map 7
Middle Gresham Lake
Vilas County, Wisconsin
Aquatic Plant
Communities



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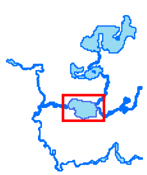
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2007
Orthophotography: NAIP, 2005
Map date: May 27, 2008



Extent of large map shown in red.

Legend

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

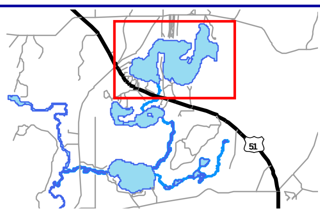
Large Plant Communities
- Emergent *(none found)*
- Floating-leaf *(0.6 acres)*
- Mixed Floating-leaf & Emergent *(5 acres)*

Map 8

Lower Gresham Lake

Vilas County, Wisconsin

Aquatic Plant Communities



Extent of large map shown in red.

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900

Feet

Onterra LLC
Lake Management Planning
135 South Broadway Suite C
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

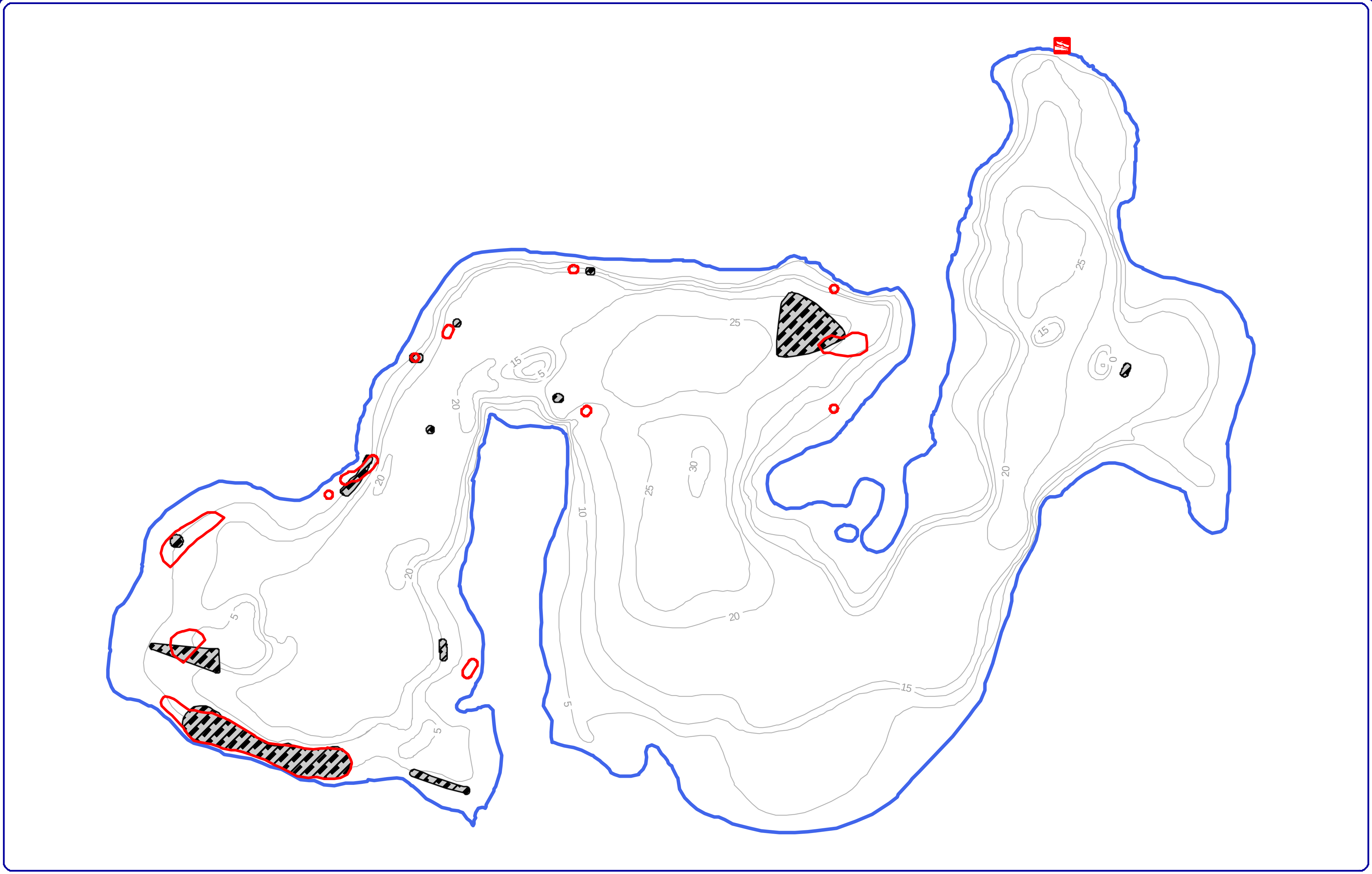
Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2007
Orthophotography: NAIP, 2005
Map date: April 9, 2007

Legend

♦ Giant Reed Location

Map 9
Upper Gresham Lake
Vilas County, Wisconsin

Giant Reed Locations - 2007



N
W E
S

800
Feet

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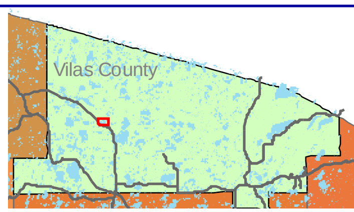
Sources:
Roads & Hydro: WDNR
Focus Areas: GLA, 2006
Treatment Areas: Onterra, 2007
Bathymetry: WDNR, Digitized by Onterra
Map date: December 3, 2007



Extent of large map shown in red.

Legend

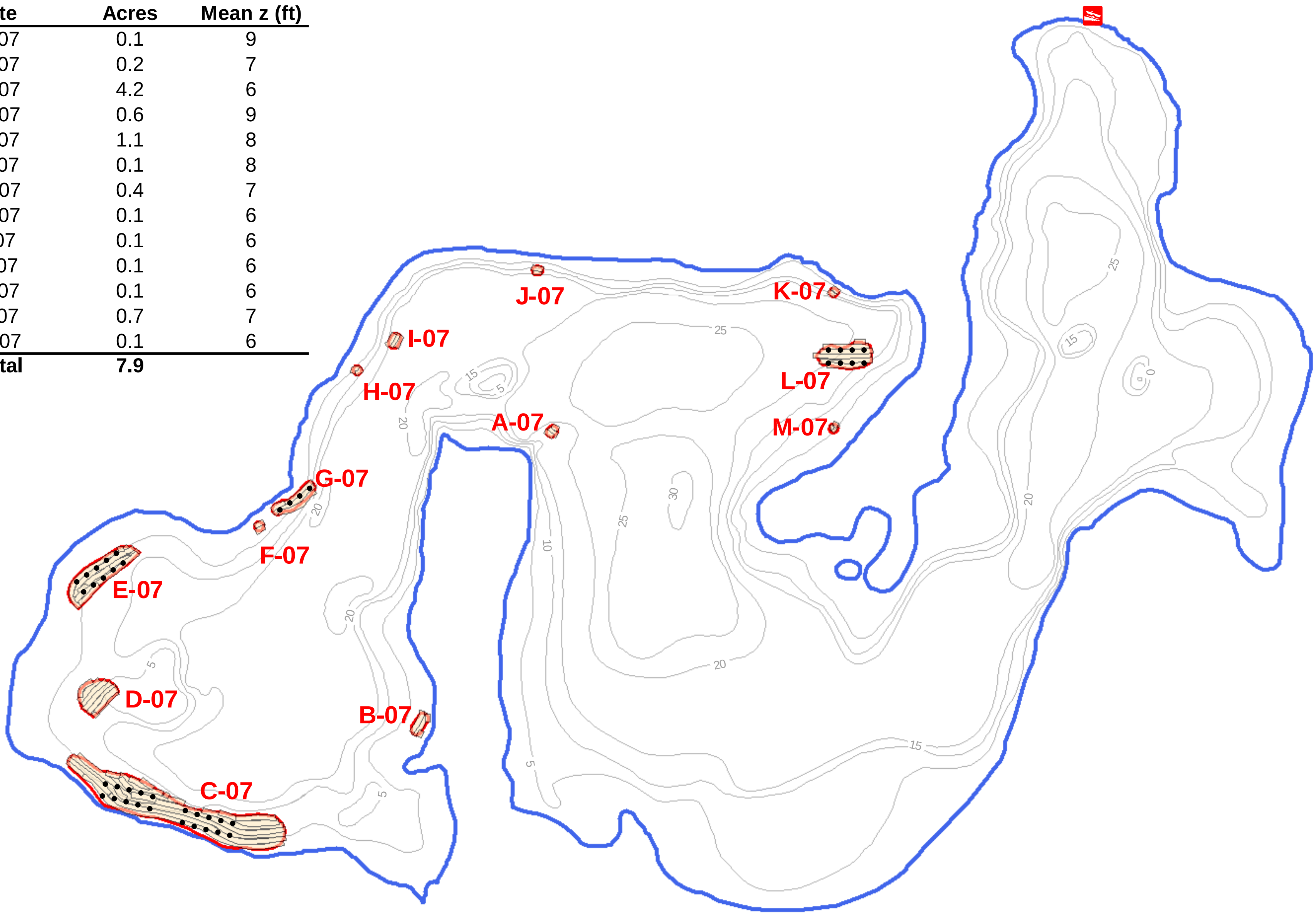
2007 Final EWM Treatment Area (7.9 Acres)

EWM Focus Area Used for Conditional Permit (8.8 acres)

Map 10
Upper Gresham Lake
Vilas County, Wisconsin

2007 EWM Focus Areas & Final Treament Locations

Site	Acres	Mean z (ft)
A-07	0.1	9
B-07	0.2	7
C-07	4.2	6
D-07	0.6	9
E-07	1.1	8
F-07	0.1	8
G-07	0.4	7
H-07	0.1	6
I-07	0.1	6
J-07	0.1	6
K-07	0.1	6
L-07	0.7	7
M-07	0.1	6
Total	**7.9**	



N
W E
S

800
Feet

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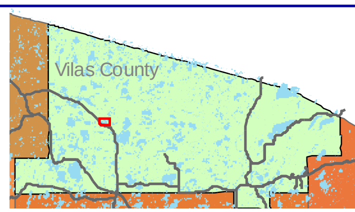
Sources:
Roads & Hydro: WDNR
Treatment Areas: Onterra, 2007
Herbicide Path: SAPC, 2007
Bathymetry: WDNR, Digitized by Onterra
Map date: December 3, 2007



Extent of large map shown in red.

Legend

- 2007 Final EWM Treatment Areas
- Point-intercept Sub-sampling Location
- Approximate Herbicide Application Path

Map 11

Upper Gresham Lake

Vilas County, Wisconsin

2007 EWM Treatment Areas & P-I Locations

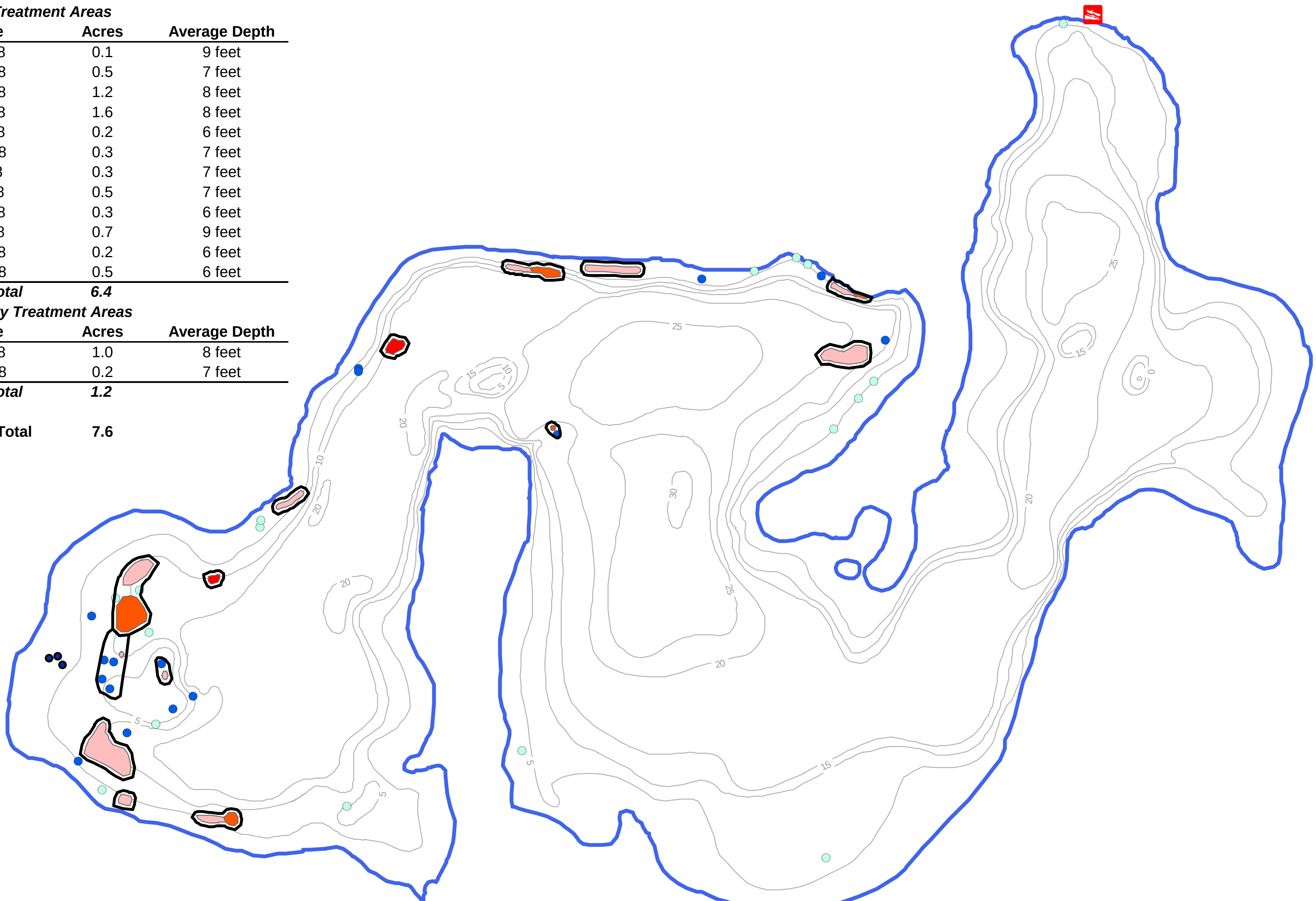
Primary Treatment Areas

Site	Acres	Average Depth
A-08	0.1	9 feet
C-08	0.5	7 feet
D-08	1.2	8 feet
E-08	1.6	8 feet
F-08	0.2	6 feet
G-08	0.3	7 feet
I-08	0.3	7 feet
J-08	0.5	7 feet
K-08	0.3	6 feet
L-08	0.7	9 feet
N-08	0.2	6 feet
O-08	0.5	6 feet
Sub Total	***6.4***	

Secondary Treatment Areas

Site	Acres	Average Depth
P-08	1.0	8 feet
Q-08	0.2	7 feet
Sub Total	***1.2***	

Grand Total	**7.6**	



N W E S

740

Feet

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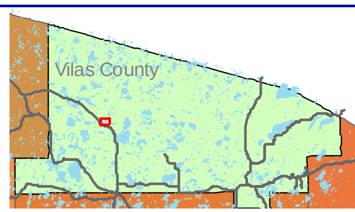
Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2007
Bathymetry: WDNR, Digitized by Onterra
Map date: December 3, 2007



Extent of large map shown in red.

Legend

2008 Preliminary Proposed Treatment Area

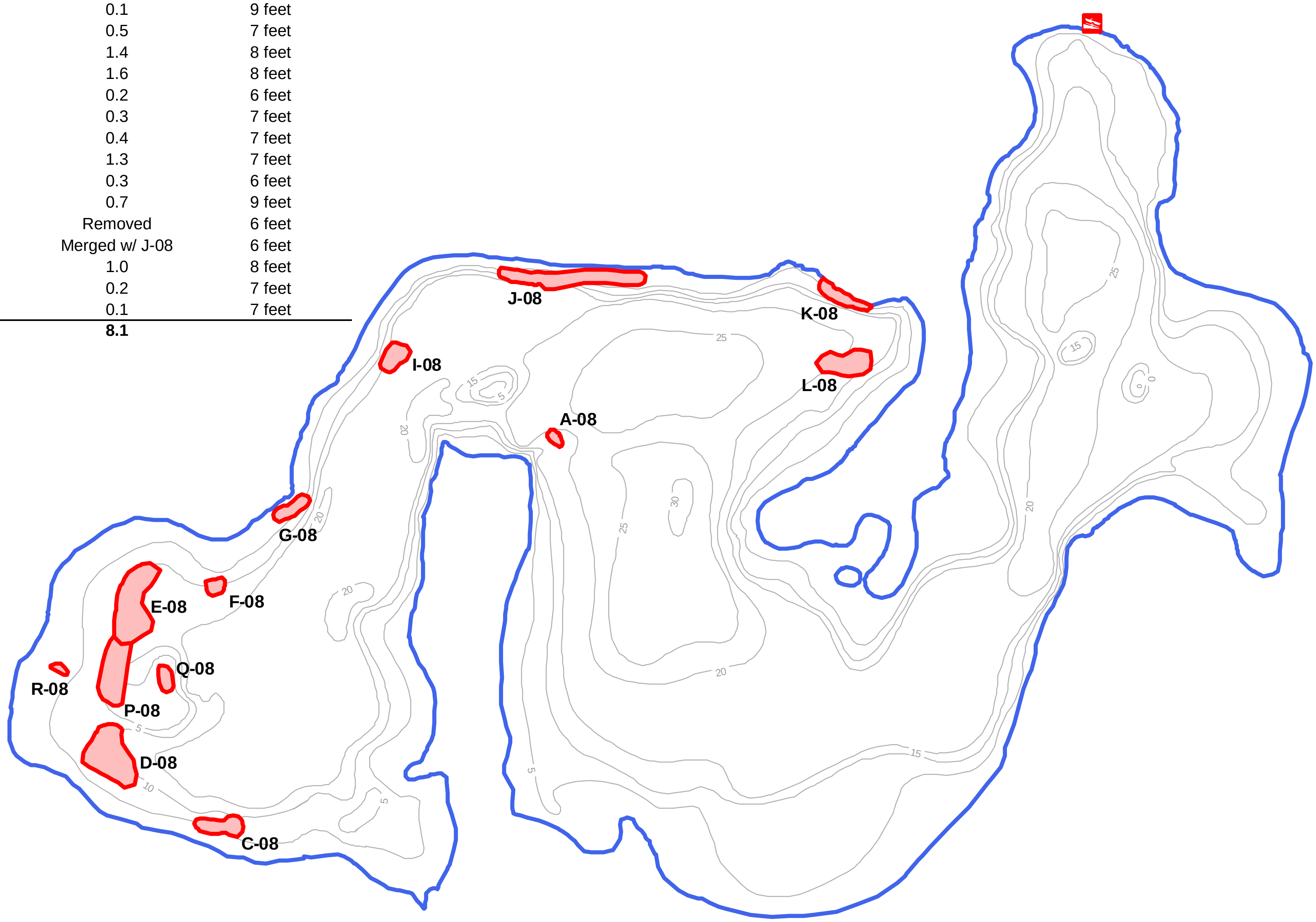
EWM Large Colony
(Mapped August 2007)
- Density = 1
- Density = 2
- Density = 3

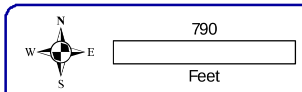
EWM Small Colony
(Mapped August 2007)
- Clumps of Plants
- Single or Few Plants

Map 12
Upper Gresham Lake
Vilas County, Wisconsin

2008 Preliminary Proposed EWM Treatment Areas v.1

Site	Preliminary Acres	Final Acres	Average Depth
A-08	0.1	0.1	9 feet
C-08	0.5	0.5	7 feet
D-08	1.2	1.4	8 feet
E-08	1.6	1.6	8 feet
F-08	0.2	0.2	6 feet
G-08	0.3	0.3	7 feet
I-08	0.3	0.4	7 feet
J-08	0.5	1.3	7 feet
K-08	0.3	0.3	6 feet
L-08	0.7	0.7	9 feet
N-08	0.2	Removed	6 feet
O-08	0.5	Merged w/ J-08	6 feet
P-08	1.0	1.0	8 feet
Q-08	0.2	0.2	7 feet
R-08	0.0	0.1	7 feet
Total	**7.6**	**8.1**	





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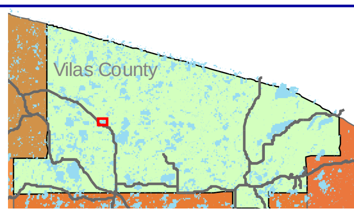
Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2007
Bathymetry: WDNR, Digitized by Onterra
Map Date: May 8, 2008



Extent of large map shown in red.

Legend

2008 Final Treatment Area (8.1 Acres)

Map 13
Upper Gresham Lake
Vilas County, Wisconsin

2008 Final EWM Treatment Areas

N
W E
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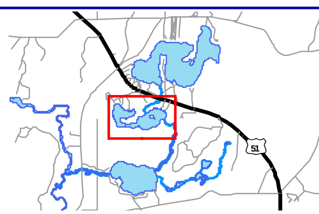
500
Feet


Extent of large map shown in red.

Legend

Eurasian Water Milfoil Locations

- Large Clump
- Single Plant

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Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2007
Orthophotography: NAIP, 2005
Map date: December 10, 2007

Map 14
Middle Gresham Lake
Vilas County, Wisconsin

Eurasian Water Milfoil Locations