INTRODUCTION

In August 2012, the Mount Morris Lakes Management District (MMLMD) successfully applied for a Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species (AIS) Established Population Control (EPC) Grant to initiate a five-year project aimed at reducing the populations of curly-leaf pondweed (*Potamogeton crispus*; CLP), Eurasian water milfoil (*Myriophyllum spicatum;* EWM), and hybrid water milfoil (*M. sibiricum X spicatum;* HWM) in Mount Morris Lake. Subsequent use of "HWM" within this report collectively includes, but does not differentiate between, EWM and HWM. The WDNR grant was not exhausted due to the project being under budget on herbicide treatments. Therefore, the 2017 activities have been added to the project and this report will be the final deliverable for the now 6-year AIS-EPC Grant-funded project.

CURLY-LEAF PONDWEED CONTROL STRATEGY

The 2012 WDNR grant-funded CLP project was designed such that roughly 36 acres of Mount Morris Lake would be targeted for 4 straight years with liquid endothall, modifying the dosing strategy along the way in response to data reflecting measured herbicide concentrations, efficacy, and selectivity. Figure 1 displays the CLP treatment history from 2013-2016. Approximately 56% of the treatment history includes areas targeted for control during all four years, whereas other areas were treated two or three years and then removed from the control strategy based on observed reductions in the CLP population to levels not warranting treatment.

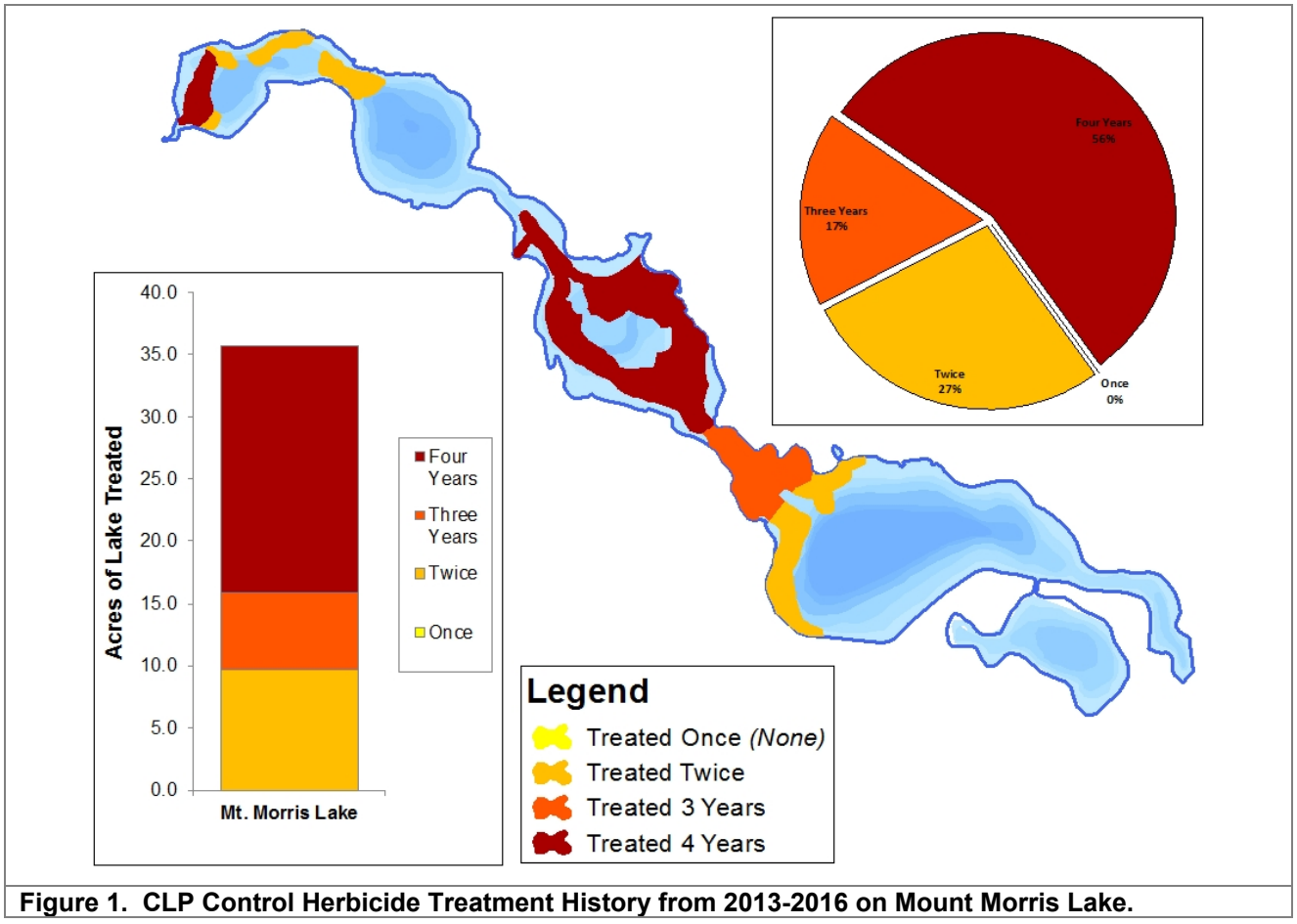


Figure 1. CLP Control Herbicide Treatment History from 2013-2016 on Mount Morris Lake.

The goal of a curly-leaf pondweed control strategy is to each year, kill the CLP plants before they are able to produce reproductive turions. Continuing to kill this annual plant before turions are produces, theoretically should result in a depleted turion base within the sediment and reduce its population. Because of these repeat treatments, an accurate assessment of the CLP population within the lake had not been made because the plants were not allowed to grow to their full potential. By forgoing a treatment in 2012, an assessment of the CLP population at its peak growth was able to be made. The 2012 CLP survey indicated that this population was still a major stressor to the ecology and recreational activities of Mount Morris Lake, with approximately 28 acres of the lake containing colonized CLP albeit less dense than a previous study (Figure 2). If the treatments between 2006 and 2011 have been causing CLP mortality before that year's plants are able to produce turions, the CLP population located in 2012 must have been a result of turions that were deposited prior to treatment in 2006. On the other hand, if the treatments have only been causing CLP injury, plant density will likely be reduced during the year of the treatment but the plants may still be able to produce viable turions to perpetuate the population.

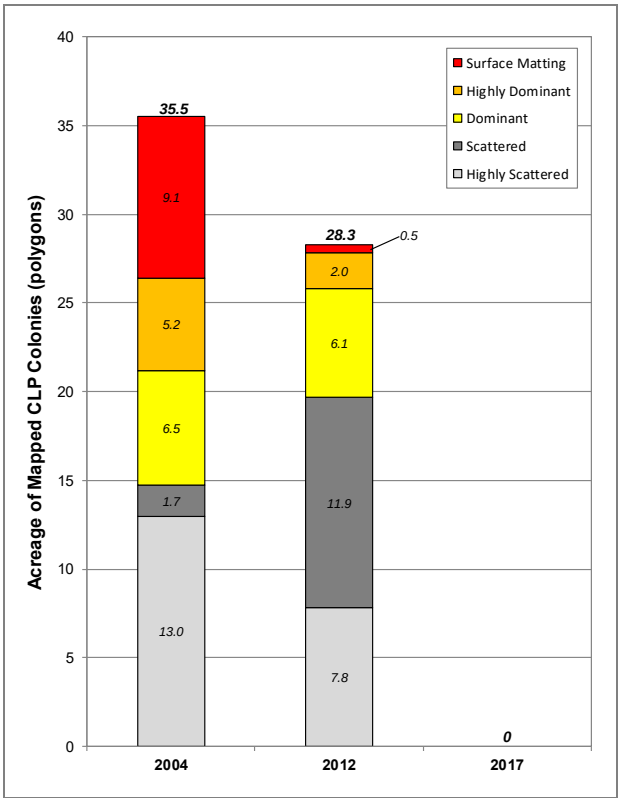


Figure 2. Acreage of mapped CLP colonies on Mount Morris Lake from 2004 and 2012.

A CLP-targeted herbicide treatment also did not occur in 2017, as pretreatment surveys yielded an insufficient amount of CLP growth to warrant management. On June 22-23, 2017, Onterra ecologists conducted an Early Season AIS survey on Mt. Morris Lake. The field crew noted fairly turbid water and recorded a Secchi disk reading of 3.6 feet. During the survey, the entire lake was surveyed for CLP and HWM. During this survey, the field-crews marked CLP occurrences with point-based methods, but no areas of colonized CLP were located during the survey (Figure 1, Map 1). The fact that CLP did not warrant treatment in 2017 suggests that the turion base may have been depleted to the point that control goals are starting to be met.

As eluded to above, the amount of CLP observed in a given year is a result of how many turions within the sediment sprouted earlier that spring (or late the previous fall/winter). It cannot be ruled out that environmental factors may have led to poor CLP turion germination during 2017 underscoring the importance of continued monitoring of the CLP population in the future.

HYBRID WATER MILFOIL CONTROL STRATEGY

Following detection of HWM within Mount Morris Lake in 2004, numerous spot-treatments and basin-wide control strategies have been implemented towards HWM. Unfortunately, many of these treatments have fallen short of expectations. Ongoing studies are indicating that in small spot treatments (working definition is less than 5 acres) the herbicide dissipates too rapidly to cause EWM mortality if systemic herbicides like 2,4-D are used. Even in some cases where larger treatment areas can be constructed, their narrow shape or exposed location within a lake may result in insufficient herbicide concentrations and exposure times for long-term control. On Mount Morris Lake, water flow also acts to reduce concentrations and exposure times of the herbicide.

Ongoing field trials are assessing the efficacy (EWM control) and selectivity (collateral native plant impacts) of herbicides that may be effective with a shorter exposure time. Herbicide combinations such as 2,4-D plus endothall have been attempted on Mount Morris Lake with only short-term successes towards HWM. Diquat is a contact herbicide that is sometimes used in spot treatment scenarios where the herbicide is expected to dissipate rapidly from the application area. This herbicide strategy is often criticized for its impacts on other native plant species with the application area. These costs were weighed and in 2016 and the MMLMD conducted a diquat treatment. The control strategy had notable impacts, but failed to meet expectations.

When diquat is mixed with endothall, as is commercially available under the Aquastrike® brand, it is theorized to have even shorter exposure times than diquat alone. This herbicide use-pattern has shown promise controlling EWM in a few Wisconsin treatments. This herbicide strategy was proposed for use on Mount Morris Lake in 2017.

Precipitation in the watershed contributes to increased water exchange rates on Mount Morris Lake. The herbicide applicator, Clean Lakes, and the district were closely monitoring the precipitation in this area as well as the water temperatures. The manufacturers of Aquastrike®, United Phosphorus, Inc. (UPI), have shown that increased systemic activity of the endothall component may occur when water temperatures are colder (<60°F). While rainfall was recorded during the days leading up to the treatment (Figure 3), these conditions may have been the best that could be expected considering the extremely rainy spring experienced in Wisconsin during 2017 without extensive delay resulting in increased water temperatures.

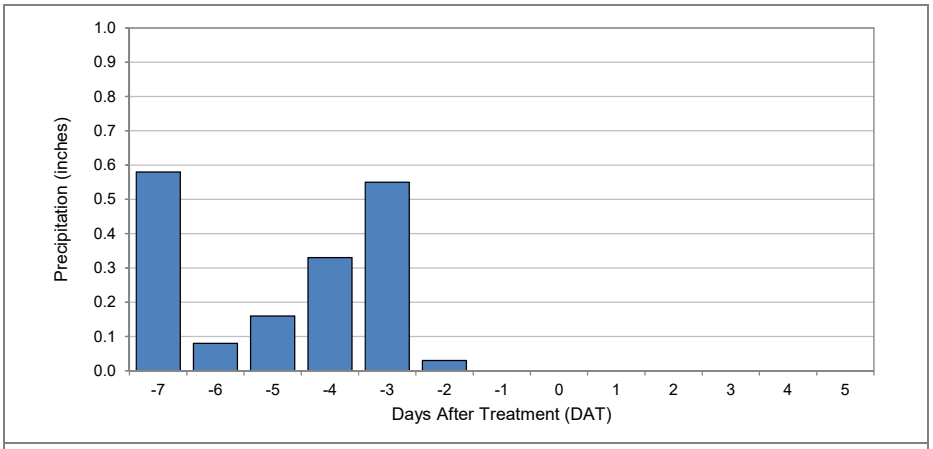


Figure 3. Rainfall recorded in Wautoma before and after treatment of Mount Morris Lake. Data from weatherunderground.com.

The permitted acres were treated with Aquastrike® on May 4, 2017 by Clean Lakes, Inc. The applicator reported northerly winds between 5.6-7.2 mph and a near surface water temperature of 59°F at the time of application. At the time of the application, Clean Lakes raised concerns with the consistency of the herbicide product. The manufacturer of Aquastrike® (UPI) was contacted by Clean Lakes while on-site to discuss the concerns with the product. UPI did not feel as though the product would impact the effectiveness of the treatment. In follow-up conversations with UPI, they stated that even though they did not feel it would impact the efficacy of the treatment, if the treatment failed, they would provide additional Aquastrike® at no cost should a retreatment be required and approved.

On September 20, 2017, Onterra ecologists conducted the HWM peak biomass mapping survey to qualitatively assess the 2017 treatment areas as well as to map HWM at its peak growth (biomass). Within Site A1-17, a highly scattered HWM colony was mapped during the survey which was approximately the same or slightly more than was observed during the spring 2017 survey before the treatment.

Within site C2-17, a *dominant* HWM colony was mapped in 2016 prior to the treatment (Figure 4). The post-treatment survey indicated that a *scattered* HWM colony of approximately the same size remained in the site indicating limited control. Similarly, within Site C3-17, HWM was found to have remained similar in density from a *dominant* colony before the treatment to a similar in size scattered and dominant colony following treatment which also fell short of the treatment expectations (Figure 4).

The long-term control of EWM targeted with diquat or diquat combinations continue 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. This likely occurs in the shallow parts of Lake C that are being targeted for HWM control.

Lake-wide, with the exception of the three colonies targeted for treatment, the HWM population was found to be relatively low with the majority of occurrences consisting of *single or few plants* or *clumps of plants* (Map 2).

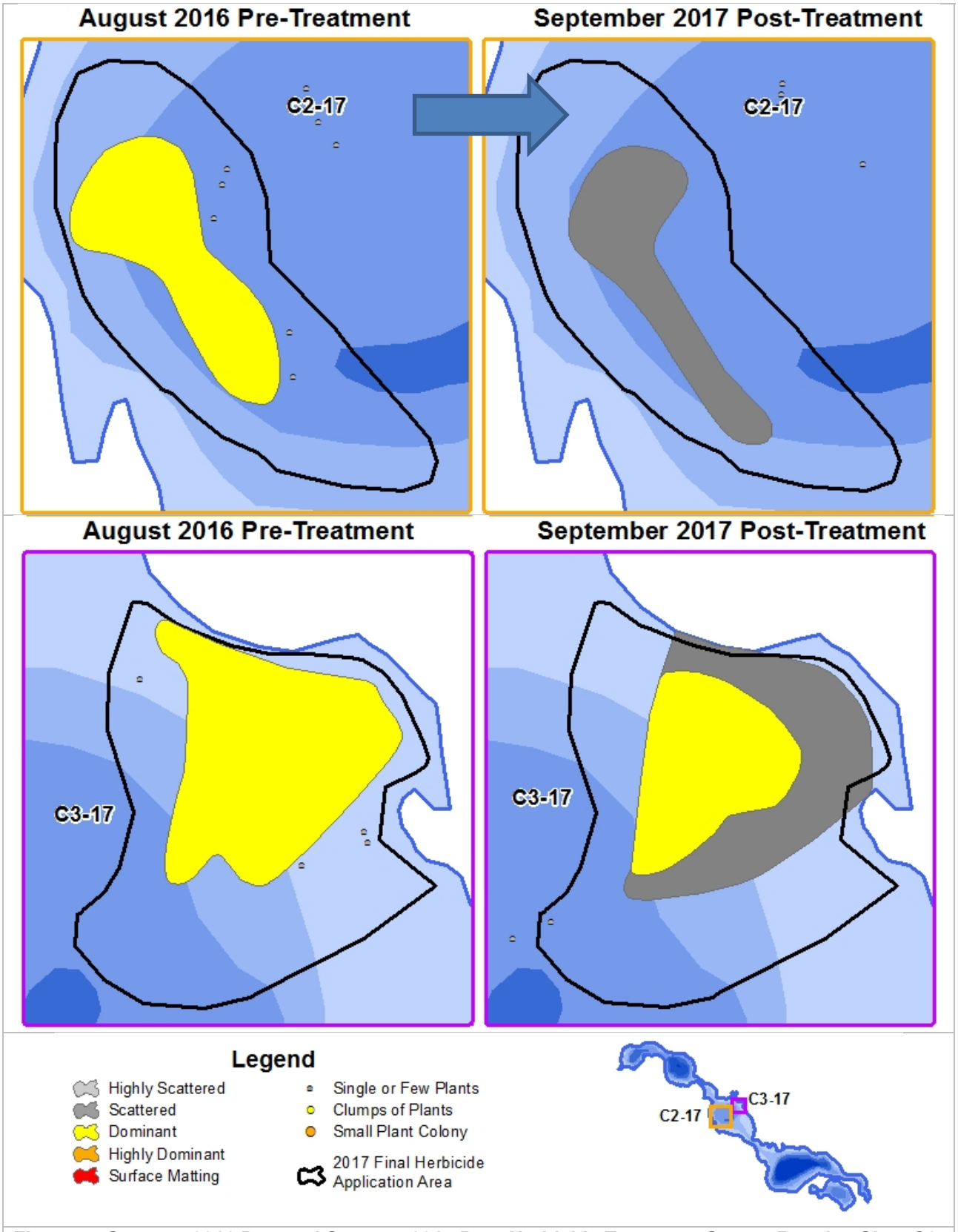


Figure 4. Summer 2016 Pre- and Summer 2017 Post-Herbicide Treatment Survey Results. Sites C2-17 & C3-17.

Quantitative Aquatic Plant Monitoring

The whole-lake point-intercept method as described by the WDNR Bureau of Science Services (PUB-SS-1068 2010) has been used to complete a quantitative evaluation of the occurrences of non-native and native aquatic plant species. On Mount Morris Lake, this survey is conducted during late-June of each year to capture the CLP population before it begins to naturally die back (senescence) but yet late enough in the growing season that the native plant population has emerged. To date, no herbicide treatments have occurred in Lake E (Emerald Lake). Due to the water exchange patterns of Mount Morris Lake, Lake E is not exposed to the herbicide treatment program (Figure 5) that occurs in the other basins and therefore was excluded from the subsequent point-intercept analysis of Mount Morris Lake .

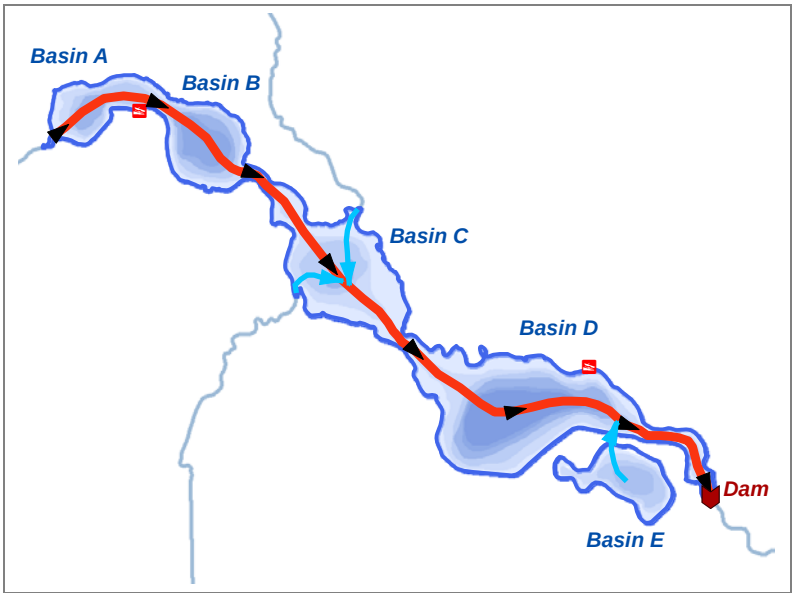


Figure 5. Morphometry of Mount Morris Lake

Over the time period where point-intercept surveys have conducted, CLP has maintained a low population within Mount Morris Lake's 4 main basins (Figure 6). In most years, this was likely influenced by the targeted CLP treatments that occurred approximately 4-6 weeks prior to the survey. HWM littoral frequency of occurrence (LFOO) has also remained relatively low over this time period, although localized high-density areas of HWM in Lake C have been confirmed.

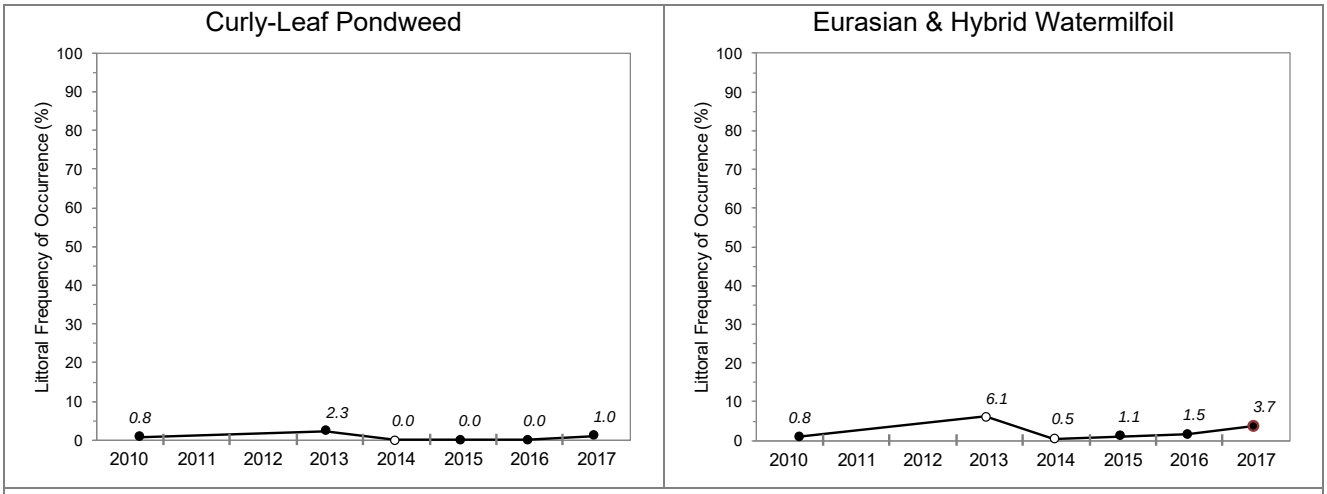


Figure 6 Littoral frequency of occurrence of AIS in Mount Morris Lake from 2010-2017. Open circle represents statistically valid change from previous survey. Circle outlined with red indicates 2017 was statistically different from 2010 (Chi-Square α = 0.05).

Figure 7 displays the average LFOO (and range of LFOO) of select aquatic plants within Mount Morris Lake from 2010-2017 compared to the 2017 whole-lake point-intercept survey (red circles). These data indicate that some aquatic plant populations like coontail, northern watermilfoil, stoneworts, naiad species, and clasping-leaf pondweed all had relatively average populations in 2017 compared to the historic dataset. Muskgrasses, water celery, and sago pondweed were all above average in 2017 whereas whorled watermilfoil, common bladderwort, common waterweed, and water stargrass were below average.

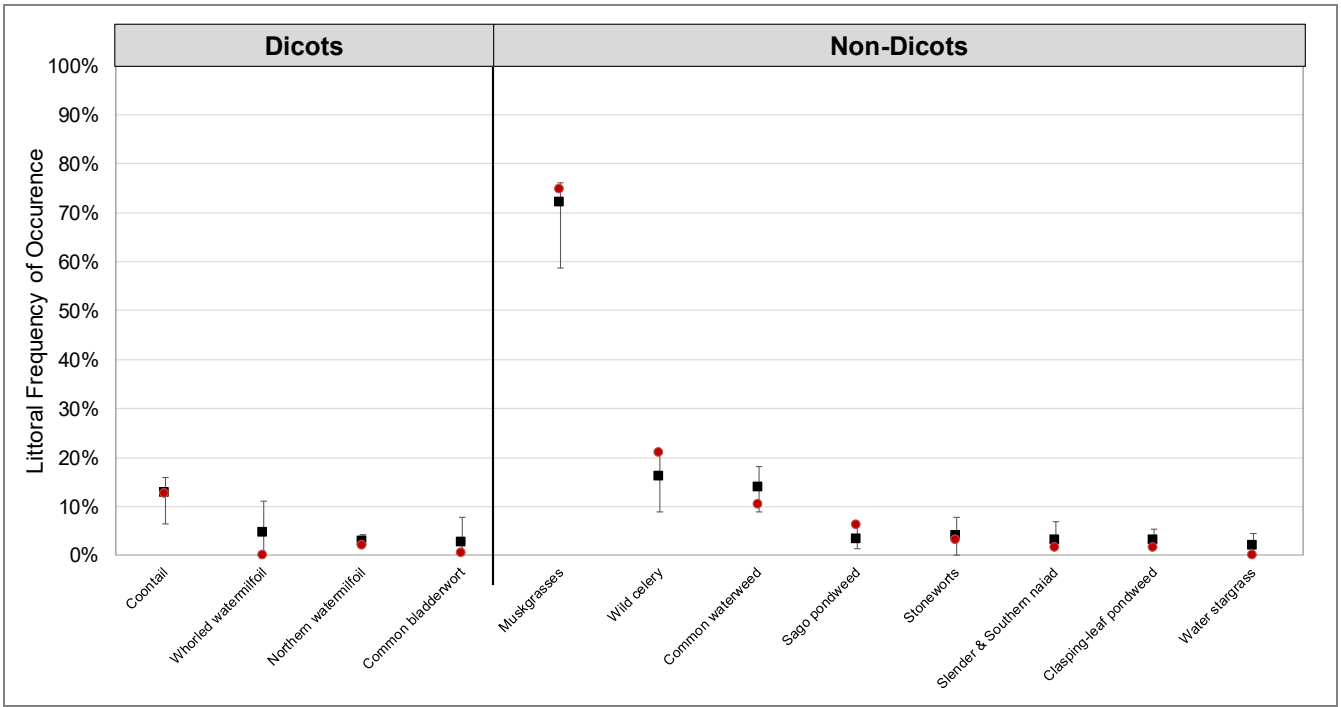


Figure 7. Mount Morris Lake aquatic plant littoral frequency of occurrence from 2010-2017. Square symbol represents mean frequency of occurrence pooled from all point-intercept surveys, error bars represent range of annual frequencies, red circle represents 2017 littoral frequency of occurrence.

Of particular concern are changes to the watermilfoil populations of Mount Morris Lake. As shown on Figure 8, northern watermilfoil populations have remained statistically unchanged over the entire dataset while whorled watermilfoil peaked in 2014 and has since declined to 0% in 2017.

A number of 2,4-D treatments have occurred on Mount Morris Lake targeting EWM. This class of herbicides was historically believed to only have impacts to dicot species. Research conducted by the US Army Corps of Engineers, the WDNR, and private consultants have shown that these herbicides can be particularly impactful to the broad-leaved plant community but also can cause declines in certain non-dicot native plants. The largest 2,4-D treatments on Mount Morris Lake took place during the springs of 2014 and 2015, which correspond with the two highest populations of whorled watermilfoil. This may suggest other factors, such as natural climactic variability, may be driving the population change of whorled water milfoil on Mount Morris Lake.

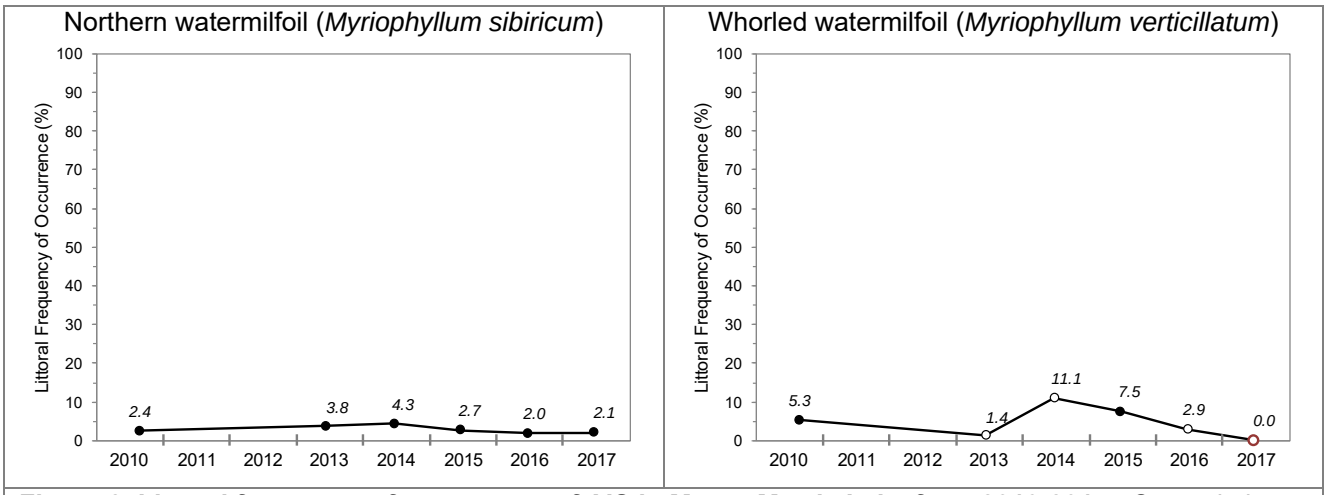


Figure 8 Littoral frequency of occurrence of AIS in Mount Morris Lake from 2010-2017. Open circle represents statistically valid change from previous survey. Circle outlined with red indicates 2017 was statistically different from 2010 (Chi-Square α = 0.05).

CONCLUSIONS AND DISCUSSION

The overall CLP control program on Mount Morris Lake has shown positive signs of control and management strategies may shift more towards maintaining the lowered CLP population within the lake. It is important to note that within a maintenance management mode, it is difficult to balance a level of CLP population tolerance while not allowing the CLP population simply to increase to pre-management levels.

The HWM management program has not been as successful as the CLP management program. This is largely due to the inability of herbicides to reach appropriate concentrations and exposure times within the high water exchange that occurs on Mount Morris Lake. That being said, the HWM population of Mount Morris Lake continues to be below levels that would cause detectable ecological impacts to the lake and below levels that would cause significant reduction in navigation, recreation, and aesthetics of lake users.

As part of this project, the MMLMD will update its management plan as it relates to AIS management based on the lessons learned over the course of this project. The 2013 Comprehensive Lake Management Plan contained a single AIS-related goal and two associated actions to help reach that goal (Figure 9). Subsequent MMLMD Planning Committee meetings and/or discussions will lead to possible changes to the management goal and associated management actions moving forward.

Goal: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Mount Morris Lake

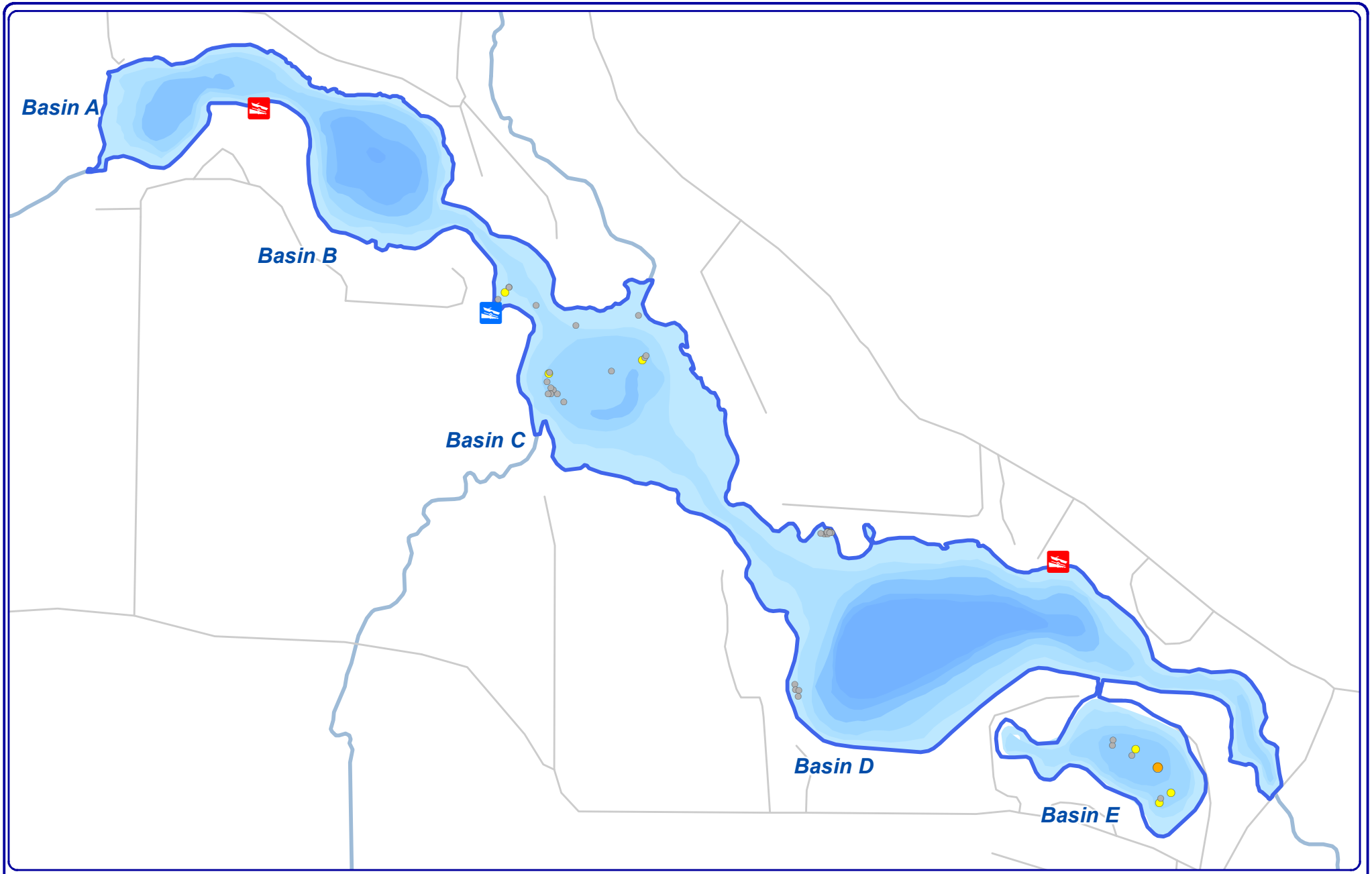
Action: Initiate/continue herbicide application strategy to control curly-leaf pondweed infestation on Mount Morris Lake.

- Trigger:
  - All areas targeted the previous year would be considered for treatment. Based upon the pretreatment survey, these areas may be reduced or removed.
  - All areas of colonized CLP mapped during the ESAIS Survey will be considered for treatment during the following spring.
- Monitoring: Annual Early-Season AIS Survey, with pretreatment survey conducted in years with an herbicide control strategy. If CLP treatments approach large-scale levels, whole-lake point-intercept surveys in late-June would occur annually.
- Funding: WDNR AIS-EPC Grant

Action: Initiate/continue herbicide application strategy to control Eurasian watermilfoil infestation on Mount Morris Lake.

- Trigger: 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
- Monitoring: Annual EWM Survey, with pretreatment survey conducted in years with an herbicide control strategy. Point-intercept sub-sampling when individual site exceeds 10 acres.
- Funding: WDNR AIS-EPC Grant

Figure 9. MMLMD's current AIS-Related Management Goals. Goals outlined in the Mount Morris Lake Comprehensive Management Plan (April 2013)



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Sources:
Roads & Hydro: WDNR
Aquatic Plant Survey: Onterra, 2017

Map date: July 7, 2017
File Name: MM_CLP_June17.mxd

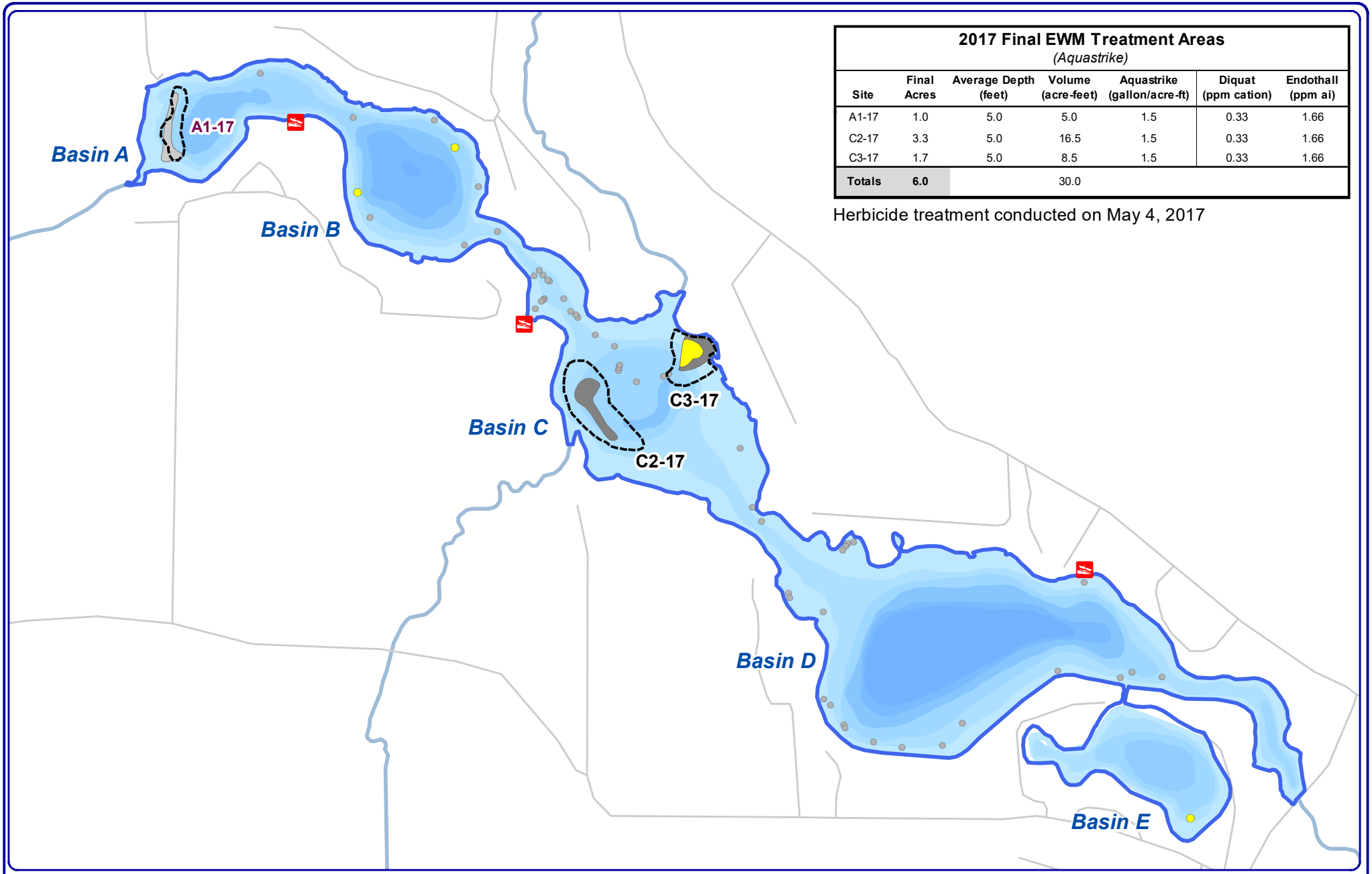
Project Location in Wisconsin

Legend

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

Map 1
Mount Morris Lake
Waushara County, Wisconsin

June 2017 CLP Survey Results



2017 Final EWM Treatment Areas
(Aquastrike)

Site	Final Acres	Average Depth (feet)	Volume (acre-feet)	Aquastrike (gallon/acre-ft)	Diquat (ppm cation)	Endothall (ppm ai)
A1-17	1.0	5.0	5.0	1.5	0.33	1.66
C2-17	3.3	5.0	16.5	1.5	0.33	1.66
C3-17	1.7	5.0	8.5	1.5	0.33	1.66
Totals	**6.0**		30.0			

Herbicide treatment conducted on May 4, 2017

N W E S

800

Feet

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Sources:
Roads & Hydro: WDNR
Aquatic Plant Survey: Onterra, 2017
Map date: October 10, 2017
File Name: MM_EWM_PB_Aug17.mxd

Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(None)*
- Surface Matting *(None)*
- Single or Few Plants
- Clump of Plants
- Small Plant Colony *(None)*
- Final 2017 Herbicide Application Area

Map 2

Mount Morris Lake

Waushara County, Wisconsin

August 2017 EWM/HWM Survey Results