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APPENDIX G

AIS-EPC Grant (ACEI-195-17) Annual Reports

Please note: The Aquatic Invasive Species Control and Monitoring Plan described in Management Goal 1, and its subsequent management actions, was prioritized to be completed at an accelerated timeline in order for a draft to be created and submitted to the WDNR by December 1, 2016. The draft was submitted prior to the deadline which made the WCOLD eligible to apply for AIS-Established Population Control Grant funds by the February 1, 2017 deadline. The grant application was successful and all actions described under Management Goal 1 have begun. Progress and results of these actions, along with appropriate refinements to them, can be found in the annual reports attached as Appendix G. Management Goal 1 remains in the future tense, nearly as it was originally submitted to the WDNR, but with some minor edits of typos and grammatical errors.

Management Goal 1: Conduct Aquatic Invasive Species Population Management in the Waupaca Chain O' Lakes

Management Action:	Conduct Three Year Field Trial Herbicide Control Program
Timeframe:	2017-2019
Facilitator:	Waupaca Chain O' Lakes District Board of Commissioners
Description:	As described in the Aquatic Plant Section (3.4), one of the most pressing threats to the health of the Waupaca Chain O' Lakes' aquatic plant community is hybrid watermilfoil. The 2015 Late-Summer HWM Peak-Biomass Survey map indicates that, excluding the Lower Chain, HWM can be found throughout much of the project waters (Maps 11-12). At this time, the most appropriate method of controlling HWM within the chain is with the use of large-scale (whole-lake) herbicide control strategies. Based upon the 2016 point-intercept surveys, many of the lakes contain HWM populations that exceed the 10% threshold between large-scale and spot treatments discussed in the Aquatic Plant Section. This suggests that if all of the HWM population is going to be targeted that the treatment would, by default, be a whole-lake treatment. On some of the smaller lakes, any spot treatment able to maintain sufficient concentration and exposure times would also end up being a large-scale treatment. As discussed within the Aquatic Plant Section (3.4), the fact that the Waupaca Chain's invasive milfoil population is largely, if not totally, comprised of HWM offers challenge to conducting effective control strategies. The WCOLD (and other managing entities) are now understanding that in order to effectively control the HWM population on a lake, more commonly employed large-scale herbicide use patterns may not be appropriate. Therefore, elevated target herbicide concentrations and/or alternative herbicide strategies may need to be considered.

Opportunities exist to conduct indoor laboratory or outdoor mesocosm studies to challenge the target plants from a specific lake against a number of herbicide treatment strategies (herbicide and dose). However, this scientific endeavor is currently at its infancy and there is uncertainty whether the results of the tests can be relayed to the field. There is no surrogate for field trials.

Due to the implementation challenges of hybridity (hybrid vigor), water exchange, and connectivity of treatment waterbodies, a 3-year trial program would be developed for a February 1, 2017 AIS-EPC Grant Application.

<u>Year 1 - 2017</u>

During the first year of the project, Dake Lake and Miner Lake would be targeted for a large-scale 2,4-D treatment at 0.375 ppm ae. This is a slightly elevated herbicide concentration over pure-strain EWM large-scale 2,4-D treatments (typically have lake-wide targets of between 0.275 ppm ae and 0.325 ppm ae). Watershed modeling indicates these lakes have relatively long water residence times (1,211 days) and water exchange is not likely to impact the results of the treatment.

Also during 2017, Otter Lake would be targeted with a large-scale treatment using a combination of 2,4-D (0.275 pm ae) and endothall (0.75 ppm ai). Otter Lake also has a long water residence time (480 days) where flow is not likely to significantly reduce herbicide concentrations faster than normal degradation. Having a comparative field trial with an elevated 2,4-D strategy (Dake/Miner) and a 2,4-D/endothall combination treatment (Otter) in the same year will prove valuable to determining future treatment strategies on the chain.

<u>Year 2 - 2018</u>

Youngs Lake, Bass Lake, Beasley Lake, and Long Lake are all in succession and contain some of the highest HWM populations within the chain. While targeting these lakes is important to control HWM on a chain-wide basis, there are a number of implementation challenges that make it more appropriate to target these lakes in year two.

Using traditional watershed modeling tools, the residence time of these lakes is quite short – approximately four days on Youngs-Bass Lakes, 14 days on Beasley Lake, and 48 days on Long Lake. However, this modeling may not be completely accurate and the whole topographic watershed may not be available for overland runoff. As is common for many lakes in the area, much of the watershed is sand, which allows water to percolate into the groundwater. If this is the case, the water residence times may be much longer than the modeling predicts.

With assistance from Waupaca County, a flow study would be completed in 2017 that will provide more accurate data on flow between the waterbodies.

Coinciding with these studies, acoustic-based bathymetric studies will be conducted and allow for an understanding of water retention times. Based upon the results of the flow study and the initial outcomes of the 2017 herbicide treatment field trials, an herbicide treatment strategy would be developed for implementation during the spring of 2018.

During 2016, whole-lake point-intercept surveys and Late-Summer HWM Mapping Surveys were conducted on the entire chain and would serve as a pretreatment dataset. These studies would be completed in 2017, 2018, and 2019 to track the efficacy of the treatments (i.e. HWM control) and selectivity of the native plant community (i.e. collateral native plant reductions).

During the *year of the treatment*, the project would include verification and refinement of the treatment plan immediately before control strategies are implemented. This potentially would include refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy.

Volunteer-based monitoring of temperature profiles would also be coordinated surrounding the treatment, as well as collection of post treatment herbicide concentration samples at multiple locations and sampling intervals.

The success criteria of a whole-lake treatment would be a 70% reduction in HWM littoral frequency of occurrence (LFOO) comparing point-intercept surveys from the *year prior to the treatment* to the *year of the treatment.* Regardless of treatment efficacy, a whole-lake treatment would not be conducted during the *year following the treatment*: Project success would be further demonstrated if significant HWM rebound does not occur during the *year following the treatment* and native plants during the *year following the treatment* are approximately at levels found *prior to the treatment.*

The WCOLD understands that HWM population rebound is inevitable following a whole-lake treatment. If a 70% reduction HWM LFOO is achieved during the timeline outlined, it is likely that the lowered HWM population will last 4 or more years before additional large-scale management would be needed. Integrated pest management activities, such as hand-harvesting and herbicide spot treatments, are outlined in the next management action (*Develop Long-Term Contingency Strategy for Rebounding HWM Populations*).

If the large-scale management strategy does not meet the control goal criteria, the WCOLD would review their goal of reducing the chain-wide HWM population within the lake. Initially, this would include investigation of alternative herbicides and use-patterns. This concept is elaborated on within

	the management action titled: *Investigate and Study Alternative Management Methodologies*. Based on the data collected over the three-year project, the WCOLD would revisit their management plan as it applies to HWM control and monitoring. Based upon the information gained during the multi-year control project, the WCOLD would update their management plan as appropriate. This may include targeting low-level HWM populations through coordinated volunteer and professional hand-harvesting efforts. Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund this control program. Specifically, funds would be applied for under the Established Population Control classification, currently on February 1st of each year.
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.	Initiate additional project to update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action:	Develop Long-Term Contingency Strategy for Rebounding HWM Populations
Timeframe:	Potentially 2019
Facilitator:	Waupaca Chain O' Lakes District Board of Commissioners
Description:	Many lake groups initiate a large-scale (aka whole-lake) herbicide strategy with the intention of implementing smaller-scale control measures (herbicide spot treatments, hand-removal) when HWM/EWM begins rebounding. This is referred to as Integrated Pest Management (IPM). Depending on the results of the *year after treatment* surveys, the WCOLD would likely initiate volunteer, or professional-based hand-harvesting activities, targeting the remnant HWM population. To properly coordinate hand-harvesting activities, an Early-Season AIS (ESAIS) Survey would be conducted during June of each year with the lakes that had large-scale herbicide treatments in the previous year. With the spatial data from the ESAIS Survey and delineated harvest areas loaded onto a GPS unit, harvesters would remove HWM following a previously outlined strategy by Onterra and the WCOLD. Hand-harvesting would take place between the ESAIS (pre) and the late-summer HWM Peak-Biomass (post) surveys, allowing for evaluation of the management activity.

	If the HWM population in some areas exceeds size or density levels that can be effectively controlled with hand-harvesting methods, the WCOLD would consider conducting herbicide spot treatments on those areas. Spot treatments of HWM populations would likely be conducted with herbicides that require short exposure times, such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). Occasionally, the HWM/EWM rebounds in a fashion that does not lend well to IPM. If the rebounded EWM population exceeds a level that can be controlled using best management practices, the WCOLD will cease coordinated small-scale population level management until the population again justifies another whole-lake treatment.
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. Please note that conducting management for the purpose of increasing navigability or recreation are not eligible for WDNR grants.
3.	Initiate control and monitoring plan.

1.0 INTRODUCTION

The Waupaca Chain O' Lakes consists of 22 lakes in Waupaca County, Wisconsin. According to the 1965 recording sonar Wisconsin Department of Natural Resources (WDNR) lake survey map, the Chain is approximately 724 acres. The WDNR website lists the Chain lakes to be approximately 809 acres and according to the WDNR Geographic Information System (GIS) lake shapes, the chain is approximately 839 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the National Agriculture Imagery Program (NAIP) collected in 2015. Based upon heads-up digitizing of the water level from that photo, the Chain was determined to be approximately 792 acres. Water quality sampling found the pH ranged from 8.3 to 8.7 in lakes sampled in 2016.

Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first documented in the Waupaca Chain O' Lakes in 2001. Due to distinct features of the EWM's morphology, Onterra field staff suspected that the EWM in the Waupaca Chain O' Lakes may be a hybrid, a cross between EWM and the indigenous northern water milfoil (*Myriophyllum sibiricum*). Investigations found that a single sample from Taylor Lake in 2013 had been sent by Golden Sands RC&D to the Annis Water Resources Institute at Grand Valley State University in Michigan for DNA analysis. The Institutes' results confirmed that the milfoil sent in from Taylor Lake was a hybrid between EWM and the native northern water milfoil. The WDNR collected additional suspect milfoil samples from Sunset, Round, George, Rainbow, and Otter Lakes in 2016 for genetic testing. All samples sent in were confirmed as being hybrid EWM (HWM).

The concept of heterosis, or hybrid vigor, is important in regards to hybrid water milfoil management in the Waupaca Chain O' Lakes. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. Hybrid water-milfoil typically has thicker stems, is a prolific flowerer, and grows much faster than pure-strain EWM (LaRue et al. 2012). These conditions likely contribute to this plant being particularly less susceptible to biological (Enviroscience personal comm.) and chemical control strategies (Glomski and Netherland 2010, Poovey et al. 2007). Data gathered from whole-lake 2,4-D treatments in Wisconsin from 2009-2016 suggest that treatments in lakes with populations of HWM were not as successful when compared to lakes with pure-strain EWM. In other words, it appears that some strains of HWM, but not all, are more tolerant of 2,4-D treatments than pure-strain EWM.

The Waupaca Chain O' Lakes Protection and Rehabilitation District, known locally as the Waupaca Chain O'Lakes District (WCOLD), has sponsored past grant-funded projects to examine the ecosystem, including a series of 1991-1992 lake management planning projects, a 2003 aquatic plant management plan, a 2005 aquatic invasive species education, prevention and control project (AIS-EPC funded) and a five-year education, planning and treatment grant project in 2009.

2.0 HWM CONTROL AND MONITORING STRATEGY

With the assistance of Onterra in 2015, the WCOLD was awarded a WDNR AIS-Education, Planning and Prevention Grant to aid in funding studies aimed at documenting the current state of the Chain's native and non-native aquatic plant populations to guide the development of future management strategies. Surveys conducted in 2015 found that HWM can be found throughout much of the project waters.

A commonly used method for controlling non-native plant populations is through herbicide applications. 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. Although a continuum of these categories exists, the research indicates two main treatment strategies: 1) spot treatments and 2) large-scale (aka whole-lake) treatments.

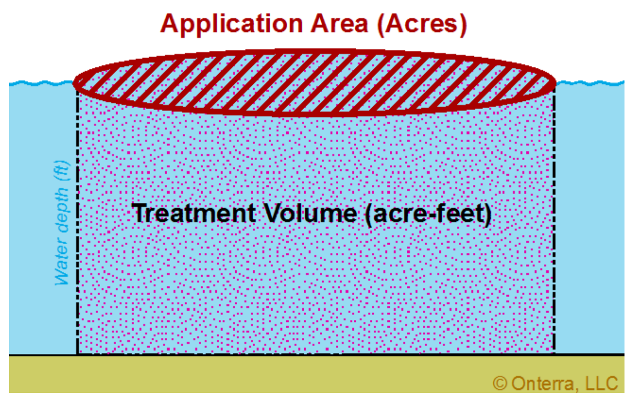


Figure 2.0-1. Herbicide Spot Treatment diagram.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area 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 2.0-1). 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 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 containing water exchange (i.e. flow) are often not able to meet herbicide concentration-exposure time (CET) requirements for control.

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. WDNR administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). The ecological basis of this standard is that if 10% of a lake were targeted with an herbicide at a standard spot treatment concentration, it may have the potential to produce lake-wide impacts. For example, if 10% of a lake is 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 (aka whole lake) 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. In Wisconsin, most large-scale AIS treatments use liquid 2,4-D amine. Properly implemented large-scale 2,4-D herbicide treatments can be highly effective on pure-strain EWM populations, with minimal EWM being detected for a year or two following the treatment (Figure 2.0-2, left frame) on some systems. Some large-scale 2,4-D treatments have been effective at reducing EWM populations for 5-6 years following the application. Following the same herbicide use pattern, HWM populations were reduced the year following treatment to a lesser degree than similar pure EWM populations (Figure 2.0-2, right frame). In almost all HWM populations, rebound took less time and the rebounded populations were at much higher frequencies than EWM populations.

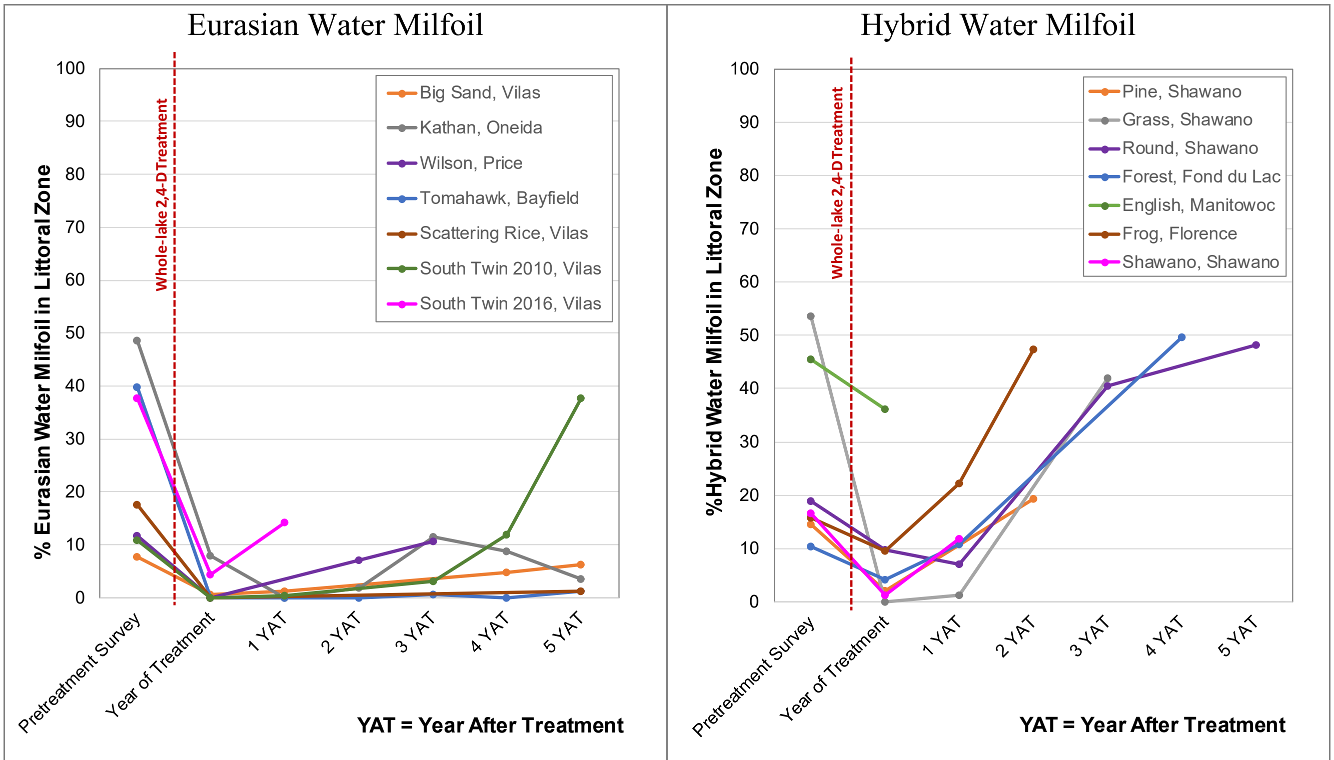


Figure 2.0-2. Littoral frequency of occurrence of invasive milfoil in lakes managed with large-scale 2,4-D amine treatments.

The concept of heterosis, or hybrid vigor, is important in regards to hybrid water milfoil management in the Waupaca Chain. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. Hybrid water-milfoil typically has thicker stems, is a prolific flowerer, and grows much faster than pure-strain EWM (LaRue et al. 2012). These conditions likely contribute to this plant being particularly less susceptible to biological (Enviroscience personal comm.) and chemical control strategies (Glomski and Netherland 2010, Poovey et al. 2007). In a recent study of 28 large-scale 2,4-D amine treatments in Wisconsin (Nault et al. 2017), HWM initial control was less and the longevity was shorter than pure-strain EWM control projects. Therefore, it appears that potentially most strains of HWM, but not all, are more tolerant of auxin-mimic herbicide treatments (e.g. 2,4-D, triclopyr) than pure-strain EWM. For clarity, that does not mean that they are resistant to the herbicide, as a higher dose would result in effective control; but the higher dose would result in increased native plant impacts and therefore is not a current best management practice.

Due to the implementation challenges of hybridity (hybrid vigor), water exchange, and connectivity of treatment waterbodies, a 3-year trial program was developed within a February 1, 2017 AIS-EPC Grant Application for the Waupaca Chain 'O Lakes (ACEI-195-17).

2.1 AIS Monitoring Strategy

During 2016, whole-lake point-intercept surveys and Late-Summer HWM Mapping Surveys were conducted on the entire Chain and would serve as a pretreatment dataset. These studies would be completed in 2017, 2018, and 2019 to track the efficacy of the treatments (i.e. HWM control) and selectivity of the native plant community (i.e. collateral native plant reductions).

During the *year of the treatment*, the project would include verification and refinement of the treatment plan immediately before control strategies are implemented. This potentially would include refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy.

Volunteer-based monitoring of temperature profiles would also be coordinated surrounding the treatment, as well as collection of post treatment herbicide concentration samples at multiple locations and sampling intervals. Waupaca County Land and Water Conservation Department (LWCD) has volunteered to assist within this project component.

The success criteria of a whole-lake treatment would be a 70% reduction in HWM littoral frequency of occurrence comparing point-intercept surveys from the *year prior to the treatment* to the *year of the treatment.* Regardless of treatment efficacy, a whole-lake treatment would not be conducted during the *year following the treatment*: Project success would be further demonstrated if significant HWM rebound does not occur during the *year following the treatment* and native plants during the *year following the treatment* are approximately at levels found *prior to the treatment.*

The WCOLD understands that HWM population rebound is inevitable following a whole-lake treatment. The rebound could be a result of survivorship, migration from other parts of the Chain, or sprouting/germinating from a seed or turion base. Depending on the results of the *year after treatment* surveys, the WCOLD would likely initiate volunteer or professional-based hand-harvesting activities, targeting the remnant HWM population. To properly coordinate hand-harvesting activities, an Early-Season AIS (ESAIS) Survey would be conducted in June 2019. With the spatial data from the ESAIS Survey and delineated harvest areas loaded onto a GPS unit, harvesters would remove HWM following a previously outlined strategy by Onterra and the WCOLD. Hand-harvesting would take place between the ESAIS (pre) and the late-summer HWM Peak-Biomass (post) surveys, allowing for evaluation of the management activity.

If the HWM population in some areas exceeds size or density levels that can be effectively controlled with hand-harvesting methods, the WCOLD would consider conducting herbicide spot treatments in those areas. Spot treatments of HWM populations would likely be conducted with herbicides that require short exposure times, such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.).

Based on the data collected over the three-year project, the WCOLD would revisit its management plan as it applies to HWM control and monitoring. This may include targeting low-level HWM populations through coordinated volunteer and professional hand-harvesting efforts.

2.2 HWM Control Strategy

Year 1 - 2017

During the first year of the project, Dake Lake and Miner Lake were targeted for a large-scale 2,4-D treatment at 0.375 ppm ae. This is a slightly elevated herbicide concentration over pure-strain EWM large-scale 2,4-D treatments. Watershed modeling indicates these lakes have relatively long water residence times (1,211 days) and water exchange is not likely to impact the results of the treatment.

Also during 2017, Otter Lake was targeted with a large-scale treatment using a combination of 2,4-D (0.275 pm ae) and endothall (0.75 ppm ai). Otter Lake also has a long water residence time (480 days) where flow is not likely to significantly reduce herbicide concentrations faster than normal degradation. Having a comparative field trial with an elevated 2,4-D strategy (Dake/Miner) and a 2,4-D/endothall combination treatment (Otter) in the same year will prove valuable to determining future treatment strategies on the Chain.

One spot-treatment site totaling 4.4 acres in Columbia Lake was targeted with diquat in 2017. This high-traffic area and boat landing was targeted to alleviate navigation impairment as well as for containment purposes. Diquat is known to require a lower CET than 2,4-D, and this herbicide treatment will be evaluated within this report.

Year 2 - 2018

Youngs Lake, Bass Lake, Beasley Lake, and Long Lake are all in succession and contain some of the highest HWM populations within the Chain. While targeting these lakes is important to control HWM on a Chain-wide basis, there are a number of implementation challenges that make it more appropriate to target these lakes in year two.

Using traditional watershed modeling tools, the residence time of these lakes is quite short – approximately four days on Youngs-Bass Lakes, 14 days on Beasley Lake, and 48 days on Long Lake. However, this modeling may not be completely accurate and the whole topographic watershed may not be available for overland runoff. As is common for many lakes in the area, much of the watershed is sand, which allows water to percolate into the groundwater. If this is the case, the water residence times may be much longer than the modeling predicts.

With assistance from Waupaca County LWCD, a flow study was completed in 2017 that will provide more accurate data on flow between the waterbodies. Coinciding with these studies, acoustic-based bathymetric studies were conducted which allow for an understanding of water retention times. Based upon the results of the flow study and the initial outcomes of the 2017 herbicide treatment field trials, an herbicide treatment strategy would be developed for implementation during the spring of 2018. The results of this study are described within the Conclusions section of this report.

3.0 HERBICIDE TREATMENT PLANNING & IMPLEMENTATION

3.1 Pre-treatment Confirmation and Refinement Survey

On April 26, 2017, Onterra ecologists conducted the HWM Spring Pre-treatment Confirmation and Refinement Survey on Otter, Dake, Miner, and Columbia Lakes. During this survey, the presence of actively growing HWM was confirmed on each of the lakes or proposed treatment sites. Minimal native aquatic plant growth was observed except for muskgrasses. Temperature profiles were taken at two foot increments in each lake. Onterra staff provided training and delivered the herbicide monitoring supplies to Waupaca County LWCD staff during the pretreatment survey.

3.2 Finalized Dosing Strategy for Treatment

In order to finalize the dosing volume for the 2017 whole-lake treatments, it was necessary to understand the volume of water in which the herbicide is expected to mix. As the water warms, a thermal barrier develops in many lakes essentially separating the lake into an upper epilimnion with warmer water temperatures and a lower hypolimnion with cooler water temperatures. The transitional area separating the upper and lower portions of the water column is known as the metalimnion. In recent years, it has become common for lake managers to predict the mixing volume of a lake based on the middle/upper-middle of the metalimnion, understanding that some amount of herbicide will be lost to the metalimnion.

Staff from Waupaca County LWCD provided numerous temperature profiles leading up to the large-scale herbicide treatments on Otter, Dake, and Miner Lakes (Figures 3.2-1 – 3.2-3). During April and early-May, the lake was warming, but not developing separate strata. Towards the middle of May, stratification parameters finally became apparent in Otter and Miner Lakes; whereas the stratification was slow to develop in Dake Lake. Despite the weak stratification parameters observed in Dake Lake, it was recommended not to postpone the herbicide treatment any longer as warming water temperatures coupled with an increase in native plant growth became factors to consider. The final dosing depth for each lake is displayed on Figures 3.2-1 - 3.2-3.

Map 1 displays the final large-scale herbicide treatment design and dosing strategy for Otter Lake in 2017. The treatment included application of 25.2 gallons of 2,4-D amine (DMA IV®) and 60.3 gallons of endothall dipotassium salt (Aquathol® K) over 9.0 acres of the lake.

Map 2 displays the final large-scale herbicide treatment design and dosing strategy for Dake Lake in 2017. The treatment included the application of 73.2 gallons of 2,4-D amine (DMA IV®) over 11.4 acres of the lake.

Map 3 displays the final large-scale herbicide treatment design and dosing strategy for Miner Lake in 2017. The treatment included the application of 139.5 gallons of 2,4-D amine (DMA IV®) over 13.6 acres of the lake.

Map 4 displays the final herbicide spot-treatment strategy for Columbia Lake. The treatment included the application of 7.65 gallons of diquat dibromide (Tribune®) over 4.4 acres of the lake. Diquat is a contact herbicide that requires a shorter contact time compared to 2,4-D necessary to achieve control and is more commonly used in smaller spot-treatment scenarios in which shorter concentration exposure times are likely to occur. The treatment area was broken into two parts to account for the differing average depths between the two sections of the site.

The herbicide treatments were conducted by Wisconsin Lake and Pond Resource on May 23, 2017. The applicator reported a near-surface water temperature of approximately 60°F and northeast winds of 5 mph at the time of application.

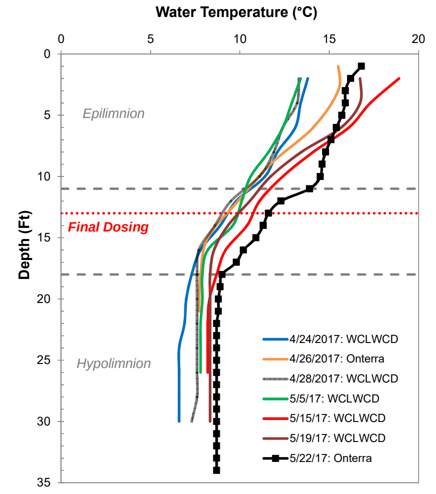


Figure 3.2-1 Pre-Treatment Temperature Profiles Collected on Otter Lake.

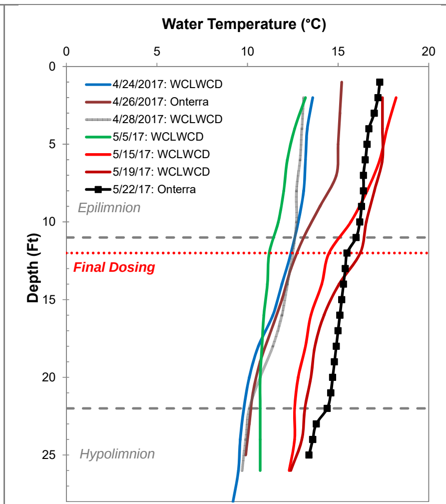


Figure 3.2-2 Pre-Treatment Temperature Profiles Collected on Dake Lake.

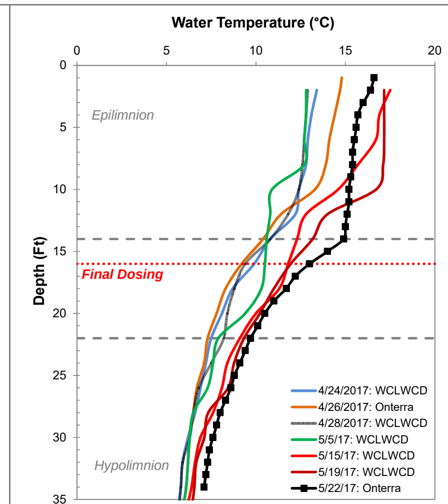


Figure 3.2-3 Pre-Treatment Temperature Profiles Collected on Miner Lake.

4.0 HERBICIDE MONITORING RESULTS

4.1 Herbicide Monitoring Results – Otter Lake

Map 1 displays the water sampling locations associated with the herbicide concentration monitoring for Otter Lake. Figure 4.1-1 shows the results of the 2,4-D monitoring for Otter Lake. The grey square symbol on Figure 4.1-1 represents water collected at 21 feet of water from the deep hole monitoring site (Site WO2). A negligible amount of herbicide was observed in the hypolimnion during the 2017 Otter Lake treatment in samples collected on 3 Days After Treatment (DAT) and 21 DAT which confirms that the herbicide was confined to its intended portion of the epilimnetic waters. Herbicide monitoring following the 2017 treatment found that the mean 1-7 DAT 2,4-D concentration was 0.310 ppm ae, slightly higher than the target concentration of 0.275 ppm ae. Monitoring showed 2,4-D levels were sustained at near the target concentration for a period of approximately 21 days. Samples collected on 28 DAT showed concentrations had decreased to 0.166 ppm ae and decreased to near detection limits by 35 DAT to 0.039 ppm ae.

Endothall concentrations were not tested at the lab and the 2,4-D values were used as a surrogate. It is theorized that endothall concentrations would approximately mimic the 2,4-D levels in the lake and an estimated endothall concentration is displayed on Figure 4.1-2. For example, mean 2,4-D concentrations were 127.3 % of the target concentration on 1 DAT (target = 0.275 ppm ae: actual = 0.350 ppm ae). Using this value, the estimated endothall concentration for 1 DAT was 127.3% of the target concentration (target = 0.532 ppm ae: estimated value = 0.677 ppm ae).

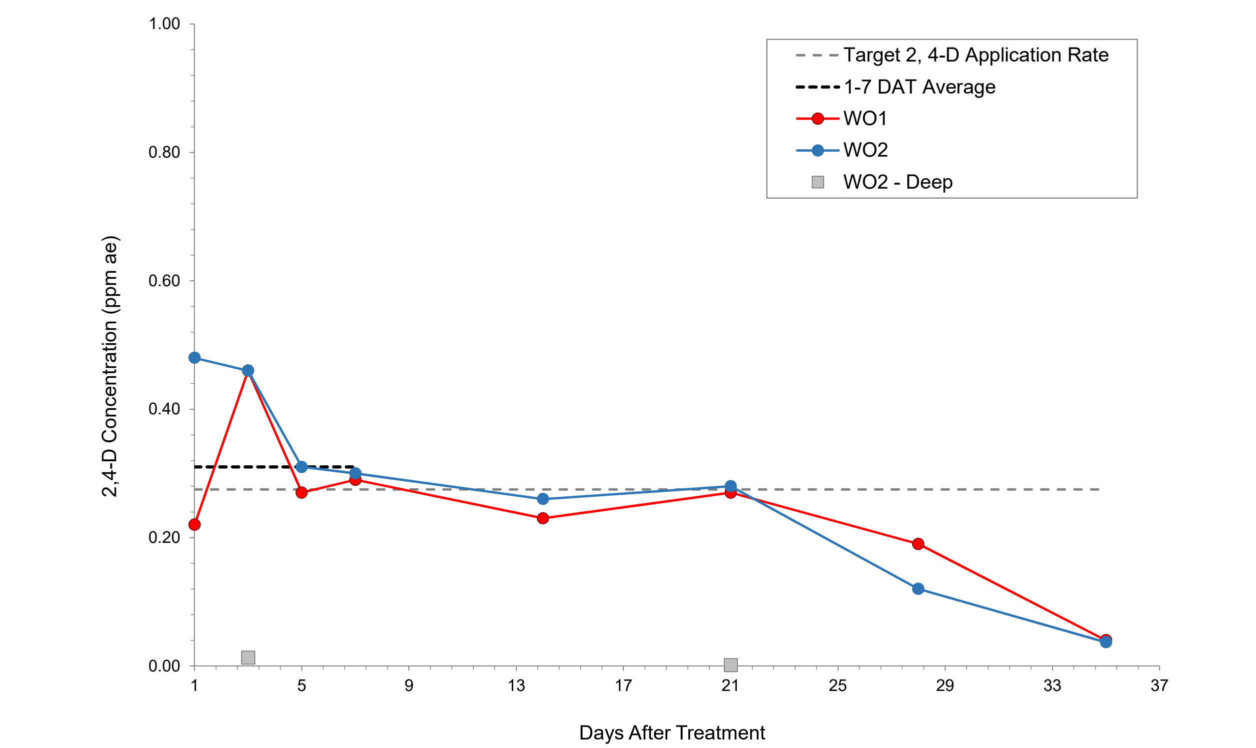


Figure 4.1-1. Otter Lake 2017 2,4-D Herbicide Concentration Monitoring Results from two monitoring locations.

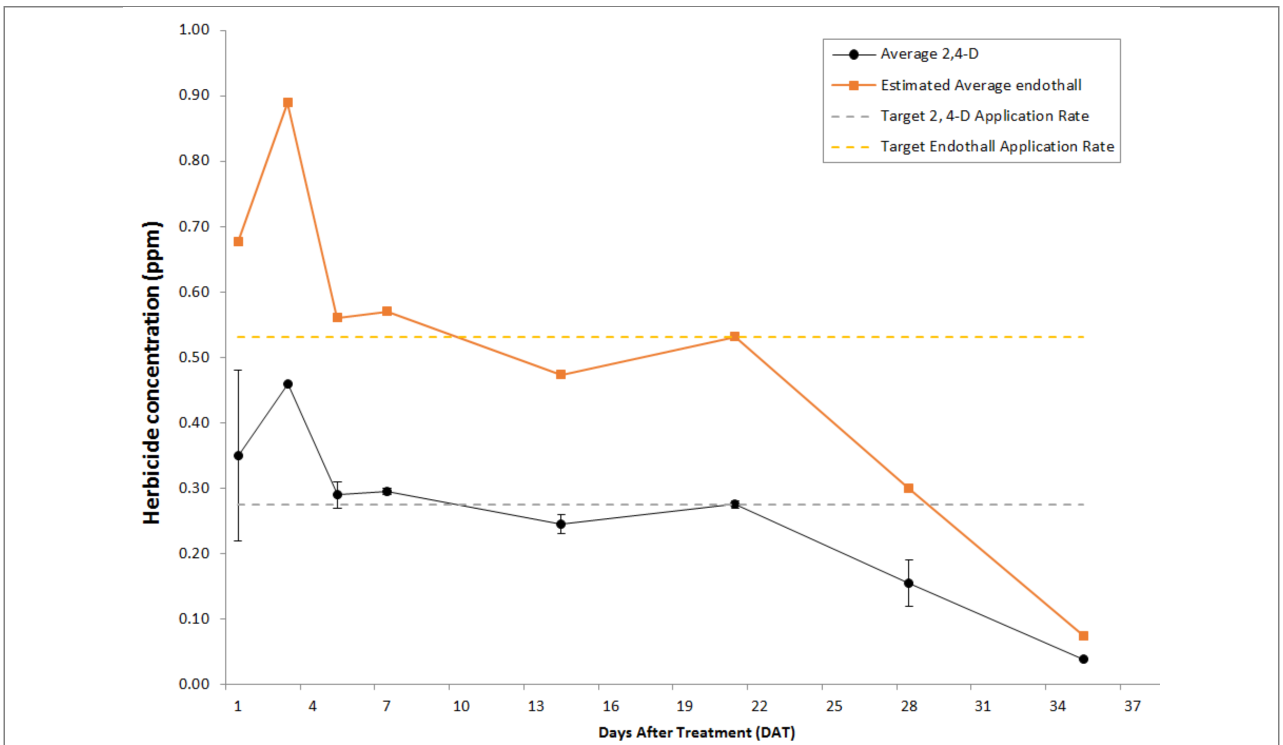


Figure 4.1-2. 2017 Otter Lake 2,4-D & estimated endothall concentration monitoring results. Black error bars represent the range of values between the two sampling sites.

Temperature profiles collected at each herbicide concentration sampling interval indicate that the lake remained thermally stratified throughout the duration of the monitoring timeframe. The closely spaced water temperature contours on the isotherm (Figure 4.1-3, left frame) indicate a thermal gradient separating the epilimnion and hypolimnion beginning at approximately 10 feet on the treatment date. As the water temperatures increased during the summer months, the thermal gradient appears to have remained at approximately 9-10 feet. This can also be observed on the temperature profiles (Figure 4.1-3, right frame), where uniform temperatures were observed down to about 10 feet before getting much colder in a short amount of depth.

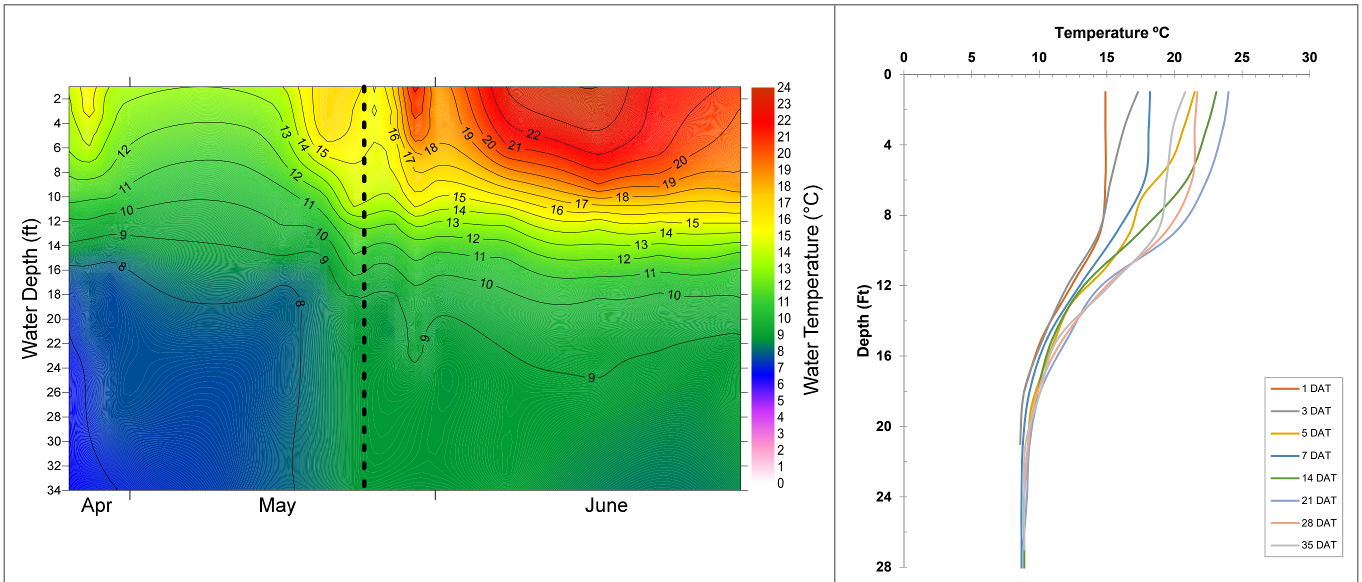


Figure 4.1-3. Temperature Isotherm (left) and Profiles (right) Collected from Otter Lake Following the 2017 Herbicide Treatment. Dashed line on isotherm represents treatment date.

4.2 Herbicide Monitoring Results – Dake Lake

Map 2 displays the water sampling locations associated with the herbicide concentration monitoring for Dake Lake. Figure 4.2-1 shows the results of the 2,4-D monitoring on Dake Lake. Concentrations showed little variation between the two sampling sites, including site WD1 where herbicide was not directly applied, confirming the herbicide had horizontally mixed within the lake. The grey square symbols on Figure 4.2-1 represent water collected at 23 feet of water from the deep hole monitoring site (Site WD1). A detectable amount of herbicide was observed in the hypolimnion during the 2017 Dake Lake treatment in samples collected on 3 DAT (0.220 ppm ae) and 21 DAT (0.210 ppm ae) which shows that some of the herbicide migrated into waters deeper than originally intended in the dosing strategy. Herbicide monitoring following the treatment found that the mean 1-7 DAT 2,4-D concentration was 0.491 ppm ae. The observed 2,4-D concentrations were significantly above the target concentration of .375 ppm ae. Monitoring showed 2,4-D levels were sustained at above the target concentration for a period of approximately 21 days. Samples collected on 28 DAT showed concentrations had decreased to 0.245 ppm ae and decreased further by 35 DAT to 0.185 ppm ae. After the initial concentration results from the lab showed detectable levels of herbicide remained at the last sampling interval on 35 DAT, another sample was collected on 80 DAT. The 80 DAT sample had a 2,4-D concentration of 0.024 which is approaching the minimum detection limit.

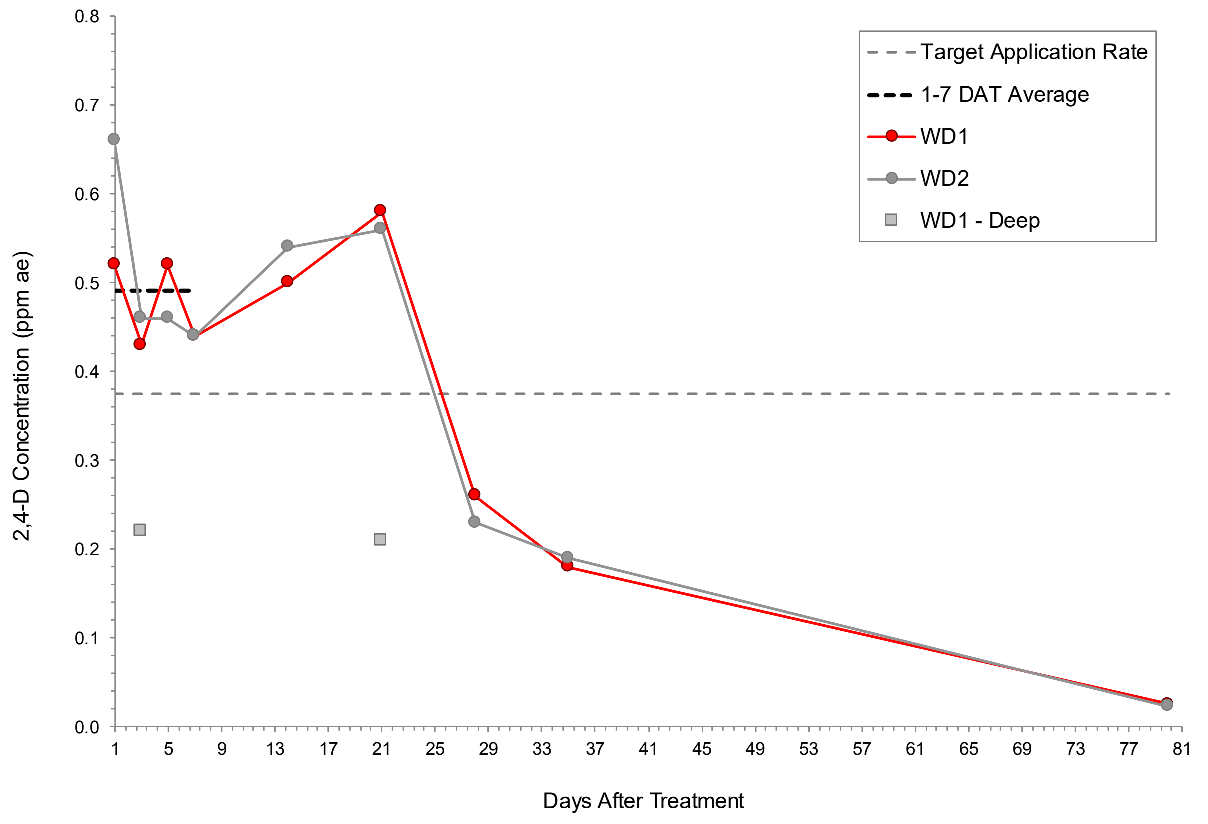


Figure 4.2-1. Dake Lake 2017 Herbicide Concentration Monitoring Results from two monitoring locations.

Temperature profiles collected before the treatment indicated that the lake did not show strong stratification during the time leading up to treatment. Temperature profiles collected after the treatment at each sampling interval showed inconsistent stratification characteristics in the weeks after the treatment (Figure 4.2-2, right frame). The profile collected on 1 DAT indicated the lake was mixed within most of the water column down to at least 21 feet. By 5 DAT and 7 DAT, the temperature profiles showed fairly strong stratification between 7 and 12 feet (Figure 4.2-2, right frame). Limnologists understand thermal stratification as occurring when there is a change of 1°C within 1 meter. The profile collected on 35 DAT showed water was mixed down to approximately 18 feet. The water temperature contours on the isotherm (Figure 4.2-2, left frame) indicate an event near the end of May corresponding with the 7 DAT sampling interval in which water temperatures cooled significantly followed by a time period in which there was a lack of a stable thermal gradient separating the epilimnion and hypolimnion. It is theorized that Dake Lake experienced multiple turnover events during the time frame surrounding the treatment monitoring in 2017. Inputs of cold water, cool ambient air temperatures, and wind events may contribute to the mixing of the water column in Dake Lake. It is unclear why the measured herbicide concentrations were higher than anticipated during the first 21 days of sampling. With herbicide being detected in the deeper water samples during the sampling period, it would be expected to result in concentrations lower than the target concentrations within the epilimnion. It may be possible that a WDNR 1965 sonar reading on Dake Lake lacked accuracy and thus, volume calculations derived from this data source resulted in a higher dose of herbicide than expected.

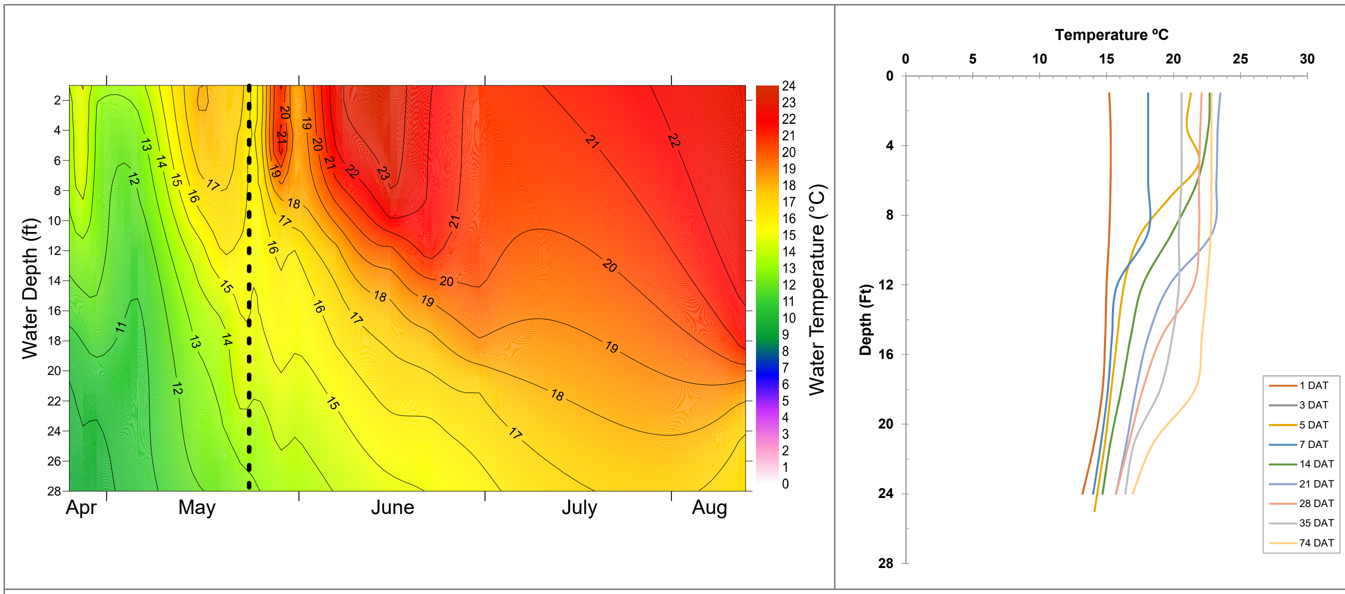


Figure 4.2-2. Temperature Isotherm (left) and Profiles (right) Collected from Dake Lake Following the 2017 Herbicide Treatment. Dashed line on isotherm represents treatment date.

4.3 Herbicide Monitoring Results – Miner Lake

Map 3 displays the water sampling locations associated with the herbicide concentration monitoring for Miner Lake. Figure 4.3-1 shows the results of the 2,4-D monitoring on Miner Lake. For the most part, concentrations showed little variation between the two sampling sites, including site WM2 where herbicide was not directly applied, confirming the herbicide had horizontally mixed within the lake. The grey square symbols on Figure 4.3-1 represent water collected at 27 feet of water from the deep hole monitoring site (Site WM2). A negligible amount of herbicide was observed in the hypolimnion in samples collected on 3 DAT and 21 DAT which confirms that the herbicide was confined to its intended portion of the epilimnetic waters. Herbicide monitoring following the treatment found that the mean 1-7 DAT 2,4-D concentration was 0.429 ppm ae. The observed 2,4-D concentrations were above the target concentration of .375 ppm ae. Monitoring showed 2,4-D levels were sustained at near the target concentration for a period of approximately 28 days. Samples collected on 35 DAT showed concentrations had decreased to 0.235ppm ae. After the initial concentration results from the lab showed detectable levels of herbicide remained at the last sampling interval on 35 DAT, another sample was collected on 80 DAT. The 80 DAT sample had a 2,4-D concentration of 0.040 which is approaching the minimum detection limit.

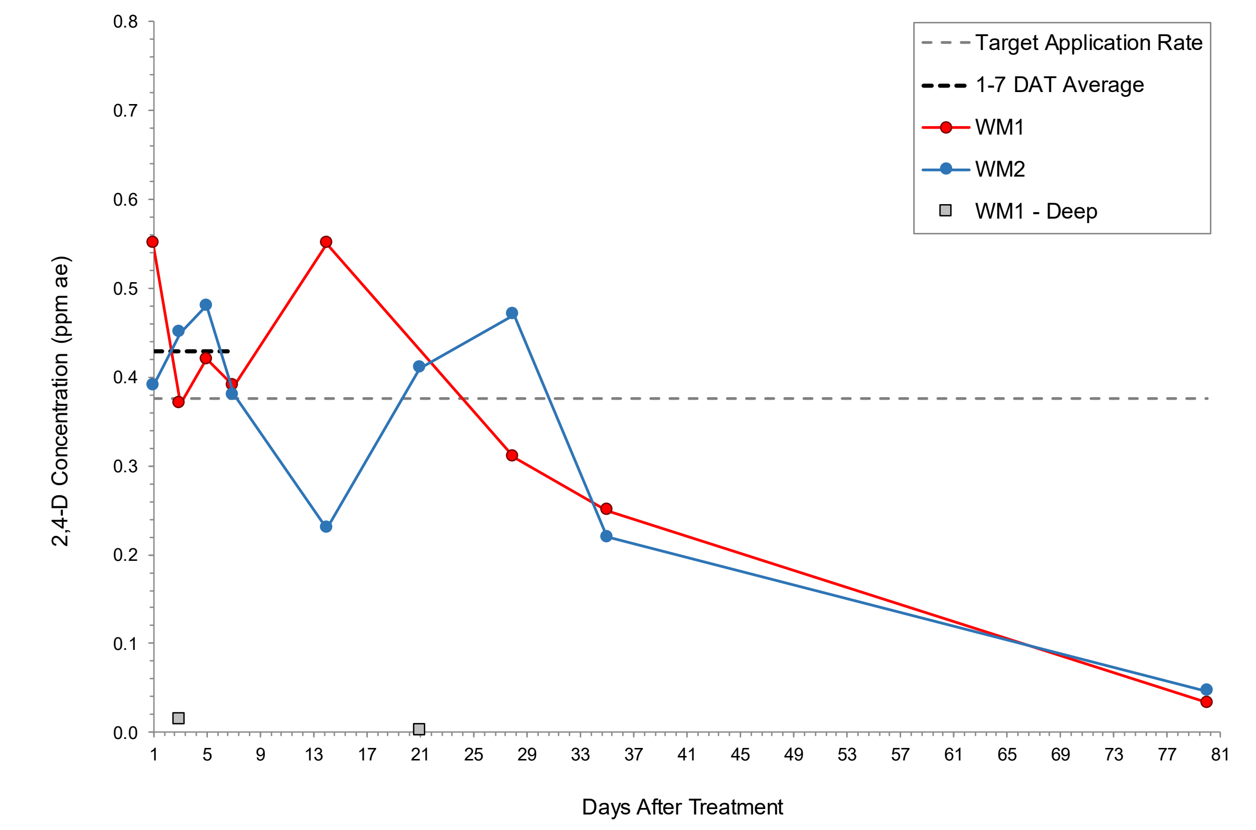


Figure 4.3-1. Miner Lake 2017 Herbicide Concentration Monitoring Results from two monitoring locations.

Temperature profiles collected before the treatment and at each herbicide concentration sampling interval indicate that the lake remained thermally stratified throughout the duration of the treatment. The closely spaced water temperature contours on the isotherm (Figure 4.3-2, left frame) indicate a thermal gradient separating the epilimnion and hypolimnion beginning at approximately 15 feet on the treatment date. As the water temperatures increased during the summer months, the thermal gradient appears to have moved closer to around 12 feet. This can also be observed on the temperature profiles (Figure 4.3-2, right frame), where uniform temperatures were observed down to about 12 feet before getting much colder in a short amount of depth.

A dosing depth of 17 feet was used for the treatment planning which corresponded to the upper metalimnion at the time just prior to treatment. As the thermal barrier set up slightly shallower than the dosing depth, a smaller water volume would have contained the herbicide and thus lead to somewhat higher than anticipated epilimnetic concentrations. Degradation rates of 2,4-D in Miner Lake were relatively slow with little change in concentrations through the 28 DAT sampling interval. 2,4-D is broken down largely by microbial activity and lakes with low productivity may see a lower herbicide degradation rate than lakes with higher productivity.

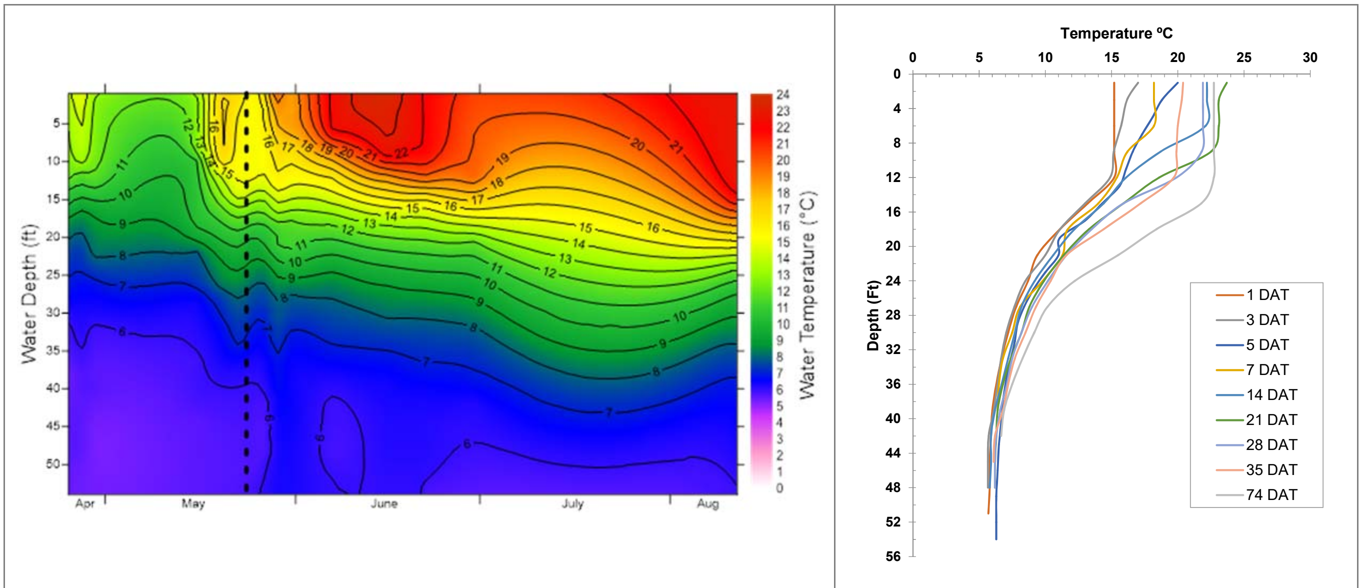


Figure 4.3-2. Temperature Isotherm (left) and Profiles (right) Collected from Miner Lake Following the 2017 Herbicide Treatment. Dashed line on isotherm represents treatment date.

5.0 AQUATIC PLANT MONITORING RESULTS

5.1 June 2017 Early-Season AIS Survey (ESAIS)

On June 15-16, 2017, Onterra staff completed the Early Season AIS Survey on the Waupaca Chain 'O Lakes. During this meander-based survey, the entire littoral areas of the lakes were surveyed for exotic plants. Lakes included in the spring 2017 whole-lake treatment program as well as Ottman Lake were not visited during the ESAIS survey.

While HWM is usually not at its peak growth at this time of year, the water is typically clearer during the early summer allowing for more effective viewing of submersed plants, and HWM is often growing higher in the water column than many of the native aquatic plants at that time of year. The HWM mapped during the Early-Season AIS Survey is refined during the Late-Summer Peak-Biomass survey. Curly-leaf pondweed (*Potamogeton crispus*; CLP) is at or near its peak growth in early summer before naturally senescing (dying back) in mid-summer, making early summer the most probable time to locate this exotic species.

Curly-leaf pondweed was located in several lakes within the Chain during the ESAIS survey. The CLP mapping results are displayed on Map 5.

Based on the June ESAIS Survey, a preliminary hand-harvesting strategy was also devised. Volunteers from the WCOLD and paid divers from the Red Granite Fire Department would target HWM occurrences in three high-use locations in Waupaca Chain (Figure 5.1-1). Approximately 2.5 hours of hand-harvesting efforts occurred in late-June 2017 near piers at Becker Marine in Lime Kiln Lake. The harvest yield from these efforts was reported to be approximately 3/4's of a 20" by 40" bag.

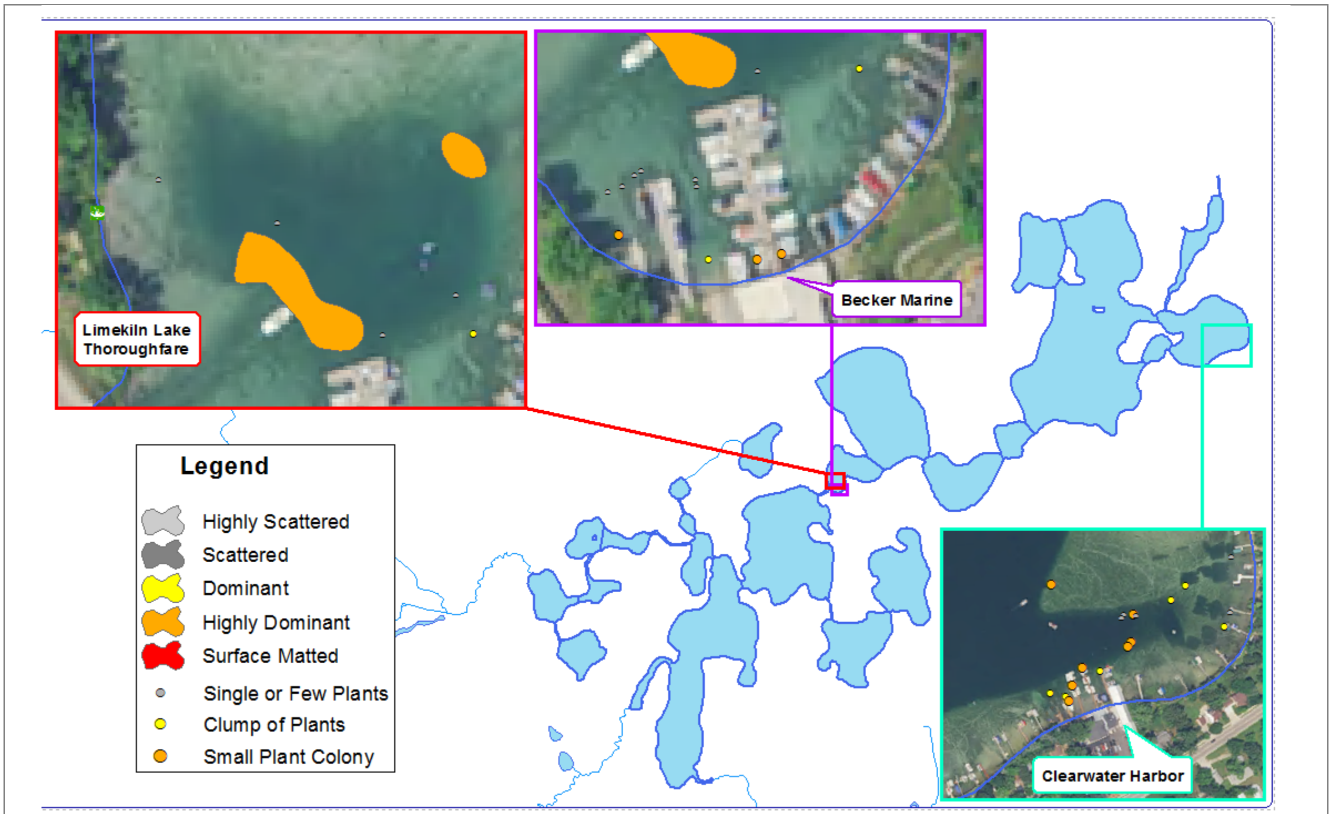


Figure 5.1-1. Waupaca Chain 2017 HWM Hand-Harvesting Control Sites.

5.2 Late-Summer HWM Peak-biomass Survey

The HWM population was mapped on September 27-28, 2017. During the survey, Onterra field crews meandered the littoral zone of the lakes and mapped HWM populations using sub-meter GPS technology. This meander-based survey, which mimics the methodology used in the ESAIS survey, was completed late in the growing season (August/September) when HWM had reached its peak growth stage. Because HWM should be at or near its maximum density, the results of this survey provide an understanding of where HWM is in the lake and what its full impact on the ecology of the lake may be. As a result, these data are useful in determining the efficacy of control actions used during the summer months as well as assisting in the next year's control planning.

Within the 4.4 acre site in Columbia Lake that was targeted for herbicide control in 2017, slightly less HWM was present than during the pre-treatment survey in 2016; however, large colonized beds of HWM remain present and the herbicide treatment fell short of control expectations for the site (Figure 5.2-1). Some level of seasonal HWM control was achieved from the 2017 diquat treatment as no HWM was visible at the time of the June ESAIS survey; however the plants that were impacted from the treatment were able to recover later in the growing season.

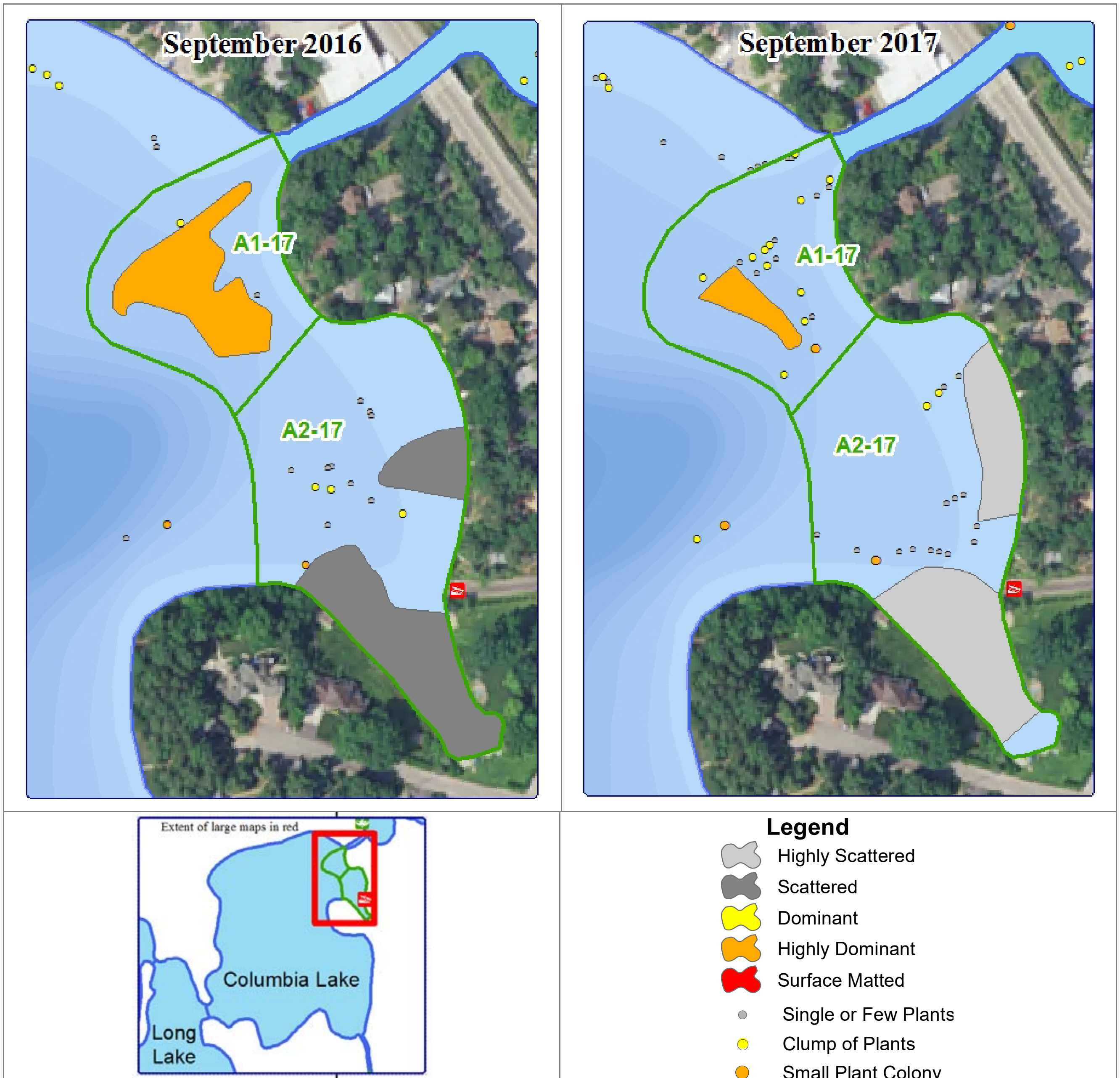


Figure 5.2-1. HWM Populations in Columbia Lake

When conducting large-scale whole lake treatments such as was done in Otter, Dake, and Miner Lakes in 2017, understanding the HWM population in the *year-of-treatment* (2017) is important; however, an insufficient amount of time has passed to understand if the control actions resulted in successful control or if the HWM plants were simply injured and will rebound the following year. No HWM was observed in Miner or Dake Lakes during the late-summer peak biomass survey and only a few single or few plant occurrences were located in Otter Lake (Map 6).

During the Chain-wide peak-biomass mapping survey, all lakes with the exception of Ottman Lake were surveyed. Ottman Lake requires access through a private property and no HWM was located in this lake during surveys completed in 2015. The population of HWM was found to be widespread throughout the Chain with some of the largest and most dense colonies being found in Long Lake, Beasley Lake and Bass Lake.

5.3 2017 Point-Intercept Survey Results – Otter Lake

Point-intercept surveys were completed by Onterra staff on the Waupaca Chain lakes on August 1-3, 2017. Zero occurrences of HWM were recorded on the 2017 point-intercept survey in Otter Lake. The littoral frequency of occurrence of HWM exhibited a 100% decrease since the 2016 survey (Figure 5.3-1). Along with understanding the level of HWM control achieved from the control action, the point-intercept data will also allow an understanding of non-target native plant impacts from the treatment. White water lily, spatterdock, muskgrasses, and stoneworts exhibited an increase in occurrence from 2016-2017 although the populations were not statistically different between the two surveys (Figure 5.3-1). Five native species that were sampled during the 2016 survey were not found during the 2017 survey and included coontail, sago pondweed, flat-stem pondweed, stiff pondweed and variable-leaf pondweed (Figure 5.3.-1). Each of these species was found on just one sampling location during the 2016 survey (LFOO = 3.8%). The decreases in occurrence for these species were not statistically valid due to a small sample size.

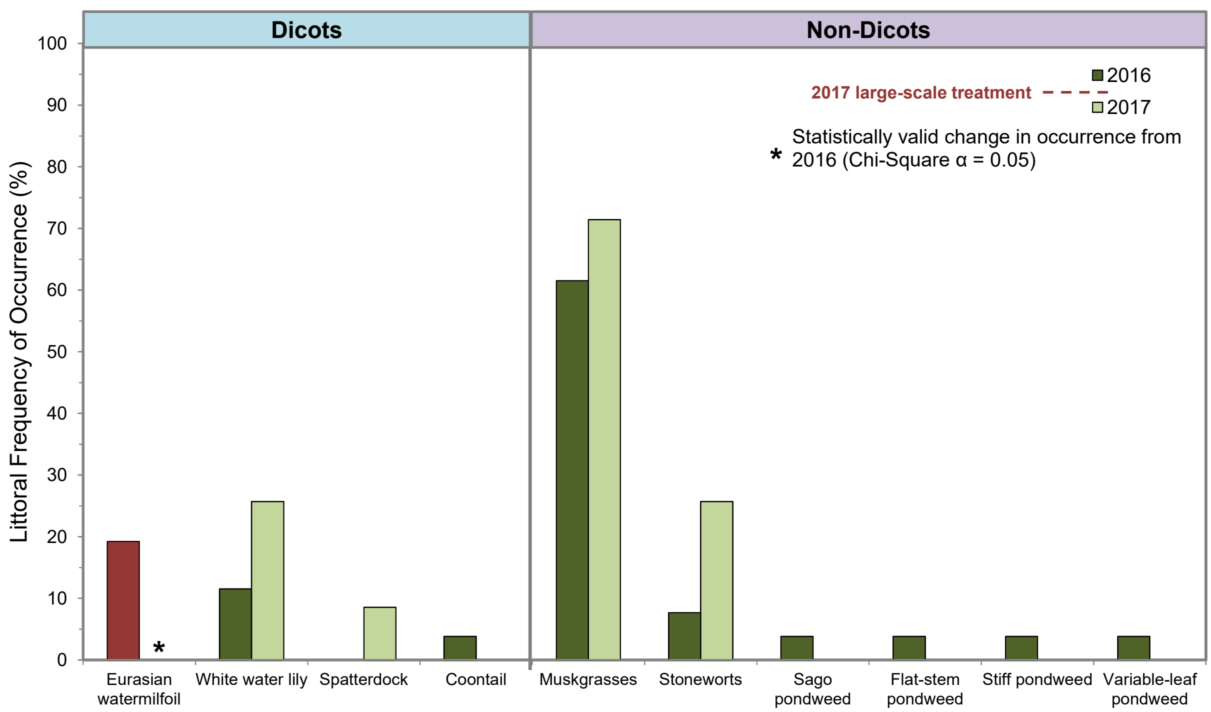


Figure 5.3-1. Littoral frequency of occurrence of aquatic plant species from 2016-2017 in Otter Lake. Whole-lake 2,4-D & endothall herbicide treatment occurred in spring 2017.

Figure 5.3-2 shows a semi-quantitative analysis of the abundance of natives through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). In 2016, 73% of the point-intercept sampling locations within the littoral zone contained vegetation compared to 83% in 2017. It is important to note that the aquatic plant fullness in 2017 is completely comprised of native plant species, whereas HWM was a contributor to the aquatic plant biomass in 2016.

Emergent and floating-leaf aquatic plant communities are also an important component of a lake's aquatic plant community. These communities provide valuable structural habitat and stabilize bottom and shoreland sediments. A community mapping survey was completed in 2016 in Otter Lake as a part of the management planning project. The community mapping survey was replicated in 2017 in order to document any changes to this important component of the plant community following the large scale herbicide treatment. Map 7 displays the results of the 2016 and 2017 community mapping surveys. Overall, the differences between the two surveys were minimal and the floating-leaf and emergent communities appeared healthy in 2017.

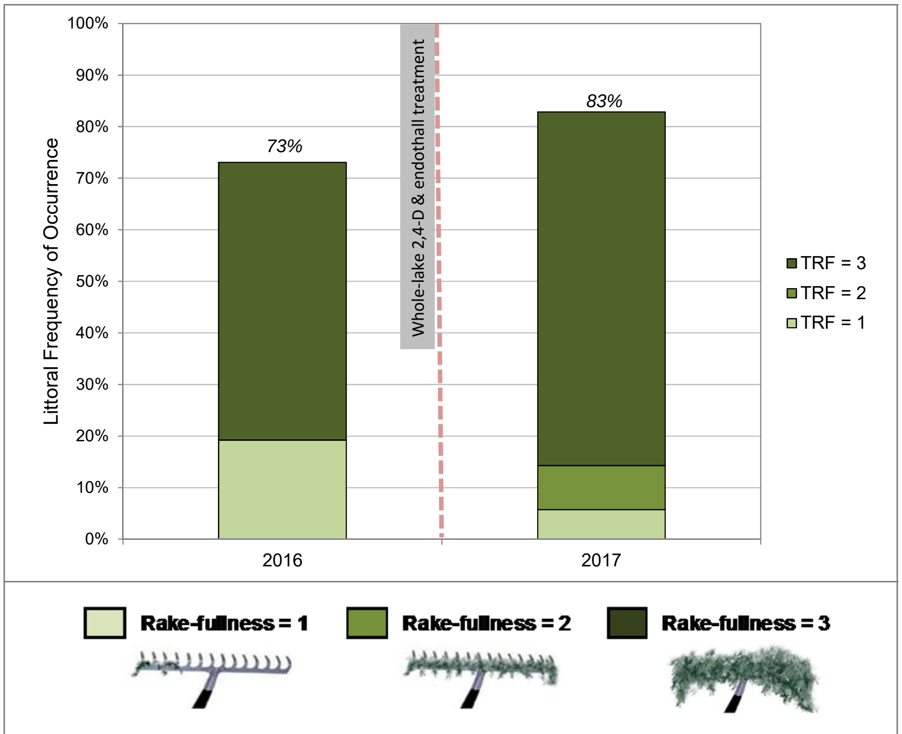


Figure 5.3-2. Otter Lake total rake fullness ratings from 2016–2017. The red-dashed line indicates the 2017 whole-lake herbicide treatment.

5.4 2017 Point-Intercept Survey Results – Dake Lake

Point-intercept surveys were completed by Onterra staff on the Waupaca Chain lakes on August 1-3, 2017. Zero occurrences of HWM were recorded on the 2017 point-intercept survey in Dake Lake. The littoral frequency of occurrence of HWM exhibited a 100% decrease since the 2016 survey (Figure 5.4-1). Along with understanding the level of HWM control achieved from the control action, the point-intercept data will also allow an understanding of non-target native plant impacts from the treatment. Two native species, sago pondweed (*Stuckenia pectinata*) and slender naiad (*Najas flexilis*), exhibited a statistically valid decrease in occurrence between the two surveys. Slender naiad is an annual that relies on seed production and has been shown to be particularly susceptible to auxin herbicides (e.g. 2,4-D, triclopyr). Additional species located on the point-intercept surveys that did not have a statistically different occurrence are displayed on Figure 5.4-1.

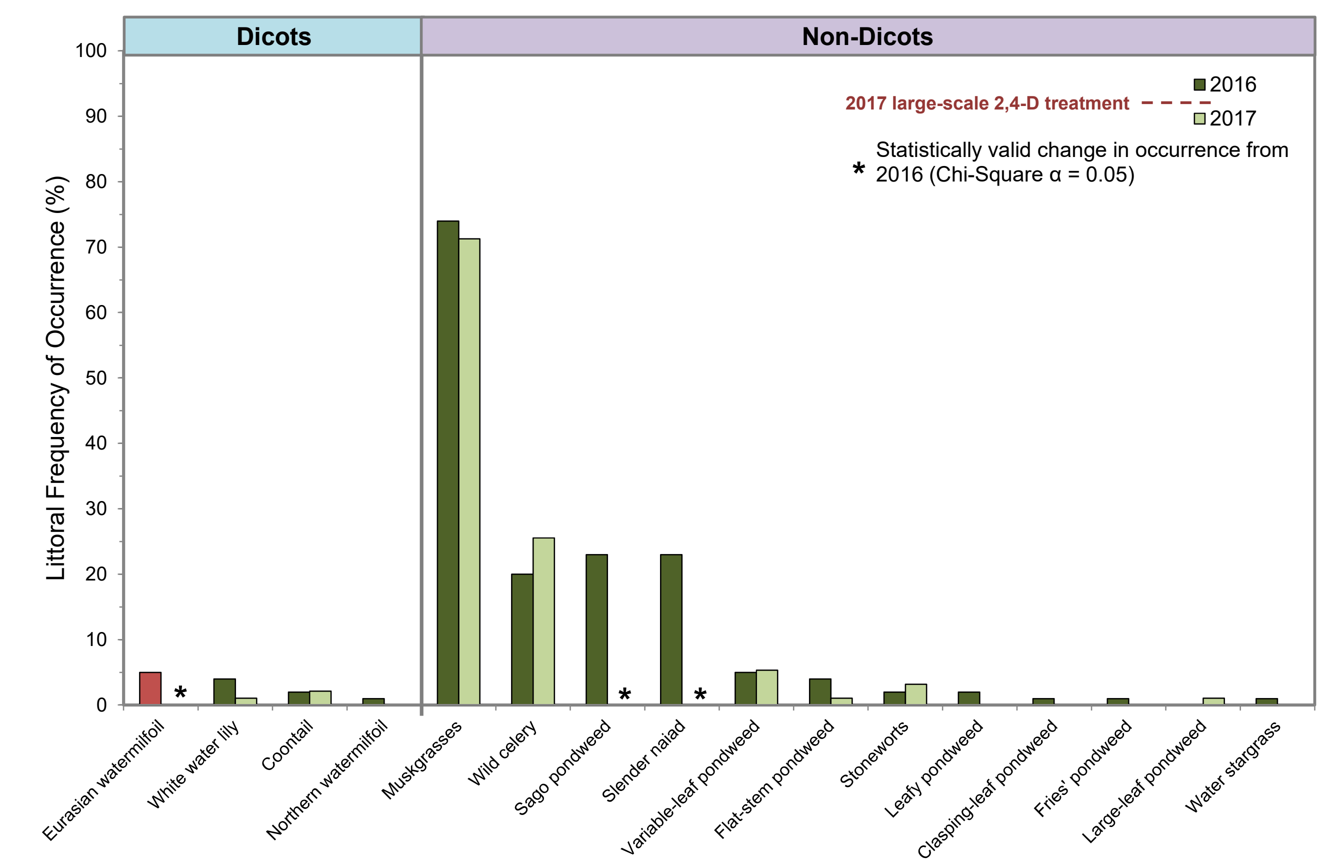


Figure 5.4-1. Littoral frequency of occurrence of aquatic plant species from 2016-2017 in Dake Lake. Data from Onterra 2016 & 2017 Point-Intercept Surveys. Whole-lake 2,4-D herbicide treatment occurred in spring 2017.

Figure 5.4-2 shows a semi-quantitative analysis of the abundance of natives through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). In both the 2016 and 2017 surveys, 84% of the point-intercept sampling locations within the littoral zone contained vegetation. It is important to note that the aquatic plant fullness in 2017 was completely comprised of native plant species, whereas HWM was a contributor to the aquatic plant biomass in 2016.

Emergent and floating-leaf aquatic plant communities are also an important component of a lake's aquatic plant community. These communities provide valuable structural habitat and stabilize bottom and shoreland sediments. A community mapping survey was completed in 2016 in Dake Lake as a part of the management planning project. The community mapping survey was replicated in 2017 in order to document any changes to this important component of the plant community following the large scale herbicide treatment. Map 8 displays the results of the 2016 and 2017 community mapping surveys. A reduction of floating leaf communities, largely white water lily, was evident within bays in the northwest and west ends of Dake Lake. Onterra's experience indicates white-water lily is typically resilient to standard large-scale 2,4-D use-patterns. It is theorized that the higher concentrations and longer exposure times observed during the 2017 large-scale 2,4-D treatment of Dake Lake resulted in the impacts to white water lilies. Continuing monitoring will take place to allow an understanding of recovery from these impacts.

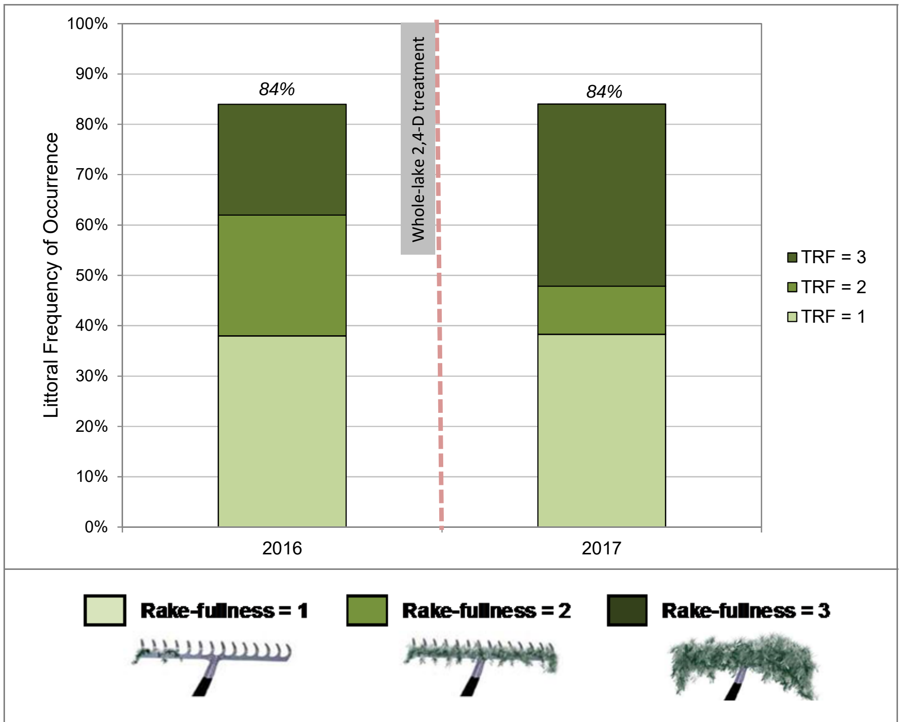


Figure 5.4-2. Dake Lake total rake fullness ratings from 2016–2017. The red-dashed line indicates the 2017 whole-lake herbicide treatment.

5.5 2017 Point-Intercept Survey Results – Miner Lake

Point-intercept surveys were completed by Onterra staff on the Waupaca Chain lakes on August 1-3, 2017. Two occurrences of HWM were recorded on the 2017 point-intercept survey in Miner Lake. The littoral frequency of occurrence of HWM exhibited a statistically valid 78.6% decrease since the 2016 survey (Figure 5.5-1). Along with understanding the level of HWM control achieved from the control action, the point-intercept data will also allow an understanding of non-target native plant impacts from the treatment. Three native species, sago pondweed (*Stuckenia pectinata*), slender naiad (*Najas flexilis*), and muskgrasses (*Chara* spp.) exhibited a statistically valid decrease in occurrence between the two surveys, while one species, stoneworts (*Nitella* spp.) showed a statistically valid increase. Additional species located on the point-intercept surveys are displayed on Figure 5.5-1.

Muskgrasses and stoneworts are actually macroalgae and due to their lack of vascular tissue are unable to translocate herbicides; therefore, they are typically unaffected by herbicide use. While field identification of muskgrasses and stoneworts is possible, some errors may have been made in one of the surveys. If these two macrophyte groups were lumped together, the populations would not be statistically different between the two surveys.

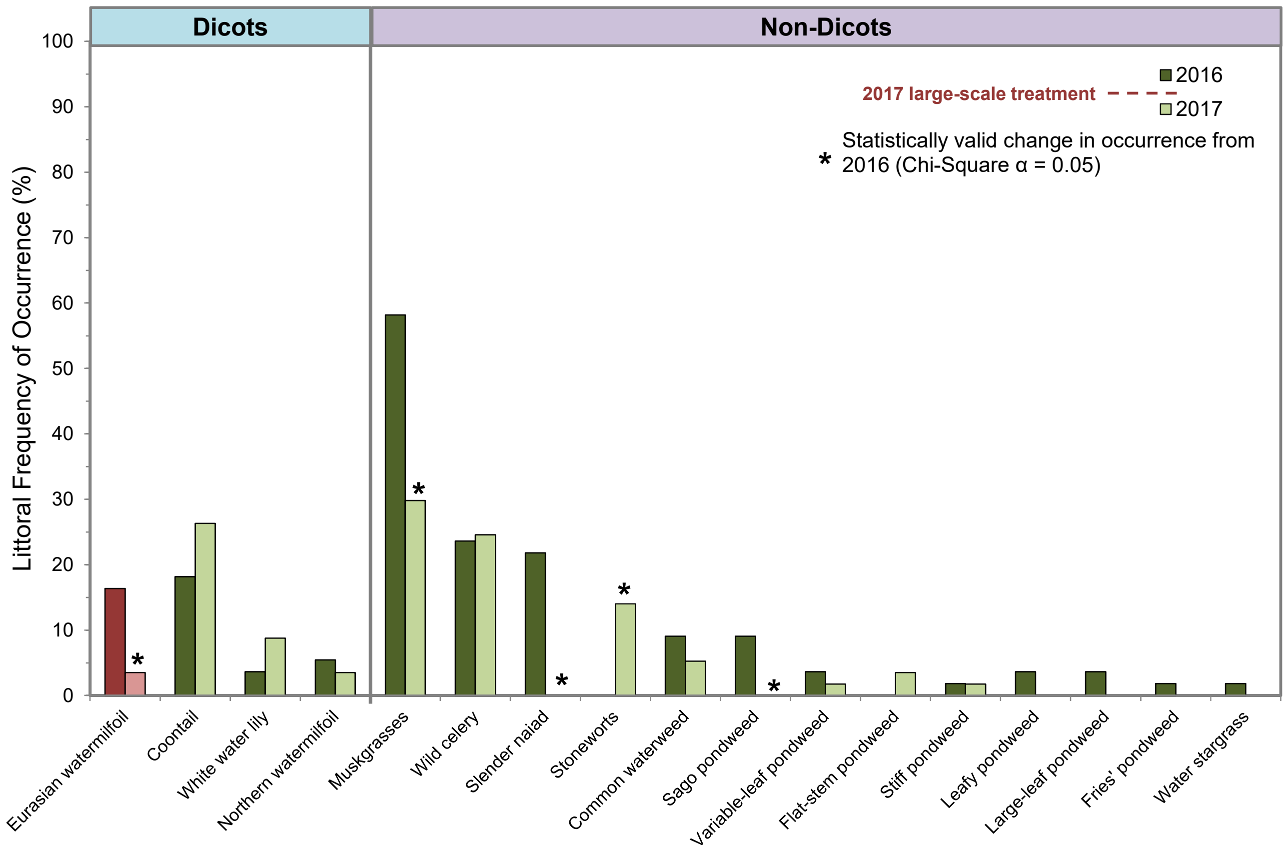


Figure 5.5-1. Littoral frequency of occurrence of aquatic plant species from 2016-2017 in Miner Lake. Data from Onterra 2016 & 2017 Point-Intercept Surveys. Whole-lake 2,4-D herbicide treatment occurred in spring 2017.

Figure 5.5-2 shows a semi-quantitative analysis of the abundance of natives through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). In 2016, 80% of the point-intercept sampling locations within the littoral zone contained vegetation compared to 72% in 2017. It is important to note that the aquatic plant fullness in 2017 was almost completely comprised of native plant species, whereas HWM was a contributor to the aquatic plant biomass in 2016.

Emergent and floating-leaf aquatic plant communities are also an important component of a lake's aquatic plant community. These communities provide valuable structural habitat and stabilize bottom and shoreland sediments. A community mapping survey was completed in 2016 in Miner Lake as a part of the management planning project. The community mapping survey was replicated in 2017 in order to document any changes to this important component of the plant community following the large scale herbicide treatment. Map 9 displays the results of the 2016 and 2017 community mapping surveys. A reduction of floating leaf communities, largely white water lily, was evident within parts of Miner Lake. Onterra's experience indicates white-water lily is typically resilient to standard large-scale 2,4-D use-patterns. It is theorized that the higher concentrations and longer exposure times observed during the 2017 large-scale 2,4-D treatment of Miner Lake resulted in the impacts to white water lilies. Continuing monitoring will take place to allow an understanding of recovery from these impacts.

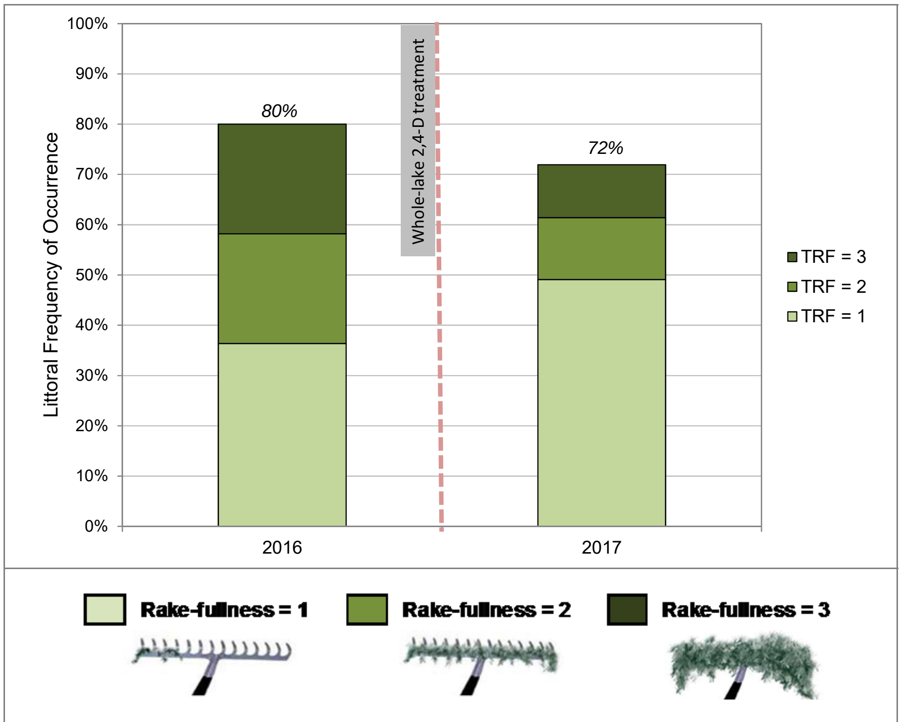


Figure 5.5-2. Miner Lake total rake fullness ratings from 2016–2017. The red-dashed line indicates the 2017 whole-lake herbicide treatment.

6.0 2017 TREATMENT STRATEGY CONCLUSIONS

Surveys conducted in 2017 on Otter, Dake and Miner Lakes show that the large-scale treatments conducted in the spring were successful in meeting the HWM control objectives. No HWM was located during the late-summer mapping surveys in Dake Lake or Miner Lake following the treatment although two HWM occurrences were found on the point-intercept survey in Miner Lake. Minimal HWM consisting of single plants was found in Otter Lake during surveys conducted in 2017. The reduction of the HWM population in 2017 exceeded the qualitative and quantitative success criteria for the whole-lake treatments and met lake managers control expectations. The diquat spot treatment in Columbia Lake provided seasonal control; however HWM in this treatment area had begun to rebound by the end of the growing season. Some reductions in native plant communities were observed in the lakes that underwent whole-lake treatments, notably slender naiad, white water lily, and sago pondweed. It will be important to continue monitoring these populations to understand long-term implications from the 2017 control strategy. Ongoing research is investigating the relationship of the pH of lakes and how it relates to the degradation pattern in treatments utilizing 2,4-D. Water quality testing completed in 2016 on select lakes in the Chain found relatively hard water with pH ranging between 8.3 and 8.7.

The results of the late-summer peak biomass survey found the lake-wide HWM population consisted of approximately 20.3 acres of colonized HWM or about 8.3 acres less than the 2016 survey (Figure 6.0-1, Map 6). Much of the reduction in acreage observed in 2017 is from lakes that were included in the herbicide treatment control efforts. The acreage estimates only take into account the HWM polygons, not HWM mapped within point-based methodologies (*Single or Few Plants, Clumps of Plants,* or *Small Plant Colonies*). Taken out of context, this figure can be misleading as it relates to the HWM population changes. For instance, large areas of the lake may be mapped using point-based methods in one year and if these areas increased in density slightly, they would likely be mapped using polygon-based methods in the following year and result in a large increase in acreage. Similarly, an increase in point-based EWM occurrences within a lake would not be represented on this figure. Of the HWM acreage mapped in 2017, approximately 8.0 acres or 39% was within Long Lake, 2.7 acres or 13% in Bass Lake, and 2.5 acres or 12% in Beasley Lake (Figure 6.0-2).

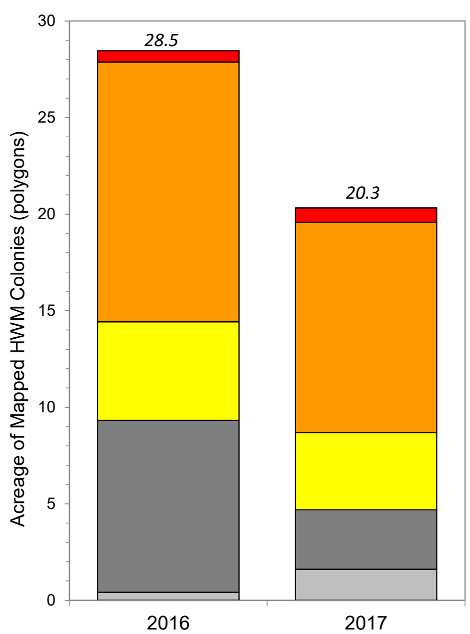


Figure 6.0-1. Waupaca Chain O' Lakes 2016-2017 HWM Colony Density Ratings. Created using data from 2016 & 2017 Late-Summer EWM Peak-Biomass Surveys.

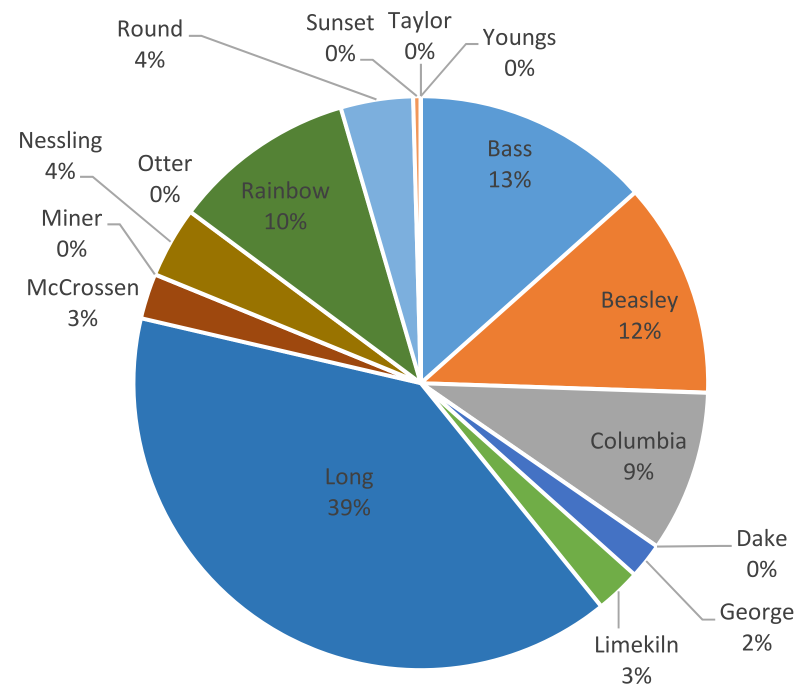


Figure 6.0-2. Waupaca Chain O' Lakes 2017 Colonized HWM Acreage Distribution by Lake. Created using data from 2017 Late-Summer EWM Peak-Biomass Survey.

Curly leaf pondweed monitoring in 2017 found that the population was localized in some areas of the Chain. Continued monitoring of this species will be valuable if active management is to occur in the future.

7.0 2017 FLOW MONITORING RESULTS

Flow data was collected on the Waupaca Chain O' Lakes at three locations in May and June of 2017; 1) at the outlet from Youngs Lake to Beasley Lake, 2) at the outlet of the Upper Chain to the Lower Chain (outlet from Knight Lake to Beasley Lake), and 3) at the mouth of the Crystal River at Long Lake's outlet (Figure 7.0-1 and Figure 7.0-2).

Figure 7.0-1 2017 Flow Monitoring Locations and Waupaca Chain Morphometry Diagram

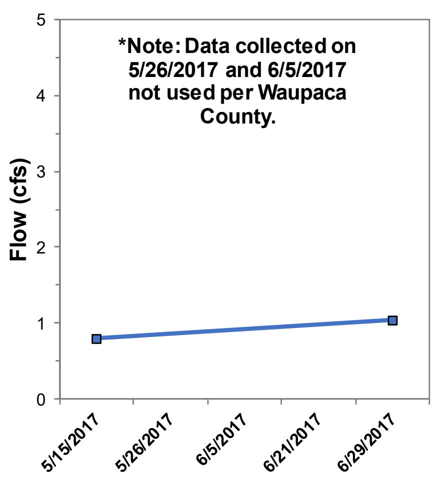
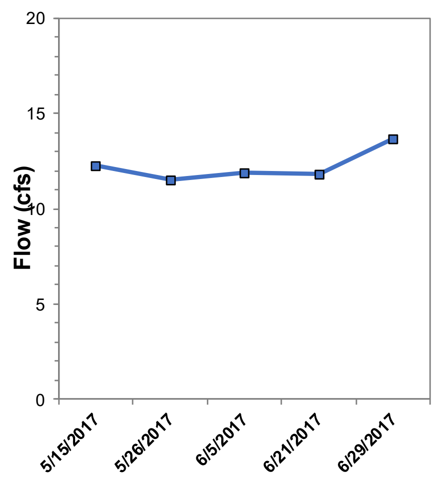
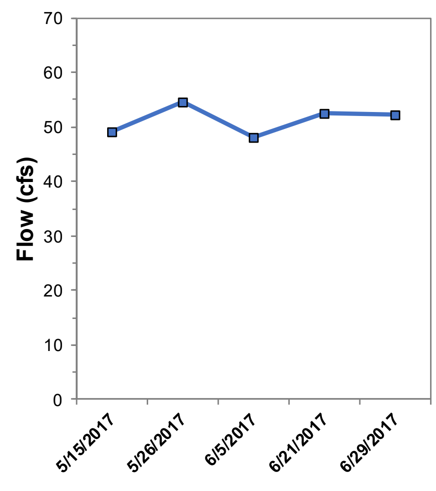
Site 1- Youngs Lake Outlet	Site 2 – Upper Chain Outlet	Site 3- Crystal River Outlet
		
May 2017 Discharge: 43 acre-ft June 2017 Discharge: 42 acre-ft	May 2017 Discharge: 730 acre-ft June 2017 Discharge: 742 acre-ft	May 2017 Discharge: 3,192 acre-ft June 2017 Discharge: 3,033 acre-ft

Figure 7.0-2. 2017 Flow Monitoring Results. Data collected and provided by Waupaca County LWCD.

Precipitation data is available from the Midwest Regional Climate Center (MRCC) from Waupaca. In the past 20 years, the average precipitation during the growing season (April through October) in Waupaca was approximately 24 inches. In 2017, Waupaca saw approximately 26 inches during the growing season, over 2 inches more than the average. While more precipitation was seen on average during the growing season in 2017, flow in Emmons Creek and Hartman Creek, for which data is available from 2011 through 2017, was not significantly higher in Emmons Creek or Hartman Creek in 2017. No significant correlation was observed between flow and precipitation in either stream (Figures 7.0-3 and 7.0-4). The Waupaca Chain O' Lakes is located within the central sands region and discharge is likely dominated by baseflow, meaning groundwater dominates the flow. The discharge modeled using the 2017 data collected on the Waupaca Chain O' Lakes is believed to be representative of an average flow in the lakes.

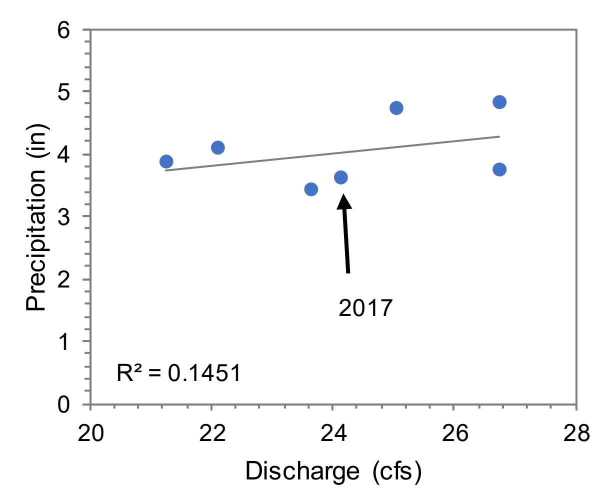


Figure 7.0-3. Spring precipitation and flow in Emmons Creek. Flow data is from May through June from 2011 to 2017 and precipitation data is from April through May from 2011-2017.

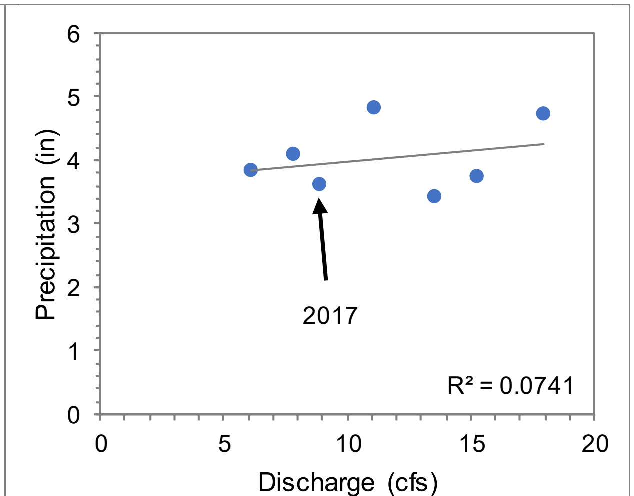


Figure 7.0-4. Spring precipitation and flow in Hartman Creek. Flow data is from May through June from 2011 to 2017 and precipitation data is from April through May from 2011-2017.

Using the available data, flushing rates for Bass, Beasley, and Long Lakes were calculated and displayed in Table 7.0-1. The modeling indicates that water residence time is about 9 days in Bass Lake, 6-7 days within the epilimnion of Beasley Lake, and 12-14 days in the epilimnion of Long Lake.

Table 7.0-1. Modeled Water Residence from Flow Study Data. May and June

	Bass Lake	Beasley Lake	Long Lake
Lake Volume (acre-feet):	12	306	3,182
Whole-Lake Residence Time (Days):	9	12	31
Epilimnetic (18 ft) Residence Time (Days):	-	7	14
Epilimnetic (15 ft) Residence Time (Days):	-	6	12

8.0 2018 PROPOSED HWM CONTROL STRATEGY DEVELOPMENT

8.1 2018 Proposed Large-Scale HWM Control Strategy

In 2018, the WCOLD will continue to implement an integrated approach to managing the HWM population in the system. As discussed above, the largest and densest HWM colonies exist in Bass, Beasley, and Long Lakes. Based on the results of the 2017 field trials and 2017 flow monitoring studies, standard large-scale use patterns with 2,4-D alone are not anticipated to provide more than limited seasonal reductions in HWM populations. Dr. Scott Nissen (Colorado State University) is currently investigating herbicide uptake and translocation of various aquatic herbicides. Within a recent newsletter, Dr. Nissen is quoted, "Based on our endothall studies in flowing water, we thought that endothall must have some systemic activity, and now we have data that confirms that endothall does translocate from shoots to root tissue. In fact, the ratio of endothall in the root vs. shoot tissue after 192 hours of exposure was greater for endothall than for other systemic herbicides that we have evaluated." These data do not indicate that a combination 2,4-D and endothall treatment requires a shorter exposure time, but they do provide perspective on the justification of adding endothall for HWM control.

The watershed-based water residence time of Otter Lake is 480 days. While the 2017 combination 2,4-D/endothall treatment in this waterbody was successful, at least in the short term, the transferability of this trial treatment to lakes with much shorter exposure times is unknown. At this time, Onterra does not feel sufficient evidence exists to know if there is a high likelihood of successful control on Bass, Beasley, and Long Lakes with a combination 2,4-D/endothall large-scale treatment. Because of the relatively small size of Bass and Beasley Lakes, a field trial with this herbicide use pattern is recommended in 2018 (Map10). Being ten times larger, a treatment of Long Lake would be postponed until after the results of the 2018 field trial are understood, potentially for 2019. Rough cost estimates to treat Bass and Beasley Lake would be $9,000, whereas Long Lake would be an additional $55,000.

This large-scale herbicide use pattern is similar to those conducted in 2017 and requires a certain level of planning, coordinating, and monitoring. Herbicide concentration monitoring will again evaluate the herbicide degradation rates in the days and weeks following the treatment and a formal document detailing the monitoring will be developed in the coming weeks leading up to the proposed treatment.

On October 25, 2017, Onterra staff systematically collected continuous, advanced sonar data across Bass, Beasley and Long Lakes. One result of this survey produced an updated bathymetric map of the system. The success of properly planning and implementing large-scale treatments rely on accurate bathymetric information with which advanced water volume calculations are conducted. This ensures meeting target concentrations outlined within the dosing strategy, which is devised to provide HWM control while balancing native plant selectivity.

Post treatment assessments would be conducted including Chain-wide point-intercept surveys, Chain-wide late-season HWM mapping surveys, and floating-leaf/emergent plant community surveys on large-scale treatment lakes.

8.2 2018 Proposed Small-Scale HWM Control Strategy

Other more isolated populations of dense HWM exist in the Chain that are not applicable for consideration in a whole-lake treatment herbicide use pattern, but may be appropriate for consideration for control through herbicide spot treatments or coordinated hand-harvesting. As discussed within the lake management planning project, control of EWM/HWM with small spot treatments (working definition is less than 5 acres) with systemic herbicides is rarely effective due to rapid herbicide dissipation. For 2017, an herbicide with a shorter exposure time requirement was recommended: diquat. Unfortunately, the 2017 spot treatment in Columbia Lake resulted in seasonal control and may completely rebound by the summer of 2018 if no additional management actions are conducted.

The long-term control of EWM/HWM targeted with diquat continues to be evaluated on many lakes across Wisconsin. On some lakes, the preliminary results appear promising. As a contact herbicide, diquat does not move (translocate) through plant tissue. Therefore, only the exposed plant material is impacted by the herbicide. Concern exists whether this herbicide has the capacity to kill the entire plant or simply removes all the above ground biomass and the plant rebounds from unaffected root crowns. Diquat also has a high affinity for binding with organic particles. In shallow waters where the application equipment creates disturbance of the lake bottom, the diquat being applied will quickly bind to the suspended particles and be instantly unavailable to cause impacts to the target plants. In lakes with high organic material encrusted on the plant, this may also reduce the efficacy of the treatment.

When diquat is mixed with endothall, as is commercially available under the Aquastrike® brand, it is theorized to have even shorter exposure time requirements than diquat alone. While diquat does not have systemic activity, endothall has proven to have a high level of systemic activity (i.e. moves throughout the plant, including into the root crown) at cold water temperatures. Within a recent United Phosphorus, Inc. (UPI) newsletter-style report, Dr. Scott Nissen (Colorado State University) is quoted, "We have data that confirms that endothall does translocate from shoots to root tissue. In fact, the ratio of endothall in the root vs. shoot tissue after 192 hours of exposure was greater for endothall than for other systemic herbicides that we have evaluated." The manufacturers of endothall (UPI), have shown that increased systemic activity of endothall occur when water temperatures are colder (<60°F).

This herbicide use-pattern has shown promise controlling EWM in a few Wisconsin treatments. Map 11 displays nine sites throughout the Chain that are preliminarily recommended for spot treatments utilizing Aquastrike®. These sites were chosen based on the presence of colonized HWM consisting largely of *dominant* densities or greater and in which at least a one-acre treatment site could be constructed with a reasonable sized buffer. Comparing HWM mapping surveys from the summer before the treatment to the summer following the treatment will allow an understanding of the level of control achieved.

As a part of an integrated HWM control strategy, the WCOLD is piloting a hand-harvesting program for select locations in the Chain in order to determine what role this management technique may have in future HWM management actions. Sites that are not of sufficient size to result in a successful herbicide treatment will be considered for professional hand-harvesting control actions. Specific sites to be prioritized for hand-harvesting may include areas that are not being targeted through herbicide treatments, but are of higher use, high visibility to lake users, near public access locations, or otherwise prioritized by WCOLD members.

There is great advantage of hiring an experienced firm that offers paid hand-harvesting services over a volunteer effort, including reliability of effort, documentation of work completed, and transferability of effort spent towards future planning. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process. DASH may be beneficial for use on the Waupaca Chain for areas that contain dense HWM and/or are in deeper water.

Based upon Onterra's HWM surveys during the summers of 2016 and 2017, two areas within the Chain have been preliminarily prioritized for DASH during 2018. Map 12 shows the two preliminary areas, one in Lime Kiln Lake (Site Y-18) and the second in George Lake (Site Z-18). Due to the area's high use, site Y-18 is set as the highest priority. The WCOLD has contracted with a professional hand-harvesting firm (DASH, LLC) to provide DASH HWM harvesting services in 2018. Map 12 may be used by DASH, LLC and the WCOLD to begin the permitting process with the WDNR to obtain a conditional permit.

In early summer 2018, Onterra will conduct an Early Season AIS Survey (ESAIS Survey). Based on the results of the ESAIS Survey, the hand-harvesting control strategy will be revised if necessary and finalized (Figure 8.2-1). The final WDNR approved mechanical harvesting permit will be based on the strategy developed following Onterra's 2018 ESAIS survey which could be different from the preliminary strategy outlined on Map 12. Onterra will provide the finalized hand-harvesting strategy and the spatial data from the ESAIS survey to the professional hand-harvesting firm for use in obtaining the final mechanical harvesting permit from the WDNR. Hand-harvesting would take place between the ESAIS (pre) and the late-summer HWM Peak-Biomass (post) surveys, allowing for evaluation of the management activity.

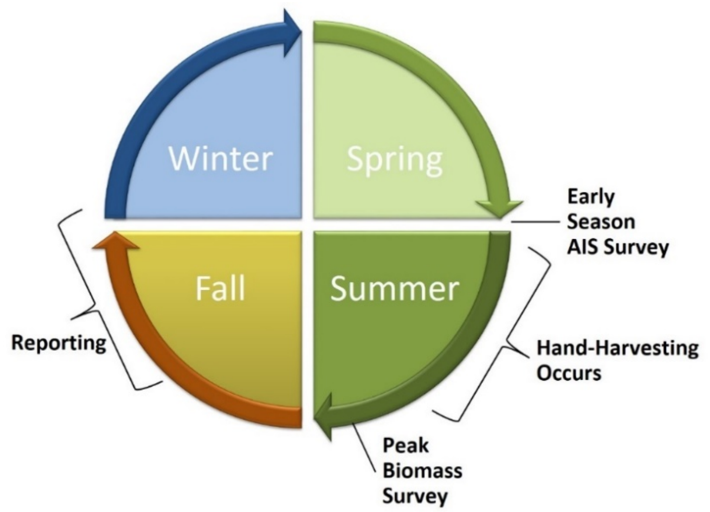
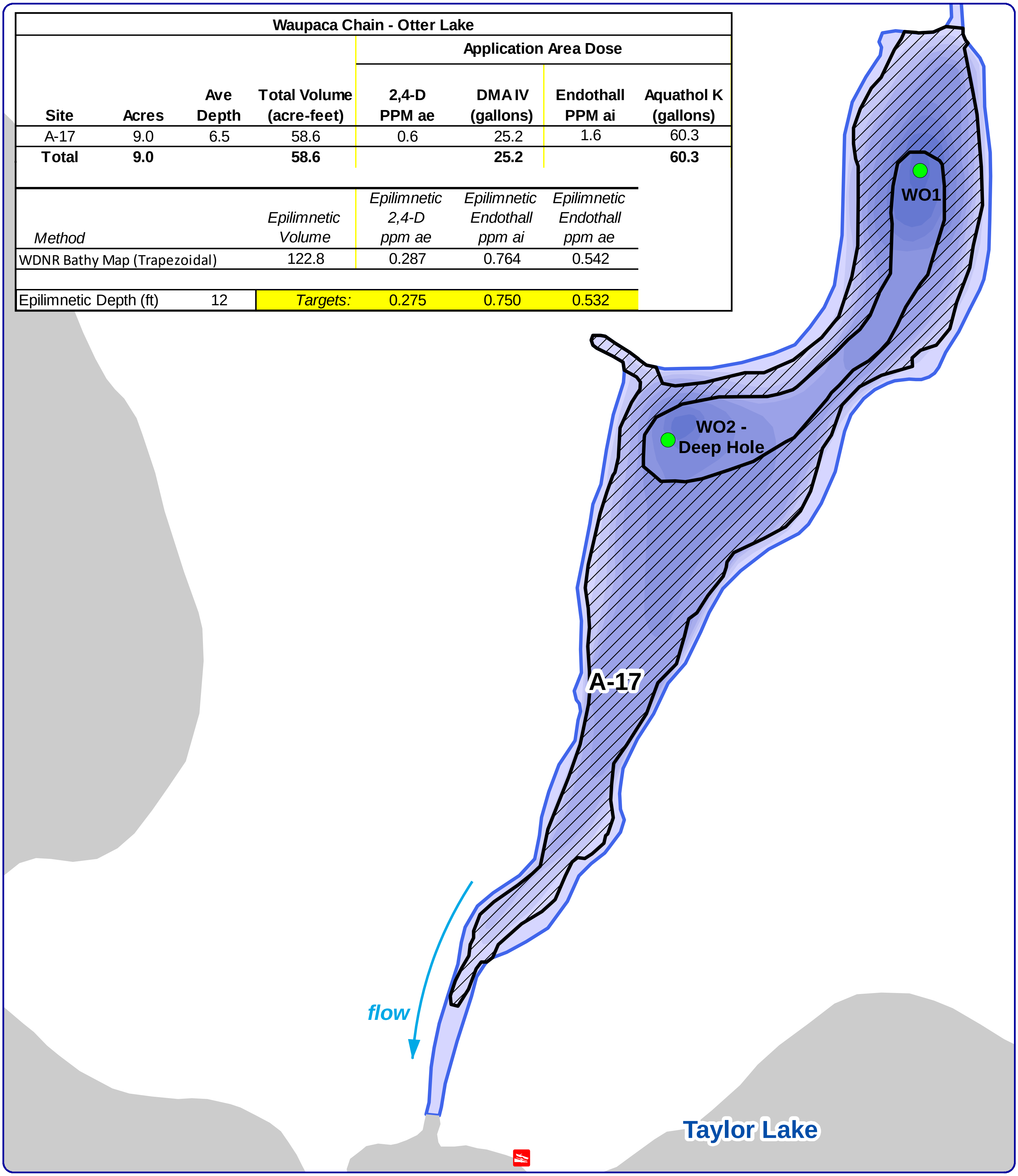


Figure 8.2-1. Hand-Harvesting Control & Monitoring Timeline. Includes potential hand-harvesting efforts which may or may not take place.

Waupaca Chain - Otter Lake

				Application Area Dose			
Site	**Acres**	**Ave Depth**	**Total Volume (acre-feet)**	**2,4-D PPM ae**	**DMA IV (gallons)**	**Endothall PPM ai**	**Aquathol K (gallons)**
A-17	9.0	6.5	58.6	0.6	25.2	1.6	60.3
Total	**9.0**		**58.6**		**25.2**		**60.3**

Method		*Epilimnetic Volume*	*Epilimnetic 2,4-D ppm ae*	*Epilimnetic Endothall ppm ai*	*Epilimnetic Endothall ppm ae*
WDNR Bathy Map (Trapezoidal)		122.8	0.287	0.764	0.542
Epilimnetic Depth (ft)	12	*Targets:*	0.275	0.750	0.532



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Feet

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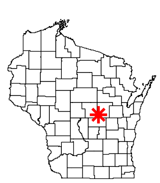
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016
Map Date: May 22, 2017
Filename: Otter_HWM_T2017_Perm1.mxd



Project Location in Wisconsin

Legend

2017 Final Herbicide Application Area

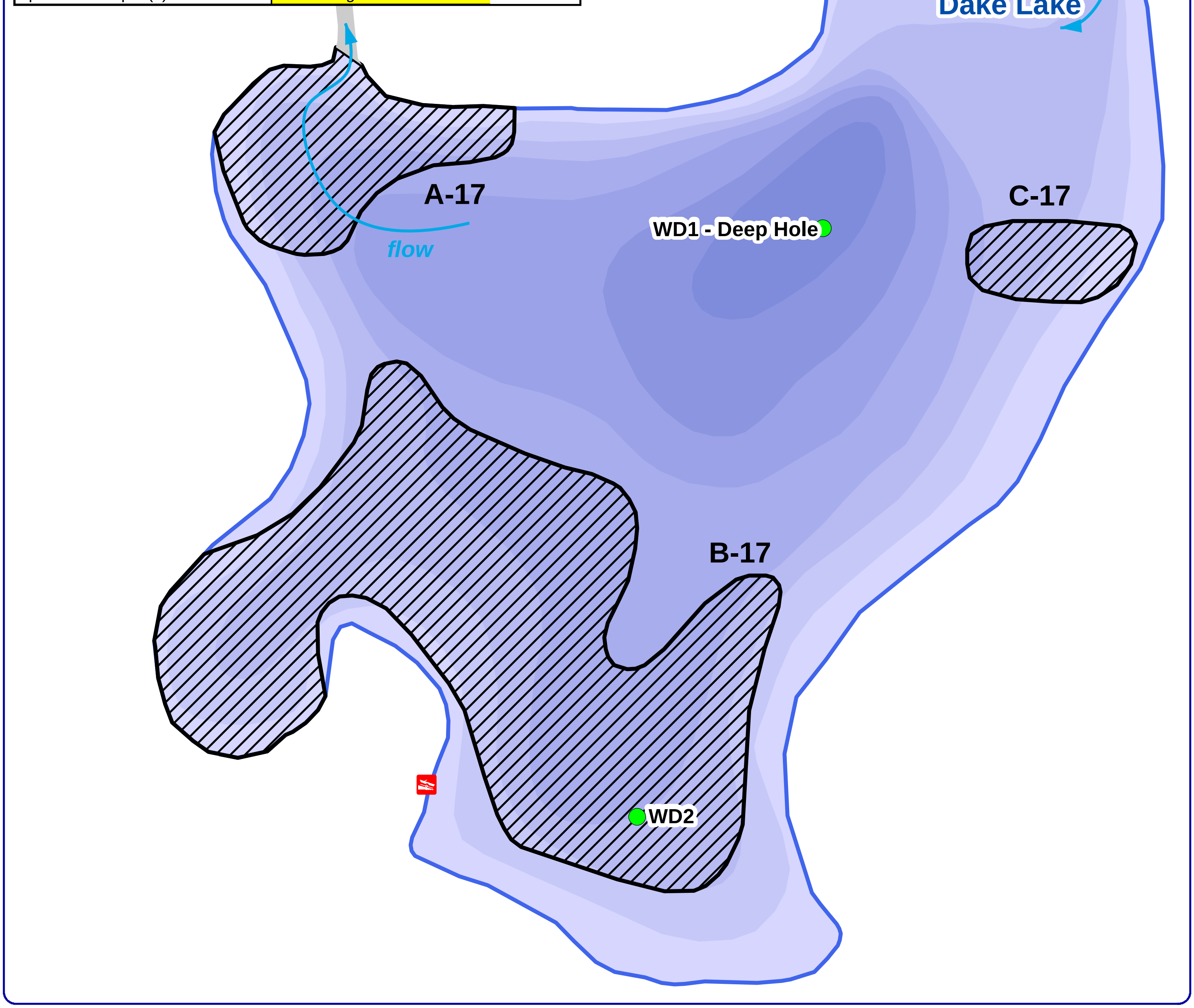
2017 Herbicide Concentration Monitoring Locations

Map 1
Otter Lake
Waupaca County, Wisconsin

2017 Final HWM Herbicide Control Strategy

Waupaca Chain - Dake Lake					
				Application Area Dose	
Site	Acres	Ave Depth	Total Volume (acre-feet)	2,4-D PPM ae	DMA IV (gallons)
A-17	1.9	5.0	9.4	1.30	8.8
B-17	8.9	7.0	62.0	1.35	59.9
C-17	0.6	7.5	4.9	1.30	4.5
Total	**11.4**		**76.3**		**73.2**

Method		*Epilimnetic Volume*	*Epilimnetic 2,4-D ppm ae*
WDNR Bathy Map (Trapezoidal)		271.5	0.377
Epilimnetic Depth (ft)	12	*Target:*	0.375



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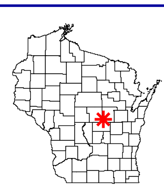
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016
Map Date: May 22, 2017
Filename: Dake_HWM_T2017_Perm1.mxd



Project Location in Wisconsin

Legend

2017 Final Herbicide Application Area

2017 Herbicide Concentration Monitoring Locations

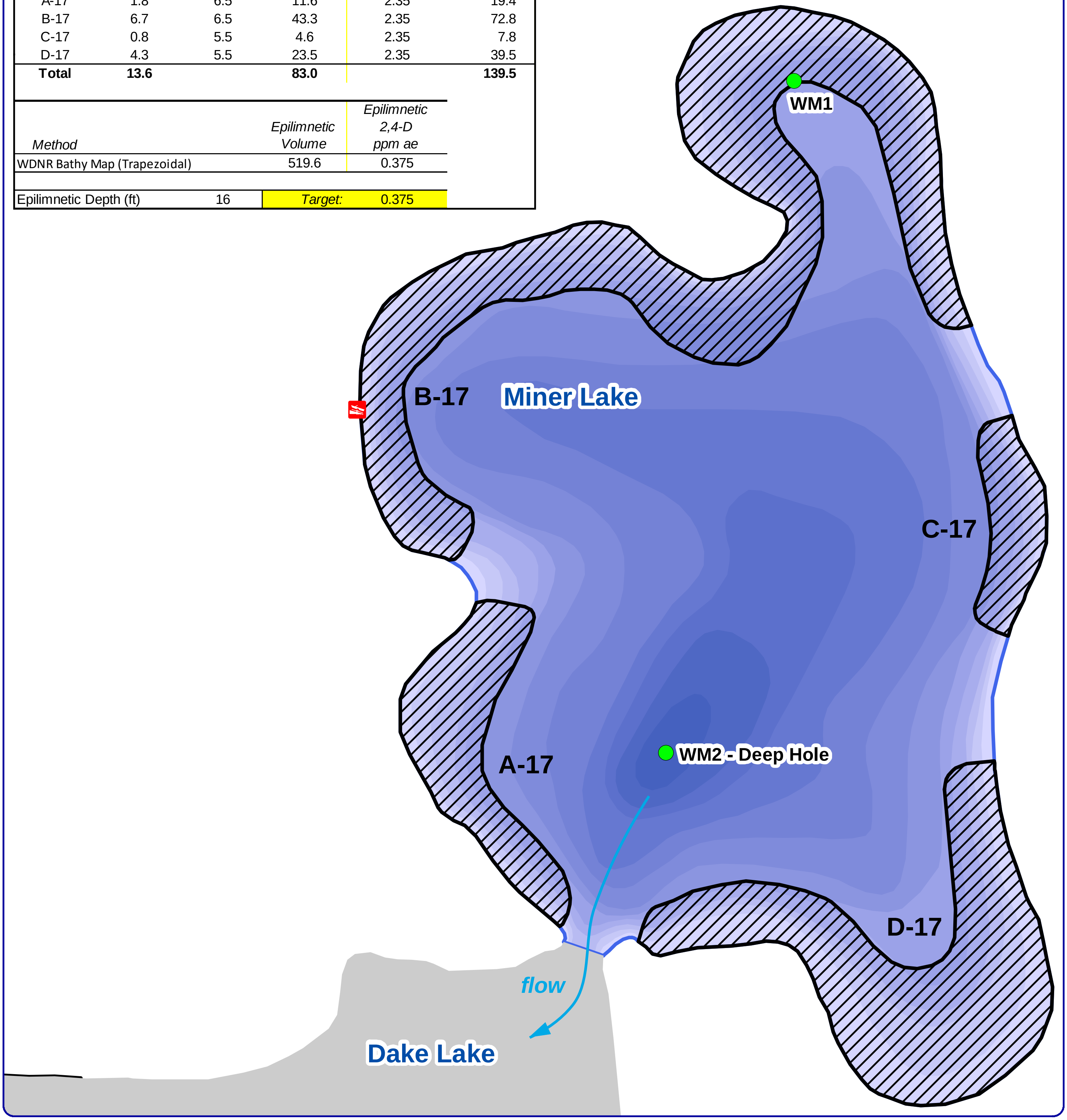
Map 2
Dake Lake
Waupaca County, Wisconsin

2017 Final HWM Herbicide Control Strategy

Waupaca Chain - Miner Lake

Site	Acres	Ave Depth	Total Volume (acre-feet)	Application Area Dose: 2,4-D PPM ae	Application Area Dose: DMA IV (gallons)
A-17	1.8	6.5	11.6	2.35	19.4
B-17	6.7	6.5	43.3	2.35	72.8
C-17	0.8	5.5	4.6	2.35	7.8
D-17	4.3	5.5	23.5	2.35	39.5
Total	**13.6**		**83.0**		**139.5**

Method		*Epilimnetic Volume*	*Epilimnetic 2,4-D ppm ae*
WDNR Bathy Map (Trapezoidal)		519.6	0.375
Epilimnetic Depth (ft)	16	*Target:*	0.375



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Feet

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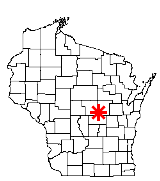
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016
Map Date: May 22, 2017
Filename: Miner_HWM_T2017_Perm1.mxd



Project Location in Wisconsin

Legend

2017 Final Herbicide Application Area

2017 Herbicide Concentration Monitoring Locations

Map 3
Miner Lake
Waupaca County, Wisconsin

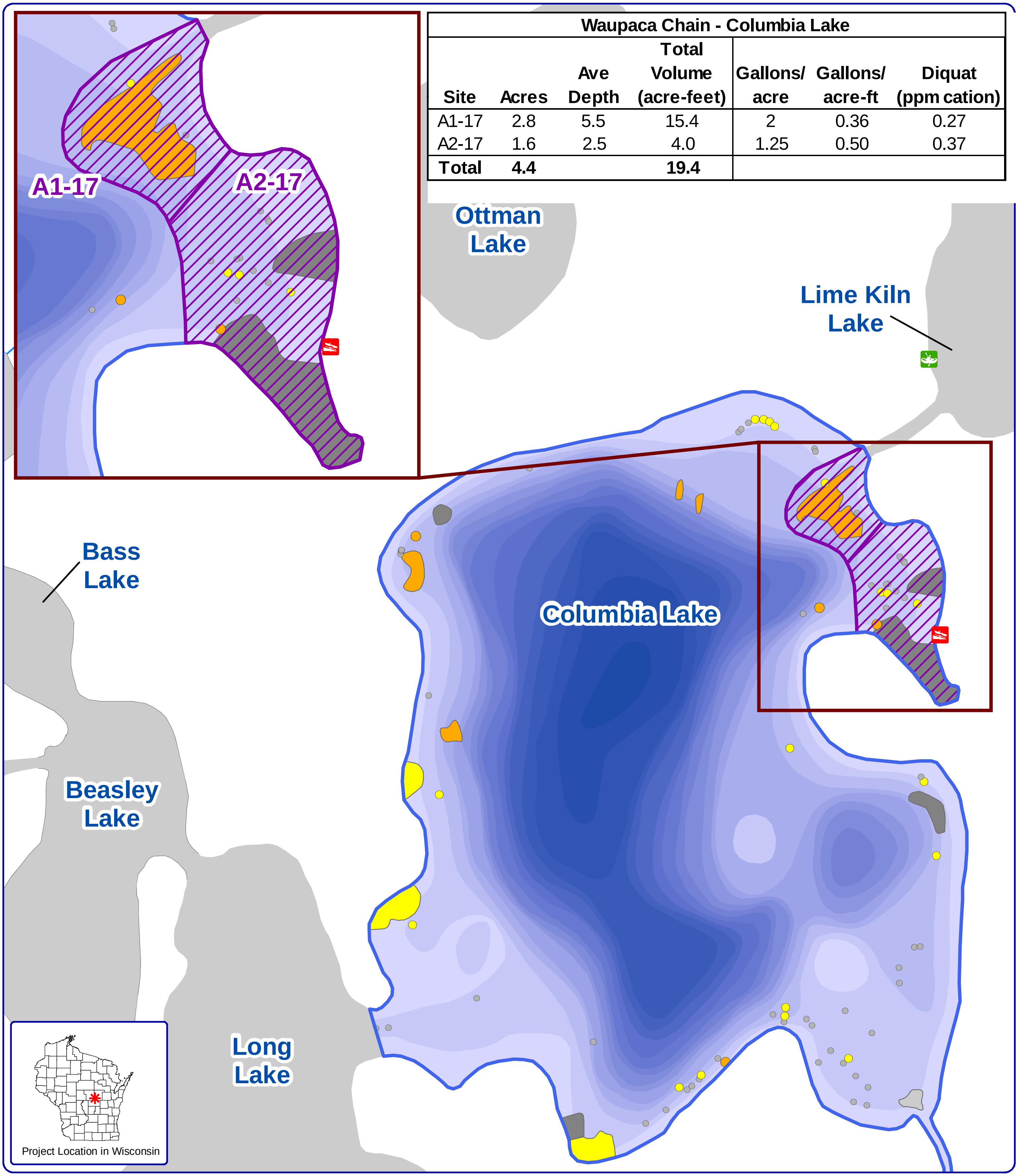
2017 Final HWM Herbicide Control Strategy

Map 4
Columbia Lake
Waupaca County, Wisconsin

2017 Final HWM Treatment Strategy

Waupaca Chain - Columbia Lake

Site	Acres	Ave Depth	Total Volume (acre-feet)	Gallons/ acre	Gallons/ acre-ft	Diquat (ppm cation)
A1-17	2.8	5.5	15.4	2	0.36	0.27
A2-17	1.6	2.5	4.0	1.25	0.50	0.37
Total	**4.4**		**19.4**			



Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2017 Final Diquat Application Area

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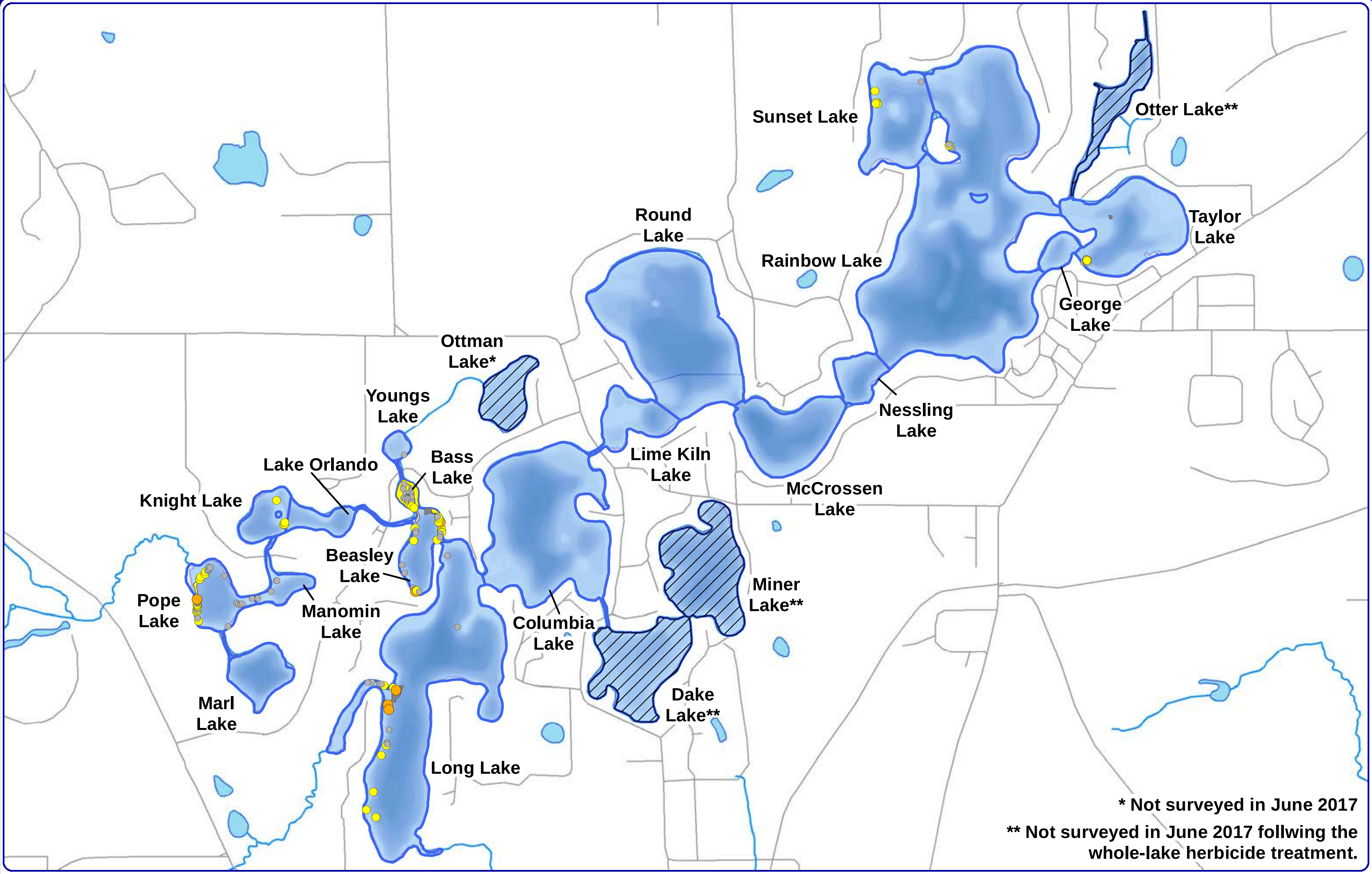
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016
Map Date: May 3, 2017
Filename: Columbia_HWM_T2017_Perm1.mxd



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Feet

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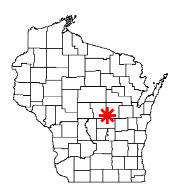
Sources:
Roads and Hydro: WDNR
EWM Survey: Onterra, 2017
Map Date: July 10, 2017
Filename: *WaupacaChain_CLP_ESAIS_June17.mxd*

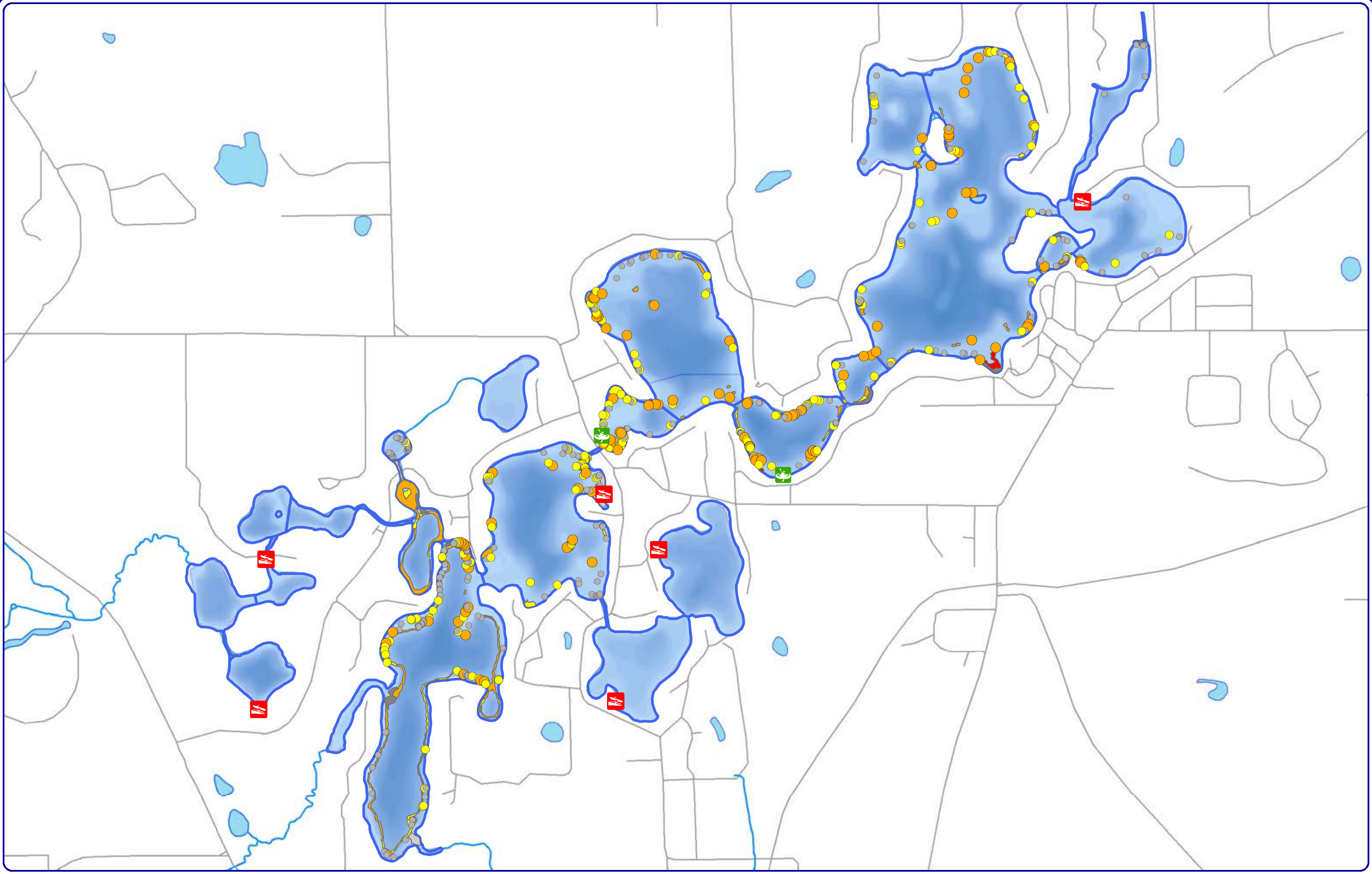

Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(None found)*
- Surface Matted *(None found)*
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 5
Waupaca Chain
Waupaca County, Wisconsin

June 2017 CLP ESAIS Survey Results



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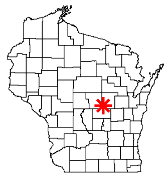
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Survey: Onterra, 2017
Map Date: October 10, 2017
Filename: *WaupacaChain_EWM_PB_Sept17.mxd*



Project Location in Wisconsin

Legend

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

Map 6
Waupaca Chain
Waupaca County, Wisconsin

September 2017 EWM
Peak-Biomass Survey Results

N
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350

Feet

Legend

Exotic Plant Communities	Small Plant Communities	Large Plant Communities
Purple loosestrife	Emergent	Emergent
Pale yellow iris	Floating-leaf	Floating-leaf
	Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent

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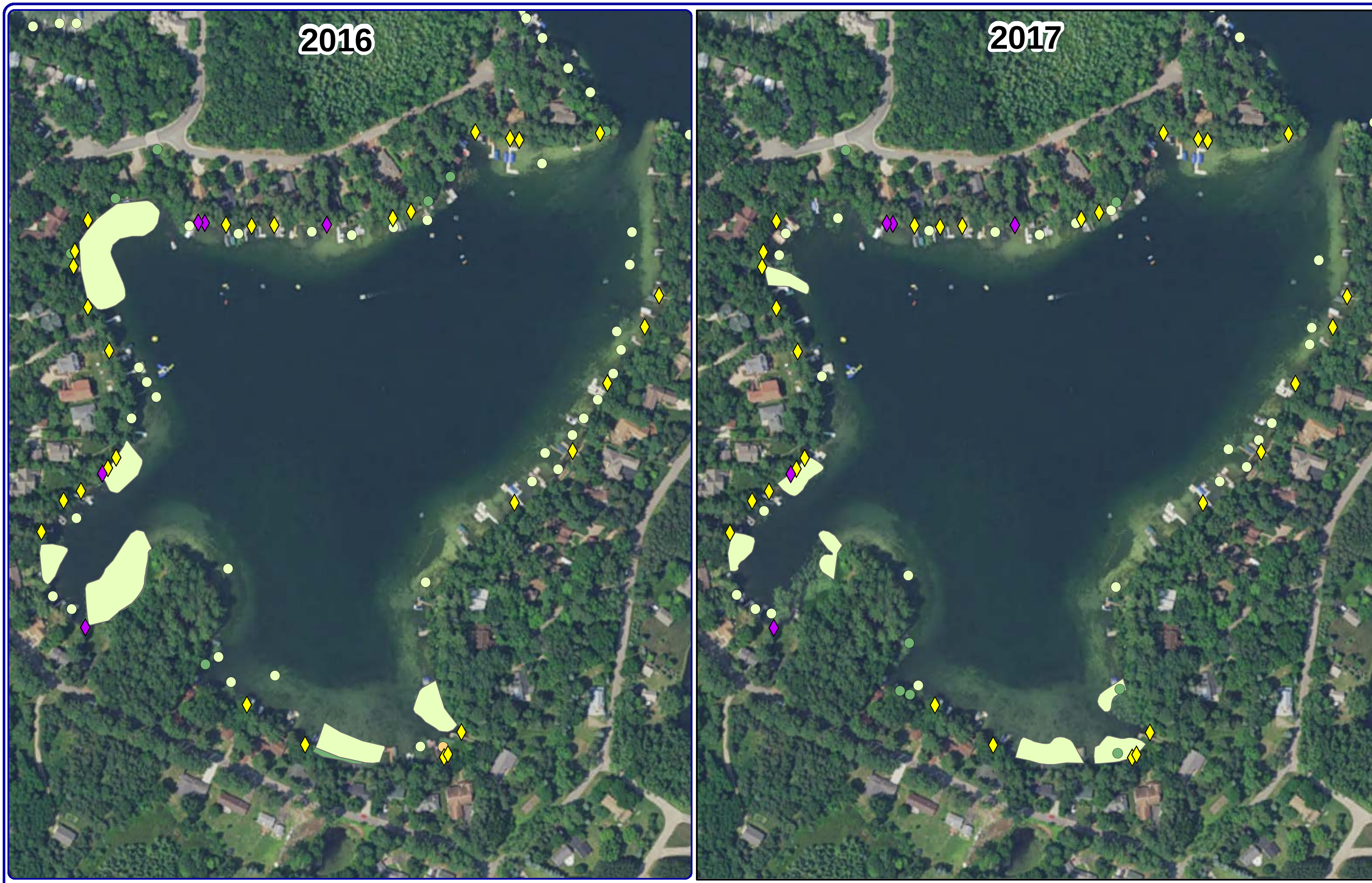
<Bol>Sources:</Bol>
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016&2017
Map Date: August 2011, 2017
Filename: Otter_Comm_2016vs2017.mxd

Map 7

Otter Lake

Waupaca County, Wisconsin

2016 vs 2017 Plant Survey: Community Mapping



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Feet

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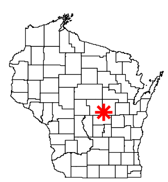
Sources:
Aquatic Plants: Onterra, 2016 & 2017
Orthophotography: NAIP, 2015
Map date: August 11, 2017
Filename:Dake_Comm_2016&2017.mxd



Project Location in Wisconsin

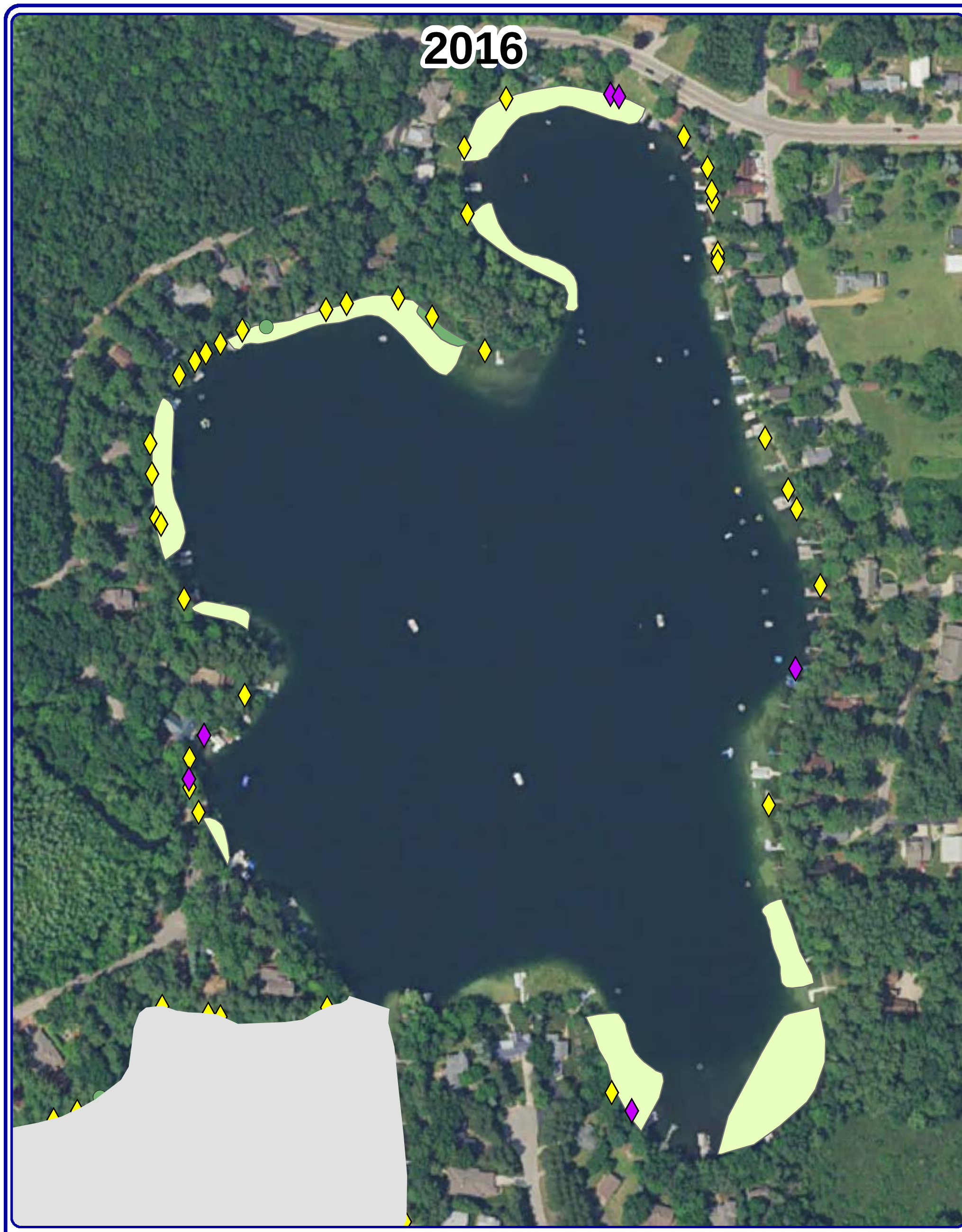
Legend

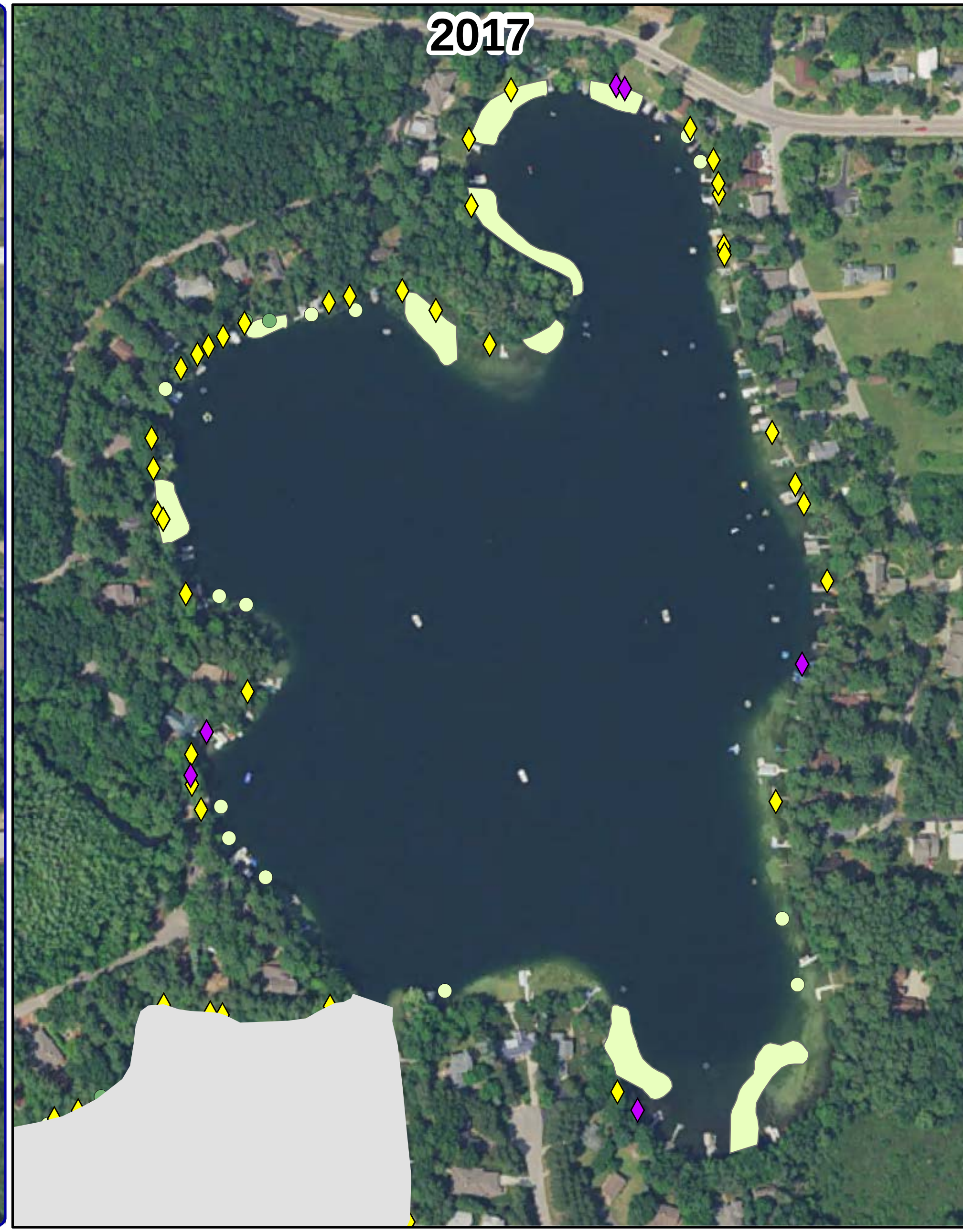
Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

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

Map 8
Dake Lake
Waupaca County, Wisconsin

2016 & 2017 Aquatic Plant Communities





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Feet

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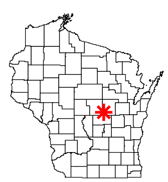
Sources:
Aquatic Plants: Onterra, 2016 & 2017
Orthophotography: NAIP, 2015
Map date: August 11, 2017
Filename:Miner_Comm_2016&2017.mxd



Project Location in Wisconsin

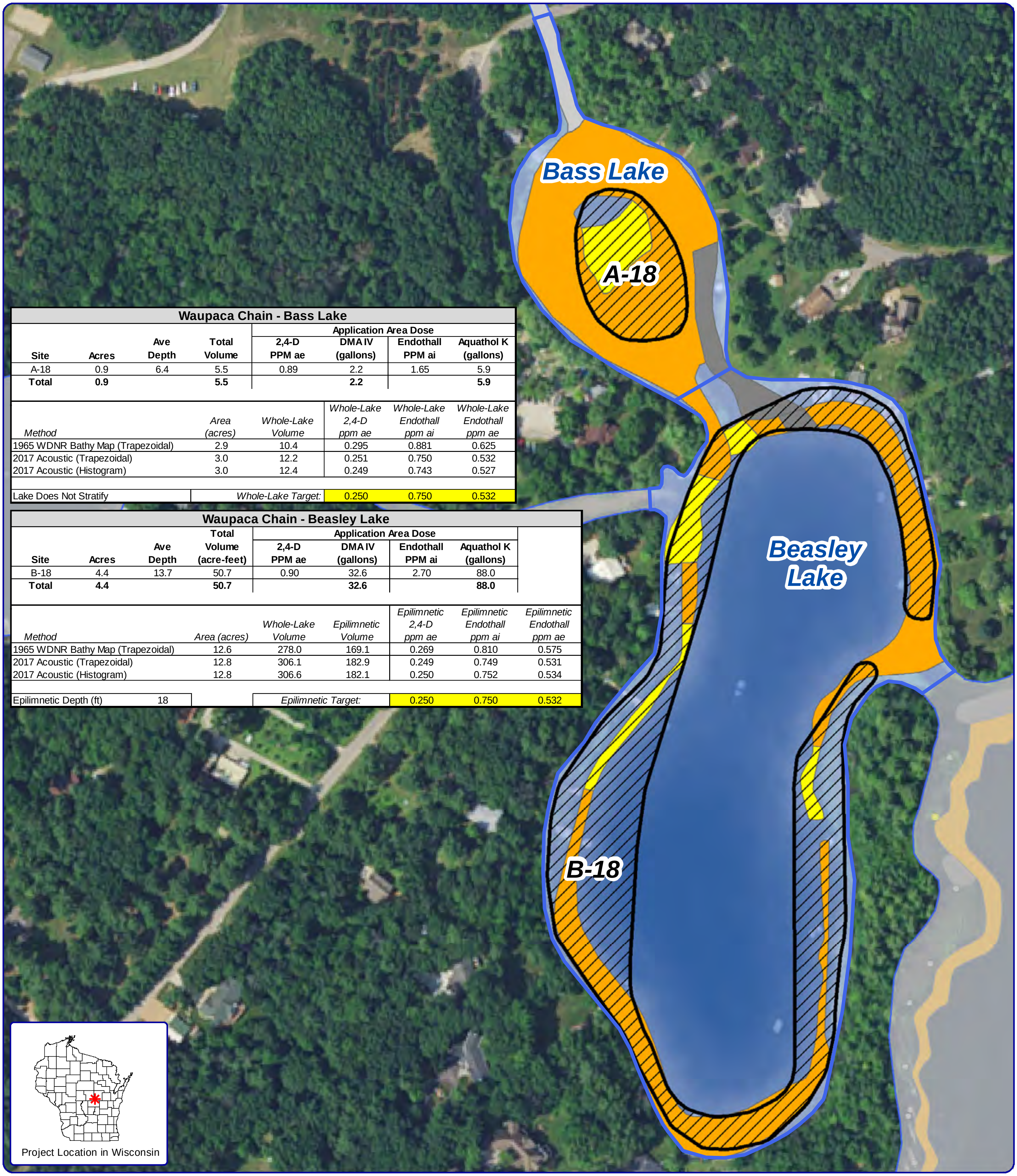
Legend

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

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

Map 9
Miner Lake
Waupaca County, Wisconsin

2016 & 2017 Aquatic Plant Communities



Waupaca Chain - Bass Lake

Site	Acres	Ave Depth	Total Volume	Application Area Dose: 2,4-D PPM ae	DMA IV (gallons)	Endothall PPM ai	Aquathol K (gallons)
A-18	0.9	6.4	5.5	0.89	2.2	1.65	5.9
Total	**0.9**		**5.5**		**2.2**		**5.9**

Method	*Area (acres)*	*Whole-Lake Volume*	*Whole-Lake 2,4-D ppm ae*	*Whole-Lake Endothall ppm ai*	*Whole-Lake Endothall ppm ae*
1965 WDNR Bathy Map (Trapezoidal)	2.9	10.4	0.295	0.881	0.625
2017 Acoustic (Trapezoidal)	3.0	12.2	0.251	0.750	0.532
2017 Acoustic (Histogram)	3.0	12.4	0.249	0.743	0.527
Lake Does Not Stratify		*Whole-Lake Target:*	0.250	0.750	0.532

Waupaca Chain - Beasley Lake

Site	Acres	Ave Depth	Total Volume (acre-feet)	Application Area Dose: 2,4-D PPM ae	DMA IV (gallons)	Endothall PPM ai	Aquathol K (gallons)
B-18	4.4	13.7	50.7	0.90	32.6	2.70	88.0
Total	**4.4**		**50.7**		**32.6**		**88.0**

Method	*Area (acres)*	*Whole-Lake Volume*	*Epilimnetic Volume*	*Epilimnetic 2,4-D ppm ae*	*Epilimnetic Endothall ppm ai*	*Epilimnetic Endothall ppm ae*
1965 WDNR Bathy Map (Trapezoidal)	12.6	278.0	169.1	0.269	0.810	0.575
2017 Acoustic (Trapezoidal)	12.8	306.1	182.9	0.249	0.749	0.531
2017 Acoustic (Histogram)	12.8	306.6	182.1	0.250	0.752	0.534
Epilimnetic Depth (ft) 18			*Epilimnetic Target:*	0.250	0.750	0.532

N W E S

210

Feet

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2018 Preliminary Herbicide Application Area

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Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2017
Bathymetry: Onterra, 2017; processed by C-Map USA
Map Date: January 22, 2018
Filename: BasBeasley_HWM_T2018_Prelim3.mxd

Map 10

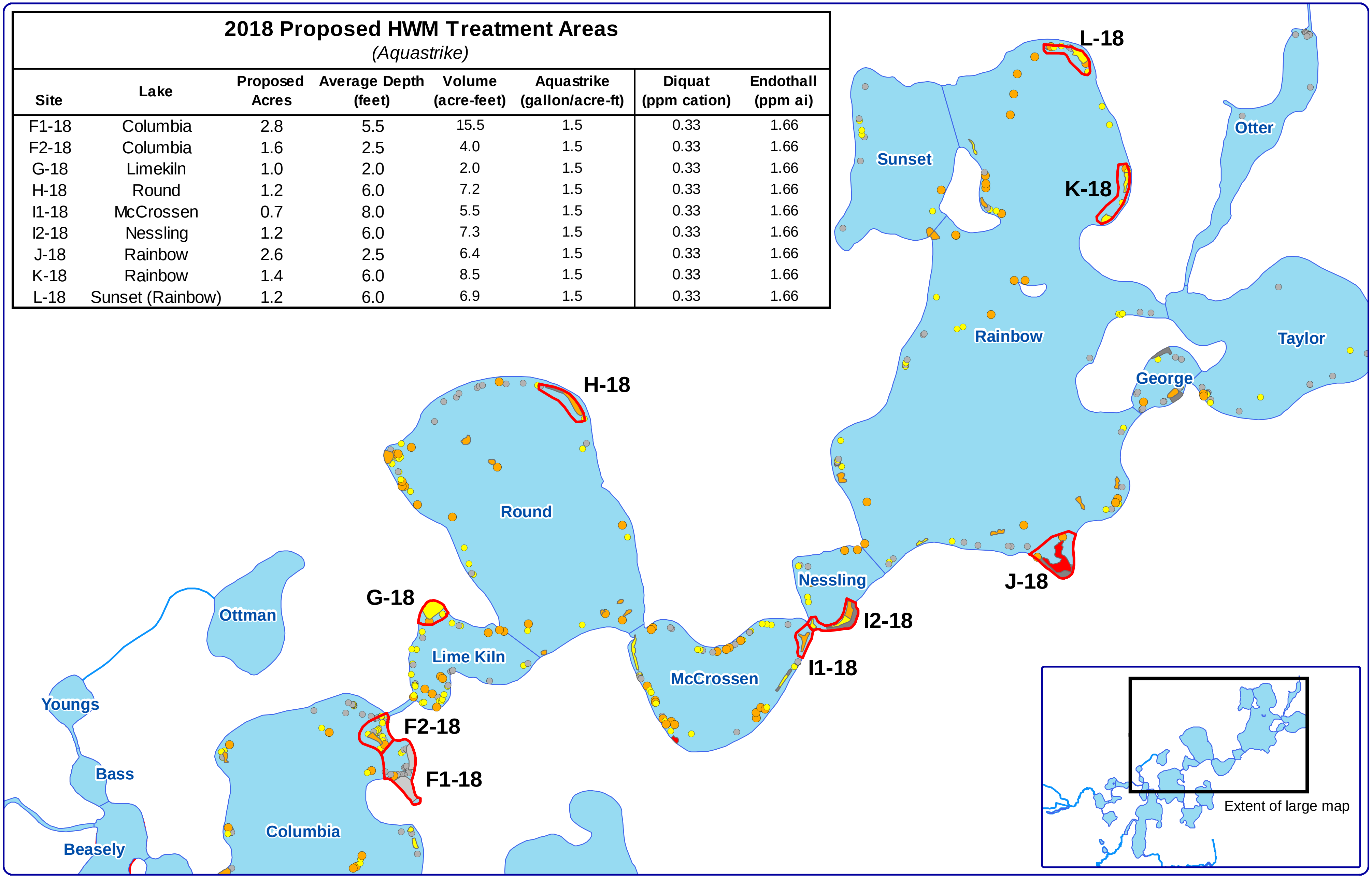
Bass & Beasley Lake

Waupaca County, Wisconsin

2018 Preliminary HWM Treatment Strategy

2018 Proposed HWM Treatment Areas
(Aquastrike)

Site	Lake	Proposed Acres	Average Depth (feet)	Volume (acre-feet)	Aquastrike (gallon/acre-ft)	Diquat (ppm cation)	Endothall (ppm ai)
F1-18	Columbia	2.8	5.5	15.5	1.5	0.33	1.66
F2-18	Columbia	1.6	2.5	4.0	1.5	0.33	1.66
G-18	Limekiln	1.0	2.0	2.0	1.5	0.33	1.66
H-18	Round	1.2	6.0	7.2	1.5	0.33	1.66
I1-18	McCrossen	0.7	8.0	5.5	1.5	0.33	1.66
I2-18	Nessling	1.2	6.0	7.3	1.5	0.33	1.66
J-18	Rainbow	2.6	2.5	6.4	1.5	0.33	1.66
K-18	Rainbow	1.4	6.0	8.5	1.5	0.33	1.66
L-18	Sunset (Rainbow)	1.2	6.0	6.9	1.5	0.33	1.66



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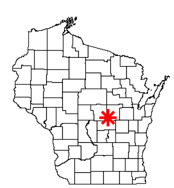

Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matted
- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- Proposed Herbicide Spot-Treatment Site

Onterra LLC
Lake Management Planning
815 Prosper Rd
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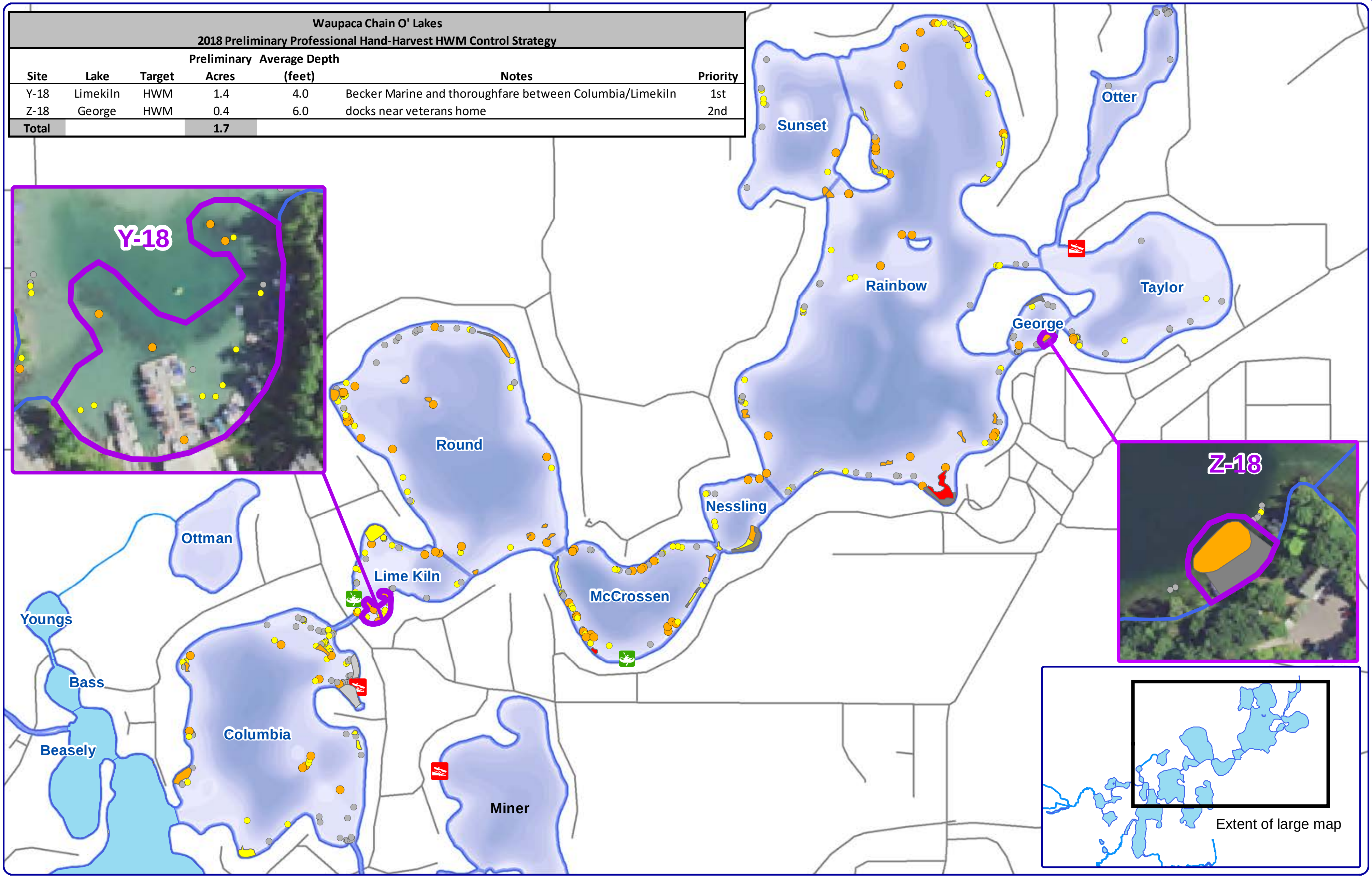
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Survey: Onterra, 2017
Map Date: January 15, 2018
Filename: *WaupacaChain_HWM_T2018_SpotTreat_Prelim_v1.mxd*

Map 11
Waupaca Chain
Waupaca County, Wisconsin

Preliminary 2018 Herbicide Spot-Treatment HWM Control Strategy v1

Waupaca Chain O' Lakes 2018 Preliminary Professional Hand-Harvest HWM Control Strategy						
Site	Lake	Target	Preliminary Acres	Average Depth (feet)	Notes	Priority
Y-18	Limekiln	HWM	1.4	4.0	Becker Marine and thoroughfare between Columbia/Limekiln	1st
Z-18	George	HWM	0.4	6.0	docks near veterans home	2nd
Total			1.7			



1,300
Feet

N
W E
S

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Survey: Onterra, 2017
Map Date: April 26, 2018 - TWH
Filename: WaupacaChain_HWM_HH_2018_Prelim.mxd

Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matted
- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- Proposed Professional Hand-Harvesting Site

Map 12
Waupaca Chain
Waupaca County, Wisconsin
Preliminary 2018 HWM Hand-Harvesting Control Strategy v1

Waupaca Chain O' Lakes

Waupaca County, Wisconsin

2018 HWM Monitoring & Control Strategy Assessment Report

April 2019

Created by: Todd Hanke, Eddie Heath, and Tim Hoyman
Onterra, LLC
De Pere, WI

Funded by: Waupaca Chain O' Lakes Protection and Rehabilitation District
Wisconsin Dept. of Natural Resources (ACEI-195-17)

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APPENDICES

1.0 INTRODUCTION

The Waupaca Chain O' Lakes consists of 22 lakes totaling approximately 792 acres in Waupaca County, Wisconsin (Figure 1.0-1). Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first documented in the Waupaca Chain in 2001. Genetic DNA analysis later confirmed that the milfoil was a hybrid (HWM) between EWM and the native northern watermilfoil. The Waupaca Chain O' Lakes Protection and Rehabilitation District, known locally as the Waupaca Chain O'Lakes District (WCOLD), is the local entity that oversees management of the Chain and has sponsored numerous WDNR funded grant projects. With the assistance of Onterra in 2015, the WCOLD was awarded a WDNR AIS-Education, Planning and Prevention Grant to aid in funding studies aimed at documenting the current state of the Chain's native and non-native aquatic plant populations to guide the development of future management strategies. Surveys conducted in 2015 found that HWM can be found throughout much of the project waters.

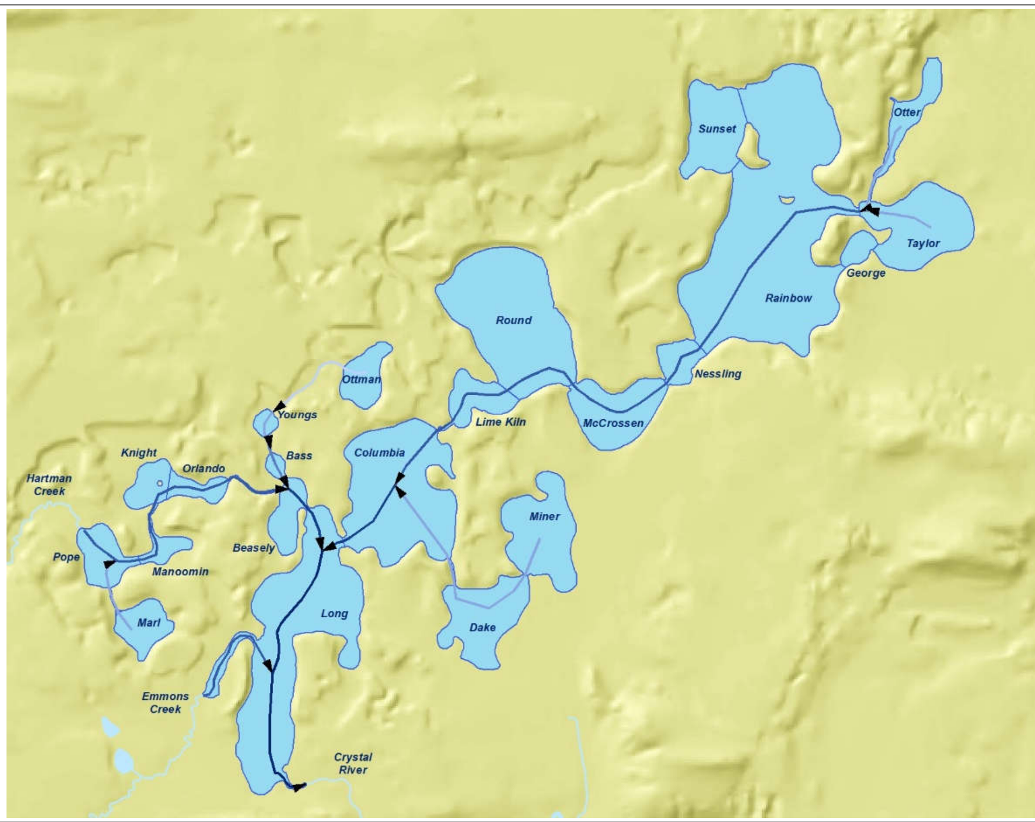


Figure 1.0-1. Waupaca Chain Flow and Lake Boundaries.

The concept of heterosis, or hybrid vigor, is important in regards to hybrid watermilfoil (HWM) management in the Waupaca Chain. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. Hybrid water-milfoil typically has thicker stems, is a prolific flowerer, and grows much faster than pure-strain EWM (LaRue et al. 2012). These conditions likely contribute to this plant being particularly less susceptible to chemical control strategies (Glomski and Netherland 2010, Poovey et al. 2007). In a recent study of 28 whole-lake 2,4-D amine treatments in Wisconsin (Nault et al. 2017), HWM initial control was less and the longevity was shorter than pure-strain EWM control projects. Therefore, it appears that potentially most strains of HWM, but not all, are more tolerant of weak-acid auxin-mimic herbicide treatments (e.g. 2,4-D, triclopyr) than pure-strain EWM.

Due to the implementation challenges of hybridity (hybrid vigor), water exchange, and connectivity of treatment waterbodies, a 3-year trial program was developed within a February 1, 2017 AIS-EPC Grant Application for the Waupaca Chain 'O Lakes (ACEI-195-17).

1.2 2017 Control Strategy Summary

During the first year of the three-year trial project, Dake Lake and Miner Lake were targeted for a whole-lake 2,4-D treatment at 0.375 ppm acid equivalent (ae). Also, during 2017, Otter Lake was targeted with a whole-lake treatment using a combination of 2,4-D (0.275 pm ae) and endothall (0.75 ppm active ingredient [ai]). Having a comparative field trial with an elevated 2,4-D strategy (Dake/Miner) and a 2,4-D/endothall combination treatment (Otter) in the same year will prove valuable to determining future treatment strategies on the Chain. One spot treatment site totaling 4.4 acres in Columbia Lake was targeted with diquat in 2017. This high-traffic area and boat landing was targeted to alleviate navigation impairment as well as for containment purposes. A limited hand-harvesting program was undertaken in 2017 which provided some modest seasonal reductions of HWM in the areas where harvesting efforts took place in Lime Kiln Lake.

A detailed analysis of the 2017 HWM management and control activities was provided in the annual *Waupaca Chain 2017 Treatment Report* that was distributed in April 2018. Surveys conducted in 2017 in Otter, Dake and Miner Lakes showed that the whole-lake treatments conducted in the spring met the HWM control objectives for *the year-of-treatment*. No HWM was located during the late-summer mapping surveys in Dake Lake or Miner Lake following the treatment although two HWM occurrences were found on the point-intercept survey in Miner Lake. Minimal HWM consisting of single plants was found in Otter Lake during surveys conducted in 2017. The reduction of the HWM population in 2017 initially exceeded the qualitative and quantitative success criteria for the whole-lake treatments and met lake managers control expectations. The continued monitoring in 2018 would determine whether the control actions implemented on Dake, Miner, and Otter Lakes in 2017 led to longer term control that extends into the *year after treatment* and will be discussed within this report. The diquat spot treatment in Columbia Lake provided seasonal control; however, HWM in this treatment area had rebounded by the end of the growing season. Some reductions in native plant communities were observed in the lakes that underwent whole-lake treatments, notably slender naiad, white water lily, and sago pondweed. Continued monitoring in 2018 allowed for a greater understanding of any potential longer-term native plant impacts and is discussed in this report in section 5.0.

1.3 2018 Whole-lake HWM Control Strategy

Bass Lake, Beasley Lake, and Long Lake are all in succession and contained some of the highest HWM populations within the Chain in 2017. While targeting these lakes is important to control HWM on a Chain-wide basis, there are a number of implementation challenges that make it more appropriate to target these lakes in year two.

Using traditional watershed modeling tools, the residence time of these lakes is quite short – approximately four days on Youngs-Bass Lakes, 14 days on Beasley Lake, and 48 days on Long Lake. However, this modeling may not be completely accurate and the whole topographic watershed may not be available for overland runoff. As is common for many lakes in the area, much of the watershed is sand, which allows water to percolate into the groundwater. If this is the case, the water residence times may be much longer than the modeling predicts.

With assistance from Waupaca County LWCD, a flow study was completed in 2017 that provided more accurate data on flow between the waterbodies. Flow data was collected on the Waupaca Chain at three locations in May and June of 2017; 1) at the outlet from Youngs Lake to Beasley Lake, 2) at the outlet of the Upper Chain to the Lower Chain (outlet from Knight Lake to Beasley Lake), and 3) at the mouth of the Crystal River at Long Lake's outlet. Using the available data, flushing rates for Bass, Beasley, and Long Lakes were calculated and displayed in Table 1.3-1. The modeling indicates that water residence time is about 9 days in Bass Lake, 6-7 days within the epilimnion of Beasley Lake, and 12-14 days in the epilimnion of Long Lake.

Table 1.3-1. Modeled Water Residence from Flow Study Data. May and June

	Bass Lake	Beasley Lake	Long Lake
Lake Volume (acre-feet):	12	306	3,182
Whole-Lake Residence Time (Days):	9	12	31
Epilimnetic (18 ft) Residence Time (Days):	-	7	14
Epilimnetic (15 ft) Residence Time (Days):	-	6	12

In October 2017, Onterra staff systematically collected continuous, advanced sonar data across Bass, Beasley and Long Lakes. One result of this survey produced an updated bathymetric map of the system. The success of properly planning and implementing whole-lake treatments relies on accurate bathymetric information with which advanced water volume calculations are conducted. This ensures meeting target concentrations outlined within the dosing strategy, which is devised to provide HWM control while balancing native plant selectivity.

Based on the results of the 2017 field trials and 2017 flow monitoring studies, standard whole-lake use patterns with 2,4-D alone were not anticipated to provide more than limited seasonal reductions in HWM populations. Because of the relatively small size of Bass and Beasley Lakes, a field trial with a combination 2,4-D/endothall was prescribed for 2018. The proposed treatment would be expected to function as a whole-lake treatment that targets the entire HWM population in Bass and Beasley Lakes. A treatment of Long Lake would be postponed until after the results of the 2018 treatment were understood, potentially for 2019.

1.4 2018 Small-Scale HWM Control Strategy

Herbicide Spot treatment

Other more isolated populations of dense HWM exist in the Chain that are not applicable for consideration in a whole-lake treatment herbicide use pattern, but may be appropriate for consideration for control through herbicide spot treatments or coordinated hand-harvesting. As discussed within the lake management planning project, control of EWM/HWM with small spot treatments with systemic herbicides is rarely effective due to rapid herbicide dissipation. Onterra's working definition of small spot treatments is less than 5 acres. For 2017, diquat, an herbicide with a shorter exposure time, was recommended. The 2017 spot treatment in Columbia Lake resulted in seasonal reductions in the HWM population in the targeted site and control was likely to be limited to one growing season.

The long-term control of EWM/HWM targeted with diquat continues to be evaluated on many lakes across Wisconsin. As a contact herbicide, diquat does not move (translocate) through plant tissue. Therefore, only the exposed plant material is impacted by the herbicide. Concern exists whether this herbicide has the capacity to kill the entire plant or simply removes all the above ground biomass and the plant rebounds from unaffected root crowns. Diquat also has a high affinity for binding with organic particles. In shallow waters where the application equipment creates disturbance of the lake bottom, the diquat being applied will quickly bind to the suspended particles and be instantly unavailable to cause impacts to the target plants. In lakes with high organic material encrusted on the plant, this may also reduce the efficacy of the treatment.

When diquat is mixed with endothall, as is commercially available under the Aquastrike® brand, it is theorized to have even shorter exposure time requirements than diquat alone. While diquat does not have systemic activity, endothall has proven to have a high level of systemic activity (i.e. moves throughout the plant, including into the root crown) at cold water temperatures. The manufacturers of endothall (UPL) have shown that increased systemic activity of endothall occurs when water temperatures are colder (<60°F).

This herbicide use-pattern has shown promise controlling EWM in a few Wisconsin treatments. Nine sites throughout the Chain were recommended for spot treatments in 2018 utilizing Aquastrike®. These sites were chosen based on the presence of colonized HWM consisting largely of *dominant* densities or greater and in which at least a one-acre treatment site could be constructed with a reasonable sized buffer.

Professional Hand-Harvesting

As a part of an integrated HWM control strategy, the WCOLD piloted a hand-harvesting program for select locations in the Chain in order to determine what role this management technique may have in future HWM management actions. Sites that are not of sufficient size to result in a successful herbicide treatment are considered for professional hand-harvesting control actions. Specific sites to be prioritized for hand-harvesting may include areas that are not being targeted through herbicide treatments, but are of higher use, high visibility to lake users, near public access locations, or otherwise prioritized by WCOLD members.

Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process. DASH may be beneficial for use on the Waupaca Chain for areas that contain dense HWM and/or are in deeper water.

A set of HWM mapping surveys were used within this project to coordinate and qualitatively monitor the hand-harvesting efforts. In early summer 2018, Onterra conducted an Early Season AIS Survey (ESAIS Survey). Based on the results of the ESAIS Survey, the hand-harvesting control strategy was revised, if necessary, and finalized (Figure 2.0-1). The final WDNR approved mechanical harvesting permit was based on the strategy developed following Onterra's 2018 ESAIS survey. Hand-harvesting activities took place between the ESAIS (pre) and the late-summer HWM Peak-Biomass (post) surveys, allowing for evaluation of the management activity.

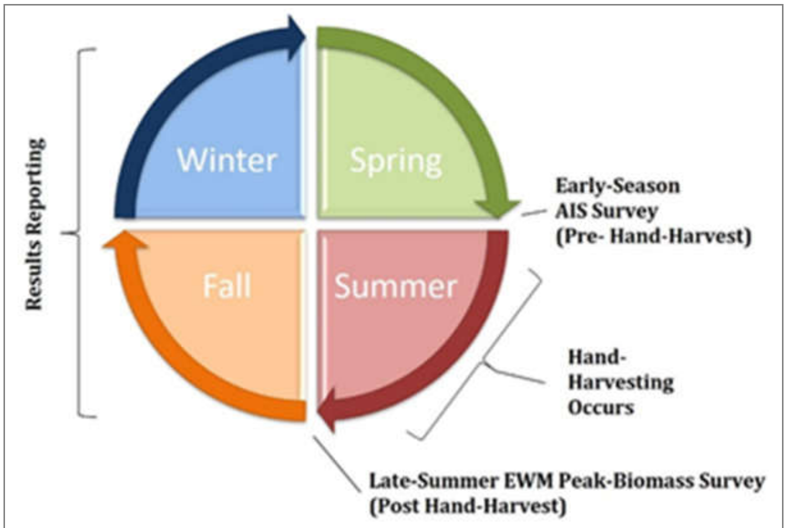


Figure 2.0-1. Hand-Harvesting Control and Monitoring Timeline.

The hand-removal program would be considered successful if the density of HWM within the hand-removal areas was found to have decreased from the ESAIS Survey to the Late-Summer Peak-Biomass Survey.

2.0 MONITORING METHODOLOGIES

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

2.1 Quantitative Monitoring

During a period of active management on the Chain, the whole-lake point-intercept method as described by the WDNR Bureau of Science Services (PUB-SS-1068 2010) will be used to complete a quantitative evaluation of the occurrences of non-native and native aquatic plant species. To monitor the whole-lake control strategy's efficacy, a whole-lake point-intercept survey was conducted in the (*year prior to treatment*), (*year of treatment*), and (*year following treatment*). The success criteria of a whole-lake treatment would be a 70% reduction in HWM littoral frequency of occurrence comparing point-intercept surveys from the *year prior to the treatment* to the *year after the treatment*. Understanding the HWM population in (*year of treatment*) is important, but an insufficient time has passed to make official judgements if HWM control occurred or if the plants were simply injured for that season and can quickly rebound.

During 2016, whole-lake point-intercept surveys were conducted on the entire Chain and served as a pretreatment dataset. These studies were replicated in 2017, 2018, and 2019 to track the efficacy of the whole-lake treatments (i.e. HWM control) and selectivity of the native plant community (i.e. collateral native plant reductions). Quantitative monitoring was not used to evaluate the spot treatment herbicide sites in 2018 as these sites are too small to conduct this type of monitoring.

2.2 Qualitative Monitoring

Qualitative monitoring was conducted annually through HWM mapping surveys on the Chain using either 1) point-based or 2) area-based methodologies. Large colonies greater than 40 feet in diameter were mapped using polygons (areas) and qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to locations that were considered *small plant colonies* (less than 40 feet in diameter), *clumps of plants*, or *single or few plants*.

During the *year of the treatment*, the project included verification and refinement of the treatment plan immediately before control strategies were implemented. This included refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy.

2.3 Herbicide Concentration Monitoring

In-lake herbicide concentrations are also monitored as a part of some treatment strategies, especially those involving anticipated whole-lake impacts. Waupaca County Land and Water Conservation Department (LWCD) volunteered to assist within this project component. In whole-lake treatment scenarios, herbicide concentrations were monitored to determine if the target concentrations were met.

With this type of monitoring, water samples are collected by trained volunteers from multiple locations over the course of numerous days or weeks following treatment.

Onterra worked with WDNR partners to develop the post-treatment herbicide concentration monitoring plan in association with the 2018 whole-lake treatments on Bass and Beasley Lakes. The sampling plan included the collection of water samples from five sites at time intervals of 1, 3, 5, 7, 14, 21, 28, 35, 49, and 70 days after treatment (DAT) using an integrated sampler or Van Dorn sampler (Table 2,0-1), Map 1). The samples were preserved with acid and shipped to the Wisconsin State Lab of Hygiene (SLOH) where the herbicide analysis was completed.

Table 2.0-1. Herbicide concentration monitoring plan for the 2018 whole-lake 2,4-D/endothall treatment on Bass and Beasley Lakes.

Waupaca Chain O' Lakes Herbicide Sample Sites					
Site	Latitude	Longitude	Station ID	Site Description	Sample Depth
BASS 1	44.331159	-89.182827	693104	Deep Hole	near surface (0-6 feet)
BEASLEY 1	44.3285	-89.181899	693106	Deep Hole	near surface (0-6 feet) & near bottom
BEASLEY 2	44.330275	-89.181011	10051052	North End of Lake	near surface (0-6 feet)
LONG 1	44.328403	-89.181011	10051053	North End of Lake	near surface (0-6 feet)
LONG 2	44.325201	-89.180505	693197	Deep Hole	near surface (0-6 feet)

DAT Interval	Bass 1	Beasley 1 (deep hole)		Beasley 2	Long 1	Long 2
	Surface	Surface	Bottom	Surface	Surface	Surface
1	X	X		X	X	X
3	X	X	X	X	X	X
5	X	X		X		
7	X	X	X	X	X	X
14	X	X		X		
21	X	X	X	X	X	X
28	X	X		X		
35	X	X	X	X		
49	X	X		X		
70	X	X		X		

X = sample to be collected (42 total samples)

3.0 HERBICIDE TREATMENT PLANNING & IMPLEMENTATION

3.1 Pre-treatment Confirmation and Refinement Survey

On May 17, 2018, Onterra ecologists conducted the HWM Spring Pre-treatment Confirmation and Refinement Survey on Bass and Beasley Lakes as well as in each of the proposed spot treatment sites. The survey crew observed actively growing HWM characterized by green growth and reddish-colored tips on the plants. A mid-depth water temperature of 58.2°F was recorded in Bass Lake and a full temperature profile in Beasley Lake was recorded. Native vegetation observed in Bass and Beasley Lakes included white water lily, muskgrasses and white-stem pondweed. No changes to the proposed treatment strategy in Bass and Beasley Lakes were made following the Pre-treatment Survey.

Each of the proposed herbicide spot treatment sites were visited during the Pre-treatment Survey. Crews confirmed treatment area extents, average water depths and growth stage of HWM and native aquatic plants during the visit. One proposed treatment site (F1-18) was found to have very sparse amounts of HWM and was removed from the control strategy. The final spot treatment strategy included targeting eight sites, totaling 10.9 acres throughout the Chain, with a diquat/endothall combination herbicide (Aquastrike®) (Map 2).

3.2 Finalized Dosing Strategy for Treatment

In order to finalize the dosing volume for the 2018 whole-lake treatments, it was necessary to understand the volume of water in which the herbicide was expected to mix. As the water warms, a thermal barrier develops in many lakes essentially separating the lake into an upper epilimnion with warmer water temperatures and a lower hypolimnion with cooler water temperatures (Figure 3.2-1). The transitional area separating the upper and lower portions of the water column is known as the metalimnion. In recent years, it has become common for lake managers to predict the mixing volume of a lake based on the middle/upper-middle of the metalimnion, understanding that some amount of herbicide will be lost to the metalimnion.

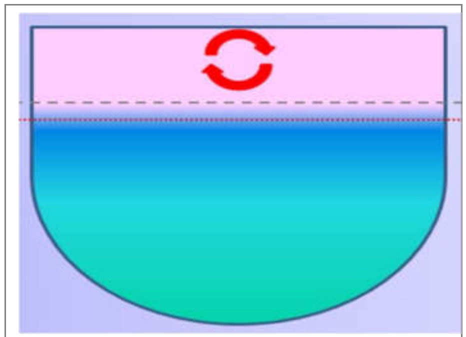


Figure 3.2-1 Mixing zone of a stratified lake. Grey dashed line indicates start of metalimnion. Red dashed line indicates mixing volume used in dosing calculations.

Staff from Waupaca County LWCD provided numerous temperature profiles leading up to the whole-lake herbicide treatment on Bass and Beasley Lakes (Figures 3.2-2). During May, the lake was warming, and towards the end of the month, stratification parameters became apparent in Beasley Lake. Due to the shallower depth and smaller size of Bass Lake, only near surface water temperatures were monitored in the weeks leading up to the treatment as the lake was not expected to thermally stratify. The final dosing depth for Beasley Lake was 14 feet.

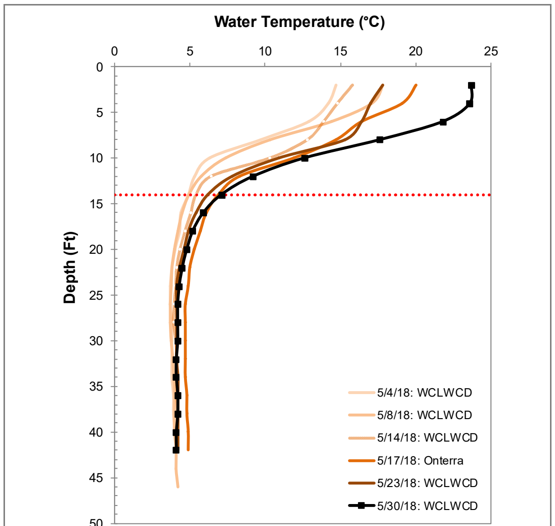


Figure 3.2-2 Pre-Treatment Temperature Profiles Collected on Beasley Lake. Red dashed line indicates dosing depth.

Map 1 displays the final whole-lake herbicide treatment design and dosing strategy for Bass and Beasley Lakes in 2018. The treatment included application of 2.2 gallons of 2,4-D amine (Alligare 2,4-D Amine) and 5.9 gallons of endothall dipotassium salt (Aquathol® K) over 0.9 acres of the Bass Lake, and 26.7 gallons of 2,4-D (Alligare 2,4-D Amine) and 71.8 gallons of endothall (Aquathol® K) over 4.4 acres in Beasley Lake. The herbicide treatments were conducted by Wisconsin Lake and Pond Resource on May 31, 2018. The applicator reported a near-surface water temperature of approximately 74°F and west winds of 5-10 mph at the time of application.

4.0 HERBICIDE CONCENTRATION MONITORING RESULTS

Map 1 displays the water sampling locations associated with the herbicide concentration monitoring for the 2018 whole-lake treatments in Bass and Beasley Lakes. One sampling site was located in Bass Lake; two sampling sites were located in Beasley Lake; and two additional sampling sites were located in Long Lake to monitor herbicide levels that moved downstream of the application areas. The top frame of Figure 4.0-1 shows the results of the 2,4-D monitoring and the bottom frame shows the results of the endothall monitoring. The data indicate that concentrations did no reach targets and dissipation was rapid. The north end of Long Lake (Long 1) had similar concentrations to the Beasley Lake sites at 1 day after treatment (DAT), indicating that herbicide was quickly exiting the target lakes.

Concentrations of both 2,4-D and endothall were well below the target for each lake and post-treatment monitoring showed that dissipation out of the application areas occurred somewhat rapidly based on concentrations observed in the downstream sampling sites in Long Lake. Herbicide concentrations at the deep hole sampling site in the middle part of Long Lake were less as the herbicide diluted within that larger volume of water. Minimal 2,4-D or endothall was detectable by 21 DAT in all sampling sites, and no 2,4-D or endothall herbicide was detected in any sample collected on 28 DAT, 35 DAT, 49 DAT, or 70 DAT.

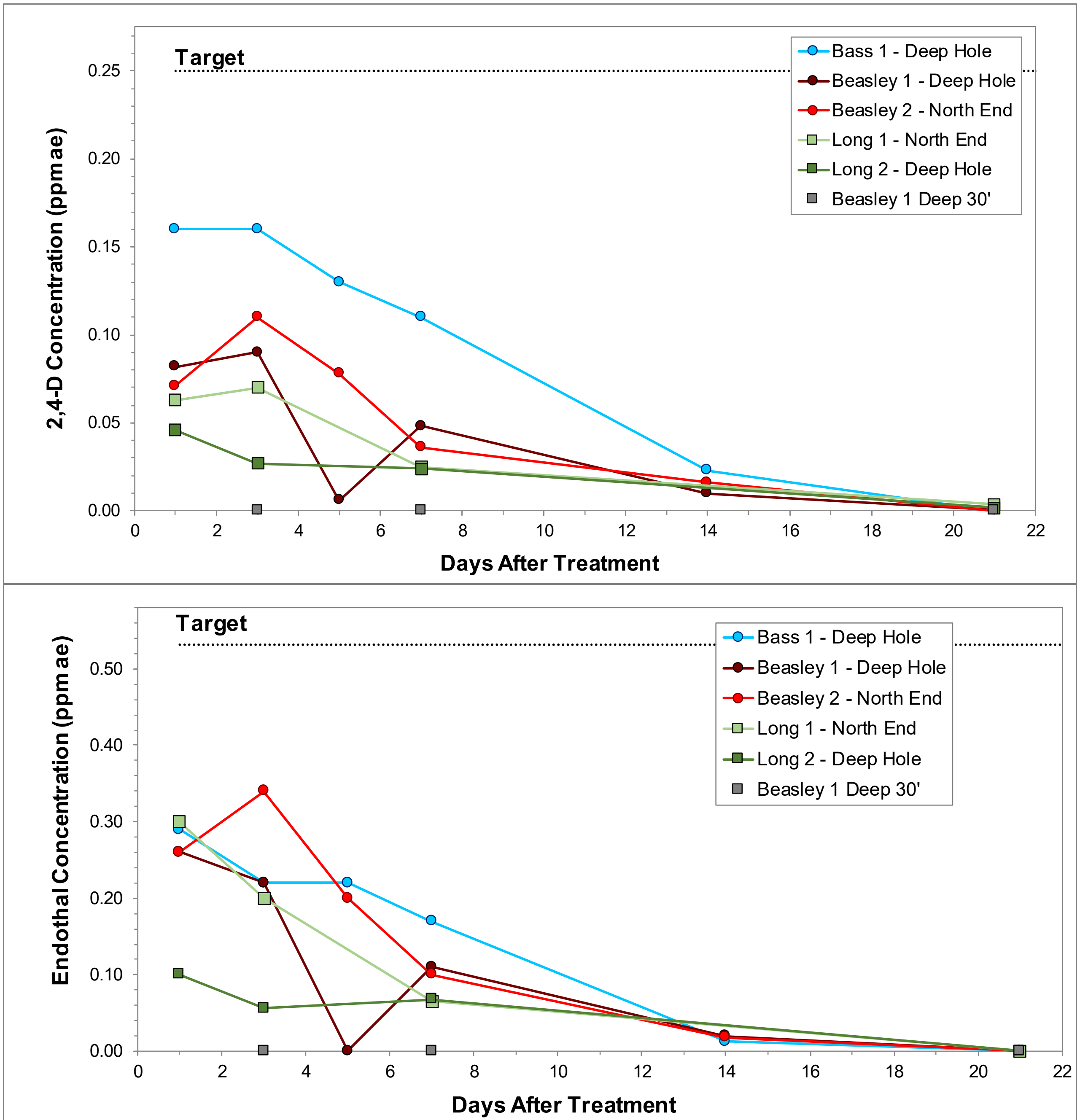


Figure 4.0-1. Waupaca Chain 2018 2,4-D Herbicide Concentration Monitoring Results. No herbicide was detected in any sample collected after 21 Days After Treatment.

The black square symbols on Figure 4.0-1 represent water collected at 30 feet of water from the deep hole monitoring site (Beasley 1). No herbicide was detected in the hypolimnion of Beasley Lake following the treatment in samples collected on 3 DAT, 7 DAT and 21 DAT which confirms that the herbicide was confined to its intended portion of the epilimnetic waters.

Temperature profiles collected at each herbicide concentration sampling interval indicate that Beasley Lake remained thermally stratified throughout the duration of the monitoring timeframe. The closely spaced water temperature contours on the isotherm (Figure 4.0-2, left frame) indicate a thermal gradient separating the epilimnion and hypolimnion beginning at approximately 12-14 feet on the treatment date. As the water temperatures increased during the summer months, the thermal gradient appears to have shifted slightly deeper. This can also be observed on the temperature profiles (Figure 4.0-2, right frame), where uniform temperatures were observed down to about 10 feet before getting much colder in a short amount of depth.

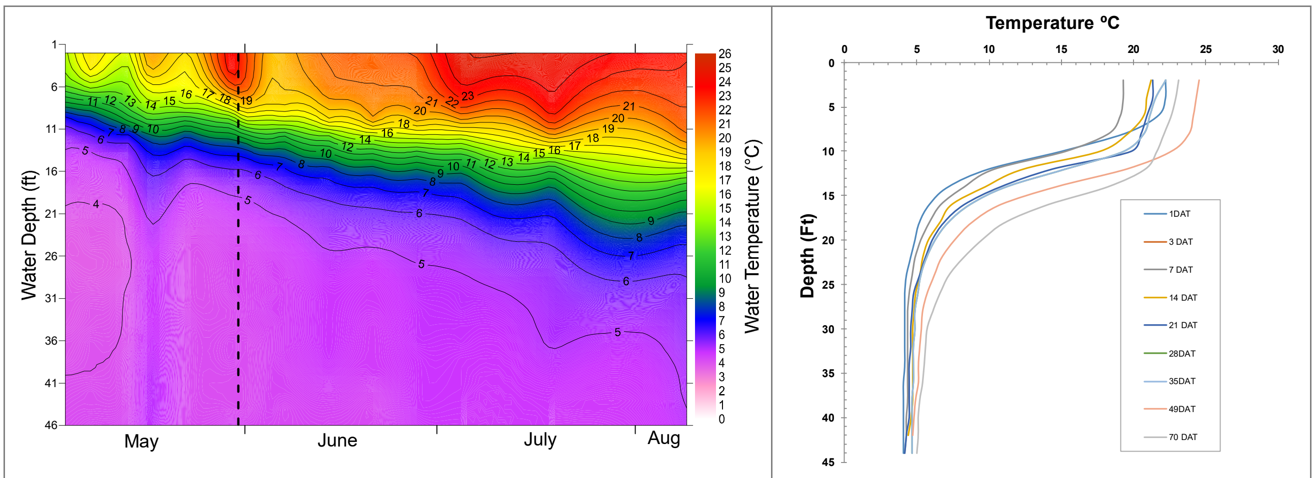


Figure 4.0-2. 2019 temperature profiles and isotherm from Beasley Lake. Dashed line on isotherm indicates date of treatment.

5.0 2018 AQUATIC PLANT MONITORING RESULTS

5.1 June 2018 Early-Season AIS Survey (ESAIS)

On June 11, 2018, Onterra staff completed the Early Season AIS Survey on the Waupaca Chain O' Lakes. Two sites that were included with a preliminary hand-harvesting strategy were visited during the survey, one site in George Lake and one site in Lime Kiln Lake. The lakes that were included in the spring 2017 whole-lake treatment program, Dake, Miner, and Otter, were also visited during the ESAIS survey. Consideration for initiating a hand-harvesting strategy to address any rebounding HWM in these lakes would be made for 2018. Based on the ESAIS survey, the final DASH strategy was developed which totaled 1.7 acres (Map 3). Site Y-18 in Lime Kiln Lake targeted a dominant HWM colony in addition to numerous point-based occurrences around riparian dock structures. Site Z-18 in George Lake targeted a colonized HWM area that included a surface matted colony as well as a larger area of scattered and dominant plants. Due to the area's high use, site Y-18 was set as the highest priority. Onterra provided the spatial data from the survey to the professional hand-harvesting firm to aid in the removal efforts.

5.2 Late-Summer HWM Peak-biomass Survey

The HWM population was mapped on September 28, and October 3,4,9, 2018. During the survey, multiple Onterra field crews meandered the littoral zone of the lakes and mapped HWM populations using sub-meter GPS technology. This meander-based survey, which mimics the methodology used in the ESAIS survey, was completed late in the growing season when HWM had reached its peak growth stage. Because HWM should be at or near its maximum density, the results of this survey provided an understanding of where HWM is in the lake and what its full impact on the ecology of the lake may be. As a result, these data are useful in determining the efficacy of control actions used during the summer months as well as assisting in the next year's management planning.

During the Chain-wide peak-biomass mapping survey, all lakes with the exception of Ottman Lake were surveyed. Ottman Lake requires access through a private property and no HWM was located in this lake during surveys completed in 2015. The population of HWM was found to be widespread throughout the Chain with some of the largest and most dense colonies being found in Long Lake, Beasley Lake, and Columbia Lake. A total of 16.1 acres of HWM was mapped throughout the Chain in the 2018 survey. Of the HWM acreage mapped in 2018, approximately 6.9 acres or 42% was within Long Lake, 1.75 acres or 11% in Columbia Lake, and 1.72 acres or 11% in Beasley Lake (Figure 5.2-1).

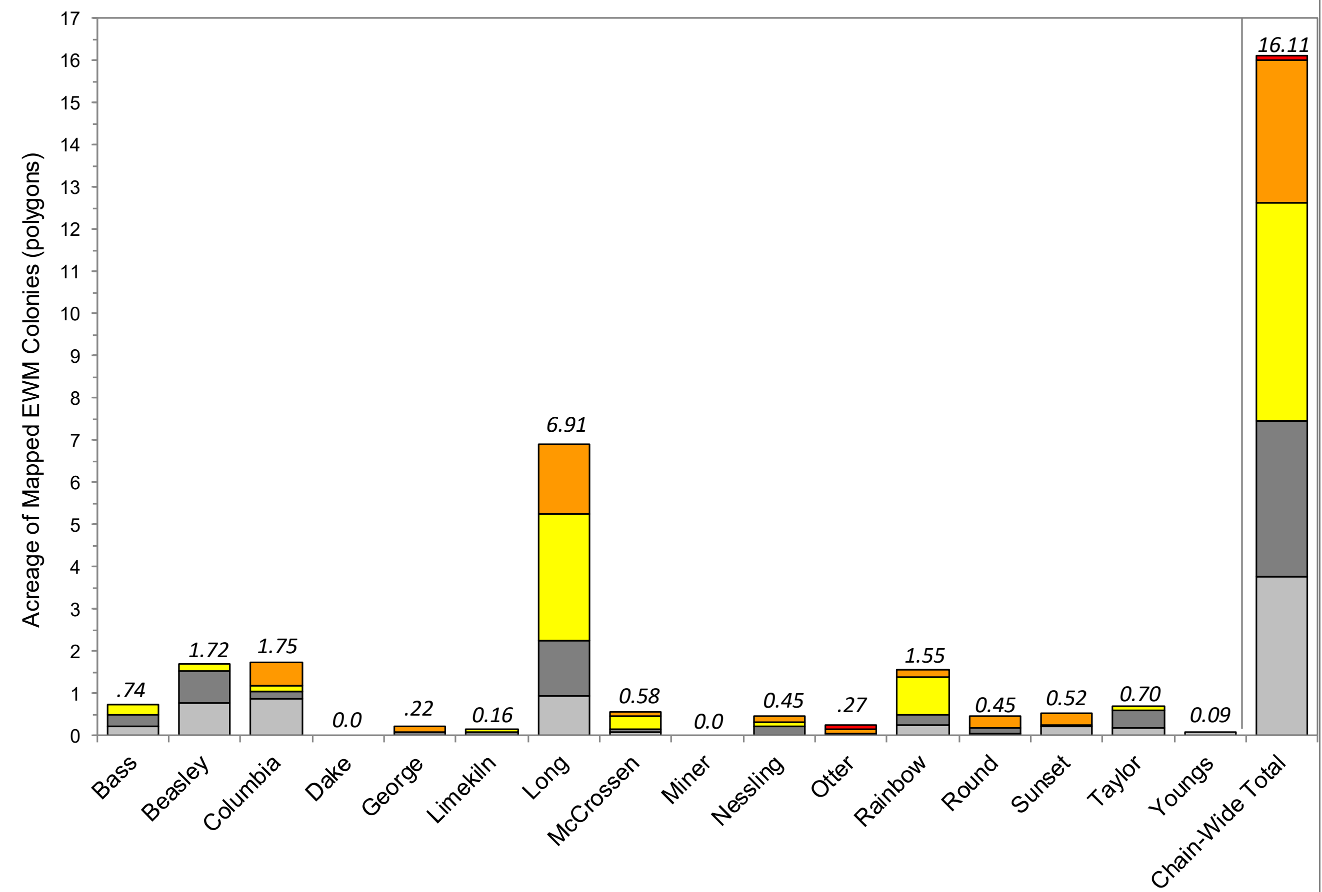


Figure 5.2-1. Waupaca Chain 2018 HWM Colony Density Ratings. Created using data from 2018 Late-Summer EWM Peak-Biomass Surveys.

Spot Herbicide Treatment (Aquastrike®) Efficacy

The sites that were targeted for herbicide control in 2018 with spot treatments using Aquastrike® (combination diquat/endothall) are highlighted in Figures 5.2-2 through 5.2-4 where the left frame shows the pre-treatment HWM population mapped in late-summer 2017 and the right frame shows the post-treatment HWM population mapped in late-summer 2018.

Site F_2-18: Site F2 is located in Columbia Lake at the mouth of the thoroughfare that connects Lime Kiln and Columbia lakes. The 2017 late-summer survey in site F2 mapped a *highly dominant* colony (0.13 acres) of HWM, as well as numerous *clumps* and *single* plants. After the application of Aquastrike®, the 2018 late-summer survey showed a *highly dominant* colony (0.07 acres) and a *dominant* colony (0.09 acres), in addition to four *single or few plant* points. Total colonized acres of HWM in site F2 was 0.15 acres in 2018, with a slight decrease in overall density when compared to 2017.

Site G-18: Site G is located on the north side of Lime Kiln Lake. The 2017 survey mapped one *dominant* colony of HWM (0.16 acres). In addition, a *small plant colony*, *clump* of plants, and a *few single plants* were mapped. After Aquastrike® was applied in 2018, a *highly scattered colony* (0.19 acres) was mapped in the 2018 late-summer survey. A handful of *single plants* were also mapped in site G in 2018.

Site H-18: Site H is located on the north side of Round Lake. The 2017 late-summer survey mapped a *highly dominant* colony (0.23 acres) and an adjacent *scattered colony* (0.08 acres) of HWM within the site. After the application of Aquastrike®, a *scattered* colony (0.12 acres), *small plant colony*, *clump of plants*, and multiple *single plants* were mapped in the 2018 late-summer survey. Overall, site H exhibited both a decrease in density and acreage of HWM when compared to the 2017 survey.

Site I_1/I_2-18: Site I_1 is located on the far east side of McCrossen Lake. Site I_2 is located in Nessling Lake, but is adjacent to site I_1. A *highly dominant* colony (0.16 acres) of HWM was mapped in I_1 during the 2017 survey. A *highly dominant* colony (0.18 acres), two *dominant* colonies (0.21 acres in total), and a *scattered* colony (0.42 acres) were mapped in site I_2 in 2017. Aquastrike® was applied to both sites in spring 2018. The late-summer survey in 2018 indicated a *dominant* colony (0.11 acres) of HWM in Site I_1. In site I_2, two *highly dominant* colonies (0.11 acres in total), two *dominant* colonies (0.22 acres in total), and a *scattered* colony (0.22 acres) were present.

Site J-18: Site J is located on the south side of Rainbow Lake. During the late-summer survey in 2017, a *surface matting* colony (0.69 acres) of HWM was mapped. A *scattered* colony (.32 acres) and two *small plant colonies* were also mapped in 2017. After Aquastrike® was applied in 2018, the late-summer survey of 2018 recorded a small *dominant* colony (0.02 acres), a *scattered* colony (0.24 acres), and a *highly scattered* colony (0.27 acres) of HWM within the site. A handful of *clumps* and *single plants* were also mapped. Results from the 2018 survey showed decreases in both density and acreage of the HWM colony in site J.

Site K-18: Site K is located on the northeast side of Rainbow Lake. During the 2017 late-summer survey, there were two *dominant* HWM colonies (0.21 acres in total) mapped, in addition to a *small plant colony* and two *clumps* of plants. After Aquastrike® was applied in 2018, one *dominant* HWM colony (0.07 acres) remained. Two *small plant colonies*, a *clump*, and numerous *single plants* were also mapped during the late-summer 2018 survey.

Site L-18: Site L is located on the north side of Rainbow Lake. A *dominant* colony (0.21 acres) of HWM was mapped in 2017, in addition to multiple *small plant colonies*, *clumps*, and *single plants*. Aquastrike® was applied to the site in spring 2018. The late-summer survey in 2018 showed a slight decrease in size of the *dominant* colony (0.14 acres) that was mapped in 2017. Two *small plant colonies*, *clumps* of plants, and *single plants* were also mapped again in 2018.

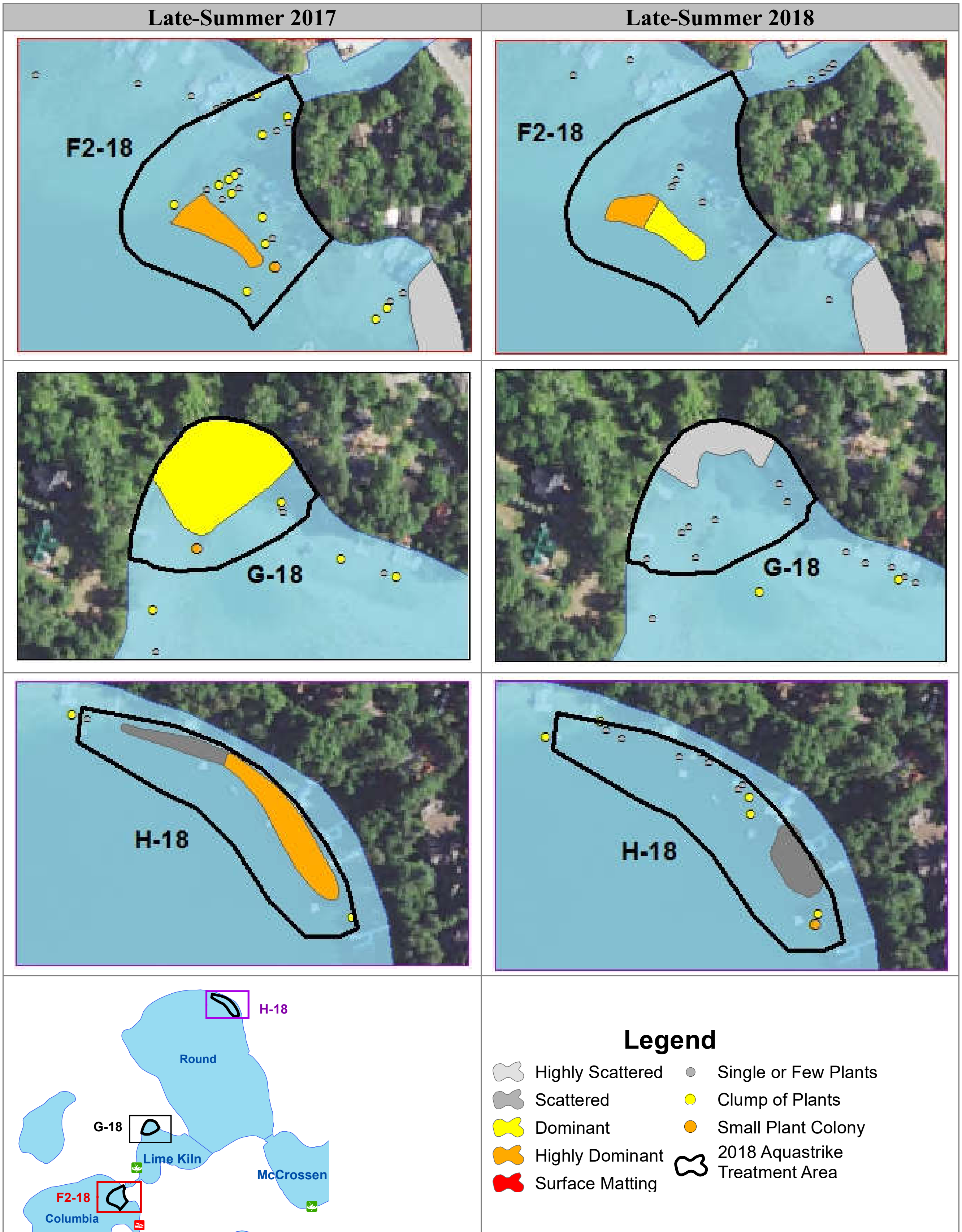


Figure 5.2-2. HWM Populations from before (2017) and after (2018) Aquastrike® herbicide spot treatments at sites F2-18, G-18, and H-18.

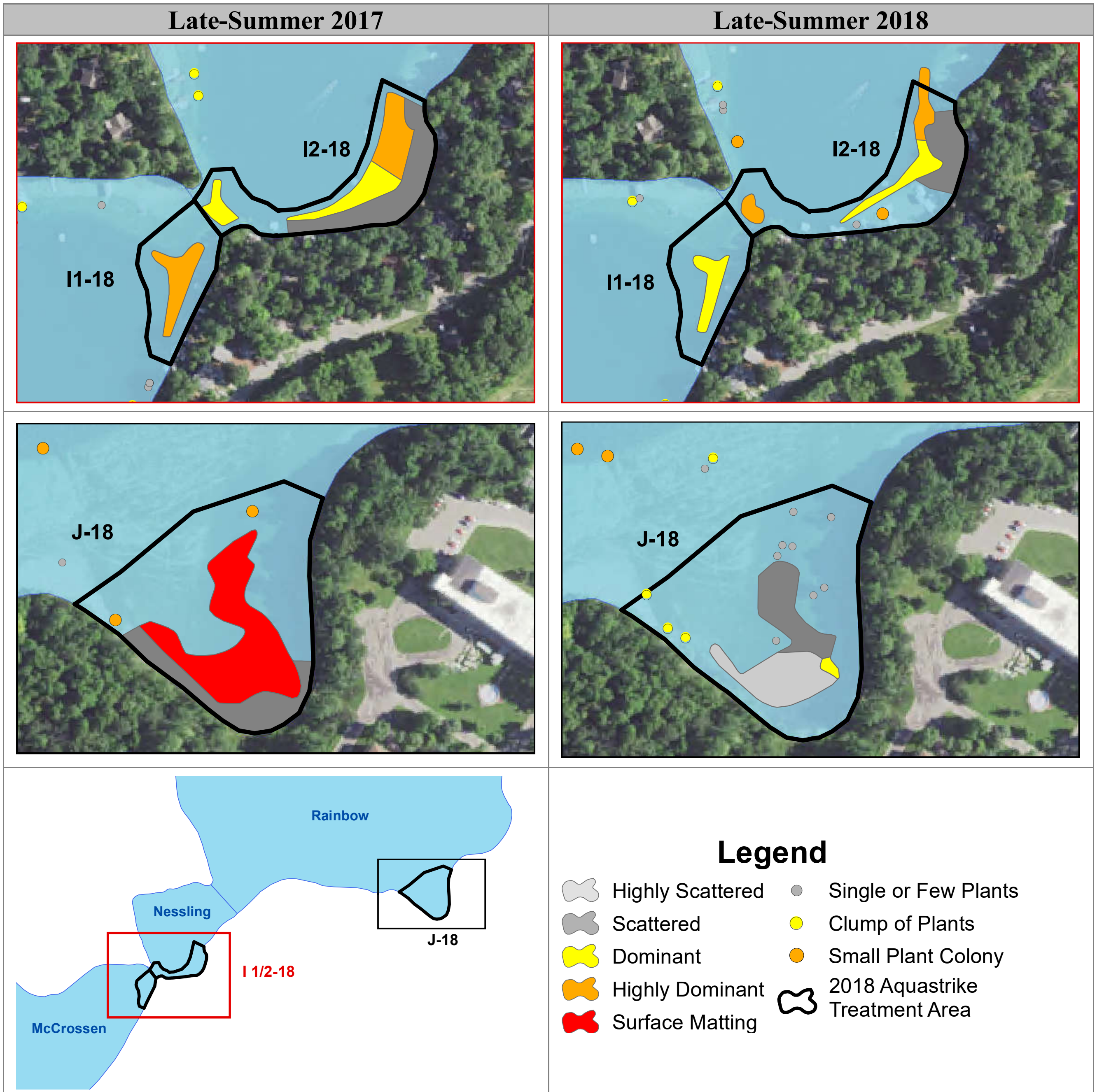


Figure 5.2-3. HWM Populations from before (2017) and after (2018) Aquastrike® herbicide spot treatments in sites I1-18, I2-18, and J-18.

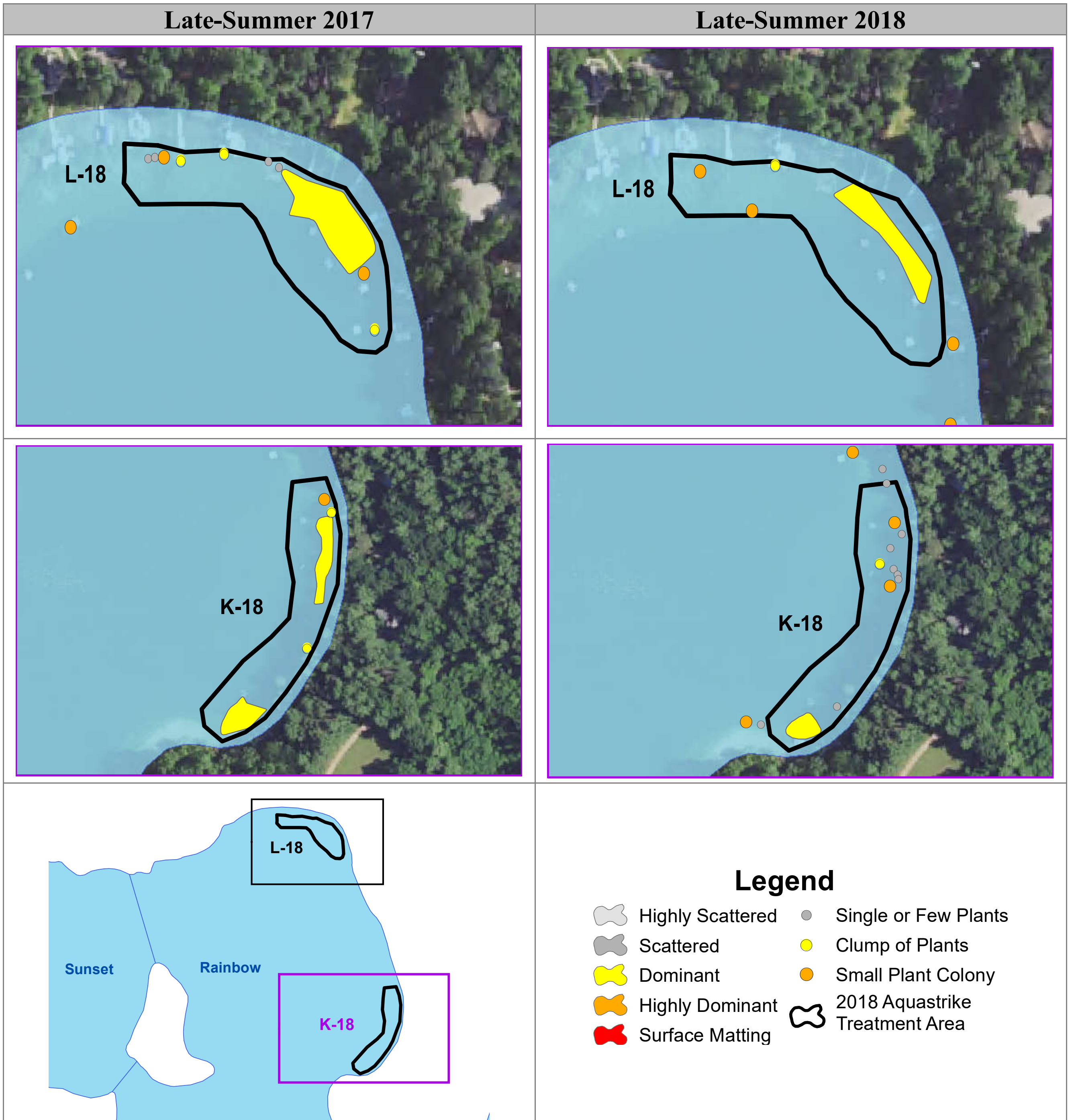


Figure 5.2-4. HWM Populations from before (2017) and after (2018) Aquastrike® herbicide spot treatments in at sites K-18 & L-18.

Whole-Lake Herbicide Treatment Efficacy – Bass & Beasley Lakes

A total of 2.7 acres of colonized HWM was mapped in Bass Lake in the late-summer 2017 survey of which the majority was designated as either *dominant* or *highly dominant* in density (Figure 5.2-5). The late-summer 2018 HWM mapping survey indicated that the HWM population was decreased in Bass Lake in total acreage to 0.7 acres. An area of *scattered* and *highly scattered* plants remained present on the north side of the lake in the late-summer 2018 survey (Figure 5.2-5).

The HWM population in Beasley lake was found to have decreased in density in the majority of the lake; however, large continuous areas of colonized HWM remained present in most of the lake in areas where it had been mapped before the treatment. Acreage of colonized HWM in Beasley Lake were reduced from 2.5 acres in 2017 to 1.7 acres in 2018. Of the 1.7 acres mapped in Beasley Lake in 2018, 1.5 acres consisted of lower density ratings of either *scattered* or *highly scattered*, with an additional approximately 0.2 acres described as *dominant* in density.

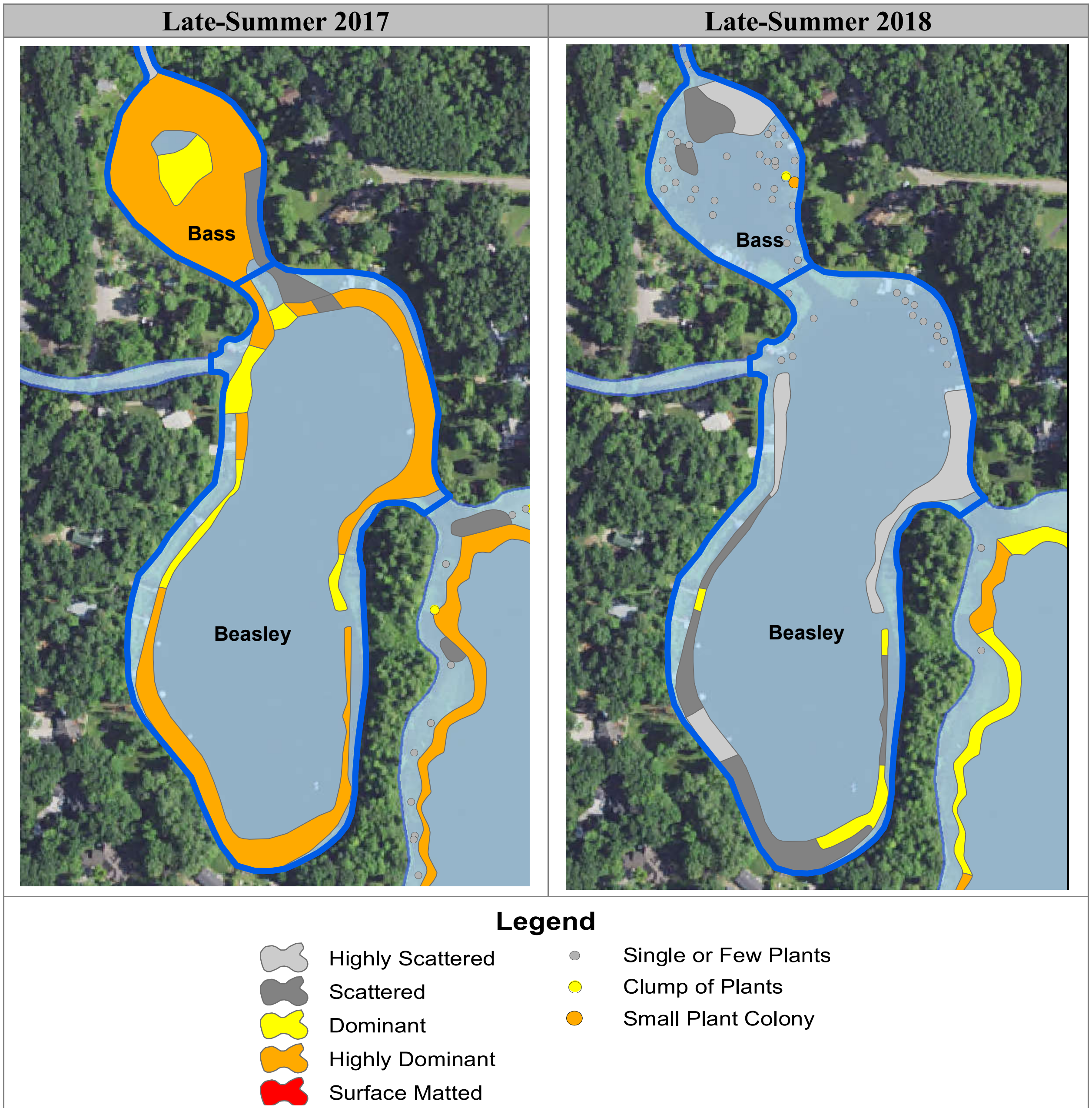


Figure 5.2-5. HWM Populations from before (late-summer 2017) and after (late-summer 2018) the Whole-Lake 2,4-D/endothall herbicide treatment in Bass and Beasley Lakes.

Professional Hand-Harvesting Evaluation – Diver Assisted Suction Harvest

The WCOLD contracted with DASH, LLC to provide professional hand-harvesting actions in 2018. Divers from DASH, LLC visited the Chain on July 10,12,13, 2018, and spent a total of 20.5 hours harvesting HWM from the permitted areas. A total of 1,116 pounds of HWM was harvested from site Z-18 and an additional 338 pounds was harvested from site Y-18. Details of the professional harvesting efforts are provided in a 2018 DASH Summary report by DASH, LLC and included with this report as Appendix A.

The sites that were targeted for HWM management in 2018 with professional hand-harvesting (DASH) efforts are evaluated in the figure below (Figure 5.2-6). The 2018 June ESAIS survey mapped a dense colony of HWM directly in front of the dock of the Wisconsin Veterans Home in George Lake (site Z-18). The colony included 0.02 acres of *surface matting,* 0.13 acres of *dominant*, and 0.12 acres of *scattered* HWM. DASH efforts concluded in late summer 2018, and Onterra staff returned to conduct the HWM peak biomass survey in October. Post hand-harvesting results showed a slight reduction in acreage in site Z-18. A total of 0.15 acres of *highly dominant* and 0.02 acres of *scattered* HWM were recorded in the October survey. Onterra staff noted HWM was less dense near shore, but denser adjacent to the dock. Small gaps from hand harvesting were present in the main colony.

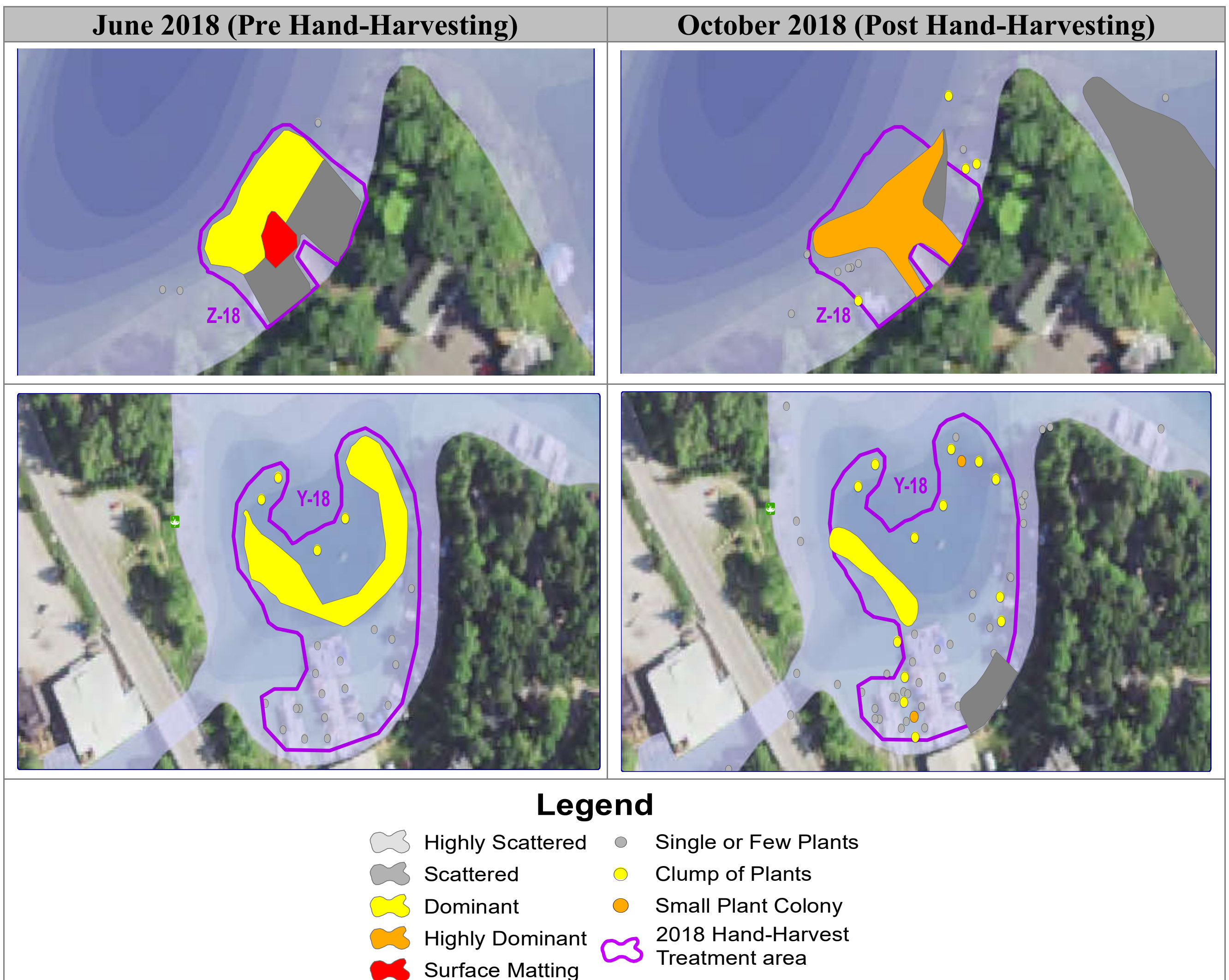


Figure 5.2-6. HWM Populations from before (June 2018) and after (October 2018) the Professional Hand-Harvesting Efforts in Lime Kiln Lake (Y-18) and George Lake (Z-18).

Site Y-18 is located in front of Becker Marine in Lime Kiln Lake. A horseshoe-shaped colony of *dominant* HWM was observed in the June 2018 survey. This colony was 0.32 acres in size and had *clumps* and *single* HWM plants also within the harvest site. After hand-harvesting efforts, the size of the *dominant* colony was significantly reduced to 0.09 acres. A new, *scattered* colony was mapped amongst the docks and shore in the marina. This colony was 0.08 acres in size. Numerous *single* plants, *clumps of plants* and two *small plant colonies* were mapped within the site.

Outside of the scope of this project, a group of riparian property owners from Sunset Lake successfully applied for a permit to solicit professional hand-harvesting efforts in 2018. A professional harvesting firm completed DASH work in late August 2018 to provide nuisance aquatic plant relief around riparian docks. A total of 11,610 pounds of vegetation was removed during the harvesting efforts, of which approximately 35% consisted of HWM or CLP, with the remainder comprised of various native species. The sites included in this DASH program were not evaluated for effectiveness as a part of the Onterra's 2018 monitoring on the Chain.

5.3 2018 Point-Intercept Survey Results – Bass & Beasley Lakes (*Year of Treatment*)

Point-intercept surveys were completed by Onterra staff on the Waupaca Chain O' Lakes in August 2018. Due to their relatively small size, Bass Lake (11 sampling points) and Beasley Lake (36 sampling points) do not have a large enough number of point-intercept sampling points on their own to allow for reliable statistical analysis. Given their proximity to each other and the fact that they were treated under the same strategy in 2018, the point-intercept sampling points are combined into one dataset (n=47) in the following analysis.

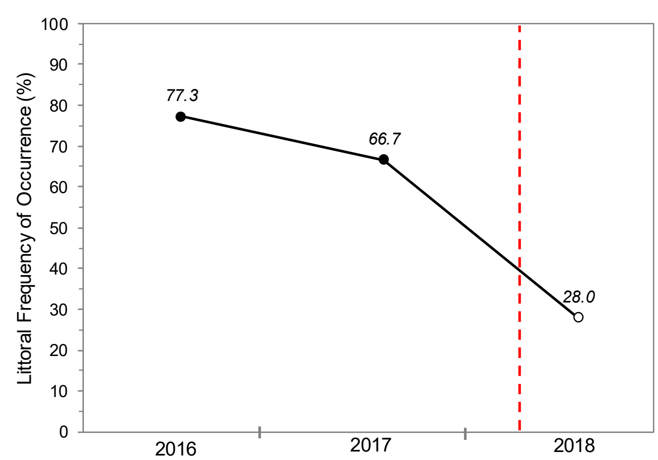


Figure 5.3-1. Littoral Frequency of Occurrence of HWM in Bass and Beasley Lakes from 2016-2018. Data from Onterra 2016-2018 Point-Intercept Surveys. Red dashed line indicates whole-lake treatment. Open circle indicates statistically valid difference from previous survey.

The littoral frequency of occurrence of HWM declined from 66.7% in 2017 to 28.0% in 2018 representing a statistically valid 63.8% decrease between the two surveys.

Slender naiad was the only native aquatic plant species that exhibited a statistically valid decrease in littoral frequency of occurrence between the 2017 and 2018 survey. Several other native species that were present in surveys completed in 2016 or 2017 were not located on the sampling rake in the 2018 survey. Declines in these species were not statistically valid likely due to the small sample size.

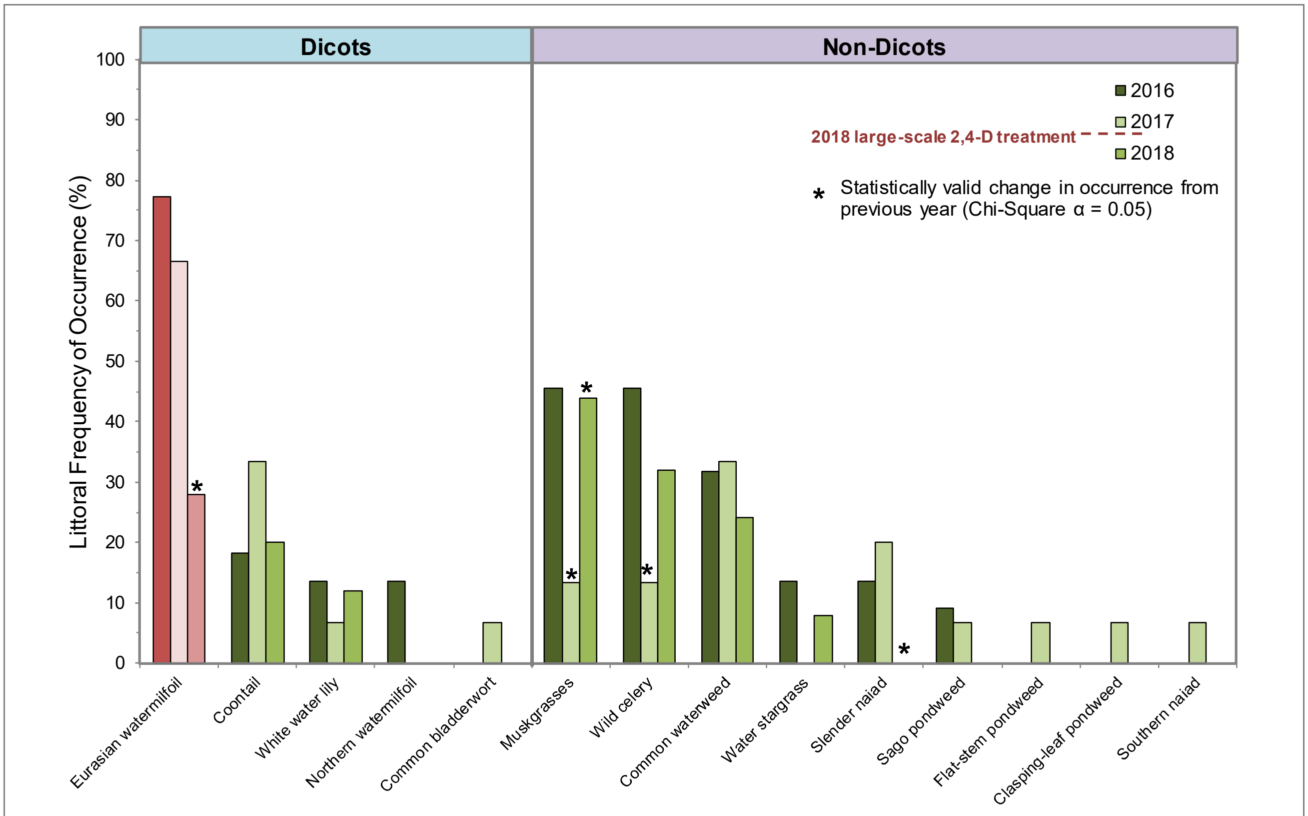


Figure 5.3-2. Littoral frequency of occurrence of aquatic plant species from 2016-2018 in Bass and Beasley Lakes. Whole-lake 2,4-D/endothall herbicide treatment occurred in spring 2018.

Figure 5.3-3 displays the number of point-intercept survey sampling locations that contained either native plants only, HWM plants only, or native plants and HWM plants from surveys completed in 2016-2018 in Bass and Beasley Lakes. In 2016, 17 sampling locations in Bass and Beasley Lakes contained HWM and in 2017, 10 of the sampling sites contained HWM. Hybrid watermilfoil was located on seven sampling points in 2018. The number of sampling locations with native plants increased from 11 in 2017 to 17 in 2018.

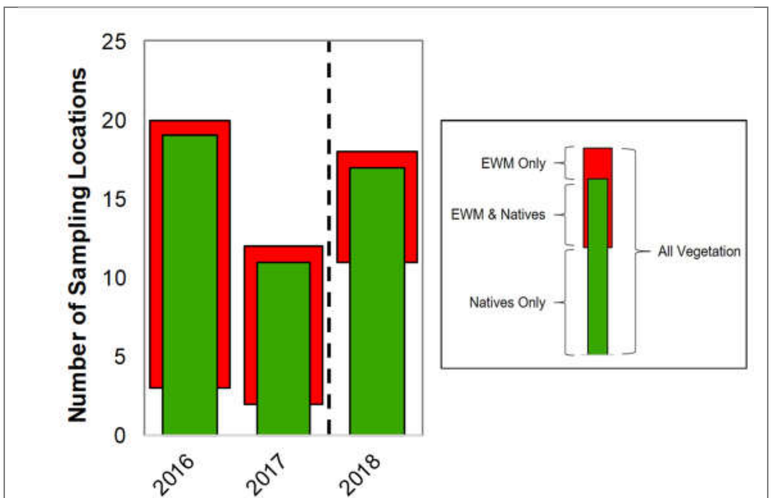


Figure 5.3-3 Vegetation composition of point-intercept locations in Bass and Beasley Lakes.

5.4 2018 Point-Intercept Survey Results – Otter Lake (*Year-After Treatment*)

Zero occurrences of HWM were recorded on the 2017 point-intercept survey in Otter Lake representing a 100% decrease since the 2016 survey (Figure 5.4-1). The 2018 point-intercept survey indicated the HWM population had increased to a littoral frequency of 13.3%. The 2018 HWM occurrence was 30.7% lower than in 2016; however, the difference is not statistically valid.

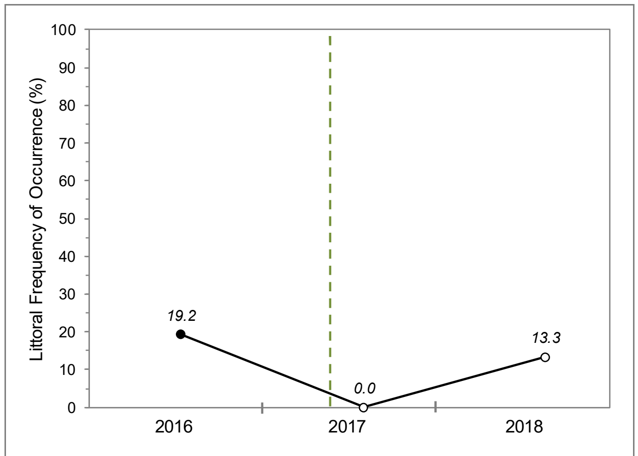


Figure 5.4-1. Littoral Frequency of Occurrence of HWM in Otter Lake from 2016-2018. Data from Onterra 2016, 2017, and 2018 Point-Intercept Surveys. Open circle indicates a statistically valid change from previous survey. Green dashed line represents whole-lake herbicide treatment.

Along with understanding the level of HWM control achieved from the control action, the point-intercept data also allows for an understanding of non-target native plant impacts from the treatment. No native species in Otter Lake exhibited a statistically valid decrease in population from 2016-2017. Sago pondweed (*Stuckenia pectinata*) exhibited a statistically valid increase in population from 2017-2018. Stoneworts (*Nitella spp.*), a type of macroalgae, exhibited a statistically valid decrease in population from 2017-2018 (Figure 5.4-2).

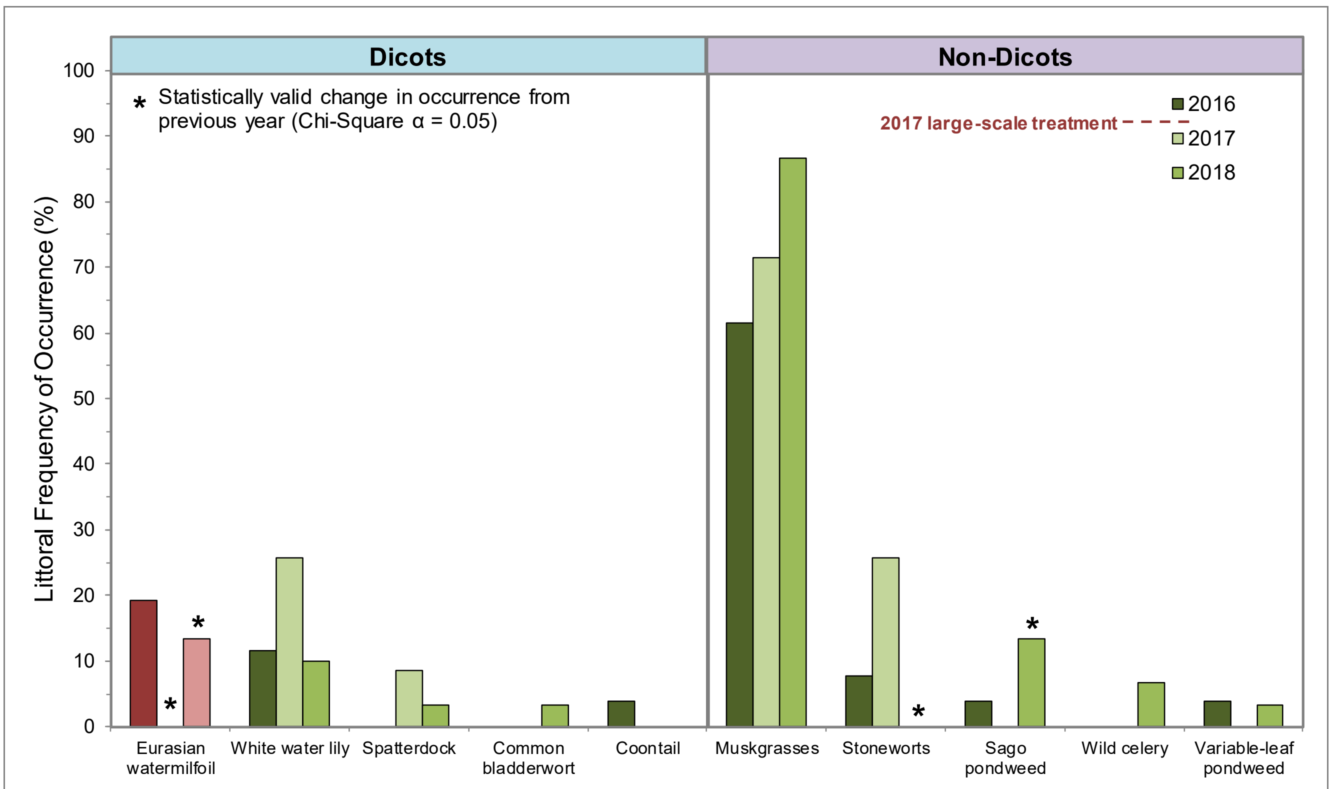


Figure 5.4-2. Littoral frequency of occurrence of aquatic plant species from 2016-2018 in Otter Lake. Whole-lake 2,4-D/endothall herbicide treatment occurred in spring 2017.

Figure 5.4-3 displays the number of point-intercept survey sampling locations that contained either native plants only, HWM plants only, or native plants and HWM plants from surveys completed in 2016-2018 in Otter Lake. An increase in the number of sampling points with native vegetation was exhibited between 2016-2017. In 2018, 26 sampling points contained native plants and four points contained HWM. Two of the sampling points contained both HWM and native plants in 2018.

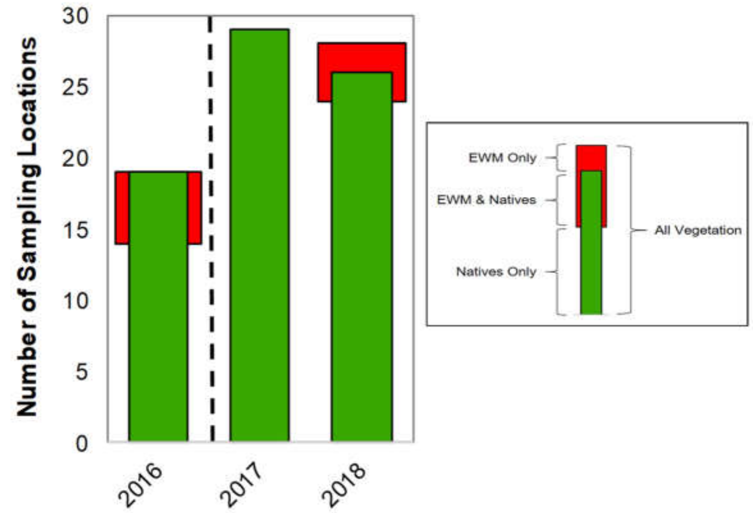


Figure 5.4-3. Vegetation composition of point-intercept locations in Otter Lake.

5.5 2018 Point-Intercept Survey Results – Dake Lake (*Year-After Treatment*)

Zero occurrences of HWM were recorded on the 2017 point-intercept survey in Dake Lake representing a 100% decrease since the 2016 survey (Figure 5.5-1). One sampling point contained HWM in the 2018 point-intercept survey representing a 1.1% occurrence. The 2018 occurrence was 78.9% lower than in 2016.

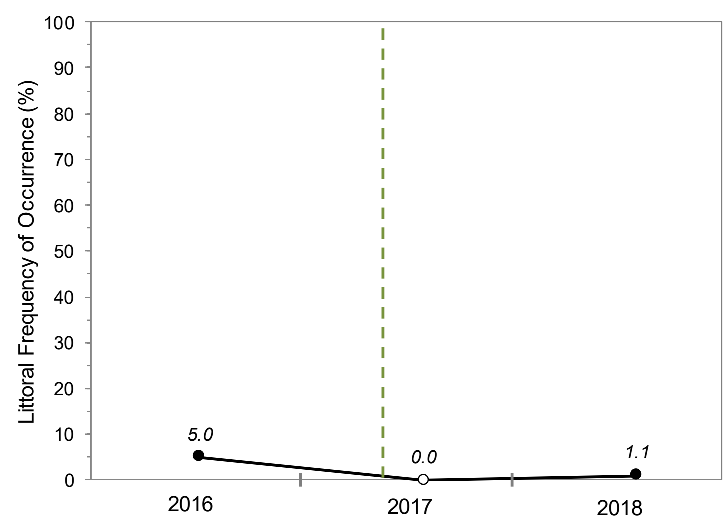


Figure 5.5-1. Littoral Frequency of Occurrence of HWM in Dake Lake from 2016-2018. Data from Onterra 2016,2017 & 2018 Point-Intercept Surveys. Green dashed line indicates whole-lake treatment. Open circle indicates statistically valid difference from previous survey.

Two native species, sago pondweed (*Stuckenia pectinata*) and slender naiad (*Najas flexilis*), exhibited a statistically valid decrease in occurrence between 2016-2017. Slender naiad is an annual that relies on seed production and has been shown to be particularly susceptible to auxin herbicides (e.g. 2,4-D, triclopyr). Both sago pondweed and slender naiad populations rebounded in 2018 to levels approximately the same as the 2016 survey (Figure 5.5-2.) Stoneworts exhibited a statistically valid increase in occurrence between 2017-2018 in Dake Lake.

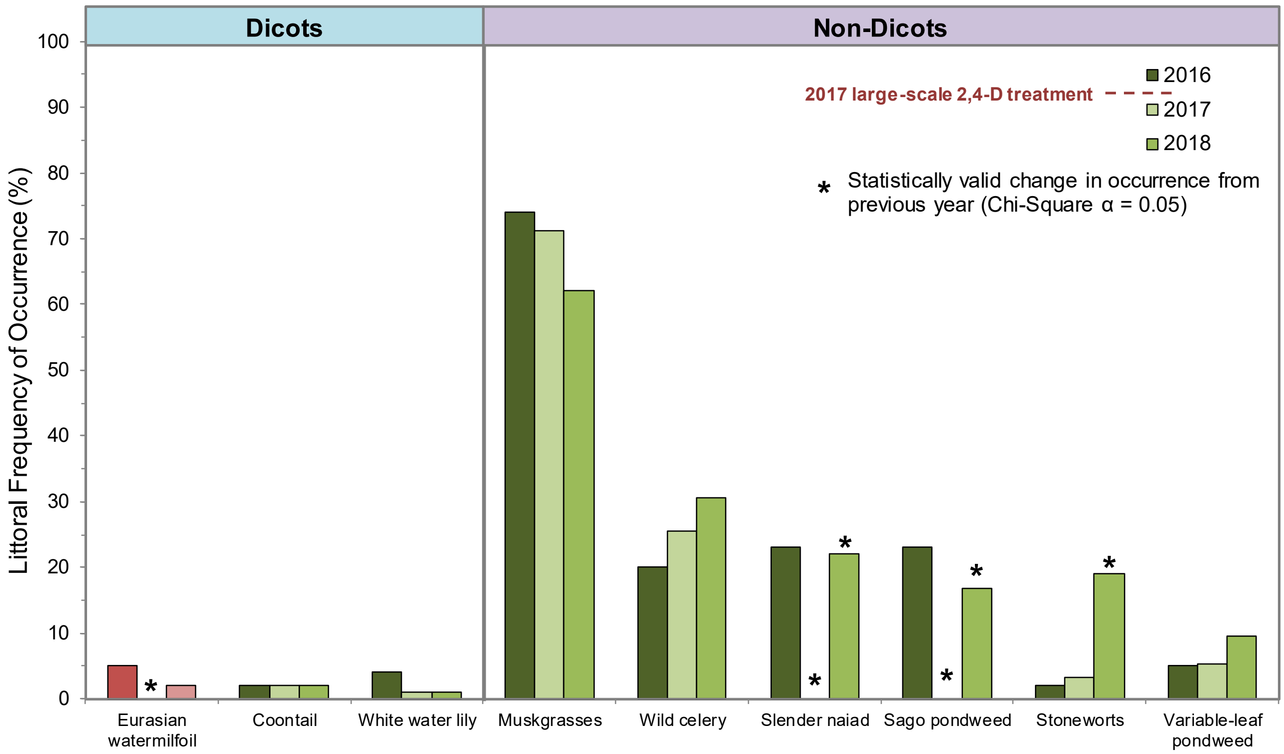


Figure 5.5-2. Littoral frequency of occurrence of aquatic plant species from 2016-2018 in Dake Lake. Data from Onterra 2016-2018 Point-Intercept Surveys. Whole-lake 2,4-D herbicide treatment occurred in spring 2017.

Emergent and floating-leaf aquatic plant communities are also an important component of a lake's aquatic plant community. These communities provide valuable structural habitat and stabilize bottom and shoreland sediments. A community mapping survey was completed in 2016 in Dake Lake as a part of the management planning project. The community mapping survey was replicated in 2017 in order to document any changes to this important component of the plant community following the large scale herbicide treatment. Map 4 displays the results of the 2016 and 2017 community mapping surveys. A reduction of floating leaf communities, largely white water lily, was evident within bays in the northwest and west ends of Dake Lake. Onterra's experience indicates white-water lily is typically resilient to standard whole-lake 2,4-D use-patterns. It is theorized that the higher concentrations and longer exposure times observed during the 2017 whole-lake 2,4-D treatment of Dake Lake resulted in the impacts to white water lilies. Continuing monitoring in 2018 indicated that the emergent and floating-leaf communities expanded somewhat since 2017 and were closer in aerial coverage to what was mapped in the 2016 survey (Map 4).

Figure 5.3-2 displays the number of point-intercept survey sampling locations that contained either native plants only, HWM plants only, or native plants and HWM plants from surveys completed in 2016-2018 in Dake Lake. The number of sampling locations with native plants has been relatively stable between all surveys completed in 2005 and 2016-2018. In 2018, 83 sampling locations contained native aquatic plants, while just two points contained HWM.

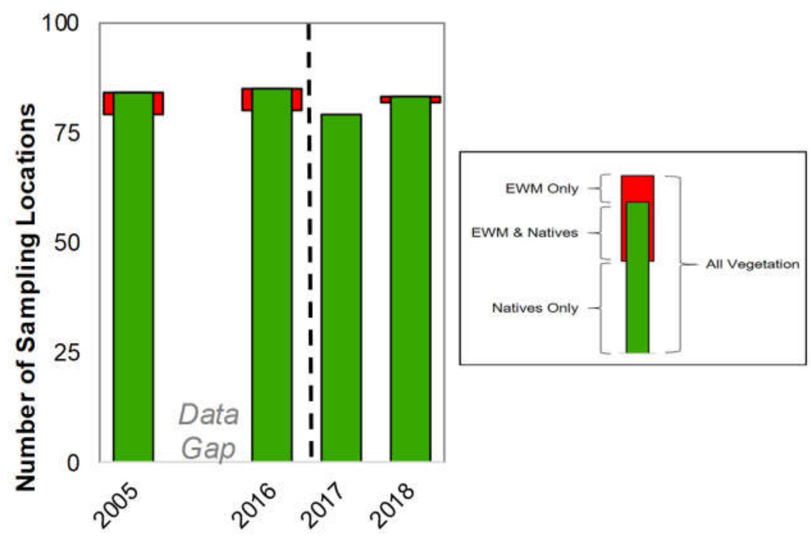


Figure 5.5-3. Vegetation composition of point-intercept locations in Dake Lake.

5.6 2018 Point-Intercept Survey Results – Miner Lake (*Year After Treatment*)

Hybrid watermilfoil was located at nine sampling locations in the 2016 survey (16.4% littoral frequency). Two sampling points contained HWM in the 2017 survey representing a statistically valid 78.6% decrease from 2016 (Figure 5.6-1). Hybrid watermilfoil was present at one sampling location in the 2018 survey (1.6%), which represents a 90% decrease in littoral frequency from the year before treatment (2016). Three native species, sago pondweed (*Stuckenia pectinata*), slender naiad (*Najas flexilis*), and muskgrasses (*Chara* spp.) exhibited a statistically valid decrease in occurrence between 2016-2017, while one species, stoneworts (*Nitella* spp.), showed a statistically valid increase. Continued monitoring in 2018 showed the population of slender naiad rebounded to approximately the same pre-treatment levels, while sago pondweed and muskgrasses increased between 2017-2018 but remained below pre-treatment levels observed in 2016.

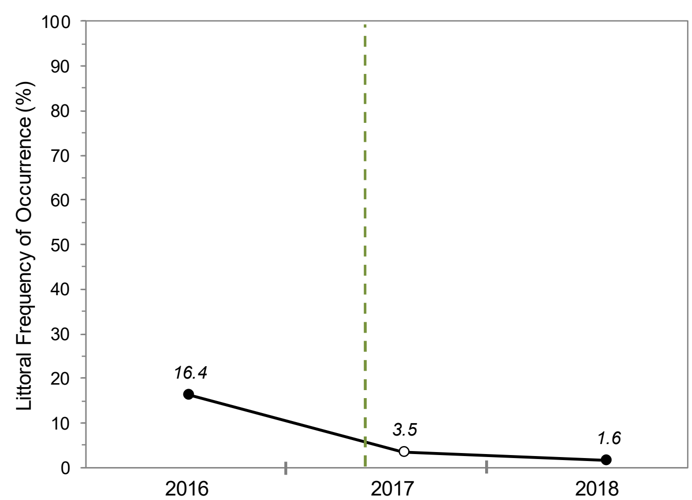


Figure 5.6-1. Littoral Frequency of Occurrence of HWM in Miner Lake from 2016-2018. Data from Onterra 2016, 2017, and 2018 Point-Intercept Surveys. Green dashed line indicates whole-lake treatment. Open circle indicates statistically valid difference from previous survey.

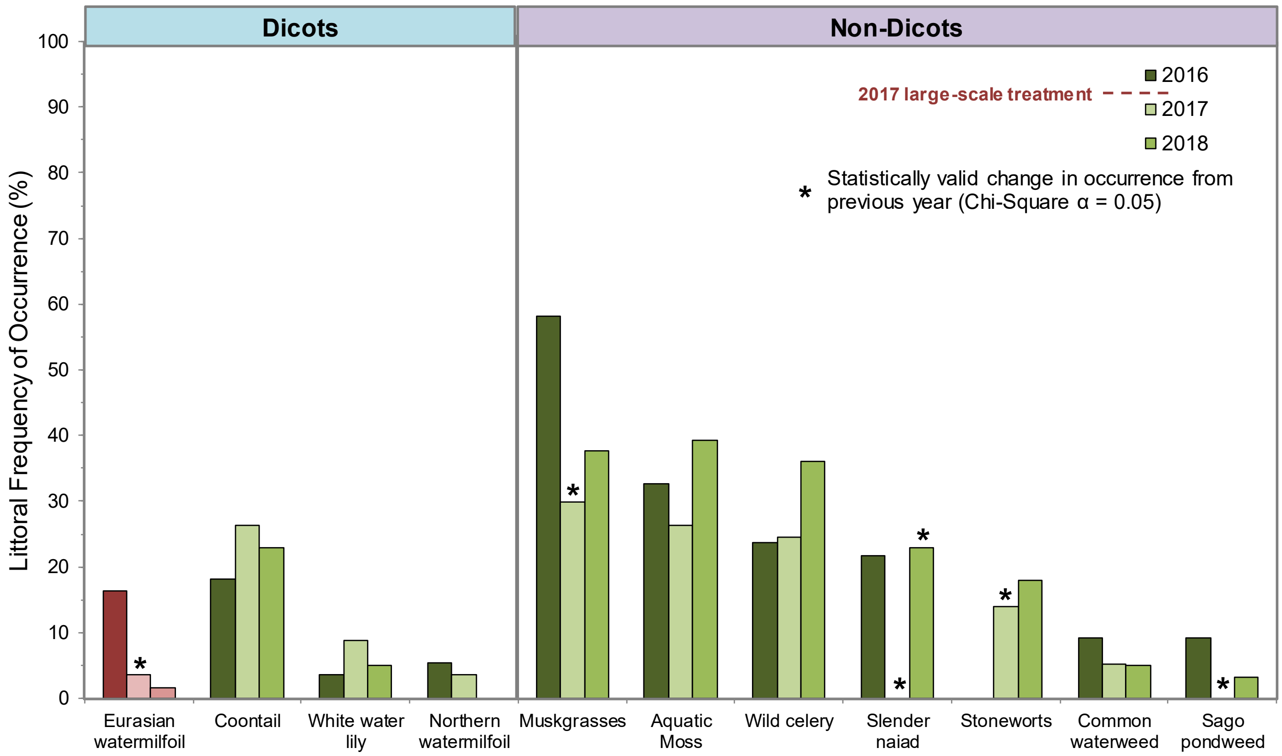


Figure 5.6-2. Littoral frequency of occurrence of aquatic plant species from 2016-2018 in Miner Lake. Data from Onterra 2016-2018 Point-Intercept Surveys. Whole-lake 2,4-D herbicide treatment occurred in spring 2017.

Emergent and floating-leaf aquatic plant communities are also an important component of a lake's aquatic plant community. These communities provide valuable structural habitat and stabilize bottom and shoreland sediments. A community mapping survey was completed in 2016 in Miner Lake as a part of the management planning project. The community mapping survey was replicated in 2017 and again in 2018 in order to document any changes to this important component of the plant community following the large scale herbicide treatment. Map 9 displays the results of the 2016, 2017, and 2018 community mapping surveys. A reduction of floating leaf communities, largely white water lily, was evident within parts of Miner Lake from 2016-2017. Onterra's experience indicates white-water lily is typically resilient to standard whole-lake 2,4-D use-patterns. It is theorized that the higher concentrations and longer exposure times observed during the 2017 whole-lake 2,4-D treatment of Miner Lake resulted in the impacts to white water lilies. Continuing monitoring in 2018 indicated that the emergent and floating-leaf communities expanded somewhat since 2017 and were closer in aerial coverage to what was mapped in the 2016 survey (Map 5).

Figure 5.6-3 displays the number of point-intercept survey sampling locations that contained either native plants only, HWM plants only, or native plants and HWM plants from surveys completed in 2016-2018 in Miner Lake. The number of sampling locations with native plants increased in 2018 to 50 points compared to 42 in 2017 and 44 in 2016. In 2018, two sampling locations contained HWM compared to two in 2017 and nine in 2016.

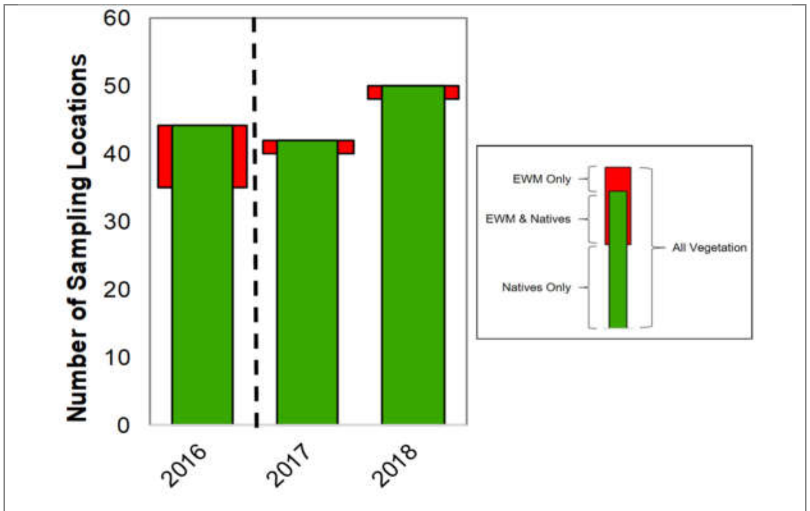


Figure 5.6-3. Vegetation composition of point-intercept locations in Miner Lake.

6.0 WAUPACA CHAIN HWM MANAGEMENT SUMMARY & CONCLUSIONS

Trial whole-lake treatment strategies implemented on the Waupaca Chain to date have provided valuable insight into this management technique. These field trials targeted Dake and Miner Lakes with 2,4-D alone at 0.375 ppm ae and Otter, Bass, and Beasley Lakes with a combination of 2,4-D and endothall at 0.25 ppm ae/0.75 ppm ai, respectively. Please note that Figure 6.0-1 only shows the 2,4-D component of the monitoring on these lakes. Otter, Dake, and Miner Lakes are all relatively isolated waterbodies, with minimal influence of water exchange (i.e. flow) to other parts of the Chain. These lakes were able to hold the herbicide concentrations longer, sustaining initial concentrations for almost 21 DAT before significant herbicide decline (Figure 6.0-1). The field trials on Bass and Beasley had the same target concentration as Otter Lake. Herbicide loss to Long Lake from the Bass and Beasley Lakes treatment on 1 DAT exemplifies why target concentrations were not met. Also, the rate of herbicide decline on Bass and Beasley Lakes was immediate, suggesting the primary method of concentration reduction was caused by dissipation downstream rather than herbicide degradation or decomposition.

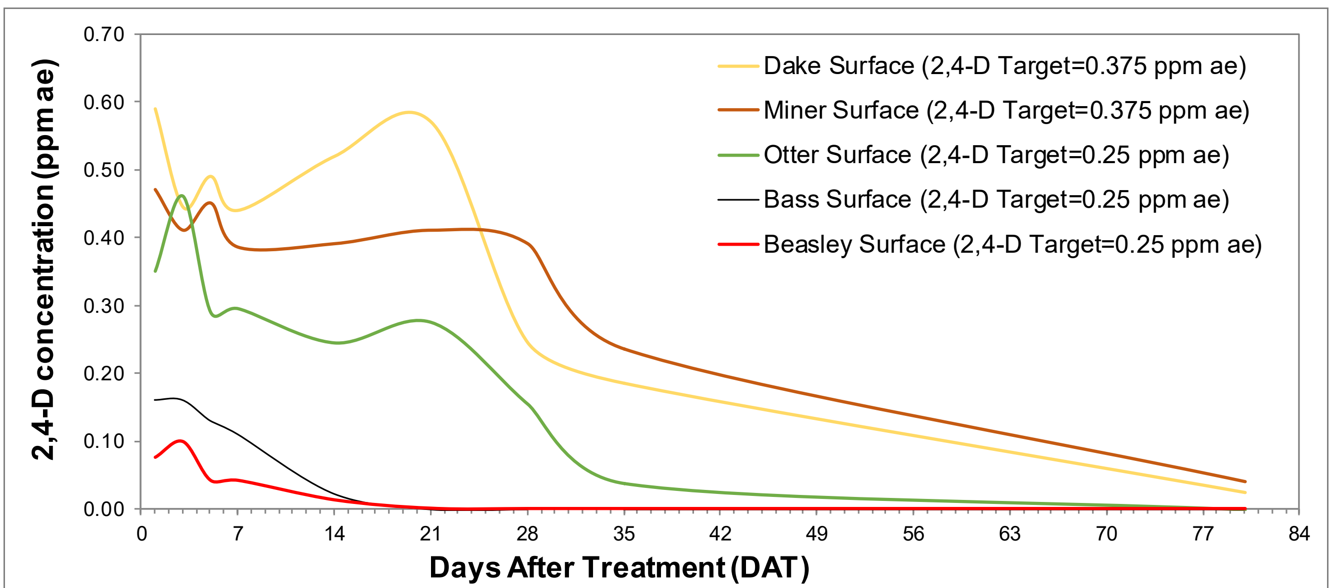


Figure 6.0-1. 2017-2018 Waupaca Chain whole-lake treatment average 2,4-D surface concentrations.

The 2018 aquatic plant monitoring surveys on Bass and Beasley Lakes confirm what would be expected based on the achieved herbicide concentrations; the herbicide control strategy in Bass and Beasley Lakes fell short of meeting control expectations. Bass Lake saw a higher level of HWM reduction than Beasley Lake in 2018 possibly as a result of slightly higher herbicide concentrations measured in the days after the herbicide application. It is anticipated that HWM population reductions in Bass Lake may be extended into 2019, and potentially beyond, before the species rebounds to pre-treatment densities. It is believed that the 2018 treatment only resulted in seasonal control of HWM in Beasley Lake, meaning that the HWM was likely injured and knocked back for part/most of the growing season; however, plant mortality was likely not achieved. It is suspected that the HWM population in Beasley Lake will make a full recovery by the end of the 2019 growing season, potentially sooner.

As discussed in the Monitoring Methodologies Section (2.0), point-intercept surveys would occur surrounding the whole-lake treatments during the *year prior to treatment*, the *year of treatment*, and the *year after treatment.* The treatment would be considered a success if the *year after treatment* HWM population from the point-intercept survey was at least 70% less than the *year prior to treatment*. As shown in Table 6.0-1, all three lakes treated in 2017 (Dake, Miner, and Otter Lakes) all exceeded this threshold during the *year of treatment*. HWM rebound on Otter Lake during the *year after treatment* resulted in this lake not meeting success criteria. The initial level of HWM control achieved on Bass and Beasley Lakes is already less than the predetermined success criteria.

Table 6.0-1. Whole-Lake treatment HWM population comparisons. Percent reductions between point-intercept surveys shown in brackets. TBD= to be determined based on 2019 point-intercept survey.

Comparsion	Dake			Miner			Otter			Bass/ Beasley		
Year Prior to Treatment	100%	5.0	78.9%	78.6%	16.4	90.0%	100%	19.2	30.7%	58.0%	66.7	TBD
Year of Treatment		0.0			3.5			0.0			28.0	
Year after Treatment		1.1			1.6			13.3			*scheduled*	

The herbicide spot treatments conducted in 2017 with diquat alone indicated seasonal EWM suppression. The combination of diquat/endothall (Aquastrike®) in spot treatments in 2018 attempted to get longer than seasonal control. The targeted sites that were located in more protected bays or areas of lower water exchange, such as G-18 and J-18, appeared to have been met with greater results that smaller sites that were in more exposed areas of the lake. These sites will be monitored in 2019 to determine whether control extends beyond the year of treatment in these areas. The WCOLD will continue to discuss whether the addition of endothall to diquat produces results that warrant the much higher cost of implementation. Other herbicides and herbicide combinations may also be considered as success is proven on other systems.

Professional hand-harvesting efforts in 2018 provided less than seasonal control in the targeted areas, such that the population was lowered for a portion of the growing season before rebounding by the time of the late-summer mapping survey. These efforts likely reduced the nuisance conditions within these areas for a period of time before rebound occurred. In order for hand-harvesting (includes the use of DASH) to achieve seasonal or greater than seasonal control, a much larger amount of effort would be required. Onterra's recent experience has been that planning a follow-up hand-harvesting event later in the season can assist with achieving longer control. This follow-up visit will allow the harvesters to remove any EWM that rebounds following the first pulling event and lead to more complete control at the targeted sites.

Maps 11 and 12 show the results of the 2018 Late-Season HWM Mapping Surveys. No HWM was located within the Upper Chain. Using the same methodology and consistent density rating system, Late-Season HWM Mapping Surveys also occurred in 2016 and 2017. Please note that Figure 6.0-2 represents only the acreage of mapped EWM polygons, not EWM mapped within point-based methodologies (*single or few plants, clumps of plants,* or *small plant colonies*). In 2016, 28.5 acres of colonized HWM was located in the system along with numerous additional locations of HWM marked with point-based data. A total of 16.1 acres of HWM were mapped throughout the Chain in 2018, demonstrating an overall reduction of colonized HWM during this timeframe. The largest reductions in HWM acreage can be attributed to the success of the whole-lake treatments in Dake and Miner Lakes, with additional HWM suppression occurring in Otter, Bass, and Beasley Lakes.

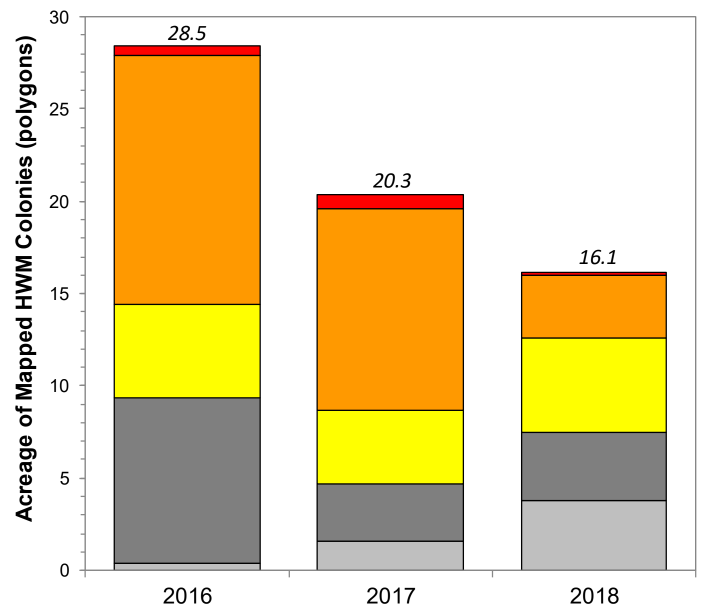


Figure 6.0-2. Acreage of HWM colonies in the Waupaca Chain from 2016-2018. Data from Onterra Late-Summer Surveys.

7.0 2019 HWM MANAGEMENT STRATEGY DEVELOPMENT

Building on the knowledge obtained over the course of the past several years of active AIS management in the Chain, a greater understanding of the anticipated efficacy of different management techniques is developing. Table 7.0-1 outlines the management strategy criteria and the anticipated efficacy for an invasive milfoil population suppression program on the Chain. Please note that these criteria are generalized and over-simplified, but can be used as a starting point for an active management discussion. The table outlines the herbicide or hand-harvesting management strategies that would be expected to achieve various levels of efficacy spanning a time frame from a less than seasonal to multiple years. In the table below, seasonal control refers to approximately the period of time during the open-water growing season during which the majority of the recreational activities typically occur on the Chain.

The whole-lake treatments that occurred in Dake, Miner, Otter, Bass, and Beasley Lakes in 2017-2018 attempted to achieve multiple year efficacy. Sufficient herbicide concentrations and exposure times (CETs) were achieved in Dake, Miner, and Otter Lakes, whereas the influence of water exchange in Bass and Beasley was too great to achieve appropriate CETs for milfoil control. This suggests that Long Lake would also have difficulty reaching desired CETs with herbicide flushing down the Crystal River outlet. Future whole-lake treatments may be applicable to other protected lakes in the Chain and can be investigated for applicability if HWM populations reach levels where the financial and environmental costs of implementation are commensurate with the desired level of HWM population reduction.

Table 7.0-1. Invasive Milfoil Management Strategy Criteria and Anticipated Efficacy on Waupaca Chain.

		Efficacy	Herbicide	Hand-Harvesting
Population Suppression	Multi-Year	Multiple Year	• Properly dosed whole-lake treatment with no flow impacts	• Early infestations • Extremely small populations
		>Seasonal	• Broad-shaped spot treatments with no flow impacts • 5 acres or greater in open water • 4 acres & protected on two sides • 1 acre & enclosed on three sides(bay)	• Typically the goal, but seldom achievable
	Single Year	Seasonal	• Broad-shaped spot treatments with no flow impacts • 3 acres in open water • 2 acres & protected on two sides	• Achievable on small sites (< ½ acre) with sufficient effort applied
		<Seasonal	• All herbicide treatments not meeting above criteria	• Not worth the cost of implementation

Many of the recent herbicide spot treatments have been limited to seasonal or less than seasonal HWM reductions. The largest factor limiting greater control is the small size of the treatment areas. Ongoing studies are suggesting that with small spot treatments, less than 5 acres, the herbicide dissipates too rapidly to cause HWM mortality if traditional systemic herbicides like 2,4-D are used. Even in some cases where larger treatment areas are planned, their narrow shape or exposed location within a lake may result in insufficient herbicide concentrations and exposure times for long-term control. Spot herbicide treatments would likely need to embrace herbicides or herbicide combinations thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides. Herbicide manufacturers have acknowledged the lack of successes conducting EWM/HWM spot treatments and are working towards new solutions. As new herbicide products become available, proper testing and vetting should occur before wide-scale acceptance on a given system. Table 7.0-1 outlines the predicted level of HWM suppression based upon specific site characteristics for herbicide spot treatments.

Hand-harvesting in the Chain has resulted in HWM population suppression; however, the length of population reduction has been shorter than desired especially considering the cost of implementation. If HWM occurrences were located in the Upper Chain, swift implementation of a sufficient effort of hand-harvesting (including DASH) could lead to multiple years of control. Follow-up hand-harvesting of rebounding HWM following a whole-lake treatment would also fall into this category. But when targeting established HWM populations, as exist in much of the remainder of the Chain, achieving seasonal or slightly longer control is the goal. This level of HWM suppression provides seasonal relief for riparians and may be an important component of future management on the Chain. While the cost of implementation is higher to achieve seasonal HWM suppression with hand-harvesting versus herbicide treatment, non-chemical methods are typically favored by lake managers and regulators as the risks are much less.

On some lakes, a coordinated HWM population suppression program is not achievable considering the current lake management tools. For instance, the only way to target the entirety of the HWM population in Long Lake would be with a whole-lake treatment. But the results of the trials on Bass and Beasley Lakes indicate that even with a combination of 2,4-D/endothall, achieving CETs to result in multiple years of control is not possible. Spot herbicide techniques may be applicable, but the narrow HWM bands will require a short CET requirement herbicide (e.g. diquat, diquat/endothall) to be implemented. These broad-spectrum herbicides have associated native plant impacts and would not be advisable to target the entire littoral zone of a lake. Therefore, subjective selection of where to implement herbicide spot treatments in a scenario like Long Lake becomes more of nuisance control strategy. The strategy could result in seasonal HWM suppression that would alleviate the unwanted conditions in riparian corridors. The use of a mechanical harvester could also provide some level of seasonal control without the risks of herbicide treatment.

2019 IPM Strategy Following Past Whole-Lake Treatments

As a part of an Integrated Pest Management strategy for 2019, and in an effort to prolong the gains that were made following the whole-lake treatments, areas within Dake, Miner, and Otter Lakes may be considered for follow-up control activities including herbicide spot treatments and/or hand-harvesting. No areas in Dake Lake or Miner Lake contain sufficient HWM densities to warrant an herbicide spot treatment; however, a hand-harvesting management strategy would be appropriate to target the current population. Map 9 displays a preliminary hand-harvesting management strategy for Dake and Miner Lakes for 2019. Any HWM occurrences that were mapped as a *clump of plants* or larger in the late-summer 2018 mapping survey are included with the preliminary hand-harvesting strategy. One approximately 1.4-acre site in Dake Lake as well as five sites totaling approximately 0.82 acres in Miner Lake are recommended for hand-harvesting in 2019.

Map 10 displays an IPM strategy for Otter Lake in 2019. One site in the northern end of the lake contains some of the densest populations of HWM. With the nature of this site, which is protected on three sides, an herbicide control strategy with a shorter-acting herbicide (diquat or diquat/endothall) could potentially provide greater than seasonal control. The majority of the rest of the HWM population in Otter Lake consisted of isolated plants that do not lend well to herbicide control techniques, but rather may be applicable to a professional hand-harvesting effort. Sixteen sites totaling approximately 1.16 acres are displayed on Map 10 to be considered for a hand-harvesting management strategy in 2019. Sites that contained at least a *clump of plants* or a *small plant colony* were included with the preliminary hand-harvesting strategy.

In lakes with large HWM populations that may be impractical to target on a lake-wide basis, WCOLD could support a strategy to improve the navigability within these lakes. This typically would be accomplished by designing common-use navigation lanes through HWM colonies that could be managed through herbicide spot treatments, mechanical harvesting, or professional hand-harvesting. The WCOLD would consider one of these forms of seasonal management for Beasley and Long and other lakes if the strategy aligns with best management practices that are supported by professional lake managers.

2019 IPM Strategy: Spot Herbicide Treatments

The majority of the spot treatments in 2017-2018 in the Chain led to seasonal HWM control rather than multi-year control. The spot treatments in 2018 yielded no better results with Aquastrike® (diquat/endothall) than the 2017 diquat spot treatment.

As outlined in Table 7.0-1, special scenarios where spot treatment sites are almost completely enclosed or protected from water movement and are of a larger and broader size or shape are the most likely to result in extended years of HWM control. Several of the EWM colonies in the Chain that were mapped in the late-summer of 2018 were of a size and density that may be too large to reasonably expect control with hand-harvesting efforts alone. Colonies that were mapped with area-based methodologies and were of at least a *dominant* or greater density meet the criteria for considering herbicide treatment in 2019. Map 11 displays eleven sites around the Chain that target HWM colonies marked as dominant or greater in density as well as adjacent occurrences for which at least a one-acre application area can be constructed with a reasonably sized buffer. Based on Table 7.0-1, the expected efficacy of these treatments would be seasonal control in most cases due to either size, location, or shape of the sites. Site I-19 in Otter Lake is somewhat more protected and is it is thought that a spot treatment may lead to control that extends beyond the 2019 growing season in this location (greater than seasonal efficacy).

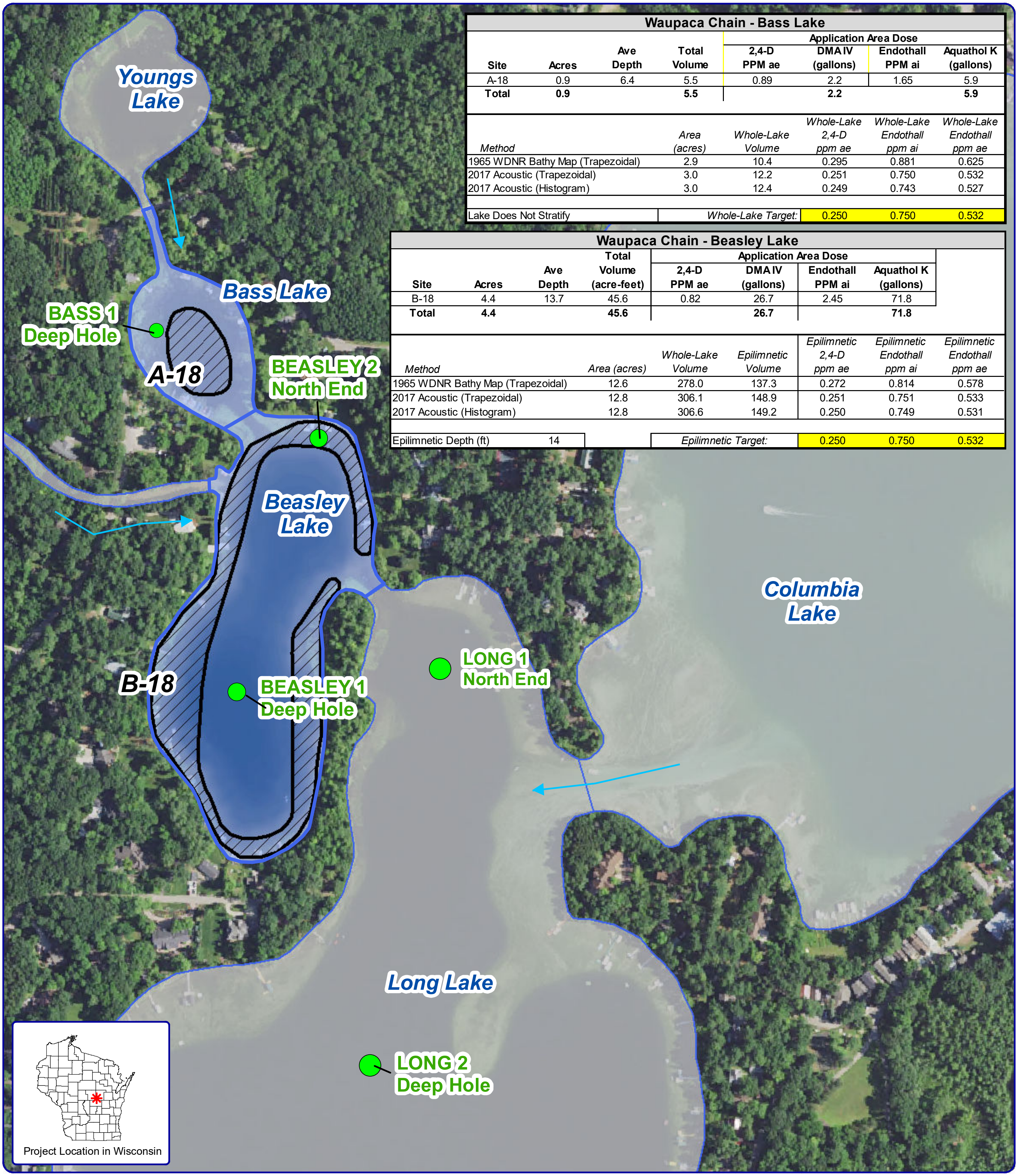
A contact herbicide such as diquat could be considered for herbicide spot treatment of these areas. Commonly used brands of diquat have a 2 gallon/surface acre maximum application rate. When mixed with the water volume in deeper sites (approximately greater than 5 feet), the concentrations may be lower than needed to provide the desired level of impact. In these instances, herbicide applicators may consider the addition of a low dose of copper. Another option often considered is to couple diquat with endothall under the commercially available Aquastrike® herbicide. When this product received EPA registration, it configured the use-rates volumetrically. This allows diquat to reach the target concentration in all water depths coupled with endothall which has activity on invasive watermilfoils. As previously discussed, Aquastrike® has been used in recent years on the Waupaca Chain whereas the combination of diquat and copper would be a new approach to HWM management on the Chain. It should be understood the WDNR limits the permitting of spot-treatment management techniques that are not expected to achieve greater than seasonal control under any grant funded project and the costs would likely be out-of-pocket by the WCOLD.

2019 IPM Strategy: Professional and/or Volunteer Hand-Harvesting

Much of the HWM population present in the Chain consists of isolated occurrences of relatively *small colonies* or *clumps of plants* that to do not meet the threshold for considering herbicide control. However, the majority of these sites may be favorable for hand harvesting control efforts. Generally clear water coupled with modest native plant populations in many parts of the Chain make hand harvesting a feasible control technique with a goal of achieving greater than seasonal control. In 2018, the WCOLD selected a few high-use areas to implement this strategy when herbicide spot treatments were not likely to be effective. For 2019, the WCOLD could again consider areas for this type of control.

It is important to understand that each riparian owner can legally harvest HWM and native plant species in a 30' wide area of one's frontage directly adjacent to one's pier without a permit. A permit is required if an area larger than the 30' corridor is being harvested or if a mechanical assistance mechanism, like DASH, is being used. Professional services to remove HWM also do not require a permit unless DASH or a mechanical device is being used in the process. Simply wading into the lake and removing HWM by hand with or without the aid of snorkeling accessories can be helpful in managing HWM on a small and individual property-based scale.

The WCOLD explored whether alleviating nuisance conditions in riparian zones would be feasible to implement for the entire Chain. The District ultimately determined not to pursue this idea due to the overwhelming increase in taxes, costs, and administrative time that would be associated with implementing this potential project.



Waupaca Chain - Bass Lake

Site	Acres	Ave Depth	Total Volume	Application Area Dose: 2,4-D PPM ae	DMA IV (gallons)	Endothall PPM ai	Aquathol K (gallons)
A-18	0.9	6.4	5.5	0.89	2.2	1.65	5.9
Total	0.9		5.5		2.2		5.9

Method	Area (acres)	Whole-Lake Volume	Whole-Lake 2,4-D ppm ae	Whole-Lake Endothall ppm ai	Whole-Lake Endothall ppm ae
1965 WDNR Bathy Map (Trapezoidal)	2.9	10.4	0.295	0.881	0.625
2017 Acoustic (Trapezoidal)	3.0	12.2	0.251	0.750	0.532
2017 Acoustic (Histogram)	3.0	12.4	0.249	0.743	0.527
Lake Does Not Stratify		*Whole-Lake Target:*	0.250	0.750	0.532

Waupaca Chain - Beasley Lake

Site	Acres	Ave Depth	Total Volume (acre-feet)	Application Area Dose: 2,4-D PPM ae	DMA IV (gallons)	Endothall PPM ai	Aquathol K (gallons)
B-18	4.4	13.7	45.6	0.82	26.7	2.45	71.8
Total	4.4		45.6		26.7		71.8

Method	Area (acres)	Whole-Lake Volume	Epilimnetic Volume	Epilimnetic 2,4-D ppm ae	Epilimnetic Endothall ppm ai	Epilimnetic Endothall ppm ae
1965 WDNR Bathy Map (Trapezoidal)	12.6	278.0	137.3	0.272	0.814	0.578
2017 Acoustic (Trapezoidal)	12.8	306.1	148.9	0.251	0.751	0.533
2017 Acoustic (Histogram)	12.8	306.6	149.2	0.250	0.749	0.531
Epilimnetic Depth (ft)	14		*Epilimnetic Target:*	0.250	0.750	0.532

N / W / E / S

370
Feet

Legend

2018 Final Herbicide Application Area

Herbicide Concentration Sampling Location

Map1

Bass & Beasley Lake

Waupaca County, Wisconsin

2018 Final Large-Scale HWM Control Strategy

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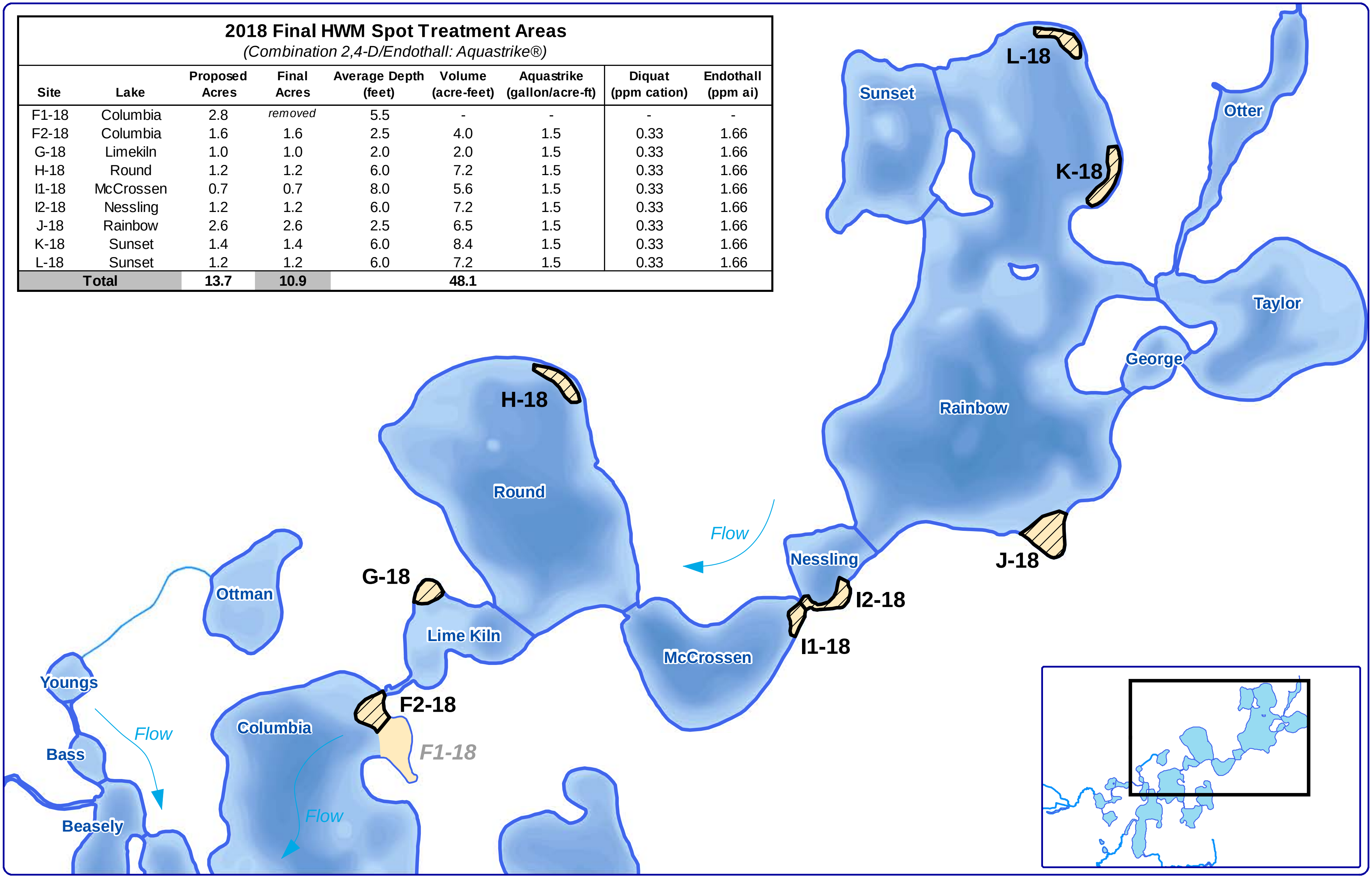
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2017
Bathymetry: Onterra, 2017; processed by C-Map USA
Map Date: May 30, 2018 - EJH
Filename: BasBeasley_HWM_T2018_Prelim3.mxd

2018 Final HWM Spot Treatment Areas

(Combination 2,4-D/Endothall: Aquastrike®)

Site	Lake	Proposed Acres	Final Acres	Average Depth (feet)	Volume (acre-feet)	Aquastrike (gallon/acre-ft)	Diquat (ppm cation)	Endothall (ppm ai)
F1-18	Columbia	2.8	*removed*	5.5	-	-	-	-
F2-18	Columbia	1.6	1.6	2.5	4.0	1.5	0.33	1.66
G-18	Limekiln	1.0	1.0	2.0	2.0	1.5	0.33	1.66
H-18	Round	1.2	1.2	6.0	7.2	1.5	0.33	1.66
I1-18	McCrossen	0.7	0.7	8.0	5.6	1.5	0.33	1.66
I2-18	Nessling	1.2	1.2	6.0	7.2	1.5	0.33	1.66
J-18	Rainbow	2.6	2.6	2.5	6.5	1.5	0.33	1.66
K-18	Sunset	1.4	1.4	6.0	8.4	1.5	0.33	1.66
L-18	Sunset	1.2	1.2	6.0	7.2	1.5	0.33	1.66
Total		**13.7**	**10.9**		**48.1**			



N
W E
S

1,200
Feet

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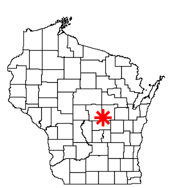
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Survey: Onterra, 2017
Map Date: May 22, 2018 - EJH
Filename: *WaupacaChain_HWM_T2018_SpotTreat_Perm1.mxd*



Project Location in Wisconsin

Legend

Preliminary Proposed Spot Treatment Area

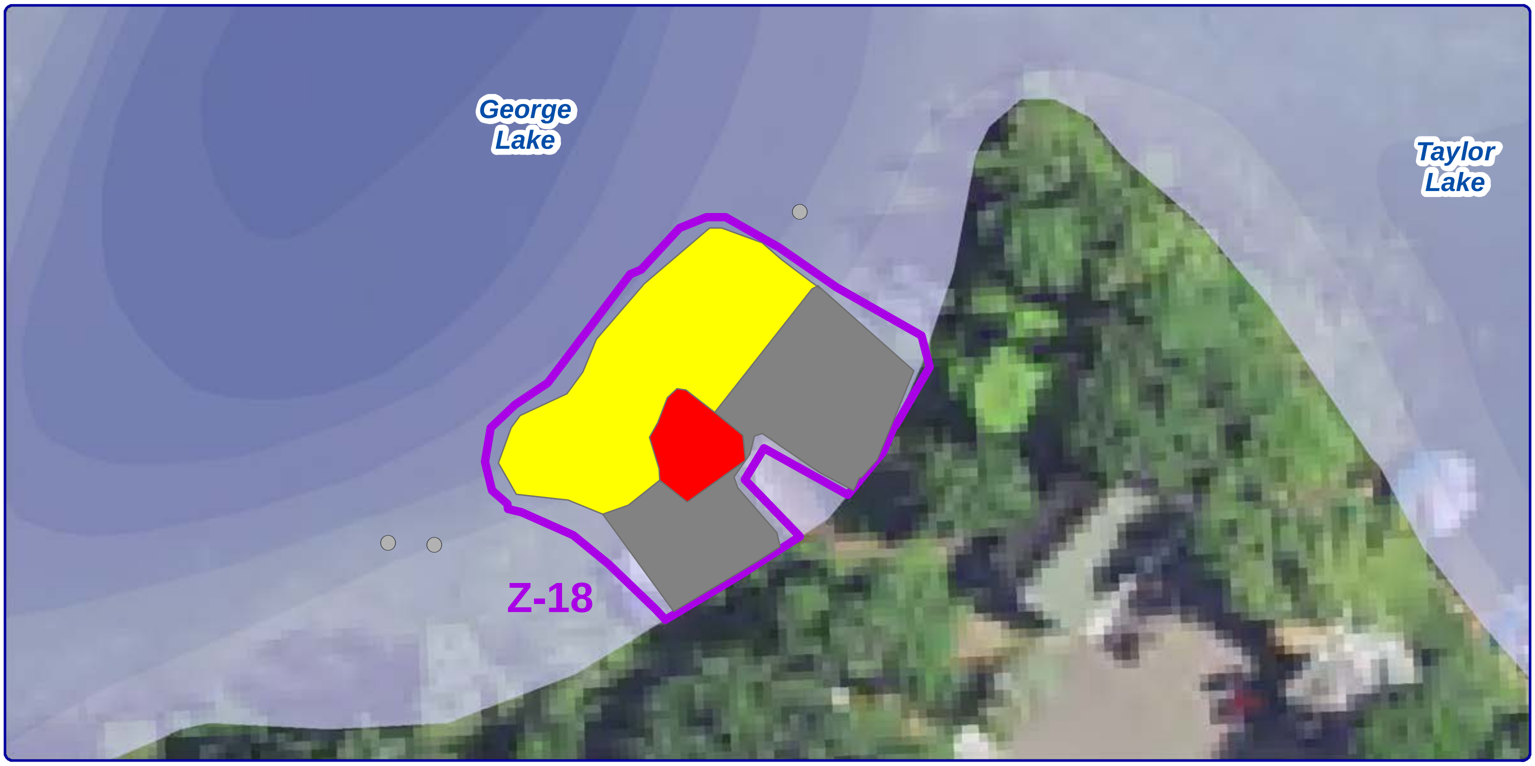
Final 2018 Spot Treatment Area

Map 2

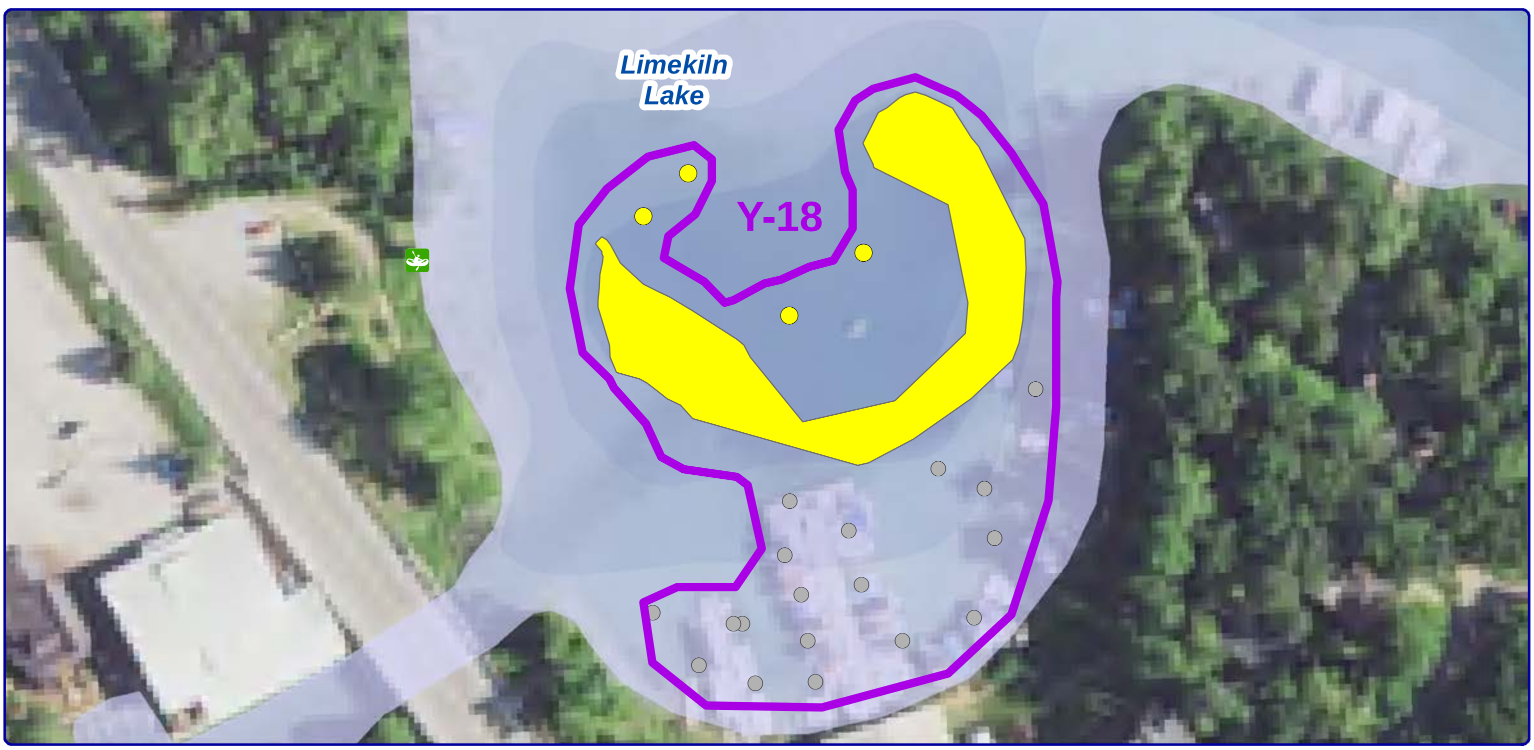
Waupaca Chain

Waupaca County, Wisconsin

2018 Final Spot-Treatment HWM Control Strategy



Waupaca Chain O' Lakes 2018 Final Professional Hand-Harvest HWM Control Strategy						
Site	**Lake**	**Target**	**Final Acres**	**Average Depth (feet)**	**Notes**	**Priority**
Y-18	Limekiln	HWM	1.4	4.0	Becker Marine and thoroughfare between Columbia/Limekiln	1st
Z-18	George	HWM	0.4	6.0	docks near veterans home	2nd
Total			**1.7**			



Legend

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

N W E S

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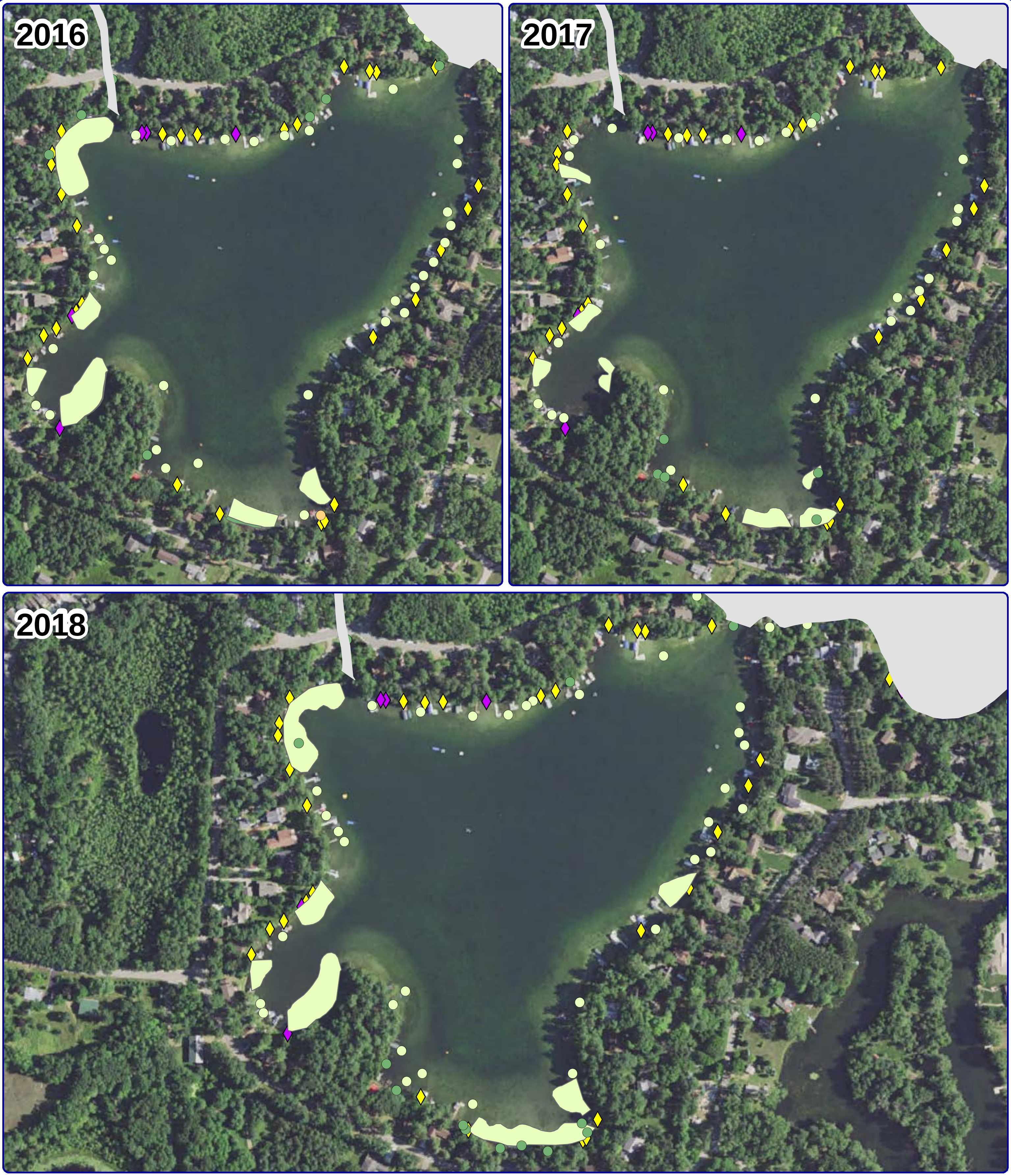
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2018
Map Date: June 22, 2018 - EJH

Map 3
Limekiln & George Lakes
Waupaca County, Wisconsin
June 2018 HWM Survey Results & Hand-Harvesting Strategy



Map 4

Dake Lake

Waupaca County, Wisconsin

2016-2018 Plant Survey: Community Mapping

Legend

Exotic Plant Communities	Small Plant Communities	Large Plant Communities
Purple loosestrife	Emergent	Emergent
Pale yellow iris	Floating-leaf	Floating-leaf
	Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent

N S W E

350 Feet

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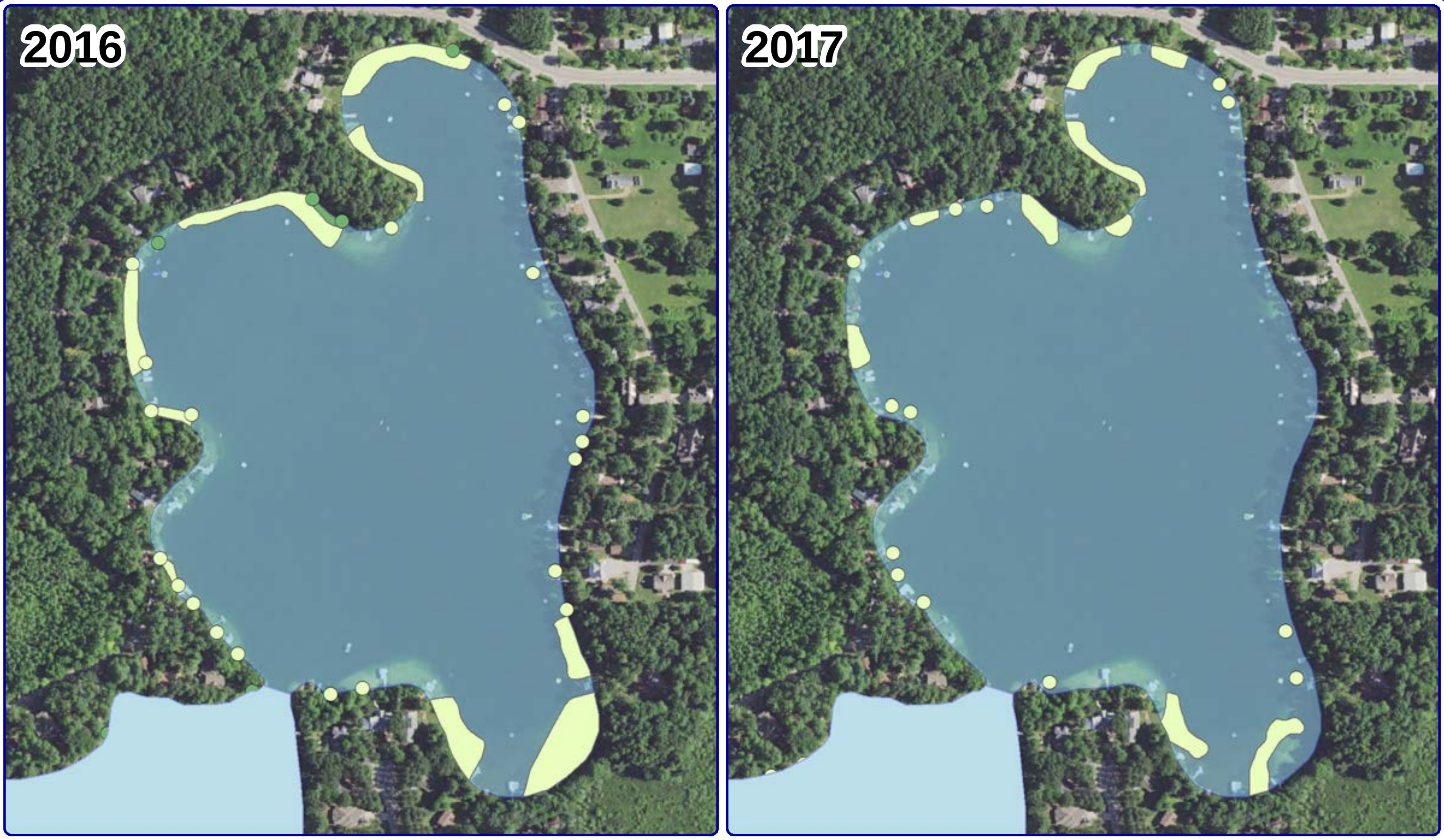
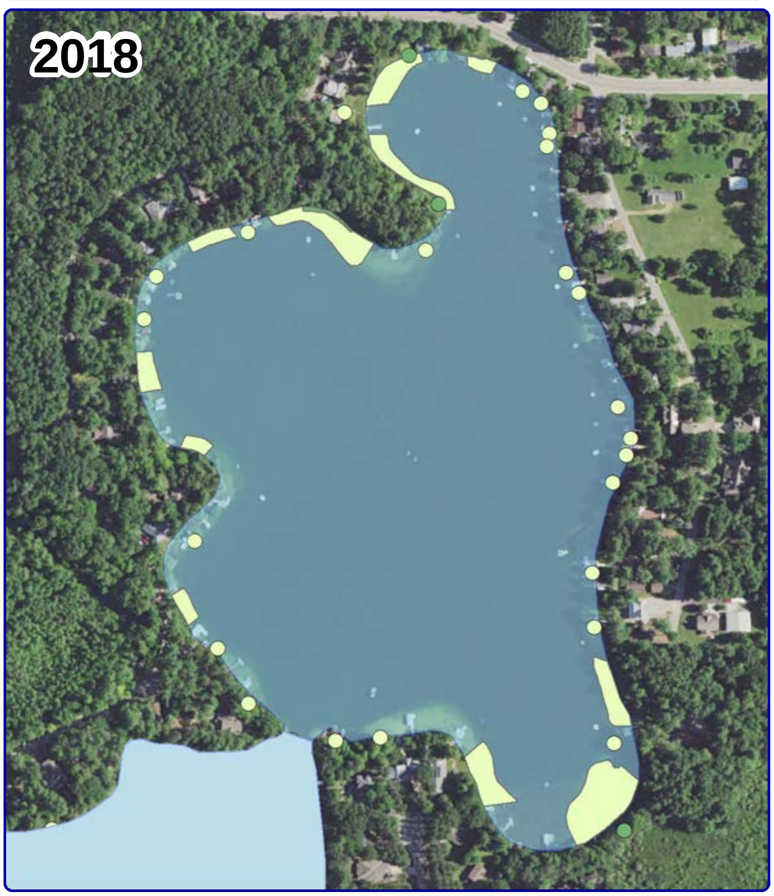
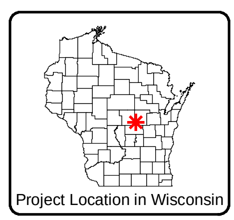
Sources:
Roads and Hyrdo: WDNR
Orthophotograph: NAIP, 2017
Aquatic Plants: Onterra, 2016-2018
Map Date: August 10, 2018 JLW
Filename: Dake_Comm_2016-2018.mxd







N
W E
S

350
Feet

Onterra LLC
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815 Prosper Rd
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920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Orthophotograph: NAIP, 2017
Aquatic Plants: Onterra, 2016-2018
Map Date: August 10, 2018 JLW
Filename: Miner_Comm_2016-2018.mxd

Legend

Exotic Plant Communities
- Purple loosestrife
- Pale yellow iris

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

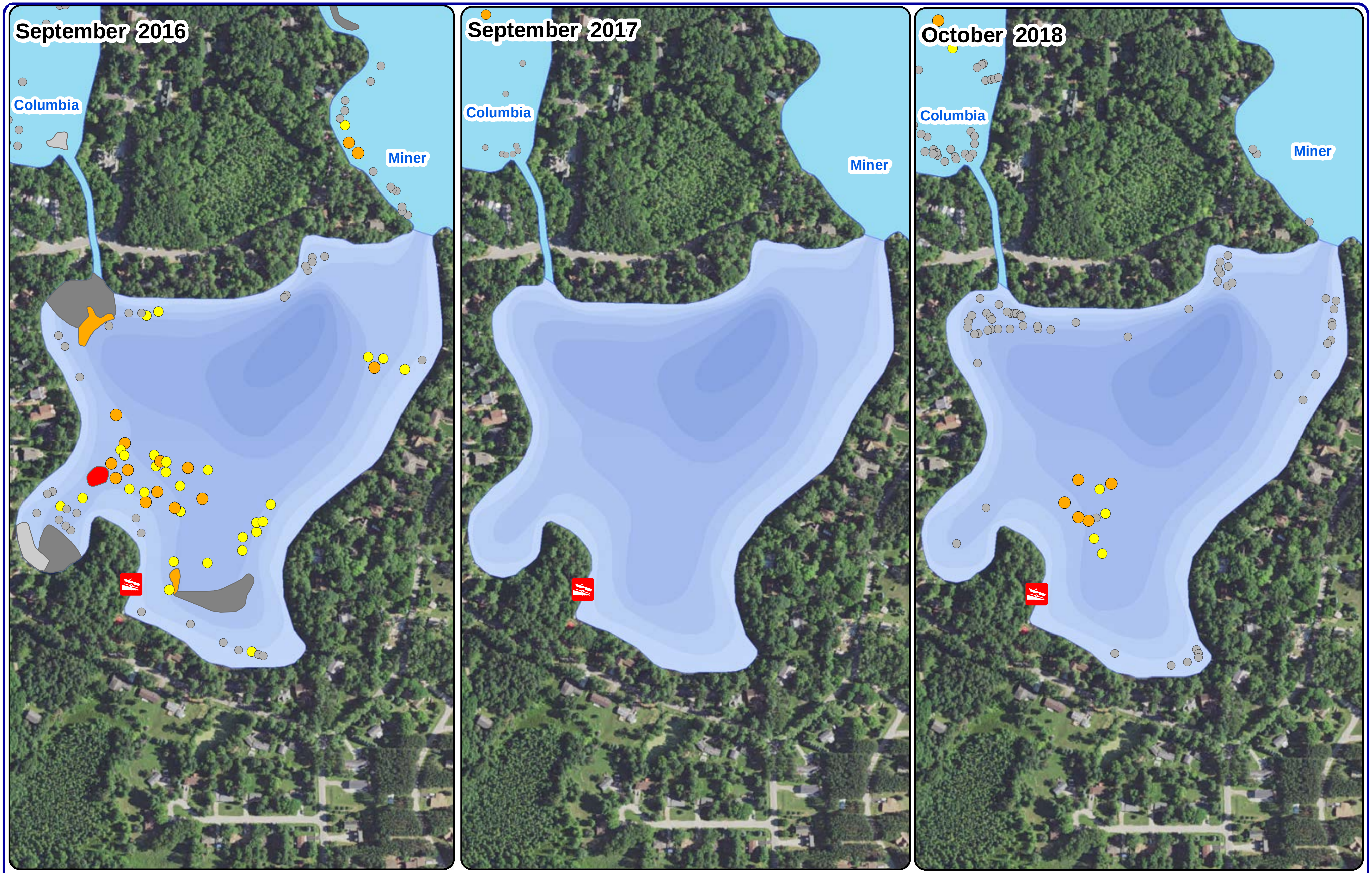
Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 5

Miner Lake

Waupaca County, Wisconsin

2016-2018 Plant Survey: Community Mapping



470
Feet

Onterra LLC
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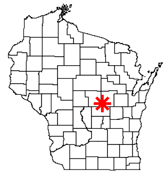
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016-2018
Orthophotography: NAIP, 2017
Map Date: 1/7/2019 AMS
Filename: WaupacaChain_EWM_Dake_2016-2018.mxd



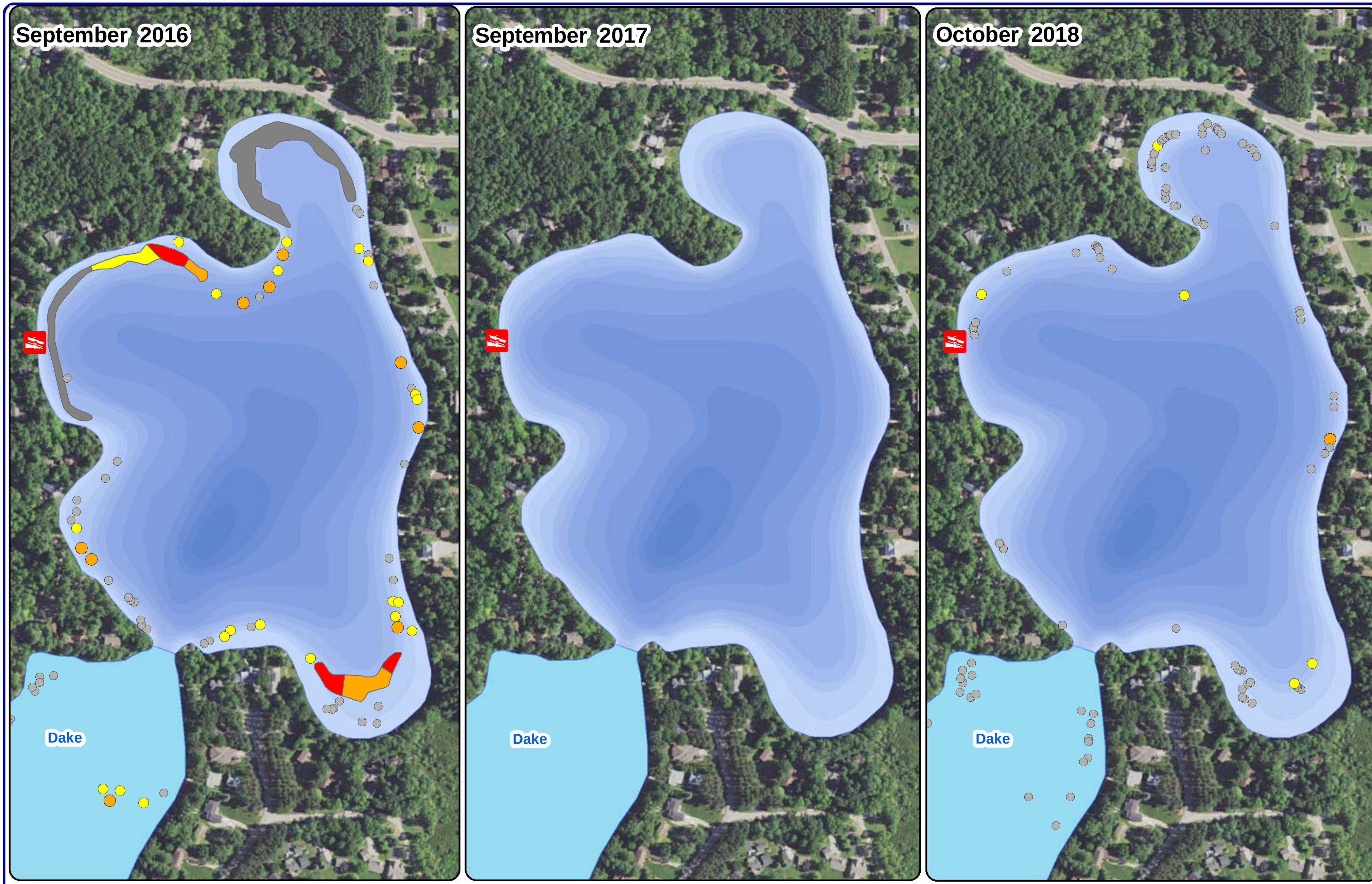
Project Location in Wisconsin

Legend

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

Map 6
Dake Lake
Wauapca County, Wisconsin

2016-2018 EWM Survey Results



425
Feet

Onterra LLC
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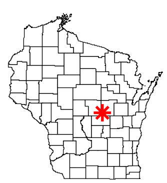
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016-2018
Orthophotography: NAIP, 2017
Map Date: 1/7/2019 AMS
Filename: WaupacaChain_EWM_Miner_2016-2018.mxd

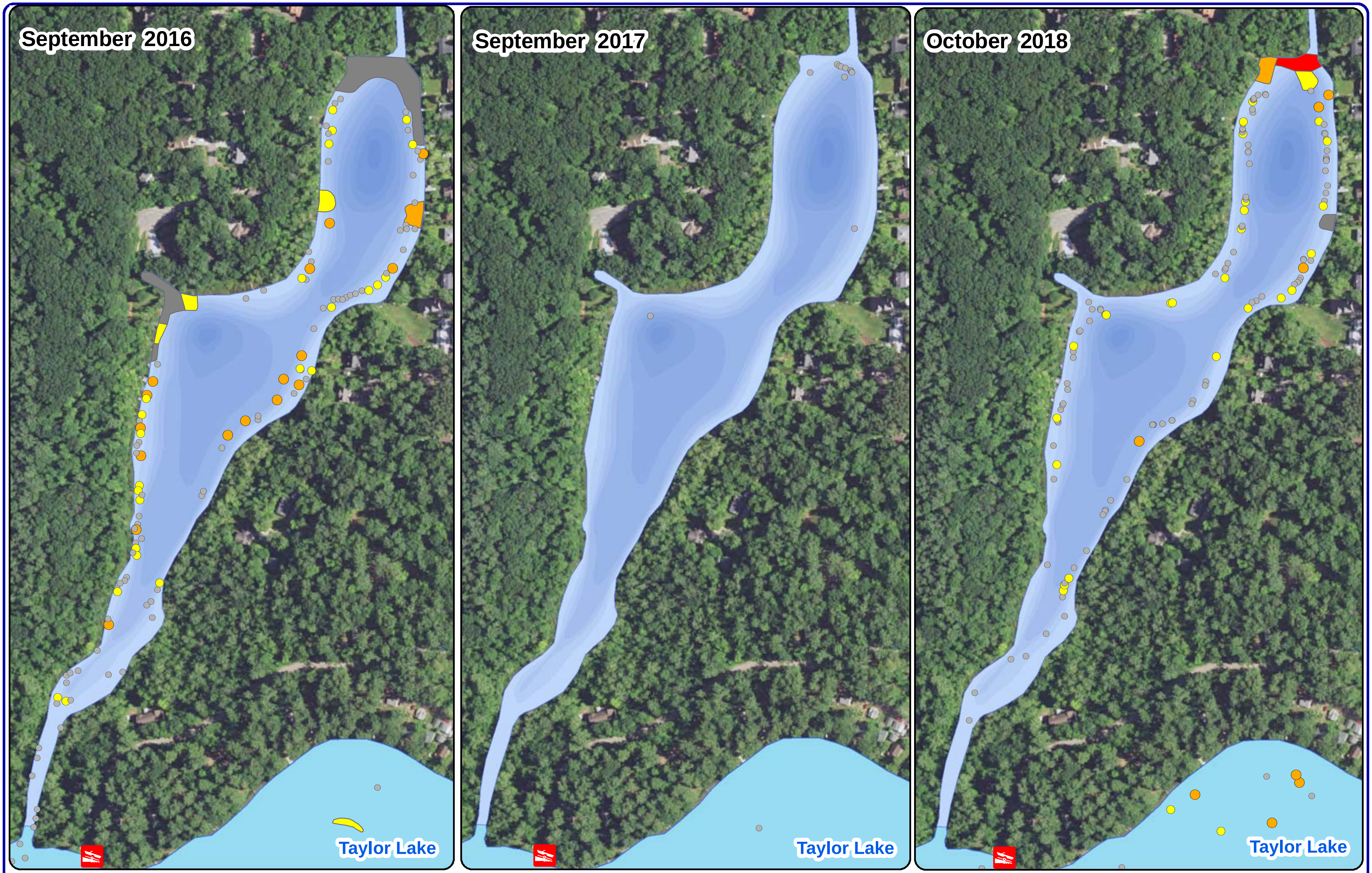


Project Location in Wisconsin

Legend

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

Map 7
Miner Lake
Wauapca County, Wisconsin
2016-2018 EWM Survey Results



390
Feet

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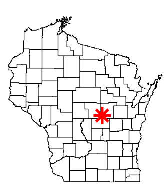
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016-2018
Orthophotography: NAIP, 2017
Map Date: 1/9/2019 AMS
Filename: WaupacaChain_EWM_Otter_2016-2018.mxd



Project Location in Wisconsin

Legend

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

Map 8

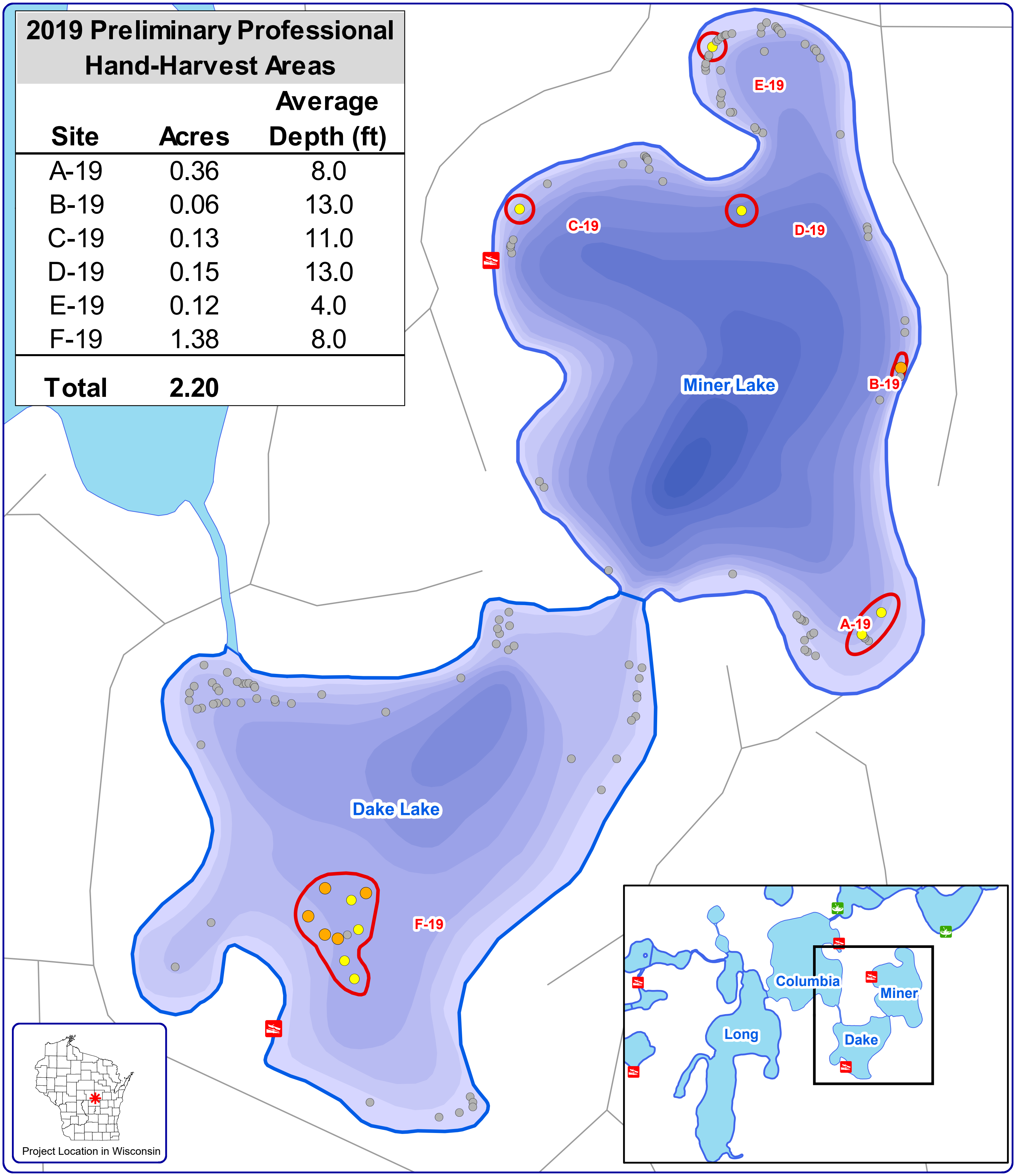
Otter Lake

Wauapca County, Wisconsin

2016-2018 EWM Survey Results

2019 Preliminary Professional Hand-Harvest Areas

Site	Acres	Average Depth (ft)
A-19	0.36	8.0
B-19	0.06	13.0
C-19	0.13	11.0
D-19	0.15	13.0
E-19	0.12	4.0
F-19	1.38	8.0
Total	**2.20**	



Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2019 Prelim Hand-Harvest Site

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Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2018
Map Date: February 4, 2019 AMS
Filename: DakeMiner_HWM_HH_T2019_Prelim1

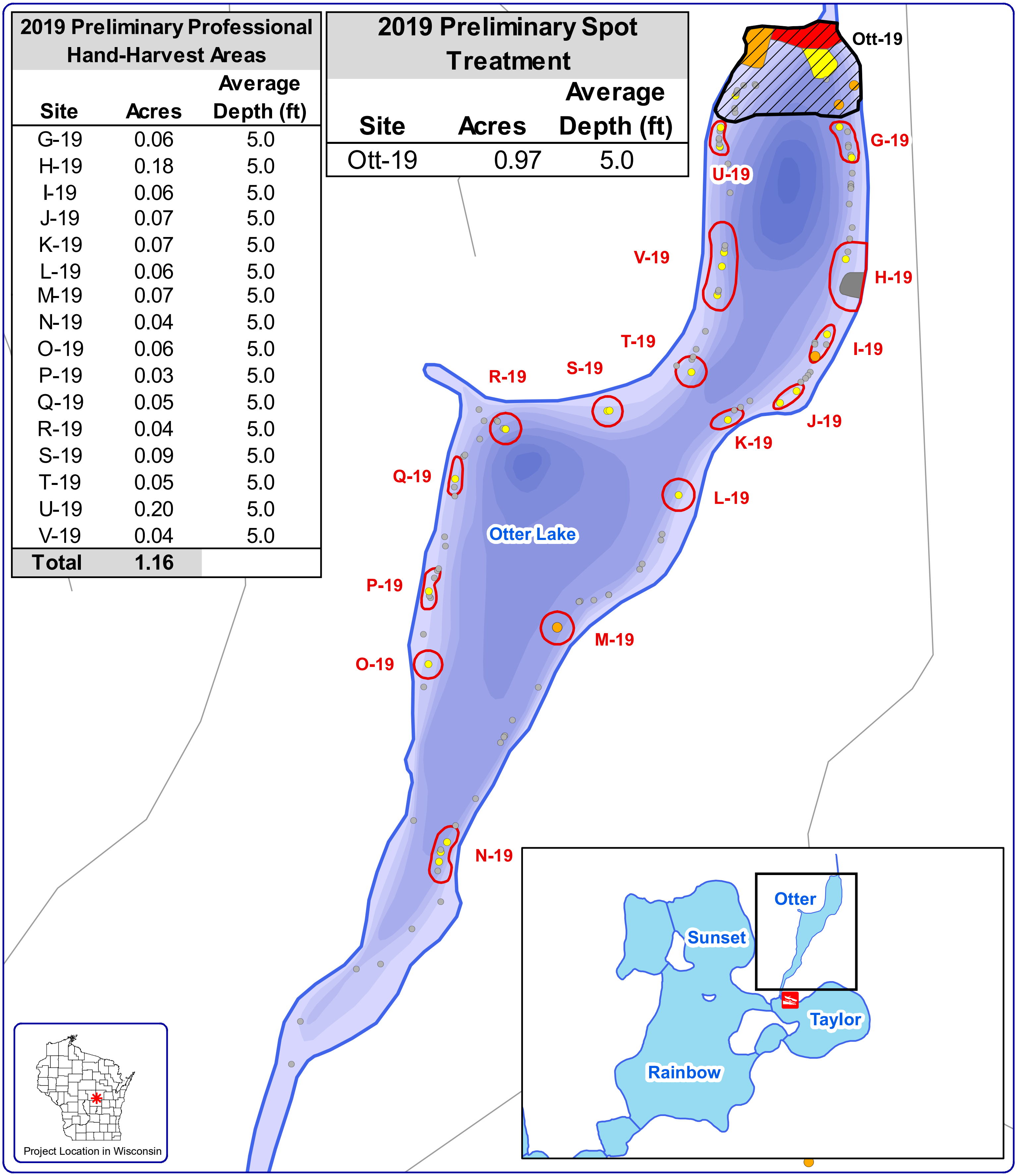
Map 9
Dake & Miner Lakes
Waupaca County, Wisconsin
October 2018 HWM Results and Preliminary 2019 Hand-Harvest Sites

2019 Preliminary Professional Hand-Harvest Areas

Site	Acres	Average Depth (ft)
G-19	0.06	5.0
H-19	0.18	5.0
I-19	0.06	5.0
J-19	0.07	5.0
K-19	0.07	5.0
L-19	0.06	5.0
M-19	0.07	5.0
N-19	0.04	5.0
O-19	0.06	5.0
P-19	0.03	5.0
Q-19	0.05	5.0
R-19	0.04	5.0
S-19	0.09	5.0
T-19	0.05	5.0
U-19	0.20	5.0
V-19	0.04	5.0
Total	**1.16**	

2019 Preliminary Spot Treatment

Site	Acres	Average Depth (ft)
Ott-19	0.97	5.0



Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2019 Preliminary Hand-Harvest Site
- 2019 Preliminary Spot Treatment Site

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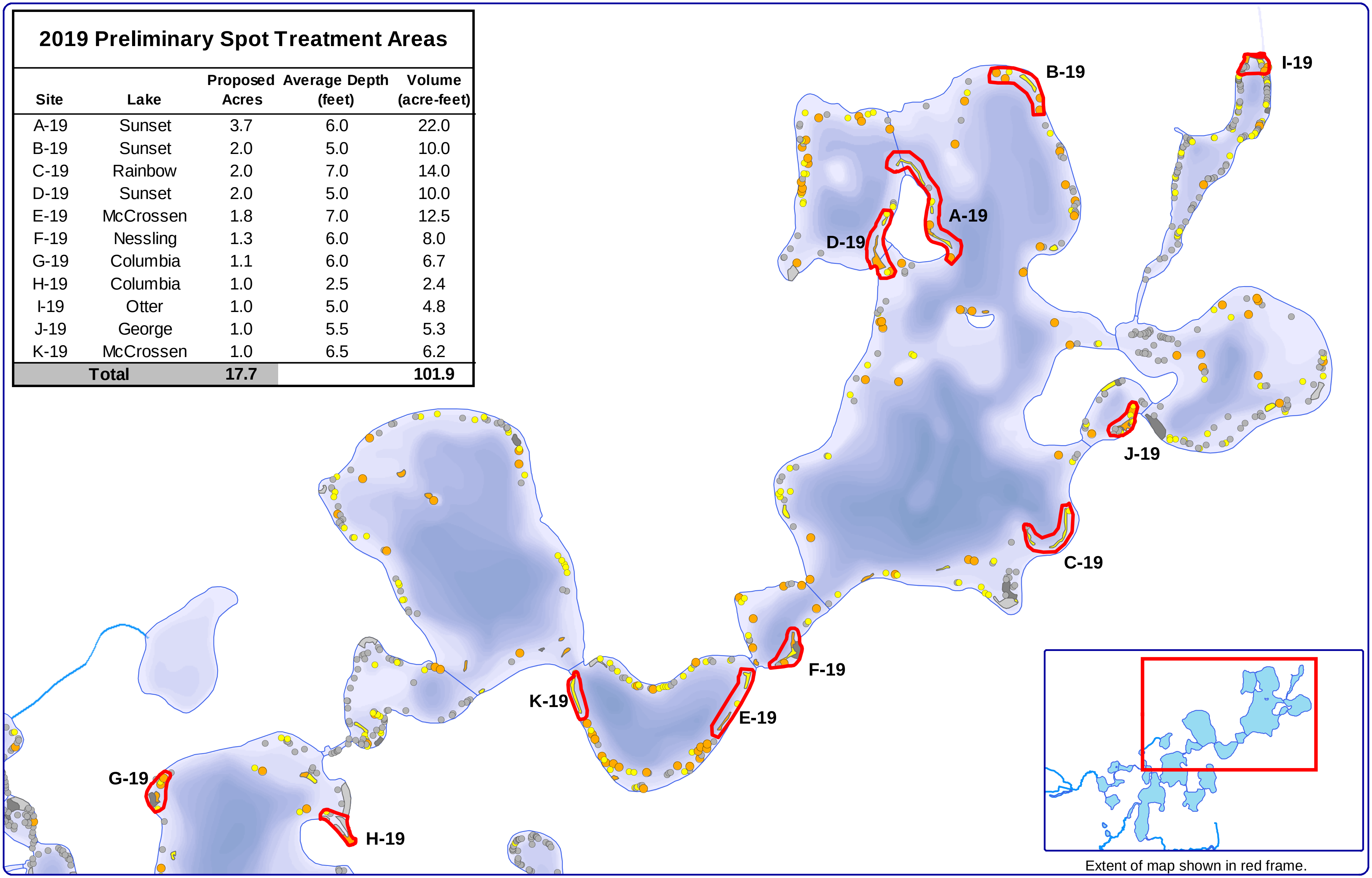
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2018
Map Date: February 4, 2019 AMS
Filename: DakeMiner_HWM_HH_T2019_Prelim1

Map 10
Otter Lake
Waupaca County, Wisconsin

2019 Preliminary HH & Spot Treatment Site

2019 Preliminary Spot Treatment Areas

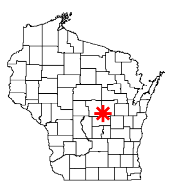
Site	Lake	Proposed Acres	Average Depth (feet)	Volume (acre-feet)
A-19	Sunset	3.7	6.0	22.0
B-19	Sunset	2.0	5.0	10.0
C-19	Rainbow	2.0	7.0	14.0
D-19	Sunset	2.0	5.0	10.0
E-19	McCrossen	1.8	7.0	12.5
F-19	Nessling	1.3	6.0	8.0
G-19	Columbia	1.1	6.0	6.7
H-19	Columbia	1.0	2.5	2.4
I-19	Otter	1.0	5.0	4.8
J-19	George	1.0	5.5	5.3
K-19	McCrossen	1.0	6.5	6.2
Total		**17.7**		**101.9**



Extent of map shown in red frame.

1,200

Feet



Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matted
- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- Proposed Herbicide Spot Treatment

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

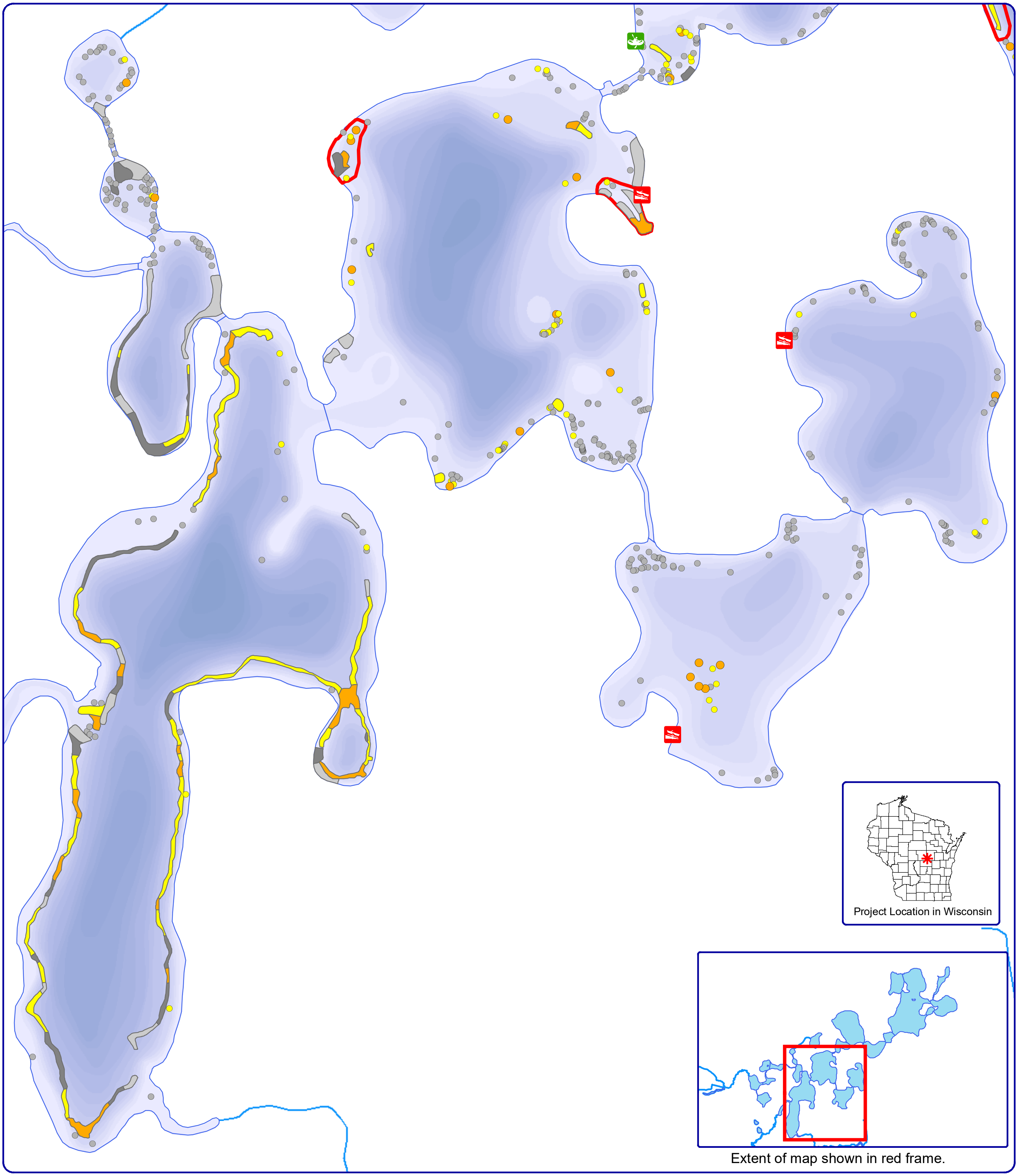
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Survey: Onterra, 2018
Map Date: March 15, 2019 - TWH
Filename: WaupacaChain_HWM_T2019_SpotTreat_Prelim_v1.mxd

Map 11

Waupaca Chain

Waupaca County, Wisconsin

2018 Late-Season HWM Survey Results



N
W E
S

740
Feet

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

Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2017
Bathymetry: Onterra, 2017;
processed by C-Map USA
Map Date: May 30, 2018 - EJH
Filename: BasBeasley_HWM_T2018_Prelim3.mxd

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- Proposed Herbicide Spot Treatment

Map12

Waupaca Chain

Waupaca County, Wisconsin

2018 Late-Season HWM Survey Results

A

APPENDIX A

2018 HWM Hand-Harvesting Report – DASH, LLC

2018 DASH SUMMARY
Waupaca Chain O Lakes, Waupaca County

Diver Assisted Suction Harvesting (DASH) of Eurasian Water Milfoil (EWM) took place on July 10, 12 & 13, 2018 on Lime Kiln and Lake George, Waupaca Co., Wisconsin. A survey performed by Onterra, LLC confirmed the locations of EWM on 1.7 acres in two areas that were targeted for harvest. The attached map was provided by Onterra, LLC. All areas were exclusively targeted for EWM.

July 10, 2018
Area Y-18 (Lime Kiln Lake) was harvested for EWM using the DASH barge with one diver on hookah air supply and another person on the barge collecting the material in mesh bags. The wind was calm, waves were calm, air temp was 75 degrees working at a depth of 4 feet.

Area Y-18: 7:10 hours with a total of 222 lbs. of material harvested (approx. 1% non-target plants)

July 12, 2018
Area Y-18 (Lime Kiln Lake) was harvested for EWM using the DASH barge with one diver on hookah air supply and another person on the barge collecting the material in mesh bags. The wind was calm, waves were calm, air temp was 75 degrees working at a depth of 4 feet.

Area Y-18: 7 hours with a total of 116 lbs. of material harvested (approx. 1% non-target plants)

July 13, 2018
Area Z-18 (George Lake) was harvested using the DASH barge with one diver on hookah air supply and another person on the barge collecting the material in mesh bags. The wind was 3 mph, waves were calm, air temp was 80 degrees working at a depth of 10 feet.

Area Z-18: 6:20 hours with a total of 1116 lbs. of material harvested (approx. 10% non-target plants)

Procedures used during the DASH operations

The lake bed was not removed or redistributed by the suction efforts. A float was used to suspend the suction nozzle off of the lake bed.

All harvested materials were placed in onion type mesh bags, drained, weighed, evaluated for plant species, and transferred to the designated plant disposal site.

Any plant fragments not retained in the bags were skimmed from the lake surface by using a pool pole/net.

Table 1 shows the acreage, lbs. harvested, time spent and lbs. per hour.

Table 1

Site	Acreage	Lbs. Harvested	Time	Lbs. / Hour
Y-18	1.4	222	7:10	31
Y-18	1.4	116	7:00	16.5
Z-18	0.4	1116	6:20	176.5
Totals		**1454**	**20:30**	**70.9**

Area GPS Coordinates

Area Y-18: 44.33.350 / -89.17.024

Area Z-18: 44.34.055 / -89.14.395