INTRODUCTION

Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first documented in Long Lake in 2000. Since 2008, the Long Lake of Phelps Lake District (LLPLD) has been actively managing and reducing the EWM population through strategically targeted herbicide spot treatments and hand-removal. With assistance from Onterra, the LLPLD was successfully awarded a Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species (AIS) Established Population Control Grant in February 2013 to aid in funding the management of EWM within Long Lake from 2013-2017.

In order to build off the success of previous years' treatments, the Long Lake Comprehensive Management Plan (July 2013) outlines an aggressive approach to EWM management for 2013-2017. This strategy includes a treatment threshold (trigger) to initiate treatment in areas containing colonized EWM and adjacent areas of EWM mapped with point-based techniques, with areas containing *Small Plant Colonies* being targeted for treatment if possible. Using this rationale, approximately 27.9 acres of EWM were treated in the spring of 2014 on Long Lake. In addition to the herbicide treatment strategy, approximately 0.72 acres were targeted with professional hand-removal. The LLPLD contracted with Many Waters, LLC to conduct EWM hand-removal within four selected areas using the Diver Assisted Suction Harvesting (DASH) program. Requiring a mechanical harvesting permit from the WDNR, the DASH program involves a scuba diver feeding EWM plants through a suction hose that delivers and filters the plants to a boat on the surface. The 2014 liquid 2,4-D spot treatments and professional hand-removal efforts were highly successful at reducing the occurrence of EWM within the targeted areas.

In 2015, the LLPLD intended to continue their aggressive approach to EWM management in Long Lake incorporating both hand-harvesting and herbicide application strategies.

2015 EWM CONTROL STRATEGY

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

Spot treatments, the strategy utilized on Long Lake, are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant effects outside of that area. Herbicide application rates for spot treatment are formulated volumetrically, typically targeting EWM with 2,4-D at 3-4.0 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

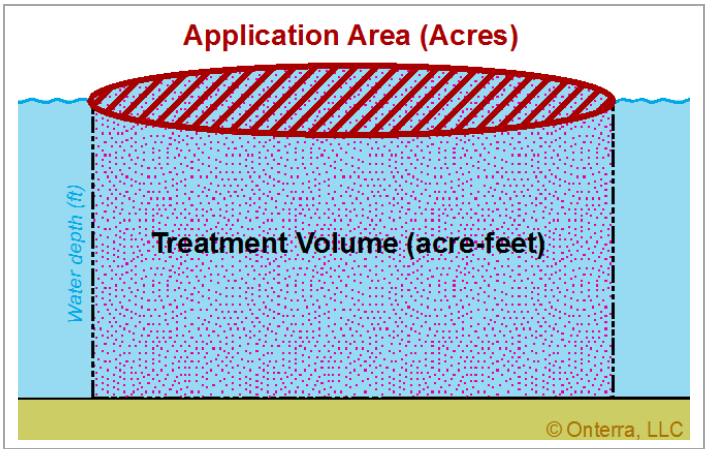


Figure 1. Herbicide Spot Treatment diagram.

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 1). While lake managers may propose that a particular volumetric dose be used, such as 3-4.0 ppm ae, it is understood that actually achieving 3-4.0 ppm ae within the water column is not likely due to dissipation and other factors.

In order to successfully control EWM in a laboratory setting, ongoing research suggest that exposure times of 2,4-D at maximum application rates (4.0 ppm ae) need to be approximately 9 hrs. There are many factors that influence exposure time, including treatment area size (larger = longer), shape (broad = longer) and location (protected parts of lake = longer) along with obvious factors such as wind and wave action. The 2015 treatment sites were initially constructed to have expanded buffers to offset the small size of the areas being targeted. The 2015 strategy also proposed to use a combination of liquid 2,4-D and endothall, as it was anticipated that the exposure times of these small sites wouldn't be adequate for 2,4-D alone to be effective, even at maximum label rates. It is believed that conducting a treatment using a combination of 2,4-D and endothall can have an additive and potentially, synergistic effects, that shorten the exposure time required for control. The four sites totaling 13.3 acres in Long Lake were proposed to be treated with a combination of liquid 2,4-D and endothall at application rates of 4.0 ppm acid equivalent (ae) and 1.5 ppm active ingredient (ai), respectively (Map 1).

Additionally, seven areas totaling approximately 3.8 acres were proposed to be targeted via professional hand-removal in 2015 (Map 2). Many Waters, LLC's implementation of DASH system in 2014 proved to be effective at removing small, but dense colonies of EWM. Onterra provided the LLPLD and the professional hand harvesting firm with the spatial data containing the EWM locations to aid in the hand removal efforts.

PRETREATMENT CONFIRMATION & REFINEMENT SURVEY

On May 12, 2015, Onterra ecologists conducted the EWM Spring Pretreatment Confirmation and Refinement Survey of Long Lake. During this survey, all the proposed control sites (herbicide and hand harvest) were visited along with areas treated in 2014 that were not proposed for retreatment. Sufficient EWM warranting treatment was confirmed in all of the originally proposed herbicide treatment areas. However, proposed hand harvesting site E-15 was removed from the control strategy as no EWM was located in the site. From this survey, the final herbicide treatment acreage was kept at the originally proposed 13.3 acres and the proposed hand removal areas were reduced from 3.82 acres to 3.57 acres (Map 2).

A temperature/dissolved oxygen profile indicated that the lake was beginning to stratify below approximately 20 feet with near-surface temperatures in the low 50s°F and temperatures in the low to mid 40s°F below 20 feet (Figure 2). Dissolved oxygen was above 10.0 mg/L throughout the top 33 feet of the water column (Figure 2). Eurasian water milfoil pulled up on the rake during this mid-May survey revealed that it was actively growing, and Onterra recommended that the treatment occur as soon as logistically possible. The treatment was conducted by Clean Lake's, Inc. on May 26, 2015 using their LittLine® NextGen Technology – an application system that reportedly minimizes herbicide diffusion by delivering the herbicide closer to the target plant's root system where plant biomass is greatest. The applicator reported east winds of 0-2 mph at the time of application.

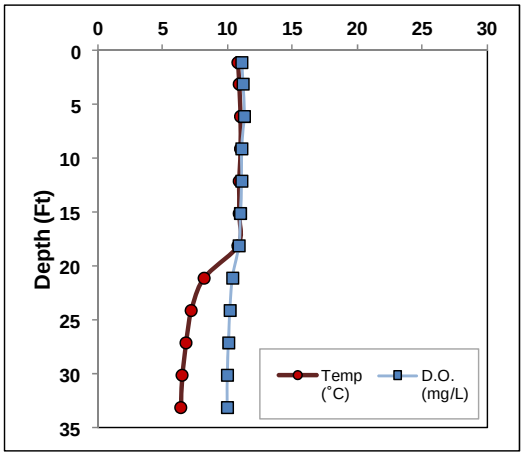


Figure 2. Pre-treatment temperature and dissolved oxygen profile collected on Long Lake. Data collected on May 12, 2015.

Wind speed and direction data were also obtained from a weather station in nearby Phelps, WI, approximately 2.5 miles from Long Lake (Figure 3). These data indicate that winds were predominantly easterly and ranged in speed from 1-3 mph during herbicide application. Over the next 14 hours following application, wind direction was predominantly northerly but remained relatively calm with speeds recorded at 3-5 mph. These data indicate that there was likely very little wind-driven water movement in Long Lake during and immediately after application that would have increased herbicide dissipation rates.

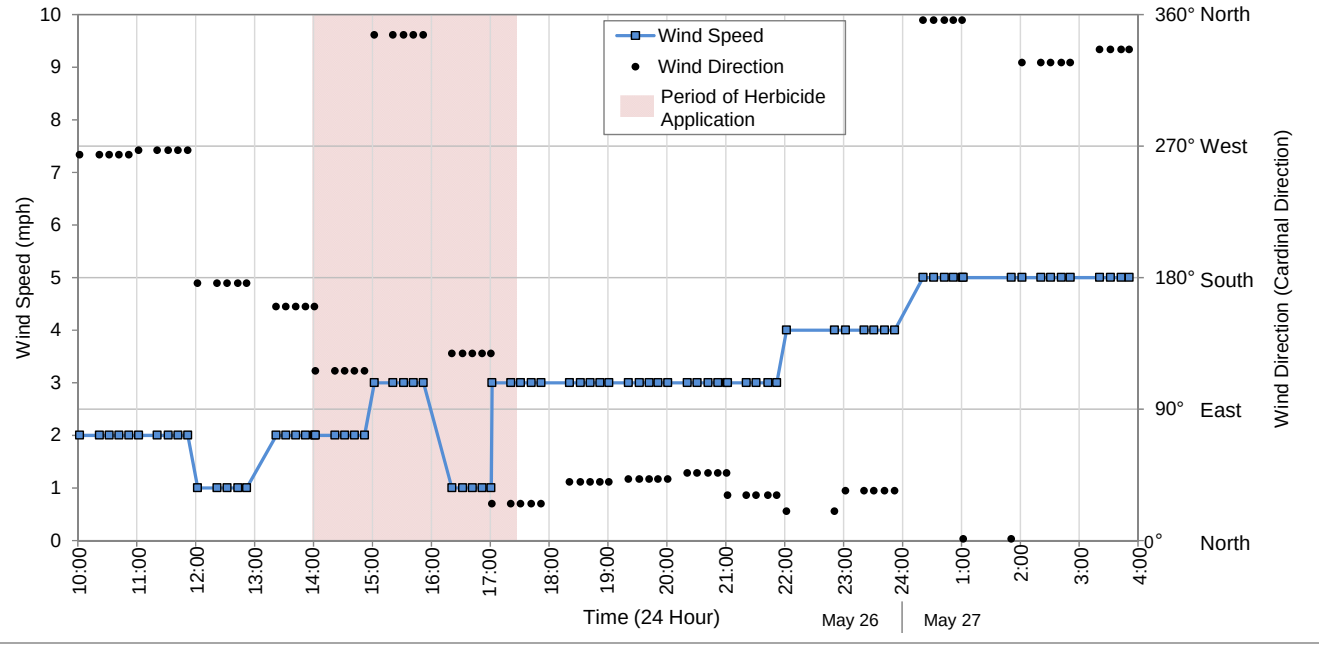


Figure 3. Wind speed and direction approximately 4 hours before and 14 hours after herbicide was applied to the Long Lake 2015 treatment areas on May 26, 2015. Graph created using data from Weather Underground Station in Phelps WI.

HAND-HARVESTING CONTROL METHODS

In 2015, the LLPLD contracted with Many Waters, LLC to conduct EWM hand-removal within the six selected areas using the Diver Assisted Suction Harvesting (DASH) program. The use of the DASH system allows divers to tackle larger, denser areas of EWM than they would be able to using just divers alone. Many Waters, LLC removed EWM from five of the six pre-determined locations over a period of eight days in June and August 2015. Table 1 displays the amount of EWM in pounds that was removed from each location. In total, 381 pounds of EWM were removed from five areas using the DASH system (20.25 hours) and an additional 57.5 pounds were hand removed by scuba divers (10.5 hours) yielding 438.5 total pounds of EWM removed (Table 1, Appendix A). No EWM was located or removed from site F-15. The 2015 hand removal summary report from Many Waters, LLC is attached with this report as Appendix A.

Table 1. Amount of EWM removed from six hand-harvesting locations in Long Lake in 2015. Adapted from Many Waters, LLC 2015 (Appendix A).

Site	DASH Hours	Dive Hours	EWM Removed (lbs)
F-15	0.00	0.50	0.0
G-15	2.75	2.50	53.0
H-15	4.50	0.00	69.0
I-15	5.00	3.75	98.0
J-15	2.50	1.25	107.5
K-15	5.50	2.50	111.0
Total	**20.25**	**10.50**	**438.5**

MONITORING METHODOLOGIES

The objective of an herbicide treatment strategy is to maximize target species (EWM) 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.

Using sub-meter GPS technology, EWM locations were mapped the year prior to treatment (2014) in late-summer when EWM is at or near its peak growth, and in the late summer immediately following the treatment (2015). The EWM population was mapped by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *Highly Scattered* to *Surface Matting*. Point-based techniques were applied to EWM locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants* (Map 1 and 2).

Qualitative monitoring of herbicide treatments includes comparing spatial data reflecting EWM locations and densities during the peak-growth stages the summer before the treatment and the summer immediately following the treatment. Based upon a pre-determined success criterion, an effective herbicide treatment would include a 75% reduction of EWM as demonstrated by a decrease in density rating (e.g. *Highly Dominant* to *Dominant*). The hand-removal program would be considered

successful if the density of EWM within the hand-removal areas was found to have decreased from the late summer 2014 survey to the late summer 2015 survey.

Due to the relatively small size of the herbicide treatment areas in 2015, a quantitative monitoring methodology was not implemented.

POST TREATMENT MONITORING RESULTS

The Late-Summer EWM Peak-Biomass Survey was conducted on September 22-23, 2015 to qualitatively assess the herbicide treatment sites and hand harvesting efforts as well as to understand the peak growth (peak-biomass) of the EWM population throughout the lake. Volunteers from the LLPLD collected GPS points suspected to be EWM during the summer of 2015 and were used to help aid the focus of the late-summer EWM peak-biomass survey (Figure 4). Onterra ecologists visited each of the volunteer points during the survey and found a number of points contained EWM and several contained only the native northern water-milfoil (*Myriophyllum sibericum*), which can take on some of the superficial characteristics (ie red-colored growth tips) of EWM.

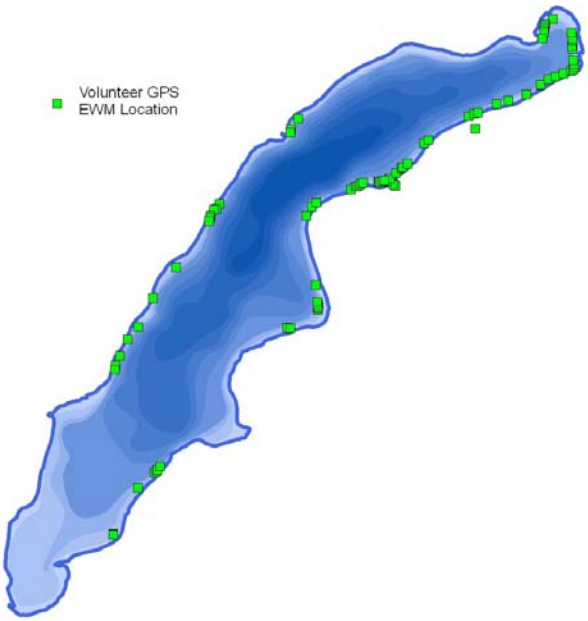


Figure 4. Long Lake 2015 Volunteer EWM Locations.

Herbicide Treatment Results

The four sites treated with herbicide in the spring of 2015 were assessed for EWM control during the survey. Site A-15 was reduced from a *dominant* 0.12 acre EWM colony and a *clump of plants* in 2014, to one *clump of plants* and several *single or few plant*s occurrences following the herbicide treatment (Figure 5). This 100% reduction in colonized EWM density exceeded the qualitative success criterion for the site. Within Site B-15, EWM was reduced from a 0.05 acre *dominant* colony, a *small plant colony*, and several *clumps of plants* and *single or few plants* in 2014 to only several *single or few plant* occurrences following the herbicide treatment (Figure 5). Qualitative success criteria were also exceeded within Site B-15.

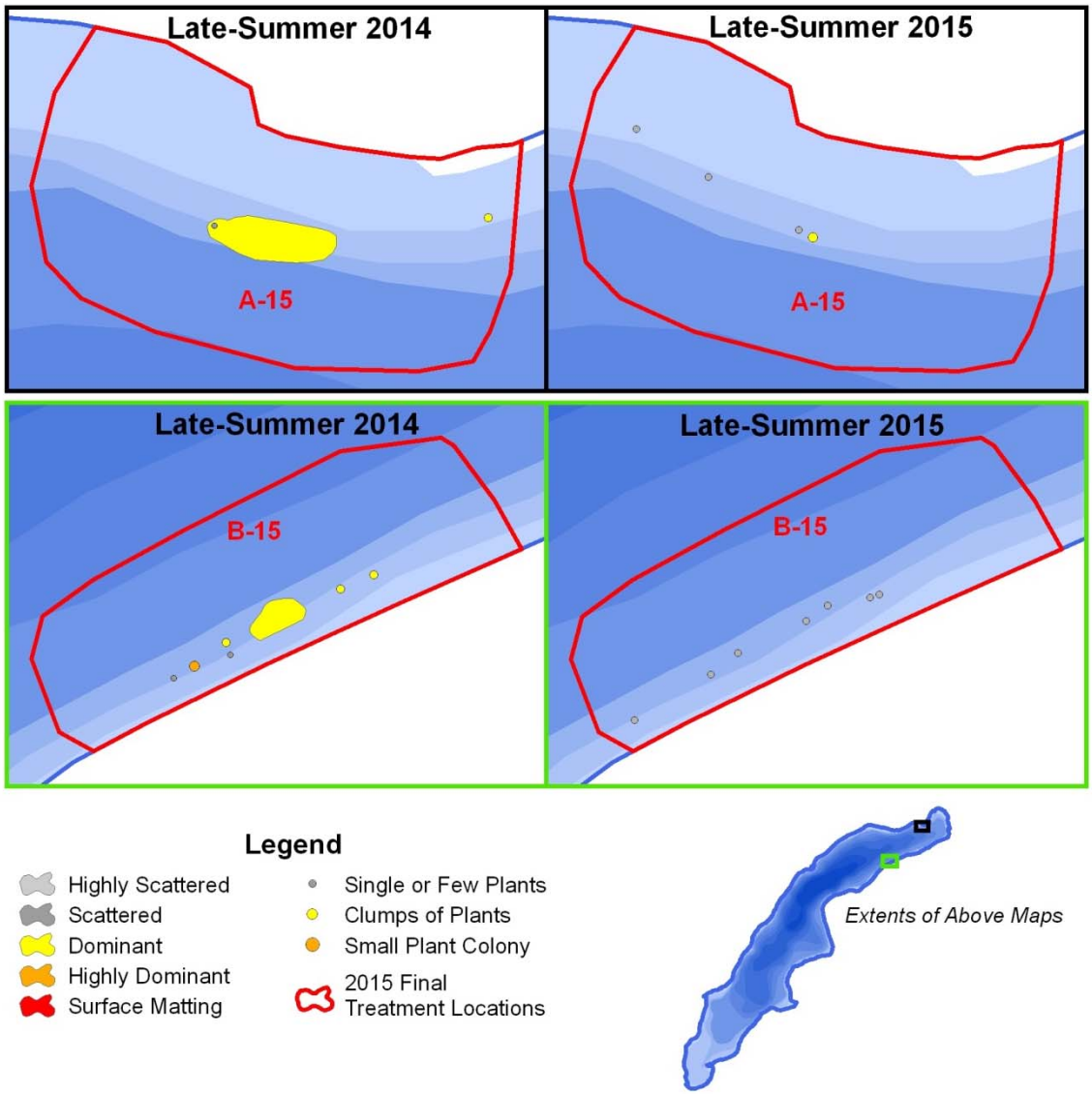


Figure 5. Late summer 2014 Pre- and late summer 2015 Post-herbicide treatment area Sites A-15 and B-15.

Within Site C-15, EWM was reduced from a 0.05 acre *dominant* colony of EWM in 2014, to one *clump of plants* following the herbicide treatment (Figure 6). This 100% reduction in EWM colony acreage exceeded qualitative success criteria. In Site D-15, EWM was reduced from a 0.12 acre *dominant* colony in 2014 to only a few *single or few plant* occurrences following the herbicide treatment (Figure 6). Qualitative success criteria were also exceeded for Site D-15.

Each of the four sites treated with herbicides in 2015 on Long Lake exhibited a reduction of EWM that exceeded the qualitative success criteria. As mentioned above, a quantitative success assessment was not conducted for the 2015 herbicide treatment sites due to their relatively small size (>4 acres).

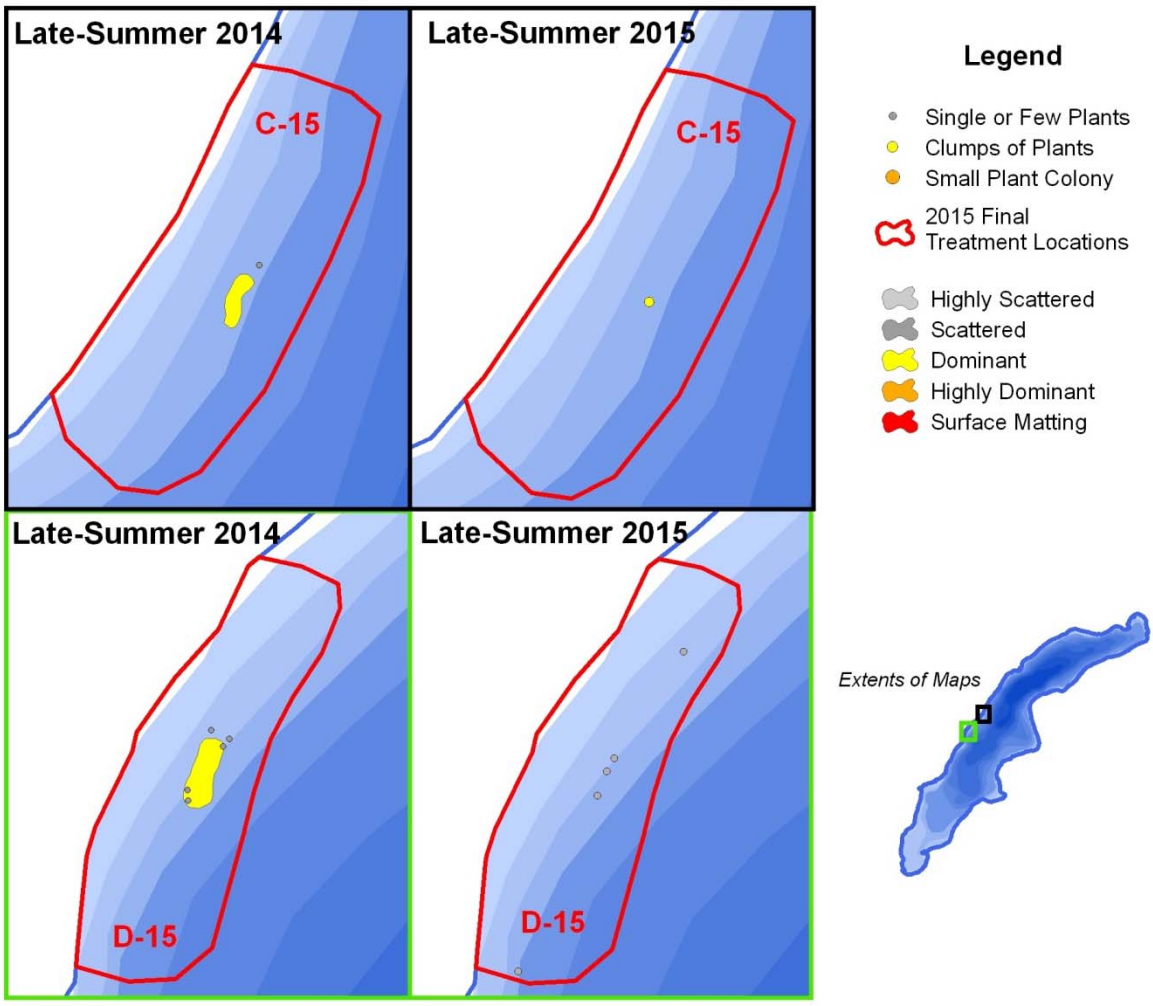


Figure 6. Late summer 2014 Pre- and late summer 2015 Post-herbicide treatment area Sites C-15 and D-15.

Hand-Harvesting Results

Figures 7 & 8 examine the level of control achieved within the areas where professional hand-harvesting efforts were undertaken in 2015. In Site G-15, Many Waters, LLC conducted both DASH based EWM removal and more conventional scuba-based removal; reporting approximately 53.0 pounds of EWM being removed from the site. Following the late summer 2015 survey, EWM was found to have decreased compared to the 2014 survey with only three *single or few plant* occurrences being mapped following the hand harvesting efforts (Figure 7). Within Site H-15, Many Waters reported removing 69.0 pounds of EWM from the site using the DASH system and also noted several underwater obstructions in the site (Appendix A). The late summer 2015 survey showed a reduction of EWM compared to the late summer 2014 survey in Site H-15 (Figure 7). A small *scattered* colony of EWM that was mapped in 2014 was not present in 2015 and only low density EWM occurrences including a *clump of plants* and *single or few plants* were located in 2015 after the hand harvesting efforts. Site I-14 contained a *scattered* colony of EWM and many point-based occurrences including *single or few plants*, *clumps of plants*, and a *small plant colony* in 2014. Many Waters reported removing 98 pounds of EWM using both DASH and conventional divers in 2015. Following the

removal efforts, EWM was found to have been reduced within the site to only a small number of *single or few plant* occurrences (Figure 7).

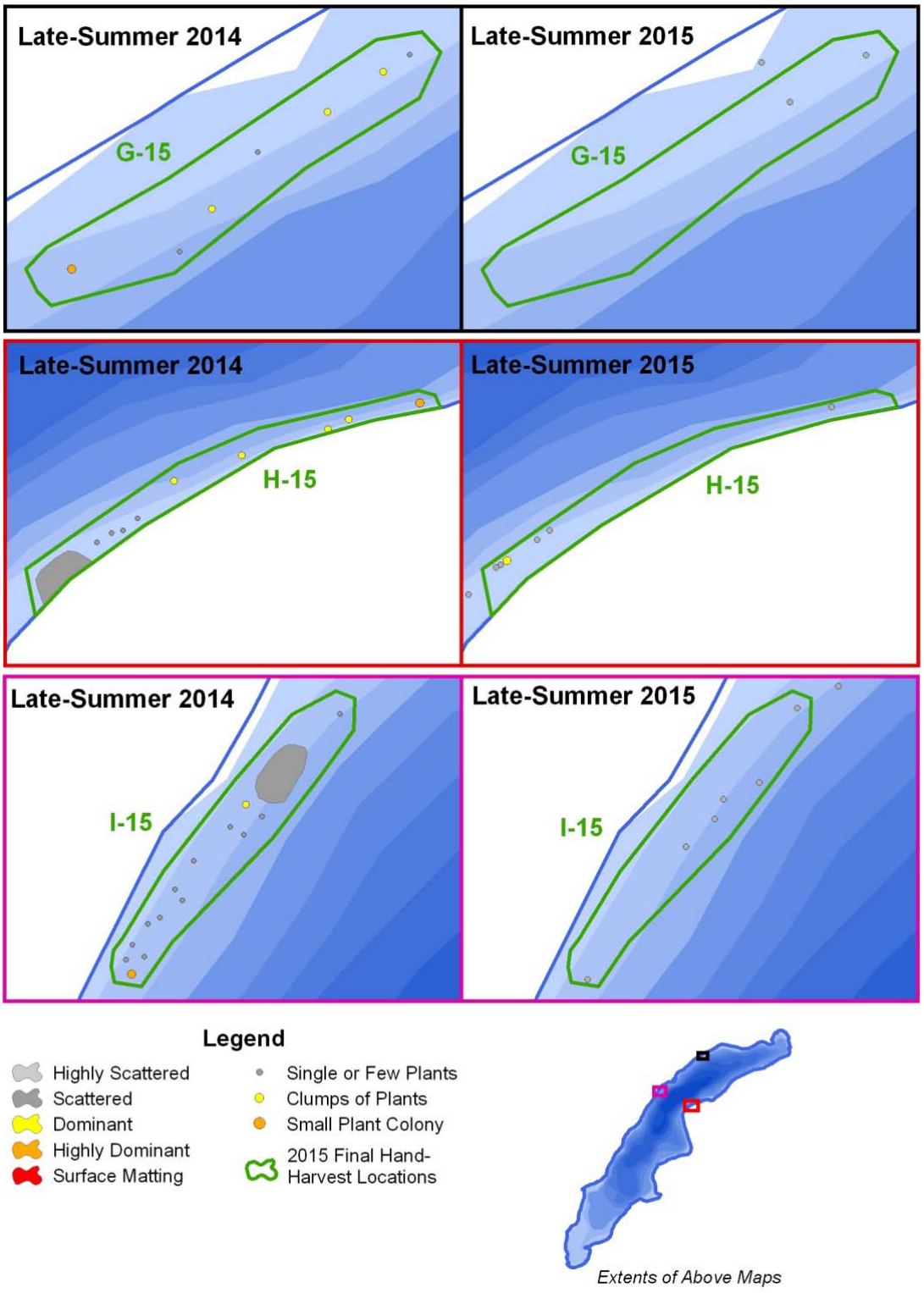


Figure 7. Late summer 2014 pre- and late summer 2015 post- professional hand-harvesting - Sites G-15, H-15 & I-15.

Prior to hand harvesting, Site J-15 contained a 0.04 acre *dominant* colony of EWM in 2014. Many Waters reported removing 107.5 pounds of EWM from the site using both DASH and conventional diving methods in 2015 (Appendix A). Following the 2015 hand removal efforts, only one *single or few plant* occurrence was located in the site indicating successful control (Figure 8). Site K-15 contained several *small plant colonies* and *clumps of plants* in 2014 and was reduced to one single or few plant occurrence in 2015 following the professional hand removal efforts (Figure 8). Many Waters reported removing 111 pounds of EWM from Site K-15 using both DASH and conventional diving methods. Post hand harvesting surveys indicated successful EWM control within all of the sites in which professional removal efforts were undertaken on Long Lake in 2015.

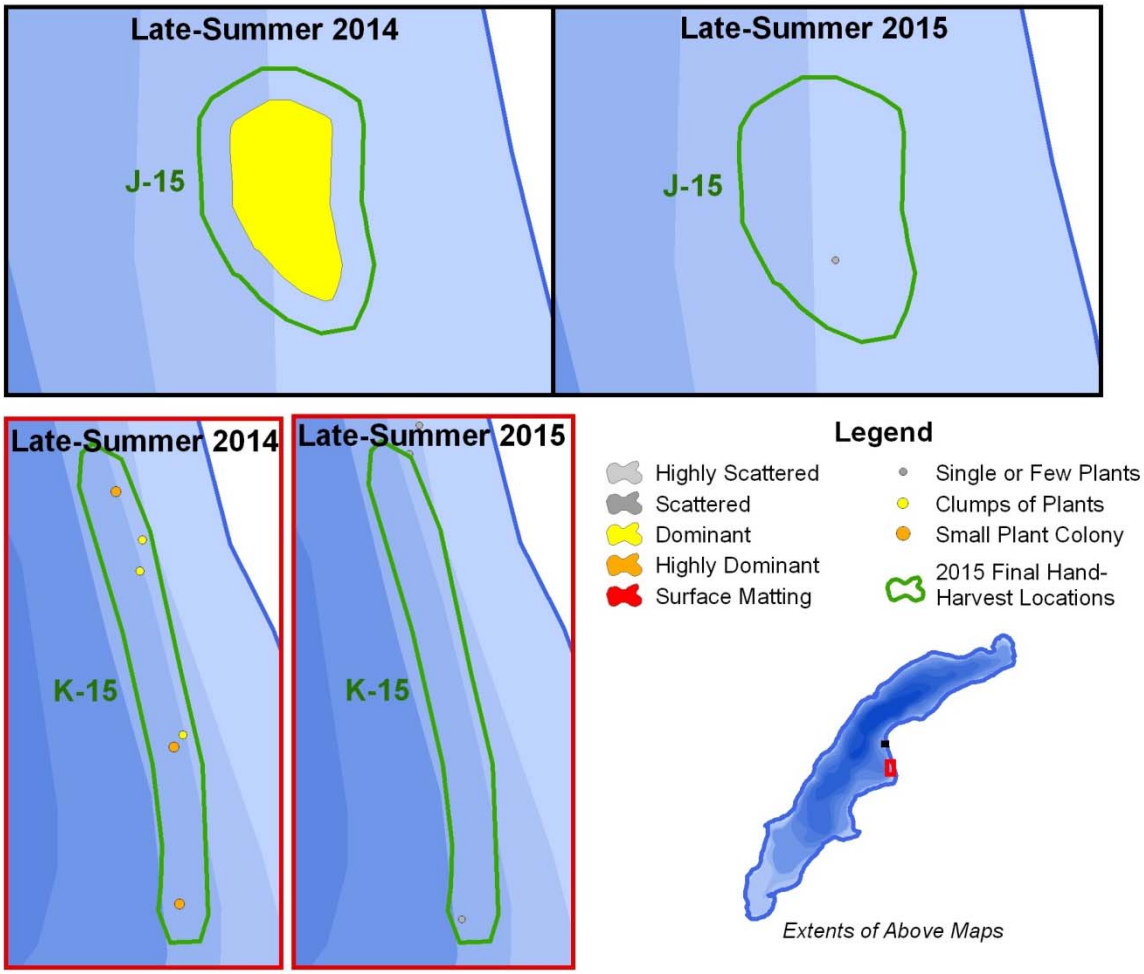


Figure 8. Late summer 2014 pre- and late summer 2015 post- professional hand-harvesting Sites J-15 & K-15.

During the late summer 2015 EWM peak-biomass survey, EWM was found to be widely spread throughout many areas of the lake (Map 2). The majority of EWM in the lake consists of relatively low density occurrences utilizing point-based mapping methodologies. No large colonies were found in 2015 that could be described with a density as *scattered, dominant, highly-dominant or surface matted*. One approximately 9.5 acre colony of *highly scattered* EWM was mapped towards the southern end of the lake (Map 2).

CONCLUSIONS AND DISCUSSION

The 2015 herbicide spot treatments as well as the professional hand-removal were highly successful at reducing the occurrence of EWM within these areas. Lake-wide levels of colonized EWM remain relatively low since the successful EWM control over the past several years (Figure 9).

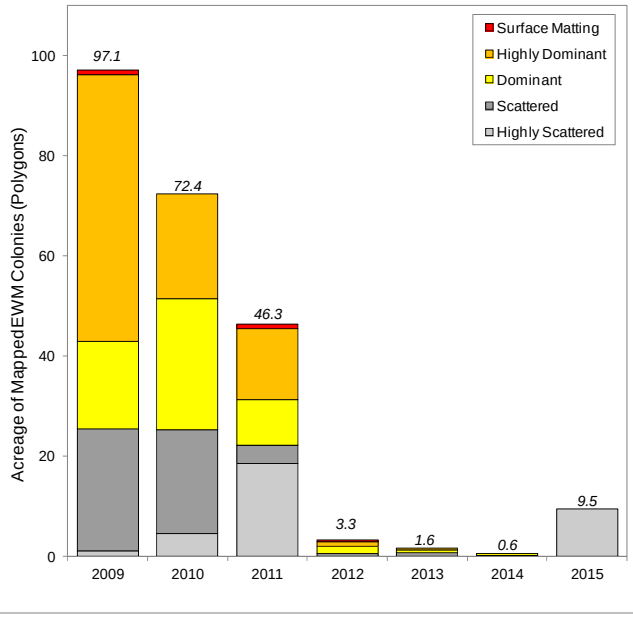


Figure 9. Acreage of mapped EWM colonies on Long Lake from 2009-2015.

In continuing an aggressive approach to EWM control in 2016, both herbicide control and professional hand harvesting methods are recommended. The relatively large *highly scattered* EWM colony identified during the 2015 peak bio-mass survey would likely be too large to be successfully controlled through hand harvesting alone and therefore this 14.0 acre site is recommended for herbicide control (Map 2). This treatment site is relatively skinny (not broad) and in an exposed part of the lake, therefore it is recommended that a combination 2,4-D and endothall be implemented in 2016 to offset the likely short exposure time that a site with those factors will have.

In anticipation of a possible 2016 herbicide treatment in this area, Onterra ecologists collected quantitative monitoring data during the late summer 2015 survey. A total of 73 sub-point intercept points were evenly spaced throughout the EWM colony at which both EWM and native plant occurrences were recorded (Figure 10). This data would serve as a pre-treatment quantitative assessment before a potential 2016 herbicide application and would be replicated during the late summer of 2016 to both assess the EWM efficacy and the native aquatic plant populations' response.

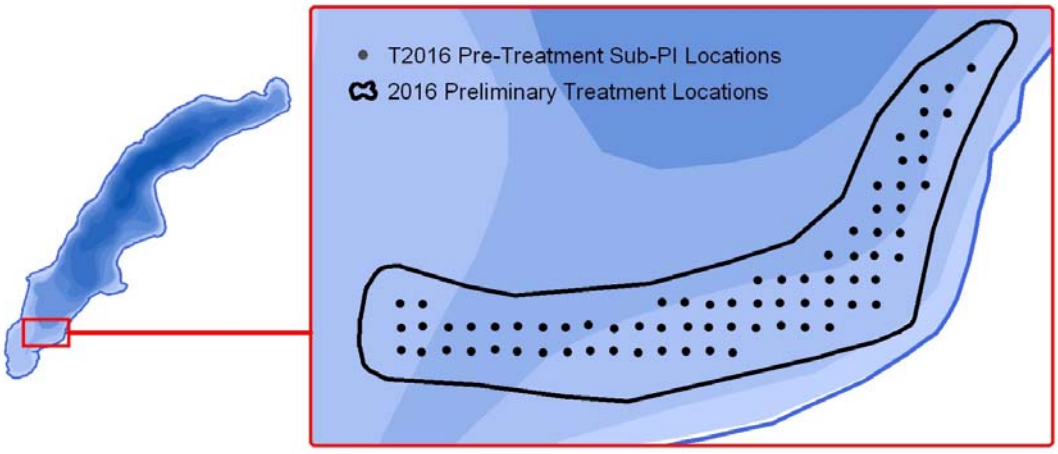
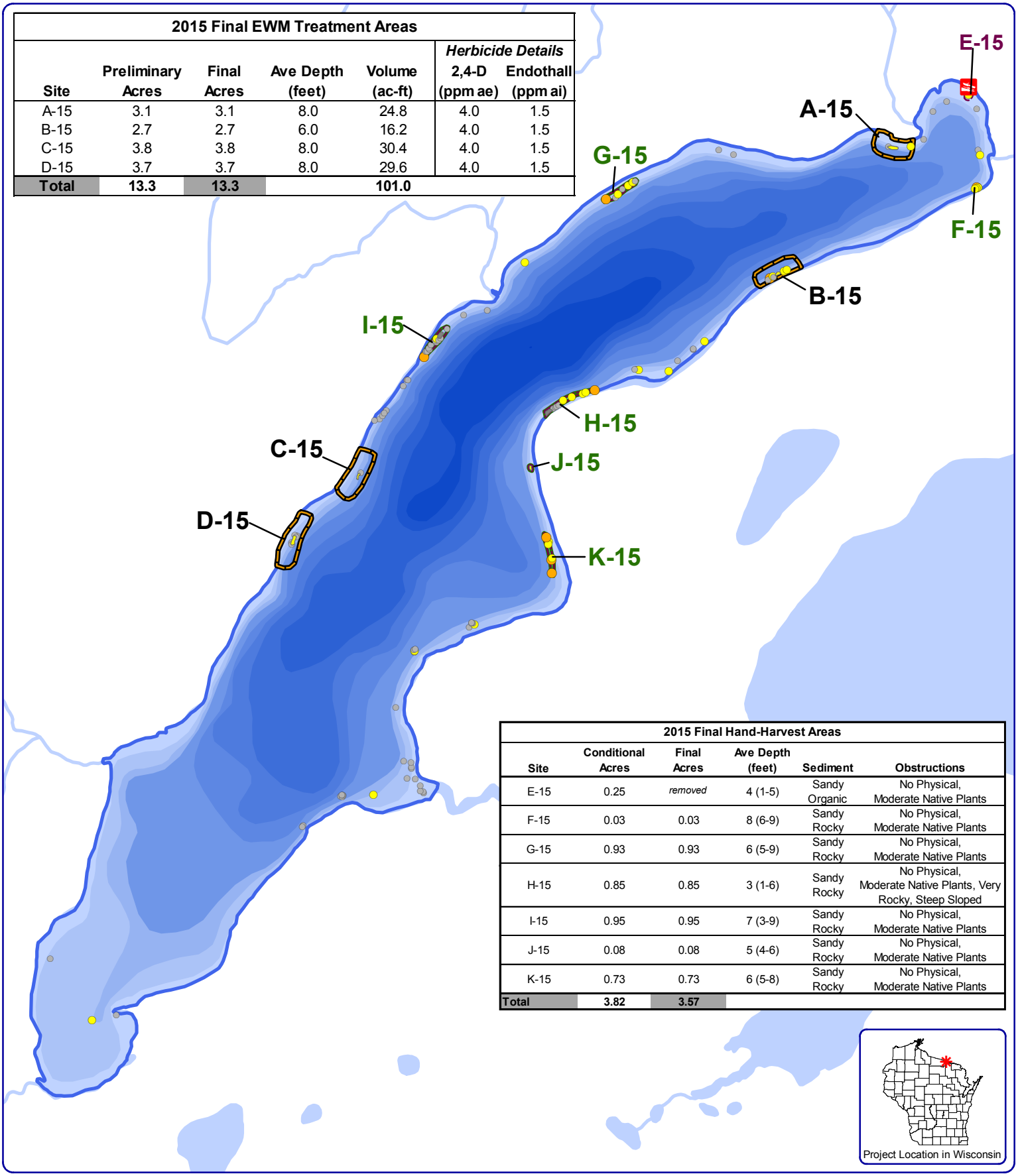


Figure 10. Quantitative monitoring locations for a proposed 2016 herbicide treatment on Long Lake. (20 meter spaced points – 73 total points)

Additionally, seven areas totaling approximately 2.0 acres are initially proposed to be targeted via professional hand-removal in 2015 (Map 3). These areas contain EWM mapped with point-based techniques (e.g. *small plant colonies* or *clumps of plants*). Many Waters, LLC's efforts in 2014 and 2015 proved to be effective at removing EWM within targeted areas of similar size and EWM density as proposed for 2016.

A spring 2016 Pre-treatment Confirmation and Refinement Survey would be used to refine the 2016 herbicide and hand harvesting sites as needed. A final permit map would then be created for the herbicide and/or hand harvesting to occur in 2016. A volunteer based EWM monitoring regimen should be continued in the summer of 2016. Any EWM located by LLPLD volunteers would be recorded on the groups GPS and the data would again be utilized by Onterra during the late summer 2016 Peak Biomass Survey. This late summer survey will also be used to assess the 2016 control activities and guide the 2017 EWM control strategy.

2015 Final EWM Treatment Areas						
					Herbicide Details	
Site	Preliminary Acres	Final Acres	Ave Depth (feet)	Volume (ac-ft)	2,4-D (ppm ae)	Endothall (ppm ai)
A-15	3.1	3.1	8.0	24.8	4.0	1.5
B-15	2.7	2.7	6.0	16.2	4.0	1.5
C-15	3.8	3.8	8.0	30.4	4.0	1.5
D-15	3.7	3.7	8.0	29.6	4.0	1.5
Total	**13.3**	**13.3**		**101.0**		



2015 Final Hand-Harvest Areas					
Site	Conditional Acres	Final Acres	Ave Depth (feet)	Sediment	Obstructions
E-15	0.25	*removed*	4 (1-5)	Sandy Organic	No Physical, Moderate Native Plants
F-15	0.03	0.03	8 (6-9)	Sandy Rocky	No Physical, Moderate Native Plants
G-15	0.93	0.93	6 (5-9)	Sandy Rocky	No Physical, Moderate Native Plants
H-15	0.85	0.85	3 (1-6)	Sandy Rocky	No Physical, Moderate Native Plants, Very Rocky, Steep Sloped
I-15	0.95	0.95	7 (3-9)	Sandy Rocky	No Physical, Moderate Native Plants
J-15	0.08	0.08	5 (4-6)	Sandy Rocky	No Physical, Moderate Native Plants
K-15	0.73	0.73	6 (5-8)	Sandy Rocky	No Physical, Moderate Native Plants
Total	**3.82**	**3.57**			

N
W E
S

1,700
Feet

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

Sources:
Roads, Hydro, and Bathymetry: WDNR
Aquatic Plants: Onterra, 2014
Map Date: December 10, 2015
Filename: Map1_LongV_EWM_T2015_Perm1.mxd

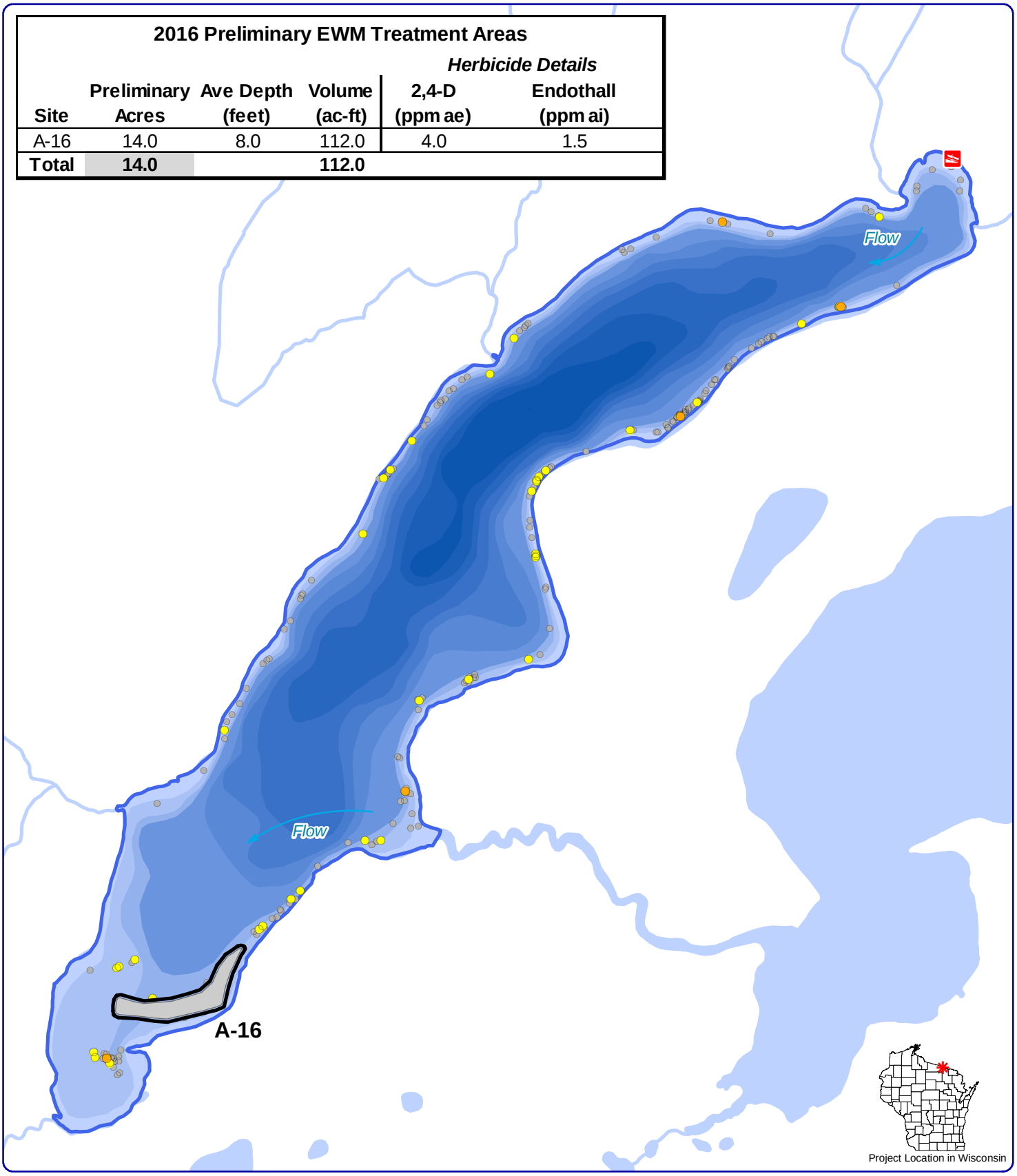
Eurasian Watermilfoil September 2014
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- 2015 Proposed Herbicide Treatment Strategy
- 2015 Final Herbicide Treatment Strategy
- 2015 Proposed Hand-Removal Strategy
- 2015 Final Hand-Removal Strategy

Map 1
Long Lake
Vilas County, Wisconsin
2014 EWM Locations & 2015 Final Treatment Areas

2016 Preliminary EWM Treatment Areas

Site	Preliminary Acres	Ave Depth (feet)	Volume (ac-ft)	*Herbicide Details* 2,4-D (ppm ae)	Endothall (ppm ai)
A-16	14.0	8.0	112.0	4.0	1.5
Total	**14.0**		**112.0**		



1,800
Feet

Legend

- Highly Scattered
- Scattered *(none)*
- Dominant *(none)*
- Highly Dominant *(none)*
- Surface Matting *(none)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Proposed 2016 Treatment Area

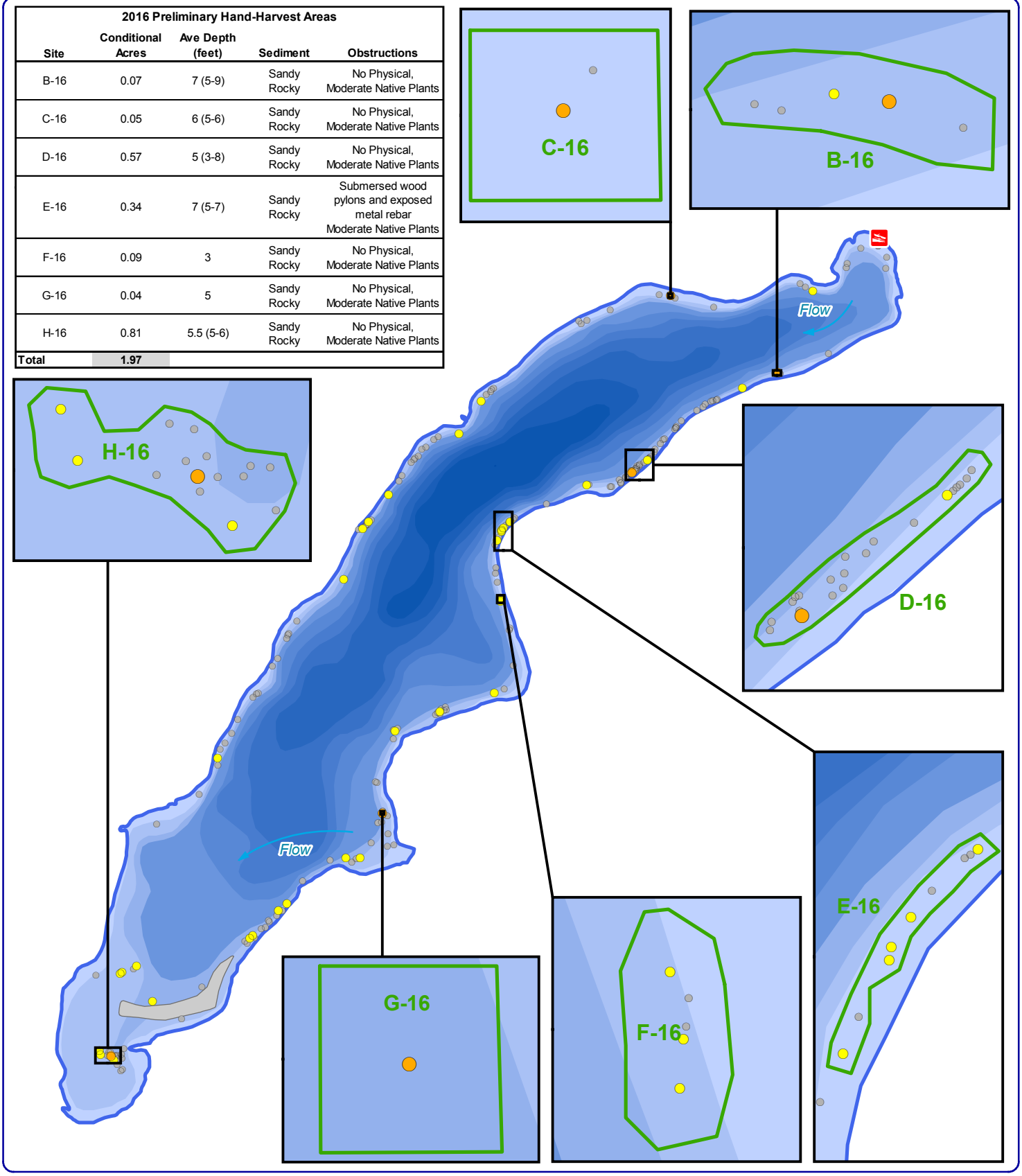
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2015
Map Date: December 10, 2015
Filename: *LongVilas_T2016Prelim1.mxd*

Map 2
Long Lake
Vilas County, Wisconsin
September 2015 EWM Survey Results & Proposed 2016 Treatment Area v1

2016 Preliminary Hand-Harvest Areas

Site	Conditional Acres	Ave Depth (feet)	Sediment	Obstructions
B-16	0.07	7 (5-9)	Sandy Rocky	No Physical, Moderate Native Plants
C-16	0.05	6 (5-6)	Sandy Rocky	No Physical, Moderate Native Plants
D-16	0.57	5 (3-8)	Sandy Rocky	No Physical, Moderate Native Plants
E-16	0.34	7 (5-7)	Sandy Rocky	Submersed wood pylons and exposed metal rebar Moderate Native Plants
F-16	0.09	3	Sandy Rocky	No Physical, Moderate Native Plants
G-16	0.04	5	Sandy Rocky	No Physical, Moderate Native Plants
H-16	0.81	5.5 (5-6)	Sandy Rocky	No Physical, Moderate Native Plants
Total	**1.97**			



N
W E
S

1,900
Feet

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

Sources:
Hydro: WDNR
Bathymetry: WDNR
Aquatic Plant Survey: Onterra, 2015
Map Date: December 10, 2015
Filename: *LongV_EWM_HH_T2016Prelim1.mxd*

Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Proposed 2016 Hand-Harvest Site

Map 3
Long Lake
Vilas County, Wisconsin
September 2015 EWM Survey Results & 2016 Hand-Removal Strategy