Summit Lake

Langlade County, Wisconsin

Comprehensive Management Plan

December 2012

Sponsored by:

Summit Association, Inc

Wisconsin Department of Natural Resources Lake Management Planning Grant Program

LPL-1346-10 & LPL-1349-10

Onterra, LLC
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Onterra LLC
Lake Management Planning

Summit Lake

Langlade County, Wisconsin

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Created by: Tim Hoyman, Dan Cibulka & Brenton Butterfield
Onterra, LLC
De Pere, WI

Funded by: Summit Lake Association, Inc.
Wisconsin Dept. of Natural Resources
(LPL-1346-10 & LPL-1349-10)

Acknowledgements

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

Summit Lake Planning Committee

Mike Dionne	Sue Lasecki	Nancy Bruce
Jim McKinzie	Carol Van Nelson	Steve Schwid
Timothy Werra	Nancy Perlberg	Jim Stoltz

Wisconsin Dept. of Natural Resources

Jim Kreitlow
Kevin Gauthier
David Seibel

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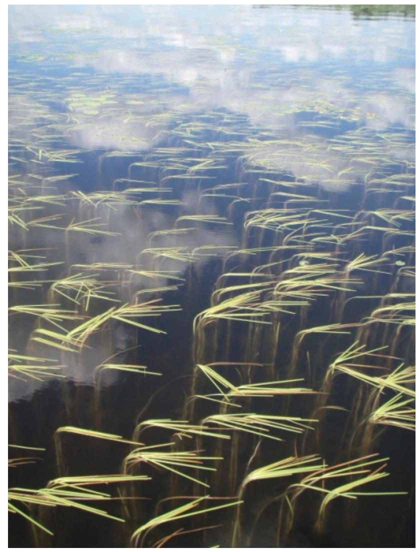
1.0 INTRODUCTION

Summit Lake, Langlade County, is a 282-acre drainage lake with a maximum depth of 26 feet and a watershed of 3,703 acres (Map 1). This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Summit Lake contains 17 native plant species, of which floating-leaf bur-reed is the most common plant. No exotic plant species are known to exist in Summit Lake.

Field Survey Notes

Heavily stained waters observed during all surveys. Rich floating-leaf and emergent plant community, including two sensitive plant species, twin-stemmed bladderwort and Oakes' pondweed. Large tracts of natural to marginally developed shoreline observed.



Photograph 1.0-1 Floating-leaf bur-reed, Summit Lake, Langlade County

Lake at a Glance - Summit Lake

Morphology	
Acreage	282
Maximum Depth (ft)	26
Mean Depth (ft)	10
Shoreline Complexity	1.7
Vegetation	
Curly-leaf Survey Date	June 11, 2010
Comprehensive Survey Date	July 21, 2010
Number of Native Species	17
Threatened/Special Concern Species	None
Exotic Plant Species	None
Simpson's Diversity	0.84
Average Conservatism	8.1
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	5.3
Sensitivity to Acid Rain	Low
Watershed to Lake Area Ratio	12:1

The Summit Lake Association (SLA) was formed in July 2008 and since its inception, the group has actively participated in the management of Summit Lake.

The SLA has worked with the Wisconsin Department of Natural Resources (WDNR) on numerous projects, including fish studies and stocking, water clarity collection as a part of the department's Citizen Lake Monitoring Network, and buoy placement over natural, but hazardous rock formations within the lake. The group also stays active in the Langlade County Waterways Association (LCWA) and the Wisconsin Association of Lakes by attending meetings, conferences, and workshops. The association works to keep its members informed about SLA activities and opportunities the members may have to participate through an association newsletter.

Efforts to search the lake for aquatic invasive species (AIS) have been in place for numerous years. The LCWA chairperson and the Langlade County AIS specialist conducted casual surveys in 2008 and 2009 in search for these species. Still, the association is motivated to prevent infestation from area lakes that contain Eurasian water milfoil and curly-leaf pondweed such as Enterprise Lake, which is less than 5 miles away and has been controlling a small Eurasian water milfoil population for several years now. This motivation led the SLA towards applying for WDNR grants to fund a comprehensive management plan on Summit Lake. The intent of this plan was to address three goals:

1) Collect baseline data to increase the general understanding of the Summit Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, if any were found.
3) Collect sociological information from Summit Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting
On July 17, 2010, a project kick-off meeting was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by SLA board members. The attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I
On July 13, 2012, Tim Hoyman met with several members of the planning committee to discuss the results of the studies that had taken place on Summit Lake. In advance of the meeting, the attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including AIS prevention, ways to better communicate through the association, and maintaining natural habitat along the shorelines and within the lake.

Planning Committee Meeting II
On August 13, 2012, Tim Hoyman met again with several members of the planning committee to discuss management goals for the SLA to pursue. Many aspects of lake management, including water quality monitoring, water quantity issues, invasive species prevention and lake association participation were discussed. The highlights of these discussions are captured within the goals the SLA decided to pursue, found within the Implementation Plan.

Management Plan Review and Adoption Process
On June 29, 2012, the SLA planning committee was provided with the results of the scientific studies that had occurred on Summit Lake as a part of this project. Their comments and review of this portion of the management plan (Section 3.0) was discussed at the first planning meeting,

with appropriate changes occurring in the following months. In October of 2012, a draft of the Implementation Plan, which stemmed from conversations had at the August 2012 planning meeting, was distributed to the planning committee for review. Their comments were incorporated within several weeks, and on November 12th, a draft management plan was provided to the WDNR for review. Onterra received the WDNR's comments on November 15th, and provided responses and changes to the draft plan on December 4th. The plan was accepted, and finalized on December 5th of 2012.

Stakeholder Survey

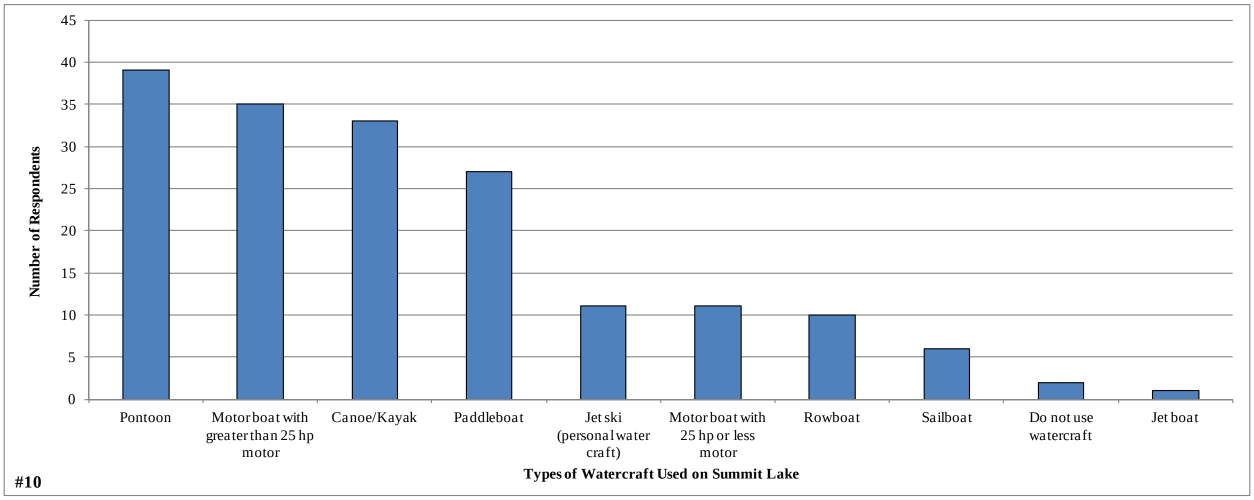
During September 2010, a seven-page, 27-question survey was mailed to 65 riparian property owners in the Summit Lake watershed. 61 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Summit Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results are summarized below and also integrated within the appropriate sections of the management plan.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Summit Lake. The majority of stakeholders (45%) are year-round residents, while 33% visit on weekends through the year and 17% live on the lake during the summer months only. 63% of stakeholders have owned their property for over 15 years, and 37% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a pontoon boat, larger motor boat, canoe/kayak, or a combination of these three vessels on Summit Lake (Question 10). Paddleboats were also a popular option. On a relatively small lake such as Summit Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 11, several of the top recreational activities on the lake involve boat use. Although boat traffic was listed as a factor potentially impacting Summit Lake in a negative manner (Question 17), it was ranked 7th on a list of stakeholder's top concerns regarding the lake (Question 18).

A concern of stakeholders noted throughout the stakeholder survey (see Question 18 and survey comments – Appendix B) was water levels within Summit Lake and the modification of the outlet channel that connects to nearby Bass Lake. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question 10: What types of watercraft do you currently use on the lake?



Question 11: Please rank up to three activities that are important reasons for owning your property on or near the lake.

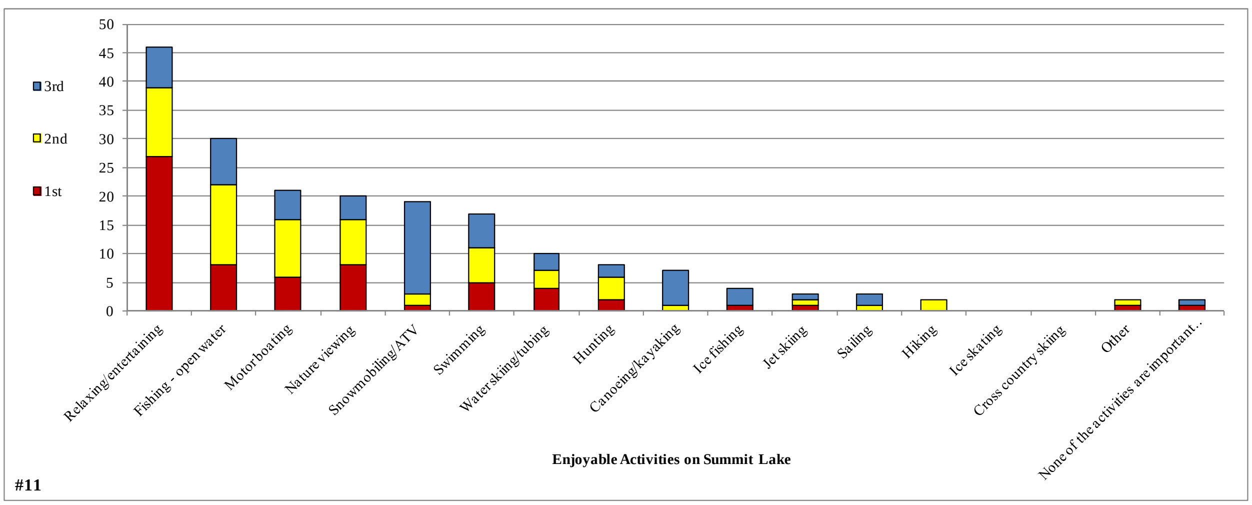
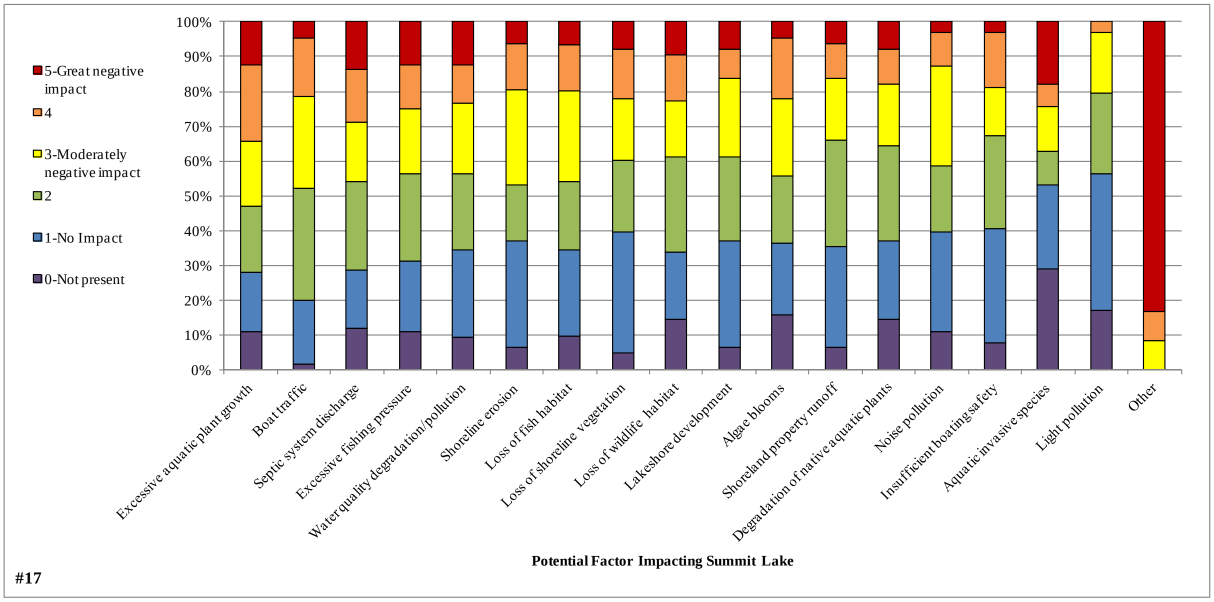


Figure 2.0-1. Select survey responses from the Summit Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 17: To what level do you believe these factors may be negatively impacting Summit Lake?



Question 18: Please rank your top three concerns regarding Summit Lake.

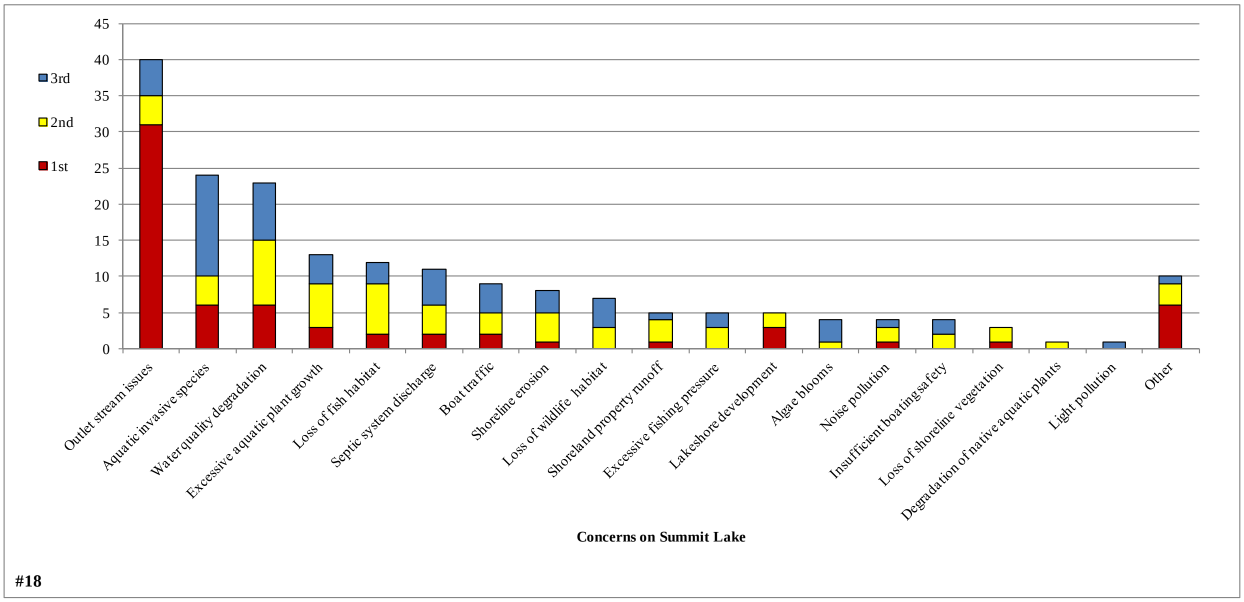


Figure 2.0-2. Select survey responses from the Summit Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, 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.

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

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

lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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.

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. Carlson (1977) presented a trophic state index that gained great acceptance among lake managers.

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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.

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

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

Non-Candidate Lakes

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

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 μg/L.

- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

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

If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

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

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

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

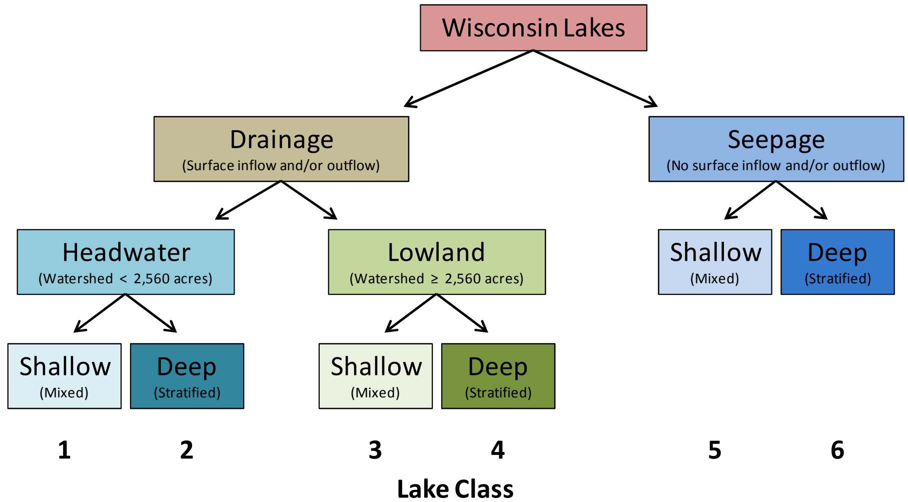


Figure 3.1-1. Wisconsin Lake Classifications. Summit Lake is classified as a deep (stratified), lowland drainage lake (Class 4). Adapted from WDNR PUB-SS-1044 2008.

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

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

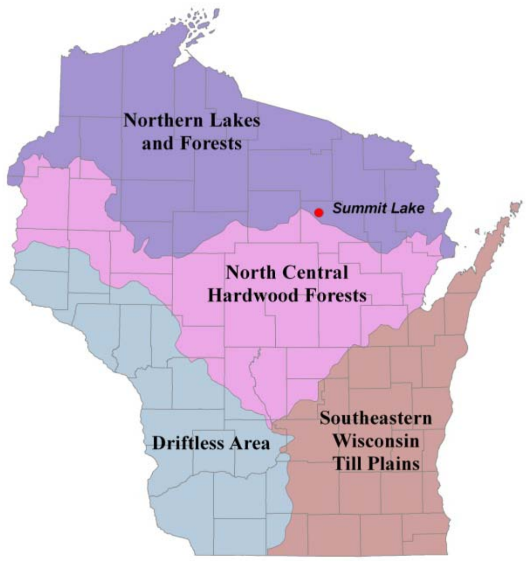


Figure 3.1-2. Location of Summit Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Summit Lake is displayed in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Summit Lake Water Quality Analysis

Summit Lake Long-term Trends

As part of the stakeholder survey associated with this project, lake residents were asked questions regarding their perspectives on the water quality of Summit Lake. Most respondents hold the water quality of Summit Lake in high regards; about 72% would describe the current water quality as good or excellent (Appendix B, Question #12). 66% of these same individuals believe the water quality has remained unchanged or improved since they obtained their property (Question #13). Perception of water quality can vary greatly between individuals, which is why scientists examine quantifiable

As seen in the figures below, historical water quality data is limited for Summit Lake. The advantage of collecting these data over many years is that trends or changes in water quality may be examined with a scientific basis, instead of relying upon anecdotal testimony solely. Phosphorus and chlorophyll-*a* data has been collected rarely on the lake, though the lake has been sampled several times in recent years (Figures 3.1-3 and 3.1-4). The weighted summer averages for both of these parameters fall below weighted averages for similar deep lowland drainage lakes. Phosphorus concentrations rank as good in the TSI classification system, while the low chlorophyll-*a* values rank as excellent.

The third primary water quality parameter analyzed in this project, Secchi disk clarity, has been monitored sparingly as well, though much monitoring has taken place in 2009 and 2010 (Figure 3.1-5). The weighted average of these values is 5.6 feet, which falls below the average of 8.5 feet for similar deep lowland drainage lakes. These averages fall into a TSI category of fair.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In a lake such as Summit Lake, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Summit Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. As discussed in the Aquatic Vegetation Section, this natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

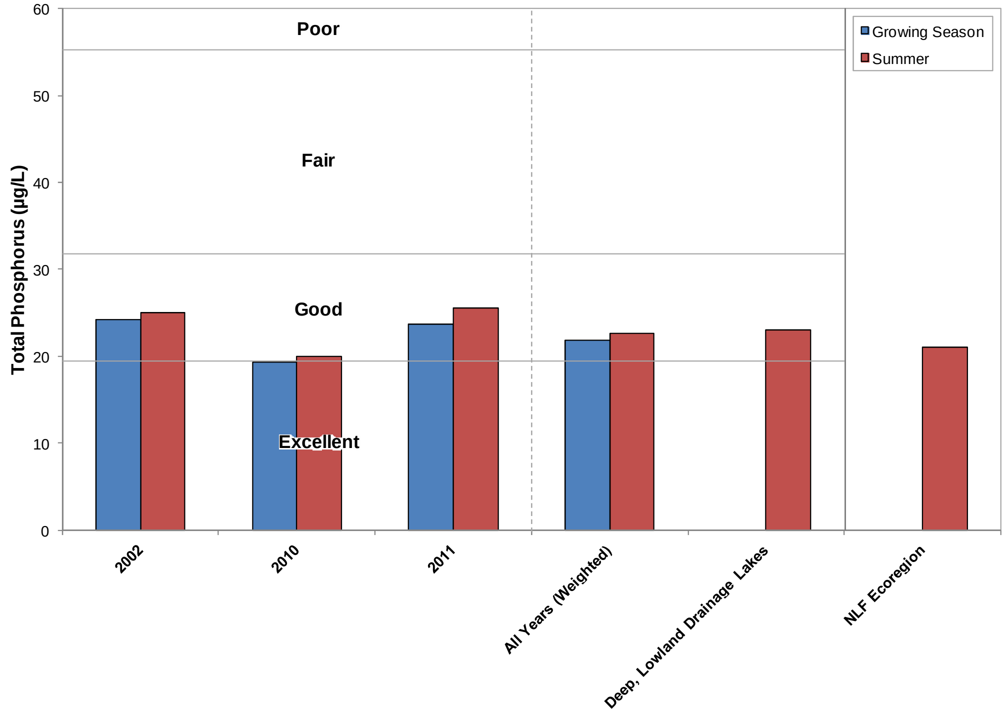


Figure 3.1-3. Summit Lake, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

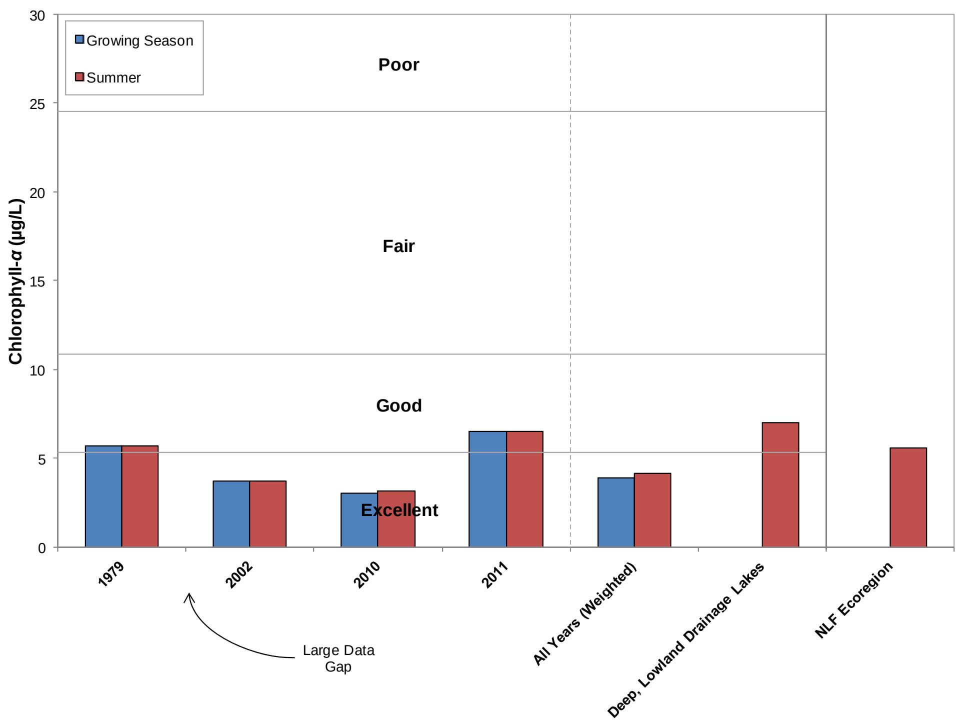


Figure 3.1-4. Summit Lake, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

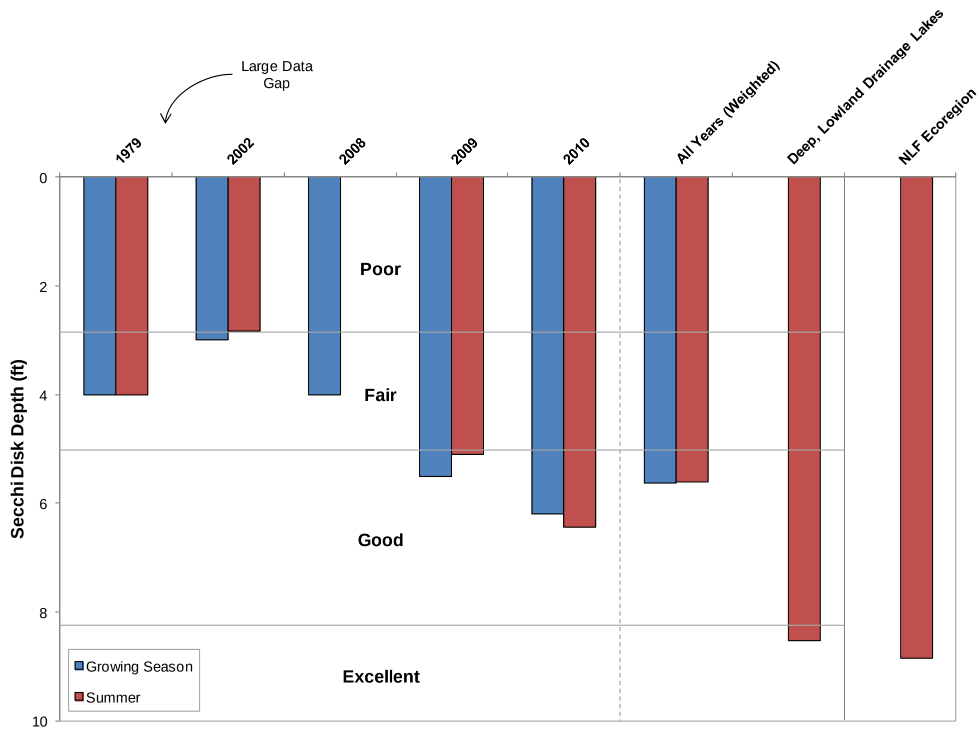


Figure 3.1-5. Summit Lake, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Summit Lake

Using midsummer nitrogen and phosphorus concentrations from Summit Lake, a nitrogen:phosphorus ratio of 27:1 was calculated. This finding indicates that Summit Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Summit Lake Trophic State

Figure 3.1-6 contains the WTSI values for Summit Lake. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from eutrophic to lower mesotrophic. 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 Summit Lake is a mesotrophic lake.

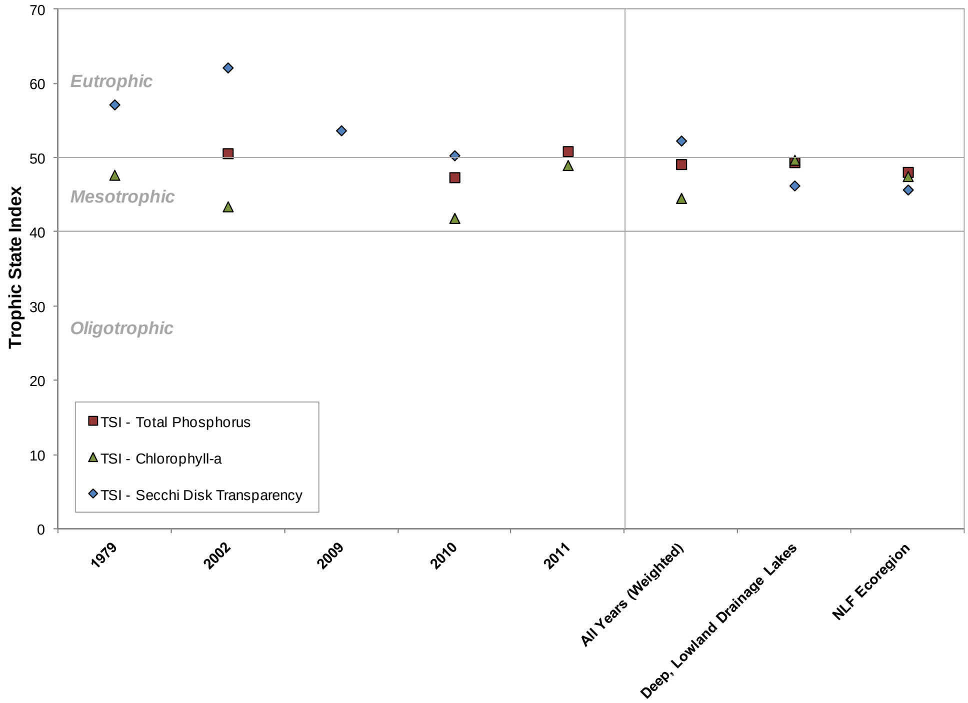


Figure 3.1-6. Summit Lake, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Summit Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Summit Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-7. In April of 2010, the lake was completely mixed, as temperature and oxygen levels were found to be consistent throughout the entire water column. During the summer months, the lake became stratified; winds kept the upper 15 feet of the water column mixed, but were not sufficient enough to mix the deepest part of the lake. During the month of June, conditions were anoxic (without oxygen) in the lower 6 feet of the water column. Summit Lake mixed completely in October, due to strong fall winds. In February of 2011, the lake was somewhat stratified as the ice prevents mixing from the wind.

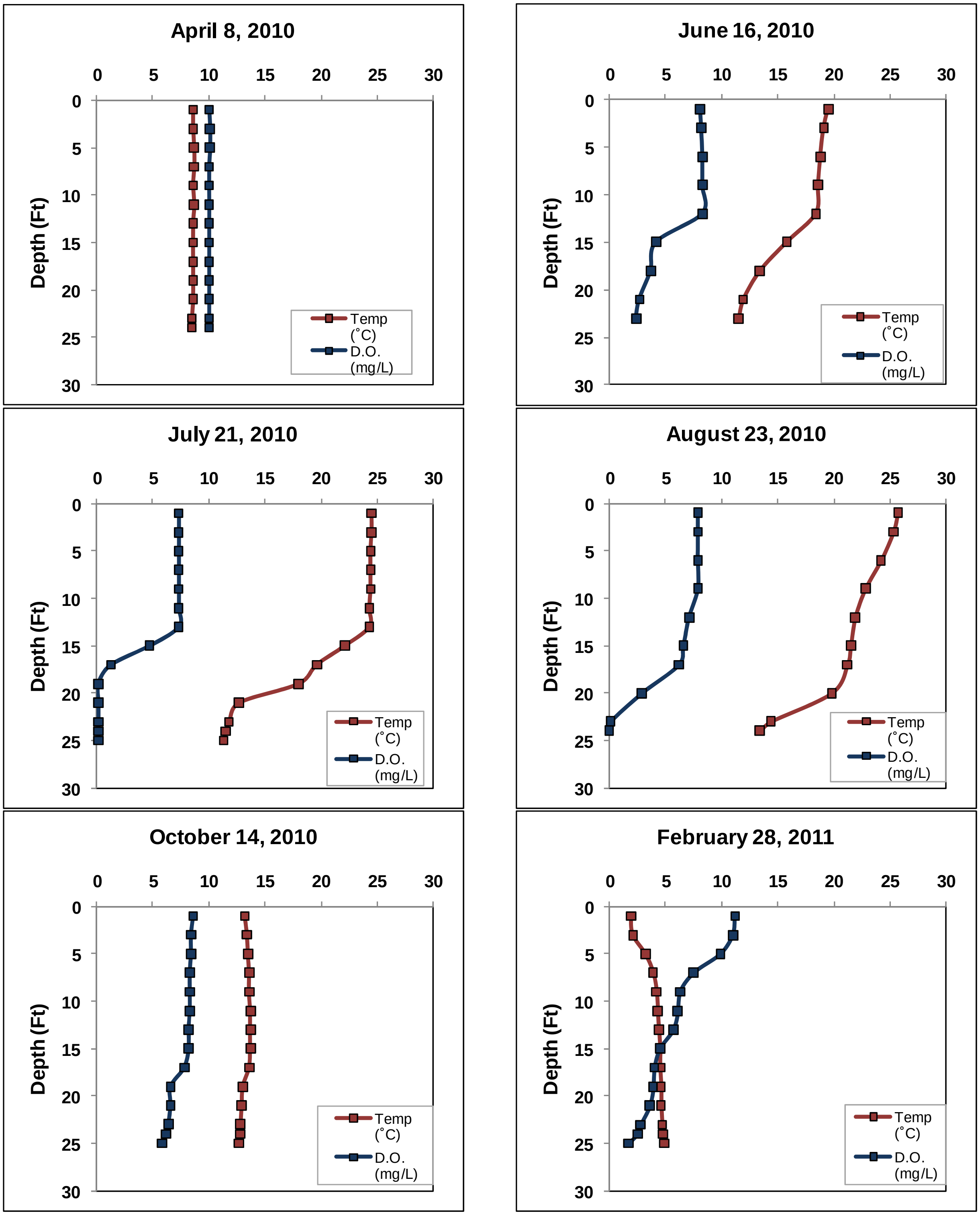


Figure 3.1-7. Summit Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Summit Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw et al. 2004). The pH of the water in Summit Lake was found to be below neutral with a value of 5.3, and falls towards the lower end, but still 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 Summit Lake was measured at 7.0 (mg/L as $CaCO_3$), indicating that the lake has little capacity to resist fluctuations in pH and has moderate 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 Summit Lake's pH of 5.3 falls slightly outside of 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 Summit Lake was found to be 1.8 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found in these samples.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Summit Lake's watershed consists of about 3,703 acres, primarily located west and northwest of Summit Lake (Map 2). The land use within this area consists primarily of wetlands (1,703 acres or 46%), forests (1,213 acres or 33%) pasture/grass (303 acres or 8%) and Summit Lake itself (282 acres or 8%). Small amounts of row crops and rural residential areas exist within the watershed as well (Figure 3.2-1). The watershed is 12 times larger than the lake itself, making for a 12:1 watershed to lake area ratio. As explained above, lakes that have a large watershed typically see more nutrient and sediment runoff from the landscape than lakes that have a smaller watershed. WiLMS calculated that, all natural conditions present, the lake will replaces its entire volume in less than a year (0.8 years).

Modeling of the land use within Summit Lake's watershed indicates that about 571 lbs of phosphorus enters the lake from these land types on an annual basis. This is moderate phosphorus load, considering Summit Lake's watershed to lake area ratio and the volume of water Summit Lake contains. The modeling indicates that 163 lbs of this load, or about 29% of the total, comes from row crops within the watershed. Wetlands and forests, the two largest land cover types within the watershed, contribute 27% (152 lbs) and 17% (97 lbs), respectively, towards this load. The Summit Lake surface collects 75 lbs of phosphorus from atmospheric deposition, and pasture/grass lands export 82 lbs of phosphorus to the lake annually. The small amount of rural residential land in the watershed provides an insignificant amount of phosphorus to Summit Lake on an annual basis (Figure 3.2-2). As previously stated, row crops cover only 5% of the watershed, yet this land use type contributes the largest percentage of the annual phosphorus load to Summit Lake (29%). Although this is a considerable amount of phosphorus stemming from a small area within the watershed, the situation is not terribly concerning for several reasons.

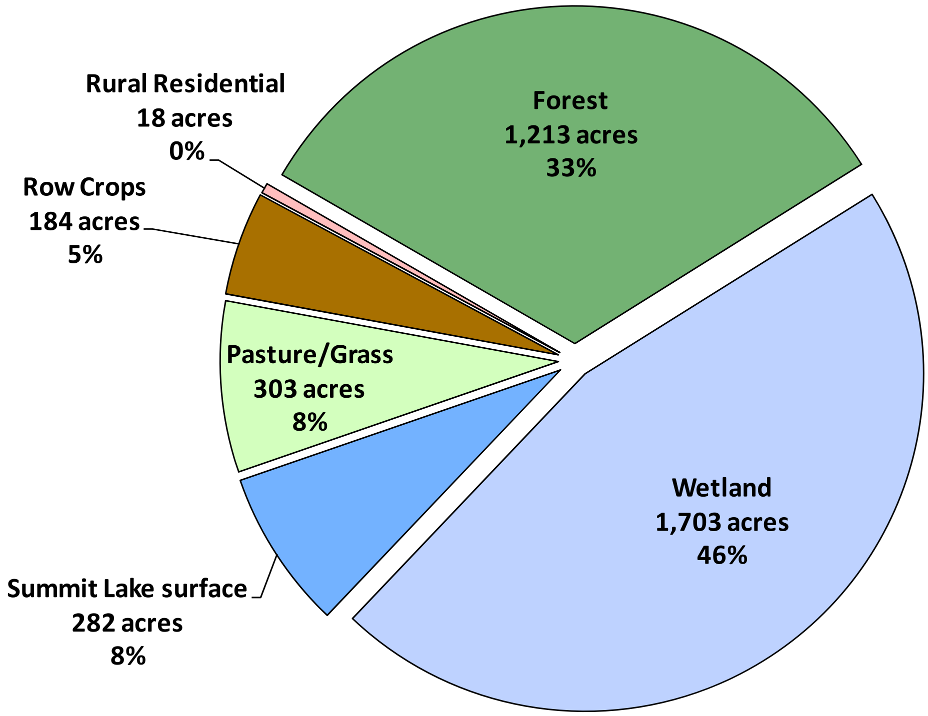


Figure 3.2-1. Summit Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

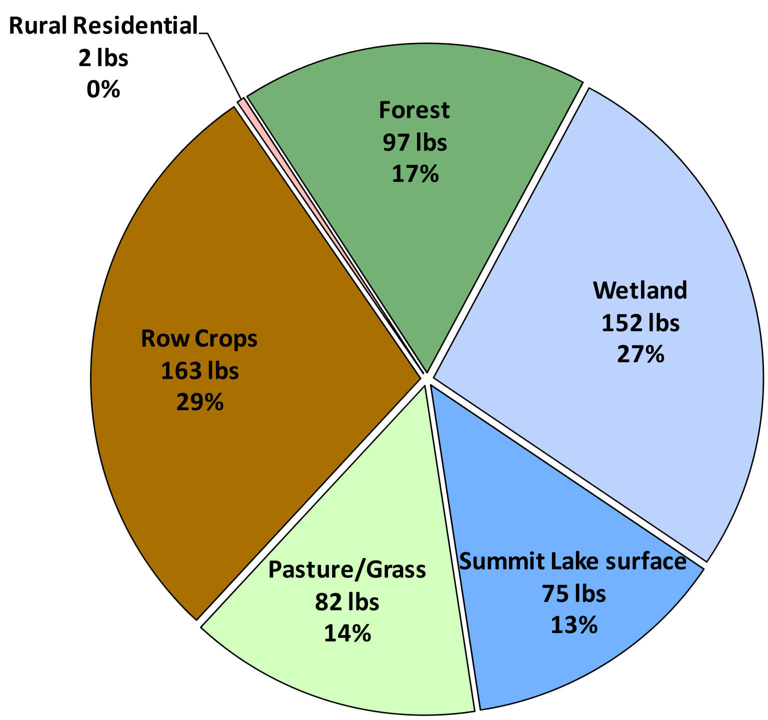


Figure 3.2-2. Summit Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

There are great expanses of wetlands situated between some of the row crop areas and Summit Lake (Map 2). Therefore, these wetlands are able to retain some of the phosphorus runoff within the biomass of the plants that reside there, thus probably reducing or slowing the rate of phosphorus export to the lake. The modeling procedures employed as a part of this project support this thought. The model estimated a higher growing season mean phosphorus value than what was observed through the water quality sampling that took place. Essentially, the model predicted there is more phosphorus in Summit Lake than was actually found to be there.

Additionally, the overall phosphorus load to the lake is not of great concern. It is actually moderate for a lake of this size. As indicated in the Water Quality Section, the water column phosphorus concentrations in Summit Lake are typical for deep, lowland drainage lake. The chlorophyll-*a* content within the water and aquatic plant biomass (discussed in the Aquatic Plant Section) is moderate as well. This indicates that the primary production within the lake is low to moderate. Primary production may be lower in this lake for two reasons. First, as discussed in the previous paragraph there is likely less phosphorus in the system than what the WiLMS model predicted. Second, the water is heavily stained by naturally occurring organic acids from nearby wetlands. This stains the water a brown color, reducing light penetration into the water column and thus limits algae and aquatic plant growth in the deeper (7+ feet) areas of the lake.

A reduction of row crop acreage within the watershed would certainly reduce phosphorus export, but by how much, and what benefit would be achieved? To answer this question, WiLMS was utilized to create a scenario in which 50% of the row crop land use (92 acres) was converted into a pasture/grass land use. Doing so only resulted in a 10% reduction of the annual phosphorus load. A reduction of this amount would have little impact on the already healthy lake ecosystem, and, additionally, the implementation of this land use conversion would be incredibly costly.

On the opposing side, if areas of pasture/grass were put into row crop production, this would have a substantial impact on the amount of nutrients entering the lake. A second scenario was tested in WiLMS, in which the amount of row crops in the watershed was doubled, the land being taken away from the pasture/grass land category. Increasing the cropland from 184 acres to 368 acres resulted in an annual increase in the total phosphorus load of 20%. This scenario is unlikely; however it stresses the fact that keeping developed lands such as cropland and urban land to a minimum is beneficial for a lake's ecology.

Shoreline Assessment

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

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

Studies conducted on nutrient runoff from Wisconsin lake shorelines have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreline development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. Ground-water inputs to the lake were found to be significant in terms of water flow and nutrient input. Nitrate plus nitrite nitrogen and total phosphorus yields to the ground-water system from a lawn catchment were three or sometimes four times greater than those from wooded catchments.

A separate USGS study was conducted on the Lauderdale Lakes in southern Wisconsin, looking at nutrient runoff from different types of developed shorelines – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites (Garn 2002). One of the important findings stemming from this study was that the amount of dissolved phosphorus coming off of regular fertilizer application lawns was twice that of lawns with non-phosphorus or no fertilizer. Dissolved phosphorus is a form in which the phosphorus molecule is not bound to a particle of any kind; in this respect, it is readily available to algae species. Therefore, these studies show us that it is developed shoreland as well as developed shoreland that is continuously maintained in an unnatural manner (receiving phosphorus rich fertilizer) that impacts lakes the greatest. This understanding led former Governor Jim Doyle passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1 2010, use of this type of fertilizer is prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

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

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

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

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

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

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

Figure 3.2-3. Shoreline assessment category descriptions.

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

Summit Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.2 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 3.2-4). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.7 miles of urbanized and developed–unnatural shoreline were observed. If restoration of the Summit Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreline lengths around the entire lake.

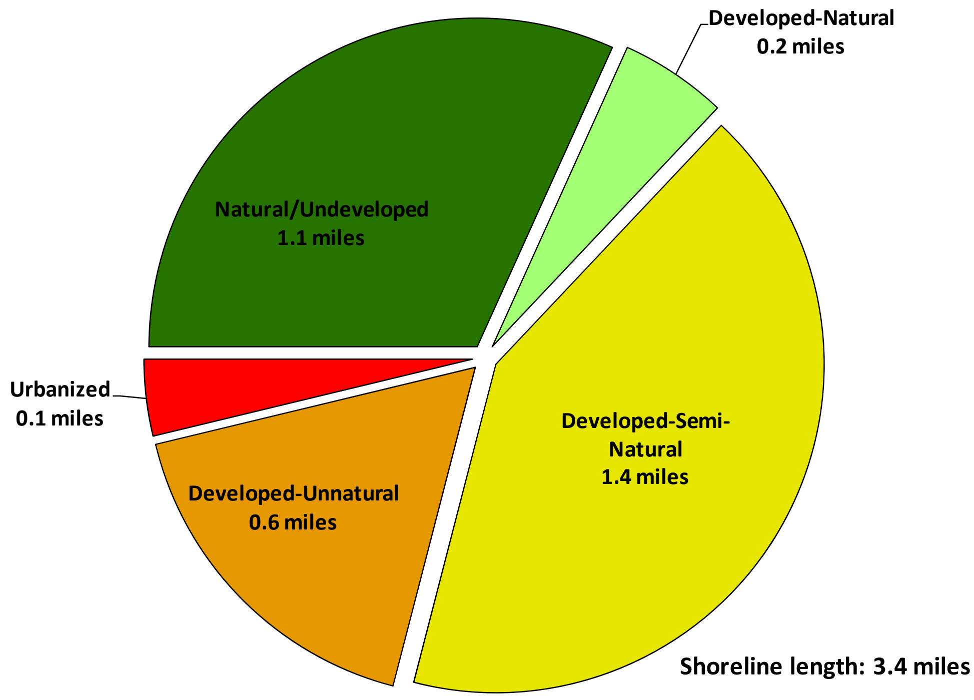


Figure 3.2-4. Summit Lake shoreland categories and total lengths. Based upon an late summer 2010 survey. Locations of these categorized shorelands can be found on Map 3.

While producing a completely natural shoreline is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Locating lawns on flat, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site.

3.3 Aquatic Plants

Introduction

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

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

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced 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

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

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*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.

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 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

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

Native Species Enhancement

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

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

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

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:

- o An upland buffer zone measuring 35’ x 100’.
- o An aquatic zone with shallow-water and deep-water areas of 10’ x 100’ each.
- o Site is assumed to need little invasive species removal prior to restoration.
- o Site has a moderate slope.
- o Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
- o Plant spacing for the aquatic zone would be 3 feet.
- o 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.
- o 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).
- o There is no hard-armor (rip-rap or seawall) that would need to be removed.
- o The property owner would maintain the site for weed control and watering.

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

Manual Removal

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

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

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

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

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

Bottom Screens

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

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 is about $120 each year.

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

Water Level Drawdown

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

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. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

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

Mechanical Harvesting

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

Costs

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

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

Chemical Treatment

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

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

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

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

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

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

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

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.

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.

Endothall (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.

Triclopyr (Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.

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 permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Imazapyr (Habitat®) Broad spectrum, system herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

Cost

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

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

Biological Controls

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

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

Cost

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

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

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

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Summit Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, 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 and Richness

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

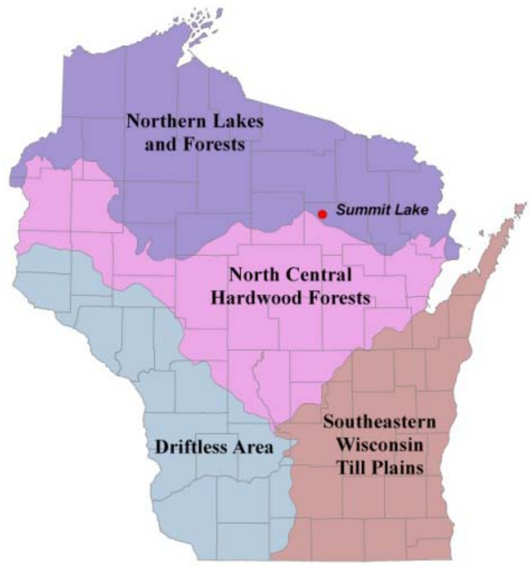


Figure 3.3-1. Location of Summit Lake within the ecoregions of Wisconsin. After Nichols 1999.

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

Simpson's diversity index is used to determine this diversity in a lake ecosystem. Simpson's diversity (1-D) is calculated as:

$$D = \sum (n/N)^2$$

where:
n = the total number of instances of a particular species
N = the total number of instances of all species and
D is a value between 0 and 1

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Summit Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

Box Plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

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

Floristic Quality Assessment

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

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

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality.

Community Mapping

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

Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-2). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

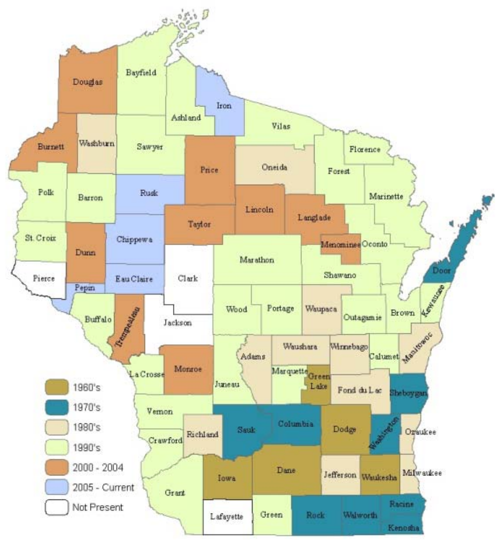


Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 part of this project. The first was conducted on June 11, 2010, with a primary focus of locating any possible occurrences of curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed, and it is believed that this aquatic invasive species either does not occur in Summit Lake or exists at an undetectable level.

The whole-lake aquatic plant point-intercept and aquatic plant community mapping surveys were conducted on Summit Lake on July 21, 2010 by Onterra. During these surveys, 17 species of aquatic plants were located in Summit Lake (Table 3.3-1), all of which are considered native species. 11 of these species were sampled during the point-intercept survey and are used in the analysis that follows.

Neither curly-leaf pondweed nor Eurasian water milfoil were located in Summit Lake. One native milfoil species, dwarf-water milfoil, was located in Summit Lake and is morphologically different from the other 6 milfoil species known to occur in Wisconsin. Rather than having larger, feather-like leaves, the leaves of dwarf-water milfoil are small and scale-like, making the plant appear as a miniature asparagus. The native northern water milfoil, often falsely identified as Eurasian water milfoil, was not located in Summit Lake, thus any other milfoil species observed growing in Summit Lake in the future other than dwarf-water milfoil should be suspect of being Eurasian water milfoil.

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

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Bolboschoenus fluviatilis*	River bulrush	5	I
	Carex utriculata	Northwest Territory sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Sagittaria latifolia	Common arrowhead	3	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Eriocaulon aquaticum*	Pipewort	9	X
	Isoetes echinospora	Spiny-spored quilwort	8	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X
	Potamogeton oakesianus	Oakes' pondweed	10	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Utricularia geminiscapa	Twin-stemmed bladderwort	9	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	I

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent;
X = Located on rake during point-intercept survey; I = Incidental Species

The majority of Summit Lake is sparsely vegetated, with approximately 24% of the 344 point-intercept sampling locations containing aquatic vegetation (Map 4). However, 66% of the 126 point-intercept sub-sampling locations that were located within the maximum depth of plant growth (littoral zone), contained aquatic vegetation. As discussed in the water quality section, the water in Summit Lake is naturally stained due to organic acids likely originating from decomposing wetland vegetation within the lake's watershed. The low water clarity limits sunlight penetration and restricts aquatic plant growth to near-shore and shallower areas within the lake. During the point-intercept survey, aquatic plants were found growing to a maximum depth of 7 feet. The majority of aquatic vegetation was located between one and two feet of water, and became less frequent with increasing water depth (Figure 3.3-3).

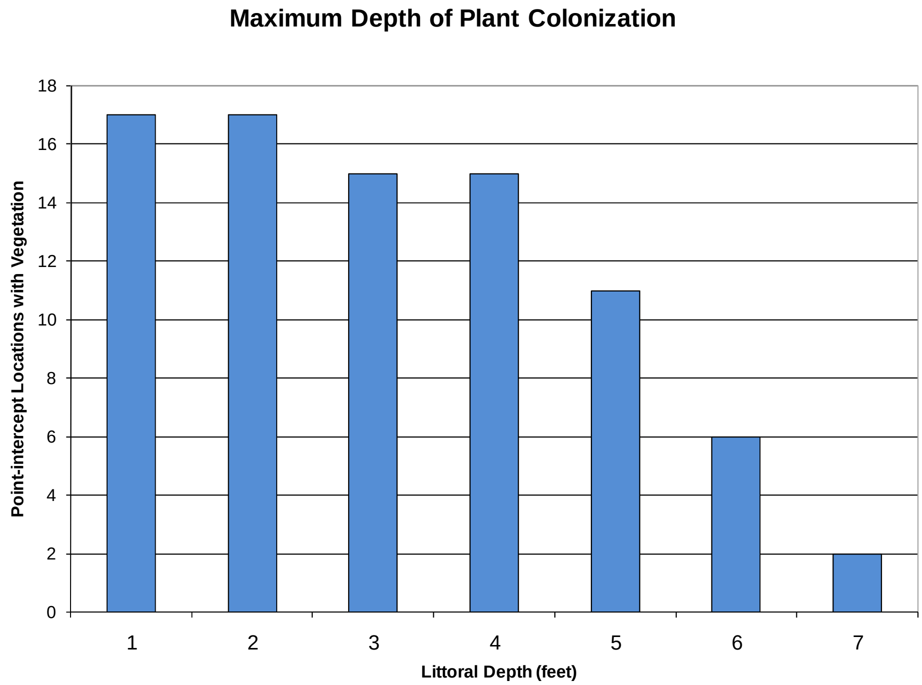


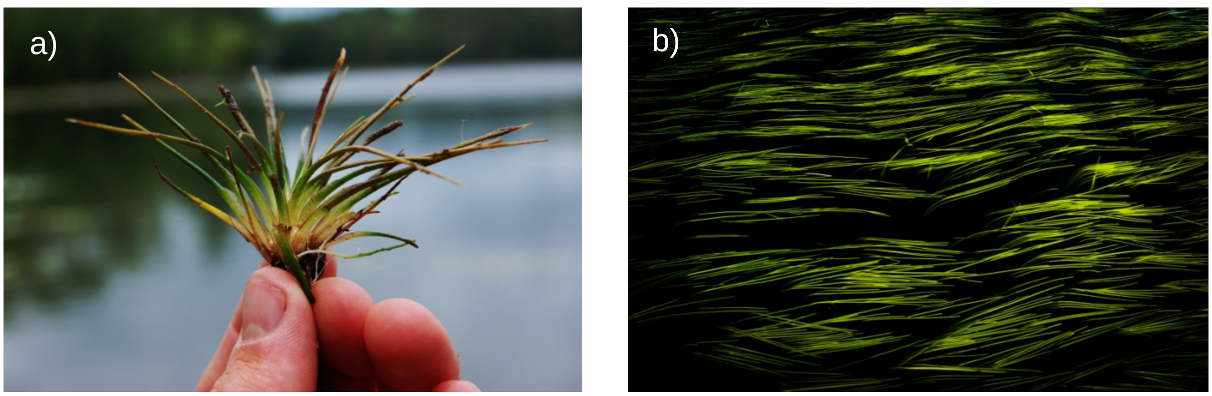
Figure 3.3-3. Summit Lake aquatic plant distribution across littoral depths. Created using data from July 2010 survey.

Summit Lake was found to have no detectable alkalinity. Alkalinity is a lake's capacity to resist fluctuations in pH by 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 will be present in a lake if the groundwater entering the lake comes into contact with minerals such as calcite and dolomite within the lake's watershed. Rainfall in northern Wisconsin is slightly acidic, with a pH of around 5.0. Consequently, lakes that have little to no alkalinity have a lower pH because they are not able to buffer against acid inputs. Unable to buffer against precipitation and organic acid inputs, Summit Lake was found to have a pH of around 5.2.

Alkalinity and associated pH greatly influence a lake's aquatic plant community in terms of species composition and diversity. The tall, robust leafy plants that most people have in mind when it comes to aquatic plants, known collectively as *elodeids*, cannot solely meet their carbon demand for photosynthesis through the dissolved carbon dioxide (CO_2) present in the water. Most of these plants require supplemental carbon from bicarbonate, which as discussed earlier, is associated with alkalinity. Thus, in lakes with little to no bicarbonate like Summit Lake, most species of elodeids are unable to grow.

However, another group of aquatic plants collectively known as *isoetids*, which are small, slow-growing, inconspicuous plants, have unique adaptations including the ability to access sediment carbon dioxide which allows them to thrive and dominate these carbon-limited systems like Summit Lake (Photo 3.3-1a). Also the growth of floating-leaf aquatic plants like water lilies, bur-reeds, and certain pondweed species, and emergent plants such as sedges and bulrushes, is not inhibited in carbon-limited lakes because they have the ability to utilize atmospheric carbon dioxide upon reaching the surface (Photo 3.3-1b).

The composition of aquatic plant species in Summit Lake is indicative of a low-alkaline, acidic lake, with the majority being comprised of isoetids, floating-leaf, and emergent aquatic plant species. The most frequently encountered species during the point-intercept survey were floating-leaf bur-reed, spatterdock, twin-stemmed bladderwort, and spiny-spored quillwort (Figure 3.3-4 and 3.3-5). Both floating-leaf bur-reed and spatterdock are floating-leaf species. Floating-leaf bur-reed was most prevalent between two and four feet of water while spatterdock was mainly located in water from one to two feet.



Photograph 3.3-1. a) Quillworts are small isoetids common to low-alkaline lakes**.**
b) Floating-leaf bur-reed is the dominant floating-leaf species located on Summit Lake**.**

Twin-stem bladderwort is a submersed species belonging to a group of carnivorous aquatic plants that possess small, sac-like ‘bladders’ used to trap and digest small zooplankton prey. Able to obtain supplemental nutrients from animals, they are often found growing in water that is lower in essential nutrients. Twin-stemmed bladderwort was listed by the Natural Heritage Inventory Program as being of ‘special concern’ in Wisconsin because of its rarity and habitat specificity. In 2011, the plant was removed from this list, but is still considered a somewhat rare species. Spiny-spored quillwort is one of two species of quillworts found in Wisconsin. It is a small, rosette-forming plant with stiff leaves that resemble porcupine quills (Photo 3.3-1a) and is often found growing in shallow, sandy areas.

Only two pondweed (*Potamogeton*) species were located on Summit Lake: Oakes’ pondweed and ribbon-leaf pondweed. Both of these species produce floating-leaves enabling them to utilize atmospheric carbon. Oakes’ pondweed is considered to be a relatively sensitive species and usually only found in near-pristine environments.

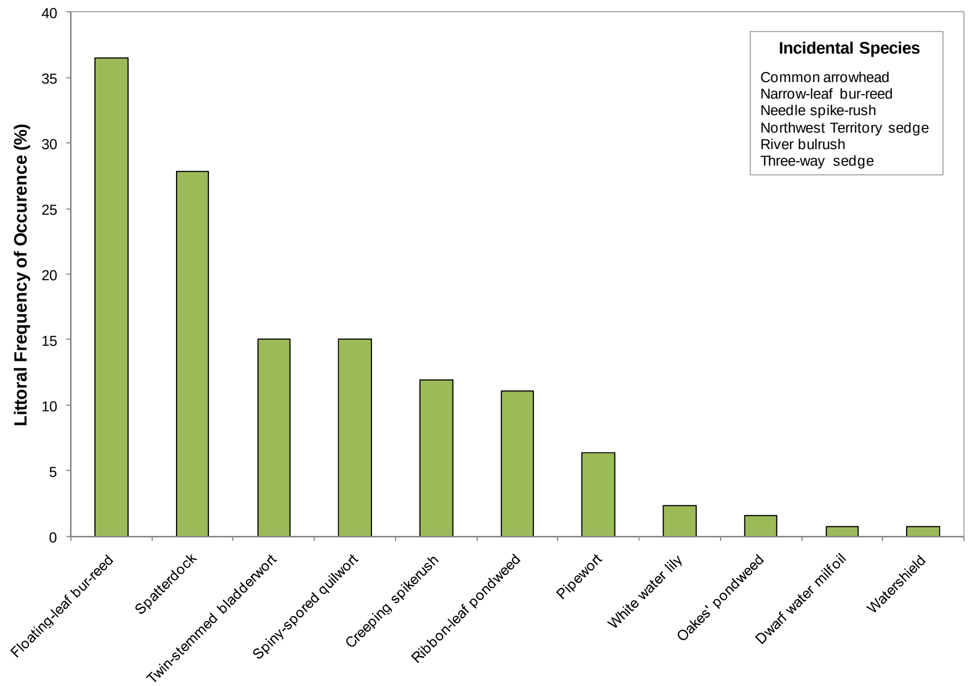


Figure 3.3-4. Summit Lake aquatic plant littoral occurrence analysis. Created using data from July 2010 point-intercept survey.

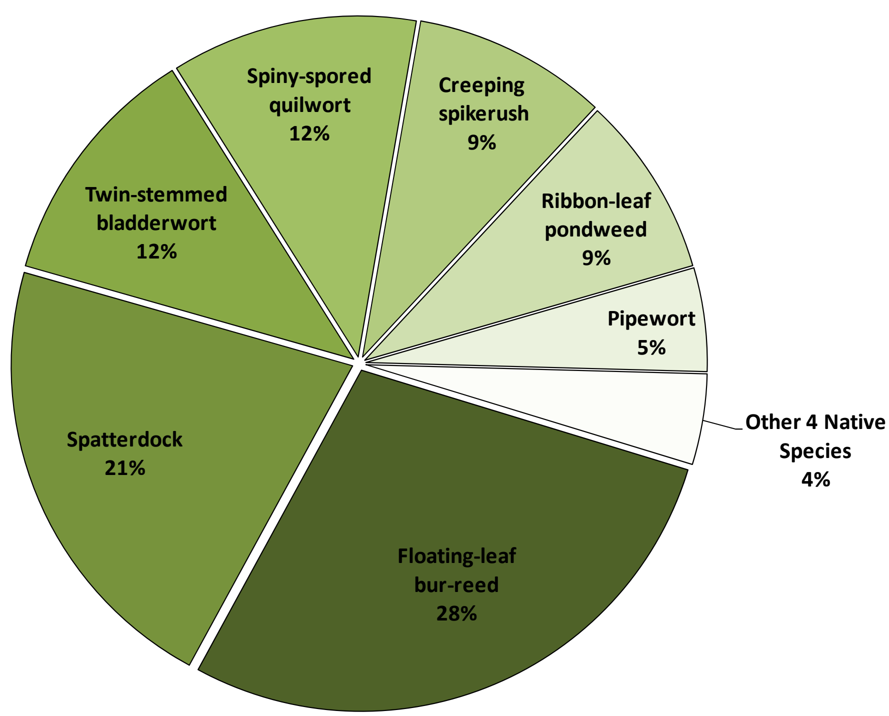


Figure 3.3-5. Summit Lake aquatic plant relative occurrence analysis. Created using data from July 2010 point-intercept survey.

The aquatic plant community in Summit Lake was found to be moderately diverse, with a Simpson's diversity value of 0.84 (Figure 3.3-6). As discussed previously, diversity is influenced by both species richness and how evenly the plant species are distributed within the community. In other words, if two individual plants were randomly sampled from Summit Lake's plant community, there would be an 84% probability that the two individuals would be of different species. Figure 3.3-5 shows that almost 50% of Summit Lake's plant community is comprised of floating-leaf bur-reed and spatterdock.

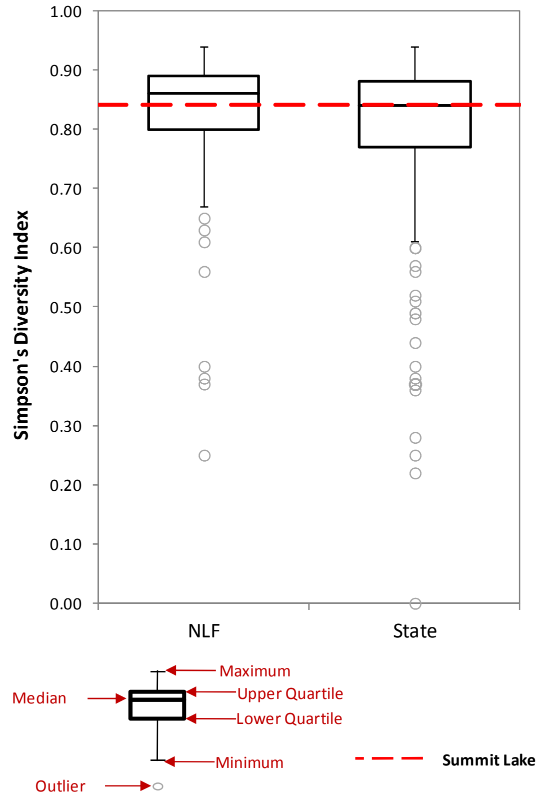


Figure 3.3-6. Summit Lake species diversity index. Created using data from July 2010 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

The number of native aquatic plant species in Summit Lake, or native species richness falls slightly below the Northern Ecoregion and Wisconsin State medians (Figure 3.3-7). Lakes with low alkalinity and pH generally to not support a high number of submersed aquatic plant species (Vestergaard and Sand-Jensen 2000). Although Summit Lake does not contain a relatively high number of native aquatic plant species, the species that are present are indicative of very high-quality conditions. Data collected from the aquatic plant surveys show that the average conservatism value (8.1) is well above the Northern Ecoregion and Wisconsin State medians (Figure 3.3-7), indicating that the majority of the plant species found in Summit Lake are considered sensitive to environmental disturbance and their presence signifies excellent environmental conditions.

Combining Summit Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a moderate value of 26.8 (equation shown below), which is slightly above the median values for the ecoregion and state (Figure 3.3-7), and further illustrating the quality of Summit Lake's plant community.

FQI = Average Coefficient of Conservatism (8.1) * √ Number of Native Species (11)
FQI = 37.1

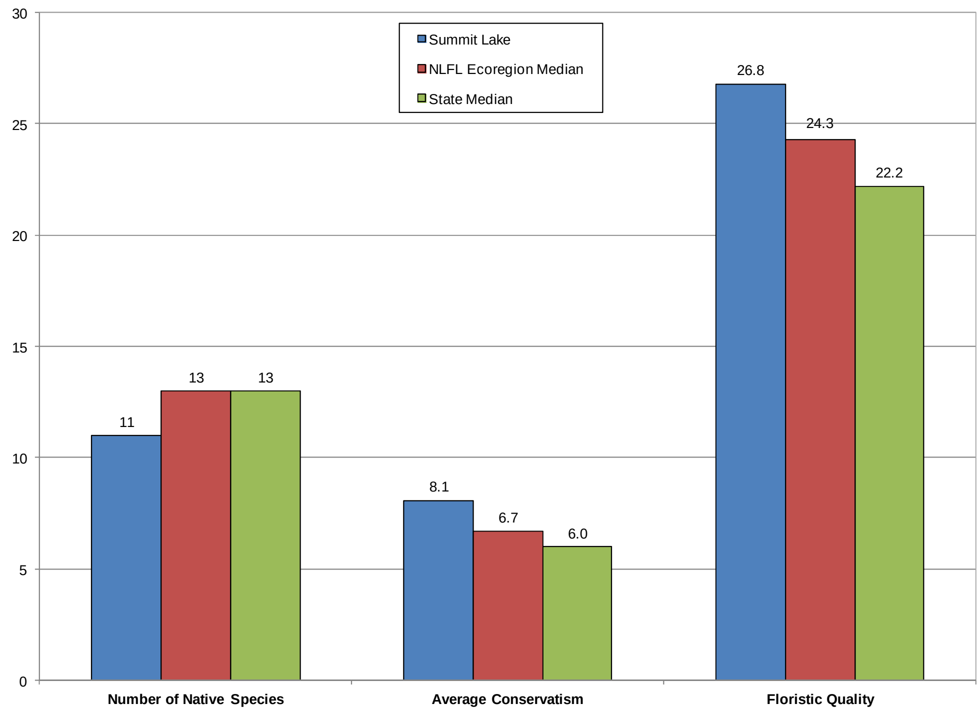


Figure 3.3-7. Summit Lake Floristic Quality Assessment. Created using data from July 2010 surveys. Analysis following Nichols (1999).

The quality of Summit Lake's plant community is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2010 community map indicates that approximately 61 acres (22%) of the 282 acre-lake contain these types of plant communities (Table 3.3-2 and Map 5). Ten floating-leaf and emergent species were located on Summit Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreline areas by dampening wave action from wind and watercraft.

Table 3.3-2. Summit Lake acres of plant community types. Created from July 2010 community mapping survey.

Plant Community	**Acres**
Emergent	.5
Floating-leaf	2.7
Mixed Floating-leaf and Emergent	57.8
Total	**61.0**

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

3.4 Summit Lake 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. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Summit Lake. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the SLA stakeholders within the stakeholder survey and other planning activities. 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 2010 & GLIFWC 2010A and 2010B).

Summit Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest ranked important or enjoyable activity on Summit Lake (Question #11). Approximately 66% of these same respondents believed that the quality of fishing on the lake was either fair or good (Question #8); and approximately 66% believe that the quality of fishing has gotten better since they began fishing the lake (Question #9).

Table 3.4-1 shows the popular game fish that are present in the system. When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its mass and composition. The gamefish in Summit Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.4-1.

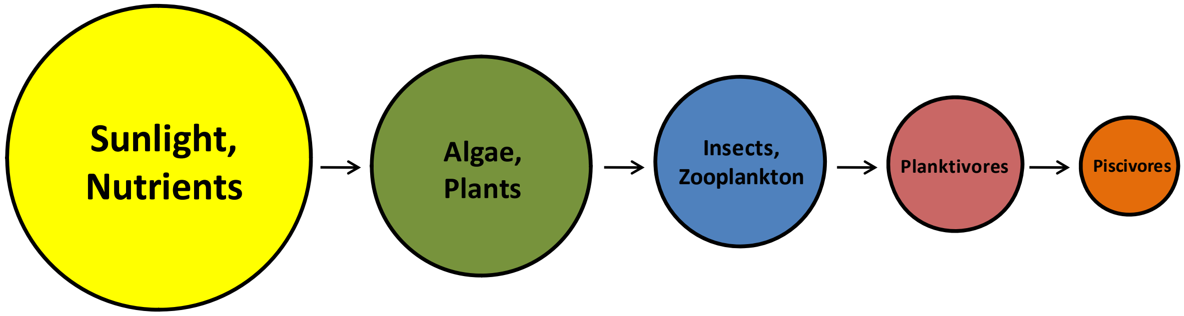


Figure 3.4-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Summit Lake is mesotrophic, meaning it has a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscivores) because the supporting food chain is relatively small.

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

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

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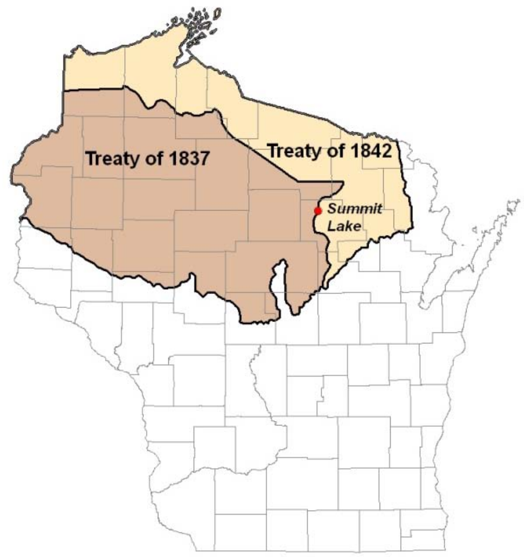

Figure 3.4-2. Location of Summit Lake within the Native American Ceded Territory (GLIFWC 2010A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

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 3.4-2). Summit Lake falls along the borderline between the Treaty of 1837 and the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an "allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The allowable catch number is then reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent, or declaration. This result is called the quota, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal quota and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2010B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly quota is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the quota is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Although Summit Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.

Because Summit Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Summit Lake. In 2011, no special regulations were initiated, so state-wide bag and minimum length limits remained in place for the lake, meaning five walleye can be taken with no length limit on a daily basis. For bass species, after the beginning of the season, the minimum length limit is 14” and a daily bag limit is limited to five fish. Summit Lake is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 34” to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and only 5 pike may be kept in a single day. Statewide regulations apply for all other fish species.

Summit Lake Fish Stocking

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

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

Year	Species	Age Class	# Stocked	Avg. Length (inches)
1972	Muskellunge	Fingerling	1,500	3
1979	Muskellunge	Fingerling	1,400	4
1982	Muskellunge	Fingerling	564	9
1985	Muskellunge	Fingerling	564	9
1988	Muskellunge	Fingerling	564	10.5
1990	Muskellunge	Fingerling	564	12
1992	Muskellunge	Fingerling	384	9.7
1995	Muskellunge	Fingerling	300	11.3
1996	Muskellunge	Fingerling	1,128	10.5
1998	Muskellunge	Large Fingerling	564	12
2000	Muskellunge	Large Fingerling	564	10.3
2002	Muskellunge	Large Fingerling	141	10.7
2004	Muskellunge	Large Fingerling	143	8.7
2006	Muskellunge	Large Fingerling	141	10.45
2008	Muskellunge	Large Fingerling	141	10.4
2010	Muskellunge	Large Fingerling	86	12.85
1998	Walleye	Small Fingerling	15,600	2.3
2005	Walleye	Small Fingerling	14,100	1.5
2006	Walleye	Small Fingerling	9,870	1.4
2007	Walleye	Large Fingerling	1,208	6.4
2008	Walleye	Large Fingerling	2,872	6.7
2009	Walleye	Large Fingerling	2,358	7.6

The extent of muskellunge natural reproduction is somewhat unknown in the lake, and natural reproduction of walleye is a goal the WDNR is seeking. To assist population numbers and hopefully establish a reproducing population, the lake is currently stocked every other year by the WDNR. In years that walleye are not stocked by the WDNR, the Summit Lake Association funds stocking. The WDNR routinely operates surveys aimed at assessing young walleye survival and muskellunge numbers.

The lake itself is currently managed for walleye and muskellunge. Dave Seibel, WDNR fisheries biologist, indicates that the lake has a good density muskellunge population. Largemouth bass are rare in the lake, and smallmouth bass not found at all during 2002, 2009 and 2010 surveys. The lake does host a sizable population of yellow perch. Other common panfish include bluegill, crappie and pumpkinseed sunfish.

Summit Lake Substrate Type

According to the point-intercept survey conducted by Onterra, 84% of the substrate sampled in the littoral zone on Summit Lake was sand, with 12% classified as muck and 4% classified as rock (Map 6). 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 (Becker 1983). 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 the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Summit Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, if any were found.
3) Collect sociological information from Summit Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

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

The studies that were completed on lake indicate that it is healthy in terms of its watershed and water quality. As described within the text of this document, Summit Lake is a unique ecosystem, with naturally stained water different water chemistry than most northern Wisconsin lakes. These factors strongly influence the type of organisms (fish, plants, etc.) the lake holds, as well as how much habitat is available to them.

Within the water quality section, an analysis on the available (historic and current) water quality is presented. It is unfortunate that more data is not available for Summit Lake, as few conclusions can be drawn from the limited dataset that exists. However, the data that has been collected points to the fact that Summit Lakes water quality is in good condition, ranking similarly to other regional lakes as well as those deep, lowland drainage lakes within the state. Of course, the water in Summit Lake is not as clear as other similar lakes regionally and statewide; however, this is due to the large amount of organic acids that accumulate in nearby wetlands and are eventually flushed into the lake. Wetlands make up nearly half (46% of the lake's watershed. As discussed within the Aquatic Plant Section, this limits the amount of light that penetrates the water column, and thus reduces the depth at which aquatic plants may grow.

Because of the different water clarity and chemistry, the aquatic plant species that are found within Summit Lake differ from those found in other area lakes. Most of the species found here are adapted to living in low-alkaline, acidic conditions. These species include isoetid (small turf-like plants) floating-leaf and emergent species. Not surprisingly, these species are all well suited for living in water with low light penetration as well. Two of these species, twin-stemmed bladderwort and Oakes' pondweed, are considered to be relatively sensitive species found only in near-pristine conditions.

There were a few concerns expressed within the stakeholder survey that was distributed to lake residents during September 2010. The issue of excessive aquatic plant growth ranked highly amongst lake stakeholders as something that may be negatively impacting the lake. Many comments received on the survey refer to the aquatic plant growth (floating-leaf burred) along the northern and western shorelines of the lake. Comments of low water levels were received also. It is likely that a reduction in the water levels has allowed growth of floating-leaf burred to extend further lakeward. However, it must be remembered that as aquatic plants only grow to six or seven feet in Summit Lake. Therefore, this type of habitat is limited to a relatively narrow ring around the Summit Lake shoreline. While these plants may be somewhat of a burden to recreation, they function as habitat for a variety of aquatic species. Because of the low water clarity in Summit Lake, it is not expected that the floating-leaf burred will advance into the lake, unless water levels decrease further. A mapping survey conducted in 2010 accurately mapped the extents of these communities, so a similar survey conducted in the future may be utilized to determine if any changes in the distribution of the community has occurred.

Overall, the studies conducted on Summit Lake indicate this ecosystem is healthy, diverse, and enjoyed much by its human stakeholders. The SLA's responsibility now is to preserve this ecosystem and maintain its high quality. This is often not a straightforward task; often, it is easier for a lake group to gain volunteers and rally behind a known problem or issue than to rally behind maintaining the lake, which is considerably less "exciting" of a challenge. However, sharing knowledge of the ecosystem and the dangers which face it, as well as having a plan to recruit and maintain volunteers, is a good start in the goal of preserving Summit Lake. The Implementation Plan that follows identifies goals and actions the SLA identified as crucial to addressing stakeholder concerns, maintaining the quality of Summit Lake, and enhancing its positive features for future generations.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Summit Lake Association, Inc. Planning Committee and ecologist/planners from Onterra. It represents the path the Summit Lake Association, Inc. 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 Summit Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under continuing 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 Summit Lake Association have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizen Lake Monitoring Program. Currently, Michael Sheehy is trained to collect Secchi clarity data as well as water chemistry samples. Stability will be added to the program by selecting an individual from the Summit Lake Association to coordinate the lake's volunteer efforts and to recruit additional volunteers to keep the program fresh. In coordination with Goal 2, it may be beneficial to include defined partners (such as students and teachers from local school district) on water quality monitoring trips to share the SLA volunteer's knowledge of lake ecology and better establish these partnerships.

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 Goal 2: Facilitate Relationships with Defined Partners

Management Action: Enhance SLA's involvement with other entities that have a hand in managing (management units) Summit Lake.

Timeframe: Begin summer 2013

Facilitator: Board of Directors to appoint SLA representatives

Description: The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. It is important that the SLA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities reduce the duplication of efforts. While not an inclusive list, the pertinent parties for Summit Lake are the WDNR (fisheries, AIS and lake management personnel), local school districts, the Langlade County Lakes Association (LCLA), Wisconsin Lakes, and Langlade County staff. Each entity is specifically addressed below:

Partner	Contact Person	Role	Contact Frequency	Contact Basis
WDNR	Fisheries Biologist (Dave Seibel – 715.623.4190)	Manages the fishery of Summit Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lumberjack AIS Coordinator (John Pruess – 715.369.9895)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Mr. Pruess.
	Lakes Coordinator (Jim Krietlow – 715.365.8947)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Contact would be necessary to update a lake management plan (every 5 years) or to seek advice on other lake issues.
Elcho School District	Administrative staff - (715.275.3225 - general number)	Educational opportunities for school, volunteer base for SLA.	As needed.	Teachers/students may be interested in partnering with SLA in educational projects such as CLMN or CBCW.
Langlade County Waterways Association (LCLA)	Contact representative (Chuck Sleeter – 715.275.4513)	Oversees Langlade Co. waters through facilitating discussion and education.	Twice a year or as needed.	Contact LCLA to become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Langlade waterways.
Local Lake Association	Greater Bass Lake – Roger Sell (roger.sue.sell@gmail.com)	Nearby waterbodies	Once a year or as needed.	May contact to discuss lake management activities.
Ladies of the Lake	Sue Bennett	Assist in lake stewardship	As needed.	May be contacted when volunteer services are needed.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters pertaining to WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	SLA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Action Steps:

Please see table guidelines above.

Management Goal 3: Increase Communication and Volunteer Stability Within the Summit Lake Association

Management Action: Support an Education Committee to promote safe boating, water quality, public safety, and quality of life on Summit Lake.

Timeframe: Begin summer 2013

Facilitator: Board of Directors to form Education Committee

Description: Education represents an effective tool to address issues that impact water quality such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. An Education Committee will be created to promote lake protection through a variety of educational efforts.

Currently, the SLA distributes newsletters to association members on a somewhat irregular basis. Communication is important within a management group because it builds a sense of community while facilitating the spread of important association news, educational topics, and even social happenings. It also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among association members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the association newsletter may contain monitoring results, association management history, as well as other educational topics listed below. The Board of Directors will approve a set allowance that the Education Committee will have to work with, in addition to investigating whether a WDNR grant would be possible to fund this initiative. Other sources of assistance include AIS Coordinator John Preuss for contributing articles, and Wisconsin Lakes representatives who may be able to assist with articles or suggestions and tips on how to develop a "formal" newsletter.

In addition to creating regularly published association newsletter a variety of educational efforts will be initiated by the Education Committee. These may include educational materials, awareness events and demonstrations for lake users as well as activities which solicit local and state government support.

Example Educational Topics:

- AIS monitoring updates
- AIS awareness (at public landing and info to Ross Cottages)
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreland restoration and protection
- Septic system maintenance

- Fishing Rules
- Specific topics brought forth in other management actions

Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. The SLA Board will identify a base level of annual financial support for educational activities to be undertaken by the Education Committee.

Management Action: Create a Succession Plan for the SLA.

Timeframe: Begin summer 2013

Facilitator: Board of Directors

Description: A lake group is only as active and effective as the volunteers who steer its direction, project its vision, and ensure its growth. Lake groups may become ineffective when communication is compromised or when volunteerism fades. The SLA will work diligently to ensure the association can maintain or improve upon its association membership and engagement.

Currently, there are several engaging annual activities the SLA has in place, such as the raffle at the annual meeting, a chili dinner, Christmas cookie exchange, boat parade, and lake picnic. These events bring lake property owners together for fun and enjoyment, but also provide opportunities to interact and discuss matters pertaining to Summit Lake.

The Board of Directors will develop a strategy to continue these interaction events. Furthermore, the Board will develop tools to engage lake property owners in an effort to recruit them as volunteers. The first step would be to develop a volunteer list. This is a spreadsheet of volunteers along with data including contact information, skills they may offer (baking skills for bake sales, carpentry skills for creating signs or a kiosk, etc.), and documentation of time they have served for the SLA. This last step is important because if a person is recognized for his or her efforts, they are more likely to continue to volunteer. Public recognition of volunteer efforts may be conducted through the association's newsletter or announcements at some of the above mentioned events.

The Board will also designate "shoreland representatives" throughout the neighborhood. The role of the shoreland representatives will be to engage their neighbors about matters pertaining to the lake, invite them to annual events such as those mentioned above, and ask them for assistance when help is needed. This would be a more effective way than approaching members through phone, mail or email contact because face-to-face interaction is more sincere and also more difficult for a potential volunteer to turn down.

Action Steps:

Please see above description.

Management Goal 4: **Prevent Aquatic Invasive Species Introductions to Summit Lake**

<u>Management Action:</u> Coordinate annual volunteer monitoring for Aquatic Invasive Species
Timeframe: Ongoing
Facilitator: Planning Committee
Description: In lakes without Eurasian water milfoil and other invasive species, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. One way in which lake residents can spot early infestations of AIS is through conducting "Lake Sweeps" on their lake. During a lake sweep, volunteers monitor the entire area of the system in which plants grow (littoral zone) annually in search of non-native plant species.

In order for accurate data to be collected during these sweeps, volunteers must be able to identify non-native species such as Eurasian water milfoil and curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. To assist association members in these identification skills, Lumberjack AIS Coordinator John Preuss may be contacted to arrange a plant identification workshop. Mr. Preuss will help volunteers positively identify native and non-native plants, as well as assist with plant collection and lake monitoring techniques/methodology. Collecting a specimen of suspicious looking plants is important for verification purposes. Additionally, if possible, GPS coordinates should be collected if suspicious looking plants are found on Summit Lake.

Action Steps:

1. Volunteers from SLA update their skills by attending a training session conducted by WDNR/UW-Extension through the AIS Coordinator for Lincoln, Langlade and Forest Counties (John Preuss – 715.369.9886).
2. Trained volunteers recruit and train additional association members.
3. Complete lake surveys following protocols.
4. Report results to WDNR and SLA.

<u>Management Action:</u> Create and implement special holiday signage at public access.
Timeframe: Ongoing
Facilitator: Education Committee
Description: In many Wisconsin lakes, recreational activities are minimal until weekends or holidays, in which even the quietest of lakes can become busy with anglers, sunbathers, kayakers, swimmers, boaters, or those just enjoying a pontoon ride during a picturesque Wisconsin lake sunset. Either way, when a lake is receiving much attention from humans, this provides the perfect opportunity to educate humans about the lake they are enjoying.

During the planning process associated with this project, SLA members discussed the possibility of creating holiday-specific signage to place at the public access points on the lake. This signage could serve several roles, such as providing information about the positive attributes of the lake (good water quality, presence of several sensitive aquatic plant species on the lake, annual return of nesting loons, etc.). The signage would also provide an educational opportunity about the threats AIS pose on the lake ecosystem. These signs would remind lake users of the importance in draining live wells and removing aquatic plants and debris from boats and other watercraft. Slogans, phrases, or text could be specific to the holiday during which the sign is being placed, such as Memorial Day, the Fourth of July, Labor Day, etc. This type of endeavor may be applicable for state funding through the WDNR's AIS grant program.

Action Steps:

1. Education Committee to develop signs and sign content
2. Investigate if WDNR AIS Grant would be appropriate to cover initial setup costs.

6.0 METHODS

Lake Water Quality

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

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Summit Lake during a June 11th, 2010 field visit, 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 Summit Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in "Appendix D" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used to complete this study on July 21st, 2010. A point spacing of 57 meters was used resulting in approximately 344 sampling points.

Community Mapping

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

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

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