INTRODUCTION

Anvil Lake, Vilas County, is an approximate 400-acre seepage lake with an average depth of 19 feet and a maximum depth of 32 feet (Photo 1). Eurasian water milfoil (*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. 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.

Photo 1. Anvil Lake, Vilas County

In 2012, the Anvil Lake Association successfully applied for a WDNR AIS Early Detection and Response Grant and contracted with Onterra, LLC to conduct comprehensive studies to aid in creating a plan to control the EWM population. This plan included professional and volunteer monitoring as well as volunteer hand-harvesting. In the spring of 2013, Onterra conducted an Early-Season AIS Survey where additional EWM was located in the northern bay of the lake. Volunteer hand-harvesting was having a positive impact in the shallow parts of the North Bay, but EWM expansion was occurring in waters greater than 4-feet deep. A decision was then made by the ALA, after many correspondences with Onterra, LLC and the WNDR, to hire a professional hand-harvesting company. The ALA hired Many Waters, LLC to use their Diver Assisted Suction Harvester (DASH) system to remove EWM. Onterra visited the lake again in the late summer of 2013 to assess the EWM lake-wide as well as to assess the professional hand-harvesting efforts. The 2013 EWM control on Anvil Lake was met with encouraging results but the efforts were not sufficient to impact the EWM population as a whole on Anvil Lake.

Following surveys conducted in the late summer of 2013, the population of EWM within Anvil Lake was still confined to low density EWM occurrences, with most occurrences being mapped with point-based methods. A hand-harvesting program utilizing professional hand-harvesters was determined to be the most appropriate option for maintaining the low-density population of EWM within Anvil Lake in 2014. Surveys in 2014 showed that EWM continued to expand within the northern bay despite hand removal efforts and EWM lake-wide remained relatively low. The 2014 professional hand-harvesting EWM control program on Anvil Lake was not able to maintain or reduce the EWM population within the North Bay as the EWM populations were found to expand in size and density.

2015 EWM CONTROL STRATEGY

A two-tiered hand harvesting approach was recommended in 2015. This included a combination of professional and volunteer-based hand harvesting of EWM. Professional hand harvesting was recommended for areas mapped in August 2014 comprised of the largest known EWM colonies within the northern bay of the lake. A volunteer effort was recommended for any known areas of EWM outside of where professional removal efforts where being undertaken. This report discusses the 2015 EWM monitoring and control activities.

A set of EWM mapping surveys were used within this project to coordinate and qualitatively monitor the hand-harvesting efforts. The first monitoring event on Anvil Lake in 2015 was the Early Season Aquatic Invasive Species Survey (ESAIS). This late-spring/early-summer survey provides an early look at the lake to help guide the hand-harvesting management to occur on the system. Following the hand-harvesting, Onterra ecologists completed the Late-Summer EWM Peak-Biomass Survey, the results of which serve as a post-treatment assessment of the hand-harvesting. The hand-removal program would be considered successful if the density of EWM within the hand-removal areas was found to have decreased from the ESAIS Survey to the Late-Summer Peak-Biomass Survey.

EARLY SEASON AIS SURVEY RESULTS (PRE-HAND-HARVESTING)

On June 17, 2015, Onterra ecologists conducted the ESAIS Survey on Anvil Lake. During the survey, the EWM population was mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *Highly Scattered* to *Surface Matting*. Point-based techniques were applied to EWM locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants*.

The largest concentration of EWM in the lake was again located in the northern most bay of the lake where EWM colonies consisted of *highly scattered*, *scattered* and *dominant colonies* (Map 1). Additional point based EWM occurrences were located in and just outside of the North Bay as well as in other areas of the lake. From this survey, the hand-harvesting control plan was finalized which included professional hand removal efforts within 12 acres in the northern bay as well as volunteer based removal in other areas of the lake (Map 1). Onterra provided the spatial data from this survey to the professional hand-harvesting firm and to the ALA to aid in the removal efforts.

HAND-HARVESTING MANAGEMENT ACTIONS

The ALA contracted with Many Waters, LLC to hand-harvest EWM in 2015. Many Waters conducts hand-harvesting using a Diver-Assisted Suction Harvest (DASH) system. The DASH system involves scuba divers removing EWM by hand and feeding the harvested plants into a suction hose emptying to a pontoon boat for removal. It is believed that the DASH system is able to remove/reduce areas of EWM more efficiently than standard manual removal by scuba divers, particularly dense colonies or those located in deep water. In addition, the DASH system likely reduces the amount of EWM fragments created during hand-removal.

Many Waters conducted hand-harvesting activities on five days between August 3 and August 12, 2015. Many Waters spent a total of 23.25 dive hours actively hand-harvesting EWM in the lake and removed approximately 791 pounds of EWM from site A-15 (Table 1). Prior to the hand-harvesting,

the original harvesting site A-15 was further sub-divided into four sections for reporting purposes (Figure 1). All of the hand–harvesting efforts conducted by Many Waters were conducted within site A4-15. Due to time constraints, no removal efforts were conducted by Many Waters in A1-15, A2-15 or A3-15. Details of the 2015 professional hand-harvesting activities as reported by Many Waters, LLC are included as an appendix to this report (Appendix A).

Table 1. Anvil Lake, 2015 professional hand-harvesting activities

	Dive Time (hours)	EWM Removed (pounds)
8/3/2015	3.00	40.0
8/4/2015	4.50	136.5
8/10/2015	5.25	262.0
8/11/2015	5.50	178.0
8/12/2015	5.00	174.5
Total	**23.25**	**791**

An extensive and well-coordinated hand-harvesting effort was also undertaken by members from the ALA during 2015. The objective of these efforts was to initially target all known EWM locations outside of the North Bay and to continue surveying and searching for new EWM locations around the lake. Additional removal efforts would then be focused in the North Bay to supplement the professional based removal efforts (Appendix B). In addition to Many Waters, the ALA obtained paid EWM removal services from two additional sources. At least 69.5 hours of on-the-water time was spent by one paid ALA diver and assistant. Of these efforts, approximately 13 hours involved surveying and removal efforts throughout known EWM locations outside of the North Bay and the majority of the effort (at least 52 hours) was focused within the North Bay (Appendix B). The yield of EWM from these efforts was reported as 3750.6 wet weight pounds and included significant by-catch weight composed largely of wild celery and some curly-leaf pondweed (Appendix B). An additional diver was hired in the late summer to conduct EWM removal within the North Bay. These efforts consisted of one SCUBA diver and two volunteer assistants and totaled 16 dive hours focusing on moderately shallow areas between 5-10 feet of water. Additional removal efforts by ALA members included three hours of EWM monitoring and removal time in the southwest part of the lake and four hours of snorkel diver harvesting the eastern part of North Bay.

LATE-SUMMER PEAK-BIOMASS SURVEY RESULTS (POST HAND-HARVESTING)

The Late-Summer EWM Peak-Biomass Survey was conducted on September 16, 2015 to qualitatively assess the hand-harvesting efforts as well as to understand the peak growth (peak-biomass) of the EWM population throughout the lake. Within the 2015 professional hand-harvest area, little change in the EWM population was observed when compared to pre-hand-harvesting in June of 2015 (Figure 1). While a small *dominant* colony located in June within A4-15 seems to have been reduced, the EWM population remained *scattered* or *highly scattered* throughout the majority of the targeted area. The combined removal efforts within site A4-15 seem to have maintained the EWM population at approximately the same level between June and September 2015. Within the other hand-harvesting areas in North Bay in which no professional removal efforts were undertaken, but significant ALA removal efforts occurred, EWM populations expanded somewhat in size and density (Figure 1). The

largest increases in EWM density in the North Bay was within sites A1-15 and A2-15 in the eastern portion of the bay where EWM expanded to form a strip of a *dominant* density colony within an overall larger *scattered* EWM colony (Figure 1). Overall, the 2015 hand-harvesting efforts within the North Bay were not sufficient to reduce the EWM population; however, the efforts of professionals and volunteers very likely slowed the overall expansion within the bay.

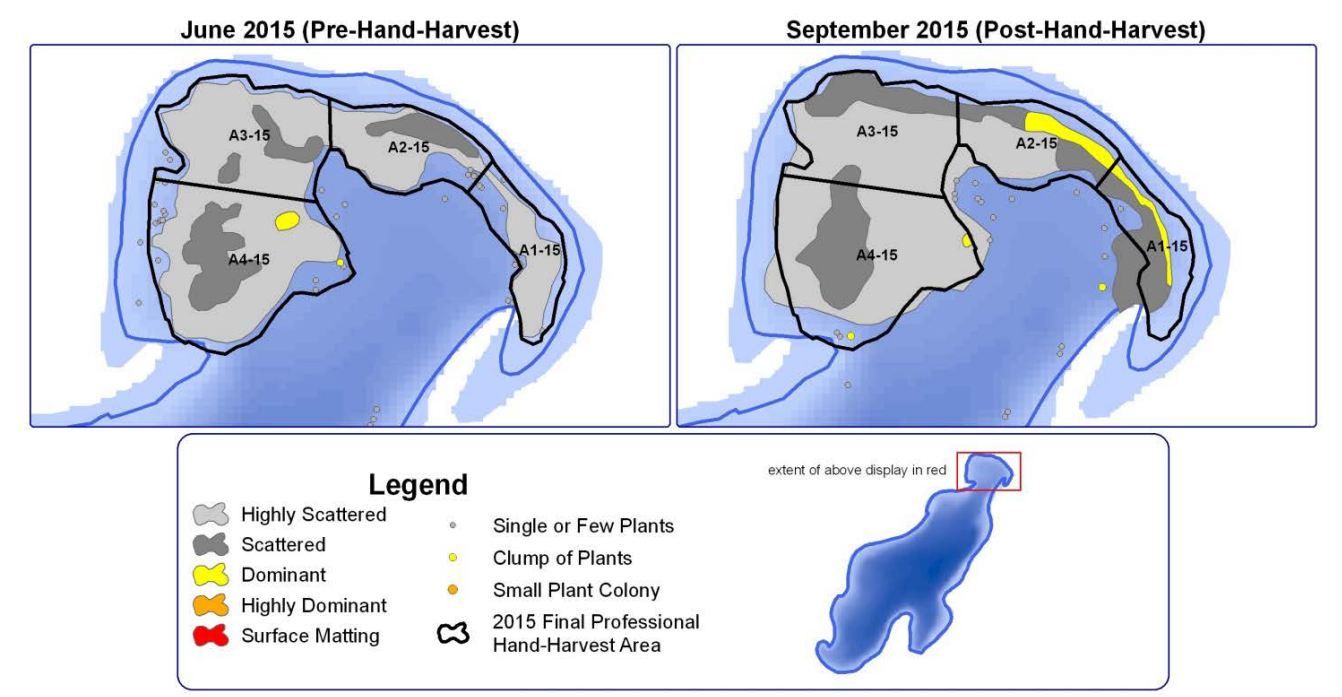

Figure 1. June 2015 pre- and September 2015 post-hand-harvesting EWM survey results in Anvil Lake.

While most EWM is concentrated in the northern bay, there was low density plant occurrences located in the southern bays of the lake near the boat landing and in the far southwest area of the lake as well as in a few locations along the western shore of the lake (Map 2). Removal efforts conducted on EWM locations outside of the northern bay seem to have helped keep the EWM population in check in these areas as EWM is yet to gain a strong presence or to form colonized populations anywhere outside of the northern bay. Overall, the amount of colonized EWM was found to have increased from 6.9 acres in 2014 to 11.2 acres in 2015, all of which are within the northern bay of the lake. Of the 11.2 acres of colonized EWM mapped in 2015, approximately 7.3 acres is of a *highly scattered* density, 3.4 acres were *scattered* and another 0.5 acres is of a *dominant* density.

CURLY LEAF PONDWEED (CLP)

In addition to mapping EWM during the Early-Season AIS Survey, ecologists are also looking for potential occurrences of other non-native aquatic plants. Curly-leaf pondweed (*Potamogeton crispus*; CLP) is at or near its peak growth in early summer before naturally senescing (dying back) in early July, making early summer the most probable time to locate this species. 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 northern bay as well as two *small plant colonies* near the southwestern bay and a *clump of plants* along the eastern shore of the lake (Map 3). Many Waters also observed CLP within the northern bay during their EWM hand-harvesting activities in August 2015 (Appendix A).

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. 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.

CONCLUSIONS AND DISCUSSION

Overall, the combined hand-harvesting EWM control program on Anvil Lake was not able to maintain or reduce the EWM population within the targeted areas in the northern bay. The rate of growth and expansion of the EWM population exceeded the pace of removal efforts during 2015. It is important to note that without the hand-removal efforts, the expansion would have likely been much greater in both density and area in the North Bay. Efforts undertaken to remove EWM from other areas of the lake have helped to keep populations very low outside of the northern bay. In light of the recent increasing CLP population within the lake, this species should be closely monitored in 2016 and beyond as the potential need for control activities may arise. The CLP population will be mapped in a June 2016 survey, the results of which may be utilized to determine whether more serious control actions are warranted.

A much larger amount of hand-harvesting effort would be required to achieve significant control of the 11.2 acres of colonized EWM within the northern bay. The exact amount of manual removal effort that would be required to control the EWM population in the North Bay is difficult to quantify. One northern Wisconsin lake in Oneida County has used an aggressive WDNR grant-funded hand removal strategy for EWM control with mixed results. That project included both professional hand-harvesting with DASH and a vast effort through a paid dive team consisting of local divers. The combined hand-removal efforts totaled over 1,200 hours of active dive time in 2014 and included diving throughout nearly the entire growing season at a cost exceeding $28,000. This amount of effort resulted in EWM reductions in many of the areas targeted, and helped to keep the overall EWM population in check. The 2015 harvesting program on the Oneida County lake included modifications in the strategy including setting clear prioritizations recommended by Onterra and initial assessments seem positive although have not yet been fully reported on. Approximately 714 hours of active EWM removal in 2015 appear to have preliminarily met the pre-determined success criteria for the Oneida County lake. However in this case, the success criteria at some sites were based on a stated goal of simply to maintain the current EWM population rather than reduce the population at the site. The level of hand-

removal effort from the paid diver team alone in 2015 equated to approximately 65 dive hours/acre with highly capable SCUBA divers and at a cost of $17,500. Additional costs were used for hiring a professional firm using DASH in 2015. Comparatively, approximately 9 hours/acre of combined on the water time (not just active diving time) was conducted by divers in Anvil Lake in 2015. Although the EWM situations are different between the Oneida County lake and Anvil Lake, the effort conducted in the Oneida County lake was at least 7-8 times greater than the levels of effort conducted in Anvil Lake in 2015. While the program on the Oneida County lake met success criteria in most of the designated hand-harvesting locations, criticism has surfaced about the long-term applicability of this technique, particularly after the WDNR grant-funded project ends. It is not clear that the WDNR would continue funding that type of project given the amount of effort and cost required to meet success criteria let alone achieve lake-wide control expectations.

Through analyzing the bio-acoustic data collected in 2014 as well as the sediment composition data obtained from the 2015 point-intercept data, an understanding of the habitat conditions within the lake where EWM seems to favor can be developed (Figures 2a & 2b). Much of the North Bay is composed of mucky or softer sediments and with the combination of water depth, seems to form a preferred habitat zone for EWM growth in the lake. Similar conditions around other areas of the lake may be suitable locations for EWM to become established. It is these areas which should be closely monitored and given high priority for EWM removal in 2016 to help contain the main EWM population within the North Bay and prevent significant EWM establishment in other areas of the lake. Areas with softer, muck substrates may be easiest to visualize in looking at the substrate composition from the point-intercept survey in Figure 2b.

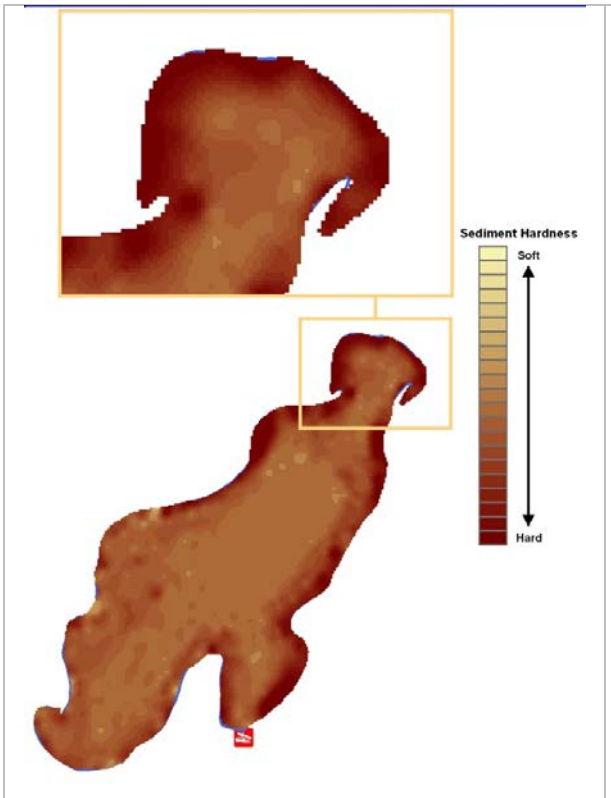

Figure 2a. Anvil Lake Substrate Hardness. Data obtained from Onterra 2014 Acoustic Survey

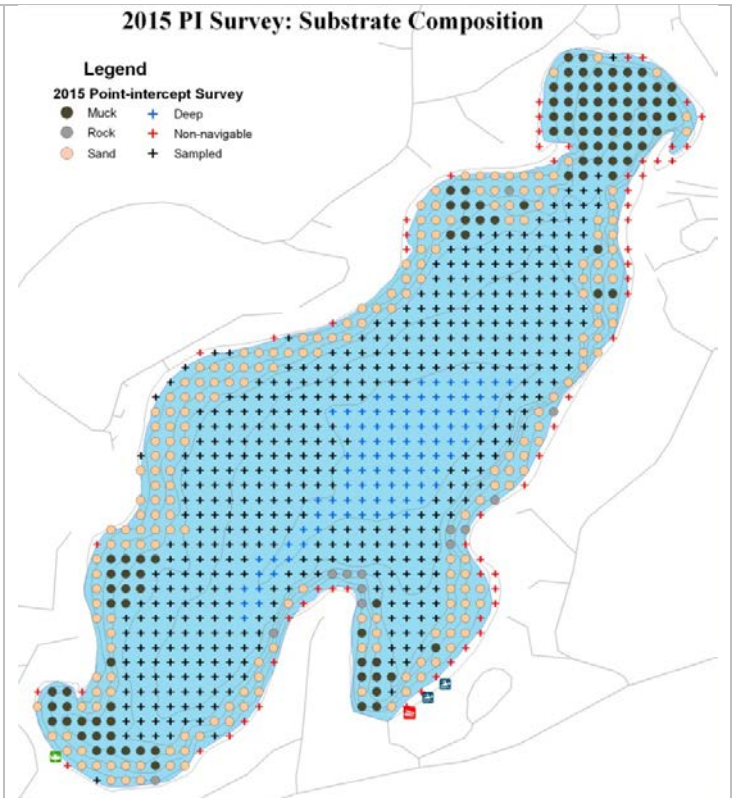

Figure 2b. Anvil Lake Substrate Composition. Data obtained from Onterra 2015 Point-Intercept Survey

An objective of the EWM control activities in 2016 should be to monitor and remove all EWM locations outside of the North Bay with particular focus on areas that have similar sediment characteristics to the North Bay as illustrated in the above figures. 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.

Any professional based DASH removal efforts should be directed within the northern bay and may be best served in the densest or deeper water areas of EWM. If the ALA believes that EWM control has been achieved in the other known locations in the lake, and sufficient time and funds remain, then directing as much effort as is available by ALA volunteers or paid local divers to harvesting the EWM within the northern bay is encouraged. Removal efforts in the northern bay could be focused on the more visible EWM plants which may impede recreational uses on the lake or in high use areas of the bay. It is critical that volunteer and paid local diver-based hand-harvesting or monitoring be again approximately tracked in the same fashion as the professional activities; where volunteers record where, when, and how much effort (time) that are spent conducting these activities. This will allow for a better understanding of how well the techniques are or are not working to keep EWM under control in Anvil Lake. Onterra will conduct an EWM mapping survey during June 2016 and provide the ALA and professional hand-harvesters with a basemap containing the survey findings which will help guide hand removal activities. Following the June survey, EWM locations in the North Bay and elsewhere in the lake will be divided into areas from which all removal efforts can be tracked and reported on over the course of the summer.

In an effort to reduce added fragmentation from boat traffic, the ALA should encourage members to limit boating activities in the North Bay and consider adding signage at the public boat landing informing general lake users about the presence of EWM in North Bay and asking that boaters refrain from driving through the EWM colonies.

During the current planning project, with its first planning meeting to be held during spring 2016, consideration to other management options will be given. Control actions including continued volunteer or paid local diver hand-harvesting, professional hand-harvesting, the acquisition of a DASH system by the ALA, and conducting an herbicide treatment in North Bay will be considered. The stakeholders involved in the planning process will clearly define future management goals for the EWM control program along with establishing thresholds (triggers) of when specific active treatment strategies warrant implementation. This discussion will inevitably also include the option of not conducting active management of the EWM population on the system; a management decision being made by some lake groups that are not willing to allocate financial resources and depending on the strategy, assume a certain level of native plant impacts in order to achieve EWM management goals.

Onterra will conduct a late-summer survey that will be used to evaluate the 2016 professional and volunteer-based hand-harvesting efforts, as well as to propose a control strategy for 2017. Discussions during the course of the ongoing planning process will ultimately lead to the formation of the AIS control strategy for 2016 and beyond.

Project Location in Wisconsin

2015 Final Control Strategy

Professional Hand-Harvest (DASH)

Site	Acres	Depth (feet)	Sediment	Obstructions
A-15	12.0	6 (4-11)	Heavy Organic, Sandier Near Shore	No Physical, Heavy Native Plants Later in Growing Season
Total	**12.0**			

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Feet

Onterra LLC
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De Pere, WI 54115
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Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2015
Orthophotography: NAIP 2013
Bathymetry: Onterra, 2014

Map date: June 22, 2015

Legend

EWM Survey (June 17, 2015)

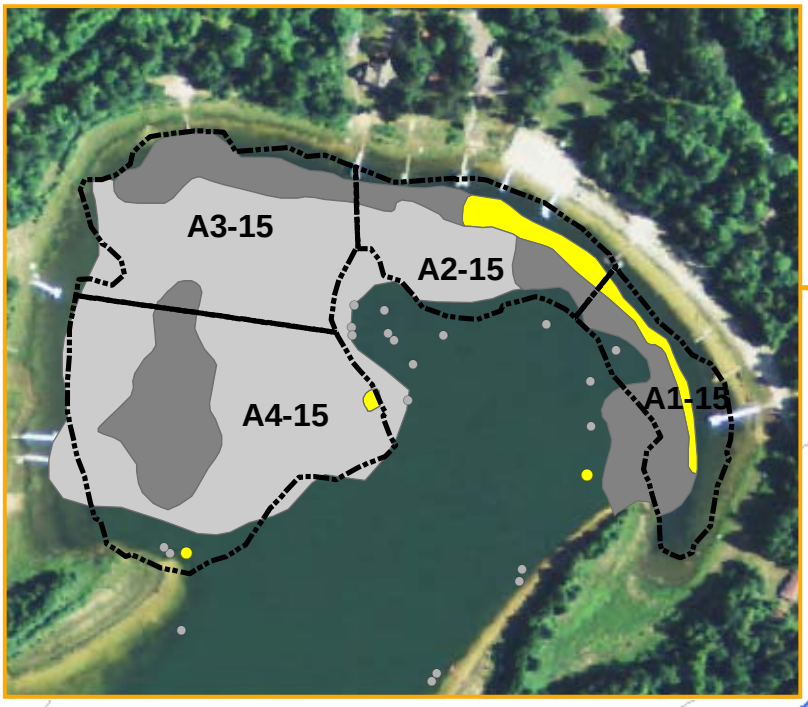
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(none)*
- Surface Matting *(none)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(none)*
- 2015 Final EWM DASH Work Zone

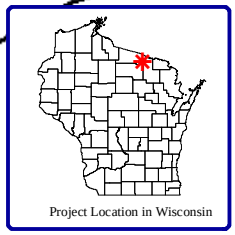
Map 1

Anvil Lake

Vilas County, Wisconsin

2015 EWM Diver Assisted Suction Harvesting Work Zones





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Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2015
Orthophotography: NAIP 2013
Bathymetry: Onterra, 2014; processed by Navico

Map date: September 24, 2015

Legend

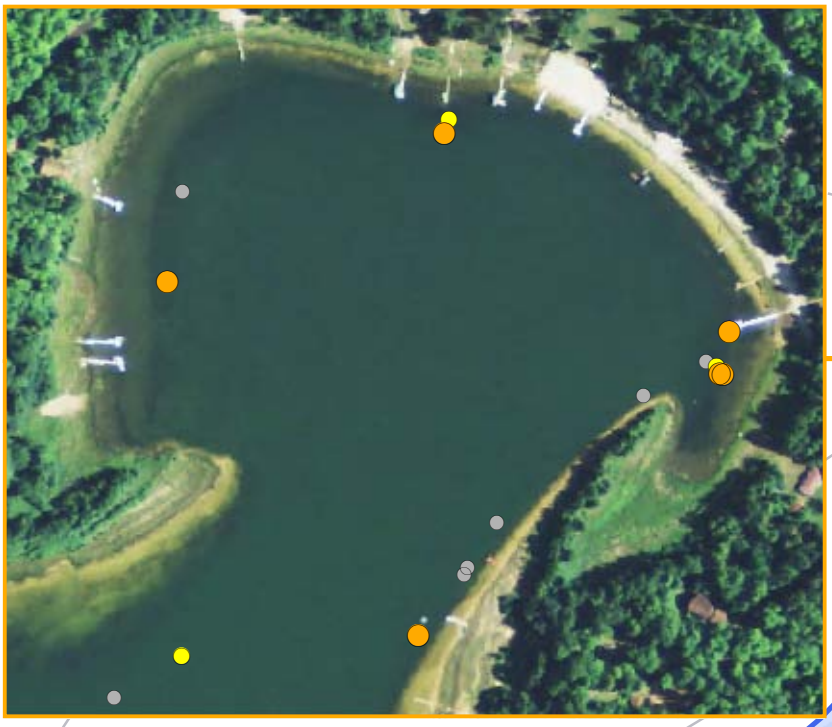
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(none)*
- Surface Matting *(none)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(none)*
- 2015 DASH Area

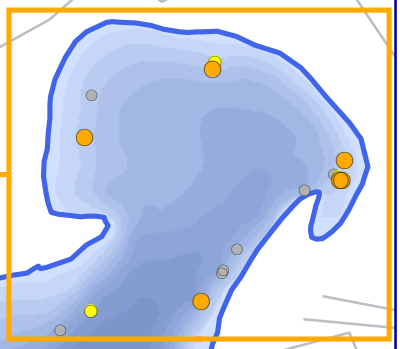
Map 2

Anvil Lake

Vilas County, Wisconsin

September 2015 EWM Survey Results





Project Location in Wisconsin

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Feet

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Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2015
Orthophotography: NAIP 2013
Bathymetry: Onterra, 2014

Map date: June 22, 2015

Legend

CLP Survey (June 17, 2015)

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

Map 3

Anvil Lake

Vilas County, Wisconsin

June 2015 ESAIS Suvey Results: CLP