Anvil Lake

Vilas County, Wisconsin

Comprehensive Management Plan

January 2018

Sponsored by:

Anvil Lake Association

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Lake Management Planning

Anvil Lake

Vilas County, Wisconsin

Comprehensive Management Plan

January 2018

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B Aquatic Plant Survey Data
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1.0 INTRODUCTION

According to the August 1975 recording sonar WDNR Lake Survey Map, Anvil Lake is 398 acres. The WDNR website list the lake as 377 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the National Agriculture Imagery Program (NAIP) collected on June 16, 2013. Based upon heads-up digitizing the water level from that photo, the lake was determined to be 357 acres. Approximately 1 year later on June 8, 2014, Onterra conducted an acoustic-based bathymetric study of the lake (Map 1). These data indicate that the lake has a maximum depth of 30 feet. Figure 1.0-1 outlines the survey timing in relation to the historic water levels of Anvil Lake.

This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Anvil Lake contains 32 native plant species, of which muskgrasses are the most common plant (although muskgrasses are actually a macro-algae). Two submergent exotic plant species are known to exist in Anvil Lake.

Field Survey Notes

Working on many lakes throughout the summer, Onterra field staff and interns always enjoy the end of the day on Anvil Lake – as that means swimming in this beautiful lake. The ambiance from the natural shoreline and the blue water cannot be surpassed.

Photograph 1.0-1 Anvil Lake, Vilas County

Lake at a Glance - Anvil Lake

Morphology	
Acreage	393 (full), 357 (2013 ortho-rectified)
Maximum Depth (ft)	30 (2014 acoustic survey)
Mean Depth (ft)	19
Vegetation	
Number of Native Species	32
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil & Curly-leaf pondweed
Simpson's Diversity	0.82
Average Conservatism	6.7
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	~7.0
Sensitivity to Acid Rain	Not Susceptible
Watershed to Lake Area Ratio	

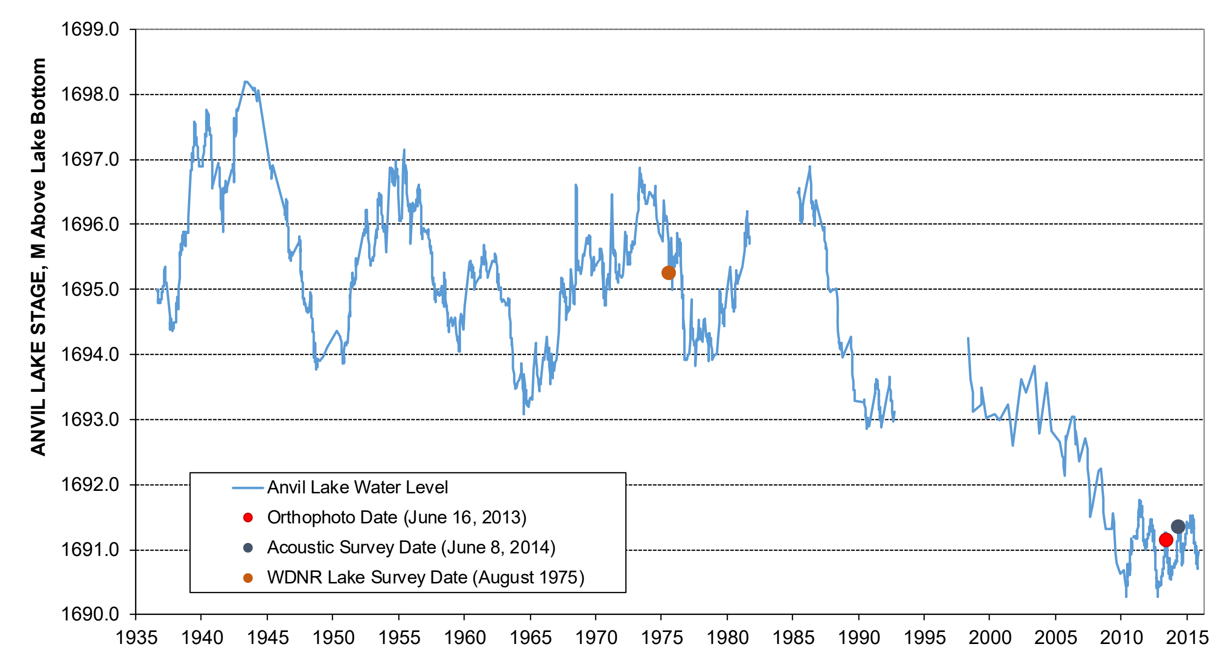

Figure 1.0-1. Anvil Lake water levels in feet above mean sea level (MSL). The period of record is from 1936 to 2016. There is a gap between 1992 and 1996 when records were not collected. No record is available for 1981-83.

Anvil Lake is surrounded by the Chequamegon-Nicolet National Forest. The US Forest Service operates the Anvil Lake Trail, which meanders through a large, mature block of northern hardwood forest. The trail was designated a State Natural Area in 2007. The lake is accessible through a paved boat launch site within the US Forest Service campground. It features parking for up to 15 vehicle/trailer units, vault restrooms and ADA accessibility features, 18 campsites, and a public beach. A second public access, owned by the Town of Washington, is an unpaved walk-in access on the lake's southwest shoreline.

The primary citizen-based organization leading management activities on Anvil Lake is The Anvil Lake Association (ALA). In 2009/2010, lake residents worked with a private consultant to create a protection plan for Anvil Lake - completed in January of 2011. The plan called for more in-depth studies pertaining to water quality and biological data collection as well as a full water budget to be completed as part of a future management plan. In May 2011, the USGS successfully applied for Lake Protection Grant funds to conduct the recommended studies. In July 2012, Eurasian watermilfoil (EWM) was first discovered in Anvil Lake. After the completion of a point-intercept survey and professional EWM mapping, the ALA received an AIS-EDR grant in spring 2013 and a second in summer 2014. The two grants funded continued professional monitoring, education, volunteer monitoring and hand-harvesting, as well as professional harvesting.

The 2011 lake protection plan created by Environmental Horizons, the current USGS studies, and continued participation of ALA volunteers in the CLMN, cover the typical management planning study components assessing the lake's watershed, water quality, use, and aquatic plant community. The management planning project incorporated aquatic plant information following the establishment of EWM and CLP and fills the gap in the lake's planning needs by developing a long-term monitoring and management of the lake.

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 and annual AIS monitoring reports.

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

Kick-off Meeting

On July 3, 2015, a project kick-off meeting was held in the backyard of the Kuhn residence to introduce the project to the general public. The meeting was announced through a mailing and personal contact by the Anvil Lake Association board members. The approximately 25 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 April 22, 2016, Eddie Heath, Paul Garrison and Tim Hoyman of Onterra met with six members of the Anvil Lake Planning Committee for nearly 4 hours. Dr. Dale Robertson from the United States Geological Survey (USGS) also presented on water quality and watershed work that this group has been conducting as a part of a separate project. Kevin Gauthier (regional WDNR Lakes Coordinator) and Catherine Higley (Vilas County Invasive Species Coordinator) were also in attendance. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including Eurasian watermilfoil hand-harvesting control results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed.

Planning Committee Meeting II

On July 26, 2016, Eddie Heath met with the members of the Planning Committee to begin developing management goals and actions for the Anvil Lake management plan. A follow-up teleconference between Onterra and the Anvil Lake Planning Committee occurred on October 27, 2016.

Management Plan Review and Adoption Process

In October 2015, a draft of the Implementation Plan Section was provided to the Planning Committee for review. Based upon comments received, additional and revised management goals were created and discussed during additional teleconference calls.

In November 2016, a an official first draft of the Anvil Lake Comprehensive Management Plan was supplied to the WDNR, Vilas County, United States Geologic Survey, United States Forest Service, Great Lakes Indian Fish and Wildlife Commission, Vilas County, and ALA Planning Committee for review.

Written reviews of the draft plan were received from Dr. Susan Knight (Interim Director UW Trout Lake Station), Steve Gilbert (NR Region Team Supervisor), Ashley McLaughlin (Water Resource Management - LTE), and Kevin Gauthier (Water Resources Management Specialist). Their comments and how they were integrated into this document are included in Appendix D.

During December of 2017, Onterra met with Hadley Boehm and additional comments to the report were made. These comments were integrated and included in Appendix D. The final draft of the report was sent to the ALA, the WDNR, Vilas County, and the Town of Washington in January 2018.

The final report will be reviewed by the ALA Board of Directors and a vote to adopt the management plan will be held during the association's next official meeting. The plan will be implemented immediately following the vote to adopt has been concluded.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality & Watershed

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Anvil Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region. 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 Anvil Lake's water quality analysis:

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

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

Trophic State

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

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

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

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 *epilimnion* is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The *hypolimnion* is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The *metalimnion*, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fish kills 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 stratification, whether throughout the summer or periodically between mixing events, 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 turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can 'pump' phosphorus from the sediments to the water column throughout the growing season. In lakes that mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add phosphorus to the water column during spring turnover that may support algae blooms long into the summer. 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks 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 Anvil 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.

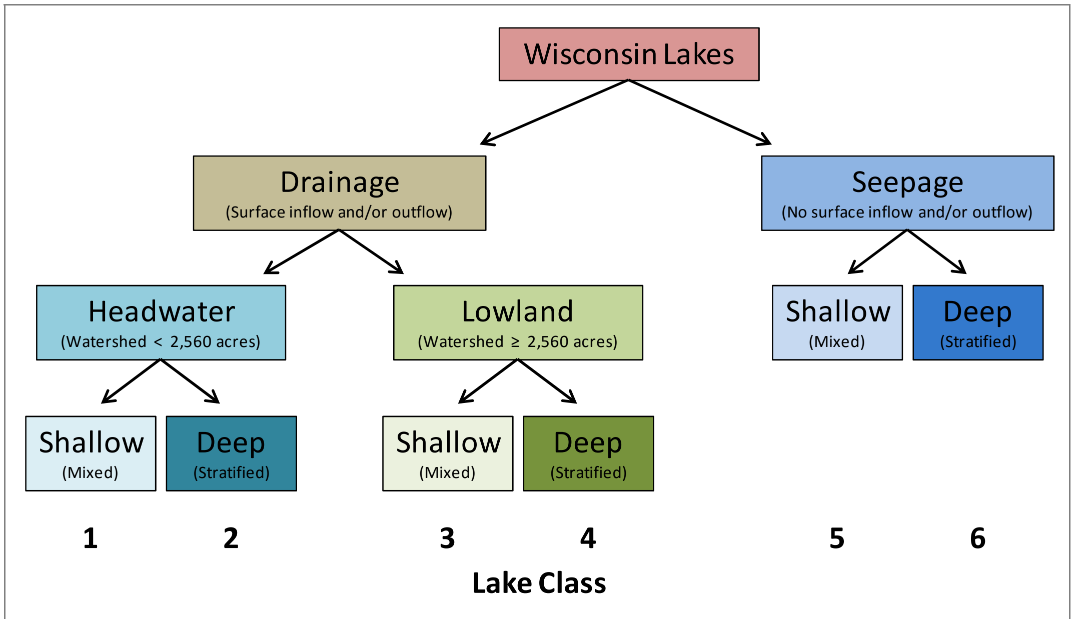

Figure 3.1-1. Wisconsin Lake Classifications. Anvil Lake is classified as a deep seepage lake (Class 6). Adapted from WDNR PUB-SS-1044 2008.

Garrison et al. (2008) 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. Anvil Lake is within the Northern Lakes and Forests ecoregion.

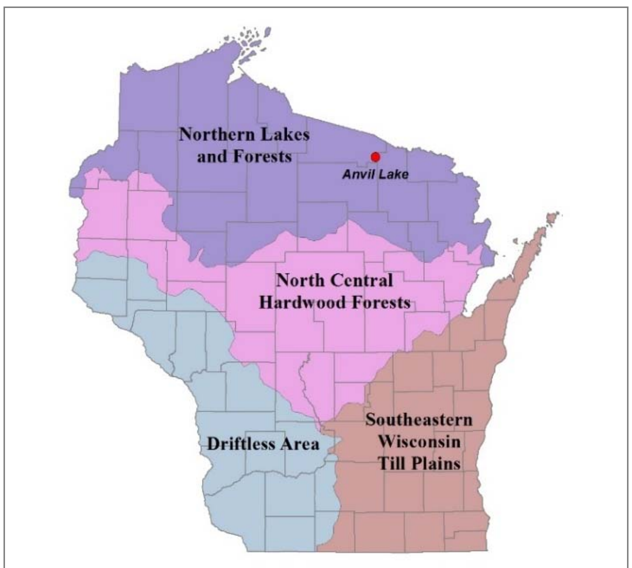

Figure 3.1-2. Location of Anvil Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2014 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. 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. One of the assessment methods utilized is Carlson's Trophic State Index (TSI). 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.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Anvil 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.

Anvil Lake Water Levels

There is a long, mostly continuous, record of lake levels for the lake. The record begins in 1936 and continues through the present. The only significant gaps were from 1981-83 and 1992-96. During the period of record the lake has experienced a fluctuation from a high of 1698 feet above MSL in 1944 to a low of 1691 MSL in 2013 (Figure 3.1-3). In general lake levels in recent years have been at the lowest level, but levels have risen slightly in the last couple of years. The fluctuation of lake level experienced in Anvil Lake is similar to other regional lakes (Watras et al. 2014) although the magnitude in Anvil Lake is less than some other lakes, e.g. Crystal Lake. The regional oscillation was near decadal until 1998 and since then there has been a downward trend.

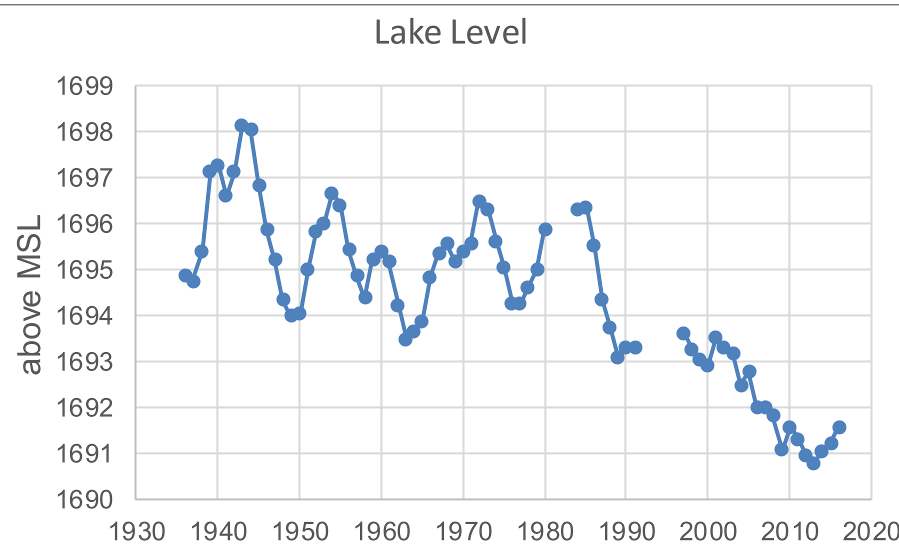

Figure 3.1-3. Anvil Lake water levels in feet above mean sea level (MSL). The period of record is from 1936 to 2016. There is a gap between 1992 and 1996 when records were not collected. No record is available for 1981-83.

Anvil Lake Water Quality Analysis

Anvil Lake Long-term Trends

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year-to-year based upon environmental conditions such as precipitation or lack thereof, and b) differences in observation and perception of water quality can differ greatly from person-to-person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, and whether its health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, one can determine what the status of the lake is by comparison.

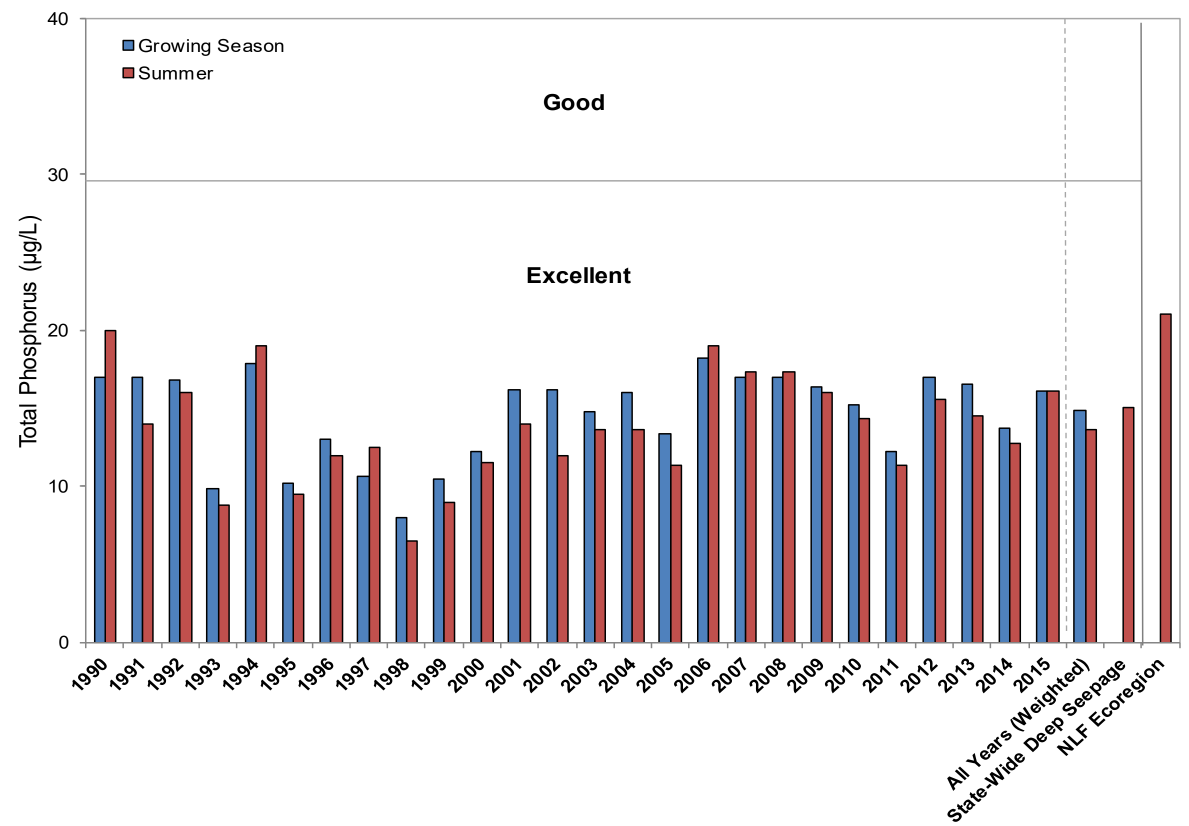

Figure 3.1-4. Anvil Lake, state-wide class 6 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Phosphorus data are available for most years from 1990 to the present. Most years at least 2 samples were collected during the summer period and more were collected during the growing season. The mean growing season concentration is 15 µg/L, while the summer mean concentration is slightly less at 14 µg/L (Figure 3.1-4). There is some variation between years with the lowest concentrations being in 1993, 1998, and 1999. The highest concentration tends to be early in the record, during the early 1990s. The summer mean value is similar to the median concentration found in deep, seepage lakes in Wisconsin and is better than the median for NLF lakes. Interannual differences in concentrations do not seem to be related to changing lake levels.

Data for chlorophyll-*a* are only available for the years 1993-2016, two years less than total phosphorus. As with phosphorus, there is some interannual variation, but the mean concentration for the period is about 5 µg/L, which is higher than the median for deep seepage lakes and about the same as other lakes in the NLF ecoregion (Figure 3.1-5). The lowest concentration was in 1999 while the highest values occurred in 1994 and 1996. While all of the phosphorus concentrations placed Anvil Lake in the excellent category, the years with the highest chlorophyll levels placed the lake in the good category. However, the weighted mean values places the lake in the excellent category. As with phosphorus there does not seem to be a relationship between changing lake levels and chlorophyll-*a* levels.

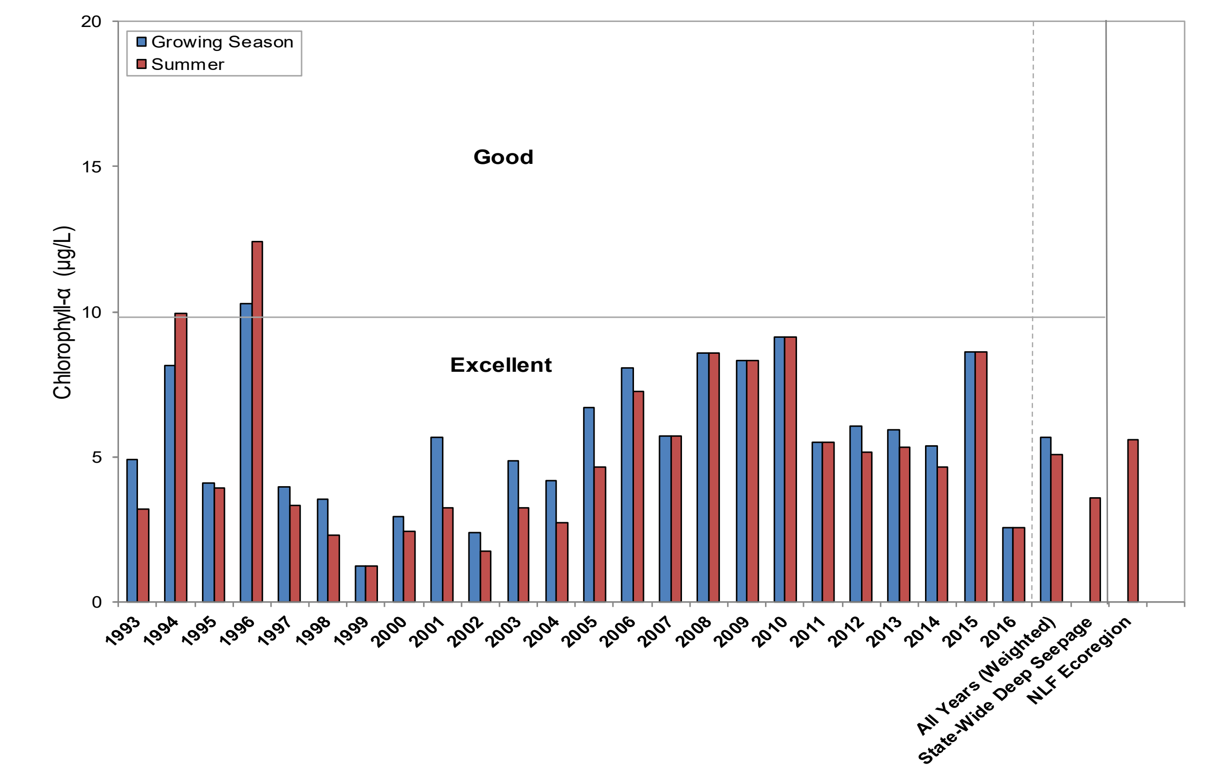

Figure 3.1-5. Anvil Lake, state-wide class 6 lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disc transparency is a measure of water clarity. In Anvil Lake the record is longer for this parameter than the previously discussed measures. The record extends from 1986 through the present time. As with the other parameters there is some interannual variability with summer mean values ranging from a low of 6.9 feet in 1994 to a high of 19.4 feet in 2002 (Figure 3.1-6). The mean value for the period of record is 11.5 feet for the growing season and 11.8 for the summer. These values are similar to the median Secchi disc transparency depths for other deep seepage lakes in Wisconsin and better than the median for NLF lakes (Figure 3.1-6). The mean value for Anvil Lake places the lake well into the excellent category.

As with total phosphorus and chlorophyll-*a*, Secchi disc transparency does not seem to vary annually as a result of changing lake level. Unfortunately, the length of record of trophic parameters is much shorter than the period of record for lake levels. Also the period of record of the trophic parameters is when lake levels have generally been at their lowest (Figure 3.1-6). Long term studies on other seepage lakes using sediment cores have found that there is limited response in the lake as a result of changing lake levels. Instead impacts from shoreland development have a greater impact which may obscure the impact from changing lake levels (Gaillard et al. 1991, Wolin 1996, Garrison et al. 2010, Garrison and LaLiberte 2011).

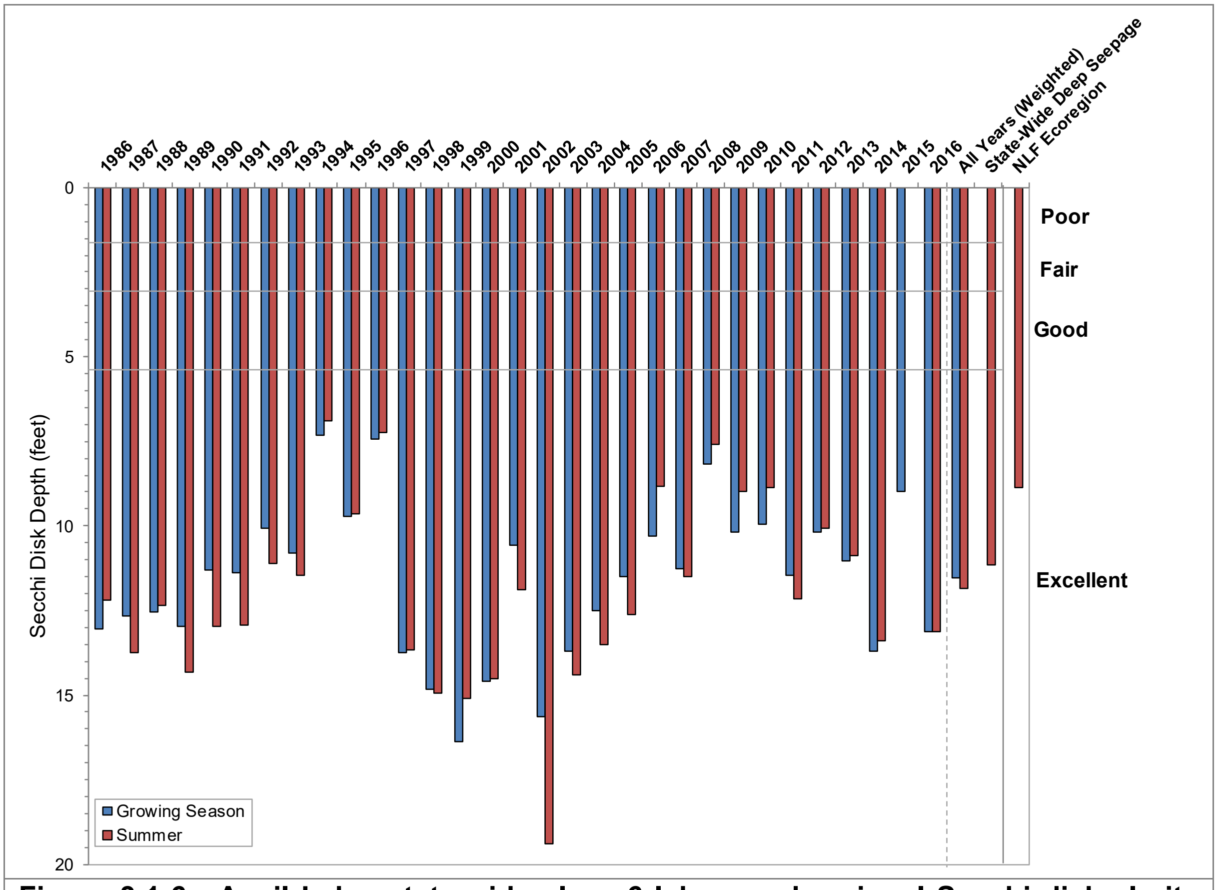

Figure 3.1-6. Anvil Lake, state-wide class 6 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Anvil Lake Trophic State

Figure 3.1-7 contains the weighted average Trophic State Index (TSI) values for which total phosphorus, chlorophyll-*a*, or Secchi disk transparency data are available. The TSI values are calculated with annual average summer month Secchi disk transparency, chlorophyll-*a*, and total phosphorus values. The weighted average TSI values for Secchi disk transparency, chlorophyll-*a* and total phosphorus indicate Anvil Lake is *mesotrophic*. During the period 1998 to 2000 values dipped into the oligotrophic range. The weighted mean value is very similar to other deep seepage lakes in Wisconsin and lower than the mean for lakes in the NLF ecoregion.

For most of the years, the TSI value for chlorophyll is higher than it is for Secchi disk transparency or phosphorus. This suggests that more algae is present than would be expected given the phosphorus concentrations and water clarity. It also suggests that the algae are not being consumed by zooplankton at a rate common in most lakes. This could be the result of the fish community which is consuming large amounts of zooplankton. Another possible reason for the low herbivory by zooplankton is the relatively low level of plants (Figure 3.4-4). Plant beds provide habitat for zooplankton which reduces predation by fish.

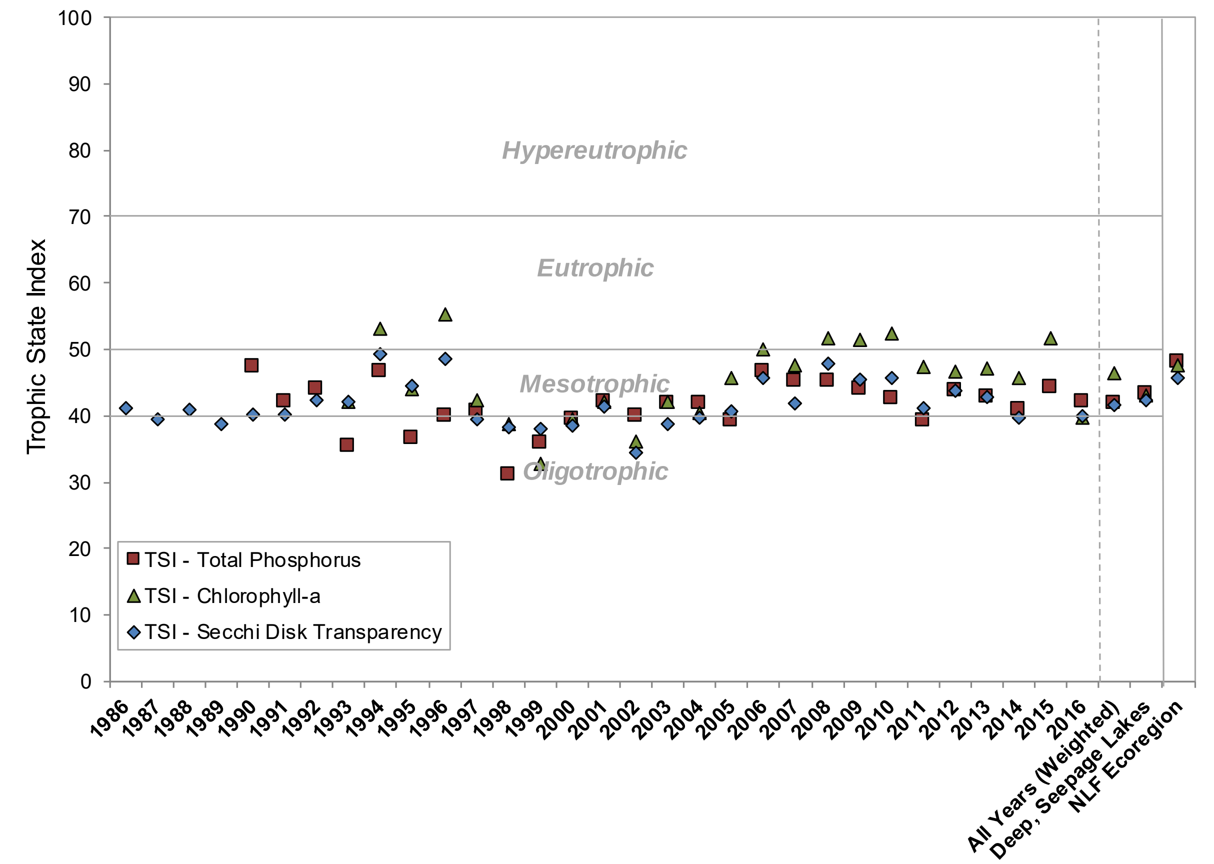

Figure 3.1-7. Anvil Lake, state-wide class 6 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Anvil Lake Water Budget

Anvil Lake is a seepage lake which means it does not have an inflowing or outflowing stream. The sources of water for the lake are precipitation, groundwater, and surface water runoff from land immediately around the lake. Water leaving the lake either is lost through evaporation or goes out through the groundwater. In a seepage lake like Anvil Lake, precipitation is often the dominant source of the input while evaporation is often the primary way water leaves the lake.

The USGS indicates that the watershed of Anvil Lake is approximately 3 square miles (Figure 3.1-8). The watershed area relative to the area of Anvil Lake yields a watershed to lake area ratio of 5.5:1, meaning that there are 5.5 acres of land draining to every one acre of Anvil Lake. However, the USGS did not consider the whole topographic watershed available for overland runoff. As is common for many seepage lakes, much of the watershed is sand and water is able to percolate into the groundwater. Within the subsequent USGS modeling, they used a 100 meter buffer of the near shoreland as their "watershed."

Figure 3.1-8. Anvil Lake Watershed. Figure provided by Dr. Dale Robertson.

During the period 2012-2014 the USGS conducted a detailed study of Anvil Lake. They found that during this period nearly two thirds of the water entering the lake comes from precipitation (Figure 3.1-9). Groundwater contributes nearly 35 percent of the water input. With this much contribution from groundwater the lake is not susceptible to acid precipitation. Even though much of the soils around the lake contain sand, there is enough buffering material associated with the substrate, e.g. calcium, to counteract inputs of acid rain. Typically, seepage lakes that are susceptible to acid rain have little or no groundwater entering the lakes. The alkalinity of Anvil Lake is about 16 mg/L and pH was measured in 2012 and 2013 and was about 7.0.

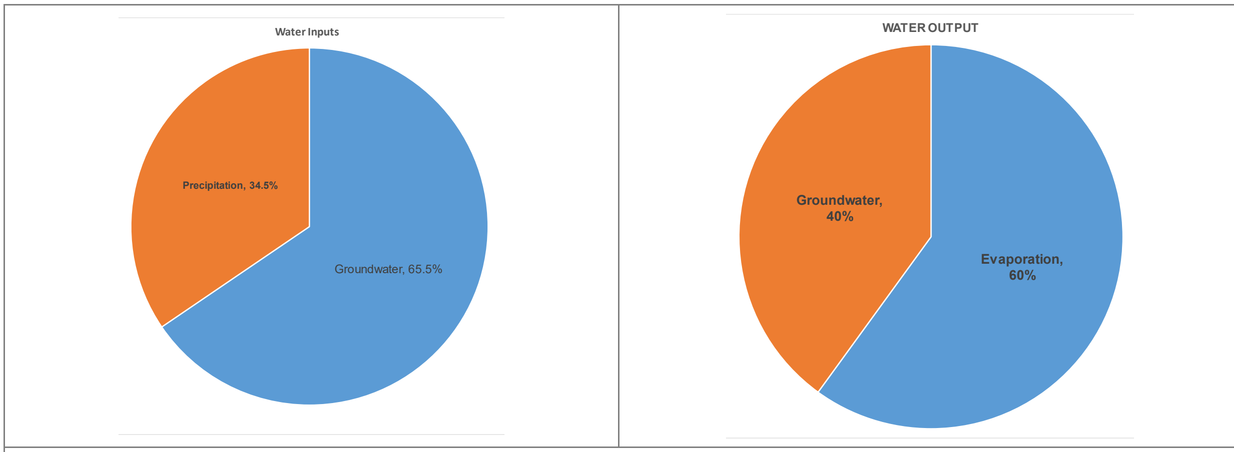

Figure 3.1-9. Water budgets for Anvil Lake for the 3 year period of 2012-2014. Budgets were calculated by the USGS and obtained from Dr. Dale Robertson.

Anvil Lake Phosphorus Loading

The amount of phosphorus entering Anvil Lake was calculated by the USGS and obtained from Dr. Dale Robertson. The budget was constructed by using various sources of water inputs and applying the appropriate phosphorus concentrations. The amount of phosphorus in precipitation was obtained from an earlier study on Whitefish Lake, Douglas Co. (Robertson et al. 2009). The concentrations for the groundwater were obtained by measuring phosphorus concentration in 9 shallow wells around the lake (Figure 3.1-10). The study found that the contributing groundwater area was the northeast part of the lake. Only 3 wells were placed in the contributing area. The groundwater at well 7 contained a much higher phosphorus concentration than the other contributing wells. The higher concentration in the area of well 7 is likely because of the unique geology in that area. It appears this area at one time was a wetland and as such concentrated nutrients which leach into the groundwater.

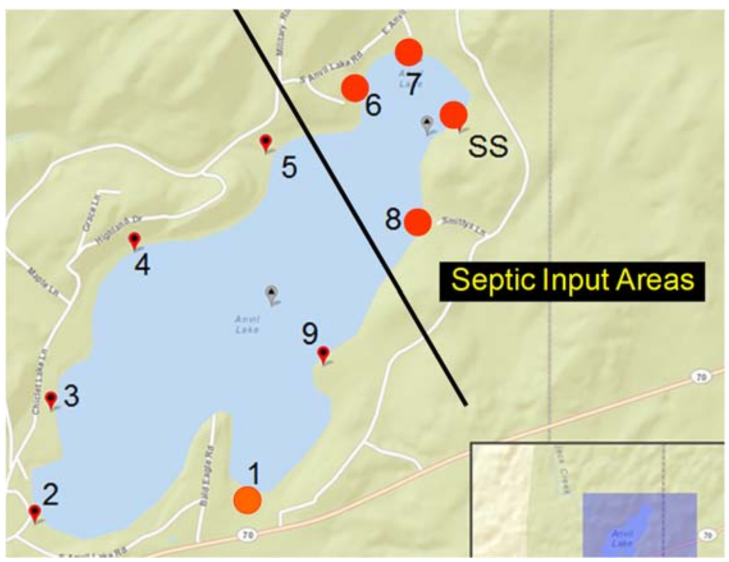

Figure 3.1-10. Location of USGS groundwater wells. The groundwater contributing area is only in the northeastern part of the lakes. Only septic systems in the part of the lakeshore contribute phosphorus to the lake.

In the fall of 2015 Onterra staff surveyed the land use of the shoreline around the lake. This survey found that over half of the shoreline is natural and undeveloped. The rest of the shoreline is developed, but the intensity of development is variable. The most developed landcover is classified urbanized and this makes up 17 percent of the shoreline (Figure 3.3-2). The greater the development the more phosphorus that is contributed to the lake. The USGS study estimated the amount of phosphorus entering the lake from nearshore runoff. Different runoff coefficients are applied to different kinds of development. The lowest coefficients are applied to natural undeveloped shoreline and the highest are applied to urbanized shoreline.

The contribution of septic systems was also estimated. Only those systems on the part of the lake that contributes groundwater are considered to be adding phosphorus to the lake. Additionally, certain amount of phosphorus is contributed to the lake from its bottom sediments as well. More phosphorus leaves the sediments when there is no oxygen in the overlying waters compared with oxygenated conditions.

The USGS collected cores from 12 areas around the lake where the bottom waters do not become anoxic and measured the release of phosphorus in the presence of oxygen. An additional 6 cores were collected in the deepest area of the lake were the bottom waters, at times, become anoxic. The mean release rate under aerobic conditions was 0.040 $mg/m^2/day$ and the anaerobic release rate was 0.087 $mg/m^2/day$. These release rates were applied to the appropriate amount of lake area that is oxic during the summer and the area that anaerobic.

By summing all the contributors of phosphorus to the lake, the USGS study estimated that during the 3 years of 2012-2014, that on average 158 (72 kg) pounds of phosphorus entered the lake annually. The largest source of phosphorus was from precipitation at 34% (Figure 3.1-11). Groundwater contributed an additional 23%. The contribution from homes around the lake was estimated to be 32% with 18% coming from septic systems and the rest from runoff from the nearshore area. Internal loading was about 11%.

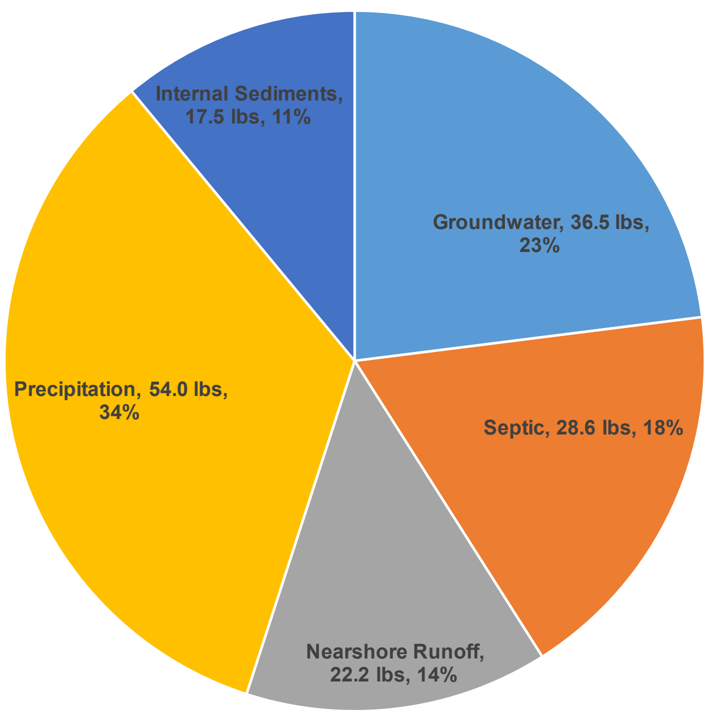

Figure 3.1-11. Sources of phosphorus to Anvil Lake as estimated by the USGS during the period 2012-2014. The sources of phosphorus that are the result of shoreland development are septic and nearshore runoff. Combined these contribute 32% of the annual phosphorus load.

Anvil Lake Modeling

An average growing season surface total phosphorus value can be estimated by inputting the annual hydraulic and phosphorus loads to Anvil Lake within a model developed by Canfield and Bachmann (1981). The result of that modeling scenario calculates an average growing season phosphorus value of approximately 14 µg/L, which is nearly the same as the lake's actual May-September average of 15 µg/l (Table 3.0-1). Using predictive equations developed by Carlson (1977), average chlorophyll-*a* and Secchi disk transparency values can be estimated using the average growing season surface phosphorus value. The estimated value for chlorophyll-*a* (4 µg/L) is slightly lower than an average of 6 µg/l calculated with water samples collected at Anvil Lake during the months of May-September, 1993-2016 (Table 3.0-1). Accounting for this difference is difficult; however, much of it may due to variance in the model and in-lake conditions, such as food web interactions where the zooplankton are not consuming as much algae as is typical.

Utilizing a similar predictive formula from Carlson (1977), an estimated average growing season Secchi disk transparency of 11.9 feet is calculated using the modeled phosphorus average of 14 µg/L. This value is very similar the actual value of 11.5 feet measured during the months of May-September 1986-2016.

The Canfield Bachmann model results for phosphorus and Secchi disk transparency are close to the measured values, but a bit lower for the modeled chlorophyll-*a* compared with measured values. The modeling procedures can shed light on how the lake may change if controllable sources such as septic system input, and nearshore runoff are reduced. (Table 3.1-1). The model was also used to predict how the trophic parameter concentrations would change if lake levels are high or if they are very low as the paleoecological study indicated was the case during the period 1000-1900 AD.

Table 3.1-1. Anvil Lake predictive modeling results. The phosphorus load is the sum of annual inputs from precipitation, groundwater, septic systems, and nearshore runoff as determined by Dr. Dale Robertson of the USGS. Target growing season mean phosphorus for calibrating model is 1990-2016 May-September average of 15 µg/l. Predicted in-lake phosphorus estimated using equations from Bachmann & Canfield (1981). Secchi disk transparency and chlorophyll-*a* values predicted from phosphorus concentrations using equations from Carlson (1977).

	Annual Phos Load (kg)			Phosphorus (µg/L)			Secchi Disk (ft)			Chlorophyll-*a* (µg/L)		
Scenario	Present	High	Low	Present	High	Low	Present	High	Low	Present	High	Low
Anvil Lake Current Conditions	75	71	73	15	12	18	11	13	9	4.0	3.0	6.0
Anvil Lake: Current without Septic	62	59	60	13	11	16	13	15	11	4.0	3.0	5.0
Anvil Lake: Current without Nearshore Runoff	65	64	63	14	12	16	12	14	10	4.0	3.0	5.0
Anvil Lake: Current without Anthropomorphic Inputs	51	52	50	12	10	14	14	16	12	3.0	3.0	4.0

Using the Canfield Bachmann model, eliminating either the septic, nearshore runoff, or both would reduce the phosphorus load by up to 23 kg which would reduce the growing season mean phosphorus value by 1-3 µg/L (Table 3.1-1). Using these values within Carlson's predictive equations reducing these phosphorus inputs would increase Secchi disk transparency 1-3 feet while chlorophyll-*a* would be reduced by only about 1 µg/L. This means that even if all sources of anthropogenic nutrients were eliminated, algal population levels would be similar although the water clarity may be somewhat better.

The Canfield Bachmann model was used to predict the lake response at the highest water levels that have been recorded in the lake since 1936 (1698 ft MSL). This level is about 6.5 feet higher than the lake is at the current time. The model predicts that phosphorus would be reduced by about 3 µg/L which is similar to the reduction in phosphorus concentration if all phosphorus input from anthropogenic sources were eliminated (Table 3.1-1). Using these values within Carlson's predictive equations, water clarity would improve about as much as eliminating septic or nearshore runoff at the present lake level.

Since the paleoecological study indicated that at one time the lake level was much lower than at the present time, the model was used to estimate phosphorus concentrations if Anvil Lake was 10 feet lower than it was in 1975. This reduction in lake level would be about 3.5 feet lower than it is now. The model results show that phosphorus levels would increase about 3 µg/L which is similar to the degree of change that is predicted if the lake level was higher than it is now. Water clarity would be reduced by about 2 feet (Table 3.1-1).

This modeling exercise implies that changing lake level is as important as anthropogenic phosphorus sources in determining the lake phosphorus concentration. The model and paleoecological studies both point towards the impact of lake level changes on phosphorus concentrations and thus water clarity and algal levels. The modeling and paleoecological study both indicate that higher lake levels result in lower phosphorus levels while lower lake levels result in slightly higher phosphorus concentrations. These results are different from other studies which concluded that development had a greater impact on phosphorus levels than did changing lake levels (Gaillard et al. 1991, Wolin 1996, Garrison et al. 2010, Garrison and LaLiberte 2011). Development around Anvil Lake may be having a reduced impact because groundwater only enters the lake in a small portion of the shoreline and housing density is not as great as the other lakes. About 50 percent of the shoreline of Anvil Lake is undeveloped. It should not be concluded that shoreland development is not having an impact on the lake's nutrient status. Both the modelling and paleoecological study imply that present day phosphorus levels would be lower by about 2-3 µg/L if there was not shoreland development.

3.2 Paleoecology

Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

Nearly all natural lakes in Wisconsin were created as a result of the last glaciation period. Most Wisconsin lakes are 12,000 to 14,000 years old as this is when the glacial ice sheets had melted and receded from the state. The exception to this are lakes along Lake Michigan, e.g. Door County. These lakes are much younger, having been formed when the lake level of Lake Michigan dramatically dropped about 2800 years ago.

Although the newly formed lakes underwent significant ecological changes immediately after the recession of the glaciers as the climate became warmer and drier, the last 150 years have generally seen the most dramatic changes to the lake's ecology. This is because of the impacts human settlement has caused in the lake's watershed and shoreline. Generally, Europeans began settling in Wisconsin after the 1830s in the southern part of the state and later in the northern part of the state. Early settlement largely consisted subsistence farming in the lake's watershed which had minor but noticeable impacts on the lake's ecology. The greatest impact that settlement has caused to lakes occurred during the twentieth and twenty first centuries. Often lakes with agriculture in their watersheds experienced significant degradation beginning in the 1940 and 50s. This was because following World War II, mechanization improved allowing more land to be tilled. There was also an increased use of synthetic fertilizers to enhance production. Many of the factories that were used to produce ammunition for the war effort were converted to producing this fertilizer. The increased mechanization and use of fertilizers resulted in increased soil erosion from the land to the lakes as well as a large input of nutrients, e.g. phosphorus, that are attached to soil particles as well as associated with the fertilizer. Also, cow herd sizes increased, resulting in additional nutrients from manure. Since the 1970s, many parts of the state have experienced increased urbanization which has resulted in increased runoff from homes and streets into the lakes.

In northern Wisconsin, the earliest impacts to the lakes were from wide spread logging operations. This activity generally had a short-term impact upon the lake's ecology. With the failure of the agricultural experiment following the early logging in the late nineteenth and early twentieth centuries, tourism increased resulting in the addition of cottages around many lakes after the late 1920s (Davis 1995). Beginning around the 1970s, lake shore homes began to become larger and lawn maintenance more common. This increased urbanization resulted in increased delivery of sediment and nutrients to the lakes. This often resulted in large impacts on shoreland habitat as well as nearshore habitat.

Parameters Analyzed

There are many parameters that can be measured in a sediment core to reconstruct changes that have occurred in the lake throughout the time period covered by the core. The most frequently utilized are:

Sedimentation rate and dating is usually measured by the constant rate of supply model (Appleby 1998, 2001; Appleby and Oldfield 1978). The radionuclides lead-210 (^{210}Pb) and cesium-137 (^{137}Cs) are measured in samples throughout the core. Lead-210 is a naturally occurring radionuclide and is the result of natural decay of uranium-238 to radium-226 to radon-222. Since radon-222 is a gas (that is why it is sometimes found in high levels in basements) it moves into the atmosphere where it decays to ^{210}Pb. The ^{210}Pb is deposited on the lake during precipitation and with dust particles. After it enters the lake sediments, it slowly decays through the radionuclides described above. The half-life of ^{210}Pb is 22.26 years (time it takes to lose one half of the concentration of ^{210}Pb) which means that it can be detected and used for dating on samples that are about 130-150 years old.

Cesium-137 is a byproduct of atmospheric nuclear testing. This testing began in 1954 by the USA. Later the USSR also did testing. Atmospheric testing was banned in 1963 with the signing of the Atmospheric Test-Ban Treaty. Since the testing conducted by the USSR was much dirtier than the USA or UK, the peak deposition of ^{137}Cs was in 1963. Therefore, the peak concentration of ^{137}Cs in the core represents a date of 1963 (Krishnaswami and Lal 1978).

Another elemental profile that can be used to verify the dating model is that of stable lead. Stable lead has an historical pattern of deposition that is very consistent among lakes, with lead concentrations increasing from around 1880 to the mid-1970s, and decreasing to the present. The decline of lead is largely the result of the discontinued use of bonded leaded gasoline in the mid-1970s (Gobeil et al. 1995; Callender and Van Metre 1997).

Another useful parameter to estimate when early settlement occurred in the lake's watershed is changes in the loss on ignition (organic matter). Studies have shown that this decline is the result of watershed activities which result in an increase in the soil erosion (Engstrom et al., 1985; Garrison, 2000a,b; Garrison, 2003; Garrison and Wakeman, 2000). This erosion is largely composed of inorganic material which dilutes the organic matter and thus organic matter concentrations decline. The increased delivery of inorganic material in southern lakes occurred in the mid-1800s. In northern Wisconsin the increase tended to occur around 1900.

Geochemical parameters are various chemicals deposited in the sediments. Some of them are useful for determining changes that have occurred in the lake and what watershed activities have caused the changes. Examples of chemicals analyzed are: phosphorus, nitrogen, carbon, aluminum, titanium, iron, manganese, uranium, zinc, and calcium. While some of these chemicals directly indicate changes in the lake's ecology, others act as surrogates for activities in the lake or watershed. Aluminum and titanium are surrogates for soil erosion as they are common components of clay particles in soils. Calcium, in the form of lime, is often used as a soil amendment in lawn maintenance, especially in sandy soils. While phosphorus and nitrogen are common components of synthetic fertilizers, their concentrations are easily affected by lake processes and thus not good indicators of fertilizer application on the landscape. Instead, other components of the fertilizer are used to track changes in fertilizer use. Two components that are more conservative are potassium and uranium. Uranium is found in many phosphate ore bodies. Changes in the nutrients phosphorus, nitrogen, and carbon are often useful in determining changes in the lake's productivity. Changes in the concentrations of iron and manganese are used to estimate changes in oxygen content in the bottom waters of stratified lakes. As the bottom waters lose oxygen with increased lake productivity, more manganese is released from the sediments than iron. Therefore, a decline in the ratio of Fe:Mn is an indication of declining oxygen levels in the sediments. While changes in the concentration of these chemicals is often useful, changes in the accumulation rate provide a more accurate picture of changes within the lake. The accumulation rate is determined by multiplying the bulk sedimentation rate times the concentration.

The **diatom community** is one of the most useful fossils for reconstructing changes in the lake over time. Diatoms are a type of alga which possess siliceous cell walls and are usually abundant, diverse, and well preserved in sediments. They are especially useful as they are ecologically diverse and their ecological optima and tolerances can be quantified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. They also live in a variety of habitats, which enables us to reconstruct changes in nutrient levels in the open water as well as changes in benthic environments such as aquatic plant communities.

Diatom assemblages have been used as indicators of trophic changes in a qualitative way (Bradbury 1975, Carney 1982, Anderson et al. 1990), but quantitative analytical methods exist as well. Ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration (Birks et al. 1990). Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

There are other types of analyses that are less frequently performed in sediment cores. These generally are not as universally useful as the more frequent analyses, but can help explain changes in lake's ecosystem in specific cases. Examples of these type of analyses are:

Blue-green algae are more common in eutrophic lakes and changes in their abundance can be an indication of increased algal blooms. Only a few species commonly leave fossils, but fortunately 2 of the 3 most problem causing taxa do leave fossils. These are *Anabaena* and *Aphanizomenon*. A third problem taxa, *Microcystis*, does not leave fossils which can confuse the interpretation of changes in algal blooms throughout the time period covered by the core. Blue-algal fossils are useful for demonstrating that a lake possessed these bloom forming algae prior to the arrival of European settlers.

Zooplankton are microscopic animals that often feed on algae. While larger zooplankters consume more algae compared with smaller taxa, the larger animals are also more susceptible to fish predation. Unfortunately not all zooplankton leave fossils. The only group that typically leaves enough fossils to be useful are cladocerans. Examples of these types of zooplankters are *Daphnia, Bosmina*, and *Chydorus*. The information from the zooplankton fossils can be used to estimate changes in fish predation and thus the type of fish present (fish eating vs plankton eating). These fossils can also be useful for documenting changes in the coverage of macrophytes as certain taxa are more common in plant beds.

Core Types

There are two types of lake sediment cores that are usually collected for paleoecological analysis. The top/bottom core only analyzes the top (usually 1 cm) and bottom sections. The top section represents present day conditions and the bottom section is hoped to represent pre-settlement conditions by having been deposited at least 100 years ago. While it is not possible to determine the actual date of deposition of bottom samples, a determination of the radionuclide lead-210 estimates if the sample was deposited at least 100 years ago. The primary analysis conducted on this type of core is the diatom community leading to an understanding of past nutrients, pH, and general macrophyte coverage.

A full core study retains the entire lake sediment core, usually in 1-2 cm sections. Typically, 15 to 20 sections are analyzed throughout the core. A much more detailed analysis of the sections is performed which results in much more detailed picture of the changes that have occurred throughout the time period encompassed by the core. Not only are ecological changes described, but often the cause of the changes is determined. Examples of analyses performed on full cores are changes in sedimentation rate, estimating dates when specific sections were deposited, geochemistry, and the diatom community. Occasionally, additional analyses are performed, e.g. zooplankton fossils, blue-green algal fossils, macrophyte remains.

Anvil Lake Paleoecological Results

During the last 200 years, Anvil Lake and its watershed has experienced a number of changes. In the early 1900s the area was initially logged and there were 2 sawmills located on the lakeshore. During the early twentieth century, farming was common in the area and cottages were built on the lakeshore beginning around 1920. Resorts, additional cottages and homes were established around the lake during the next 3 decades. By today’s, standards these cottages and resorts were primitive, used outhouses, and the buildings were small. During the last half of the twentieth century, many cottages were upgraded and additional homes built. These new structures were larger and greatly expanded the amount of impervious surface around the lake.

Along with these anthropogenic impacts, Anvil Lake also experiences significant water level changes. Records going back to 1936 indicate that the difference in lake level between the highest and lowest levels measured exceeds 7 feet.

A sediment core was taken from Anvil Lake on 5 September 2013 in the deep area of the lake

(N45.94264, W-89.0625) (Figure 3.2-1) using a piston corer. The total length of the core was 78 cm and the core was sectioned into 1 cm slices for depths 0-30 cm and then into 2 cm sections to the bottom of the core. The samples were placed in plastic freezer bags and kept in a dark refrigerator. The water depth at the site was 29 feet.

Sedimentation Rate

Sediment age for the various depths of sediment were determined by constant rate of supply (CRS) model (Appleby and Oldfield 1978). Bulk sediment accumulation rates (g cm^{-2} yr^{-1}) were calculated from output of the CRS model. The sedimentation rate was much lower than expected which meant that depths older than 150 years were submitted to the lab. This resulted in only 5 depths being suitable for this analysis.

Figure 3.2-1. Anvil Lake sediment core location. The red star indicates the location of the sediment coring site.

In part because this lake has such a slow sedimentation rate and because of discrepancies between the diatom community in this core and an earlier top/bottom core, 7 depths were analyzed for carbon-14. This analysis allows the determination of dates in the core that are much older than 150 years. The sample at the bottom of the core indicated that the time period covered by this core was the last 1480 years.

The mean mass sedimentation rate for the last 170 years was 0.002 cm^2/yr. This is the lowest rate measured in 59 Wisconsin lakes (Figure 3.2-2). The rate is low partially because the lake is a soft water lake so there is not a significant amount of precipitation of calcium carbonate. Because the lake is a seepage lake there is reduced sediment input from the watershed compared with a lake with a significant inflowing stream. The average linear rate for the same time period is 0.13 cm/yr., which equates to a rate of 0.015 inches per year.

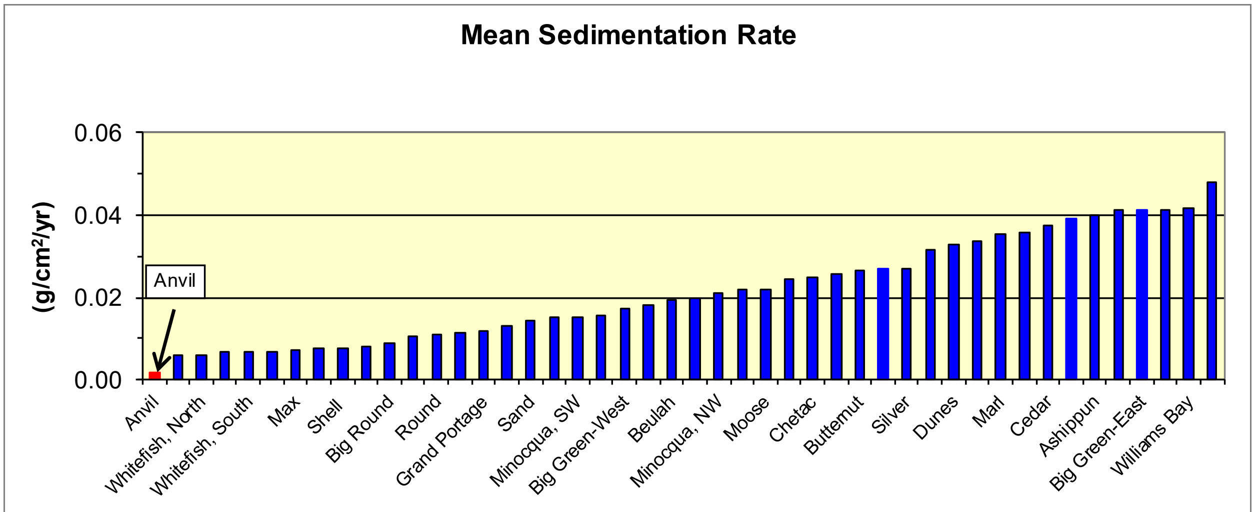

Figure 3.2-2. Mean sedimentation rate for the last 150 years for 59 Wisconsin lakes. The arrow indicates Anvil Lake**.** The rate is low, in part, because the lake has soft water and is a seepage lake.

To account for sediment compaction and to interpret past patterns of sediment accumulation, the dry sediment accumulation rate was calculated. Because only 5 depths are included in this analysis, the resolution is not as great as is typical. The historical sedimentation rate was about 0.001 cm^{-2} yr^{-1} but the rate increased after 1940 (Figure 3.2-3). The highest sedimentation rates occurred in the 1990s. The rate declined at the very top of the core but it still is greater than the 1800s rate. Even though there is an increase in sedimentation rate at the top of the core, it is much less than has been observed in other lakes in northern Wisconsin. While it is likely the recent increase is the result of increased sediment delivery from shoreline activities it is less than from other similar lakes.

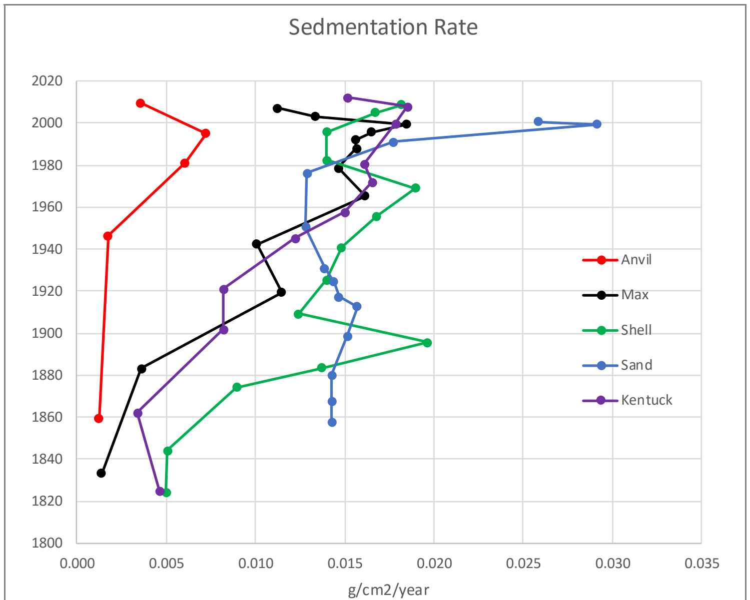

Figure 3.2-3. Sediment accumulation rate in Anvil Lake for the last 150 years. The rate increased in recent years likely from shore land development but the increase is much less than other northern WI lakes. The other lakes are essentially seepage lake with the exception of Sand Lake. Sand Lake has a higher historical rate because it is a drainage lake.

As mentioned above, radiocarbon dates were determined at 7 depths in the core. This analysis indicates that the increase in sedimentation rate in the last few decades may not be completely the result of shoreland development. The rate near the bottom of the core, which was covers the time period 1200-1500 years ago is similar to what was measured at the top of the core (Figure 3.2-4). Since this time period is prior to the arrival of European settlers, the increase is most likely climate driven. It appears that the sedimentation rate can be separated into three time periods. The oldest period would be from 450 to 800 AD, the second period would be from 800 to 1950 AD, and the third period would be the latter part of the twentieth and early part of the twenty first centuries. As will be discussed later in the diatom community section, it appears the historical changes in sedimentation rate is largely driven by changes in the lake level. This means that during the first time period (450-800 AD), the lake level was likely similar to that experienced in the last few decades, but during the second time period the lake level was lower.

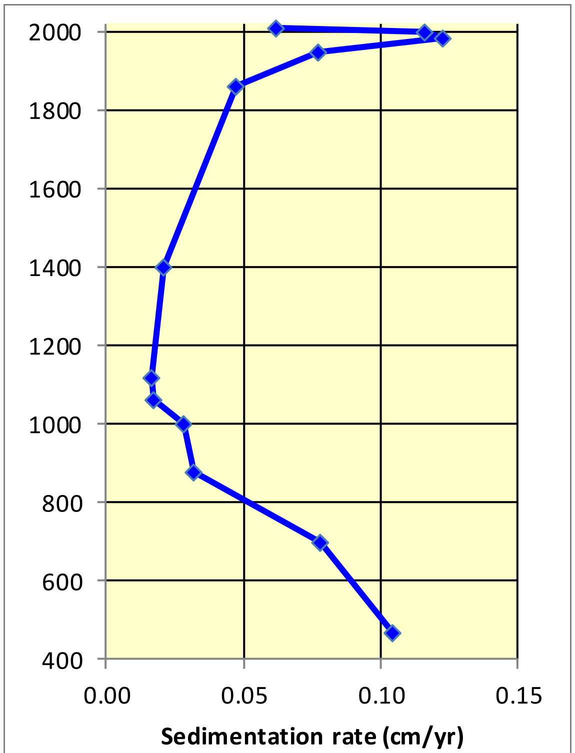

Figure 3.2-4. Sediment accumulation rate in Anvil Lake for the last 1500 years.

Sediment Geochemistry

Selected geochemical elements were analyzed in the core covering the last 900 years. Most of the elements exhibit little change in concentration between 1100 and 1950 (Figure 3.2-5). During the last 60 years there have been very slight increases in the nutrients phosphorus and nitrogen. These increases are much smaller than have been exhibited in other lakes in northern WI, e.g. Shell Lake, Washburn Co. (Garrison and LaLiberte 2011); Honest John Lake, Ashland Co. (Garrison 2011); Whitefish Lake, Douglas Co. (Garrison 2006).

The greatest increase in concentration since 1990 has been in the heavy metals zinc and cadmium. The increase in zinc likely reflects an increase in emissions from smelting of lead-zinc ores (Dean 2002) and has been observed in Lac Courte Oreilles, Sawyer Co. (Garrison and Fitzgerald 2005). The peak in the lead concentration occurs during the latter part of the twentieth century (Figure 3.2-5). During much of the twentieth century, bonded lead was used in gasoline. This practice was discontinued in the 1970s and consequently, lead deposition declined (Gobeil et al. 1995, Callender and Van Metre 1997). Uranium is often present in synthetic fertilizers because it is a contaminant in the ore body where phosphate is obtained; therefore, it can be used as a surrogate for the use of synthetic fertilizers in a lake's watershed. Uranium (not shown) did not show any increase in recent years. This implies that not a significant amount of phosphate containing fertilizer which may be applied to lawns is reaching the lake.

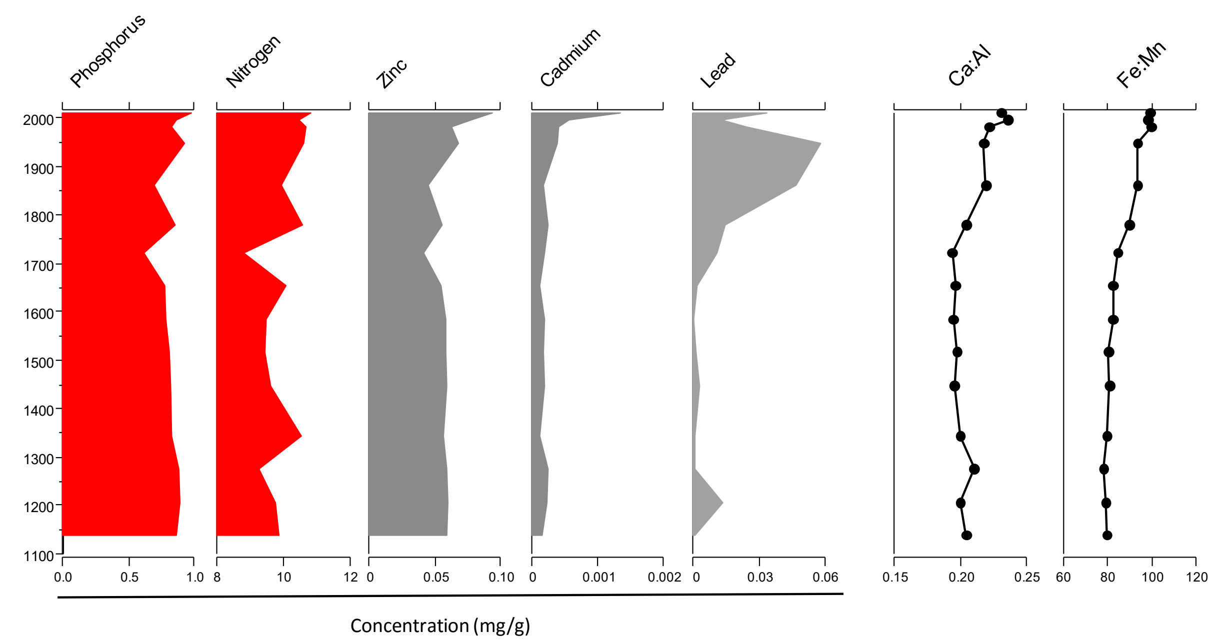

Figure 3.2-5. Profiles of the concentration of selected geochemical elements. Nearly all of the elements change little for the period 1100 to 1940s but most increase slightly in the last 60 years. The increases in zinc and cadmium are likely from smelters in the region. The lead peak is the result of the use of bonded lead in gasoline and then its discontinued use in the 1970s. The increase in the ratio of Ca:Al is indicative of soil amendments often used in lawns. The ratio of Fe:Mn indicates there has not been a decline in oxygen levels in the bottom waters.

In order to better understand changes in the deposition of geochemical elements in the core some elements were examined using ratios. The ratio of calcium to aluminum (Ca:Al) increases at the top of the core. While calcium is present naturally in soils the increase in the ratio of Ca:Al indicates that calcium is entering the lake from a source other than soil particles. Calcium is often used as a soil amendment on agricultural fields and lawns. It appears that lime is being applied to lawns around Anvil Lake and some of this is reaching the lake.

As the bottom waters become increasing devoid of oxygen, manganese (Mn) is mobilized from the sediments. This manganese then moves into the deepest waters resulting in enrichment of manganese in the sediments of the deeper waters. While this also occurs with iron, it happens sooner with manganese as it tends to stay in solution longer (Jones and Bowser 1978). Therefore as the bottom waters lose oxygen, manganese is preferentially moved with respect to iron (Engstrom et al. 1985). The result is that with the loss of oxygen, the ratio of iron to manganese (Fe:Mn) declines (Mn increases). In Anvil Lake the ratio is largely unchanged during the last 900 years (Figure 3.2-5) indicating little change in the oxygen content in the bottom waters of the lake. This is good news for the lake as the decline in hypolimnetic oxygen is a classic sign of increased eutrophication of a lake. A decline in the Fe:Mn was found in the sediment core from Whitefish Lake, Douglas County (Garrison 2006) even though the lake is still an oligotrophic lake.

Diatom Community

For the last 200 years, the diatom community was composed of nearly equal parts planktonic and nonplanktonic taxa. This reflects the fact this lake has a significant amount of littoral area even though it is a clear water, stratified lake. The dominant species are *Aulacoseira ambigua* and *Discostella stelligera* (Figure 3._-6). For most of the last 200 years the diatom community has been unchanged. The most significant change has occurred starting about 1990. At this time there was a decline in *A. ambigua* and an increase in *D. stelligera*.

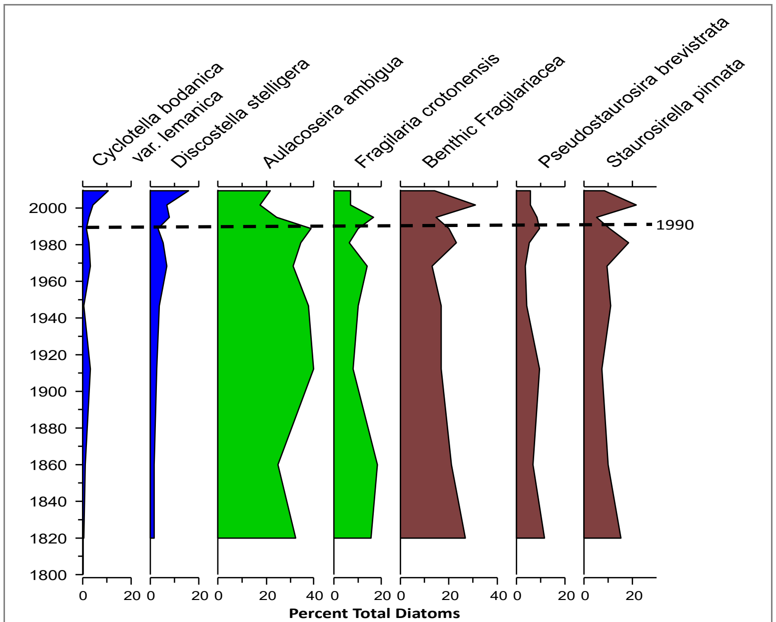

Figure 3.2-6. Profiles of common diatoms found in the core in the last 200 years. The diatoms in blue are indicative of low nutrients while those in green are indicative of moderate nutrient levels. The brown colored diatoms grow attached to plants and on the sediments.

A similar pattern was observed in the diatom community in Lake of the Woods, Ontario (Rühland et al. 2008). In Lake of the Woods there was a strong indication the change in the community was the result of decreased ice cover which resulted in a longer period of stratification. While we do not have data for ice-free days in Anvil Lake prior to 1990, this is consistent with a broader trend of more ice-free days across lakes during the twentieth century in the Laurentian Great Lakes region (Magnuson et al. 2005). Anvil Lake has experienced a decline in the number of ice days over the last 20 years. The small *D. stelligera* strives during stratification while the larger and heavier *A. ambigua* does not. Saros et al. (2012) demonstrated that *D. stelligera* will increase in numbers with the addition of nitrogen. However in Anvil Lake, other species that increase with higher nitrogen levels, e.g. *Fragilaria crotonensis*, *Asterionella formosa*, did not increase when *D. stelligera* did, implying that the latter diatom is responding to a longer period of stratification.

Although the diatom community composition during the last 200 years was stable until 25 years ago, the record for the last 1500 years indicates that non-anthropogenic factors have impacted the lake. During the period 950 to 1900 AD, the diatom community was dominated by nonplanktonic species (Figure 3.2-7). However, during the previous 500 years planktonic diatoms were more common implying that stratification was longer likely because of higher lake levels.

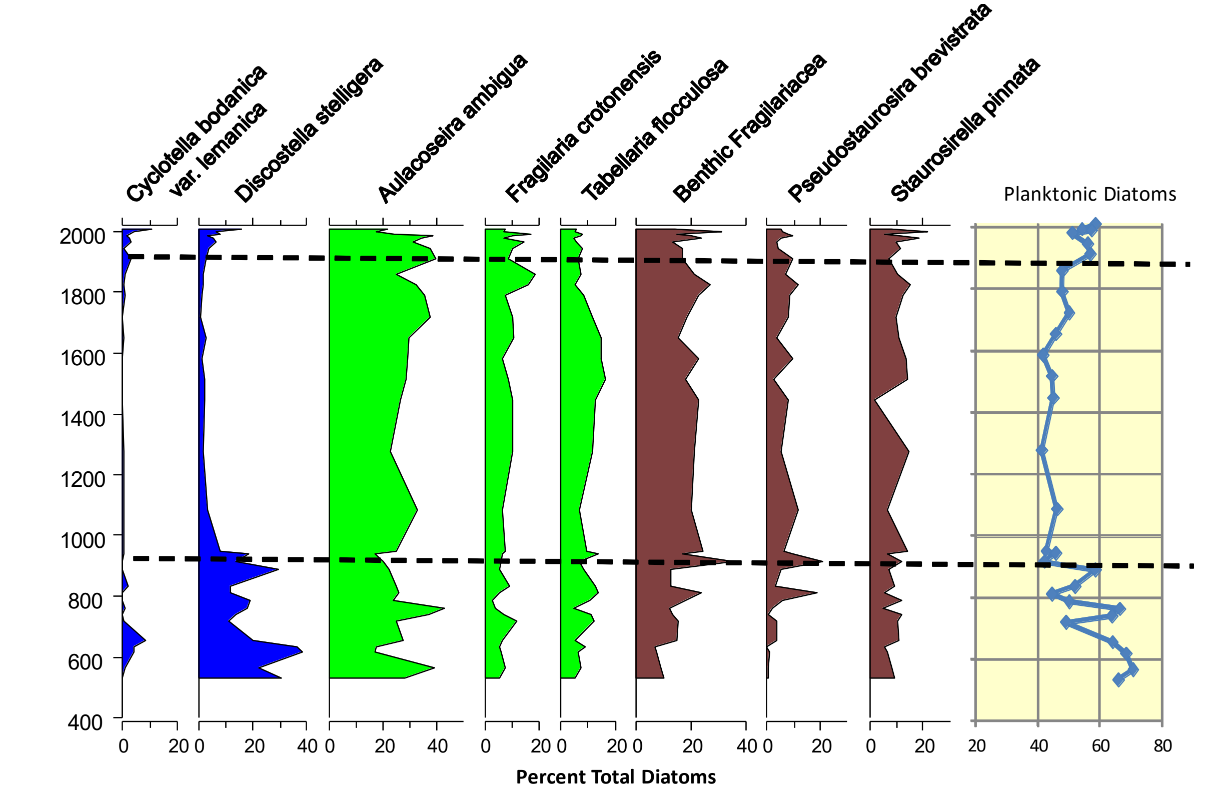

Figure 3.2-7. Blue colored diatoms indicate longer periods of stratification either because of higher water levels or shorter ice cover. Brown colored diatoms grow attached to submerged aquatic plants. Planktonic diatoms float in the open water and higher numbers indicate longer periods of stratification, i.e. higher water levels.

It seems reasonable that the diatom community is indicating that Anvil Lake has a long history, at least 1500 years, of significant lake level fluctuations. It appears that lake levels during the last 100 years are similar to what they were over 1000 years ago. The current water levels (although they are lower than they were a decade or so ago) are significantly higher than they were during the period 900 to 1900 AD.

Weighted averaging calibration and reconstruction (Birks et al., 1990) were used to infer historical water column summer average phosphorus in the sediment core. A training set was developed from 59 stratified Wisconsin lakes. Training set species and environmental data were analyzed using weighted average regression software (C2; Juggins 2003). The resulting transfer functions (bootstrapped 999 cycles $r^2 = 0.71$, $P < 0.05$) were subsequently applied with weighted averaging calibration to the fossil diatom assemblages (Birks et al., 1990, Juggins, 2003). Initial TP estimates from weighted averaging regression were corrected using classical deshrinking. Bootstrapped error estimates are based on initial log transformed data with the TP log error being 0.2061.

The diatom inferred summer phosphorus concentration at the top of the core is about 15 µg/L, which is similar to the values measured in the lake for the last few years, implying that the model works well. The lowest concentrations in the core were during the period 550-950 AD (Figure 3.2-8). The middle period had the highest phosphorus values, corresponding to the time when lake levels were lower (Table 3.2-1). The analysis indicates that phosphorus levels have declined in recent years. This likely is not true but reflects a decline in the diatom *A. ambigua* and increase in *D. stelligera* as a result of longer stratification as a result of climate change.

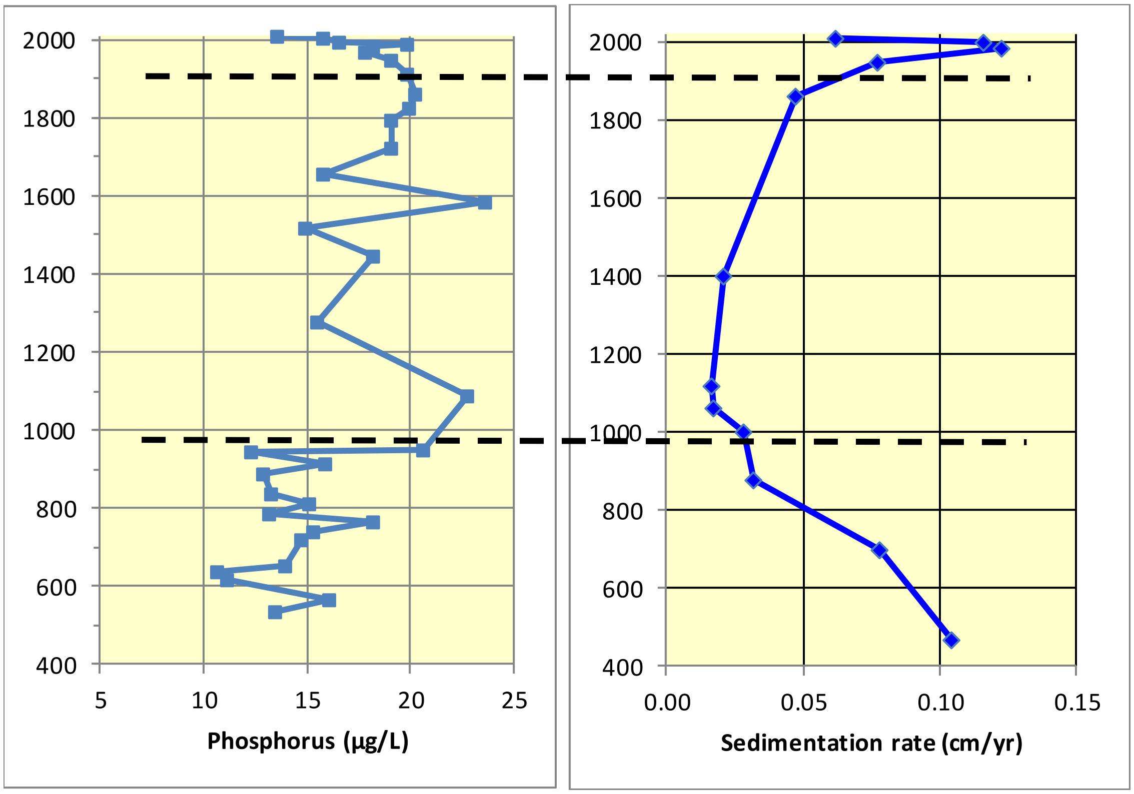

Figure 3.2-8. Profiles of diatom inferred summer phosphorus and the sedimentation rate. Both profiles indicate three distinct periods of the lake's ecology during the last 1500 years. The first and third (present day) periods indicate higher lake levels while the middle period (1000-1900 AD) indicate lake levels lower than at the present time.

Table 3.2-1. Summary of lake condition inferred from the diatom community.

Period	Trends	Mean TP concentration (µg/L)
I	Higher water levels, higher P	17.2
II	Lower water levels, higher P	18.4
III	Higher water levels, Lower P	13.9

The profiles of both sedimentation rate and the diatom community indicate significant changes in Anvil Lake during the last 1500 years. While some of the recent changes are partially the response to shoreland development, climatic changes which have affected lake levels are the dominant driver. The change in phosphorus levels with changing lake levels inferred by the diatom community agree with modeling done (see *Water Quality* section). The Canfield Bachmann model indicates that lower lake levels result in slightly higher phosphorus concentrations. Higher phosphorus concentrations in shallow vs deep lakes is common and is related to internal loading from sediments. Further, shallow lakes tend to keep phosphorus suspended in the water column longer. The modelling also indicates that phosphorus concentrations in Anvil Lake, without inputs from shoreland development, would be about 12 µg/L which is close to what the diatom community estimates for the lake over 1000 years ago.

Although climate is the largest driver of phosphorus levels in Anvil Lake, it is apparent that shoreland development is increasing phosphorus levels in the lake, probably on the order of 2-3 µg/L. If this were not the case, we would expect phosphorus levels at the present time to be more similar to those 1000 years ago. The lesser impact of shoreland development compared with changing lake levels on phosphorus concentrations in Anvil Lake is less than has been observed in other small lakes. Gaillard et al. (1991) found in a study encompassing 3000 years that climate induced lake level fluctuations until significant anthropogenic development occurred in the watershed. This development overshadowed the impact of lake level fluctuations. Likewise, Wolin (1996) found in a lake in Michigan that climate variability controlled lake processes until the arrival of European settlers. In two Wisconsin lakes which experience lake level fluctuations similar to Anvil Lake, shoreland development had a greater impact on phosphorus levels than did changing lake levels.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

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

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmers itch. Development such as rip rap or masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails; this is not desirable for lakes that experience problems with swimmer's itch, as the flatworms that cause this skin reaction utilize snails as a secondary host after waterfowl.

In the end, natural shorelines provide many ecological and other benefits. Between the abundant wildlife, the lush vegetation, and the presence of native flowers, shorelands also provide natural scenic beauty and a sense of tranquility for humans.

Shoreland Zone Regulations

Wisconsin has numerous regulations in place at the state level which aim to enhance and protect shorelands. Additionally, counties, townships and other municipalities have developed their own (often more comprehensive or stronger) policies. At the state level, the following shoreland regulations exist:

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more strict shoreland ordinances. Passed in February of 2010, a revised NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances of their own. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013. These policy regulations require each county a ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. No permit is required for removal of vegetation that meets any of the above criteria. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: New language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods, dependent on the county.

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county's regulations/zoning department.

Wisconsin Act 31

While not directly aimed at regulating shoreland practices, the State of Wisconsin passed Wisconsin Act 31 in 2009 in an effort to minimize watercraft impacts upon shorelines. This act prohibits a person from operating a watercraft (other than personal watercraft) at a speed in excess of slow-no-wake speed within 100 feet of a pier, raft, buoyed area or the shoreline of a lake. Additionally, personal watercraft must abide by slow-no-wake speeds while within 200 feet of these same areas. Act 31 was put into place to reduce wave action upon the sensitive shoreland zone of a lake. The legislation does state that pickup and drop off areas marked with regulatory markers and that are open to personal watercraft operators and motorboats engaged in waterskiing/a similar activity may be exempt from this distance restriction. Additionally, a city, village, town, public inland lake protection and rehabilitation district or town sanitary district may provide an exemption from the 100 foot requirement or may substitute a lesser number of feet.

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland 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 shorelands – 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. Therefore, these studies show us that it is a 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 into 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.

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay et al. 2002). And studies on shoreland development and fish nests show that undeveloped shorelands are preferred as well. In a study conducted on three Minnesota lakes, researchers found that only 74 of 852 black crappie nests were found near shorelines that had any type of dwelling on it (Reed, 2001). The remaining nests were all located along undeveloped shoreland.

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. Coarse woody habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

Photo 3.3-1. Example of coarse woody habitat along a natural lakeshore

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area as well as spawning habitat (Hanchin et al 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon in many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

With development of a lake's shoreland zone, much of the coarse woody habitat that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions due to logging practices. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities (boating, swimming, and, ironically, fishing).

National Lakes Assessment

Unfortunately, along with Wisconsin's lakes, waterbodies within the entire United States have shown to have increasing amounts of developed shorelands. The National Lakes Assessment (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers from all 50 U.S. states in an effort to assess waterbodies, both natural and man-made, from each state. Through this collaborative effort, over 1,000 lakes were sampled in 2007, pooling together the first statistical analysis of the nation's lakes and reservoirs.

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat*".

The results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect and restore lakes. This will become increasingly important as development pressured on lakes continue to steadily grow.

Native Species Enhancement


Photograph 3.3-2. Example of a biolog restoration site.

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 shoreland. 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 shoreland 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 depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq. ft and 2 shrubs/100 sq. ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.

- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreland erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Once native plants are established, they require less water, maintenance, no fertilizer; provide wildlife food and habitat, and natural aesthetics compared to ornamental (non-native) varieties. • 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.

Anvil Lake Shoreland Zone Condition

Shoreland Development

Anvil Lake’s shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, from “Urbanized”, meaning the shoreland zone is completely disturbed by human influence, to “Natural/Undeveloped”, meaning the shoreland has been left in its original state.

Urbanized: This type of shoreland 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 shorelands 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 shoreland 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 shoreland that was restored would likely be included here, also.

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

3.3-1. Shoreland assessment category descriptions.

Photograph 3.3-3. Water levels in Anvil Lake compared to the OHWM at the public access location. (Photo taken on 10-7-2015)

On Anvil Lake, the development stage of the entire shoreland was surveyed during the late summer of 2015 using a GPS unit. Onterra staff only considered the area of shoreland 35 feet inland from the ordinary high water mark (OHWM) and did not assess the shoreland on a property-by-property basis. It is important to note that during the time of the shoreland survey, water levels were considerably lower than the OHWM on Anvil Lake (Photo 3.3-3). The exposed lake-bed between the OHWM and water's edge was not included within the 35 foot shoreland zone for which shoreland categories were assigned (Map 1). During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Anvil Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.2 miles of natural/undeveloped and developed-natural shoreland (66%) were observed during the survey (Figure 3.3-2). 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, 1.1 miles of urbanized and developed–unnatural shoreland (22%) were observed. If restoration of the Anvil Lake shoreland 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 2 displays the location of these shoreland lengths around the entire lake.

Seawalls are often placed on shorelands to protect from erosion caused by wave action. Seawalls however, provide little positive ecological benefits and thus the presence of seawalls was considered in rating shoreland development categories. A total of approximately 0.4 miles or 2,255 feet of seawalls constructed of either rip-rap, masonry or wood was identified on Anvil Lake during the late-summer 2015 survey and are displayed on Map 2.

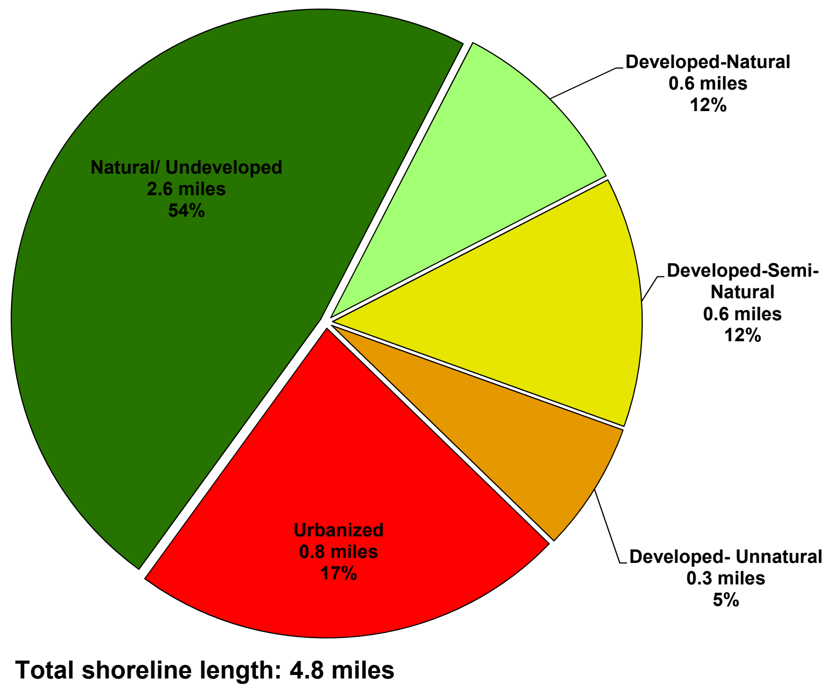

Figure 3.3-2. Anvil Lake shoreland categories and total lengths. Based upon a late summer 2015 survey. Locations of these categorized shorelands can be found on Map 2.

While producing a completely natural shoreland 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. Placing 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. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

Anvil Lake was surveyed in 2015 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter or cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 19 total pieces of coarse woody habitat were observed along 4.4 miles of shoreline (Map 3), which gives Anvil Lake a coarse woody habitat to shoreline mile ratio of 4:1 (Figure 3.3-3). Most if not all of the coarse woody habitat occurrences identified during the survey appeared to be man-made rather than naturally occurring. It is suspected that some pieces of coarse woody habitat that previously extended into the lake no longer reached the water's edge due to the lower water levels observed in the lake in 2015. Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey.

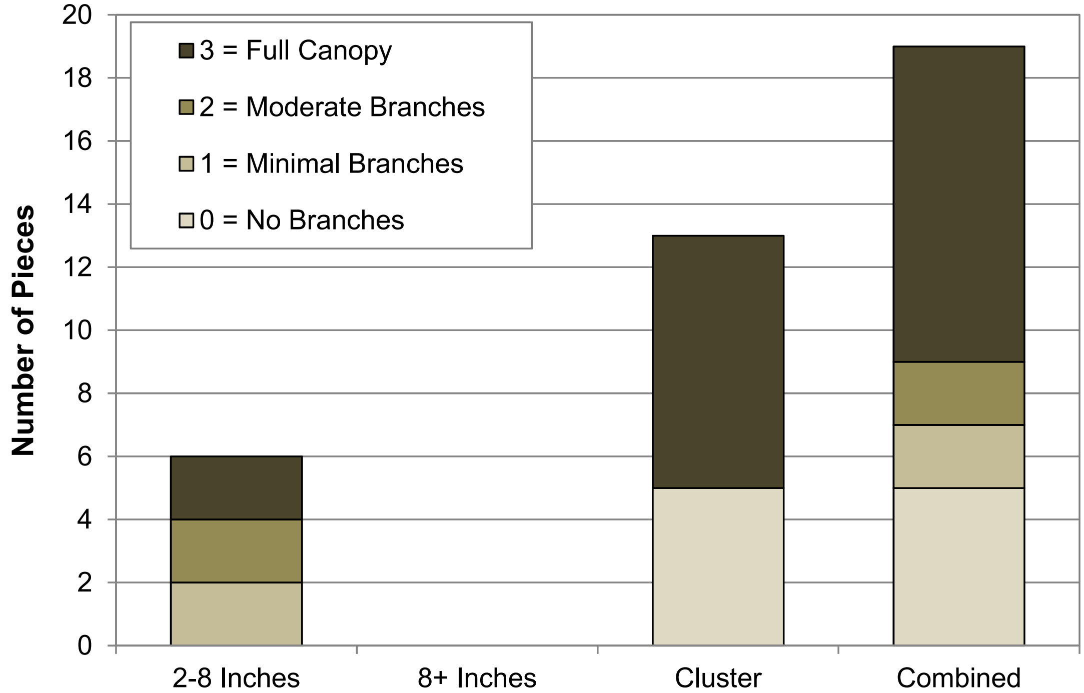

Figure 3.3-3. Anvil Lake coarse woody habitat survey results. Based upon a late summer 2015 survey. Locations of Anvil Lake coarse woody habitat can be found on Map 3.

3.4 Aquatic Plants

Primer on Aquatic Plants

Photo 3.4-1. Example of aquatic plant community. White water lily and pickerelweed shown.

Although the occasional lake user considers aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, these 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 shoreland erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian watermilfoil (*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 Anvil 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 Anvil 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.

Manual Removal

Photo 3.4-2. Nuisance native aquatic plants. Southern naiad (*Najas guadalupensis*) after being raked from a shoreline.

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. Please note that depending on the size of the screen a Wisconsin Department of Natural Resources permit may be required.

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 watermilfoil 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 effects 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 and reed canary grass. • Permitting process may require an environmental assessment that may take months to prepare. • Non-selective.

Mechanical Harvesting


Photo 3.4-3. Mechanical harvester.

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.

Cost

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.

Herbicide Treatment

Photograph 3.4-4. Herbicide applicator. Applying granular herbicides with a gravity-fed dispersion method.

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially-targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Treatments occurring roughly each year before June 1 and/or when water temperatures are below 60°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides and an extensive list can be found in the Appendix of Gettys et al. (2009).

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.

Aquatic herbicides can be classified in many ways. Organization of this section follows Netherland (2009) in which mode of action (i.e. how the herbicide works) and application techniques (i.e. foliar or submersed treatment) group the aquatic herbicides. The table below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

The arguably clearest division amongst aquatic herbicides is their general mode of action and fall into two basic categories:

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 in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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.

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 and 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. Much information has been gathered in recent years, largely as a result of an ongoing cooperative research project between the Wisconsin Department of Natural Resources, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra). This research couples quantitative aquatic plant monitoring with field-collected herbicide concentration data to evaluate efficacy and selectivity of control strategies implemented on a subset of Wisconsin lakes and flowages. Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) whole-lake treatments, and 2). spot treatments.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant affects outside of that area. Spot treatments typically rely on a short exposure time (often hours) to cause mortality and therefore are applied at a much higher herbicide concentration than whole-lake treatments. This has been the strategy historically used on most Wisconsin systems.

Whole-lake treatments are those where the herbicide is applied to specific sites, but when the herbicide reaches equilibrium within the entire volume of water (entire lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire lake or basin. The application rate of a whole-lake treatment is dictated by the volume of water in which the herbicide will reach equilibrium. Because exposure time is so much longer, target herbicide levels for whole-lake treatments are significantly less than for spot treatments.

Cost

Herbicide application charges vary greatly between $400 and $1,500 per acre depending on the chemical used, who applies it, permitting procedures, and the size/depth of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • 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 watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • 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 aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

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.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil 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 watermilfoil 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 watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

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 watermilfoil 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, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergent or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. 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 Anvil 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 Anvil Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity 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.

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

> A 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.

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 Anvil 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.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreland. 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 shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland 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 shoreland 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 shoreland 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 Anvil Lake will be compared to lakes in the same ecoregion and in the state. Ecoregional and state-wide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

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

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values.

For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plan surveys.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible and these plants were not mapped in Anvil Lake.

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 watermilfoil are the primary targets of this extra attention.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian watermilfoil 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 watermilfoil 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 watermilfoil 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.

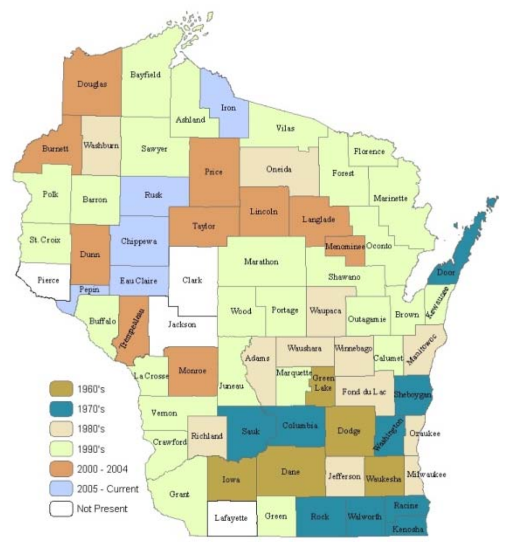

Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 watermilfoil, 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 watermilfoil 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

> The **Littoral Zone** is the area of a lake where adequate sunlight is able to penetrate down to the sediment and support aquatic plant growth.

As mentioned earlier, numerous plant surveys were completed as a part of this project. During the 2015 aquatic plant surveys on Anvil Lake, at total of 34 aquatic plant species were located; two of these, Eurasian watermilfoil and curly-leaf pondweed, are considered to be non-native, invasive species (Table 3.4-2). Given their ecological, economical, and sociological significance, the Eurasian watermilfoil and curly-leaf pondweed populations in Anvil Lake will be discussed the following *Non-Native Aquatic Plants* Section. The majority of the aquatic plants located in Anvil Lake were recorded during the whole-lake point-intercept and community mapping surveys completed by Onterra on July 28 and 29, 2015. Whole-lake point-intercept surveys were also completed on Anvil Lake by the WDNR in 2010 and 2012, and the data collected 2010, 2012, and 2015 were compared to ascertain if any changes in Anvil Lake's aquatic plant community have occurred over this time.

Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. In June of 2014, Onterra ecologists completed an acoustic survey on Anvil Lake (bathymetric results shown on Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. While the primary goal of this survey was to locate potential occurrences of EWM and/or CLP growing in water too deep to be visible from the surface (reported on within 2014 *AIS Monitoring & Control Strategy Assessment Report*), data pertaining to Anvil Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2014 acoustic survey reveals that Anvil Lake's average substrate hardness ranges from hard to moderately hard with few areas containing soft, flocculent sediments (Figure 3.4-2). Substrate hardness is highest within the shallowest areas of Anvil Lake, and between one and ten feet, hardness declines relatively rapidly with depth. From ten and deeper, substrate hardness remains relatively constant. Figure 3.4-3 illustrates the spatial distribution of substrate hardness in Anvil Lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

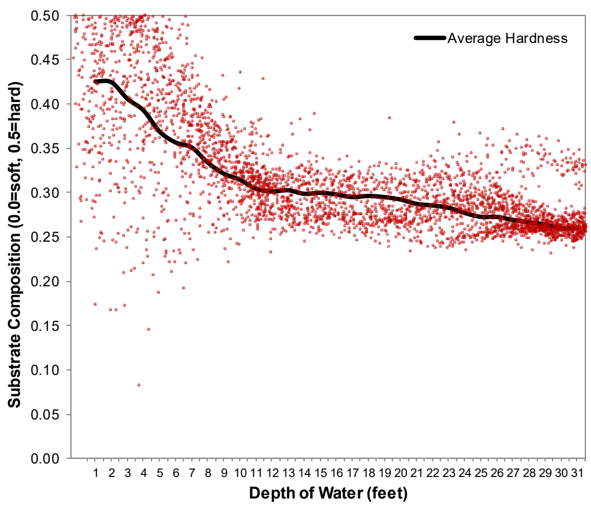

Figure 3.4-2. Anvil Lake substrate hardness across water depth. Individual data points are displayed in red. Creating using data from June 2014 acoustic survey.

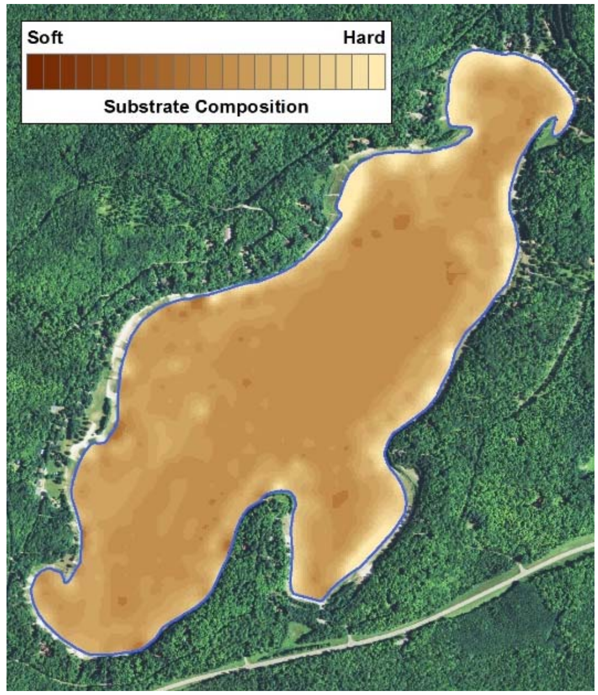

Figure 3.4-3. Anvil Lake substrate hardness. Created using data from June 2014 acoustic survey.

Table 3.4-1. Aquatic plant species located in Anvil Lake during WDNR 2010, WDNR 2012, and Onterra 2015 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2010 WDNR	2012 WDNR	2015 Onterra
Emergent	*Carex lasiocarpa*	Narrow-leaved woolly sedge	9			I
	Carex utriculata	Common yellow lake sedge	7			I
	Eleocharis palustris	Creeping spikerush	6		X	X
	Iris versicolor	Northern blue flag	5			I
	Juncus effusus	Soft rush	4			I
	Pontederia cordata	Pickerelweed	9		X	I
	Sagittaria latifolia	Common arrowhead	3	X		I
	Schoenoplectus acutus	Hardstem bulrush	5			I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		X	I
	Scirpus cyperinus	Wool grass	4			I
	Typha spp.	Cattail spp.	1		X	I
FL	*Nuphar variegata*	Spatterdock	6			I
	Nymphaea odorata	White water lily	6			I
	Persicaria amphibia	Water smartweed	5			I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X		X
	Sparganium natans	Little bur-reed	9		X	
Submergent	*Chara* spp.	Muskgrasses	7	X	X	X
	Elatine minima	Waterwort	9	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	
	Elodea nuttallii	Slender waterweed	7	X	X	X
	Eriocaulon aquaticum	Pipewort	9			X
	Isoetes spp.	Quillwort spp.	8	X	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic/Invasive		X	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X	X	X
	Najas gracillima	Northern naiad	7	X		
	Nitella spp.	Stoneworts	7	X	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X
	Potamogeton berchtoldii	Slender pondweed	7	X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic/Invasive			X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X	X
	Potamogeton gramineus	Variable-leaf pondweed	7			X
	Potamogeton natans	Floating-leaf pondweed	5		I	
	Potamogeton spirillus	Spiral-fruited pondweed	8	X		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X		X
	Ranunculus flammula	Creeping spearwort	9			X
	Vallisneria americana	Wild celery	6	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X	X
	Juncus pelocarpus	Brown-fruited rush	8	X	X	X
	Sagittaria cristata	Crested arrowhead	9		X	

FL = Floating-leaf; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidentally located
** Listed as a native 'species of special concern' in Wisconsin due to rarity and/or uncertainty regarding state-wide population*

While the 2014 acoustic survey on Anvil Lake also recorded data pertaining to the location and density of aquatic plants within the lake, the plants were likely not at or near their peak growth stage during this early-summer survey. To obtain a more representative picture of Anvil Lake's aquatic plant community at peak growth, a second acoustic survey was completed by Onterra on Anvil Lake in July of 2015. This survey recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants.

The 2015 aquatic plant bio-volume data are displayed in Figure 3.4-4. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2015 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 28 feet; however, the acoustic data indicate that aquatic plant growth quickly diminishes and is sparse beyond 20 feet. The tallest aquatic plants in Anvil Lake, with an average height of around 2.5 feet, are found between 8-10 feet of water, likely where there is a combination of optimal substrate type and light availability. Overall, the 2015 acoustic survey indicates that approximately 32% of Anvil Lake, or 114 acres of the lake contains aquatic vegetation (Figure 3.4-4). The remaining area of the lake is too deep to support aquatic plant growth. The highest aquatic plant bio-volume was recorded in within the northern bay; however, overall bio-volume lake-wide is relatively low.

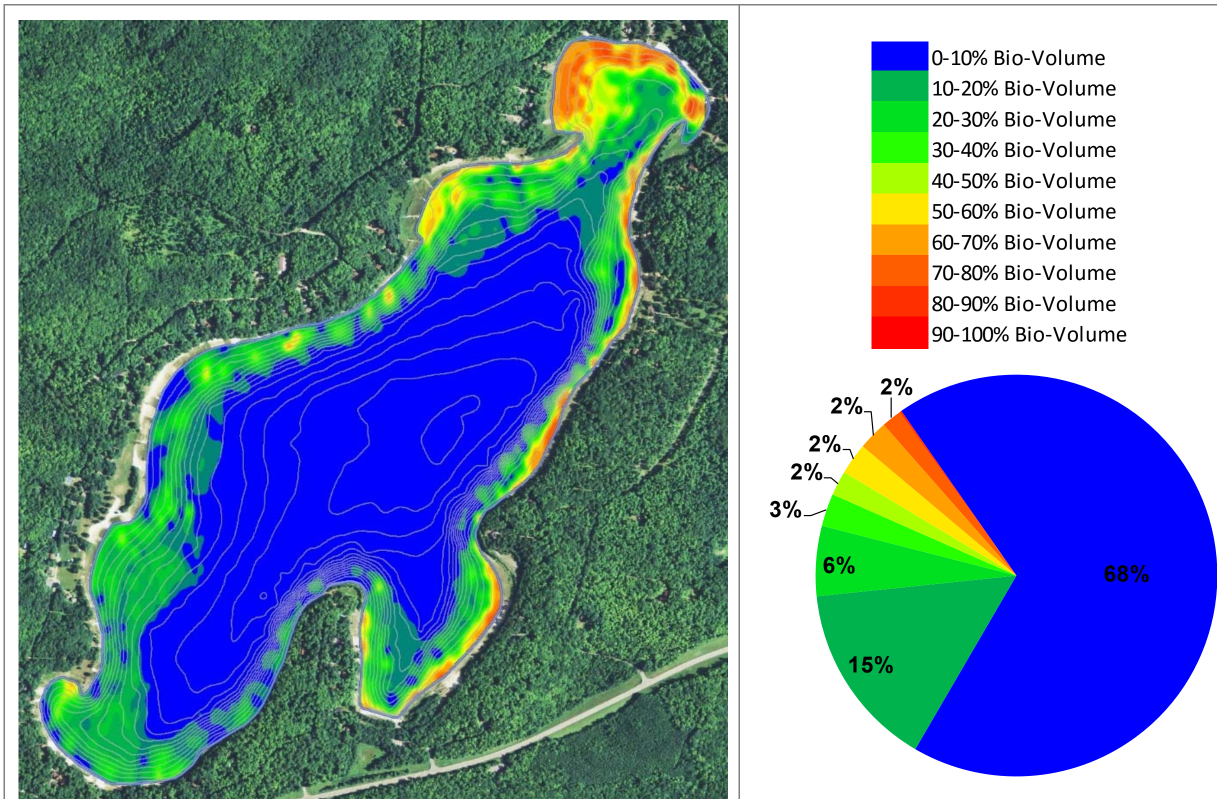

Figure 3.4-4. Anvil Lake 2015 aquatic plant bio-volume. Created using data from July 2015 acoustic survey data. Contour lines represent two-foot increments.

While the acoustic mapping is an excellent survey for quantifying the levels of aquatic plant growth throughout the lake, this survey does not differentiate aquatic plant species. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. During the 2015 whole-lake point-intercept survey, 21 aquatic plant species were physically encountered on the rake (Figure 3.4-5). Of these 21 species, muskgrasses, slender waterweed, and wild celery were the three-most frequently encountered.

Muskgrasses, the most abundant aquatic plants in Anvil Lake with a littoral frequency of occurrence of approximately 39%, are a group of macroalgae of which there are several species in Wisconsin. While they are not vascular plants, muskgrasses still grow to a considerable size and form large, dense beds along the lake bottom where the supply oxygen to deeper waters and provide structural habitat for aquatic invertebrates and fish. Studies have also shown that these plants stabilize bottom sediments and improve water quality by removing nutrients to the water that would otherwise be available to algae.

The second-most frequently encountered aquatic plant in Anvil Lake in 2015 was slender waterweed (Figure 3.4-5). A close relative of common waterweed, slender waterweed possesses long stems with whorls of many leaves and provides beneficial habitat and acts as a food source for aquatic wildlife. Slender waterweed is more often found in less productive lakes like Anvil Lake, and is an indicator of good water quality.

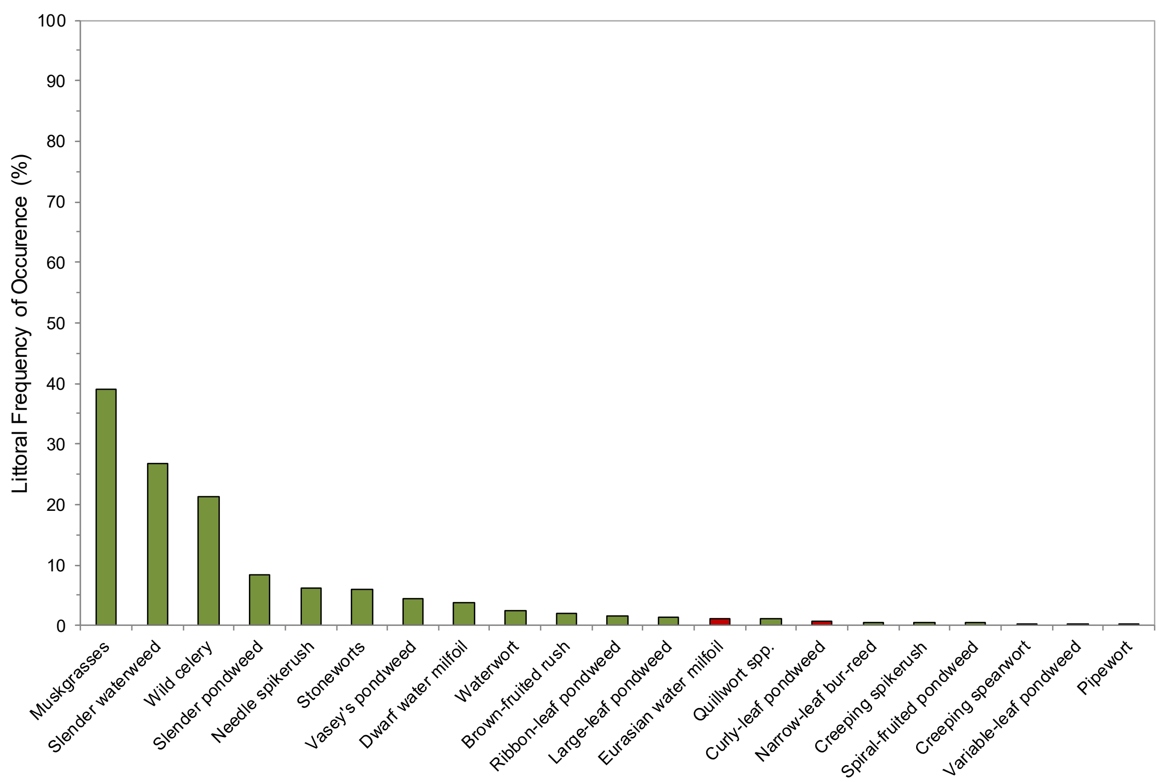

Figure 3.4-5. Anvil Lake 2015 littoral frequency of occurrence of aquatic plant species. Created using data from July 2015 point-intercept survey (N = 755). Non-native plants indicated with red.

Wild celery, also known as tape or eel grass, was the third-most common native species encountered during the 2015 point-intercept survey on Anvil Lake (Figure 3.4-5). Wild celery has long, slender leaves which emerge from a basal rosette. These long leaves provide excellent habitat for aquatic wildlife, and its deep and extensive root systems stabilize bottom sediments. In addition, wild celery produces a banana-like pod full of seeds later in the summer which provide food for migratory waterfowl and other wildlife.

One aquatic plant species located in 2010 and 2015, Vasey's pondweed (*Potamogeton vaseyi* – Photo 3.4-5), is listed as special concern in Wisconsin by the Natural Heritage Inventory due to uncertainty regarding its population and rarity in the state (WDNR PUBL-ER-001 2014). It is one of a number of narrow-leaf pondweeds in Wisconsin, and possesses long, narrow submersed leaves and small round floating leaves. It was located at approximately 4% of the littoral sampling locations in 2015, and its presence in Anvil Lake is an indication of high-quality environmental conditions.

Photo 3.4-5. Vasey's pondweed (*Potamogeton vaseyi*). A native species found in Anvil Lake that is listed as special concern in Wisconsin.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 3.4-6). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

Photo 3.4-6. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 3.4-6). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-watermilfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern watermilfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Anvil Lake (~16 mg/L as $CaCO_3$), the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

In the summer of 2010 and 2012, the WDNR conducted a whole-lake point-intercept surveys on Anvil Lake using the same sampling locations and methodology that were used in 2015. The data collected from these three surveys can be statistically compared to determine if any significant changes in Anvil Lake's plant community have occurred over this time period. Figure 3.4-6 displays the littoral frequency of occurrence of aquatic plant species from the 2010, 2012, and 2015 point-intercept surveys. Only the species that had at least an occurrence of 4% were included in the analysis. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of muskgrasses and stoneworts and the occurrences of common and slender waterweeds were combined for this analysis.

The littoral occurrence of muskgrasses and stoneworts has declined by a statistically valid 21% since 2010, declining from an occurrence of 57% in 2010 to 45% in 2015 (Figure 3.4-6). The littoral occurrence of common and slender waterweeds exhibited statistically valid reductions in their occurrence from 2010 to 2012, followed by a statistically valid increase in occurrence in 2015. Wild celery and needle spikerush saw slight reductions in their occurrence in 2015 when compared to 2010 and 2012. Slender pondweed increased from 2010 to 2012 and declined again from 2012 to 2015. Vasey's pondweed was not recorded during the 2012 survey, but was found at a similar occurrence in 2015 to its occurrence in 2010. Overall, the occurrence of aquatic vegetation in Anvil Lake has declined from 2010 to 2015, with an occurrence of 70% in 2010, 66% in 2012, and 56% in 2015.

However, the perceived decline in the occurrence of vegetation in Anvil Lake from 2010 to 2015 is likely due to differences in the maximum depth of plant growth recorded in these years. The maximum depth of plant growth was 24, 25, and 28 feet in 2010, 2012, and 2015, respectively. This difference in the maximum depth of aquatic plant growth results in a differing number of littoral sampling points; 601 in 2010, 661 in 2012, and 755 in 2015. Looking solely at the number of sampling locations that contained aquatic vegetation indicates relatively similar results. In 2010, 420 locations contained aquatic vegetation, compared to 437 in 2012 and 423 in 2015.

Aquatic plant communities are dynamic, and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, and disease among other factors. It is not known which factor(s) caused the detected changes in occurrence of the aquatic plants species previously discussed between 2010 and 2015. However, these changes were relatively small and not of concern as they likely represent fluctuations driven by natural variations in environmental conditions. A large reduction in occurrence or a complete loss of a certain species would be cause for concern as that may indicate an environmental disturbance.

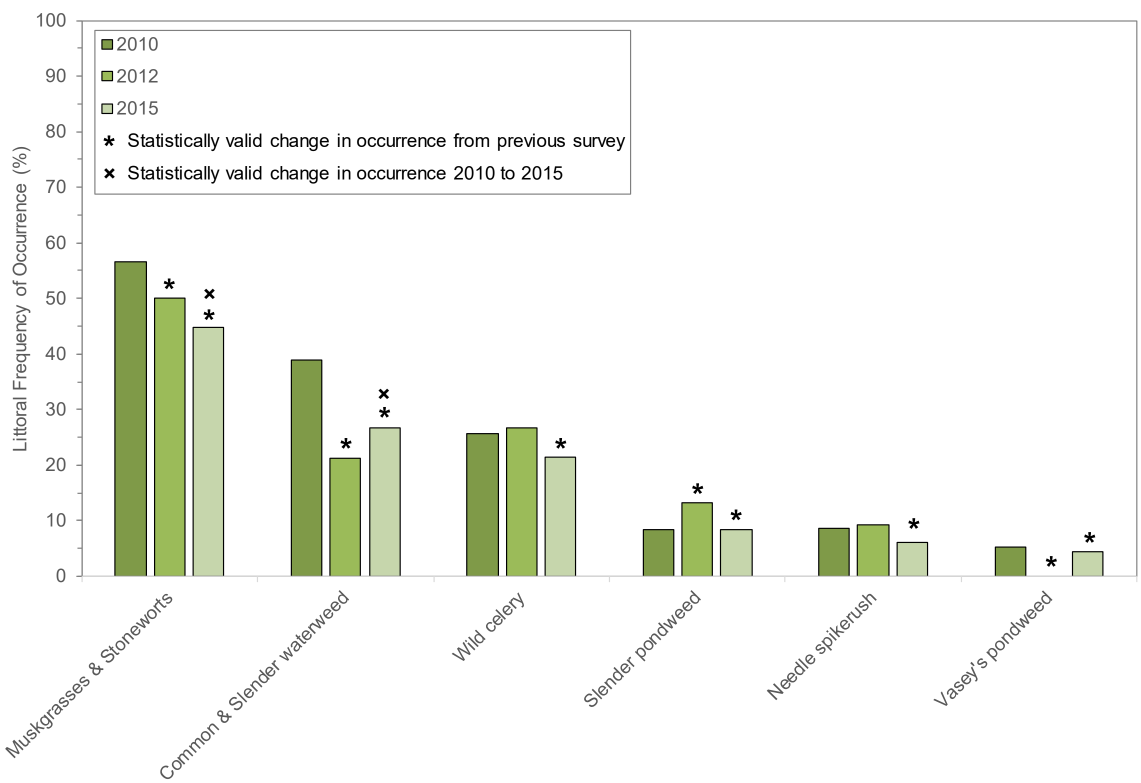

Figure 3.4-6. Anvil Lake littoral frequency of occurrence of select aquatic plant species from WDNR 2010, WDNR 2012, and Onterra 2015 point-intercept surveys. Species with an occurrence of at least 4% in either survey are displayed. Created using data from WDNR 2010 and 2012 and Onterra 2015 point-intercept surveys.

As discussed in the primer section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The native species encountered on the rake during the 2010, 2012, and 2015 point-intercept surveys and their conservatism values were used to calculate the FQI of Anvil Lake's aquatic plant community (equation shown below).

$$FQI = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

Figure 3.4-7 compares the 2010, 2012, and 2015 FQI components of Anvil Lake to median values of lakes within the Northern Lakes and Forests (NLF) ecoregion and lakes throughout Wisconsin. The number of native aquatic plant species encountered on the rake, or native species richness, was the same in 2010, 2012 and 2015 at 19 species. Anvil Lake's species richness falls slightly below the median value for lakes within the NLF ecoregion but is equal to the median value for lakes throughout Wisconsin. Anvil Lake is relatively small and has a lower shoreline complexity value of 2.8, meaning that the lake has a lower ratio of shoreline perimeter relative to its area. Lakes with higher shoreline complexity generally have higher species richness given the higher variance in habitat types. In addition, species richness also tends to increase with lake area. However, despite being a smaller lake with lower shoreline complexity, Anvil Lake's species richness is still relatively high.

While native species richness was the same between the 2010, 2012, and 2015 surveys, average conservatism was higher in 2010 and 2015 when compared to 2012. This increase in average conservatism was the result of the presence of species with higher conservatism values being recorded in 2010 and 2015 that were not recorded in 2012. These species include: creeping spearwort (C = 9), pipewort (C = 9), variable pondweed (C = 7), spiral-fruited pondweed (C = 8), Vasey's pondweed (C = 10), and narrow-leaf bur-reed (C = 9). These species were likely present in Anvil Lake in 2012, and their absence may indicate differences in ability and experience among the surveyors. Anvil Lake's 2015 average conservatism is higher than the median values for lakes within the NLF ecoregion and lakes throughout the state.

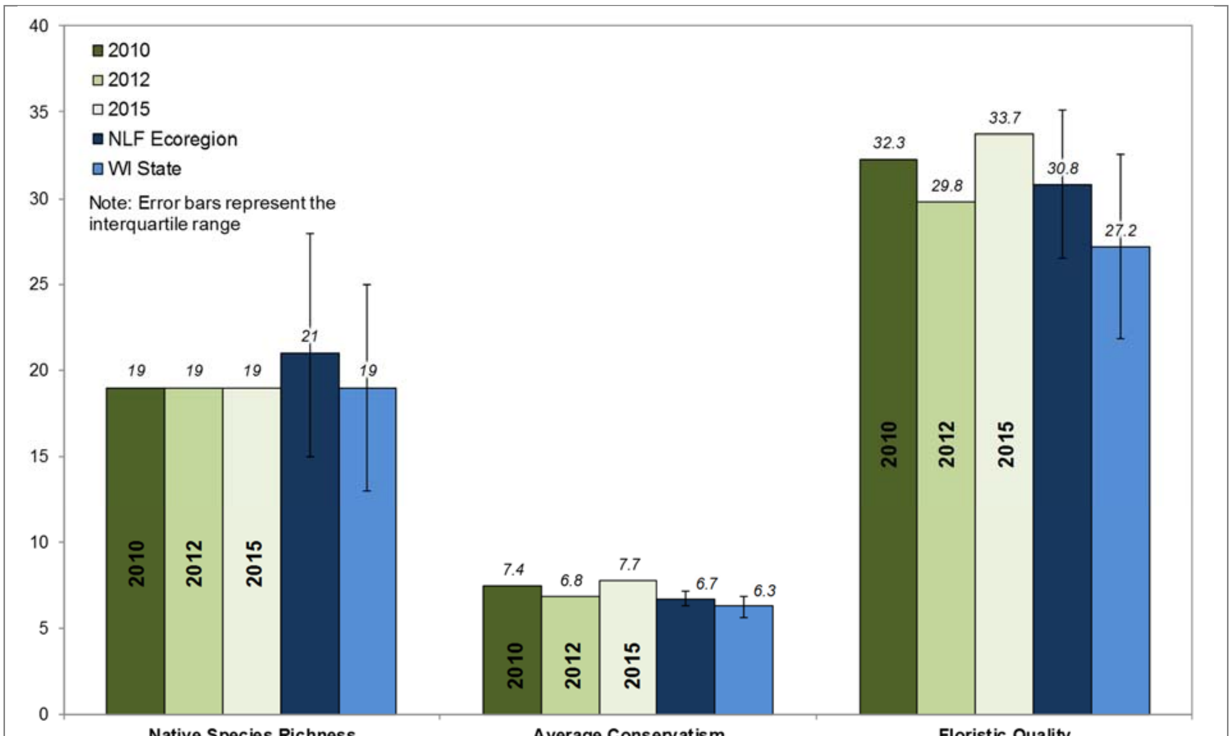

Figure 3.4-7. Anvil Lake Floristic Quality Assessment. Created using data from WDNR 2010, WDNR 2012, and Onterra 2015 point-intercept surveys. Analysis follows Nichols (1999).

Combining the native species richness and average conservatism values for the 2010, 2012, and 2015 yields high FQI values of 32.3, 29.8, and 33.7, respectively (Figure 3.4-7). The 2015 FQA value for Anvil Lake exceeds the median values for both lakes within the NLF ecoregion and the state, and is an indication that Anvil Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the state.

As explained earlier, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Anvil Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Anvil Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF Ecoregion (Figure 3.4-8). Using the data collected from the 2010, 2012, and 2015 point-intercept surveys, Anvil Lake's aquatic plant community was shown to have lower species diversity with values of 0.78, 0.81, and 0.82 in 2010, 2012, and 2015, respectively. In other words, if two individual aquatic plants were randomly sampled from Anvil Lake in 2015, there would be an 82% probability that they would be different species. And while this may seem high, these values fall below the lower quartile for lakes within the NLF ecoregion and below the median value for lakes state-wide.

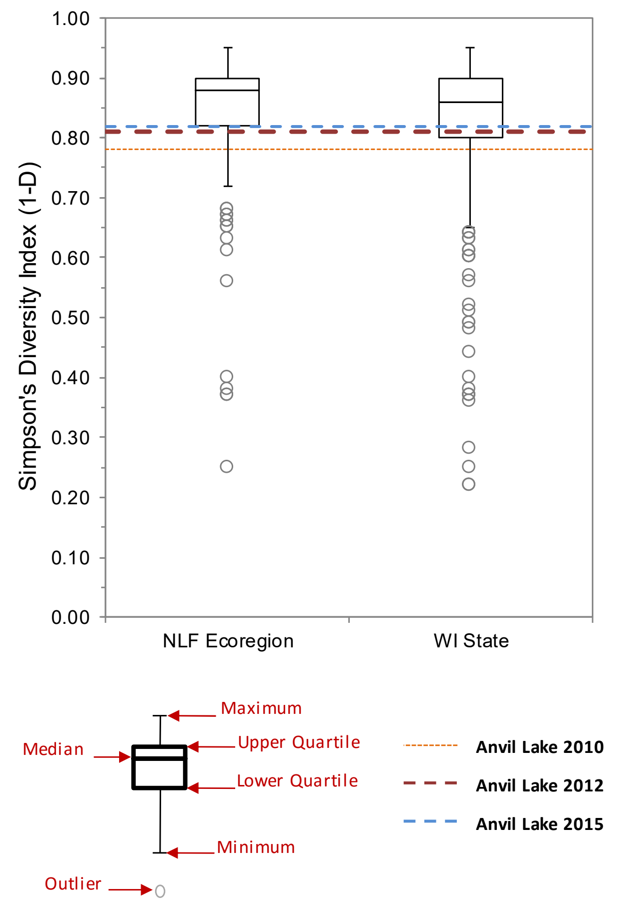

Figure 3.4-8. Anvil Lake species diversity index. Created using data from WDNR 2010, WDNR 2012, and Onterra 2015 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

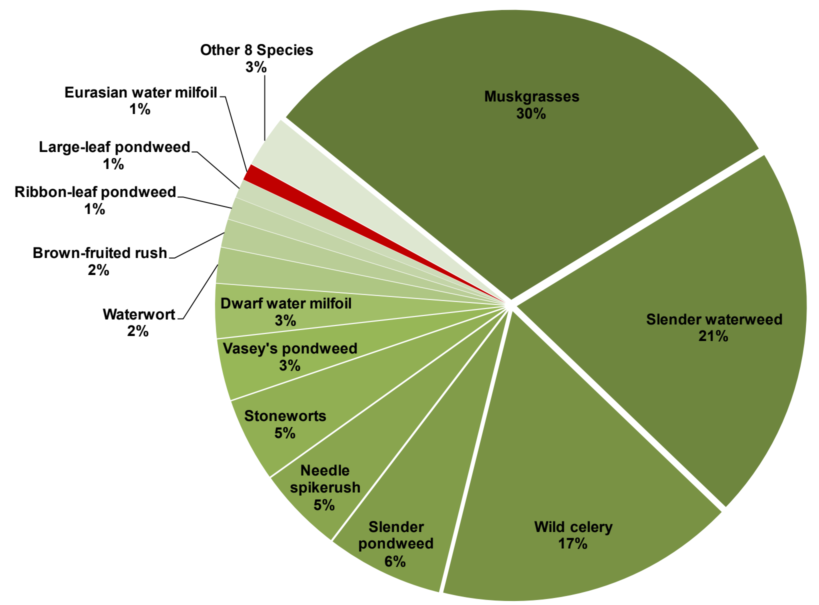

Figure 3.4-9. Anvil Lake 2015 relative frequency of occurrence of aquatic plant species. Created using data from 2015 point-intercept survey. Non-native species indicated with red.

Anvil Lake's lower species diversity is a result of the species not having relatively even distributions within the community. Just three plants, Muskgrasses, slender waterweed, and wild celery comprise 68% of the aquatic plant community (Figure 3.4-9). Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while muskgrasses were found at 39% of the littoral sampling locations in Anvil Lake in 2015, their relative frequency of occurrence is 30%. Explained another way, if 100 plants were randomly sampled from Anvil Lake, 30 of them would be muskgrasses. Figure 3.4-9 displays the relative occurrence of aquatic plant species in Anvil Lake in 2015, and illustrates the uneven distribution of species within the community.

As mentioned, Onterra ecologists also conducted an aquatic plant community mapping survey in 2015 aimed at mapping communities of emergent and floating-leaf vegetation. During this survey, 15 emergent and floating-leaf aquatic plant species were located (Table 3.4-2). This survey also revealed that Anvil Lake contains approximately 7.3 acres emergent and floating-leaf aquatic plant communities dominated by native species (Map 4). The native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines.

Table 3.4-2. Anvil Lake 2015 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2015 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	4.0
Floating-leaf	3.3
Mixed Emergent & Floating-leaf	0.0
Total	**7.3**

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Anvil Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Non-native Aquatic Plants in Anvil Lake

Curly Leaf Pondweed (CLP)

Curly-leaf pondweed (*Potamogeton crispus*; CLP) 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. The plants begin growing almost immediately after, if not immediately before, ice-out and by early-summer they reach their peak growth. As they are growing, each plant produces numerous turions (asexual reproductive structures) which break away from the plant and settle to the bottom following the plant's senescence. The deposited turions lie dormant until autumn when they sprout to produce small winter foliage, and they remain in this state until spring foliage is produced. The advanced growth in spring gives the plant a significant jump on native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition. However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance.

Curly-leaf pondweed was first encountered in Anvil Lake during a July 2013 survey by Onterra. This lone occurrence consisting of a few plants were identified and removed by ALA members during the summer of 2013. Several low density CLP occurrences were located in the northern bay during 2014. The June 2015 survey indicated a relatively small, but increasing CLP population within Anvil Lake with several *small plant colonies*, *clumps of plants* and *single or few plants* located in the North Bay as well as two *small plant colonies* near the southwestern bay and a *clump of plants* along the eastern shore of the lake. The June 2016 survey revealed new locations of CLP within North Bay with few *clumps of plants* and *small plant colonies* and several scattered *single or few plants* as well as *clumps of plants* and *single or few plants* on the eastern shore and *single or few plants* near the southwestern bay (Map 5). In light of the recent increasing CLP population within the lake, this species should be closely monitored in 2017 and beyond as the potential need for control activities may arise. The CLP population will be mapped in a June 2017 survey, the results of which may be utilized to formulate a control strategy if warranted.

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first discovered in Anvil Lake in July of 2012 by the Great Lakes Indian Fish & Wildlife Commission (GLIFWC). The WDNR was alerted of GLIFWC's findings and proceeded to complete a point-intercept survey which confirmed additional EWM in the northern bay (North Bay). Onterra, LLC was then contacted by the Anvil Lake Association (ALA) and a EWM peak-biomass survey was completed in August of 2012 with the assistance of the volunteer EWM locations provided by the ALA. Volunteer- and professional-based hand-harvesting activities have taken place on Anvil Lake from 2013 to present. Details of the control and monitoring activities were fully reported on within each years' annual *AIS Monitoring & Control Strategy Assessment Report*.

The August 2016 survey indicated an expanding EWM population with an increase in *dominant* colonies and new occurrences of *highly dominant* and *surface matting* colonies (Figure 3.4-10).

The first EWM survey conducted by Onterra in August 2012 indicated that EWM was very sparse within North Bay, consisting of widely-scattered *single or few plants* and *clumps of plants* (Map 6). In September 2013 EWM was found to have increased in this region with numerous *single or few plants* and *clumps of plants*. During both these years, EWM was only mapped using point-based methodologies with no polygon-based colonies being mapped on the lake. Therefore, the acreage of mapped colonies from 2013 and 2014 was zero acres (Figure 3.4-10).

The 2014 EWM peak-biomass survey indicated the EWM increased to consist of colonized EWM and scattered *single or few plants* and *clumps of plants*. The colonized EWM was comprised of *highly scattered*, *scattered*, and *dominant* colonies. Approximately 6.9 acres of EWM, all located in the North Bay, were mapped in 2014.

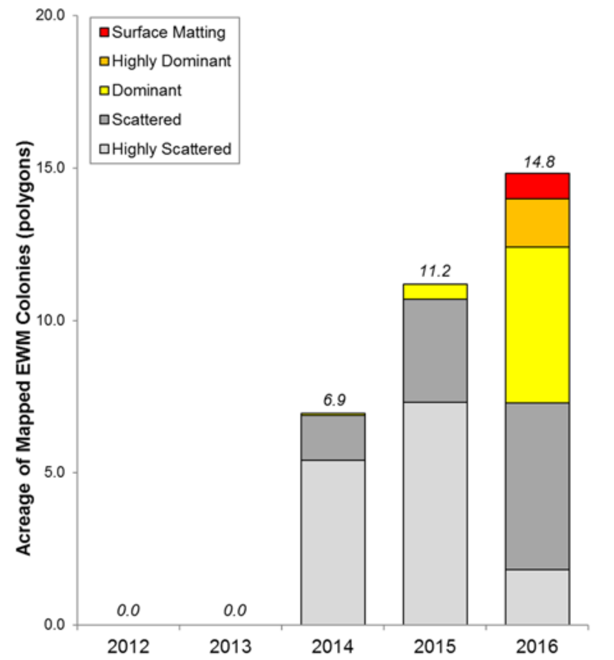

Figure 3.4-10. Anvil Lake comparison of colonized EWM from 2012 to 2016. Created using data from Onterra EWM peak-biomass surveys.

The 2015 EWM survey revealed the *highly scattered*, *scattered*, and *dominant* EWM colonies had approximately doubled in acreage (Figure 3.4-10). The 2016 survey again indicated an increase in both colonized EWM and point-based EWM (Map 7). While the increase in acreage was not all that significant because it is limited by the actual acreage of the bay itself, the increase in density of the EWM within the colonies was great. Point-based EWM in North Bay increased to include *single or few plants*, *clumps of plants*, and *small plant colonies*. Due to declines in water clarity during the late-summer 2016 survey, much of the point-based data within and adjacent to North Bay was discovered using a submersible camera and were not visible from the water's surface.

Following the increase in colonized EWM in North Bay, Onterra volunteered to conduct a subset point-intercept survey within North Bay in September 2016. During the survey 61 sites were visited (Figure 3.4-11). The subset point-intercept sites were extracted from past point-intercept surveys conducted by the WDNR and Onterra to compare the littoral frequency of occurrence of EWM in North Bay. Of the 61 sites sampled in 2016, 35 contained EWM resulting in a 57.4% littoral frequency (Figure 3.4-12) and result in at least 4.6% lake-wide.

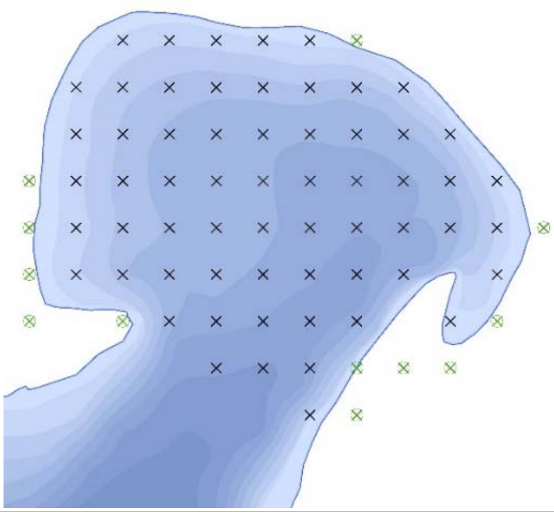

Figure 3.4-11. Anvil Lake subset point-intercept survey sample locations. Black points represent 61 sampled locations, green points represent terrestrial points not sampled.

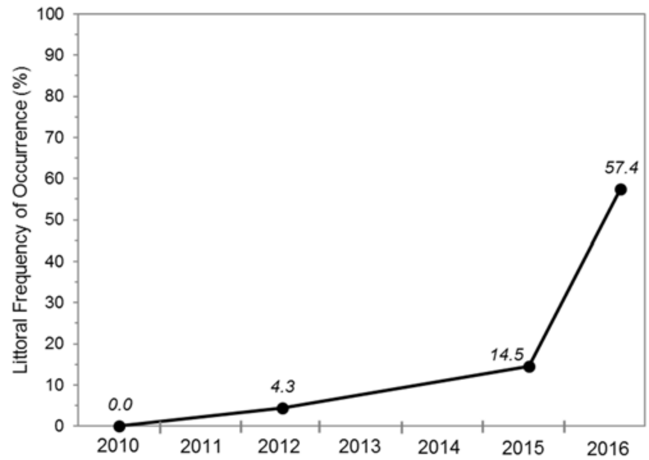

Figure 3.4-12. Anvil Lake EWM littoral frequency of occurrence in North Bay. Created using data from WDNR 2010, WDNR 2012, Onterra 2015, and Onterra 2016 point-intercept surveys.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. Because the state of Wisconsin's waters are managed for multiple uses (Statue 281.11), it is important to understand if EWM populations would increase and cause either; 1) ecological impacts to the lake and/or 2) reductions in ecosystem services (i.e. navigation, recreation, aesthetics, etc.) to lake users. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes is not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.4-13). Some lakes, such as Hancock Lake, maintained low EWM populations following initial detection (first documented in 2006). At these low levels, there are likely no observable ecological impacts to the lake and are no reductions in ecosystem services to lake users. The EWM population of Hancock Lake has increased in recent years to 11% in 2016, 10 years following initial detection

EWM populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake trended to almost 25% only to decline to approximately 5% by the end of the study period. There are many factors that could contribute to the decline in the EWM population of these lakes, including climactic conditions and water quality parameters. Little Bearskin is known to contain a robust population of milfoil weevils and this native insect may be having an impact on the EWM population within the lake. Boot Lake is a eutrophic system with low water clarity (approx. 3-ft Secchi depth) due to naturally high phosphorus concentrations. It is hypothesized that water clarity conditions in some years may favor EWM growth whereas keep the population suppressed in other years.

Extreme changes in EWM populations like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before spiking above 50% in 2012. Then the population declined back to approximately 15% in 2014 and down to 7.5% in 2015 and 2016.

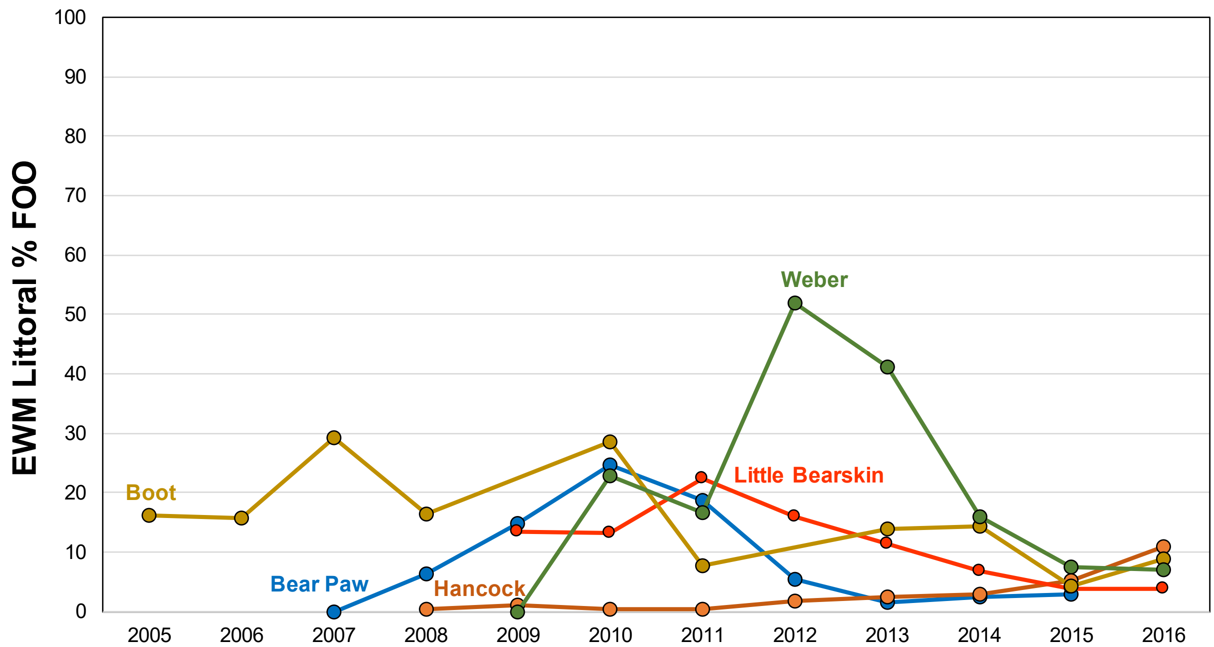

Figure 3.4-13. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Some lake managers interpret the Science Service's data to suggest that in some circumstances, it is not appropriate to manage the EWM population as in some years the population may become less. However, even a lowered EWM population of approximately 10% exceeds the comfort level of many riparians because it is potentially approaching a level than can be impactful to the function of the lake as well as not allowing the lake to be enjoyed by riparians as it had been historically.

While it appears that the EWM population outside of the North Bay of Anvil Lake may be slow to increase (more like Hancock Lake), the population within the North Bay clearly has greatly increased and is currently at 56% of the littoral zone of the bay (2016 PI sub-set survey) and at least 4.6% lake-wide.

Some lake groups chose to manage the EWM population to keep it at an artificially lowered level. Following detection of an EWM population within a lake, it is common for a lake group to initiate management activities and not wait to see if the EWM population will become a problem in their lake. In other instances, the management strategy is simply to maintain a lower level population of EWM for the purposes of allowing the ecosystem to function as it had before the exotic was introduced to the lake. And yet other lakes are managed simply to alleviate the lost ecosystem services, most notably to manage for multiple human uses. As discussed within the Primer sub-section (pages 45-54), there are a number of different management techniques used for controlling EWM with the most commonly implemented being hand-harvesting and herbicide control.

Following EWM detection on Anvil Lake, professional and volunteer hand-harvesting was determined to be the appropriate initial control strategy. In many lakes, this method is able to slow the spread and population of EWM throughout the lake and may even be able to cause a decline in the EWM population where the activities were conducted. But in other lakes, the EWM population progression is too great for the method to provide effective lake-wide control. Continuing the hand-harvesting efforts on these lakes may be able to provide localized EWM reductions where the control strategy is applied and reduce that specific colony from contributing to the overall population increase to the lake. These efforts may also reduce recreational impediments that are caused by dense EWM colonies.

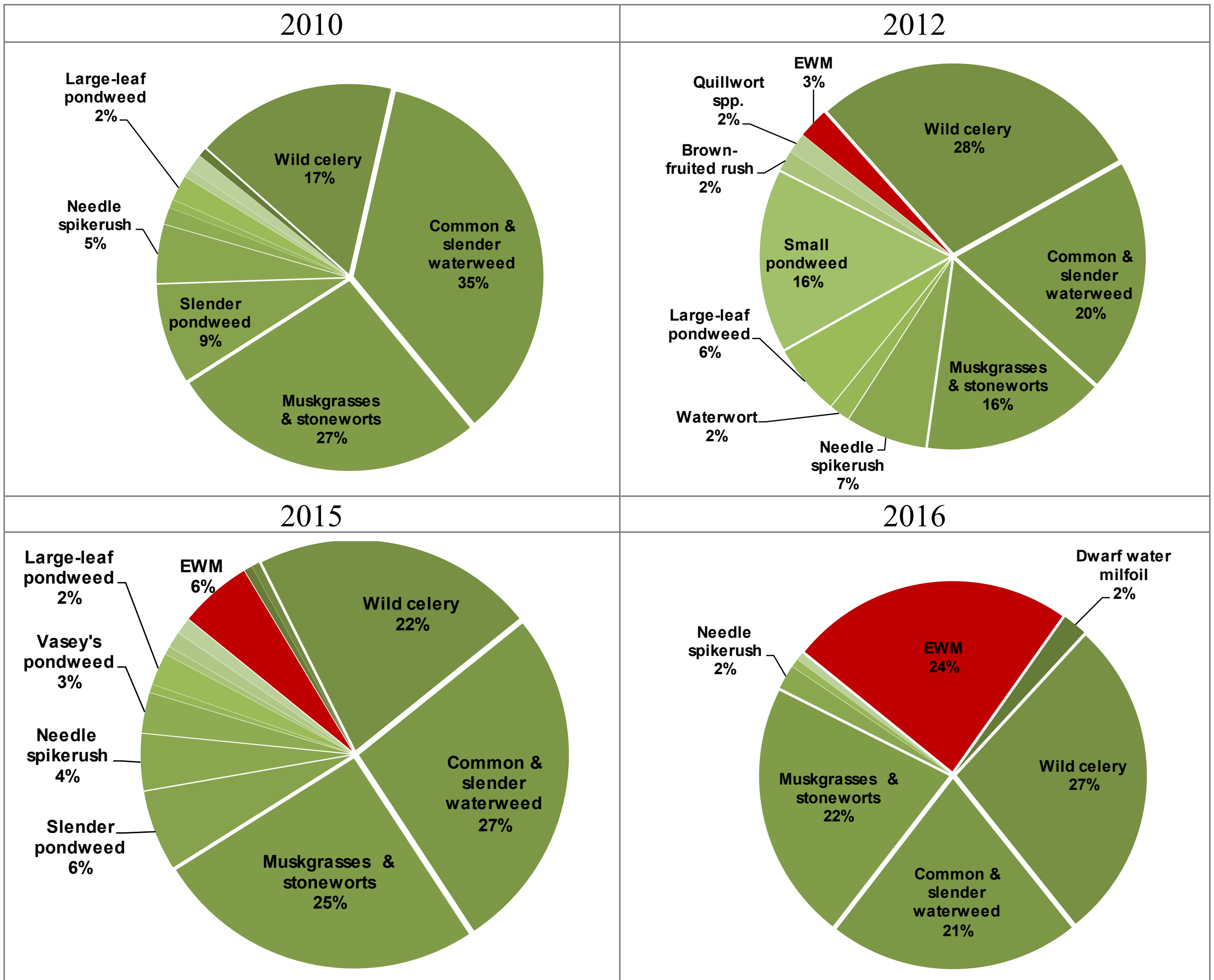

Figure 3.4-14. Relative frequency of occurrence analysis of the plant community in North Bay. Created using data from WDNR 2010, WDNR 2012, Onterra 2015, and Onterra 2016 point-intercept surveys. Only species with relative frequencies > 2% are labeled.

While it appears that the EWM population outside of the North Bay of Anvil Lake may be slow to increase, the population within the North Bay clearly has greatly increased over time and is currently approaching 60% of the littoral zone of the bay (Figure 3.4-12). As discussed in the Water Quality & Watershed Section (3.1), the North Bay has naturally occurring high phosphorus inputs and has sediments that may be indicative of a remnant wetland – two factors that contribute to a historically high aquatic plant population in this part of the lake. For that reason, the North Bay was once considered a locally important habitat within Anvil Lake. However, the ecological function of the bay is likely currently been altered as EWM density has changed the structural composition of the habitat in this area as evident of the proportional composition (relative frequency of occurrence) of the plant species in this area (Figure 3.4-14).

While the ALA plans to continue using hand-harvesting methods to control the EWM population within the lake, much discussion within the planning project involved potential and future use of aquatic herbicides. The following section provides information on herbicide treatments that were an important component of their education process and ultimate decision making.

Background on Herbicide Application Strategy

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 dilute herbicide concentration within aquatic systems. Understanding Concentration-Exposure Times (often referred to as CETs) is an important consideration for the use of 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.

A Cooperative Research and Development Agreement between the Wisconsin Department of Natural Resources and U.S. Army Corps of Engineers Research and Development Center in conjunction with significant participation by private lake management consultants have coupled quantitative aquatic plant monitoring with in-lake herbicide concentration data to evaluate efficacy, selectivity, and longevity of chemical control strategies implemented on a subset of Wisconsin waterbodies. Based on the preliminary findings from this research, lake managers have adopted two main treatment strategies: 1) spot treatments, and 2) large-scale (whole-lake) treatments.

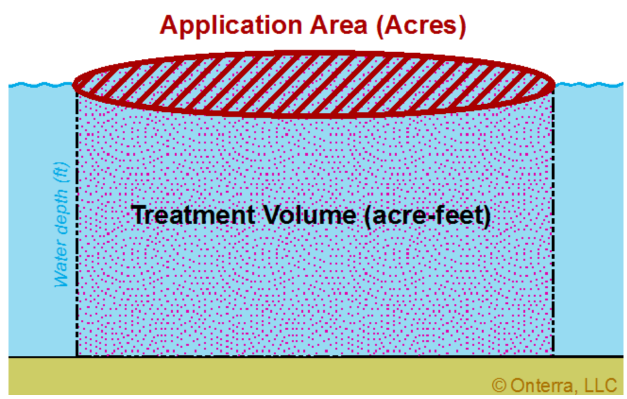

Figure 3.4-15. Herbicide Spot Treatment diagram.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant effects outside of that area. Herbicide application rates for spot treatment are formulated volumetrically, typically targeting EWM with 2,4-D at 3.0-4.0 ppm acid equivalent (ae). This means that sufficient 2,4-D is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal 3-4.0 ppm ae. This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 3.4-15). While lake managers may propose that a particular volumetric dose be used, such as 3.0-4.0 ppm ae, it is understood that actually achieving 3.0-4.0 ppm ae within the water column is not likely due to dissipation and other factors.

Ongoing research clearly indicates that the herbicide concentrations and exposure times of large (> 5 acres each) treatment sites are higher and longer than for small sites (Nault et al. 2015). Research also indicates that higher herbicide concentrations and exposure times are observed in protected parts of a lake compared with open and exposed parts of the lake. Areas targeted containing water exchange (i.e. flow are often not able to meet herbicide concentration-exposure time (CET) requirements for control.

WDNR administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). From an ecological perspective, large-scale (whole-lake) treatments are those where the herbicide is applied to specific sites, but when the herbicide reaches equilibrium within the entire volume of water (of the lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume. In regards to the WDNR's 10% littoral frequency of occurrence threshold discussed above, there is ecological basis in this standard. In general, if 10% of a lake was targeted with 2,4-D at 4.0 ppm ae, the whole-lake equilibrium concentration would be approximately 10% of that rate or 0.4 ppm ae. The target 2,4-D concentration for large-scale EWM treatments is typically between 0.250 and 0.400 ppm ae understanding that the exposure time would be dictated by herbicide degradation and be maintained for 7-14 days or longer. Therefore spot treatments that approach 10% of a lake's area will become large-scale treatments.

Large-scale treatments have become more widely utilized by many lake managers (and public sector regulatory partners) as they impact the entire EWM population at once. This minimizes the repeated need for exposing the lake to herbicides as is required when engaged in an annual spot treatment program. Properly implemented large-scale herbicide treatments can be highly effective, with minimal EWM, often zero, being detected for a year or two following the treatment (Figure 3.4-16). Some large-scale treatments have been effective at reducing EWM populations for 5-6 years following the application.

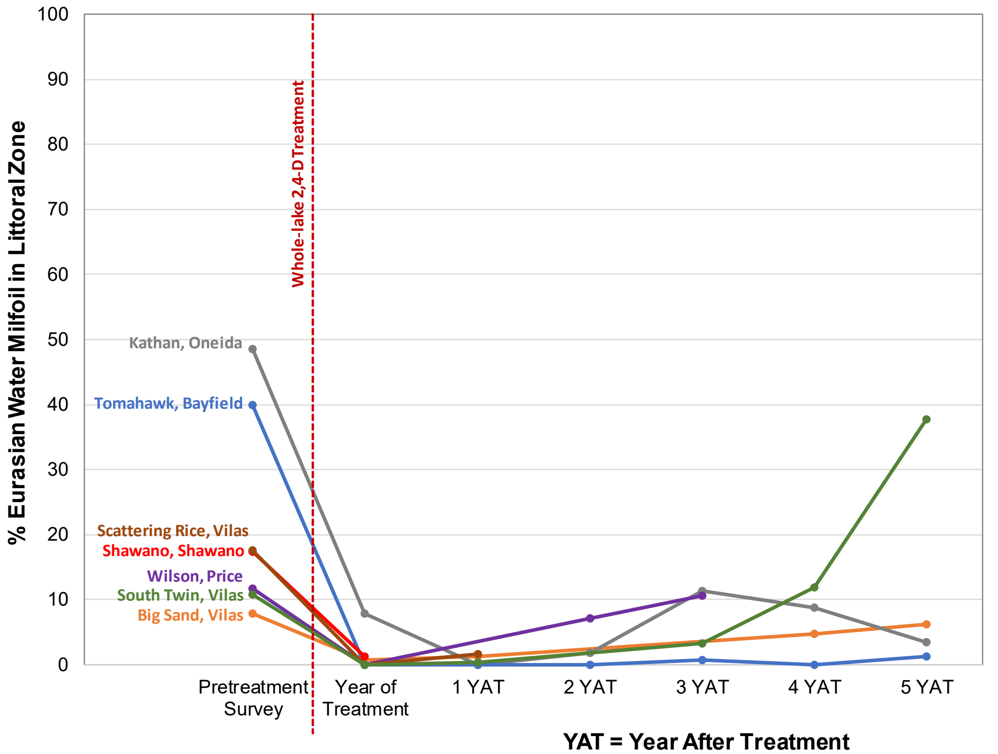

Figure 3.4-16. Littoral frequency of occurrence of EWM in lakes managed with large-scale 2,4-D treatments.

Predicting success (EWM control) and native plant impacts from whole-lake treatments is also better understood than for spot treatments. Some native plants are quite resilient to this herbicide use pattern, either because they are inherently tolerant of the herbicide or they emerge later in the year than when the herbicide was active in the lake. Other species, particularly dicots, some thinleaved pondweeds, and naiad species, can be impacted and take a number of years to recover. Often during the year of treatment, overall native plant biomass can be lessened but typically (not always) rebounds the following year.

Pesticides are registered by the US Environmental Protection Agency, which provide instructions for safe handling and operational usage. This does not mean that the US EPA believes the use of registered herbicides is benign, rather that proper usage of the product will result in minimal impact to human and ecosystem health. Social concerns question the US EPA's determinations amongst fear that the approved herbicide may eventually uncovered as harmful, particularly in regards to long-term effects.

US EPA registration of aquatic herbicides typically requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with spot-treatment use patterns (high concentrations, short exposure times). Therefore, only limited organismal toxicity data is available for concentrations and exposure times consistent with whole-lake treatment use patterns (low concentrations, long exposure times).

Because of their durability as a laboratory species, fathead minnows are often the subject of organismal toxicity studies. The LC50 (lethal concentration when half die) for fathead minnow exposure to 2,4-D (amine salt) has been determined to be 263 ppm ae sustained for 96 hours, a thousand times higher than fish would be exposed to in a large-scale treatment (target of approximately 0.3 ppm ae). With the assistance of a WDNR AIS-Research Grant, DeQuattro and Karasov (2015) investigated the impacts on fathead minnow of 2,4-D concentrations more relevant to what would be observed in large-scale treatments. The focus of their investigations was on reproductive toxicity and/or possible endocrine disruption potential from the herbicide. The study revealed morphological changes in reproducing male fathead minnows, such that they had lower tubercle scores (analogous to smaller antlers on a male white-tail deer) with some 2,4-D products/use-rates and not with others. This may suggest that the "inert" carrier may be the cause, not the 2,4-D itself. At a static exposure of 0.05 ppm ae for 58 days (fish exposed for 28 days then eggs they laid were continued to be exposed for 30 more days post fertilization) uncovered a reduction in larval fathead survival from 97% to 83% at the lowest dose of one herbicide that was tested (no reduction at higher doses).

As discussed above, large-scale treatments can have potential secondary impacts to the lake and lake users in addition to the financial costs to the lake group. Therefore, large-scale EWM treatments are typically postponed until the population exceeds a pre-defined threshold in an attempt to balance these factors. In regards to Anvil Lake, the North Bay is a relatively protected part of the lake that if targeted with herbicides, may function like a large-scale treatment such that the contained nature of the bay may hold herbicide concentrations and exposure times for an extended period of time compared to traditional spot-treatment scenarios. These factors would likely lead to a more efficacious treatment, but also make it more difficult to devise a proper dose that would balance unintended impacts to the valuable native plant community.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a 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 Anvil Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologists Steve Gilbert and Hadley Boehm (WDNR 2017 & GLIFWC 2017).

Energy Flow of a Fishery

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 Anvil 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 piscovorous 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 3.5-1.

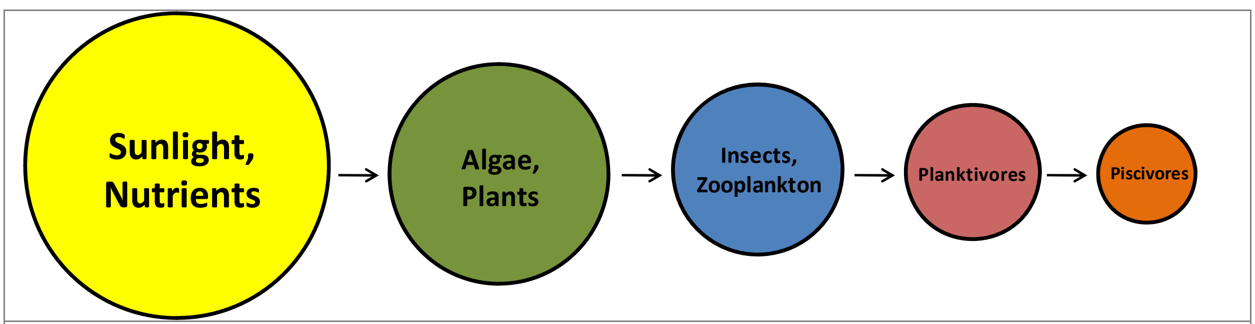

Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Anvil Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Anvil Lake should be able to support an appropriately sized population of predatory fish (piscovores) when compared to eutrophic or oligotrophic systems. Table 3.5-1 shows the popular game fish present in the system.

Although not an exhaustive list of fish species in the lake, additional species documented in past surveys of Anvil Lake include white sucker (*Catostomus commersonii),* mimic shiner (*Notropis volucellus*) and bluntnose minnow (*Pimephales notatus*).

Table 3.5-1. Gamefish present in Anvil 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
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)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
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

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photo 3.5-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip) then release the captured fish.

The other commonly used sampling method is electroshocking (Photo 3.5-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.


Photo 3.5-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photo 3.5-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Anvil Lake has been stocked from 1972 to 1991 with walleye. Stocking efforts for walleye discontinued because natural reproduction was occurring. The 2017 fall electrofishing survey documented a continuance of walleye natural reproduction. Stocking efforts from 1972 to 1991 are displayed in Table 3.5-2.

Photo 3.5-2. Fingerling walleye. (Photo: UW-Stevens Point)

Table 3.5-2. Stocking data available for walleye in Anvil Lake (1972-1991).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Fingerling	10,200	3
1974	Fingerling	10,000	3
1976	Fingerling	18,000	3
1983	Fingerling	12,650	3
1985	Fingerling	19,000	2
1989	Fingerling	10,200	2
1991	Fingerling	5,187	2

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Anvil Lake Spear Harvest Records

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 3.5-2). Anvil Lake falls within the Ceded Territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for Ceded Territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the Ceded Territory. 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 limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. The safe harvest is then multiplied by the Tribal communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009).

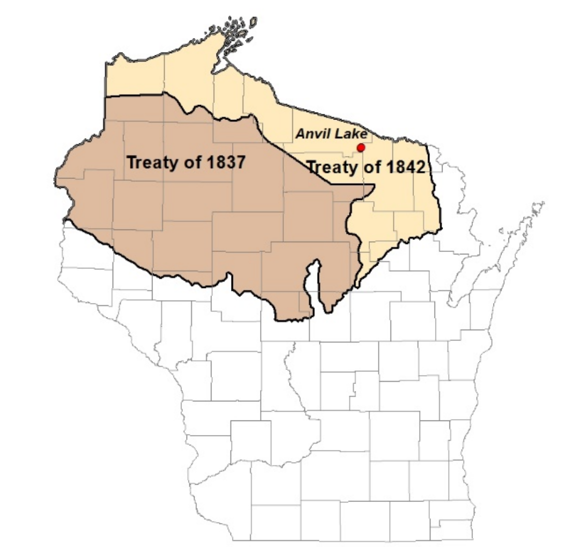

Figure 3.5-2. Location of Anvil Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Harvesters are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice, walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2017). 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. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2017). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration 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 declaration is met or the season ends.

Walleye open water spear harvest records are provided in Figure 3.5-3 from 1989-2015. As many as 247 fish have been harvested from the lake in the past (1993), however the average harvest is roughly 90 fish in a given year. On the average, spear harvesters take 89% of their declared quota.

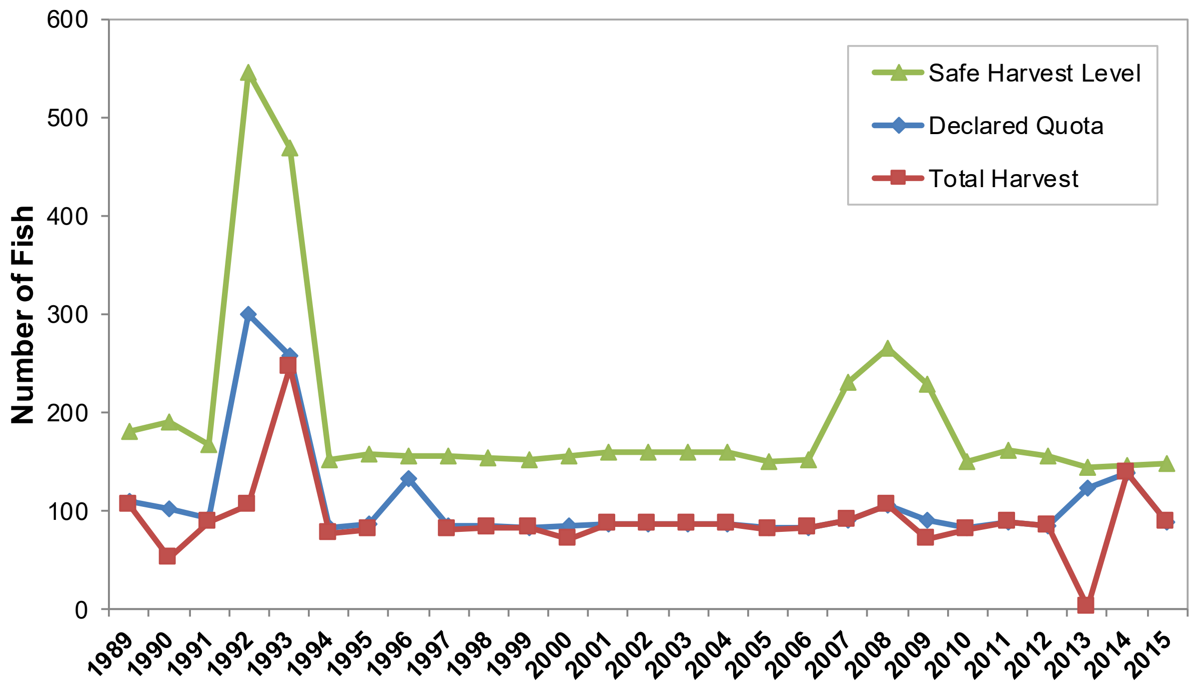

Figure 3.5-3. Anvil Lake walleye spear harvest data. Annual total walleye harvest statistics are displayed since 1989 from WDNR records and GLIFWC (1999-2015).

Anvil Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Lakes with primarily a silty/soft substrate, many aquatic plants, and coarse woody debris may produce a completely different fishery than lakes that are largely sandy/rocky, and contain few aquatic plant species or coarse woody habitat.

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye are 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 and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in 2015, 63% of the substrate sampled in the littoral zone of Anvil Lake was sand, 33% was composed of muck and 4% was rock.

Coarse Woody Habitat & Fish Sticks Program

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006).

Photo 3.5-3. Fish stick example. (Photo courtesy of WDNR 2013).

The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photo 3.5-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A summer 2015 survey documented 19 pieces of coarse woody along the shores of Anvil Lake, resulting in a ratio of approximately 4 pieces per mile of shoreline. Anvil Lake may be a candidate to consider enhancing coarse woody habitat through the deployment of fish sticks. Contact the local WDNR fisheries biologist to discuss the applicability of this program as it relates to the fisheries habitat goals for Anvil Lake.

Regulations and Management

The 2017-2018 fishing regulations for Anvil Lake gamefish species are displayed in Table 3.5-3. For current and specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.5-3. WDNR fishing regulations for Anvil Lake (2017-2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	June 17, 2017 to March 4, 2018
Smallmouth bass	Catch and release only	None	May 6, 2017 to June 16, 2017
Largemouth bass	5	14"	May 6, 2017 to June 16, 2017
Muskellunge and hybrids	1	40"	May 27, 2017 to November 30, 2017
Northern pike	5	None	May 6, 2017 to March 4, 2018
Walleye, sauger, and hybrids	3	18"	May 6, 2017 to March 4, 2018

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.5-4. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways		
	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 3.5-4. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

Fishery Management & Conclusions

In the 1990's there was data to suggest good recruitment for walleye on Anvil Lake. During 2006 surveys, WDNR surveys resulted in a population estimate of 2,171 adult walleye, or 5.5 fish per acre (WDNR 2007). WDNR biologists have set a management goal of 3 to 4 adult fish per acre for the lake, given its trophic state and habitat characteristics. While the estimated adult walleye population exceeded the 3 to 4 fish per acre management goal, a recent (2015) survey by GLIFWC biologists put the population estimate at roughly 2.7 fish per acre. Fisheries biologists believe the primary stressor on Anvil Lake fish is the water level, which has receded much from its typical level since the early 2000's. Biologists have noted that in periods of low water levels, some of the preferred walleye spawning habitat has been exposed above the water level. Additionally, the lake has historically been a good northern pike and bass fishery. In recent years however, bass habitat has been exposed due to low water levels as well, including engineered habitat such as tree drops and half-logs built by Anvil Lake residents and National Forest Service staff. Water levels have begun to rebound during the most recent years (2016-2017) which may be leading to some re-establishment of important near-shore habitat areas.

Biologists from the WDNR have completed surveys of Anvil Lake during 2017 to refresh data on the fishery and help to drive management decisions.

4.0 SUMMARY AND CONCLUSIONS

Through the studies conducted on Anvil Lake, overall the ecosystem is in a healthy condition. As discussed within the Water Quality & Watershed Section (3.1), Anvil Lake's water quality is exceptional and largest contributor to changes in water clarity are from alterations in water levels. The largest source of phosphorus to the lake was precipitation (34%), groundwater (25%), and internal sources (11%). This means that 70% of the nutrient inputs to the lake are from sources that cannot be controlled by the Anvil Lake Association. However, additional sources such as nearshore runoff and septic inputs (particularly in the northern part of the lake) can be controlled and stress the importance of shoreland stewardship practices.

When looking at the results of the paleoecology study, the sediment delivery from shoreline activities is much less than for other lakes studied. The majority of Anvil Lake's immediate shoreland zone (66%) is completely natural or lightly developed. In regards to protecting Anvil Lake, conserving the existing natural shoreline and restoring areas of disturbed shoreline may be one of the best options at this time.

A concerning aspect of the lake that was voiced by stakeholders during the project was the low water level of the lake. As discussed, Anvil Lake is a seepage lake, meaning that it does not have a tributary feeding water to the lake; its primary sources of water include surface water flow, groundwater, and direct deposition by precipitation. Seepage lakes typically have water levels that are controlled by the balance between groundwater and precipitation. The USGS study found that groundwater input and output did not change appreciably during drought and wet periods. The driving force in controlling the lake levels was the amount of precipitation.

While a lower water level does not appeal to property owners or those trying to navigate the lake, this condition does not necessarily impact the lake's ecological health in a negative manner. When the water recedes from a shoreline, loose sediment may consolidate. Additionally, new habitats may be created for smaller shoreline plants, shorebirds or fish species. In fact, some plants and animals depend upon fluctuating water levels for some or all of their life cycle and thrive under these conditions. In the long-term, the fluctuating water levels in a seepage lake like Anvil Lake may enhance the ecosystem by increasing diversity.

The aquatic plant community within the lake and along the shorelines of Anvil Lake was found to be of good quality. The overall plant community contains a high number of native aquatic plant species. Due to a moderate alkalinity, Anvil Lake consists of both elodeid (tall and leafy) plant species and isoetid (small and turf-grass like) species. Changes in sedimentation and eutrophication of Anvil Lake can greatly impact the isoetid plant community, resulting in a much different functioning lake if that occurred.

While the lake contains a high number of species, the diversity metric is relative low because the plant community is overly dominated by three species (muskgrasses, waterweed, and wild celery). This potentially makes the lake more vulnerable to environmental disturbances, including exotic species populations.

Exotic species, particularly EWM have been a focus of management for the Anvil Lake Association. EWM was first discovered in 2012 (4 years ago) an the ALA have been able to watch the population increase quickly, particularly in the North Bay. During this time, the ALA was proactive and conducted volunteer and professional hand-harvesting efforts only to learn the amount of effort was nowhere near what would be needed to keep the population in check or reduce it. This was not a fault of the ALA, simply the understanding of this control method continues to be in its infancy and Anvil Lake became a field trial to understand its applicability. Before any of the Planning Committee Meetings took place and EWM management goals were able to be discussed, the ALA started on the creation of Diver-Assisted Suction Harvesting (DASH) equipment. The primary goal was to increase their capacity for conducting EWM hand-removal operations on the lake. The DASH unit was able to be deployed at a limited basis in 2016 and therefore ALA members developed short-term management actions to include the use of their newly purchased and constructed equipment. As outlined within the Implementation Plan Section, the ALA intends to give this method a three-year trial period before considering other management options.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the ALA Planning Committee and ecologist/planners from Onterra. It represents the path the ALA 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 Anvil Lake stakeholders as portrayed by the members of the Planning Committee, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

While the ALA Board of Directors is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee or an individual director (e.g. Education and Communication Committee, Water Quality Director/Committee, Invasive Species Committee, Shoreland Improvement Director/Committee). The ALA will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Increase ALA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	ALA Board of Directors – possibly formation of an Education and Communication Committee
Description:	Education represents an effective tool to address many lake issues. The ALA regularly distributes (2-3 times per year) its newsletter, (*The Chime*,), frequent email communications, and is in the process of creating a more-usable website. These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings. The ALA will also give consideration to periodic expansion of its communication strategy past those that belong to the association and include all property owners around Anvil Lake. The ALA continues to increase its ability to educate lake users by providing new signage at the USFS boat landing in 2016, as well as placing 2 buoys at the entrance to the north bay alerting boaters about Eurasian watermilfoil. Completed in late-May 2017, the ALA provided 40 packets of information to non-members asking them to get involved. The ALA will continue to make the education of lake-related issues a priority. 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* • Specific topics brought forth in other management actions • Aquatic invasive species identification and spread • Safety of dive teams hand-removing AIS • Basic lake ecology • Sedimentation • Boating safety (promote existing guidelines, recommendations, courtesy code) • Noise, air, and light pollution • Shoreline habitat restoration and protection • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Septic system maintenance (i.e. list of questions for septic pumper professionals to ask)
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Continue ALA's involvement with other entities that have responsibilities in managing (management units) Anvil Lake
Timeframe:	Continuation of current efforts
Facilitator:	ALA Board of Directors – possibly formation of an Education and Communication Committee
Description:	As outlined on the ALA's website: "The Anvil Lake Association works for the improvement of the lake watershed and also plans social activities for members." The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while other organizations rely on voluntary participation. It is important that the ALA 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 understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Washington	Chairman (James Spring – 715.891.1095)	Provides information and networking related to the advancement of the Anvil Lake community.	Once a year, or more as needed. May check website (http://www.town-of-washington.org/ for updates.	The Township serves a valuable role in promoting local businesses, tourism, and community within the Anvil Lake area. They have also been instrumental in leading environmental projects in the township.
Vilas County Lakes & Rivers Association	President (Rollie Alger– president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	Invasive Species Coordinator (Cathy Higley – 715.479.3738)	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 Coordinator
Vilas County Land & Water Conservation Department.	Conservation specialist (Mariquita Sheehan – 715.479.3721)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Steve Gilbert – 715.358.9229)	Manages the fishery of Anvil Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
United States Forest Service	Biologist (Mike Peczynski – 715.479.2827)	Oversees conservation efforts on Federal Lands	As needed	To keep informed on USFS management intentions and ecological survey results. Partner with for habitat improvements (e.g. coarse woody habitat)
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	ALA 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.

Management Goal 2: Manage the Existing Aquatic Invasive Species Population in Anvil Lake

Management Action:	Three Year Trial Diver Assisted Suction Harvest EWM Control Strategy in the North Bay.
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee
Description:	As discussed in the Aquatic Plant Section (3.4), Eurasian watermilfoil was first discovered in Anvil Lake during the summer of 2012. The ALA has conducted hand-harvesting (professional and volunteer-based) since 2013 with funding assistance from a series of two WDNR AIS-Early Detection and Response Grants. Overall, the combined hand-harvesting control program on Anvil Lake has not been able to maintain or reduce the Eurasian watermilfoil population within the northern bay. The rate of growth and expansion of the Eurasian watermilfoil population exceeded the pace of removal efforts during 2013-2016 (Map 6). It is important to note that without the hand-removal efforts, the expansion may have been much greater in both density and area in the North Bay. The vast majority of the current EWM population is within the approximate 25-acre North Bay (Map 7). Based on the 2016 point-intercept survey in this part of the lake, 35 of the 61 (57.4%) sampling locations that are contained within this bay had Eurasian watermilfoil. This suggests that this population is established. Approximately 15 acres of this bay contains colonized EWM, with approximately half of that acreage being *dominant, highly dominant* colony, or *surface matting* (Map 7). At these populations levels, the EWM has altered the ecology of this bay as well as diminished the cultural ecosystem services the lake provides (i.e. navigability, recreation, aesthetics, etc.). Discussions about the use of aquatic herbicides to target the Eurasian watermilfoil population took place between WDNR, Onterra, and ALA Planning Committee members. The ALA Planning Committee was informed about the current knowledge and research base regarding aquatic herbicide strategies as well as discussed some of the known and unknown impacts of herbicide use patterns. Based upon the list of discussion points outlined below, the ALA Planning Committee has determined that herbicide control strategies are not appropriate at this time: • Anvil Lake has not been exposed to aquatic herbicides to date and many Planning Committee Members believe that should hold true until alternative strategies have been exhausted. • Initially following EWM detection, a segment of ALA members voiced opposition to herbicide use. At this time, the ALA has not

conducted a stakeholder survey to see if the opposition to herbicide control strategies is/was a vocal minority and if their positions have potentially changed in light of the expanded EWM population.

- Prior to the completion of the management planning effort, the ALA constructed its own Diver Assisted Suction Harvesting (DASH) equipment but has not had a chance to fully its use in a control strategy.

As discussed above, the ALA constructed a DASH removal boat in mid-summer 2016 (Photo 5.0-1). The ALA was only able to staff the boat approximately 75 hours during the inaugural summer. It is foreseen that the new equipment will allow a larger hand-harvesting effort to be completed moving forward.

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund a 3-year trial program where 250 hrs. of paid DASH removal efforts would be conducted and an additional 100 hrs. of volunteer efforts. The goal of the project would be to understand if this level of effort can reduce the EWM population within the North Bay of Anvil Lake.

Photo 5.0-1. ALA's DASH Boat. Photo courtesy of Robert Mendlesky.

The objective of this management action is not to eradicate EWM from Anvil Lake, as that is impossible with our current tools and techniques. The objective is to maintain an EWM population that exerts little to no detectable impacts on the lake's native aquatic plant community and overall ecology, recreation, and aesthetics. Monitoring is a key aspect of any AIS control project, both to prioritize areas for control and to monitor the strategy's effectiveness. The monitoring also facilitates the "tuning" or refinement of the control strategy as the control project progresses. The ability to tune the control strategies is important because it allow for the best results to be achieved within the plan's lifespan. It must be noted that hand-removal methodology is still experimental, and success criteria for assessing the efficacy of hand-removal are difficult to define. Because of this, the following series of steps to manage EWM via hand-removal in Anvil Lake should remain flexible to allow for modifications as the project progresses (Figure 5.0-1). The series includes:

1. A lake-wide assessment of EWM (Peak-Biomass Survey) completed while the plant is at or near its peak growth (late summer). This meander-based survey of the lake's littoral zone is designed to locate all possible occurrences of EWM, and the findings would be compared to results from the previous summer's Peak-Biomass Survey to assess the efficacy hand-harvesting.

2. Using EWM findings from the most recent Peak-Biomass Survey, professional ecologists will work with the ALA to delineate priority areas within the North Bay over the winter months. Those areas containing EWM populations of *dominant* density or greater would be targeted first by the DASH operations as they exert the greatest ecological strain and are the largest sources for future spread. Volunteer-based efforts using snorkelers would occur in the shallow margins of the lake.

3. During the late-winter, a Mechanical Harvesting Permit Application would be sent to the WDNR outlining the entirety of the North Bay as the DASH area. The application fees are based on acreage and cap at 10 acres, so the ALA will outlay $300 per year in WDNR fees.

4. A lake-wide assessment of EWM (Early-Season AIS Survey) would be completed in early June to reassess areas of EWM located during the previous year's Peak-biomass Survey to ensure the presence of EWM within these areas and re-prioritize hand-removal areas if necessary. The data from this survey, as well as the outlined prioritized areas, will be provided to the ALA on a dedicated GPS unit capable of loading these type of data (i.e. basemaps).

5. Hand-harvesting activities would take place following the June Early-season AIS Survey and prior to the late-season EWM Peak-Biomass Survey. The firm would provide detailed information relating to their efforts (hours broken down by site, quantity of EWM removed,

assessment of native plant bi-catch, etc.) following the activities being conducted.

6. EWM Peak-Biomass Survey conducted in September to determine hand-removal efficacy and hand-removal sites/strategy for the following year. The crux of this activity is included within the first step.

7. Reports generated on hand-removal success and recommendations for following year's strategy.

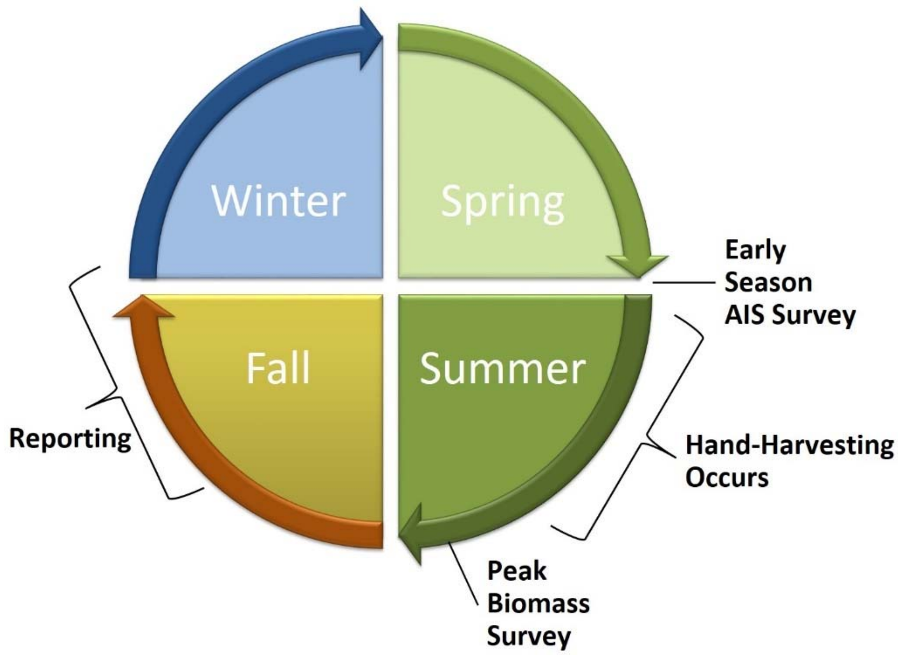

Figure 5.0-1. Project timeline diagram.

The success of the hand-harvesting program in the North Bay would be evaluated using both qualitative and quantitative methodologies. The qualitative monitoring would be completed by comparing pre-hand-harvesting (summer before hand-harvesting) with post-hand-harvesting (summer immediately following hand-harvesting) EWM Peak-Biomass Mapping Surveys. The efforts in the north bay would be considered a success if the EWM colonies of *dominant* density or grater are reduced by one density level (5-tiered scale).

The quantitative monitoring would compare a subset of point-intercept locations from summer before and after the control activities take place. Success will be determined by a reduced EWM frequency of occurrence.

In the final year of the project (2019), a whole-lake point-intercept survey would be conducted on Anvil Lake to reassess the EWM population and

	native aquatic plant population at the lake-wide level. The results of these studies would be compared to studies conducted as part of this management planning project. Based on the data collected over the three-year project, the ALA would revisit their management plan as it applies to Eurasian watermilfoil control and monitoring. Based upon the information gained during the multi-year control project, the ALA would update their management plan as appropriate. The ALA would also solicit stakeholder input by sending out a written stakeholder survey to judge the level of support for alternative control options (i.e. do nothing, herbicide treatment, etc.).
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant (February 1, 2017) based on developed project design.
3.	Initiate control and monitoring plan.
4.	Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action:	Keep isolated EWM populations from expanding in areas outside of North Bay
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee
Description:	Confirmed by the acoustic survey, the North Bay is composed of softer sediments (aka muck) than many areas of the lake. And based upon the USGS Study, the north bay of the lake also contains groundwater inputs, some with naturally high phosphorus concentration. These factors, in combination with the proper water depth, seems to form a preferred habitat zone for aquatic plant growth, including EWM growth, in the lake. An objective of this management action is to monitor and remove all EWM locations outside of the North Bay. This objective would be a good use of volunteer or local paid diver efforts particularly because the areas can be visited regularly throughout the growing season. These efforts will be instrumental in keeping EWM from becoming established in other parts of the lake. Some of the EWM occurrences outside of the North Bay are isolated in nature (Map 7), and may not be applicable to the use of the DASH system. The DASH boat would continually need to be repositioned and it may simply be easier for a non-tethered diver to remove these occurrences. The isolated EWM occurrences outside of the North Bay would be categorized based upon the level of EWM within each area. Sites containing *small plant colonies* would be classified as areas requiring the greatest need

	for hand-removal, or primary focus sites, while areas containing *clumps of plants* and only *single or few plants* would be classified as secondary and tertiary focus sites, respectively. Hand-harvest sites will be deemed successful if the level of EWM is maintained at the point-based mapping level; for example, a site would be considered unsuccessful if it contained *single or few plants* (point-based mapping) prior to hand-harvesting and expanded to contain colonized EWM (polygons) following hand-harvesting. However, measuring success of targeting low-density EWM occurrences with hand-harvesting methods can be complex and require revision as the project progresses.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3.	Initiate control and monitoring plan.
4.	Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action:	Monitor CLP population within Anvil Lake
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee
Description:	As discussed in the Aquatic Plant Section (3.4), CLP was first discovered in Anvil Lake during July 2013. Since that time, the CLP population remains small but increasing slightly each year. This invasive species can cause great ecological and recreational impacts on some lake. But in other lakes, the CLP population remains low and does not cause these impacts. The ALA would like to continue monitoring the CLP population within Anvil Lake over the next few years to understand the dynamics. A lake-wide assessment of curly-leaf pondweed will be completed during the June ESAIS survey while the plant is at its peak growth stage for the year. Comparing annual surveys will indicate if population expansion is occurring and if directed active management techniques should be explored.
Action Steps:	
	See description above

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Anvil Lake public access location
Timeframe:	Continuation of current effort

Facilitator:	AIS Committee
Description:	Currently the ALA monitors the public boat landing using training provided by the Clean Boats Clean Waters program. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that originated in Anvil Lake. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. Due to the large number of activities that volunteers are called upon on Anvil Lake (AIS monitoring, stakeholder education, etc.), paid watercraft inspectors would be sought to monitor the Anvil Lake's single public boat landing. In 2015, the ALA utilized over 200 hours of paid watercraft inspections through Vilas County's student intern program and plans to continue that level of commitment. In 2015, they also conducted over 85 hours of volunteer-based water craft inspections to offset the need for cash outlay to pay for the professional watercraft inspections.
Action Steps:	
	See description above as this is an established program.

Management Goal 3: Improve Lake and Fishery Resource by protecting and restoring the shoreland condition of Anvil Lake

Management Action:	Investigate restoring highly developed shoreland areas around Anvil Lake
Timeframe:	Initiate 2016.
Facilitator:	ALA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. In 2015, the shoreland assessment survey indicated that 1.1 miles, or 22% of Anvil Lake's 4.8-mile shoreline, consisted of *urbanized* or *developed-unnatural* areas (Map 3). The ALA has actively discussed the importance of shoreland health with association members. In approximately 2005-2006, an ALA member (Tom Reardon) conducted a shoreland restoration

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	demonstration project on his property. Because property owners may have little experience with or are uncertain about restoring a shoreland to its natural state, the ALA has decided to take the following steps to increase shoreland restoration on Anvil Lake: 1. Educate riparians about the importance of healthy and natural shorelands, highlighting the Reardon Property's restoration project when possible. 2. Set a goal to solicit 3-5 riparians to allow shoreland restoration and storm water runoff designs for their property within the next few years. 3. The ALA work with Vilas County (Quita Sheehan) or private entity to create design work. Small-scale WDNR grants may be sought to offset design costs. 4. Designs be shared with ALA members to provide further education of shoreland restoration projects. 5. Move forward with implementing shoreland restoration per the designs that were developed for those riparians that wish to. Project funding would partially be available through the WDNR's Healthy Lakes Implementation Plan (see below). 6. Shoreland restoration sites will serve as demonstrations sites to encourage other riparians to follow same path of shoreland restoration. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Vilas County. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available
Action Steps:	
1.	Recruit facilitator from Planning Committee

2.	Facilitator contacts the Vilas County Land and Water Conservation department to gather information on initiating and conducting shoreland restoration projects. If able, the County Conservationist would be asked to speak to ALA members about shoreland restoration at their annual meeting.
3.	The ALA would encourage property owners that have restored their shorelines to serve as demonstration sites.

<u>Management Action:</u>	Promote proper care of exposed lake beds on Anvil Lake
Timeframe:	Initiate 2016
Facilitator:	ALA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	Water levels periodically fluctuate on Anvil Lake, and have been at a relatively low point for the past 6-7 years. During the 2015 Shoreland Condition Assessment Survey, Onterra staff assessed the shoreland 35 feet inland from the ordinary high water mark (OHWM). As can be observed on Map 2, there is significant stretches (45.6 acres) of exposed lake bed between the ordinary high water mark and the current water level. Some of the exposed lake bed has been left to succession whereas other areas have been manicured into an urban-like landscape. Below are some important regulations about what can legally be done on an exposed lake bed: • As long as it is disposed of in an upland location, you can remove by hand (shovel, rake, wheel barrow) washed up debris, algae, mussels, and dead fish. Use of a motorized vehicle is prohibited on the lake bed (except when launching a boat). • Removal of vegetation on the exposed lake bed is restricted to a 30-ft wide path, so long as it is not a state or federally listed species. This can be accomplished by hand removal, cutting, or a push lawn mower with all materials being disposed of in an upland location. Use of a riding lawn mower or other motorized vehicles are prohibited. • Removal of invasive species (phragmites, reed canary grass, thistles, and purple loosestrife) can be removed by hand in an unlimited area as long as the method is selectively targeting these species. • Rocks, logs, and stumps cannot be removed without a permit. • Filling material such as sand, gravel, rocks cannot be added to the exposed lakebed without a permit. The ALA intends to educate and promote landowners to follow the regulations on how to care for the exposed lake beds in front of their properties. In addition, the ALA has an ongoing organized property-owner focused program to control invasive thistle species (Canada

	thistle, European marsh thistle). Thistles are pioneering species that can quickly colonize the now exposed lake bed. Control of thistles is accomplished by cutting and removing the plant (attempt to dig and remove tap root) before it begins to flower. However, underground rhizomes can continue to spread colonially if the entire root is not removed.
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).

<u>Management Action:</u>	Protect natural shoreland zones around Anvil Lake
Timeframe:	Initiate 2015
Facilitator:	ALA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	Approximately 3.2 miles (66%) of Anvil Lake's shoreline was found to be in either a *natural* or *developed-natural* state. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to Anvil Lake, and that these shorelands remain in a natural state. The inset on Map 2 indicates the locations of *natural* and d*eveloped-natural* shorelands on Anvil Lake. Less than 0.2 miles of shoreline (4%) of the lake's shoreland is part of the Chequamegon -Nicolet National Forest. This indicates that over 3 miles of private shorelands are in either a *natural* or *developed-natural state* that should be prioritized for education initiatives and physical preservation. Members of the ALA Planning Committee believe that the majority of the lands that are held in this condition are by non-ALA members. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the ALA in preserving the Anvil Lake shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Vilas County Land and Water Conservation Department. Several websites of interest include: • Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands) • Conservation easements or land trusts: (http://www.northwoodslandtrusts.org/)

	• UW-Extension Shoreland Restoration: (www.uwex.edu/ces/shoreland/Why1/whyres.htm) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).

Management Action:	Coordinate with USFS and private landowners to expand coarse woody habitat in Anvil Lake
Timeframe:	Initiate 2016
Facilitator:	ALA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	ALA stakeholders must realize the complexities and capabilities of the Anvil Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove course woody habitat (e.g. downed trees, stumps, etc.) from a shoreland area because these items may impede watercraft navigation, shore-fishing, or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. With the lowered water levels on Anvil Lake, existing coarse woody habitat becomes located above the current water line and starts to dry out and decay. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.5) discuss the benefits of coarse woody habitat in detail. During the proceeding decades, course-woody habitat improvements on many lakes were in the form of fish cribs and bass half-log structures. However, current fisheries recommendations have focused on increasing tree drops. The ALA is currently working with the United States Forest Service (USFS) to implement increased coarse-woody habitat in Anvil Lake. This involves downing a tree at a location short distance from the lake, dragging it into place, and securing it into place over the winter months. The ALA will also discuss with its membership the potential for riparians to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the USFS and WDNR fisheries biologists. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require

	advanced engineering design may seek alternative funding opportunities, potentially through the county. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per cluster of 3-5 trees (best practice cap) • Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances • Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or : o The landowner would need to commit to leaving the area un-mowed o The landowner would need to implement a native planting (also cost share thought this grant program available) • Coarse woody habitat improvement projects require a general permit from the WDNR • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts Kevin Gauthier (WDNR Lakes Coordinator), Steve Gilbert (WDNR Fisheries Biologist), and the USFS Biologist to gather information on initiating and conducting coarse woody habitat projects.
3.	The ALA would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Management Goal 4: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	ALA Board of Directors – possibly formation of a Water Quality Director or Committee
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Volunteer water quality monitoring has been completed annually by Anvil Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. Data has been

	collected through the advanced CLMN program in the past on Anvil Lake. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring, as well as water temperature profiles at the lake's deep hole. It is the responsibility of the current CLMN volunteer in conjunction with the ALA Board of Directors to coordinate new volunteers as needed. When a change in the collection volunteer occurs, Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2.	CLMN volunteer and/or ALA Board of Directors would facilitate new volunteer(s) as needed
3.	Coordinator contacts Sandra Wickman (715.365.8951) to acquire necessary materials and training for new volunteer (s)

6.0 METHODS

Lake Water Quality and Watershed Analysis

The water quality and watershed data from this report were provided by Dr. Dale Robertson from the United States Geological Survey (USGS) as a part of a separate project. Anticipated during the spring of 2018, the USGS will create a written report of these data and additional analysis, including documentation of the methods utilized.

Paleoecology

A Paleoecological Study of Anvil Lake, Vilas County, WI (Garrison 2015) contains a complete report of the paleoecology work conducted on Anvil Lake. Prior to his employment at Onterra, Paul Garrison was employed in the Bureau of Science Services at the WDNR and spearheaded this study. This report outlines the methods of those studies. The paleoecology section of this report was written by Paul Garrison for the audience of the Anvil Lake Association.

Shoreline Condition Assessment

The development stage of the entire shoreland was surveyed during the late summer of 2015 using a GPS unit. Onterra staff only considered the area of shoreland 35 feet inland from the ordinary high water mark (OHWM) and did not assess the shoreland on a property-by-property basis. Point data is collected at locations where shoreland conditions categories change using a GPS-enabled rangefinder connected to the onboard computer system.

Coarse Woody Habitat Assessment

During the Shoreland Condition Assessment Survey, the margins of the lake were searched for coarse woody habitat that is observed extending from land into the water. Points are collected on each coarse woody habitat occurrence using a GPS-enabled rangefinder connected to the onboard computer system. During this survey, submersed coarse woody habitat nor stumps were marked. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter or cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy.

Aquatic Vegetation

Early-Season AIS Survey

The Early-Season AIS (ESAIS) survey occurs in mid-June to early-July of each year, when clear water and minimal native plant growth allows for better viewing of AIS. CLP and pale yellow iris are at their peak growth during this time. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Point-Intercept Survey

The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study. A point spacing of 40 meters was used resulting in approximately 952 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Anvil Lake (emergent and floating-leaved vegetation) were mapped using a Trimble 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.

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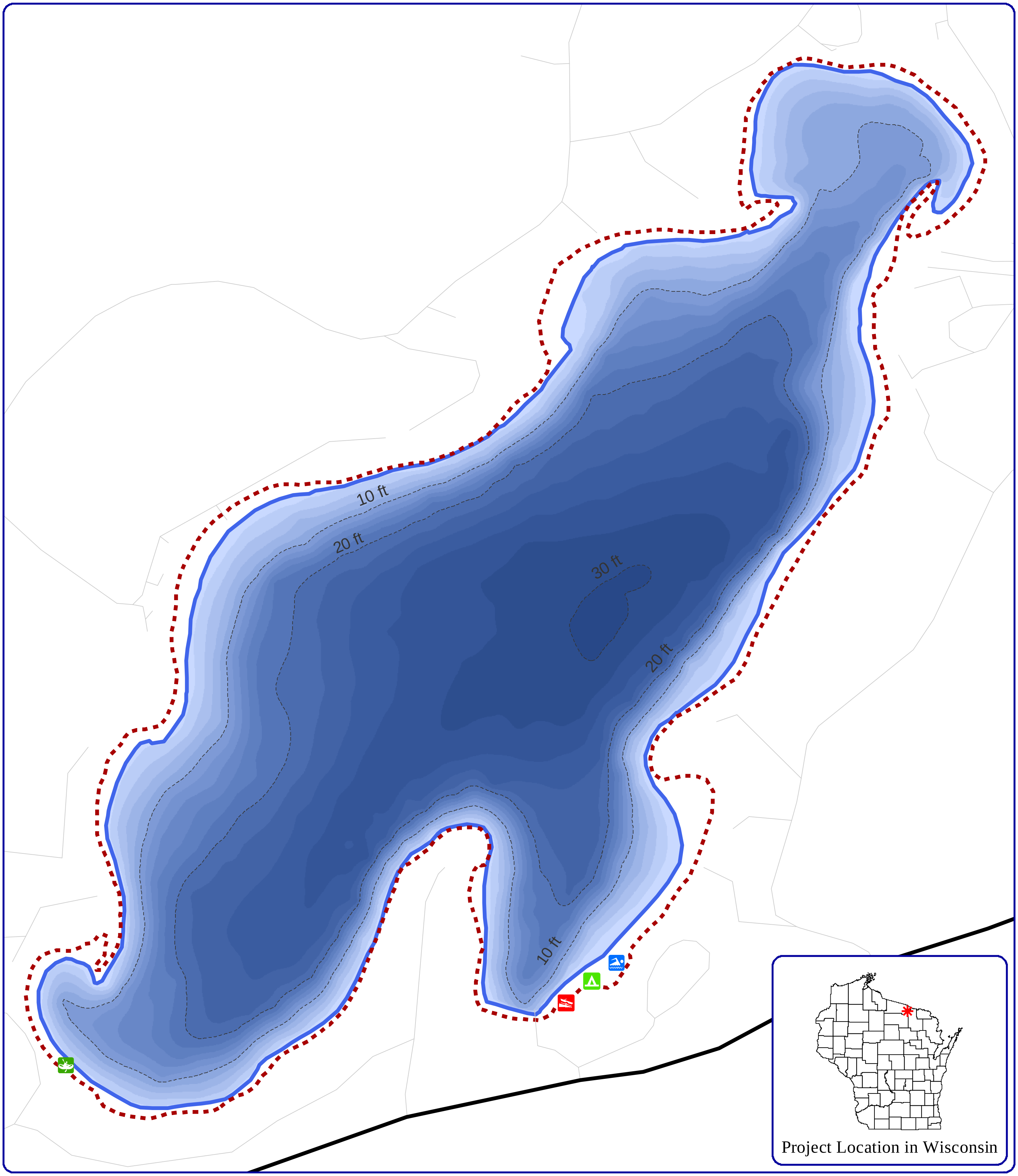
Woodford, J.E. and M.W. Meyer. 2003. Impact of Lakeshore Development on Green Frog Abundance. Biological Conservation. 110, pp. 277-284.



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Feet

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

Sources:
Roads & Hydro: WDNR
Bathymetry: Onterra, 2014; processed by Navico
Map date: April 14, 2016
Filename: *Map1_Anvil_Location.mxd*

Legend

Anvil Lake Estimated 2013 Water Mark
2013 Ortho-rectified

Anvil Lake Estimated Ordinary High Water Mark (OHW)

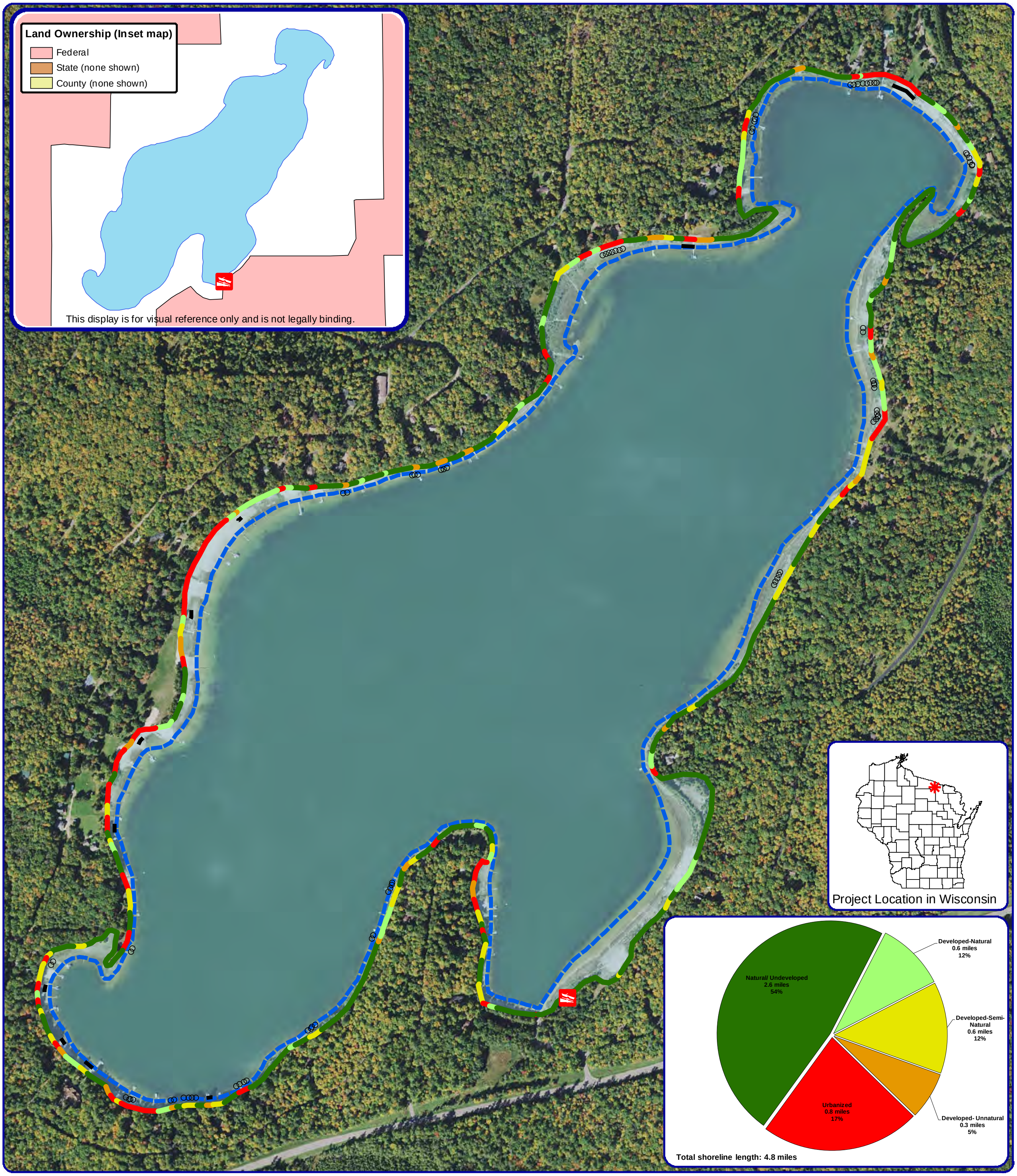
Carry-In Landing
Public Boat Landing
Public Beach
Campsite

Map 1

Anvil Lake

Forest County, Wisconsin

Project Location & Lake Boundaries



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Feet

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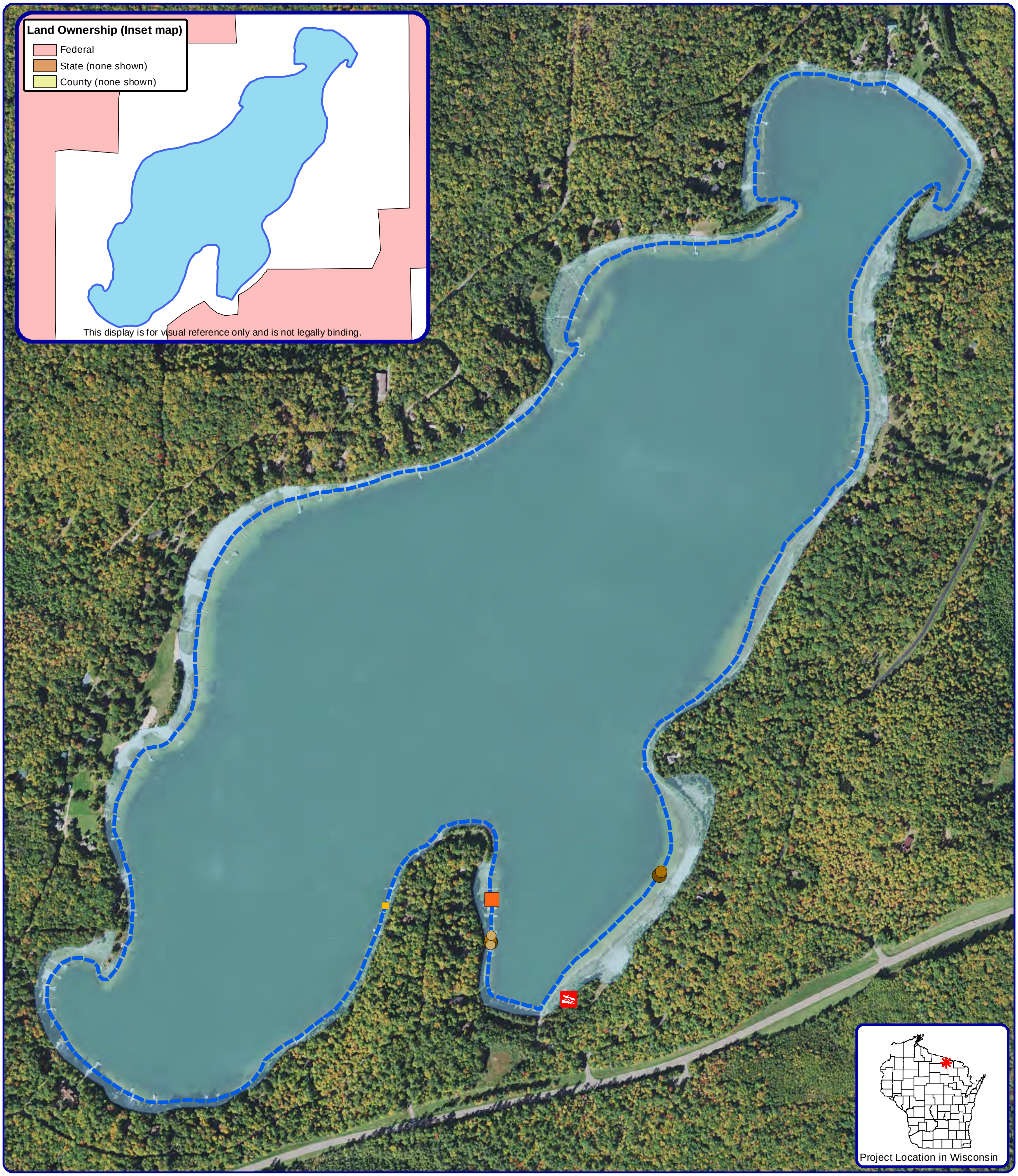
Sources:
Roads and Hydro: WDNR
Shoreland Survey: Onterra, 2015
Ortho: WDNR, 2013
Map Date: November 3, 2015
Filename: Map2_Anvil_SCA_Fall15.mxd

Legend

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

Seawall
- Masonry/Metal/Wood
- Rip-Rap
- Approximate 2015 Water Level

Map 2
Anvil Lake
Vilas County, Wisconsin
2015 Shoreland Condition Assessment



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Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy

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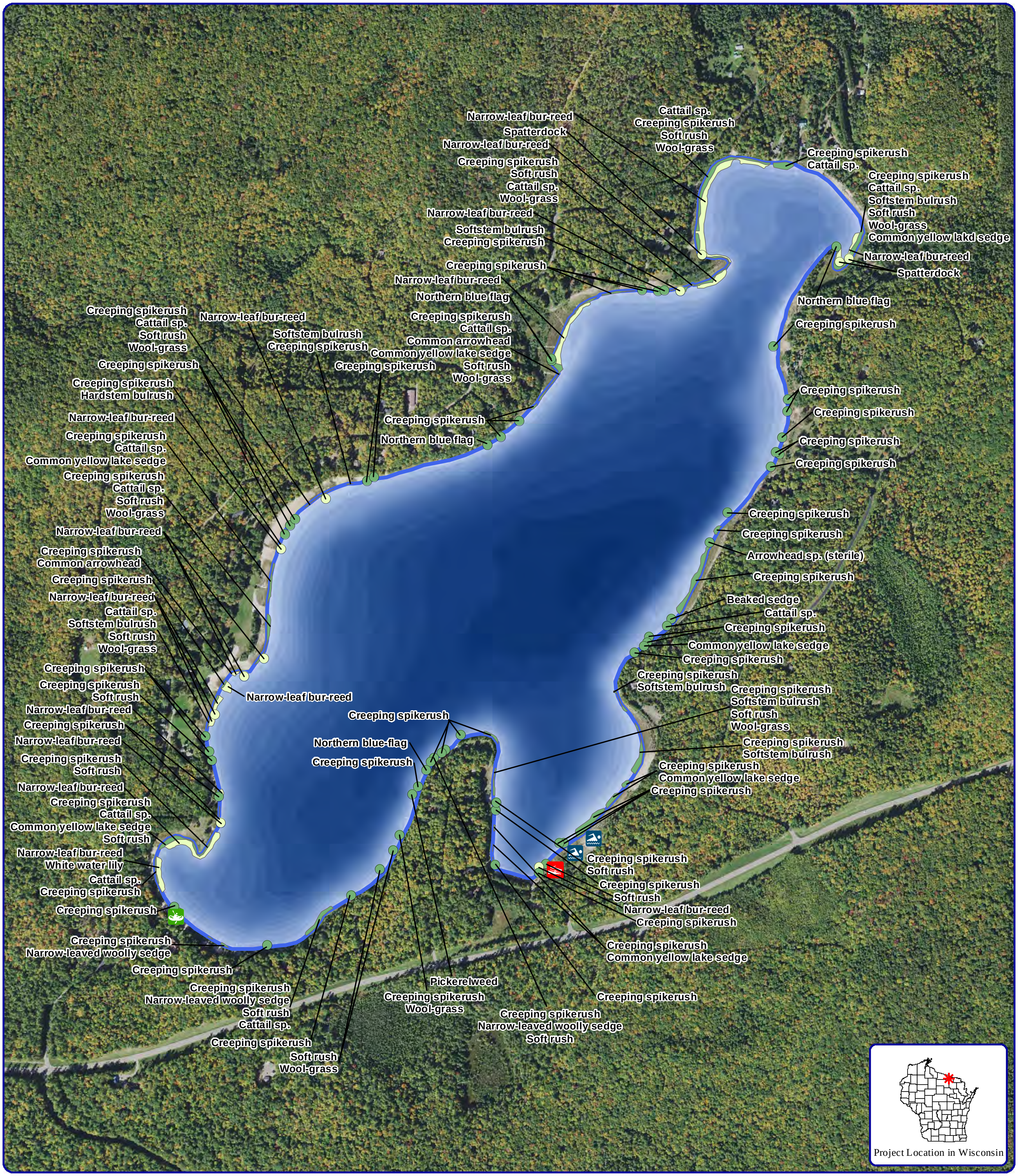
Sources:
Hydro: Onterra, 2015
CWH Survey: Onterra, 2015
Ortho: WDNR, 2013
Map Date: November 4, 2015
Filename: Map3_Anvil_CWH_Fall15.mxd

Map 3
Anvil Lake
Vilas County, Wisconsin

2015 Coarse Woody Habitat



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Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2015
Orthophotography: NAIP, 2013
Map date: December 29, 2015
Filename: *Map4_Anvil_Comm_2015.mxd*

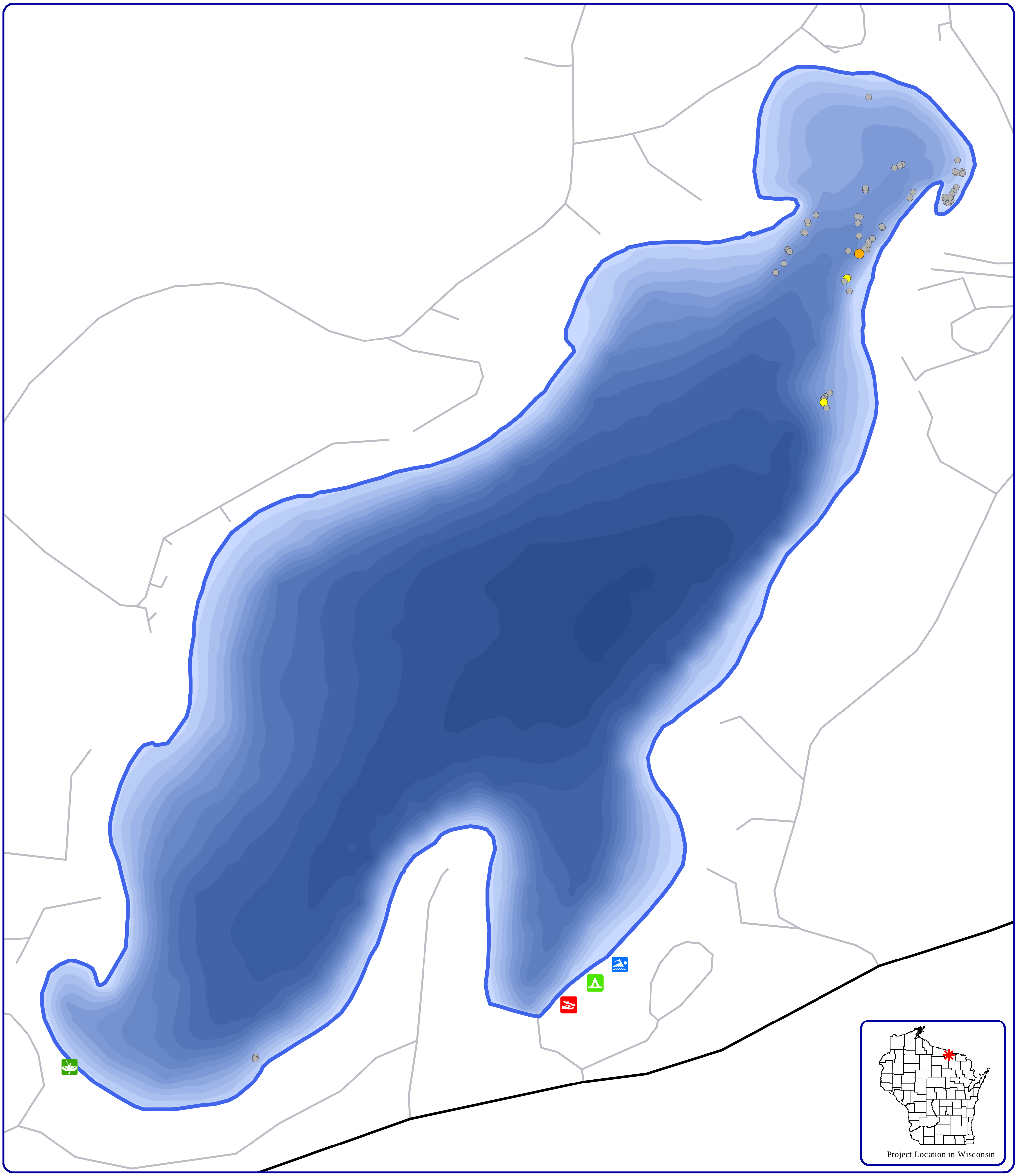
Legend

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

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

Map 4
Anvil Lake
Vilas County, Wisconsin

Aquatic Plant Communities



Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2016
Orthophotograpy: NAIP 2015
Bathymetry: Onterra, 2014; processed by Navico
Map date: June 21, 2016
Filename: *Map5_Anvil_CLP_June16.mxd*

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Legend

CLP Survey (June 15, 2016)

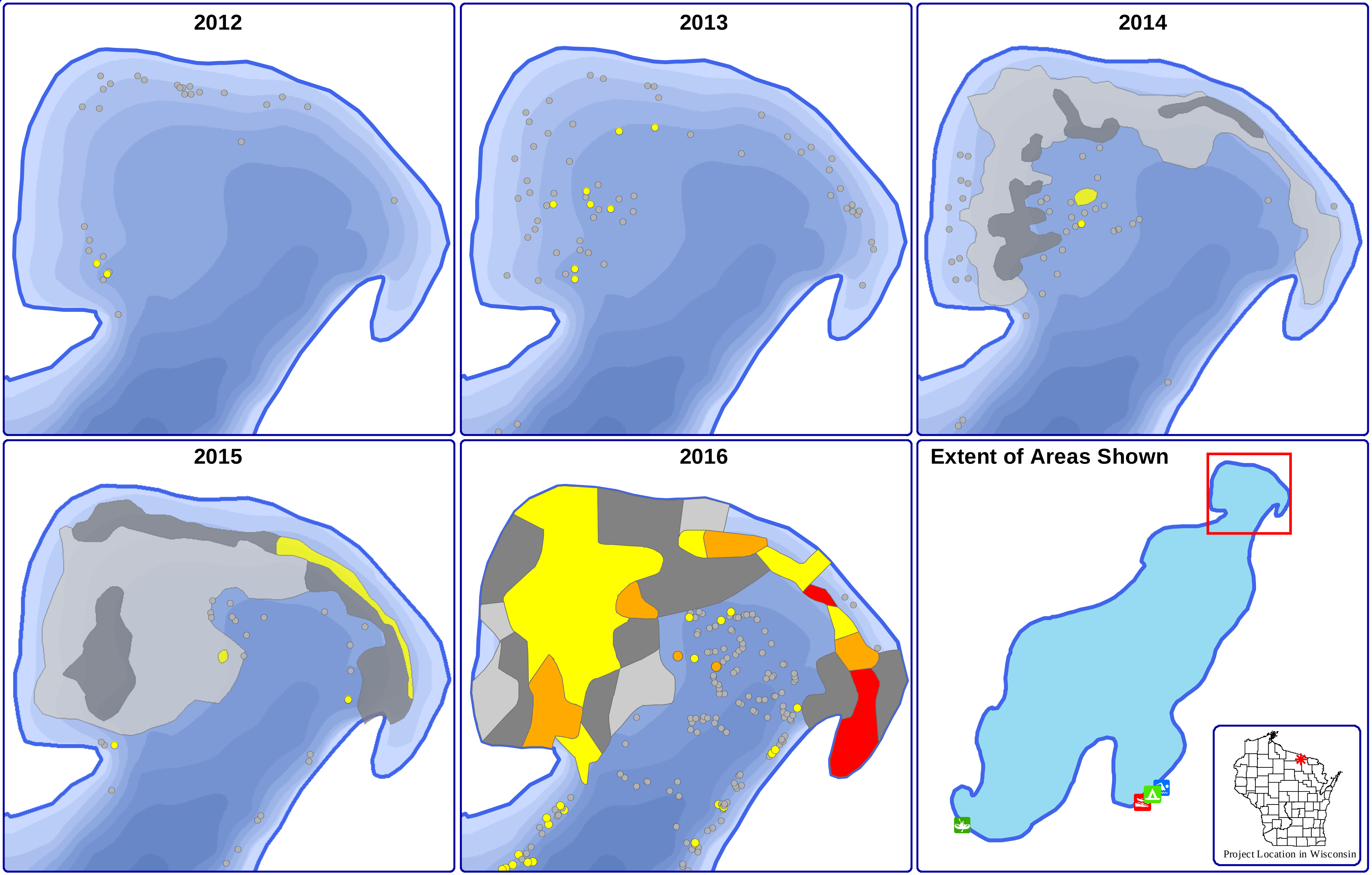
- Highly Scattered *(none)*
- Scattered *(none)*
- Dominant *(none)*
- Highly Dominant *(none)*
- Surface Matting *(none)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

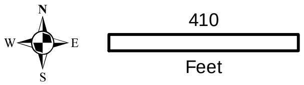
Map 5

Anvil Lake

Vilas County, Wisconsin

June 2016 ESAIS
Suvey Results: CLP





Legend

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

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Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2014; processed by Navico
Plant Survey: Onterra, 2012-16

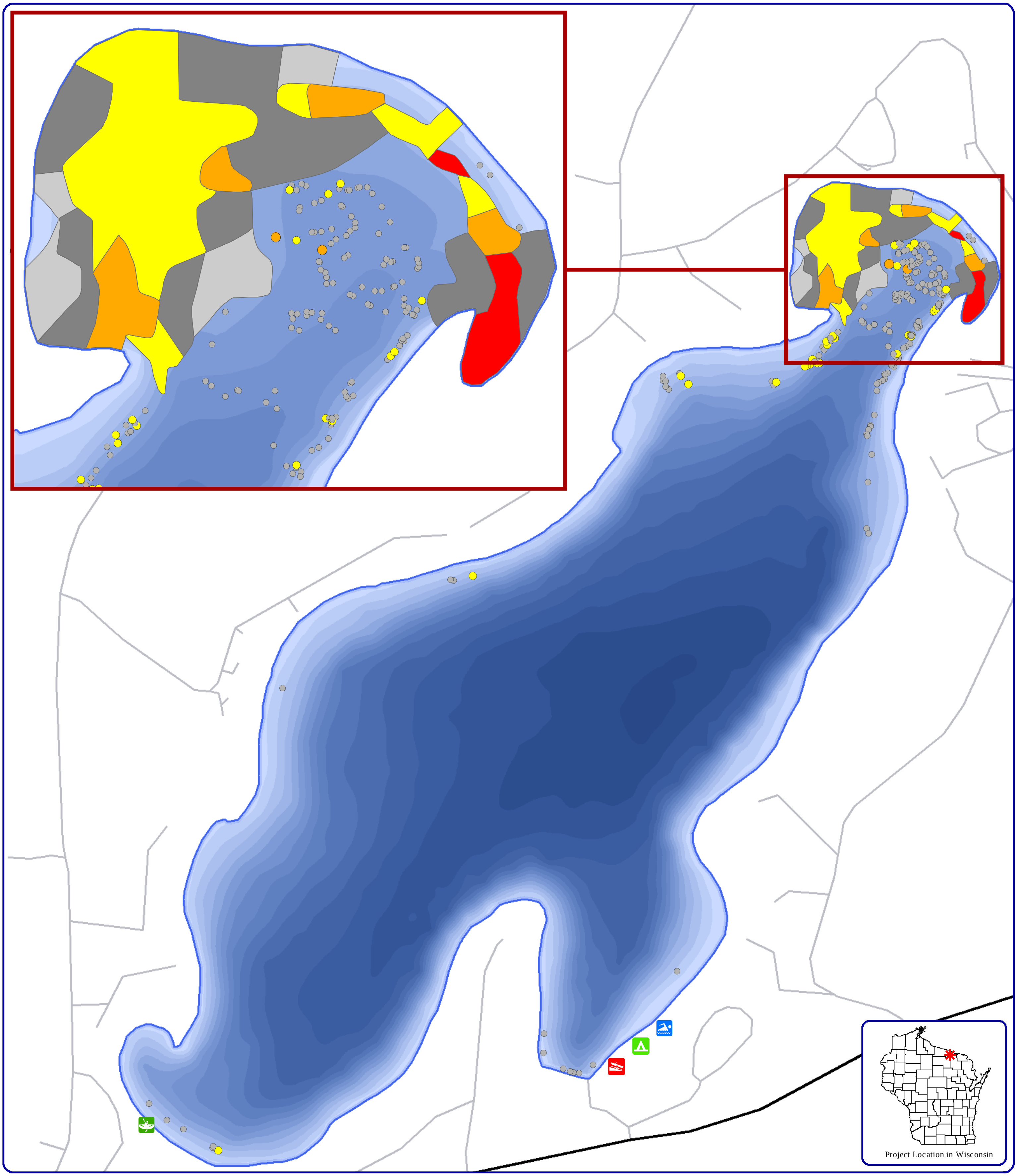
Map Date: November 23, 2016

Filename: *Map6_Anvil_EWM_Progression_2012-16.mxd*

Map 6

Anvil Lake
Vilas County, Wisconsin

2012-2016 North Bay EWM Progression



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Feet

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Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2016
Orthophotography: NAIP 2015
Bathymetry: Onterra, 2014; processed by Navico
Map date: October 10, 2016
Filename: *Map7_Anvil_EWMPB_Sept16.mxd*

Legend

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

Map 7

Anvil Lake
Vilas County, Wisconsin

September 2016
EWM Survey Results