Wisconsin
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Weyauwega Lake - Lake Management Plan

Weyauwega Lake Restoration Inc.

WDNR Lake Planning Grant
LPL-1558-15

Prepared by:
Wisconsin Lake and Pond Resource

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Executive Summary

Weyauwega Lake is the name of the impoundment created 161 years ago when a dam was built on the Waupaca River at Weyauwega, WI in 1855. As the impoundment ages, it has experienced decreasing water depths due to inorganic and organic sediment accumulation and an overall dense aquatic plant community, exacerbated by the presence and expansion of aquatic invasive species (AIS) curly-leaf pondweed (*Potamogeton crispus – CLP*) and flowering rush (*Botumus umbulatus - FR*). These are the main issues of concern for Lake users and hamper navigation throughout the Lake, limit enjoyment, and cause increased expenditure on actions to alleviate them. Current issues have caused the need for understanding of what is happening and why. Development of a comprehensive lake management plan for better management of the Lake is needed.

Currently, management has focused solely on periodic water level manipulation, including an extensive, complete drawdown from 2011 – spring 2013. The drawdown had dramatic results in increased depth through sediment compaction and reduction. However, this provided only temporary relief to navigation as nuisance aquatic vegetation has rebounded, mostly through a fairly new but extensive infestation of flowering rush. Additionally, continued water level manipulation for AIS control requires significant sacrifice from users of Weyauwega Lake and can many times also be controversial.

This management plan provides a multi-faceted approach to address issues and recommend management options based on best fit, cost, feasibility, and desires based on direct input from the lake user survey questions. Many sediment management options are evaluated and, while there is not one silver bullet, it is likely a combination of techniques over a period of several years will begin to yield positive results. The basic plan is based on exploration of new aquatic plant management techniques with expanded actions for AIS control, water quality improvement and a reduction in sedimentation. Some of these actions potentially include dredging, in lake or in-stream sediment control measures, addressing point and non-point source nutrient loading, herbicide applications, enhanced dam operation, and water level manipulation. It would be recommended the group start small with a specific project component or area of the lake to gain early and immediate success and build off of that for future projects.

1.0 INTRODUCTION

Weyauwega Lake (the Lake) is a shallow, 253 acre man-made drainage lake (impoundment), created by damming the Waupaca River with an average depth of 5 feet. Located in south central Waupaca County (the County) and adjacent to the City of Weyauwega, the Lake provides ample year-round recreational opportunities. The Weyauwega Lake Restoration, Inc. (WLRI) is a group of over 135 members who support the restoration and management of the Lake with a strong tradition in conservation and resource management to protect and enhance these opportunities. The WLRI has been active in a number of lake management activities on Weyauwega Lake including: aquatic plant management, water quality sampling and management, invasive species sampling, and fisheries management through stocking. The WLRI received a grant from WDNR and contracted with Stantec, which was then mutually assigned to Wisconsin Lake and Pond Resource (WLPR) to help develop a comprehensive lake management (CLM) plan for Weyauwega Lake.

2.0 LAKE USER SURVEY AND PRIMARY CONCERNS

Any management plan can only be successful if accepted by the Lake users it impacts the most. If options are laid out that are not needed or feasible, a plan is set to fail due to lack of support and this management plan is no different. Prior to drafting this plan, a questionnaire was sent out to all members of the WLRI and made available at City Hall to any interested Lake user, as this is the direct audience, and was available online for 60 days. Results of the questionnaire are included in Appendix A. This questionnaire gives us a unique look at all Lake users and a better understanding of issues, from which to develop a plan that will not only strive to improve current Lake conditions, but be successfully implemented and supported by lake users through direct response actions by the people the Lake impacts the most.

In total, 132 respondents completed the survey across an array of users with a majority (88%) residing off the water (non-riparian), showing that the Lake is important not only to riparian owners, but many surrounding residents. Responses give an opportunity to look into personal histories with Weyauwega Lake and to create an average user profile. Overall, the average user looks like this:

- 63% have used the lake for over 10 years
    - Average of 22+ year history with the lake
- Spend an average time on the water of
    - 5.5 days per month during open water
    - 4.4 days per month during ice cover
- 40% find their time enjoyable with low impact activities their top choice, including:
    - Nature viewing (#1)
    - Fishing – open water (#2) and through the ice (#3)
    - Canoeing or kayaking
    - Snowmobiling or ATV-ing

Though responses indicated enjoyable experiences on the Lake, they have changed over time.

- 24.5% indicated no change
- 68.6% indicated their use has become less enjoyable, due to:
    - Excessive aquatic plant growth
        - Negatively impacted users of the 89.3% of the time
        - Due to dense growth of native AND invasive species
    - Fishing has deteriorated
    - Increased sedimentation leading to decreased water depths – second choice
        - 87.6% believe the lake has decreased in depth
        - 39.3% chose the whole lake to be impacted by sedimentation
- Main concerns on lake health
    - Excessive aquatic plant growth
    - Aquatic invasive species
    - Quality of fishery and water quality (tie)

This plan will focus on the main two contributing factors, aquatic plants and sedimentation.

- Users very knowledgeable about AIS and potential harm, 64.3% responded in kind

- 84.9% of respondents want action to manage aquatic plants with top options being:
  - Dredging
  - Mechanical Harvesting
  - Unsure and would rely on outside recommendations from professional consulting firm
  - Drawdowns, though used in the past, are the least desired management option
- Dredging was far and away the most desired action to combat increased sedimentation
  - Focusing on surface water runoff was second, but received mainly neutral responses
  - Drawdowns were generally not desired by users for sediment control, though a partial overwinter drawdown was more palatable than an entire year or longer

The Weyauwega Lake CLM Plan includes a review of available Lake information, an aquatic plant survey, watershed assessment, and water quality evaluation to determine the most appropriate management alternatives (physical, mechanical, biological or chemical) for protection and health of the Lake. Though not all activities desired for management by lake users may be viable or appropriate, their input above provides a strong base to form this plan. The CLM plan that follows recommends specific management activities for Weyauwega Lake based on the top two management concerns indicated in the questionnaire, dense aquatic plant growth and sedimentation, to ensure not only the health of the Lake but also the enjoyment by future generations of Lake users.

3.0 LAKE HISTORY & PAST MANAGEMENT

Located in south central Waupaca County in the Town and City of Weyauwega, the Lake was created by damming of the Waupaca River in 1855 to power a grist mill. This dam was replaced in 1931 for hydroelectric power generation, which operates to this day to power over 200 homes within and around the City of Weyauwega.

Once installed on the river, the dam immediately created a new normal for the ecosystem above river flows, allowing sediment to drop out of the water column and deposit, leading to decreased water depth. One of a river's primary purposes is to transport sediment, and the installation of a dam stops this process, essentially creating a lake. This also accelerates the normal "aging" process by accumulation of sediment above the dam. The slowing of flows and increased sediment also creates new habitat for aquatic plants. When water flow is impounded and slowed down it allows sediment to disperse and accumulate within the ponded area, creating a nutrient rich environment for aquatic plants, which can lead to dense growth. Both of these problems increase as the impoundment ages.

Sedimentation and dense aquatic plant growth have increased throughout the life of Weyauwega Lake and have become the main issues for management concerns. These have been dealt with in the past by various management plans and studies, including the following:

- **Weyauwega Plant Survey – 1977**: The first documented aquatic plant survey on Weyauwega Lake indicated dense growth throughout all sampled areas with moderate diversity.
- **Weyauwega Lake Conservation Club – 1978**: Was formed to deal with lake management issues and while protecting and enhancing the lake for future generations. The club stopped management efforts in 2002, giving way to WLRI and officially disbanded in 2014. All below activities, including this plan, would not have been possible without them.
- **Weyauwega Lake Management Plan – 1991**: Work for this plan included an updated aquatic plant survey that found continued, dense aquatic plant growth including curly-leaf pondweed (CLP), an AIS. Sedimentation, both inorganic and organic, was noted as a potential issue. Recommendations focused on controlling macrophyte growth and watershed land use best management practices for nutrient and sediment control. A significant outcome of this plan was a recommendation for the Waupaca River watershed to be designated as a priority watershed, which was accomplished in 1993.
- **Weyauwega Lake Water Quality Monitoring and Sedimentation Study - 1993:** A continuation of work started in 1991. It referenced the above plan and expanded on management recommendations. Mechanical harvesting for aquatic vegetation issues was a primary recommendation. Continued emphasis on watershed land use practices upstream was recommended.
- **Weyauwega Lake Management Plan and Survey - 2001:** A review of past management plans and studies to summarize and prioritize recommendations were conducted to complete this plan. It referenced all of the above for management of aquatic plants, non-point source nutrient loading, and water chemistry.
- **Weyauwega Lake Restoration, Inc. - 2008:** WLRI holds its first meeting and immediately commits to enhancing the health of Weyauwega Lake through funding its first project, an aquatic plant survey. WLRI became an officially recognized lake association by the

WDNR in 2010 and continues to this day, providing funding and support for the following projects:

- **Aquatic Plant Survey – 2008** Updated, in-depth aquatic plant study of the lake. Only three species were sampled, down considerably from historic levels
- **Bathymetric Study – 2009** A map of water depth and depth of soft sediment within the Lake was created to estimate the amount of accumulated sediment. Measurements were made through the ice at sample points located along eight transects. Soft sediment depth ranged from none in areas scoured by the river to 8 feet, with a total estimated amount of accumulated sediment at 1,200,000 cubic yards.
- **Whole-lake drawdown – 2009-2013 Organized** and managed work completed for the whole-lake drawdown for sediment and aquatic plant control in conjunction with many interested parties, including: UW Extension, City of Weyauwega, WDNR, and Eagle Creek Renewable Energy. Associated projects with this task include:
  - **2009 –** User survey with UW Extension indicating initial public support for lake restoration.
  - **2010 –** Work with the City of Weyauwega to establish additional funding of $30,000 to complete the project
  - **July 17, 2011** – Lake drawdown begins
  - **April 11, 2013 –** Lake is refilled
  - **2014 –** Follow up bathymetric survey repeating the 2009 study. Results show that 20 inches of water depth was gained on the west end and 8 inches on the east end to do sediment compaction and reduction.

As an impoundment, the Waupaca River's watershed upstream of the dam has an immense impact on the water quality of Weyauwega Lake itself. Land use within the watershed has varying impacts on the runoff coming into the river and lake. In order to alleviate some of these issues, there have been numerous, non-point source projects to address these issues:

- **1993**: The Waupaca River Watershed was established as a priority watershed project. Throughout the course of this project work was completed by numerous conservation minded groups to protect water quality within the watershed. A priority watershed plan was prepared, which expired in 2007
- **2011 - Present**: After great initial success through the initial watershed management plan, an updated plan was created for water quality management and updated again in 2015 to be current until 2017. Priority issues were focused on continuing erosion control for sediment and nutrient loading into the Waupaca River, increased focus on groundwater withdrawals resulting in decreased base flow of streams, continued planning for lakes and rivers within the watershed, and a new focus on ground water quality degradation from excess nutrients and pesticides leaching into groundwater.

Management actions carried out for aquatic plant growth within the Lake have concentrated on nuisance management, through primarily periodic drawdowns. Issues still persisted in Weyauwega Lake after several plans were created and some management actions enacted to the level feasible, as evidenced by the concerns raised in the user questionnaire. Continuation of sedimentation and aquatic plant issues, as well as the desire to continue plant management activities, which requires an updated plan approved by the Wisconsin Department of Natural Resources (WDNR), led to creation of this CLM plan.

3.1 FISHERIES SUMMARY

As evidenced by the survey results, the fishery of Weyauwega Lake is a popular recreational pursuit, both open water and ice fishing, and important aspect for management activities. Prior to the 2011-2013 drawdown, the Lake contained a fairly robust fishery with the primary focus on panfish (mainly bluegills and black crappies), northern pike, and largemouth bass, typical of many shallow impoundments in the State.

The 2011-2013 drawdown wiped out much of the fishery, as the Lake reverted back to a small river. One of the main priorities after refilling was to re-establish the fishery with an aggressive stocking schedule. Since 2013, the WLRI has stocked over 40,000 fish in addition, augmenting those stocked by the WDNR (chart below).

Fish Stocking Within Weyauwega Lake

DNR Fisheries Stocking					
	Walleye		Northern Pike		Largemouth Bass
Year	Fry	Fingerling	Fry	Fingerling	Fingerling
1972	3111110	6000	3614000	---	3140
AFTER 2011-2013 DRAWDOWN					
2013	---	---	---	25098	7819
2014	---	---	---	25085	6215
WLRI STOCKING - 2013-2015					
Northern Pike		**Yellow Perch**	**Black Crappie**		**Largemouth Bass**
21000		2500	2500		16250

As part of the lake restoration process from the drawdown, the WDNR is monitoring the fisheries after refilling and has completed fisheries surveys using by fyke netting and electroshocking in 2014-2015 and a forth coming 2016 survey. The 2014 survey data indicated that , bluegill populations are lagging and require additional stocking in 2016 (2015 data not available as of this writing). Bluegills are difficult for the WDNR to rear in hatcheries, limiting the amount available for stocking. In order to increase the bluegill population, the WDNR will be capturing and transporting adult fish from lakes upstream, such as from the Waupaca Chain of Lakes, and transplanting them into Weyauwega Lake. The WLRI is providing substantial monetary assistance for this effort.

The 2014 survey also showed higher than average growth rates for largemouth bass and northern pike, though all fish sampled were below the legal minimum size for harvest. However, this is not unexpected due to the short time period between refilling the lake and restocking fish populations. Populations of both species have been augmented by stocking by both the WDNR and WLRI.

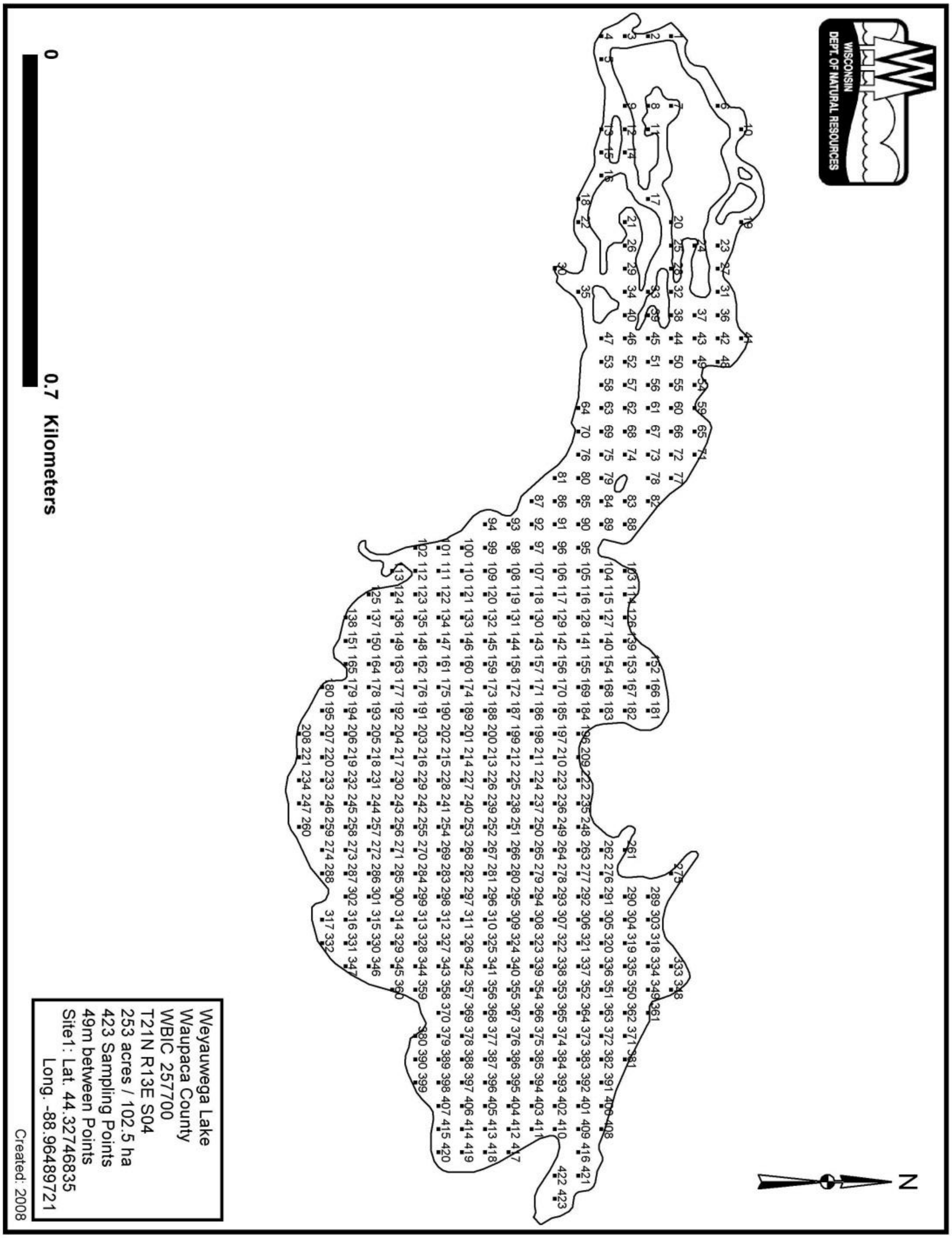
4.0 AQUATIC PLANTS

Aquatic plants are vital to the health of a water body. Unfortunately, they are often negatively referred to as "weeds". The misconceptions this type of attitude brings must be overcome in order to properly manage a lake ecosystem. Rooted aquatic plants are extremely important for the well-being of a lake community and possess many positive attributes. Despite their importance, they sometimes grow to nuisance levels that hamper recreational activities and are common in degraded ecosystems. The introduction of AIS, such as CLP or FR, often can increase nuisance conditions, particularly when they successfully out-compete native vegetation and occupy large portions of a lake.

To assess the state of the current plant community, a full point-intercept survey was completed on July 6, 2015 following all WDNR survey protocol. The survey included sampling at 423 pre-determined locations uniformly spaced 49 meters apart to document the following at each site:

- Individual species present and their density
- Water depth
- Bottom substrate

Each location was assigned coordinates and loaded into a GPS unit, which was used to navigate to each point. Data collected at each point was then entered into a WDNR spreadsheet, which outputs various aquatic plant community indexes and data, allowing for a comparison to past data to monitor changes over time. Information on methods and all referenced tables or charts is included in Appendix B.


WISCONSIN DEPT. OF NATURAL RESOURCES
N
0
0.7 Kilometers
Weyauwega Lake
Waupaca County
WBIC 257700
T21N R13E S04
253 acres / 102.5 ha
423 Sampling Points
49m between Points
Site1: Lat. 44.32746835
Long. -88.96489721
Created: 2008

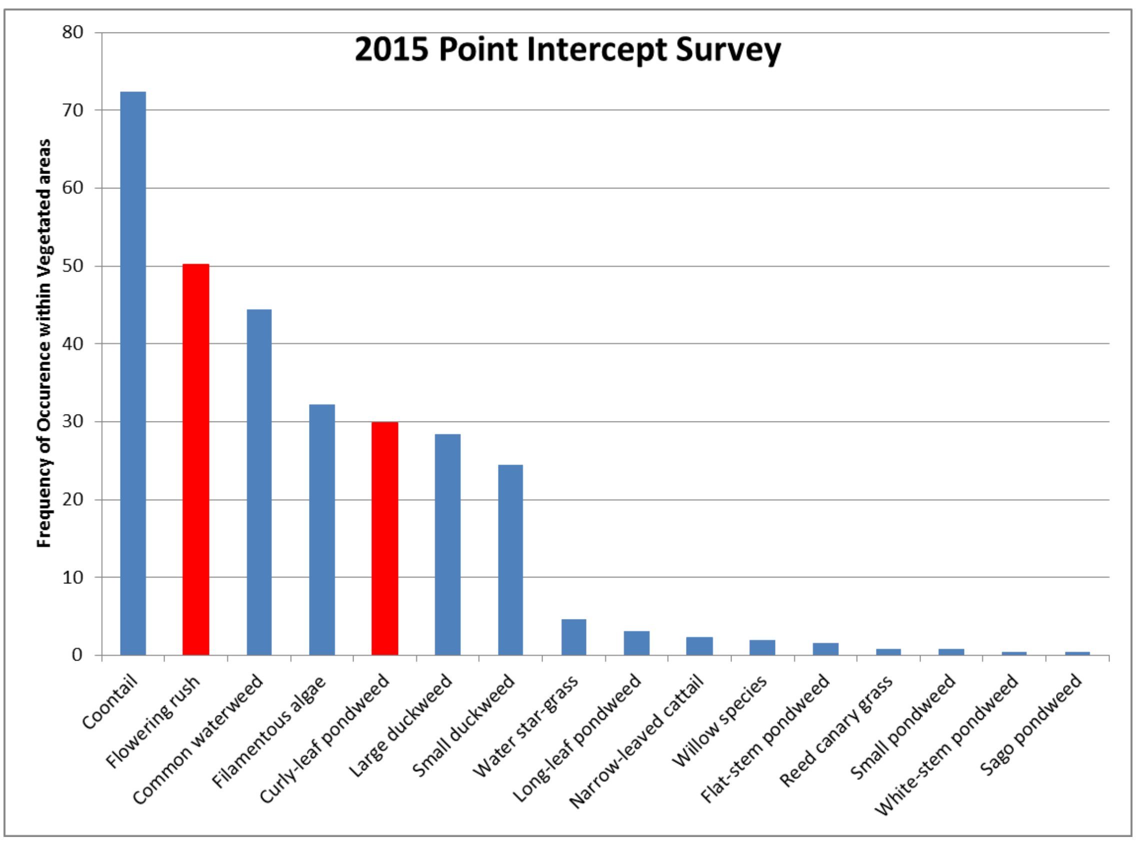
4.1 2015 POINT INTERCEPT SURVEY

In 2015, the aquatic plant survey identified a moderately diverse community with large sections of dense emergent vegetation growth. In total, 17 species were identified; two of them being AIS – curly-leaf pondweed and flowering rush (Table 1). All remaining species identified are common of such systems in Wisconsin and tolerant of disturbance.

Table 2: 2015 Aquatic Plant Community Statistics, Weyauwega Lake, Waupaca County, WI

Aquatic Plant Community Statistics	2015
F.o.o. at sites shallower than maximum depth of plants	93.5
Simpson Diversity Index	0.85
Maximum depth of plants	9.5
Avergage number of all species per site	2.65
Average number of all species per vegetated site	2.84
Average Number of native species per site	2.34
Average Number of native species per vegetated site	5.55
Species Richness	16

Species sampled in Weyauwega Lake were present in three categories: free floating plants (duckweed species - *Lemna sp.*) which do not root, float on the water's surface and uptake nutrients directly from the water; emergent, near shore species which are rooted below the water's surface with growth extending above the water (cattail - *Typha sp.);* and submersed species which root on the Lake bottom and remain below the water's surface (common waterweed – *Elodea canadensis*).



With nearly the entire Lake within the photic zone, <9.5 feet deep, plant growth was locally dense with 93.5% of the waterbody vegetated. Much of the sediment is muck. This soft, rich sediment provides ideal conditions for aquatic plants. Species richness was about average at 18 and exhibited moderately good diversity per sample point averaging 2.84 species per vegetated site with a moderately good spread throughout the system, as exhibited by a Simpson Diversity Index (SDI) of 0.83. An SDI value closer to 1.0 indicates a healthier, more evenly spread plant community. Coontail (*Ceratophyllum demersum*) and flowering rush, an AIS, were the most dominant species present (Table 3, Figures 1.1 – 1.7).

Curly-leaf pondweed (CLP) was sampled during the 2015 survey at 78 locations, the fifth most common species, and approximately 51 acres. As an invasive species with aggressive growth tendencies, CLP has nearly doubled in abundance since the past survey in 2014 (28.7 ac) and expanded beyond pre-drawdown amounts from 2008 (Figure 2).

Flowering rush, an emergent AIS, was the second most common species sampled at 189 locations, or 44.4% of the photic zone. This species was new to the lake during the 2015 survey, but was first documented growing in exposed sediments during the 2011-2013 drawdown. Flowering rush is unique as a mainly emergent species in that it can survive as a completely submersed form as well. The 2013 refilling of Weyauwega Lake was expected to have drowned out nearly all of the flowering rush present. However, as the 2015 survey shows (Figure 3), it was not successful and there is roughly a 2:3 ratio of emergent versus submersed flowering rush present. Much of the emergent flowering rush is extremely dense, hampering and even preventing navigation of watercraft through it, even in water up to three feet deep while the submersed form was found growing in water up to 7.5 feet deep. The 2015 survey found approximately 60 acres of submersed and 80 acres of emergent flowering rush (Figure 4).

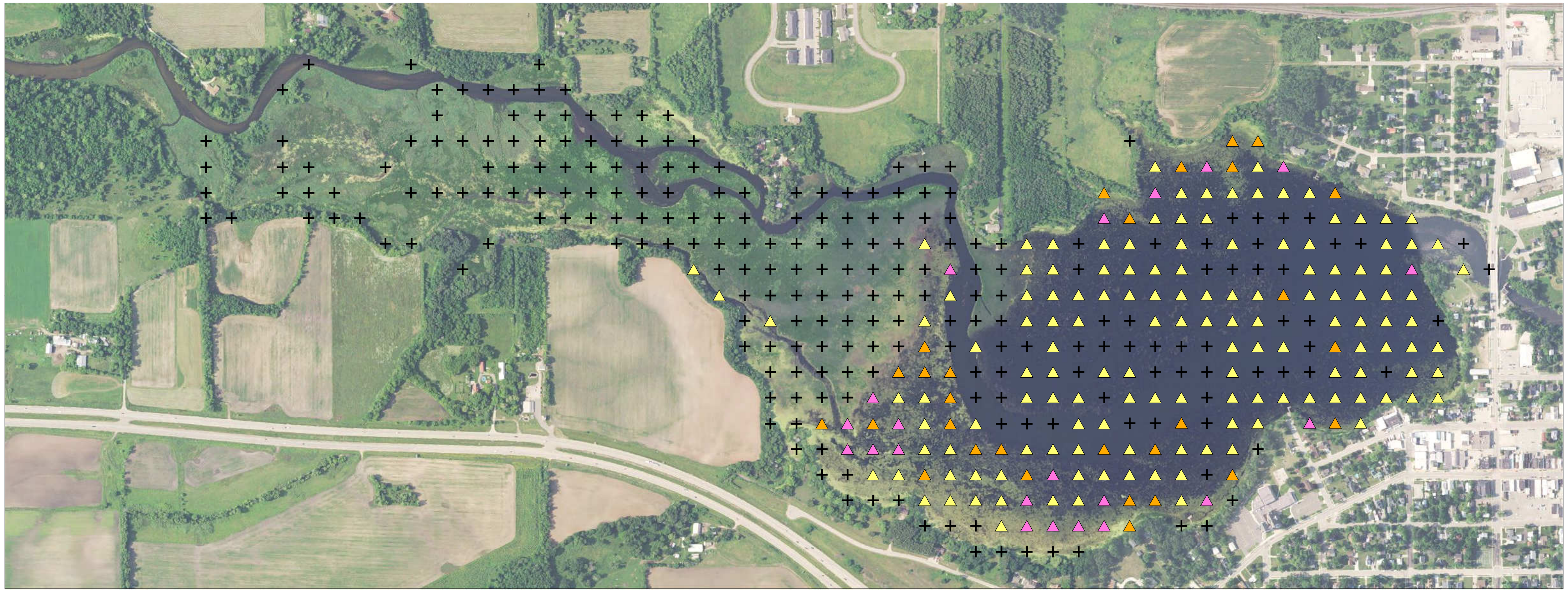
4.2 FLORISTIC QUALITY INDEX

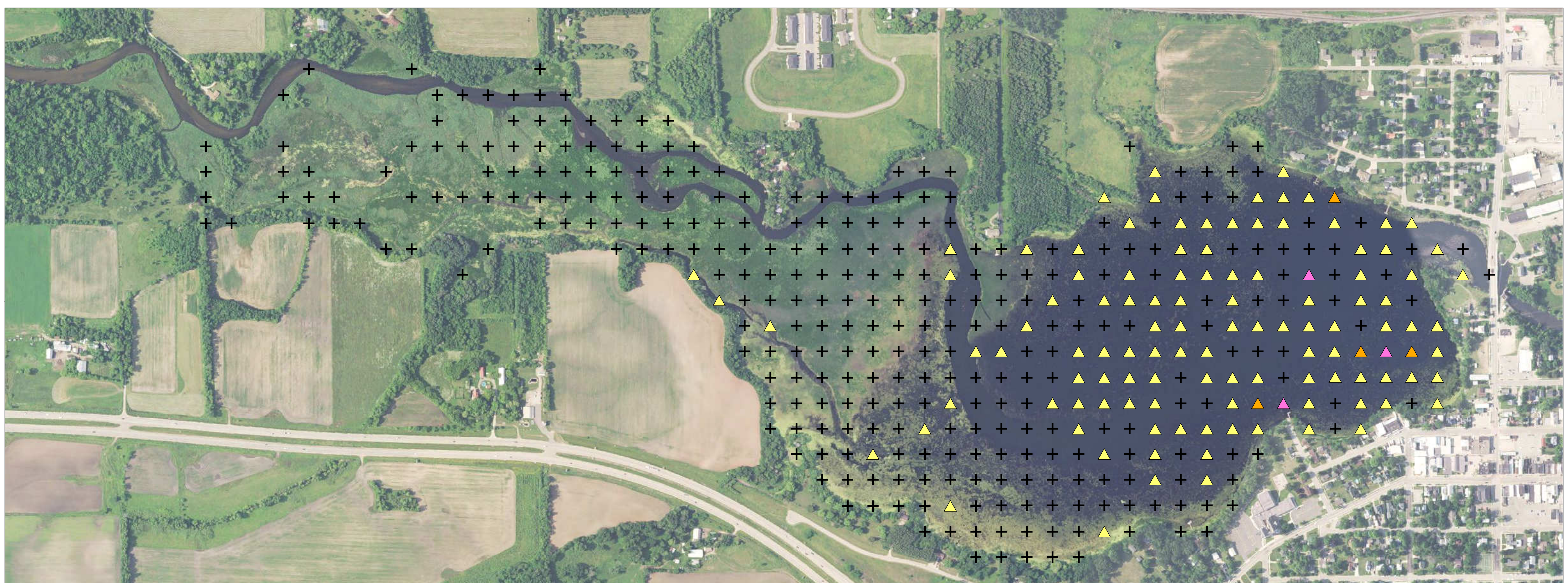
To compare changes in the plant community over time within Weyauwega Lake and to similar lakes in Wisconsin, the floristic quality index (FQI) can be used. FQI provides the ability to compare aquatic plant communities based on species presence. This value varies throughout Wisconsin, ranging from 3.0 to 44.6 with a statewide average of 22.2. To achieve this, each plant species, except for AIS, is assigned a coefficient of conservatism value (C values). A plant's C value relates to a plant species' ability to tolerate disturbance. Low C values (0-3) indicate that a species is very tolerant of disturbance, while high C values (7-10) indicate species with a low tolerance of disturbance and typically found in systems of higher water quality. Intermediate C values (4-6) indicate plant species that can tolerate moderate disturbance.

Table 4: 2015 Floristic Quality Index, Weyauwega Lake, Waupaca County, WI

Common Name	Coefficient of Conservatism C
Common waterweed	3
Coontail	3
Flat-stem pondweed	6
Large duckweed	5
Long-leaf pondweed	7
Narrow-leaved cattail	1
Sago pondweed	3
Small duckweed	4
Small pondweed	7
Water star-grass	6
White-stem pondweed	8
Total Species	11
Mean C	4.82
Floristic Quality Index (FQI)	**15.98**

Coontail *(Ceratophyllum demersum)*





Common Waterweed *(Elodea canadensis)*

Figure No.
1.1

Title
2015 PI Survey: Weyawega Lake Common Waterweed and Coontail

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

0 400 800
Feet
1:9,600 (At original document size of 11x17)

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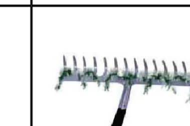
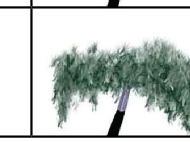
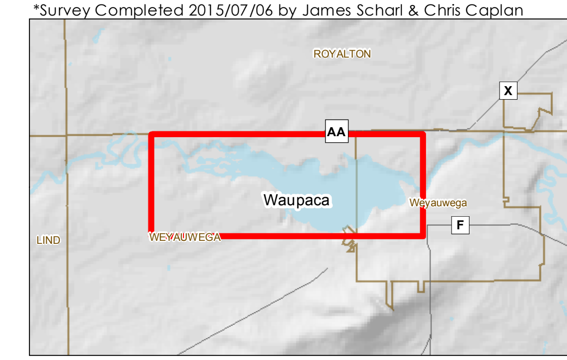
Legend
- + GPS Sample Points*
- △ Fullness Rating 1
- △ Fullness Rating 2
- △ Fullness Rating 3

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover tines.
3		The rake is completely covered and tines are not visible.

*Survey Completed 2015/07/06 by James Scharl & Chris Caplan



Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

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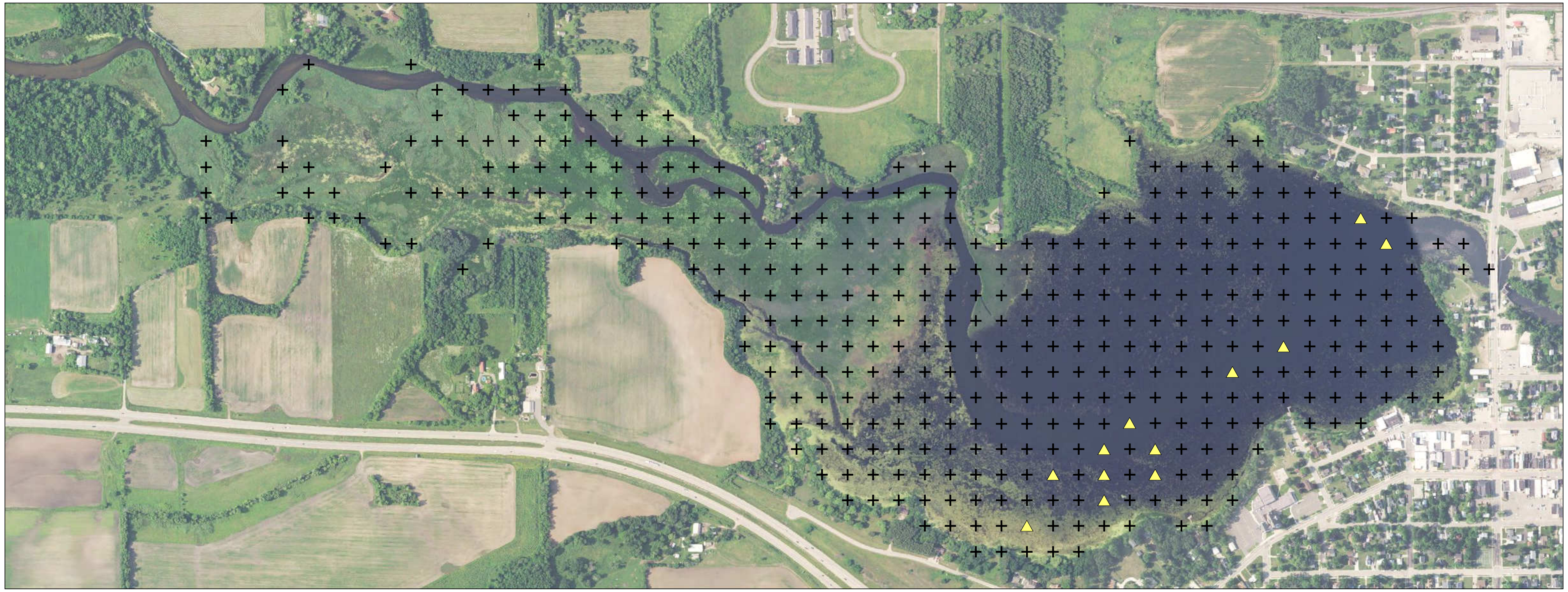
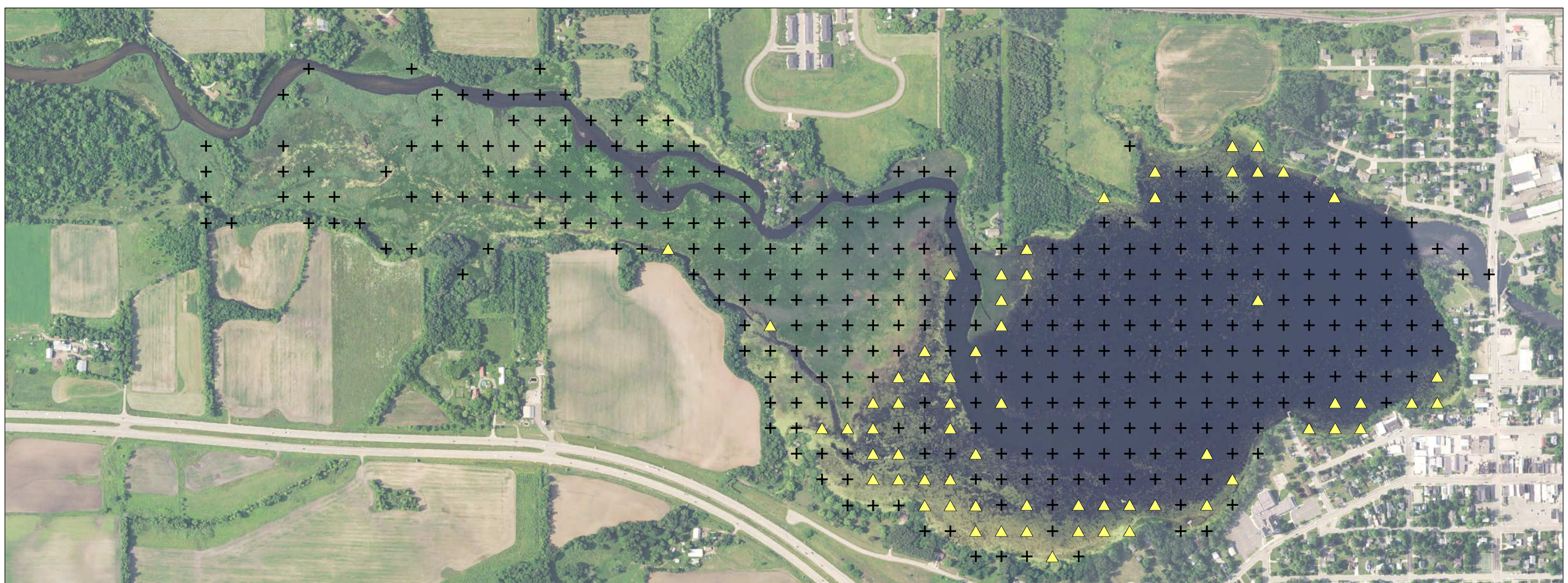
Water Star-grass *(Heteranthera dubia)*





Small Duckweed *(Lemna minor)*

Figure No.
1.2

Title
2015 PI Survey: Weyawega Lake Water Star-grass and Small Duckweed

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

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1:9,600 (At original document size of 11x17)

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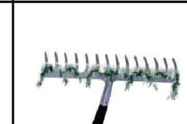
Legend
- GPS Sample Points*
- Fullness Rating 1
- Fullness Rating 2
- Fullness Rating 3

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
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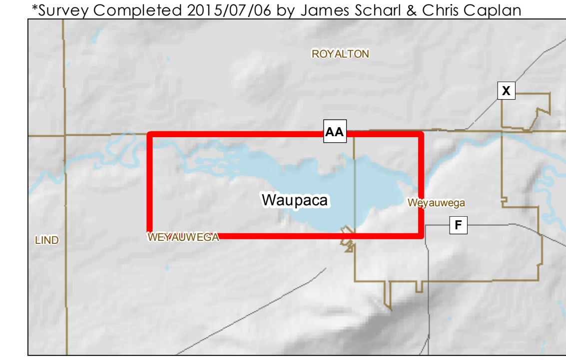
*Survey Completed 2015/07/06 by James Scharl & Chris Caplan



Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

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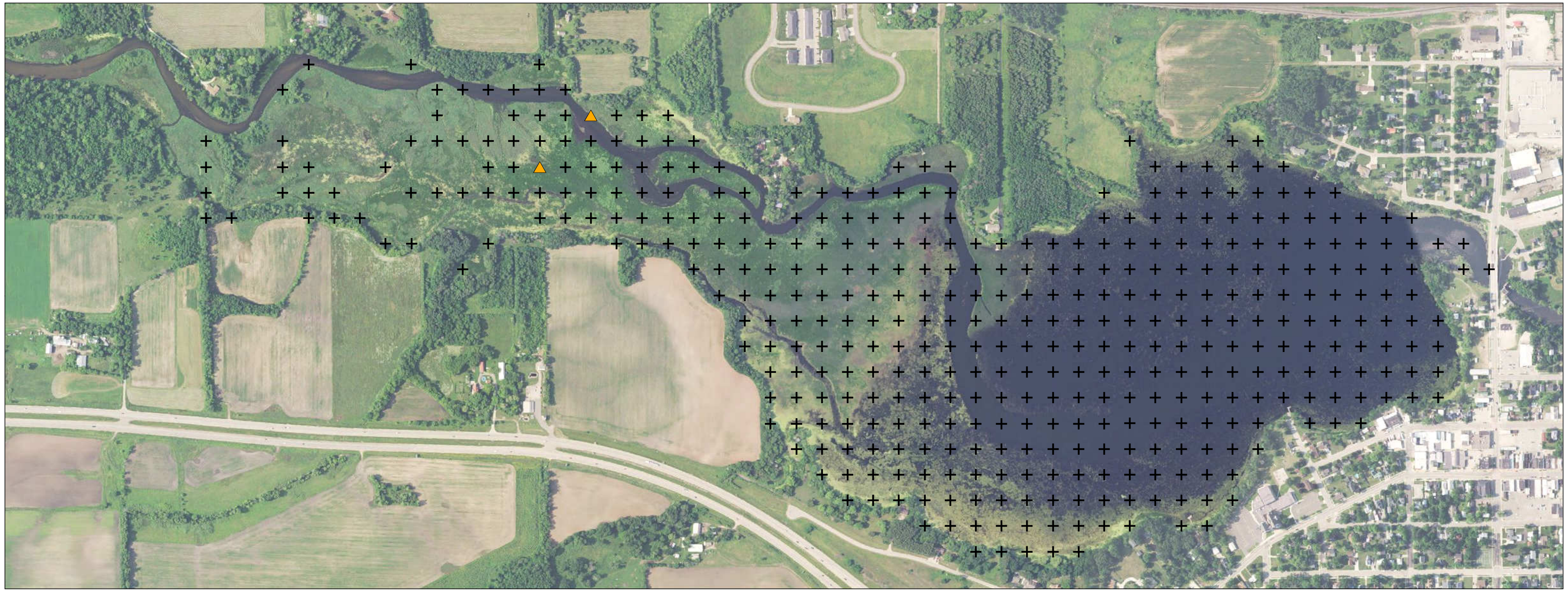
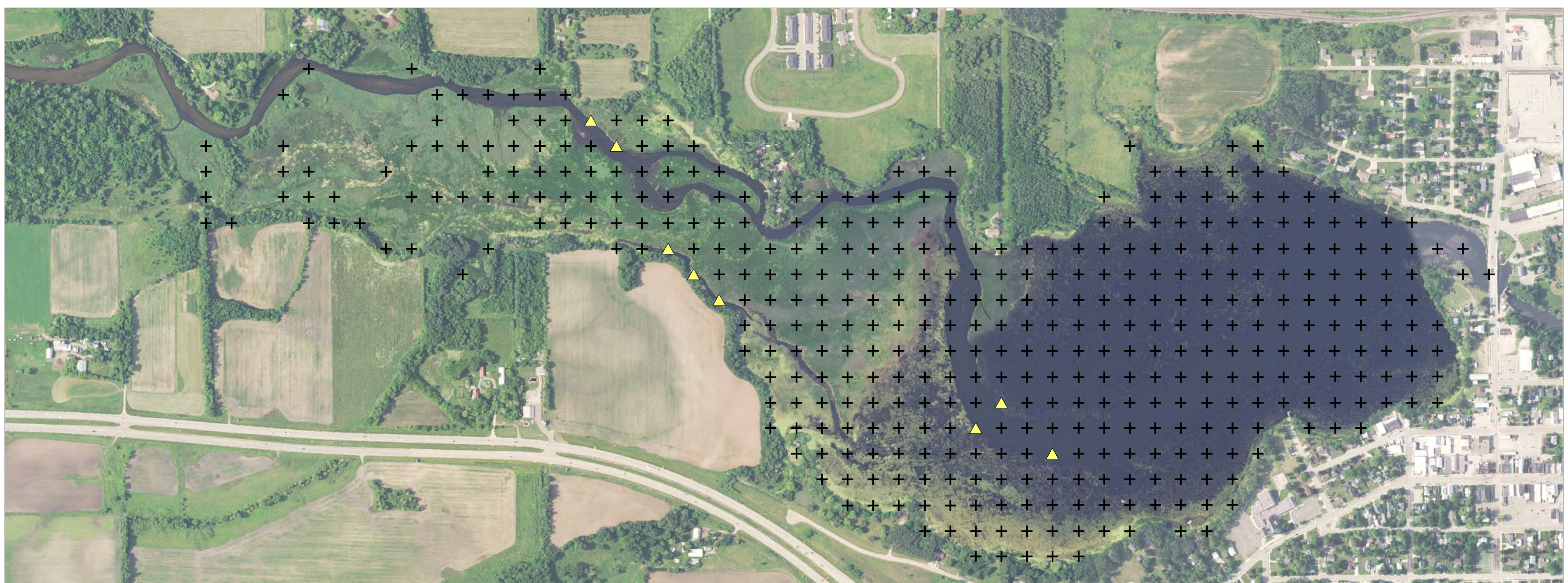
R:\gis\other PCs\193702943 AIS Waupaca ChainLakes\07 gis\mxds\2015\PI Weyauwega Star SmallDuck 2015.mxd Revised: 2016-01-04 By: Ksoltau

Reed Canary Grass *(Phalaris arundinacea)*





Long-leaf Pondweed *(Potamogeton nodosus)*

Figure No.
1.3

Title
2015 PI Survey: Weyawega Lake Reed Canary Grass and Long-leaf Pondweed

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

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Feet
1:9,600 (At original document size of 11x17)

N

Legend
- + GPS Sample Points*
- △ Fullness Rating 1
- △ Fullness Rating 2
- △ Fullness Rating 3

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
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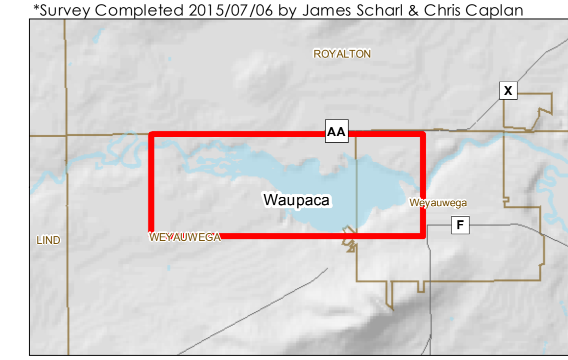

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1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

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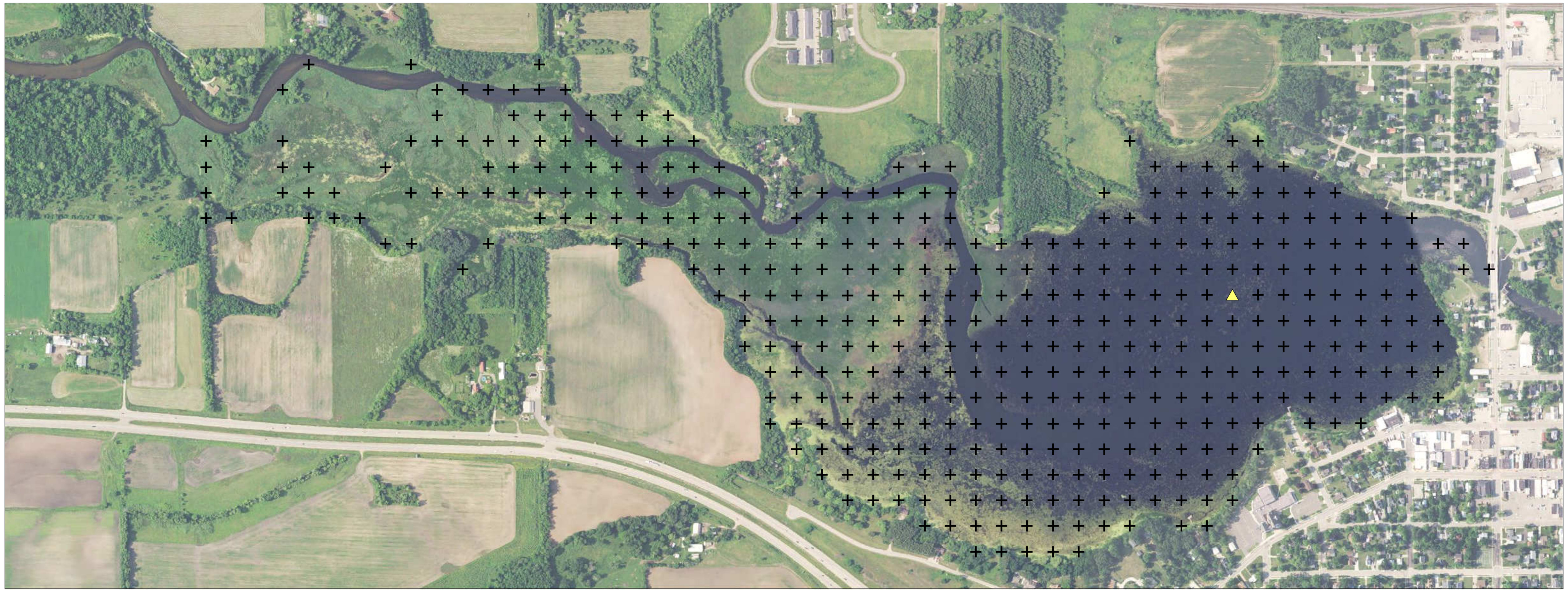
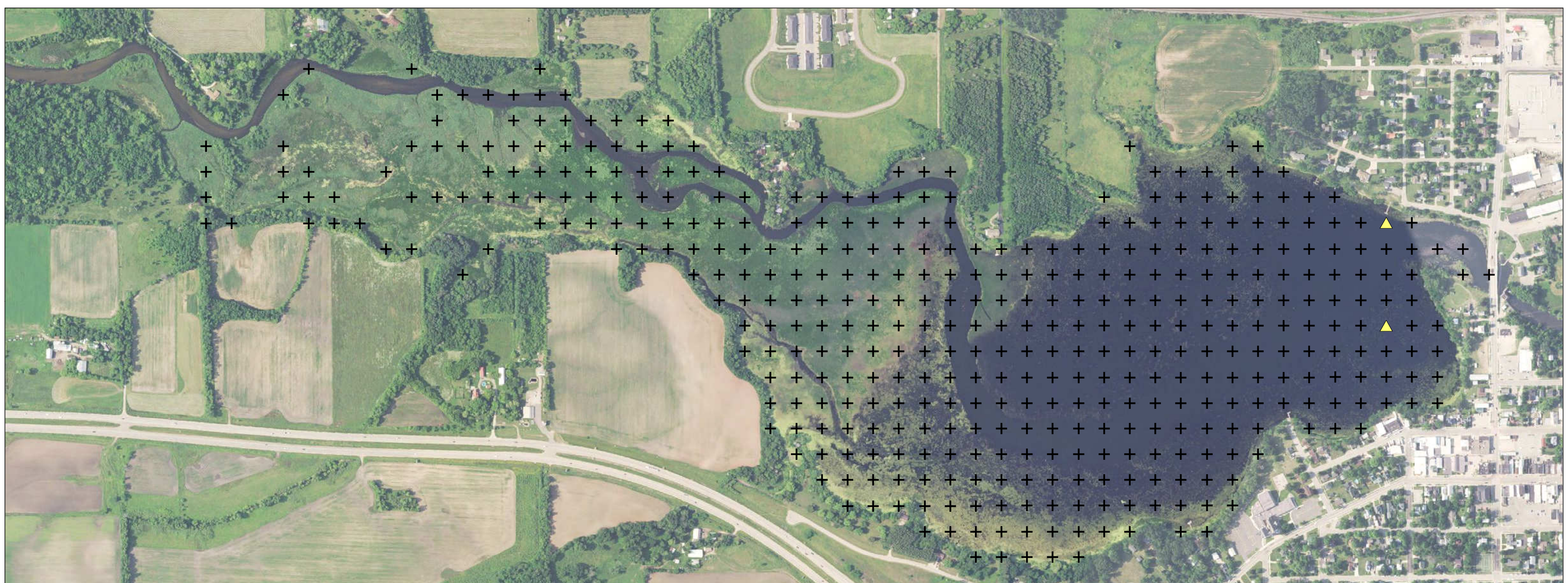
White Stem Pondweed *(Potamogeton praelongus)*





Small Pondweed *(Potamogeton pusillus)*

Figure No.
1.4

Title
2015 PI Survey: Weyawega Lake White Stem Pondweed and Small Pondweed

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

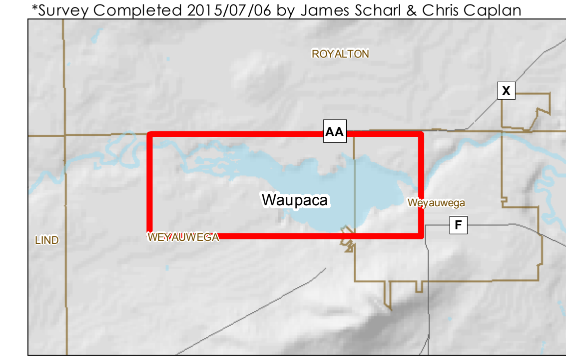
0 400 800 Feet
1:9,600 (At original document size of 11x17)

N

Legend
- + GPS Sample Points*
- △ Fullness Rating 1
- △ Fullness Rating 2
- △ Fullness Rating 3

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover tines.
3		The rake is completely covered and tines are not visible.

*Survey Completed 2015/07/06 by James Scharl & Chris Caplan

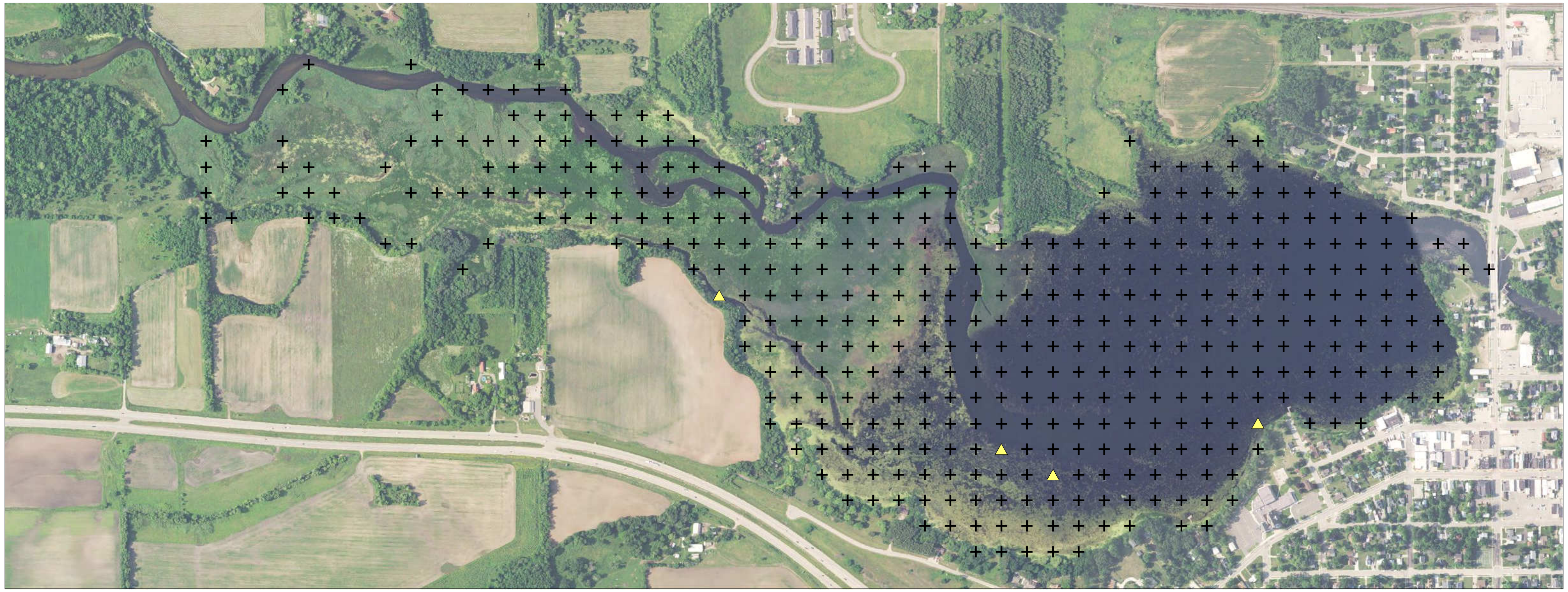


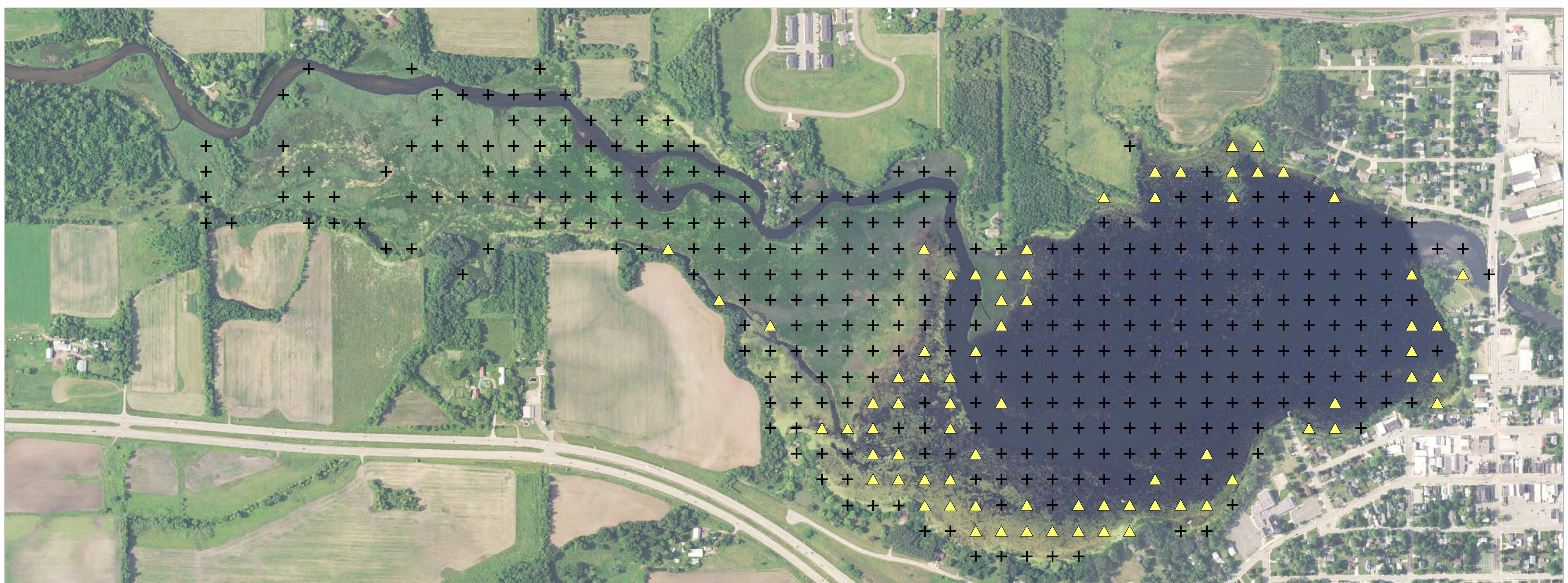
Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

[redacted]

R:\gis\other PCs\193702943 AIS Waupaca ChainLakes\07 gis\mxds\2015\PI Weyauwega WhiteStem SmallPond 2015.mxd Revised: 2016-01-04 By: Ksoltau

Flat Stem Pondweed *(Potamogeton zosteriformis)*





Large Duckweed *(Spirodela polyrhiza)*

Figure No.
1.5

Title
2015 PI Survey: Weyawega Lake Flat Stem Pondweed and Large Duckweed

Client/Project
Weyauwega Lake Restoration, Inc.

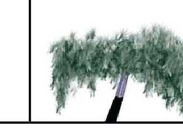
Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

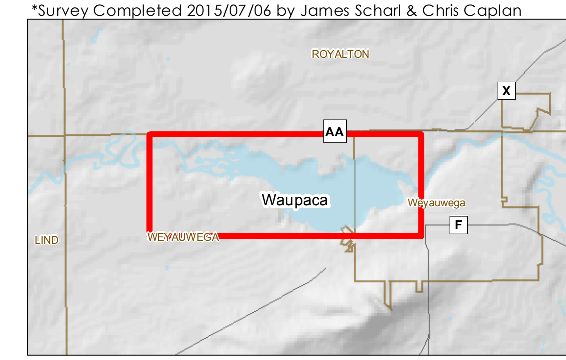
0 400 800 Feet
1:9,600 (At original document size of 11x17)

N

Legend
+ GPS Sample Points*
△ Fullness Rating 1
△ Fullness Rating 2
△ Fullness Rating 3

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover tines.
3		The rake is completely covered and tines are not visible.

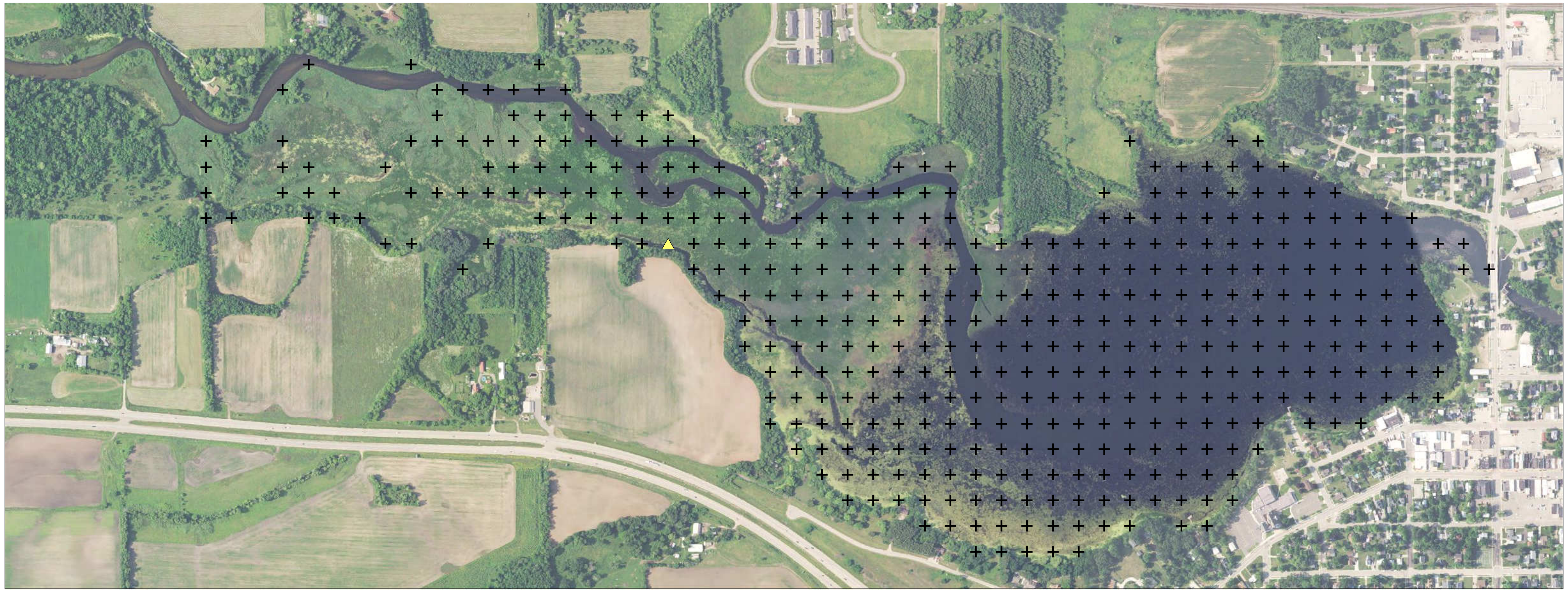
*Survey Completed 2015/07/06 by James Scharl & Chris Caplan

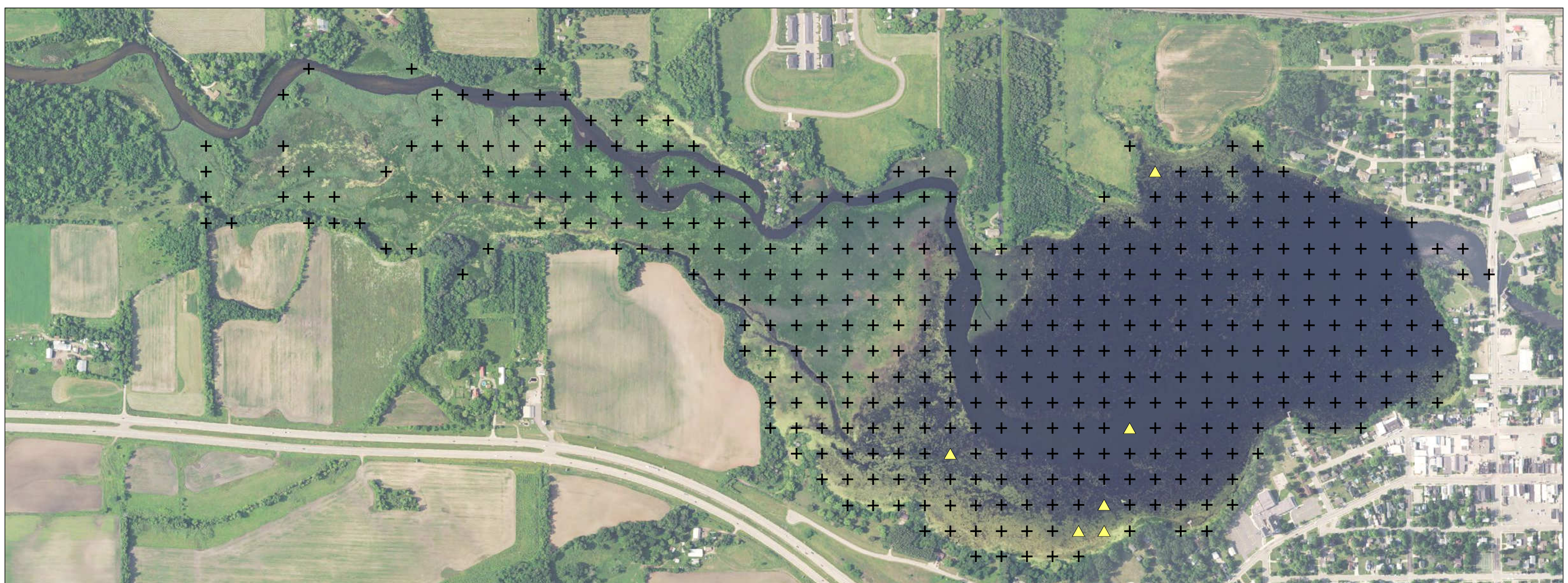


Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

[redacted]

Sago Pondweed *(Stuckenia pectinata)*





Narrow-leaved Cattail *(Typha angustifolia)*

Figure No.
1.6

Title
2015 PI Survey: Weyawega Lake Sago Pondweed and Narrow-leaved Cattail

Client/Project
Weyauwega Lake Restoration, Inc.

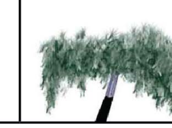
Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

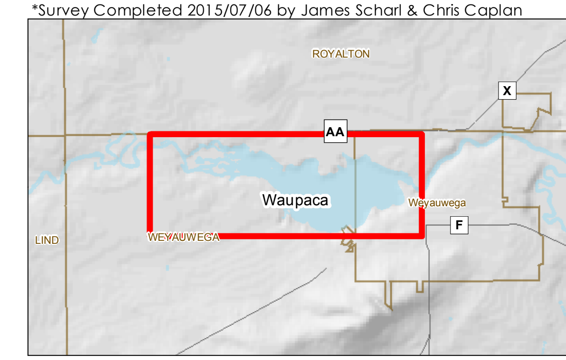
0 400 800 Feet
1:9,600 (At original document size of 11x17)

N

Legend
- + GPS Sample Points*
- Fullness Rating 1
- Fullness Rating 2
- Fullness Rating 3

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

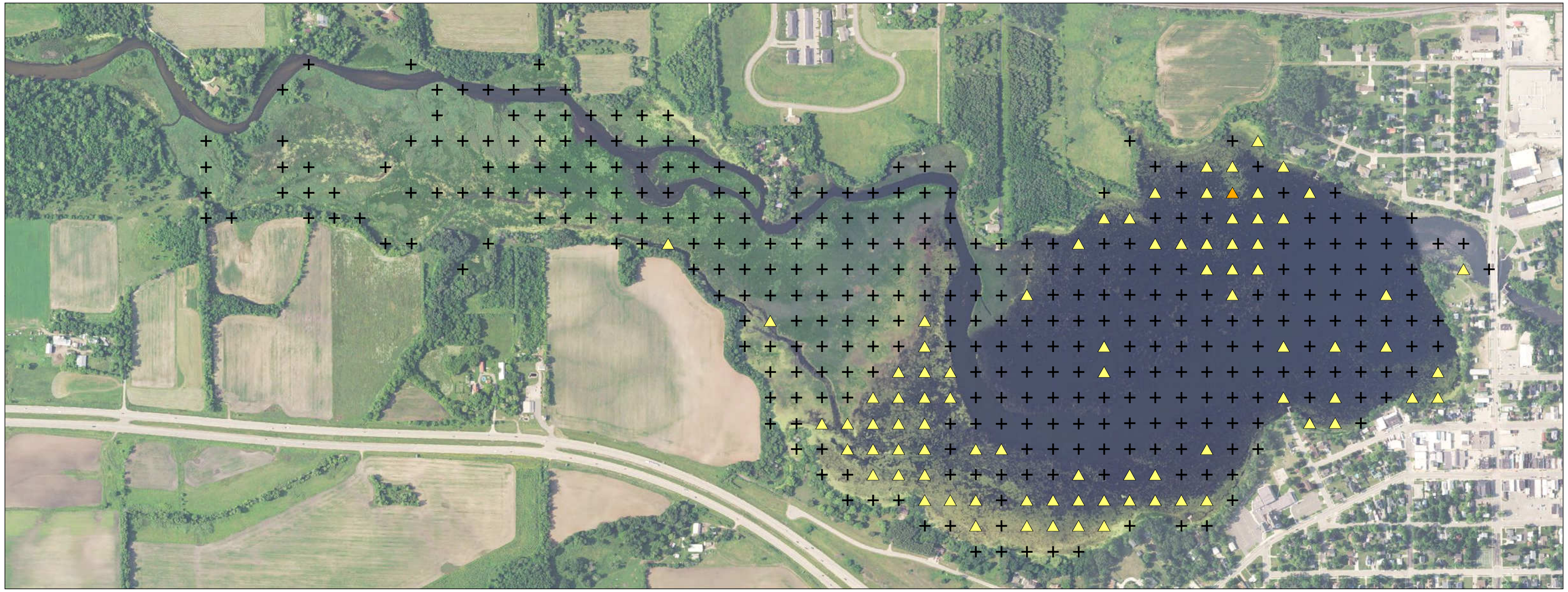
*Survey Completed 2015/07/06 by James Scharl & Chris Caplan

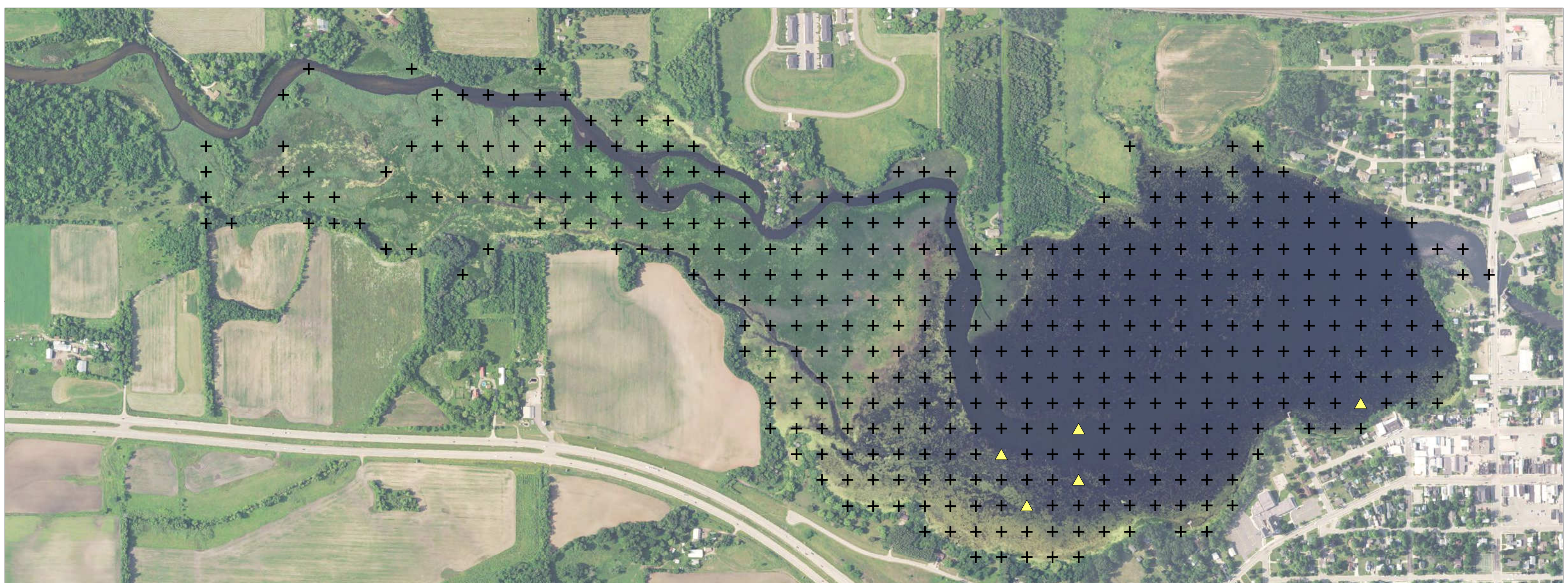


Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

[redacted]

Filamentous Algae





Willow *(Salix sp.)*

Figure No.
1.7

Title
2015 PI Survey: Weyawega Lake Filamentous Algae and Willow

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by XXX on 2016-XX-XX

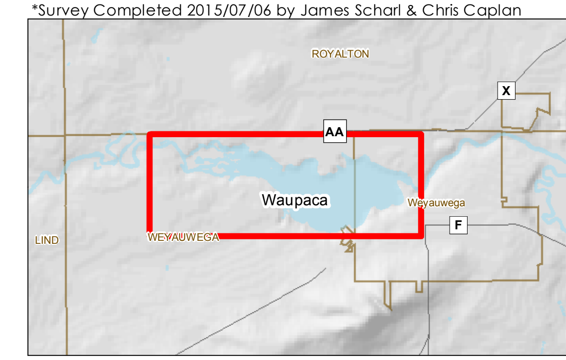
0 400 800 Feet
1:9,600 (At original document size of 11x17)

N

Legend
- GPS Sample Points*
- Fullness Rating 1
- Fullness Rating 2
- Fullness Rating 3

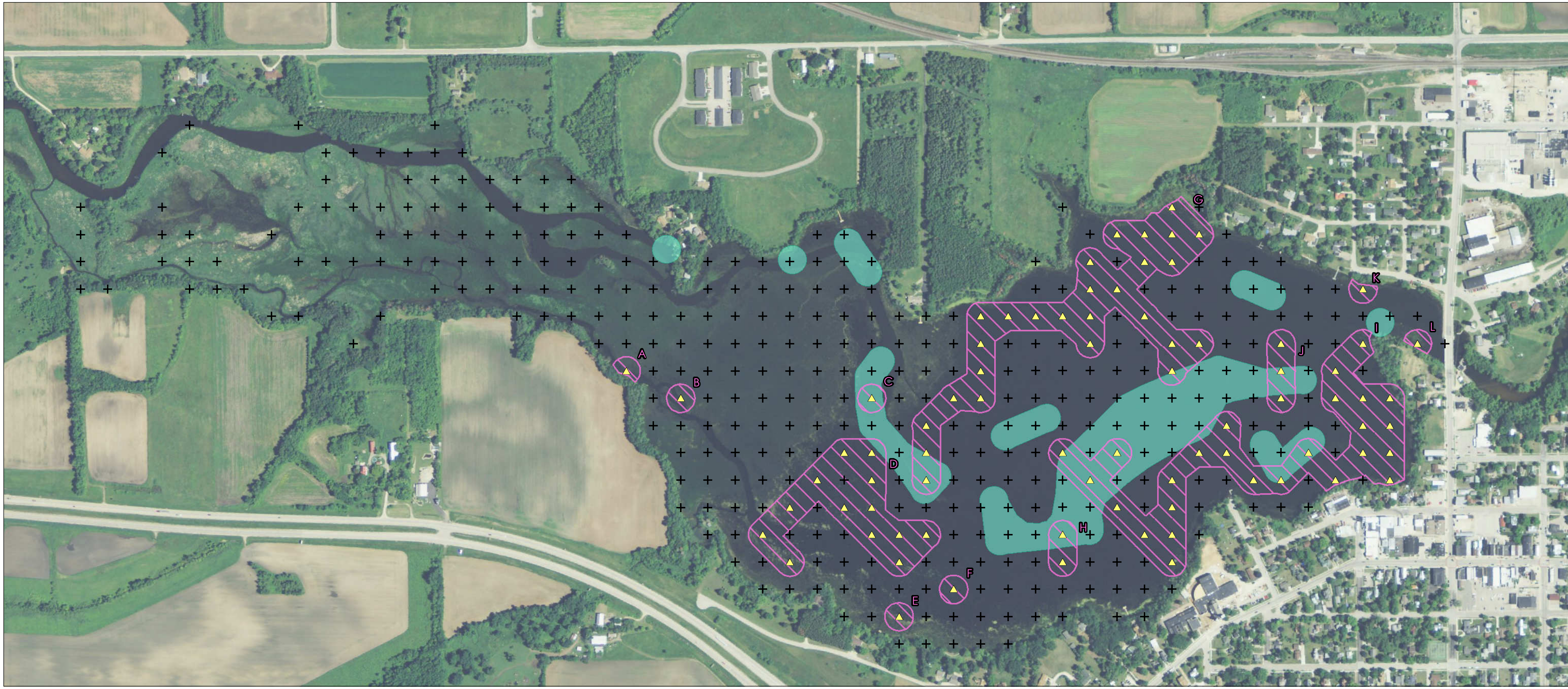
Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover tines.
3		The rake is completely covered and tines are not visible.

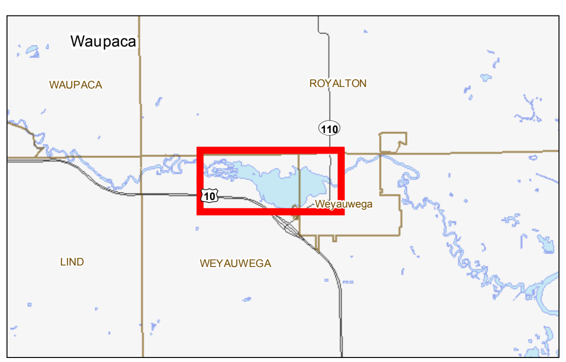
*Survey Completed 2015/07/06 by James Scharl & Chris Caplan



Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec
3. Orthophotography: 2015 NAIP

[redacted]





Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec, WDNR, WisDOT
3. Orthophotography: 2013 NAIP

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2015 AIS Area (acreage)												
A	B	C	D	E	F	G	H	I	J	K	L	**Total**
0.33	0.50	0.50	9.78	0.50	0.50	17.58	1.11	17.92	1.71	0.36	0.34	**51.12**

Legend
- GPS Sample Points*
- Curly-leaf Pondweed (Fullness Rating 1)
- 2015 Aquatic Invasive Plant Area (51.12 ac)
- 2014 Aquatic Invasive Plant Area (28.68 ac)

*Survey Completed 2015/07/06 by James Scharl & Chris Caplan

Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover tines.
3		The rake is completely covered and tines are not visible.

Figure No.
2

Title
Weyauwega Lake Curly-leaf Pondweed

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2015-07-30
Technical Review by JD on 2015-07-30
Independent Review by MK on 2015-08-27

0 300 600 Feet
1:7,200 (At original document size of 11x17)

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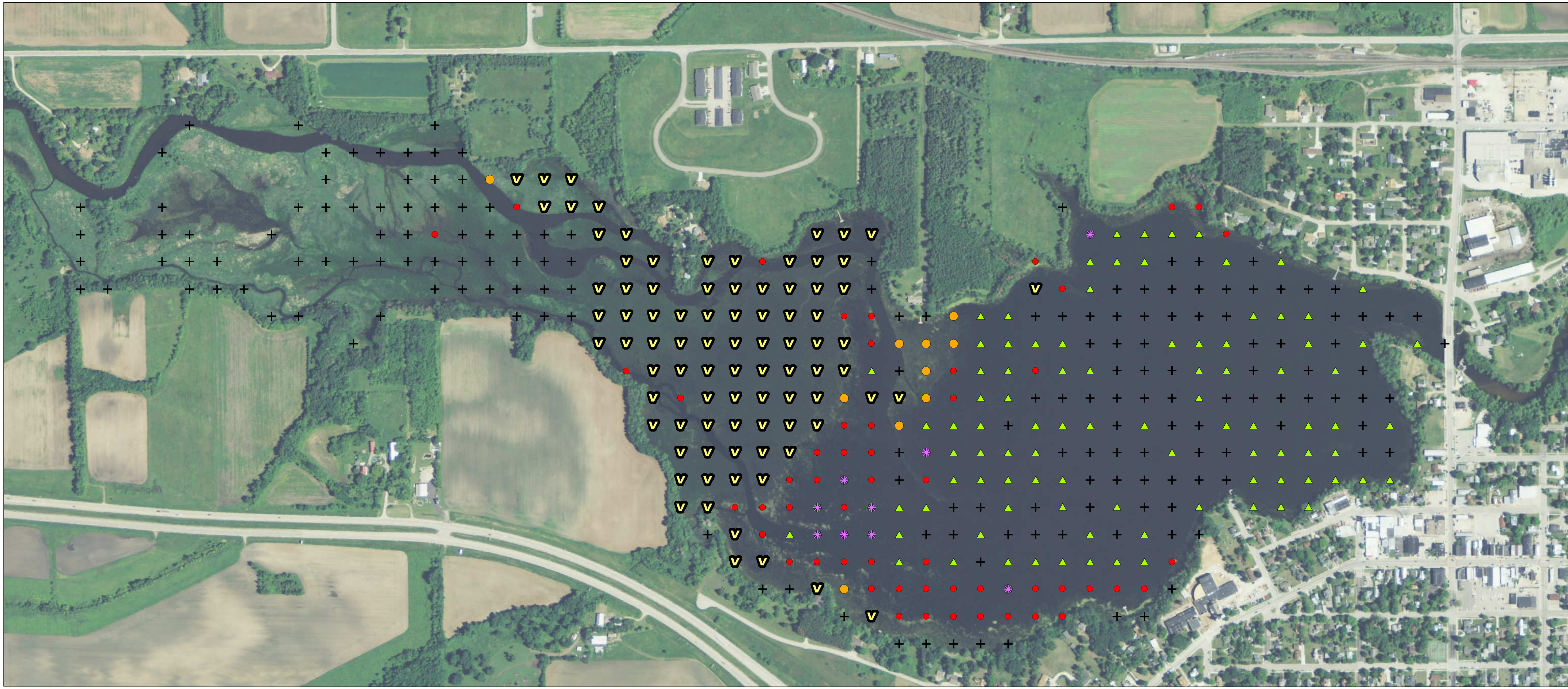
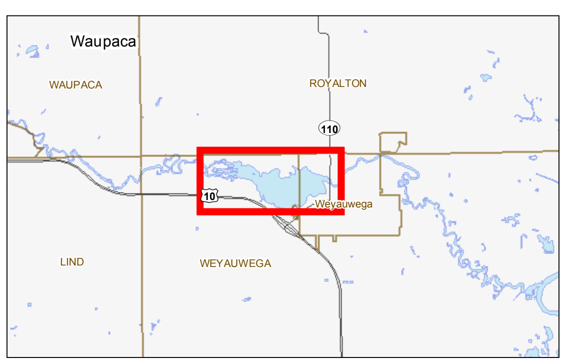




Legend

- + GPS Sample Points*
- ▲ Submergent (Fullness Rating 1)
- ● Emergent (Fullness Rating 1)
- ● Emergent (Fullness Rating 2)
- V Emergent Visual (Too dense/thick to survey)
- ✳ Emergent & Submergent (Fullness Rating 1)

*Survey Completed 2015/07/06 by James Scharl & Chris Caplan

Notes

1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec, WDNR, WisDOT
3. Orthophotography: 2013 NAIP

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

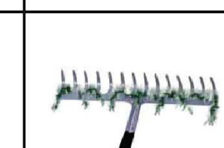
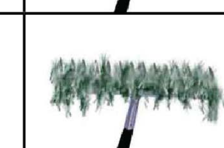
Fullness Rating	Coverage	Description
1		Few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover tines.
3		The rake is completely covered and tines are not visible.

Figure No.
3

Title
Weyauwega Lake Flowering Rush

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

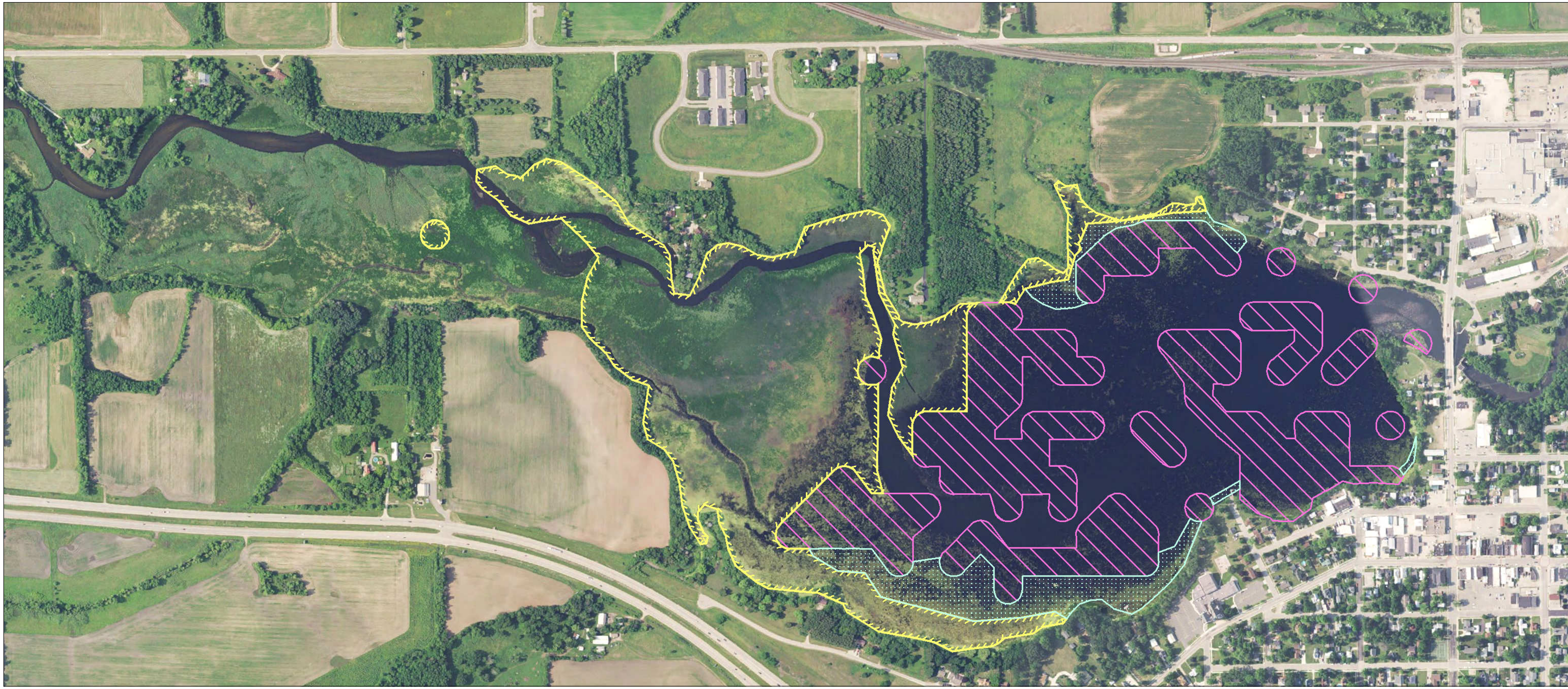
193703396
Prepared by KAS on 2015-07-30
Technical Review by AB on 2015-07-30
Independent Review by MK on 2015-08-27

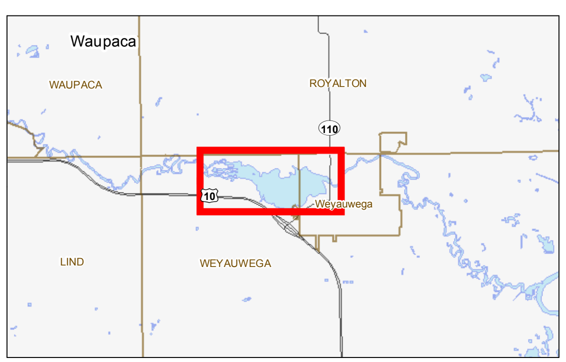
0 300 600 Feet
1:7,200 (At original document size of 11x17)

N

[redacted]

R:\gis\other_PCs\193702943_AIS_Waupaca_ChainLakes\07_gis\mxds\2015\AIS_Weyauwega_Rush_Survey_2015.mxd Revised: 2015-08-06 By: ksoltau





Legend

Submergent Aquatic Invasive Area - 60.9 ac

Emergent Aquatic Invasive Area

Scattered - 12.9 ac

Thick/ Dense (non-navigable) - 76.2 ac

Notes

1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec, WDNR, WisDOT
3. Orthophotography: 2015 NAIP

Figure No.
4

Title
Weyauwega Lake Flowering Rush Areas

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2015-07-30
Technical Review by AB on 2015-07-30
Independent Review by MK on 2015-08-27

0 300 600 Feet
1:7,200 (At original document size of 11x17)

N

[redacted]

Not only does this track changes over time within the Lake, but allows for comparison of the Lake to lakes with similar environmental conditions within a delineated area, called an eco-region, to be compared. Weyauwega Lake is located within the North Central Hardwood Forests eco-region. Lakes within the North Central Hardwoods region are typically natural lakes created by glaciation.

Weyauwega Lake is found near the eastern border of the ecoregion within the Green Bay till and lacustrine plain sub-region. Lakes within this area are primarily seepage lakes that can have fluctuating water levels, especially during dry years, due to the mainly sandy soils. Land use varies within the region from primarily forest to agricultural watersheds with most lakes having at least moderate development along the shoreline.

This area also contains numerous, small impoundments. These impoundments were created by damming and originally established for hydro power for various milling practices and commonly called millponds. Many of these impoundments have exceeded their life expectancy and are deteriorating while some have converted to produce hydro-electric power. Lakes within this eco-region have increased development around the lake and increased overall use leads to more disturbances from an expected natural condition, which leads to lower plant community metrics like FQI and coefficient of conservatism. Both of these are below the average for all Wisconsin lakes due to this (Table 5).

Table 5: FQI and Average Coefficient of Weyauwega Lake Compared to Wisconsin and North Central Hardwoods Ecoregion.

	Average Coefficient of Conservatism			Floristic Quality		
Quartile*	Lower	Mean	Upper	Lower	Mean	Upper
Wisconsin Lakes	5.5	6	6.9	16.9	22.2	27.5
North Central Hardwoods Ecoregion	5.2	5.6	5.8	17	20.9	24.4
1977	4.5			12.73		
1991	5.21			19.51		
2000	4.4			13.91		
2008	3.57			9.45		
2015	4.82			15.98		

* - Values indicate highest value of the lowest quartile, mean, and lowest value of the upper quartile

Due to high agricultural use within watershed for lakes within the region, many impoundments have a disturbed plant community. Excess nutrients and increased sedimentation, speed up shallowing of the lake and allow light to penetrate to more area, often causing dense plant growth, hampering navigation and use of the Lake. This is true for Weyauwega Lake and though AIS are present, there is a moderately diverse native plant community still present. 12 native species were found during the 2015 survey with an average of 2.08 native species per sample point with vegetation present with many sample points having more than this and up to five native species present. This native plant community is important, should any AIS management continue, as they are already established and present to populate areas vacated by AIS due to potential management. Many impoundments with AIS growth, especially within this region, lack a native community to do so.

The FQI calculated from the 2015 aquatic plant survey data was 15.98 with an average C of 4.82. These values, when compared to the North Central Hardwood Forests Eco-region means of 20.9 and 5.6 respectively, are below average for both.

4.3 HISTORICAL COMPARISON

The aquatic plant community of Weyauwega Lake has been sampled numerous times throughout its history, providing a unique opportunity to gauge changes over the years. Sampling began with line-transect surveys in 1977 and was repeated in 1991 and 2000. Aquatic plant sampling protocol was changed by the WDNR to be more repeatable with point intercept surveys. A full point intercept survey was first completed in 2008 and repeated at all locations in 2015.

The relative plant community within the lake has fluctuated over time, decreasing as the impoundment aged from 1977 to 2008 with a high of 16 species in 1991 to a low of 10 in 2008. However, this trend was reversed after the full drawdown, which helped to rejuvenate the community and increase diversity up to 16 species (Table 6).

Table 6: Species sampled by year, Weyauwega Lake, Waupaca County, WI.

	1977	1991	2008	2015
Invasive Species				
Curly-leaf Pondweed	X	X	X	X
Flowering rush				X
Free-floating Species				
Common watermeal		X	X	
Duckweed species	X			
Large duckweed				X
Small duckweed		X	X	X
Floating-leaf species				
Watershield		X		
White water lily		X		
Emergent Species				
Arrowhead species	X			X*
Bur-reed species			X*	X*
Cattail	X	X	X*	X
Common arrowhead			X	
Reed canary grass				X
Rush species		X		X*
Sedge species	X			X*
Willow species				X
Submersed Species				
Clasping-leaf pondweed		X		
Common waterweed	X	X	X	X
Coontail	X	X	X	X
Fern pondweed	X			
Flat-stem pondweed	X	X		X
Large-leaf pondweed		X		
Leafy pondweed	X	X		
Long-leaf pondweed				X
Milfoil species	X			
Muskgrass		X		
Sago pondweed	X			X
Small pondweed				X
Water star-grass	X			X
White-stem pondweed		X		X
Wild celery / eel grass		X	X	

* - Species noted visualy only

As the Lake aged, species diversity, average coefficient of conservatism, and FQI had declined over time. These trends play out and are shown below for all metrics over time when comparing historical survey data.

Table 7: Historical Aquatic Plant Community Statistics, Weyauwega Lake, Waupaca County, Wisconsin.

	1977	1991	2000	2008	2015
F.o.o. within photic zone	---*	---*	---*	99.52	93.49
Most Dominant Species	Coontail	Coontail	Coontail	Coontail	Coontail
	Common waterweed	Common waterweed	Common waterweed	Filamentous algae	**Flowering rush (AIS)**
	Flat-stem pondweed	Small duckweed	Small duckweed	Common waterweed	Common waterweed
	Fern pondweed	**Curly-leaf pondweed (AIS)**	**Curly-leaf pondweed (AIS)**	Common watermeal	Filamentous algae
	Curly-leaf pondweed (AIS)	Rush species	Filamentous algae	Small duckweed	**Curly-leaf pondweed (AIS)**
Maximum Depth of Plants	---	---	---	---	9.5
Species Richness	13	16	13	10	16
Community FQI	12.73	19.51	13.91	9.45	15.98
Average Coeffecient	4.50	5.21	4.40	3.57	4.82

*** - data not sufficient enough to calculate**

Total community frequency of occurrence and maximum depth of plants from the 1977, 1991, and 2000 transect survey cannot be determined as the sample locations were biased entirely within the photic zone and did not sample points deep enough to establish maximum depth.

While the 2008 survey was done as a point intercept and was repeated at all survey locations in 2015, some data cannot be used due to sampling error. Depth at all points was not recorded and entered as "6" by the sampler, which does not allow an established maximum depth of plants. Additionally, there were many points that were non-navigable in the shallow, upstream portion of the lake, similar to 2015. However, data for these locations was estimated and entered as cattail and common bur-reed (*Sparganium eurycarpum*) at densities of 1 for each. Based on our field experience at similar lakes within the region and 2015 survey results, it is highly unlikely that common bur-reed existed at such high levels. No voucher specimens were collected to verify this data. In turn, any data from the 2008 survey that included estimations at points not directly sampled (i.e. points 1- 162 and other locations) was eliminated.

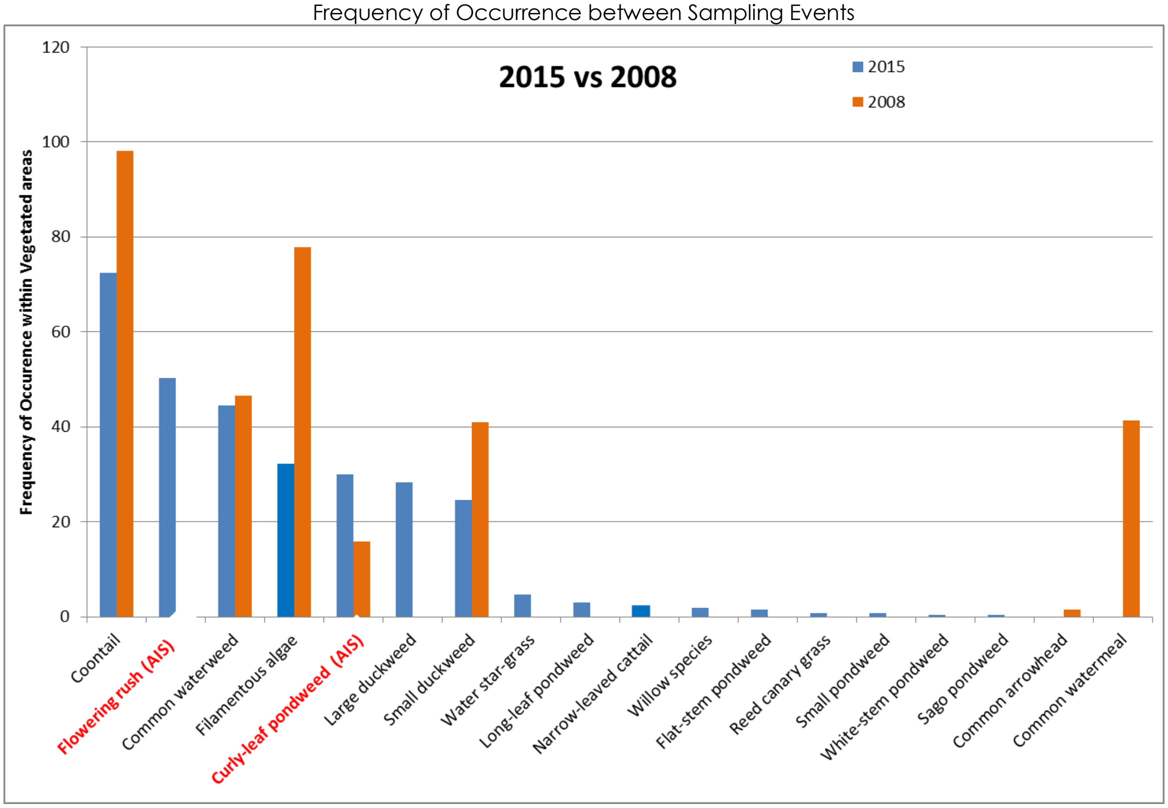
Over the two most recent surveys (2008 and 2015) as shown below, the aquatic plant community has seen changes in overall species composition while an increase in diversity. Species sampled in 2008 but not present in 2015 include common watermeal, common arrowhead, and wild celery. Of these, common arrowhead was likely still present, but wasn't directly sampled, as species of arrowhead were visually noted growing outside of sample locations. Both common watermeal and wild celery were found in surveys prior to 2008.

The 2015 survey had nine species sampled that were not in 2008; flowering rush (AIS), large duckweed, reed canary grass (AIS), willow shrub species, flat-stem pondweed, long-leaf pondweed, sago pondweed, small pondweed, water star-grass, and white-stem pondweed. Willow shrub is an anomaly in the lake. This species does not typically grow in water, but became established on exposed lake bed during the drawdown. When the lake was refilled, some willow shrubs with branches extending above the water's surface were able to continue to grow. It is expected that they will eventually drown out.

The plant community prior to the drawdown was noted to be in decline due to increased sedimentation, growth of AIS, and overall accelerated aging of the system. The drawdown was used to not only control AIS and reduce sediment, but also turn back the clock on Weyauwega Lake to an ecosystem that mimicked a "younger" Weyauwega Lake.

This approach has also worked for the native aquatic plant community. Though the aquatic plant community has always been noted as dense, prior surveys indicated a declining diversity. Of the nine aquatic plant species found in 2015 but not 2008, four of them were also found in surveys prior to 2008. Many of these species are more desirable, native pondweeds (white-stem and flat-stem pondweeds). Additionally, a significant decrease in filamentous algae abundance was noted, but this may be due to many factors outside of the plant community.

Frequency of Occurrence between Sampling Events



Data comparison between years on the Lake shows that the Lake exhibits a moderately diverse and dense aquatic plant community. Dominant species will vary year to year depending on many factors including weather patterns, community composition in year's prior, water levels and more. Some conditions may be favorable for certain species during one growing year but not others and vice versa. This is common and indicative of a healthy lake. Variance is normal and noted within the Lake is currently not a cause for concern.

AIS are an ever increasing threat. Flowering rush is the most prevalent AIS present and has increased dramatically from prior surveys. This species was found growing in dense, often monotypic colonies above the water's surface within the Lake and has dominated shallow, soft-sediment areas.

In many small impoundments, coontail although a native species, can grow to nuisance levels, hampering navigation and enjoyment of the waterbody. Throughout all surveys, coontail has remained the most prevalent aquatic plant species and continues to cause navigational nuisance within the system. Coontail is loosely rooted and can easily break loose and float within the water column and is able to take in nutrients directly from the water, remaining one of the few green plants while under ice cover. This makes it very opportunistic in nutrient rich environments and is one of the first plants to begin growing once ice cover leaves in the spring.

4.4 POTENTIALLY ENVIRONMENTALY SENSITIVE AREAS

Environmentally sensitive areas are locations within a lake that offer critical and/or unique fisheries or wildlife habitat areas or areas that offer water quality and erosion control benefits. Such areas play important roles within the lake's ecosystem such as offering fisheries spawning, nursery, feeding or cover areas, areas of rare species occurrence or habitat, or erosion and nutrient buffer locations. During the aquatic plant survey, special note was taken to inventory and delineate such potential areas on Weyauwega Lake as none currently exist. These have been mapped (Figure 5) and are described in detail below.

- **Sensitive Area #1**: This possible location encompasses much of the up-stream portion of Weyauwega Lake, south of the original river channel and is largely compromised of emergent wetland with good plant diversity. In this location, the Lake is more riverine, with navigation limited to a swift flowing, hard bottom channel. Though much of the shallow areas to the east, downstream of this location are dominated by flowering rush, an AIS, this species drops out significantly here.

  The adjacent emergent wetland has a mix of desirable, native wetland species important to both food for waterfowl and nesting habitat for the common and black tern. Both of these species are listed as endangered in Wisconsin and have been identified as actively nesting in Weyauwega Lake and were noted during the 2015 plant survey. The species composition in the wetland includes cattail, multiple species of bur-reed and arrowhead, sedges, and southern wild rice.

- **Sensitive Area #2**: Potentially sensitive area #2 is a small, remnant patch of dense common bur-reed growth. Much of the remainder of the shallow western half of Weyauwega Lake has been overtaken by the AIS flowering rush. This small location is an isolated island of native vegetation still left.

- **Sensitive Area #3**: This possible area is a shallow sand bar dominated by emergent vegetation and bordered by the historical river channel to the west. Though currently overgrown with flowering rush, the locations continues to provide a large location of hard, sand bottom when much of the Lake has a muck substrate. This offers the largest area of suitable spawning habitat in the Lake for species such as bluegills and bass, which require a firm bottom. Flowering rush should be effectively controlled before considering designating this area.

Only the WDNR can officially designate sensitive areas and those outlined above are submitted as recommendations for further assessment by the State of Wisconsin.

5.0 WATER QUALITY & WATERSHED

The water quality within a lake and its surrounding watershed are tied directly to each other. Runoff from rainfall on the watershed contributes nutrients and sediment to the waterbody, with each affected directly by land use within the watershed. Varying land uses yield differing amounts of nutrient and sediment loads in the form of surface water runoff. Areas of agriculture or with large amounts of paved and impermeable surfaces (industrial, commercial and high density residential) contribute more loading than natural areas, such as wetlands and forests, which may act as sponges, more readily able to soak up precipitation and slow down runoff.

As the land use affects the quality of surface water runoff, that runoff then has an effect on the overall water quality of a lake. When high nutrient loads are contributed by land use that disturbs or impacts more surface area, the water quality of the lake usually suffers. High nutrient loads lead to increased plant and algae growth, with an excess of nutrients leading to potential algae blooms, which can than lead to reduced water clarity, ultimately culminating in reduced overall water quality.

To assess water quality, water samples were taken according to WDNR protocol and tested for various parameters at a certified lab. The watershed was delineated with each land use type mapped and tallied. All of this data was then used within a modeling program from the WDNR to calculate impact to the lake by land use, compare current water quality to predicted water quality using land use within the watershed, and predict what future changes may do to nutrient input into Weyauwega Lake. Information on methods and all referenced tables or charts is included in Appendix C.

5.1 WATER QUALITY

Weyauwega Lake is a drainage lake, or dammed impoundment, relying mainly on input from waterways flowing into the system to maintain water levels. Water quality within the Lake depends primarily on annual rainfall and amount of nutrient runoff. In years of high rainfall, water quality is expected to decrease and may take a year or longer to return to normal due to residence time; while years of drought show an increase in water quality parameters due to less runoff.

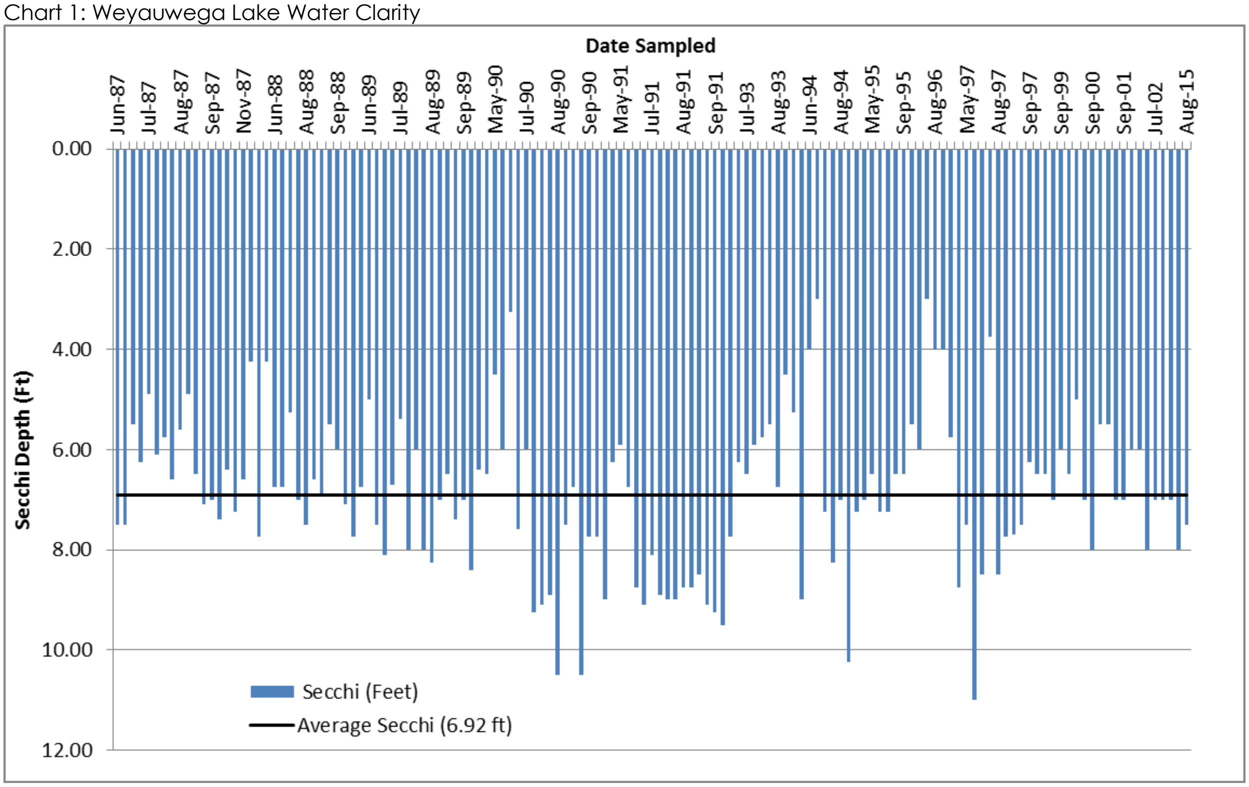
Weyauwega Lake water quality data has been collected sporadically as part of various projects since 1987, including:

- Water clarity (Secchi depth) – 1987-1997, 1999-2002, & 2015
- Total phosphorus – 1994-1997, 1999-2002 (except 2001), & 2015
- Chlorophyll *a* – 1994-1997, 1999-2002, & 2015

Due to the lack of recent data, all three parameters were again collected and tested for during this project period (2015) by WLRI members.

Higher **secchi depth** (water clarity) readings indicate clearer water and deeper light penetration, allowing plants to grow in deeper areas of the Lake. Historical water clarity for the Lake is 6.96 feet (Chart 1), indicating marginal clarity when compared to the average for all lakes in Wisconsin (10ft), but quite good for a reservoir. However, the secchi reading reached bottom on multiple occasions, indicating clarity was only limited by the depth of the lake. Impoundments often have reduced water clarity due to impact from its watershed, including turbid water and increased nutrient loads. Since the secchi reached bottom during many sample dates, water clarity of Weyauwega Lake is better than indicated by its overall average.

Chart 1: Weyauwega Lake Water Clarity



Nutrients within the water play an important part for the productivity of the water, leading to impacts on water quality. These include total phosphorus, nitrogen and chlorophyll *a*. **Phosphorus** is the key nutrient or food source influencing plant growth in waterbodies. Phosphorus promotes excessive aquatic plant growth and originates from a variety of sources, many of which are related to human activities. Major sources include human and animal wastes, soil erosion, wastewater treatment plants, detergents, septic systems and runoff from farmland or lawns. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form. For natural lakes, the average total phosphorus should be between 0.016 and 0.030 milligrams per liter (mg/L) and average approximately 0.065 mg/L in impoundments. The below table outlines average phosphorus readings and their respective water quality:

Water quality vs. Total Phosphorus

Water Quality Index	Total Phosphorus (mg/L)
Very Poor	0.150+
Poor	0.053 – 0.149
Fair	0.031 – 0.052
Good	0.016 – 0.030
Very Good	0.002 – 0.015
Excellent	0.001 or less

Weyauwega Lake

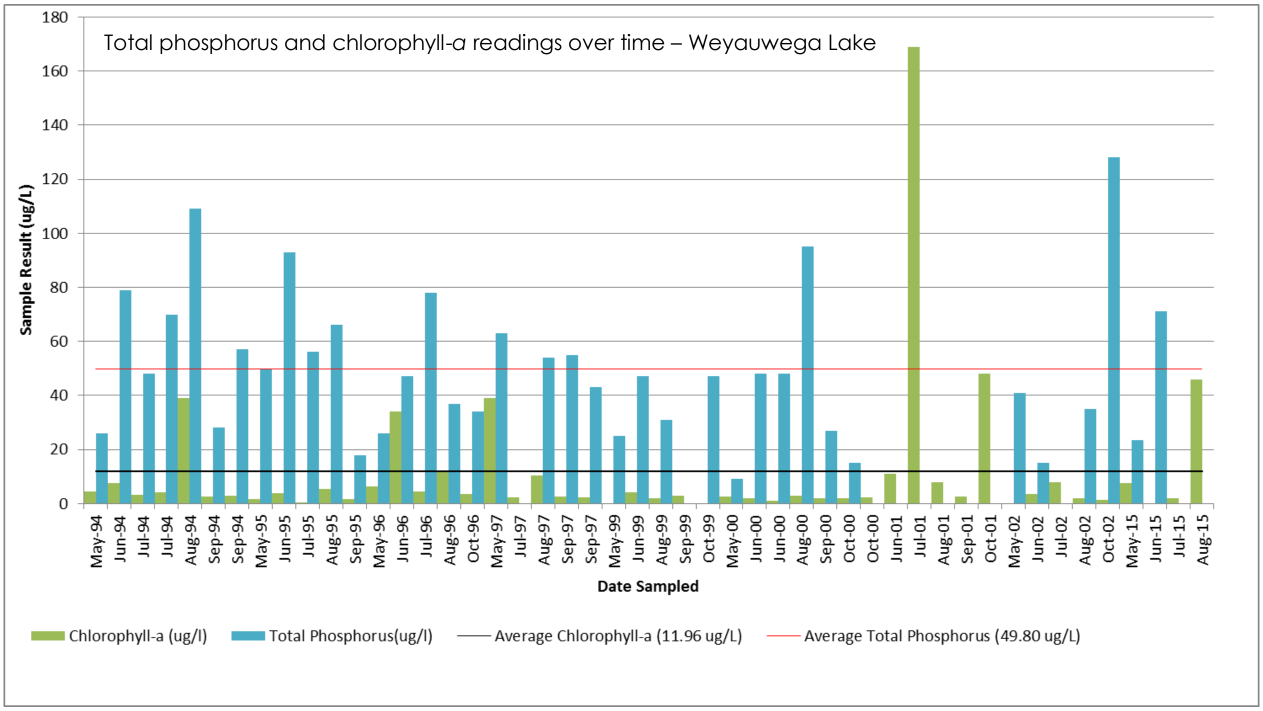
All samples averaged 0.0498 mg/L (49.8 ug/L) for total phosphorus, indicating fair water quality, better than Wisconsin impoundments on average, and moderate availability of nutrients (Chart 2). This value is lower than expected given the large watershed upstream of Weyauwega Lake. Much of the watershed of the Waupaca River is agricultural use, which leads to higher nutrient inputs. The lower than expected reading may be indicative of the dense plant community present using much of the incoming nutrient load or greater use of best management practices within the watershed.

Nitrogen is the second most important nutrient for plant and algae growth. A waterbody's nitrogen sources vary widely. In most cases, the amount of nitrogen in lake water is related to local land use. Nitrogen may come from fertilizer and animal wastes on agricultural lands, human waste from sewage treatment plants or septic systems, and lawn fertilizers used on lakeshore property. Nitrogen may enter a lake from surface runoff or groundwater sources. Organic nitrogen is a measure of the nutrient not readily available for plant or organism use, typically locked into plant matter. All inorganic forms of nitrogen (nitrate, nitrite and ammonia) can be used by aquatic plants and algae. If these inorganic forms of nitrogen are available in high amounts they could support summer algae blooms and the growth of AIS has been correlated with such fertilization of the sediment.

Nitrogen levels on their own are typically not tracked in comparison to other lakes, such as with phosphorus above. Instead, they are compared with the phosphorus concentration of the lake to establish a ration between nitrogen and total phosphorus present to describe the water quality. If the ratio of nitrogen to phosphorus is less than 10:1, nitrogen is the limiting nutrient. Waters with a ratio between 10:1 and 15:1 are considered transitional with little or no limitations while lakes with ratios greater than 15:1 are limited by phosphorus. No sampling for nitrogen has been completed for Weyauwega Lake. Based on similar impoundments within the region, it is expected that the Lake would fall into the phosphorus-limited category. This is common for most lakes in Wisconsin.

Chlorophyll *a* is a green pigment present in all plant life and necessary for photosynthesis. The amount present in surface water depends on the amount of algae, and is used as a common indicator of water quality. Higher chlorophyll a values indicate lower water clarity. Values of 10 ug/L and higher are associated with algal blooms while values between 5 and 10 ug/L indicate good water quality.

In flowing systems, these values are typically low as water movement does not allow for accumulation of algae. However, the presence of a dam on the system allows for the stagnation of water flow and chlorophyll *a* accumulation. Weyauwega Lake has experienced algae blooms in the past, such as in July, 2001 in the chart below, with an overall average value of 11.96ug/L.



Water quality is a component of three factors: Water clarity (secchi), total phosphorus and chlorophyll *a*. All factors are linked to each other and as one changes so do the others. For example, if nutrient loads, such as phosphorus or nitrogen, increase, that increases available resources for algae (chlorophyll a), which can cause an increase in this reading all while leading to a decrease in water clarity. Data is collected over time and averaged, allowing these factors to be used to assess the Trophic State Index (TSI) for a lake. TSI values are assigned to a lake based on all three values and are a measure of a lakes' biological productivity. Lakes with higher TSI values are more biologically productive, but have lower water clarity, increased nutrient input and the potential for frequent algae blooms. On the opposite end, lakes with low nutrient input and very clear water are typically less productive, having lower TSI values.

Historical water clarity, total phosphorus and chlorophyll *a* data show no reliable trends or patterns in annual variances of individual TSI averages for any of the three parameters. However, the overall average indicates that Weyauwega Lake is a borderline eutrophic lake with an average TSI rating of 51.06. This is unexpected due to the large watershed contributing to the relatively small water volume of Weyauwega Lake with large nutrient inputs from primarily agricultural lands and further indicates good water quality.

5.2 WATERSHED

All above factors are impacted by the lake's watershed. To gauge the watershed's effect on the water quality of Weyauwega Lake, Wisconsin Lake Modeling Suite (WiLMS), a WDNR computer program, was used to model lake water quality based on watershed land use and current water quality data. WiLMS can be used as a planning tool to assist in management recommendations or procedures within a watershed to ensure stable or increased water quality. Using WiLMS, a lake total phosphorous prediction model and a lake eutrophication analysis procedure (LEAP) model was developed for Weyauwega Lake. Information on methods and all referenced tables or charts and direct model outputs is included in Appendix D.

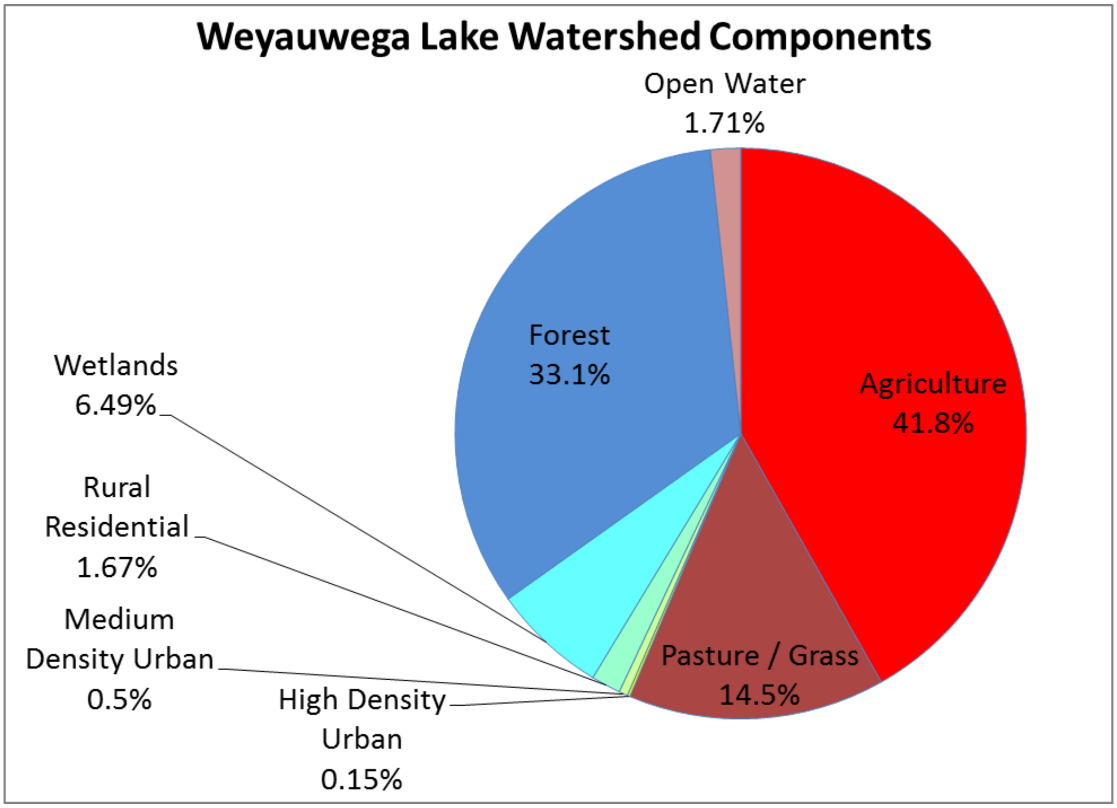
LEAP is a program within WiLMS that predicts lake trophic status indices based on watershed area, lake depth and lake ecoregion. Weyauwega Lake is near the down-stream end of the Tomorrow/Waupaca River and encompasses a fairly large area across Portage, Waushara, and Waupaca Counties before emptying in to the Wolf River. Major tributaries and waterbodies within the watershed include the Crystal River, Waupaca Chain of Lakes, and many other creeks including numerous trout streams, adding to increased water quality coming in to River. Weyauwega Lake is the largest lake in the watershed and, without the lake itself, ***the watershed encompasses 180,094.6 acres, or 281.4 square miles*** terminating at the dam. This gives a watershed to lake ratio of 712:1, meaning for every 712 acres of watershed there is one acre of lake. A lake and its water quality is a representation of the watershed around it, specifically its landuse, soils, topography, vegetation, and geology. All of these factor directly into the nutrient loading to the lake. The larger watershed to lake ratio for Weyauwega Lake leads to increased nutrient loading relative to the lake size. The Lake has a mean depth of 5 feet and total surface area of 253 acres within the watershed and it belongs in the North Central Harwood Forests ecoregion (Figure 6).

In order to complete WiLMS modeling, land use within the watershed first had to be calculated. Land use was calculated using data from the National Land Cover Database – 2011 (NLCD). Aerial and satellite imagery was used to assess and assign land cover to areas within the watershed across 14 types. WiLMS modeling, however, uses simplified land cover with less cover types, eight in this instance. To best fit the NLCD data for the WiLMS model, some cover types were combined into areas of best fit – i.e. Mixed, deciduous, and evergreen forests under NLCD were all combined to Forest for WiLMS. Landover breakdown for WiLMS and associated NLCD cover types are as follows:

Table 8: Land cover within Weyaywega Lake Watershed.

WiLMS**	NLCD - 2011*	Acres
Mixed Agriculture	Cultivated Crops	75416.47
Pasture / Grass	Hay / Pasture	16159.13
	Developed, Open Space	8867.53
	Barren Land	188.91
	Herbaceous	576.46
	Shrub / Scrub	417.15
High Density Urban	Developed, High Intensity	278.93
Medium Density Urban	Developed, Medium Intensity	894.57
Rural residential	Developed, Low Intensity	3014.56
Wetlands	Woody Wetlands	10734.29
	Emergent Herbaceous Wetlands	963.31
Forest	Mixed Forest	4143.18
	Deciduous Forest	45993.30
	Evergreen Forest	9609.61
Open Water	Open Water	3090.18
	TOTAL	**180347.58**

* - National Land Cover Database - 2011
** - Wisconsin Lake Modeling Suite



LEAP then takes into account the current, collected water quality data of phosphorus, chlorophyll a and secchi depth and statistically compares these values against predicted values to screen for any potential problems.

LEAP was also used to predict the possibility of nuisance algae blooms within the Lake. This occurs when excess nutrients are available for planktonic algae, causing an explosion in growth, or "bloom" and is typically associated with chlorophyll *a* reading of >20.0 ug/L. This excess growth leads to soupy, green colored water with reduced water clarity and recreational value. Based on current conditions of the Lake and its watershed, the chance that these levels meet or exceed the nuisance threshold at any one time annually are extremely high, approximately 99%, and remain high when extrapolated out to multiple years. The data appears to be overestimating the amount of nuisance algal blooms within Weyauwega Lake due to the large watershed associated. The current average chlorophyll *a* is 11.96 ug/L and only 6 of 44 individual samples taken for chlorophyll *a* have ever exceeded the 20 ug/L threshold.

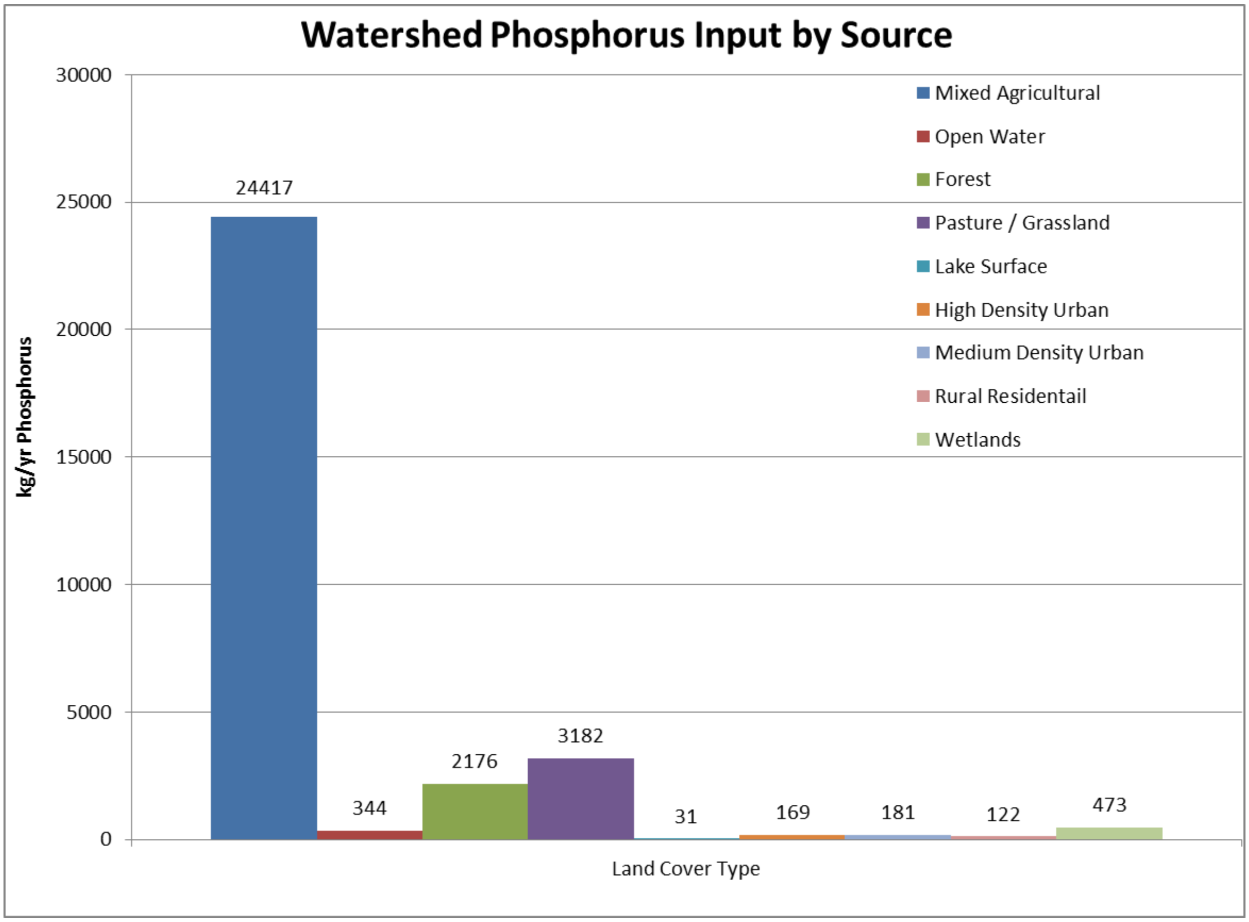
Using WiLMS, a Lake Total Phosphorous Prediction (LTPP) model was used to predict the amount of phosphorus loading into the Lake within its watershed through point and non-point sources. This is important because in many lakes, phosphorus is the limiting nutrient for plant growth. An increase in phosphorus levels will allow for increased plant growth and possibly cause problematic algae blooms if phosphorus loading becomes too high. There are four point-sources for phosphorus introduction to Weyauwega Lake; the Village of Amherst wastewater treatment facility, City of Waupaca wastewater treatment facility, Waupaca Foundry, and Weyauwega Star Dairy. The City of Weyauwega's wastewater treatment facility and Agropur are also permitted discharges within the watershed, but discharge downstream of the dam and do not impact the lake.

The LTPP predicted a total phosphorous amount of 31095 kg per year being added to the waterbody through non-point sources. The amount of phosphorous put into the watershed through each land use is different (Table 9). Agricultural land inputs the most annually at approximately 24417 kg/year while internal loading or recycling of phosphorus already in the Lake accounts for 31 kg of the lake's budget per year based on the model. There are four known direct, point source for phosphorus loading into the Lake as mentioned above. However, data related to these point sources was not available at the time of this writing.

Areas of natural land cover, such as forests and wetlands, have reduced runoff and release lower rates of phosphorus into the lakes compared to developed areas with higher amounts of impervious surfaces, such as roads and buildings. Meaning, though forests may occupy the largest percent of land cover, they do not contribute the largest percent of phosphorus loading into the Lake. Agricultural land, though only 41.8% of the total watershed, attributes 78.5% of the annual phosphorus load into the lake (Table 10).

Table 10: Pecent phosphorus loading by source. Weyauwega Lake, Waupaca County, WI

Land Use	Acres	Percent of Watershed	Percent of Phosphorus Loading
Mixed Agricultural	75416.47	41.82%	78.52%
Open Water	2837.18	1.57%	1.11%
Forest	59746.09	33.13%	7.00%
Pasture / Grassland	26209.18	14.53%	10.23%
Lake Surface	253	0.14%	0.10%
High Density Urban	278.93	0.15%	0.54%
Medium Density Urban	894.57	0.50%	0.58%
Rural Residentail	3014.56	1.67%	0.39%
Wetlands	11697.6	6.49%	1.52%
TOTAL	**180347.58**	**100.00%**	**100.00%**



Weyauwega Lake TSI - Observed vs Model Predicted Values

Parameter	Observed	Predicted
Total Phosphorus (ug/L)	49.8	118
Chlorophyll-a (ug/L)	11.96	70.4
Secchi (m)	2.1	0.6

Currently, water quality is moderate within the Lake, but significantly higher than predicted when comparing with model data. All three trophic status indices are below predicted values for its ecoregion, further indicating better water quality than expected, especially given the large size of the watershed.

Though agricultural land covers less than half of the watershed, it is estimated to contribute over three quarters of nutrient input into the Lake. An extensive watershed management plan already exists and was started in 1993 by designating the Tomorrow/Waupaca River watershed as a priority watershed. Work continued in to 2007 under a plan cooperatively prepared by WDNR, DATCP, NRCS, University of Wisconsin Extension, and Portage, Waushara, and Waupaca Counties' Land and Water Conservation Departments. Through work completed under direction of this plan, over 100% of the goals related to sediment and phosphorus loading into surface waters were exceeded. An updated Watershed plan focusing on water quality management was created in 2011 by WDNR and again updated in 2015. The focus of the updated plan is on groundwater contamination due to the highly permeable soils found throughout the watershed, specifically from nitrogen and phosphorus. Best management practices (BMPs) are currently in place and expanding with ongoing data collection to determine their effectiveness.

Though the watershed draining to Weyauwega Lake does continue to be the primary factor affecting water quality within, actual management recommendations within this plan are likely not feasible due to the immense size of the watershed relative to this plans focus on immediate lake issues, such as AIS. There are previously completed and currently ongoing watershed management plans that are in place, having a positive affect towards Weyauwega Lake and its watershed. It is recommended WLPI work with the County land and water conservation department and landowners following BMPs and recommendations outlined in the current plan(s) to keep moving toward protection and improvement of water quality within the Lake. Watershed management recommendations in respects to this plan are therefore referred to the current watershed plan: *Waupaca River Watershed - 2011 Water Quality Management Plan Update, December, 2011 – updated May, 2015*.

6.0 DAM HISTORY, DESIGN AND CURRENT OPERATION

The dam impounding Weyauwega Lake, commonly called the Weyauwega Dam, is owned and operated by Eagle Creek Renewable Energy for generation of hydroelectric power.

The WDNR classifies the Weyauwega Dam as a low hazard, large dam. A dam is classified as "large" if either of the following condition applies:

- The dam has a structural height of over 6 feet and impounds 50 acre-feet or more of reservoir volume.
- The dam has a structural height of 25 feet or more and impounds more than 15 acre-feet of reservoir volume.

Even though the dam has a structural height of only 21 feet, the impoundment (Weyauwega Lake) is large with an estimated volume of 1259 acre-feet. The "low" hazard rating is not related to the dam's perceived potential to fail. Instead, a low hazard dam has a limited potential to cause loss of life in the event of failure.

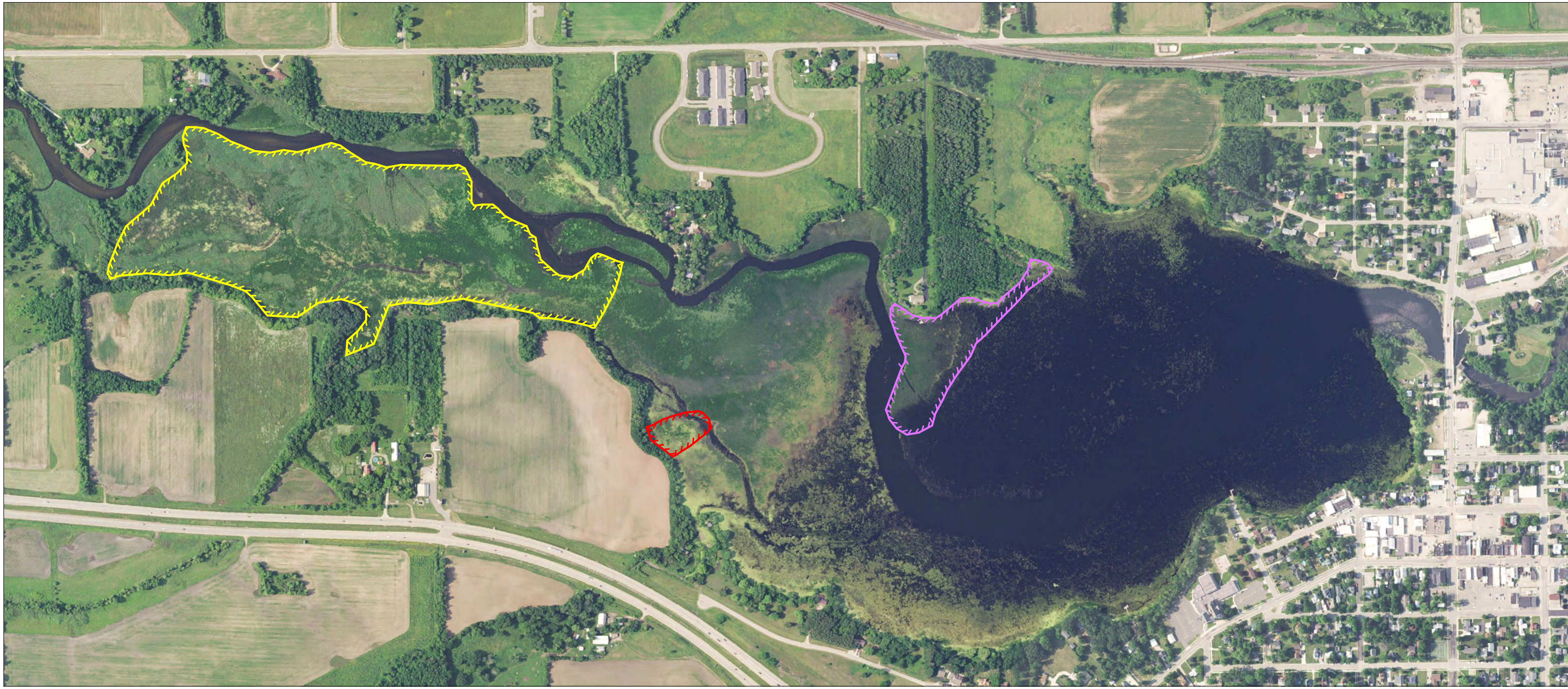
According to records available through the WDNR, the lake was created in 1855 with the first dam inspection in 1915 and approved for enlargement in 1920. The current structure was completed in 1931, and according to WDNR records, has the following physical characteristics:

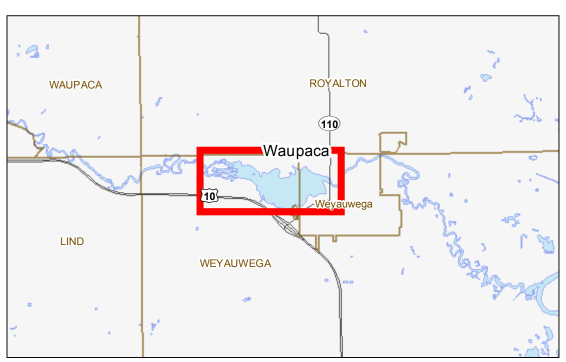
- Age: 85 years
- Structural Height: 21 feet
- Hydraulic Height: 12 feet
- Crest Length: 240 feet
- Maximum Storage Volume: 1760 acre-feet
- Normal Storage Volume: 1259 acre-feet
- Spillway: Two operable gates, total capacity 5000 cubic feet per second.

Available information from WDNR and aerial photos of the dam reveal that it consists of 3 operable tainter gates (gates that open from the bottom), each of which measures approximately 10 feet in width. The dam continues to produce power as its sole function.

Reservoir Sedimentation and Channel Morphology
Weyauwega Lake is over 100 years old and been affected by changes in land use within the watershed. The Waupaca River's watershed underwent dramatic change during initial settlement, including removal of primeval forest and conversion of the land to agriculture. Much of this land is still under agricultural use today, yielding tremendous volumes of sediment, and Weyauwega Lake, being a quiescent water body, served as a settling basin. A river transports a great deal of sediment in addition to water. This process continues to this day, although likely at a reduced rate for sediment loads.

Deposited sediment is a source or nutrients to aquatic plants, provides favorable root substrate, covers granular bottom sediments desirable to many favored aquatic organisms and creates shallow water depths. These factors combine to make the lake less desirable for recreational use. Although the rate of sediment accumulation is undoubtedly reduced compared to the settlement period, sediment continues to be contributed to the Lake by its watershed. Urbanization, intensified agriculture, forest fires, and other current and future factors can increase the volume of sediment produced by the watershed. Areas that are quiescent and have disturbed and/or large contributing watersheds are most prone to sedimentation.





Legend
- Sensitive Resource Area 1
- Sensitive Resource Area 2
- Sensitive Resource Area 3

Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec, WDNR, WisDOT
3. Orthophotography: 2015 NAIP

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Figure No.
5

Title
Sensitive Vegetation Areas

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Waupaca Co., WI

193703396
Prepared by KAS on 2016-01-12
Technical Review by PM on 2016-01-12
Independent Review by JS on 2016-01-13

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The 253 acre lake presently has an average depth of 5 feet, and a maximum depth of approximately 11 feet. The deepest water areas are located just upstream of the dam, a narrow channel area with higher water velocity. Significant inorganic sedimentation was noted throughout much of the lake and was partially the cause for the extended 2011-2013 drawdown. According to historic and current lake survey data, both organic rich silt and sand covers much of the Lake's bottom. While the organic silt has a reasonable ability to reduce in thickness if dewatered, inorganic (sandy) sediment has a limited ability to change in thickness if dried. Given what is known about reservoir sediment dynamics, isolated bays and coves without significant tributaries have the greatest propensity for silt accumulation and therefore are the only areas well suited to sediment volume reduction through dewatering.

A situation which often evades consideration is the influence of a dam on downstream streambed morphology. Reservoirs retain granular sediment (gravel, sand and oftentimes silt) that are a natural and normal component of a stream's morphology and ecology. The reservoir interrupts the stream's bedload "conveyor belt". Erosion of transport of such materials continues downstream of the dam, but the materials are no longer replenished by upstream sources. This results in scoured and poorly embedded channel morphology, a condition less conducive to high quality habitat. Restoring natural sediment transport can replenish natural substrate conditions in downstream areas.

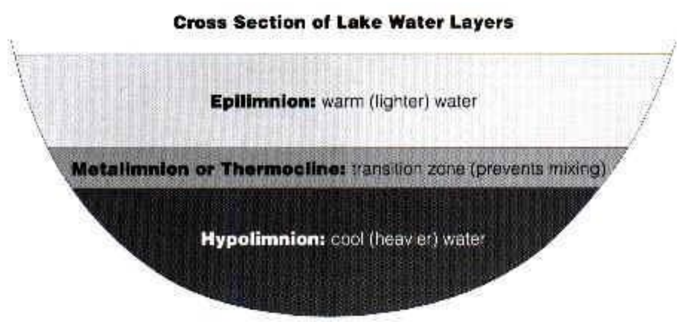
7.0 IN-LAKE RESTORATION OPTIONS

Controlling external nutrient sources will not improve lake water quality immediately. In many cases several years may pass before lakes cleanse themselves of accumulated nutrients, if ever. Due to this, in-lake restoration techniques may be used in conjunction with watershed control to potentially accelerate recovery. Consider using one or more of these techniques only after consulting a WDNR water management specialist for permitting and other requirements. Some may not be feasible due to a wide variety of reasons but all are none the less presented below.

This provides an overview of some common in-lake treatment techniques. Please refer to the third edition of *Restoration and Management of Lakes and Reservoirs*; by G. Dennis Cooke, Eugene B. Welch, Spencer A. Peterson and Stanley A. Nichols, 2005, for a comprehensive and scientific discussion of these and other lake management methods.

Hypolimnetic aeration

Oxygen (or air) is pumped into the deep, often nutrient-enriched, oxygen-depleted layer that forms in deeper lakes called the hypolimnion (see the illustration of the cross section of lake water layers to the right). The goal of hypolimnetic aeration is to maintain oxygen in this layer to limit phosphorus release from sediments without causing the water layers to mix (destratify).



Hypolimnetic aeration increases habitat and food supply by providing more oxygenated waters. On the down-side, hypolimnetic aerators are expensive to operate. It may be difficult to supply adequate oxygen to the hypolimnion without destratification and subsequent algal blooms. This technique is suitable for deep lakes with an oxygen-deficient hypolimnion. Weyauwega Lake is a shallow impoundment that does not stratify. This technique would not affect its current condition.

Hypolimnetic withdrawal

Some lake managers use siphons to remove nutrient rich water from the hypolimnion. This reduces nutrients and eliminates some of the low oxygen water. Hypolimnetic withdrawal is suitable for small, deep lakes with oxygen-poor or nutrient-rich bottom water. This technique can have severe repercussions on downstream receiving waters which receive nutrient-enriched waters.

Artificial circulation (aeration)

Artificial circulation provides increased aeration and oxygen to a lake by circulating the water to expose more of it to the atmosphere. Aeration systems are generally used in shallow water bodies. A number of artificial circulation systems can provide aeration including surface spray (fountains), paddlewheels and air diffusers. Artificial circulation disrupts or prevents stratification and increases aerobic habitat, but this can also disturb sediments which can cause problems for fish and other macro invertebrates. Aeration can also be used in conjunction with additional microbial metabolism to aid more in aerobic “digestion”.

The effect of aeration on algae varies. Aeration does not necessarily decrease algal biomass, but may lead to fewer cyanobacterium (blue-green algae). Some cyanobacteria have gas vacuoles which allow them to regulate their position in the water column. By circulating the water, cyanobacteria may spend more of their time in the dark, reducing their competitive advantage over other kinds of algae. Internal loading of phosphorous may also decline if sediments remain oxygenated. When lake sediments lack oxygen, conditions exist to release phosphorus into the water.

Dilution
Dilution projects direct a low-nutrient water source into and through a lake as a means of diluting and flushing nutrients from the higher-nutrient lake water. Flushing may wash out surface algae and replace higher-nutrient lake water with lower-nutrient dilution water. Lower-nutrient water may lead to fewer problem algae in the water. On the downside, dilution requires large volumes of low-nutrient water (which may be scarce or expensive) and does not eliminate sources of phosphorous from the sediments or the watershed.

Nutrient diversion
Drainage channels or pipes are used to divert nutrient-rich waters to the downstream side of lakes. In some lakes, nutrient diversion meant diverting sewage discharge from the lake. Depending on the project, major engineering may be required at great expense and other receiving waters may be affected by the nutrient-rich water. Diverting streams also eliminates a water supply to the lake and may interfere with fish runs. This option is not viable for Weyauwega Lake.

Dredging
Heavy equipment or specialized hydraulic dredges can remove accumulated lake sediments to increase depth and to eliminate nutrient-rich sediments. Dredging may control rooted aquatic vegetation, deepen the water body and increase lake volume. By removing nutrient-rich sediment, dredging may improve water quality. Some dredging drawbacks include resuspension of sediments during the dredging operation and the temporary destruction of habitat. On impounded lakes with a constant, incoming sediment load dredging may only be a temporary solution and be required again after a period of time. Large-scale dredging is extremely expensive due to equipment costs, permitting issues, and spoils disposal. Because of costs, dredging is typically done on a limited scale. Although some shallow lakes may benefit from this method, dredging's great expense limits its widespread use in most water bodies.

With a dam on this Lake, the most cost effective manner to dredge may be in conjunction with a drawdown, as the Lake bed is fully exposed and would allow for use of typical earth moving equipment verses specialized dredging equipment and floating barges. This could be through either a full or partial drawdown as the areas likely most in need of dredging are near shore and off the main channel.

Though desired by lake users for Weyauwega Lake, dredging would prove to be a cost prohibitive action for WLRI and is not recommended for management actions.

Biological Controls
Biological controls try to mimic Mother Nature by recreating the natural biological activity of a floating bog, similar to a product like Biohaven® Floating Island. This process uses plants to reduce phosphorus and total suspended solids (TSS). A typical 1000 sq. ft. island can reduce loading of phosphorus by around 35 lbs/year and TSS by 200 lbs/year with an added bonus of providing excellent fish and wildlife habitat. They do require a permit and it is likely the WDNR will treat these as a dock or pier and restrict their location to near shore areas as well as the overall size of each island.

Nutrient inactivation
Aluminum, iron, calcium salts or lanthanum-modified clay (brand name Phoslock®) can inactivate phosphorus in lake sediments. Lake projects typically use aluminum sulfate (alum) or Phoslock to inactivate phosphorus. Either product may also be applied in small doses for precipitation of water column phosphorus. When applied to water, as the products precipitate it is called a floc. As the floc settles, it removes phosphorus and particulates (including algae) from the water column (precipitation). The floc settles on the sediment where it forms a layer that acts as barrier to phosphorus. Phosphorus released from the sediments combines with the alum or clay and is not released into the water to fuel algae blooms (inactivation). Algal levels decline after treatment because phosphorus levels in the water are reduced.

The length of treatment effectiveness varies with the amount of product applied, depth of the lake and incoming new phosphorus load to the lake. Treatment in shallow lakes for phosphorus inactivation may last for five or more years, in deeper lakes, treatment may last longer.

7.1 AQUATIC PLANT MAINTENANCE ALTERNATIVES

Based on the goals of the stakeholders outlined above, several management alternatives are available for this CLM plan. Some general alternatives are discussed below. More information on management alternatives are included in Appendix E. The following management alternatives are based on historical, aquatic plant management approaches and incorporate needs established by the questionnaire and recommendations of Wisconsin Lake and Pond Resource.

AQUATIC PLANT MAINTENANCE ALTERNATIVES

A combination of management alternatives may be used on a lake with a healthy native aquatic plant community wth invasive or non-native plant species present. Maintenance alternatives tend to be more protection-oriented because no significant plant problems exist or the issues are at levels that are generally acceptable to lake user groups with no active manipulation is required. These alternatives can include an educational plan to inform lake shore owners of the value of a natural shoreline and encourage the protection of the lake water quality and the native aquatic plant community.

AQUATIC INVASIVE SPECIES MONITORING

Two AIS were identified within the Project Area during the 2015 full point-intercept survey. In order to monitor existing populations of current AIS and for new AIS in the future, a consistent and systematic Weyauwega Lake monitoring program that conducts surveys for AIS is highly recommended. In some lake systems native aquatic plants "hold their own" and AIS never grow to nuisance levels; however, in others active management is required. The spread of AIS can be caused by several factors, including water quality.

It is recommended to complete pre and post treatment aquatic plant monitoring in any areas that are actively managed for AIS control to evaluate management effectiveness. Aquatic plant communities may undergo changes for a variety of reasons, including varying water levels, water clarity, nutrient levels and aquatic plant management actions. In general, lake-wide aquatic plant surveys are recommended every year to monitor changes in the overall aquatic plant community during large-scale treatments and then again every 5 years once small scale, maintenance treatments take place to monitor and the effects of the aquatic plant management activities.

In addition to invasive plants, excessive native plant growth combined with shallow water depths can cause navigational issues for Lake users, these have historically been addressed through a harvesting program, though herbicides in water too shallow for a harvester to operate may be a viable option also.

CLEAN BOATS/CLEAN WATERS CAMPAIGN

Prevention of the introduction of new AIS to the Lake and spread of existing AIS from the Lake should be a priority. To prevent the spread of AIS from Weyauwega Lake, a monitoring program such as Clean Boats/Clean Waters (CB/CW) is a good choice. This program is carried out by trained volunteers who inspect incoming and outgoing boats at launches. Boat landing signage also accompanies the use of CB/CW to inform lake users of proper identification of AIS and boat inspection procedures. Education of club members about inspecting watercraft for AIS before launching a boat or leaving access sites on other lakes could help prevent new AIS infestations.

CB/CW use on Weyauwega Lake has not been completed, though participation in this program is strongly encouraged. Especially when considering the amount of AIS, including a unique infestation of flowering rush. Joint participation of this program is recommended and should be promoted within the WLRI, WDNR, Golden Sands RC&D and the County.

AQUATIC PLANT PROTECTION AND SHORELINE MANAGEMENT

Protection of the native aquatic plant community is needed to slow the spread of AIS from lake to lake and within a lake once established. Therefore, riparian landowners should refrain from removing native vegetation. Additionally, EWM and CLP can thrive in nutrient (phosphorus and nitrogen) enriched waters or where nutrient rich sediments occur. Two relatively simple actions can prevent excessive nutrients and sediments from reaching the lake.

The first activity is the restoration of natural shorelines, which act as a buffer for runoff containing nutrients and sediments. This can be a potential issue within the Lake, as much of the watershed is agricultural use. Good candidates for shoreland restorations include areas that are mowed to the lake's edge, or that have structures directly adjacent to the lake edge. Establishing natural shoreline vegetation can sometimes be as easy as not mowing to the water's edge. Native plants can also be purchased from nurseries for restoration efforts. Shoreline restoration has the added benefits of providing wildlife habitat and erosion prevention. Or many times a simple "no mow" buffer strip 35'–50' back from the water's edge can provide effective and economical restoration for shoreland property owners. A vegetated buffer area can also prevent surface water runoff from roads, parking areas and lawns from carrying nutrients to the lake. Currently, much of the Lake's shoreline is developed, providing potential avenues for increased impacts from runoff.

The second easy nutrient prevention effort is to use lawn fertilizers only when a soil test shows a lack of nutrients. Importantly, fertilizers containing phosphorus, though readily available to the consumer, are illegal for use in Wisconsin, unless a soil test shows a deficiency in phosphorus. The fertilizers commonly used for lawns and gardens have three major plant macronutrients: Nitrogen, Phosphorus and Potassium. These are summarized on the fertilizer package by three numbers. The middle number represents the amount of phosphorus. Since most Wisconsin lakes are "Phosphorus limited", meaning additions of phosphorus can cause increased aquatic plant or algae growth, preventing phosphorus from reaching the Lake is a good practice. Local retailers and lawn care companies can provide soil test kits to determine a lawn's nutrient needs. Of course, properties with an intact natural buffer require very little maintenance, and no fertilizers.

Another possible source of nutrients to a lake is the septic systems surrounding it. Septic systems should be properly installed and maintained in order to prevent nutrient laden wastewater from reaching the lake. A professional inspector can assess septic systems to determine if they are adding undue nutrients to the Lake. Many times the age and type of septic system is a likely indication as to the current functionality of the system and would not require an on-site visit, which at times can be controversial. The local County Zoning Department or Health Department can many times assist in this regard.

The Waupaca County Land and Water Conservation Department may be able to offer assistance with agricultural buffer strips, shoreland restoration projects, rain gardens and soil testing to determine nutrients needs for lawns and gardens. Interested landowners can contact the Land and Water Conservation Department at (715) 258-6245 to request additional information.

PUBLIC EDUCATION AND INVOLVEMENT

The WLRI should continue to keep abreast of current AIS issues throughout the County and State. The County Land and Water Conservation Department, WDNR Lakes Coordinator and the UW Extension are good sources of information. Many important materials can be ordered at the following website: http://www.uwsp.edu/cnr/uwexlakes/publications/

If the above hyperlink to web address becomes inactive, please contact WDNR for appropriate program and contact information.

MANUAL (HAND) REMOVAL

Native plants may be found at nuisance levels in scattered locales throughout the waterway. Manual removal efforts, including hand raking or hand pulling unwanted native plants (except wild rice in the northern region), is allowed under Wisconsin law, to a maximum width of 30 feet (recreational zone) per riparian property. The intent is to provide pier, boatlift or swimming raft access in the recreation zone. A permit is not required for hand pulling or raking if the maximum width cleared does not exceed this 30-foot recreation zone (manual removal of any native aquatic vegetation beyond the 30-foot area would require a permit from the WDNR that satisfies the requirements of Chapter NR 109, Wisconsin Administrative Code, see Appendix E). However, manual removal is not recommended because it could open a niche for non-native invasive aquatic plants to occupy. Removal of native plants also destroys habitat for fish and wildlife.

Manual removal of aquatic plants can be quite labor intensive and time consuming. This technique is well suited for small areas in shallow water. Hiring laborers to remove aquatic vegetation is an option, but also increases cost. SCUBA divers can be contracted to remove unwanted vegetation in deeper areas. Benefits of manual removal by property owners include low cost compared to chemical control methods, quick containment of pioneering (new) populations of invasive aquatic plants and the ability for a property owner to slowly and consistently work on active management. The drawback of this alternative is that pulling aquatic plants includes the challenge of working in the water, especially deep water, the threat of letting fragments escape and colonize a new area, and the fact that control of any significant sized population is quite labor intensive, and therefore very costly; $1,500 - $2,000 per 5,000 square feet, or $10,000 - $20,000 acre depending on plant densities.

MECHANICAL HARVESTING / NUISANCE AQUATIC PLANT GROWTH

Aquatic plants may be mechanically harvested up to six feet below the water surface and can be a practical and efficient means of controlling plant growth as it generally removes the plant biomass from the lake. It can also be effective in control AIS such as curly-leaf pondweed if the

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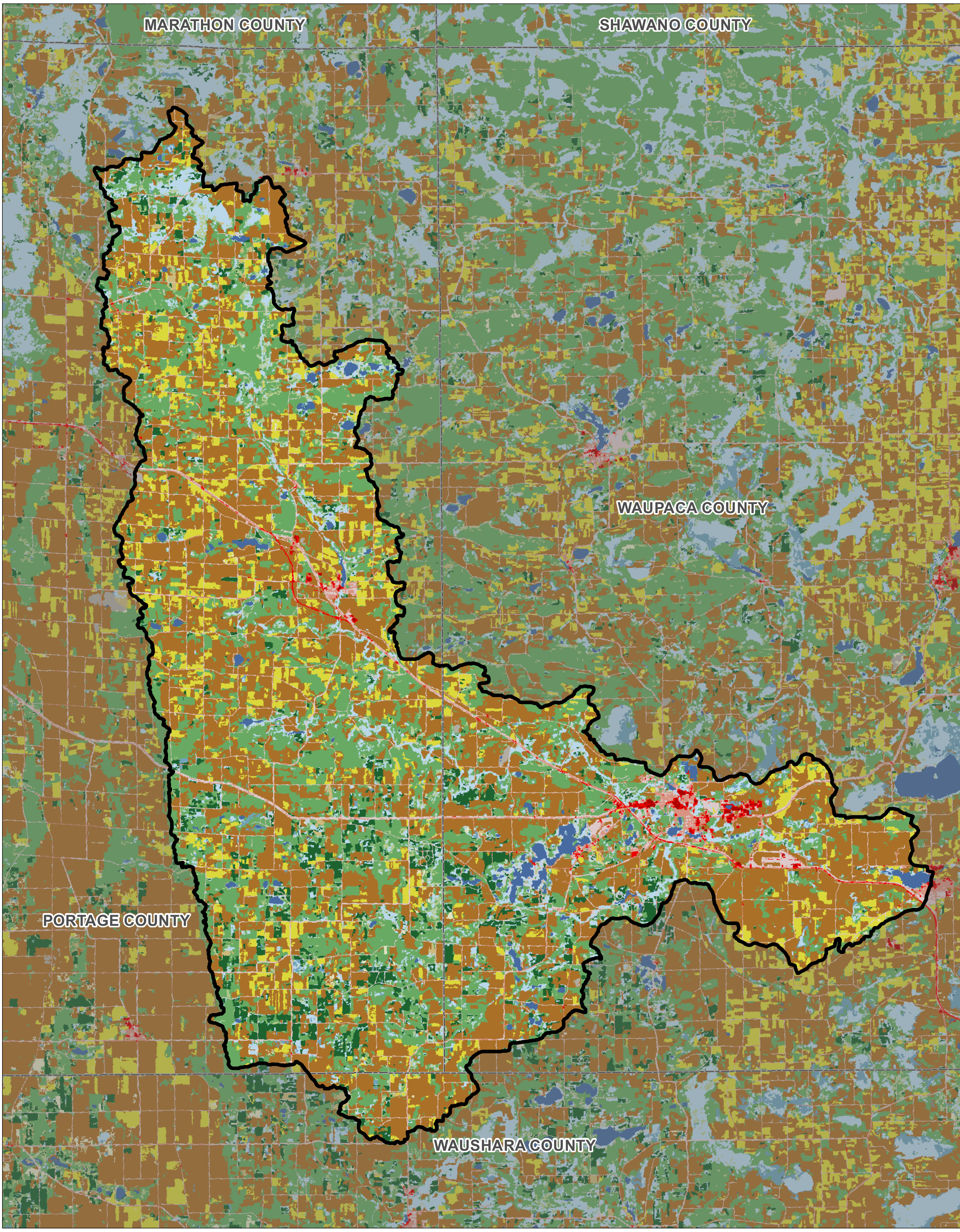
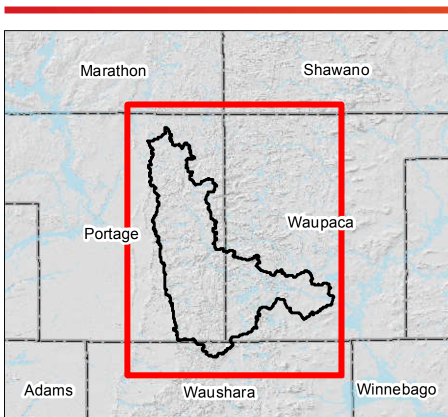




Legend

- Waupaca River Watershed

National Land Cover Database

- Barren Land (188.91 ac)
- Cultivated Crops (75,416.47 ac)
- Deciduous Forest (45,993.30 ac)
- Developed, High Intensity (278.93 ac)
- Developed, Low Intensity (3,014.56 ac)
- Developed, Medium Intensity (894.57 ac)
- Developed, Open Space (8,867.53 ac)
- Emergent Herbaceuous Wetlands (963.31 ac)
- Evergreen Forest (9,609.61 ac)
- Hay/Pasture (16,159.13 ac)
- Herbaceuous (576.46 ac)
- Mixed Forest (4,143.18 ac)
- Open Water (3,090.18 ac)
- Shrub/Scrub (471.15 ac)
- Woody Wetlands (10,734.29 ac)

Figure No.
6

Title
National Land Cover Dataset

Client/Project
Weyauwega Lake Restoration, Inc.

Project Location
Portage, Waupaca, & Waushara Counties., WI

193703396
Prepared by KAS on 2016-01-04
Technical Review by JD on 2016-01-04
Independent Review by JS on 2016-01-04

0 1.5 3 Miles
1:190,080 (At Original document size of 11x17)

N

Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec, USGS
3. Background: NLCD (2011)

[redacted]

plants are cut prior to the start of turion production. Harvesting can be an effective measure to control large-scale nuisance growth of aquatic plants.

The advantages of harvesting are that the harvester typically leaves enough plant material in the lake to provide shelter for fish and to stabilize the lake bottom. Navigation lanes cut by harvesting also allow predator fish, such as bass or pike, better ambush opportunities. Many times, prey like minnows or panfish, are able to hide in thick vegetation lacking predation and potentially causing stunting to the population due to too many prey individuals and not being thinned out by predators. The disadvantages of the harvesting is that it does cause fragmentation and may facilitate the spread of some plants, including EWM, and may disturb sediment in shallow water increasing water turbidity and suspended sediment issues. Another disadvantage is harvesters are limited in depths to which they can effectively operate; typically it must be greater than 2' – 3' of water. Aquatic plant harvesting is subject to State permitting requirements which are renewable every 5 years.

In some areas of excessive plant growth, in particular in shallow water areas that can't be effectively managed using a harvester, contact herbicides can sometimes provide effective season long relief for navigational channels 30' – 50' in width as described in the section above with the difference being the control mechanism would be chemical herbicides, verses mechanical cutting. Since selectivity is not a concern for navigational treatment, contact herbicides such as diquat or more recently flumioxazin are used for submersed species. They are typically mixed with a copper based algaecide for increased efficacy. For floating leaf species, an herbicide such as imazapyr is typically used with a surfactant or sticking agent. A combination of harvesting and treatment is sometimes a wise approach to compare length of control, costs and season long performance.

Mechanical harvesting requires significant infrastructure to complete, many times requiring the purchase of a harvester by the group and, unless already being completed, has significant startup costs. Currently, no harvesting is being done on Weyauwega Lake and at this time would prove to be cost prohibitive to WLRI in the short term. Additionally, much of the nuisance is being caused by the emergent AIS flowering rush, which does not harvest well. Control efforts associated with flowering rush will, in turn, reduce nuisance vegetation. If harvesting is desired to be explored in the future, it will be most beneficial for WLRI to purchase, operate, and maintain their own harvesting equipment for most efficient use. There are WDNR grant program available to aid in the purchase of mechanical harvesters. Prior to finalization of any future actions, all harvesting areas and methods will need to be reviewed and approved by the WLRI, creating guidance for harvesting operations and permitting.

8.0 INVASIVE PLANT MANAGEMENT ALTERNATIVES

8.1 AQUATIC INVASIVE SPECIES HERBICIDE TREATMENT

An aquatic herbicide treatment may be an appropriate way to treat larger areas of AIS and to conduct restoration of native plants. When using chemicals to control AIS, it is a good idea to reevaluate the lake's plant community and the extent of the AIS conditions before, during and after chemical treatment. The chosen herbicide may impact native plant communities including coontail, common waterweed, naiad species and others, especially during whole-lake applications and/or extended periods of herbicide exposure. The WDNR may require another aquatic plant survey and may require an AIS survey prior to approving a permit for treatment. Surveys should be included for all aquatic plant treatments and is typically a WDNR requirement.

The science regarding what chemicals are most effective, dosages, timing and how they should be applied is constantly evolving and being updated. Current WDNR and Army Corps of Engineer research has shown that herbicide applied to water diffuses off site due to a variety of environmental and physical conditions including wind, waves, water depth, and treatment area relative to lake volume. Due to these actions, as treatment areas decrease, herbicide retention time needed for impact is lessened due to diffusion off site because of the small amount of area treated and herbicide applied relative to the entire water volume. To combat this, it is recommended to apply at higher rates when compared to a whole-lake rate and typically with a granular herbicide with a combination of active ingredients in hopes to extend contact time.

Chemical treatment is usually a long term commitment and requires a specific plan with a goal set for "tolerable" levels of the relevant AIS. One such landmark might be 10% or less of the littoral area being occupied by aquatic invasive plants. WDNR recommends conducting a whole-lake point-intercept survey on a five year bases (for Weyauwega Lake the next would be 2019). Such a survey may reveal new AIS and at the very least would provide good trend data to see how the aquatic plant community is evolving.

Herbicides provide the opportunity for broader control over a larger area than hand pulling, and unlike harvesters, allow for a true restoration effort. Disadvantages include negative public perception of chemicals in natural lakes, the potential to affect non-target plant species (if not applied at an appropriate application rate and/or time of year), and the fact that water use restrictions may be necessary after application.

8.1.1 Flowering Rush

Currently flowering rush is the most common aquatic invasive plant species within Weyauwega Lake. The fact that almost half of the flowering rush is submersed creates additional challenges for management. Submersed FR is more susceptible to treatment, which can be a combination of systemic herbicide's such, as 2,4-D and triclopyr, or a contact herbicide such as diquat, which will typically require multiple years of repeated application. Treatment usually occurs in later spring.

Emergent FR can be more robust and resistant to treatment. These plants are typically foliar sprayed with imazapyr and/or carfentrazone in early spring pre-emergent and all the way through late summer when the majority of the plant surface is exposed with a surfactant. Foliar spray treatments are much less costly and it may be viable to do a 4' drawdown (area shown below) for about 2 - 3 weeks. This would expose submersed plants and allow them to be surface sprayed. This would take coordination with hydro dam operator and it also requires a permit and coordination with WDNR. Area in brown on the following map shows portions of Weyauwega Lake expected to be exposed in the event of a four foot drawdown.

8.1.2 Curly-leaf Pondweed

Curly-leaf pondweed is the second most prevalent aquatic invasive plant species targeted for chemical treatment in the State. At present, endothall, a contact herbicide is the most common active ingredient in herbicides used for CLP management in Wisconsin, although imazamox has been used periodically in the last several years. Imazamox has shown promise in that it is a systemic herbicide for CLP control and can potentially have a much lower impact to the native plant community than a contact herbicide and appears to show increased year after treatment control than endothall. It is not entirely clear as to why this happens but it may be due to the systemic effect on turion production within the plants, resulting in fewer plants the following year.

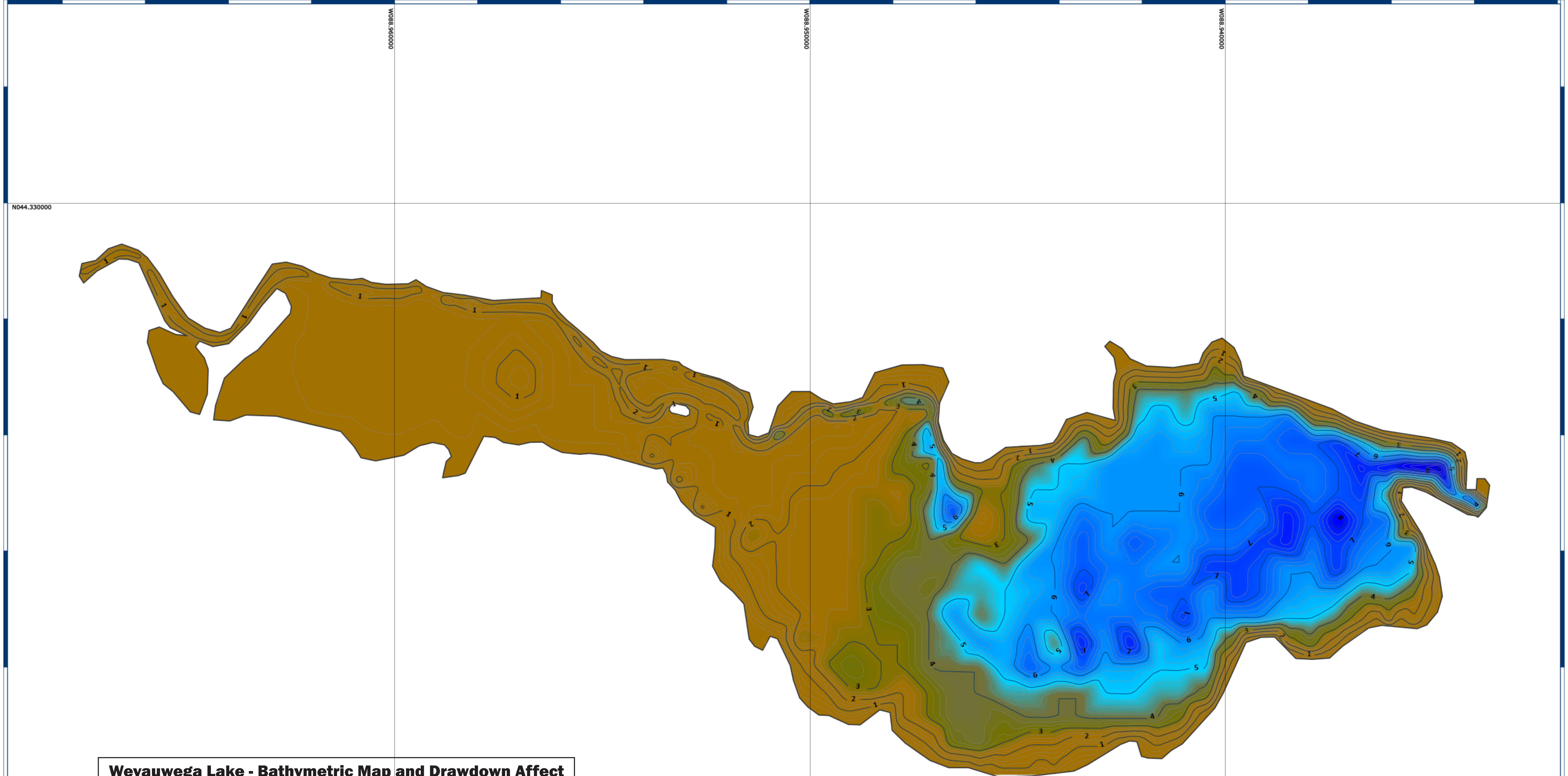
Granular based formulations are generally more costly and used for smaller spot type treatments while liquid formulations are less costly and generally used for larger contiguous treatment areas or whole lake type treatments. In order to decrease any potential impact to native plants and be as selective as possible for CLP, treatments are completed in the spring when native plant growth is minimal, typically prior to 60˚ water temperatures, but perhaps most importantly prior to the start of turion production. CLP seems to prefer and flourish in mucky or highly flocculent substrate, which is generally not present in most of Weyauwega Lake. Given the lack of appropriate substrate and the limited expansion of this invasive within Weyauwega Lake, monitoring may be the best option for management.

8.1.3 Eurasian Water-milfoil

EWM is the most commonly managed AIS within Wisconsin lakes. EWM is an extremely opportunistic plant and could easily become reestablished within Weyauwega Lake. Should such an event take place, it is prudent to include potential management actions for EWM within this plan to provide a quick and concise reference for management.

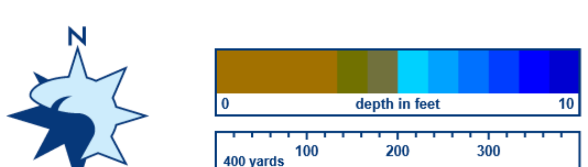
At present, 2,4-D is the most common active ingredient for selective systemic herbicides used for EWM management in Wisconsin, although triclopyr use is increasing and has been commonly used in Minnesota for well over a decade. Granular based formulations are typically more costly and used for smaller spot type treatments, while liquid formulations tend to be less costly and used for larger contiguous treatment areas or whole lake type treatments. In order to maximize effectiveness and decrease any potential impact to native plants to the greatest extent possible, treatments should be completed in the spring when native plant growth is minimal, typically prior to 65˚ water temperatures.

Current WDNR and Army Corps of Engineer research has shown that herbicide applied to water diffuses off site due to a variety of environmental and physical conditions including wind, waves, water depth, and treatment area relative to lake volume. Due to these actions, as treatment areas decrease, herbicide retention time needed for impact is lessened due to diffusion off site because of the small amount of area treated and herbicide applied relative to the entire water volume. To combat this, it is recommended to apply at higher rates when compared to a whole-lake rate and typically with a granular herbicide with a combination of active ingredients in hopes to extend contact time. As EWM abundance lessens within Weyauwega Lake and smaller treatment areas (>2.0 ac) are mapped, it is recommended to use either 2,4-D or a 2,4-D/triclopyr combination herbicide applied between 3.0 – 4.0 parts per million (ppm), depending



Weyauwega Lake - Bathymetric Map and Drawdown Affect		
	Full-pool	4-foot drawdown
Volume (ac/ft)	847.5	201.9
Area (ac)	259.8	114
Area exposed (ac)*		145.8

* In brown on map



Wisconsin Lake & Pond Resource LLC

"Providing Professional Resources for Management of Your Lake or Pond" on water depth and volume of the treatment area. This approach has shown to be an effective management tool in various lakes throughout Wisconsin and is continuing to be researched for efficacy and long term control.

It is worth noting there are various hybrid strains of EWM being genetically confirmed throughout the State and many of these are showing resistance to typical systemic herbicides, Research projects are currently underway, with the WDNR and herbicide manufacturers' testing various combination herbicides (systemic, such as 2,4-D & contact, such as endothall) at 1:2 or 1:3 ratio as well other modes of action like pigment bleaching herbicides (fluridone) in the field and lab that may be more effective on these strains of hybrid EWM, in particular on a whole lake basis maintaining a 2-4 PPB residual for 90+ days.

Fluridone is also available in different pelletized slow release formations that are designed to release off the carrier over extended periods of time; from several weeks to several months. These may be useful in a flowing water situation as the pellets can be placed upstream and the herbicide allowed to be carried downstream by the current as it is released off the pellet.

Please Note: Consideration should be given for any "whole lake" type herbicide management activities on a flowing reservoir system as to the potential impacts of the herbicide as it migrates downstream and label should be reviewed for possible precautions for fish and other organisms based on the rates proposed.

The size of the infestation tends to dictate the type of the treatment. Small treatment areas or beds less than 5 acres are many times consider spot treatments and usually targeted with granular type herbicides, or fast acting contact liquid herbicides. When there are multiple "spot" treatment areas within a lake, it most often makes more sense from economic and efficacy standpoints to target the "whole" lake for treatment. This typically entails calculating the entire volume of water within the lake, in acre/feet, and applying a liquid herbicide, such as 2,4-D, at a low dose at a lake wide rate of typically between 250 – 350 parts per billion (PPB).

8.2 PARTIAL, OVER WINTER WATER LEVEL DRAWDOWN

Having a dam on this waterway presents unique opportunities to potentially manage sediment, water quality and aquatic plants. Over winter drawdowns typically occur from September through May and can be effective at controlling EWM, as well as reinvigorating native plant communities by stimulating dormant seed banks and changing their dynamics sometimes offering navigational relief for one to two or more years post drawdown. This can reduce the need for harvesting frequency. Recreational access to lake during this time can be limited during late fall and early spring to small carry in watercraft and unstable ice conditions may be present during winter.

Drawdown of water level can be a very effective tool in managing EWM if an available option, however it does not seem to affect CLP and may even increase populations of flowering rush. During a drawdown the water level is lowered to expose the lake bed where AIS are present, allowing winter temperatures to fatally freeze and dry plants and associated root systems. Drawdowns have drastically reduced AIS frequencies in some lakes, although populations typically rebound after several years. Drawdowns do impact native plants, but not to the extent that it does AIS. Many native plants respond well to fluctuating water levels with typically an increase in diversity and density of native aquatic plants following the first summer after refilling the reservoir. This was noted in Weyauwega Lake as species diversity increased from 10 prior to the drawdown to 16 after.

Periodic, over winter partial (2 – 4 feet) drawdowns mimic normal water level fluctuations experienced by “natural” seepage type lakes and can also help turn back the clock on the aging process of a flowage by reducing plant biomass and offering temporary changes in the overall plant community. It also aids in sediment compaction, especially in mucky areas of a lake and potential head cutting at the upper end of the reservoir serving to deepen and redefine the channel. These areas can experience sediment reduction, though less than a completed extended drawdown mentioned above, of a few inches. These two actions, reduction of plant biomass and soil compaction, deepen the lake, which creates a “youthful” trophic condition.

Limited overwinter drawdowns can have a potential negative affect as well. Perhaps the biggest impact being that a drawdown reduces lake use by limiting direct access to the waterway. However, this impact is usually minimal because drawdowns are typically over-winter events. There is a popular belief that drawdowns negatively impact fish populations, but that has not been scientifically proven. Although, given the reduced volume of water, the likelihood of possible overwinter fish kill due to reduced oxygen can increase. This depends on the severity of the winter and late season runoff events. There are area lakes that have undergone periodic over winter drawdowns with no noticeable negative impact to the fishery. Fish do become more concentrated during drawdown conditions, but this allows for greater predator opportunities that help thin out populations of smaller fish. Some also believe that fish populations can become “fished out” during drawdown conditions. But, the concentrated conditions create increased predator opportunities as well, making it less likely for a fish to take an angler’s bait.

Over winter drawdowns have the potential to benefit impoundments in multiple ways. Even though drawdowns were the least desired management actions by lake user questionnaire respondents, partial over winter drawdowns can be a useful tool for AIS management and should be included as a potential management option for Weyauwega Lake. This recommendation follows that outlaid in the *Waupaca River Watershed - 2011 Water Quality Management Plan Update* to help improve or maintain the water and habitat quality of the Waupaca River. The use of limited (2’- 4’ as measured at the head of the dam) overwinter drawdowns should be further explored for as a management tool if EWM becomes a future problem, or for minor sediment compaction. This is less obtrusive and may be a more popular option with lake users given the limited impact to most recreational activities.

8.3 AQUATIC INVASIVE PLANT HARVESTING

MECHANICAL HARVESTING

Aquatic plants may be mechanically harvested up to six feet below the water surface and can be a practical and efficient means of controlling plant growth as it generally removes the plant biomass from the lake. It can also be effective in control AIS such as curly-leaf pondweed if the plants are cut prior to the start of turion production, and continually cut throughout the season to prevent turion production until the plant dies on its own in mid to late summer. Harvesting can be an effective measure to control large-scale nuisance growth of invasive aquatic plants.

Harvesting can also be used as a means to facilitate native aquatic plant growth by “top cutting” AIS growth that has canopied out. This is done by removing a canopy of AIS that shades out native, lower growing species, such as pondweed species. Use of a top cut only in areas of dense AIS growth, can provide additional sunlight for growth, increasing diversity and available fisheries habitat quality. As stated above, mechanical harvesting requires significant investment in equipment. No harvesting is currently ongoing for Weyauwega Lake and at this time and would be cost prohibitive for WLRI.

MANUAL (HAND) REMOVAL

If a small isolated stand of AIS is present, hand pulling may be a viable option. No permit is required to remove non-native invasive aquatic vegetation, as long as the removal is conducted completely by hand with no mechanical assistance of any kind. All aquatic plant material must be removed from the water to minimize dispersion and re-germination of unwanted aquatic plants. Portions of the roots may remain in the sediments, so removal may need to be repeated periodically throughout the growing season. This can be a very effective control mechanism for EWM if the entire plant mass and root structure is completely removed. The drawback of this alternative is that pulling aquatic plants includes the challenge of working in the water, especially deep water, threat of letting fragments escape and colonize a new area, and control of any significant sized population is quite labor intensive and very costly. Hand harvesting costs using professionally contracted SCUBA divers are around $1,500 - $2,000 per 5,000 square feet, or $10,000 - $20,000 acre depending on plant densities.

9.0 SEDIMENTATION & WATER QUALITY MANAGEMENT ALTERNATIVES

SEDIMENTATION AND WATER QUALITY MANAGEMENT ALTERNATIVES

The increasingly shallow depth of the reservoir and nutrient enrichment has been recognized as problems for decades. As soft sediment loads increase water quality decreases, which is the case on Weyauwega Lake. Work has already been completed to evaluate the practicality of several options. Most of these analyses focused on the short-term -- that is changing the problematic condition but not considering if the option produced desirable changes in the long term. To help assure that lake management dollars are invested wisely, the sustainability of solutions should be a primary consideration along with implementation cost.

A few management options if implemented on their own are extremely unlikely to be practical, affordable, sustainable, or meet the lake WLRI's goals. Such options should likely be eliminated from consideration to allow focus on options or combinations of options that are truly feasible. Therefore, we suggest certain options be dismissed from further consideration including large scale dredging and dam removal. Large scale dredging is difficult to permit, is exceedingly expensive and has an extremely low likelihood of receiving support from grants. Dam removal eliminates the lake that WLRI members seek to protect. While dam removal is a very pragmatic option, and while it provides desirable stream habitat, it is not congruent with the mission of the WLRI.

We have prepared the following table to summarize options. As in most situations, a "silver bullet" single element solution is unlikely to exist and/or be practical. Therefore, a combination of approaches may provide the best overall value to the WLRI. See the table following this section for further details.

Enhanced Dam Operation for Water Quality Improvement and Sediment Reduction

Of all the alternatives presented above, enhanced dam operation is commonly the least well understood by most stakeholders. The overall logic behind this approach is to adjust dam operation to better emulate a free-flowing river. This allows more sediment to pass downstream and helps avoid water conditions conducive to nutrient release from lake bottom sediment. More on each of these elements is presented in the following paragraphs.

A river transports a great deal of sediment in addition to water. The sediment can be classified into two forms: suspended sediment (sediment essentially floating in the water column) and bedload (sediment that bounces along the river bed). Even small dams are particularly efficient at blocking bedload transport, and coarser grained sediment is detained in the dam until a new equilibrium is reached. This new equilibrium is typically the partial or complete filling of the reservoir. At the same time, areas downstream of the reservoir continue to transport sediment but no upstream sediment is available to take its place. This creates an unnaturally coarse bed downstream of the dam and conditions not supportive of all native species.

While it may not be possible to eliminate all effects of a dam on sediment transport, actions can be taken to allow more bedload to pass through the system. This slows or can even reverse reservoir sedimentation. It also allows downstream areas to receive some bedload sediment, restoring channel conditions for native species. Sediment discharge through the reservoir is increased by opening gates when water flows are low to decrease reservoir water depths in turn increasing water velocity in channel areas. Ideally, water levels are lowered immediately before forecast high runoff events or seasons. It is not a drawdown in the traditional sense since the goal is to increase reservoir storage to accommodate soon-to-arrive flood water. As opposed to opening gates as an afterthought to pass more flood water downstream, the reservoir uses excess stream flow to scour sediment and quickly refill the reservoir. An added benefit to this approach may be slight reduction of minor downstream flooding.

The process increases scour by decreasing water depth in the active channel, and maintaining the shallower water depth during early-stage storm flow. Effects extend to the main channel and tributaries but have little effect in quiescent backwater areas. Care must be taken to assure excessive sediment is not released at any one time. The process partially restores normal stream function without removing the dam. Sediment in a reservoir should be considered detained, not retained, in the watershed.

Revised dam operation can also help reduce lake internal phosphorus loading. Phosphorus minerals in lake sediment are sensitive to the concentrations of oxygen present in adjacent lake water. Phosphorus is relatively insoluble when oxygen is present. When oxygen is absent, phosphorus minerals become more soluble. Therefore, lake-bottom sediment in contact with anoxic water tends to release phosphorus into the lake. Since phosphorus is normally the nutrient limiting plant growth in Wisconsin lakes, this situation can fuel additional growth of rooted plants and algae.

Even though the Lake is not deep, water near the sediment surface in the areas immediately upstream of the dam may become anoxic during warm, low flow, summer conditions. At present, low flow exits the Lake over the fixed weir section, an action that skims warm well-oxygenated water out of the Lake. We suggest that low flow during warm summer months could be wholly or partially passed through the bottom-most section of one tainter gate to help reduce the chance of anoxic water forming upstream of the dam. This action could reduce internal phosphorus cycling and in turn reduce the mass of the limiting plant nutrient during the growing season.

Extended Drawdown for Sediment Reduction

Longer multiyear drawdowns typically over two growing seasons can provide sediment compaction of 6" to 30" to exposed sediment that has the ability to thoroughly dry out during this time. To have maximum effectiveness throughout the reservoir, the Lake should be drawdown as far as possible. This sometimes does have a negative secondary effect of potentially depleting the fish population, which then needs to be reestablished after refill. Also, recreational access to lake during this time is limited to small carry in type watercraft.

Lengthy drawdowns effective for sediment control can be controversial and do require a permit from WDNR and required a public hearing. The positives and negatives need to be carefully weighed if this option is to be further explored for sediment reduction purposes. Currently WDNR staff is compiling sediment compaction data from several multiyear drawdown projects throughout the State. This report is expected to be completed shortly and may provide additional information to assist in making a decision if this option may be right for the Lake.

Certain emergent plants that need lowered water levels to germinate and reproduce, such as bulrush, benefit from drawdowns. Growth of the emergent AIS flowering rush also appears to be aided by drawdowns. During the 2011-2013 drawdown, flowering rush was very opportunistic and grew on much of the exposed lakebed. After refilling, much was expected to naturally drown out, which did not take place. Additional drawdowns done when flowering rush remains a large component of the overall aquatic plant community are likely not warranted as it may continue to facilitate the spread of this plant which thrives during water level fluctuation.

Though extended drawdowns have the potential to benefit impoundments in multiple ways, the use of them in the near future is not viable at the current time for Weyauwega Lake. Extended drawdowns were the least desired management action by lake user questionnaire respondents. Additionally, during a drawdown, revenue generated through hydroelectric power is lost by the dam owner and requires recoupment by WLRI. *Use of extended multiyear or over summer drawdowns on Weyauwega Lake for management activities are not recommended at this time, based on lack of public support, but should be re-explored as an option during the next lake management plan update.*

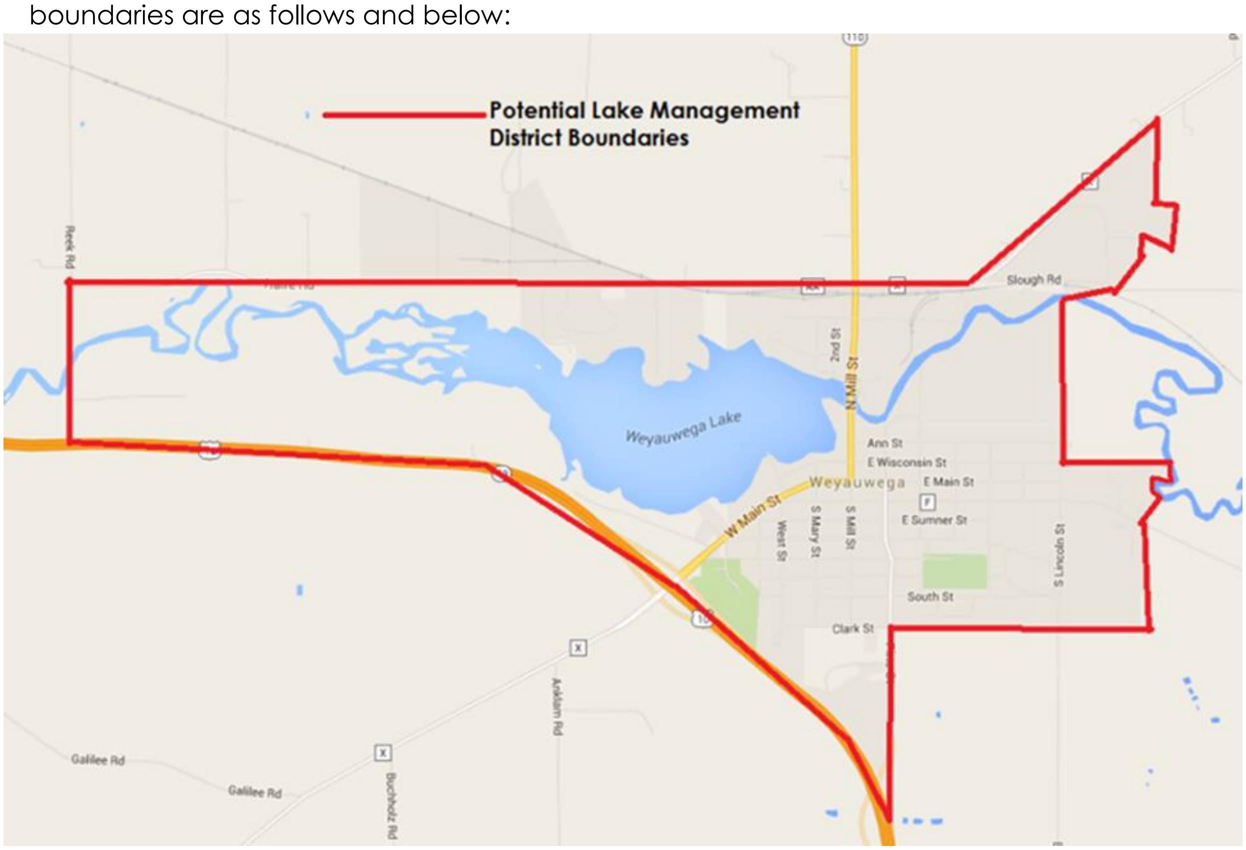
Approach	Practical/Matches Lake Resident Goals?	Permittable?	Affordable?	Sustainable?	Benefits Water Depth and/or Water Quality	Comments
Dam Removal	No, eliminates lake	Yes	Yes, grants available.	Yes, lowest cost option in the long term. Requires no future intervention. Improves downstream areas.	Yes, water depth good for fish but not for boating, water quality improves	Grants available, eliminates AIS barrier which must be considered from a watershed perspective
Dredging, Large Scale	No, large lake and significant sediment depth	Yes, but difficult	No, extremely costly	No, watershed continues to deliver sediment	Yes, in short term.	Hydraulic dredging or reservoir dewatering with mechanical excavation
Dredging, Limited or Small Scale	Yes, for targeted areas	Yes	Possibly, but goals may not extend to all parties footing the bill.	No, sediment slumping and new deposition will likely reverse gains in relatively short time.	Benefits water depth and possibly quality in limited areas.	Limited to areas that constrain navigation, habitat, water flow or other issues.
Drawdown and Sediment Consolidation	Debatable. Long-term or multi-year full drawdown unacceptable to some.	Yes	Yes	Yes, in medium term, in that process can be repeated when conditions reoccur.	Limited impact by partial drawdown. More substantial impacts from full and/or multi-year.	Requires deep reservoir drawdown for 2 growing seasons for maximum compaction benefit.
Upstream Sediment Traps	Debatable. Yes to water quality. Does not directly increase water depth but prevents further shoaling.	Probably yes, may be difficult.	Debatable Moderate execution cost however significant maintenance costs continue indefinitely.	Yes, but potentially high annual costs	Yes, stabilizes water depth and reduces delivery of sediment-bound nutrients to the lake.	Can be combined with other options to increase sustainability and effectiveness.
Watershed-Management Options/TMDLs	Debatable Yes to water quality. Does not directly increase water depth but reduces further shoaling.	Yes, regulators strongly support and some elements will be driven by legislation	Yes, costs largely born by agencies and point source dischargers.	Yes, the entire initiative is to increase sustainability and resilience.	Yes, stabilizes water depth and reduces delivery of sediment-bound nutrients to the lake.	Can be used to increase sustainability of other options. Execution costs may be borne by others. Consider a watershed group to foster, and/or advance ideas contributing to PLPRD goals and objectives.
Enhanced Dam Operation	Yes. Increases water quality, limits additional shoaling, may reduce existing volume of sediment in reservoir including sandy sediment.	Yes, may require negotiating. Requires cooperation from City of Clintonville	Elements may be implemented for little cost. Revisions to infrastructure could improve performance or ease operation. Infrastructure revisions could be expensive.	Yes, partially restores natural river dynamics.	Yes, improves water quality and sediment upstream. Improves downstream habitat.	Can be used to increase sustainability of other options. Sediment transport through reservoir increased with pre-emptive short-term drawdown before high runoff events. Hypolimnion drawn off through bottom draw in summer.
In-Lake Aeration – typically subsurface diffusers	Yes, perhaps not lakewide but in smaller specific problem areas, more effective for water quality improvement than for sediment reduction	Likely yes, but not without some contests on size/scope and possibly a public hearing	Moderate, and is there an on-going annual cost for maintenance, installation and removal and electricity to operate	Yes, if kept in operation each year	Will improve water quality and may offer additional secondary benefits with sediment reduction longer term	Best suited for smaller and more confined problem areas of the lake rather than a whole lake solution

10.0 FORMATION OF A LAKE MANAGEMENT DISTRICT

Weyauwega Lake Restoration, Inc. is currently recognized as a lake association with voluntary membership. As such, WLRI relies on donations and fund-raising events as the sole sources of income. As the main group responsible for lake management activities and projects, this can and has been an issue for WLRI for funding.

A lake district differs in that it is a taxable entity, which creates much more stable and steady funding for lake management, allowing project planning. Additionally, membership is not voluntary and all those who directly benefit from the Lake within district boundaries are submitting funds. However, as with any creation of new taxes, transitioning from an association to a district can be met with local resistance. WLRI has already explored creating a district, most recently in 2014, and included specific questions on the user survey in regards to gauge local input. It should be noted that the questions on the survey are not binding and used as exploratory purposes only.

Gaining local for support for formation of a district is the first hurdle encountered. Support for formation of a lake district was noted in the user survey. 64.3% responded as in support of a district while 21.9% were unsure and only 13.6% responded as not in favor. Once support is established, boundaries must be set. These are not set in stone or predetermined. Multiple options were outlaid in the survey with an irregular boundary following common areas of demarcation chosen as the most desired, chosen by 40% of respondents. The desired boundaries are as follows and below:



- **North Boundary** – County Road AA
- **South boundary** – State Highway 10
- **East boundary** – extents of the City of Weyauwega
- **West Boundary** – Reek Road between County Road AA and Highway 10

Another item left to decide is annual District dues. User results were across the board with the highest response rate indicating they were unsure at the moment (40%). Of responses that assigned a value range, the most preferred choice was an annual cost of $50-149 at 26%. It was clear that costs over $150 a year were not desired as survey choices at or above this limit only elicited a 10.9% approval.

Taking into account user questionnaire results, the support for formation of a lake district appears present with a reasonable annual fee desired, within the $50-$150 range. Prior to setting a yearly assessment, it is prudent to take into account the total potential amount of properties within proposed boundaries and compare to expected expenditures for both short and long term lake management activities.

11.0 OVERALL LAKE MANGEMENT GOALS

Weyauwega Lake is an aging impoundment that has seen decreased satisfaction and enjoyment of use with increased sedimentation issues hampering navigation and recreation, as witnessed by the questionnaire responses and data collected through all phases. As an impoundment, sediment is allowed to accumulate, shallowing the Lake and hampering navigation and access through out – this was noted by 62.4% of questionnaire respondents.

Dense aquatic plant growth only worsens navigational issues throughout the lake, and is increased by the nutrient rich water and the presence of fast-growing AIS species like EWM. Excessive aquatic plant growth negatively impacted users of the lake 82.7% of the time, with the same amount of users wanting management action to reduce aquatic plant issues.

However, not all desired management options are viable or feasible for each situation. All options are disused further in Appendix D. Only those options that will be supported by the users and WLRI with high likelihood of subsequent approval from the WDNR will be selected to help accomplish management goals.

As an impoundment, Weyauwega Lake provides a unique opportunity for management through water-level manipulation. This option is not only proven to alleviate nuisance and invasive aquatic plant growth, and a lesser extent sedimentation issues, but is also cost effective. The following recommended action plan includes a combination of management actions to achieve desired results.

Goal: Reduce Nuisance Aquatic Plant Growth Hampering Navigation

> **Primary Action:** For riparian landowner access areas that require nuisance relief, hand pulling should be completed up to a width of 30'.

Goal: Reduce Sediment

> **Primary Action:** Engage the WDNR and WLRI members on the available options (dredging, drawdown, etc.) and chose those that have the highest likelihood of success and are economically feasible, this may involve multiple options and additional cost/feasibility analysis, rather than a one size fits all solution.
>
> ***Possible Action*:** Discuss the ability to alter dam operation with the Owner to maintain water quality and better manage sediment and storm loads to the system.

Goal: Manage AIS to improve recreation, increase opportunities, and rehabilitate native plants, reducing AIS abundance and frequency of occurrence within the littoral zone. If active AIS management is pursued, the goal should be to reduce presence of flowering rush to 10% and/or CLP to 5% frequencies of occurrence within the littoral zone, over a 3 – 5 year active management window.

> **Primary Action:** Apply for WI DNR AIS control grant funding to aid in flowering rush management.
>
> **Primary Action:** Use a combination of foliar sprayed herbicides for emergent flowering rush and systemic herbicides for submersed plants, possibly including a limited partial drawdown to expose submersed plants to be able to utilize less costly foliar spray.
>
> **Primary Action:** Continue monitoring for EWM. Though none was found after the drawdown, EWM may become established and quickly populate the Lake as much is habitat suitable for growth.

Possible Action: Spring large-scale (>10ac) herbicide treatment of curly-leaf pondweed areas using endothall at max label rates, expecting some loss of herbicide due to water flow. This will require a WDNR permit which would be applied for in late winter with a recent AIS survey supplementing the permit application. Results of the treatment should be monitored for the following effects; impact to native plants, reduction in AIS numbers, and cost on an annual basis.

***Possible Action*:** Each year direct AIS management is to take place, continue to complete aquatic plant surveys to monitor AIS and native plant responses to the management and plan for the future. AIS should be surveyed and mapped before and after treatment, according to DNR protocol, to evaluate effectiveness, or at least post-treatment each year following management activities. Comparison of data between years allows calculating reduction of targeted species in relation to established frequency of occurrence goals.

Goal: Reduce Existing Sediment

Primary Action: Engage the WDNR and WLRI members on the available options (dredging, drawdown, etc.) and chose those that have the highest likelihood of success and are economically feasible, this may involve multiple options and additional cost/feasibility analysis, rather than a one size fits all solution.

***Possible Action*:** Discuss the ability to alter dam operation with Eagle Creek Renewable Energy to improve water quality and better manage sediment and storm loads to the system.

Goal: Explore Creation of a Lake Management District

Primary Action: Bring forth a binding vote to association members and potential future district members within proposed boundaries to further gauge input and support for formation of a district.

Goal: Resume and establish a framework for comprehensive water quality monitoring within Weyauwega Lake through the WDNR Citizen Lake Monitoring Network and support CB/CW efforts.

Primary Action: Continuing monitoring in 2016 and beyond, have the trained citizen volunteers monitor water quality through secchi readings, chlorophyll a, and total phosphorus water samples and take temperature and dissolved oxygen profiles. Samples will be taken once monthly between May – September or at least 3 times a year spaced 30 day apart, or at bare a minimum once a year mid-summer.

***Possible Action*:** Train citizen volunteers for boat landing monitoring activities and/or work with Golden Sands RC&D or the County to increase the number of CB/CW hours at the boat landing.

There are multiple resources and organizations able to help achieve plan goals and related actions. Contacts for those referenced in the plan and additional groups are included as follows.

Golden Sands Resource Conservation and Development Council, Inc.
1100 Main Street, Suite 150
Stevens Point, WI 54481
(715) 342-6215

Wisconsin Department of Natural Resources
Ted Johnson – Water Resources Management Specialist
(920) 424-2104
Tedm.johnson@wisconsin.gov

Waupaca County Land and Water Conservation Department
Brian Haase – County Conservationist
(715) 258-6482
Brain.haase@co.waupaca.wi.us

University of Wisconsin – Extension Lakes
(715) 346-2116
uwexlakes@uwsp.edu

12.0 REFERENCES

While not all references are specifically cited, the following resources were used in preparation of this report.

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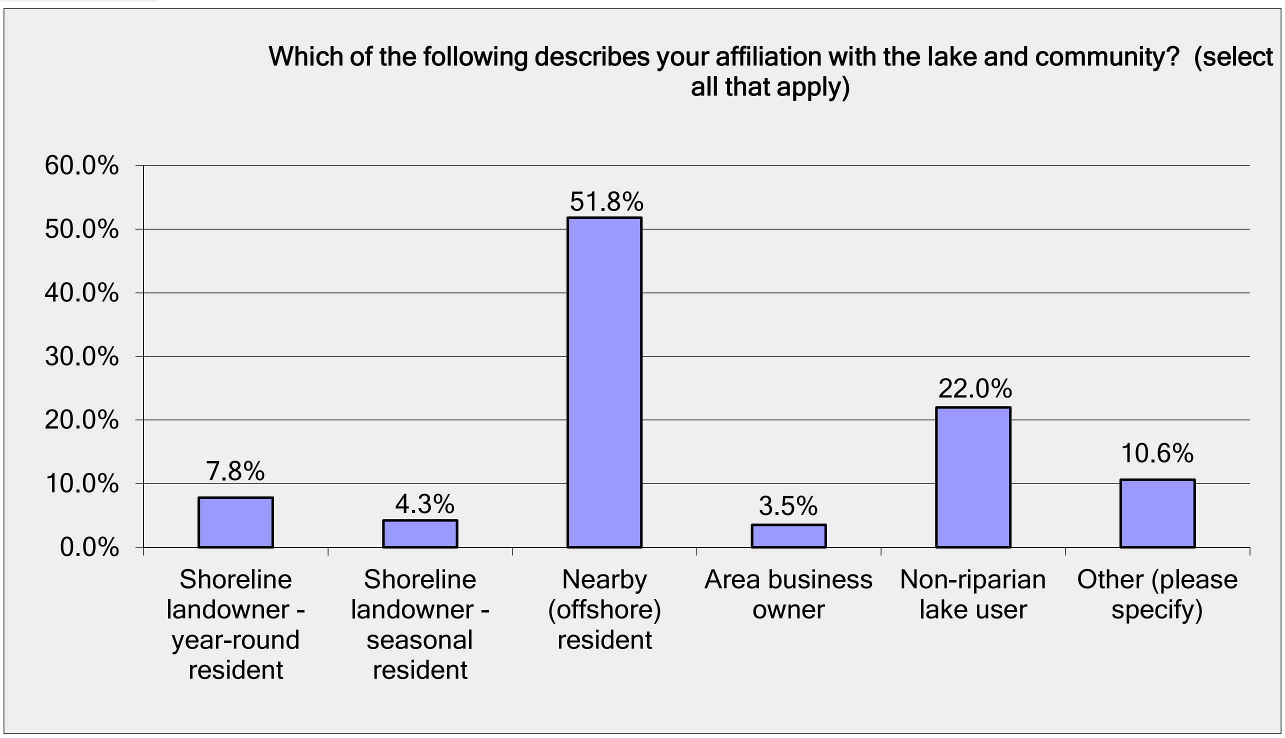
Wisconsin Department of Natural Resources, *Wisconsin Lakes,* Publication # PUB-FH-800, 2005

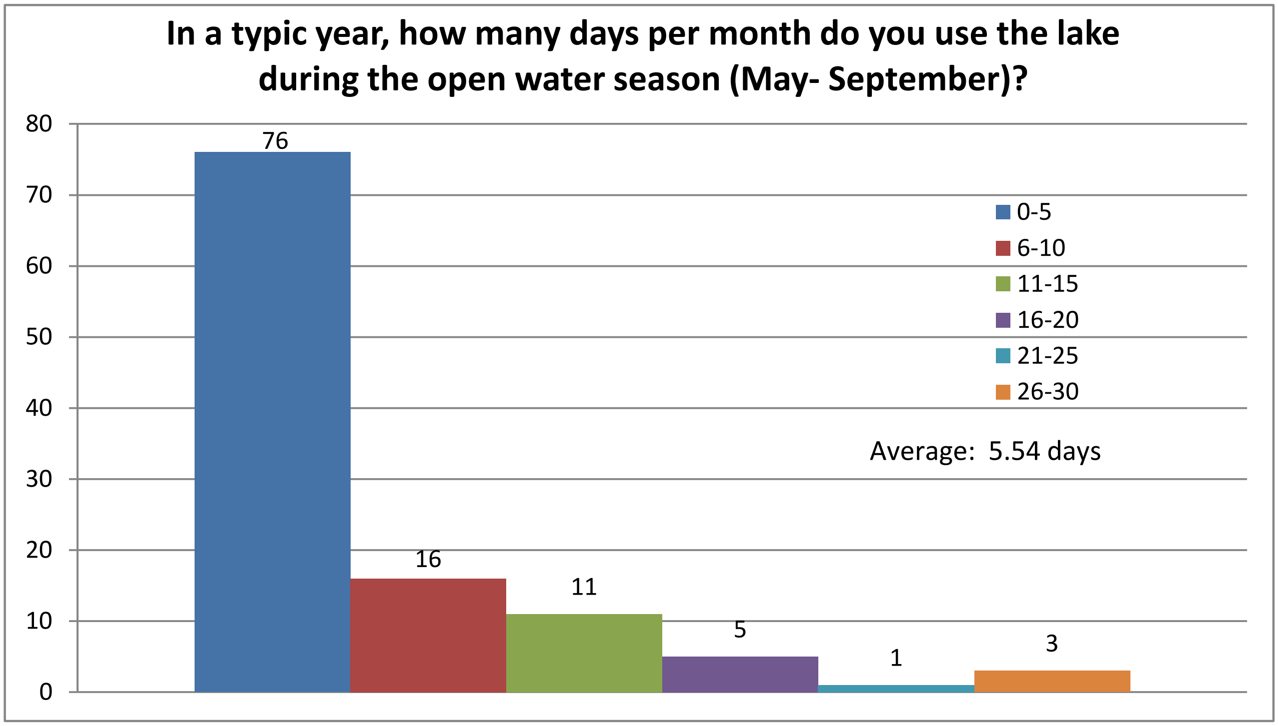
APPENDIX A

Which of the following describes your affiliation with the lake and community? (select all that apply)		
Answer Options	Response Percent	Response Count
Shoreline landowner - year-round resident	7.8%	11
Shoreline landowner - seasonal resident	4.3%	6
Nearby (offshore) resident	51.8%	73
Area business owner	3.5%	5
Non-riparian lake user	22.0%	31
Other (please specify)	10.6%	15
	answered question	132
	skipped question	0

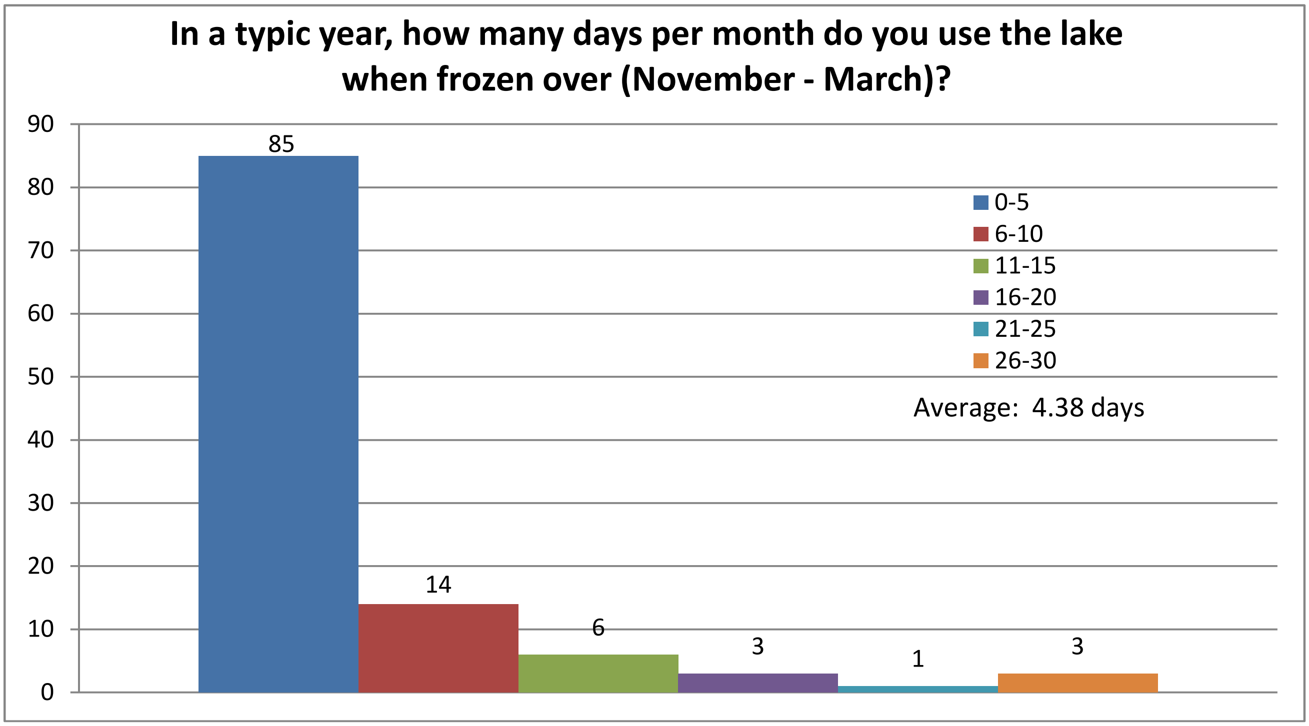
Number	Other (please specify)
1	Own property along river/marsh up stream
2	Resident
3	city resident
4	Community member
5	Live in community
6	used to fish it before it was ruined.
7	Former resident and lake admirer
8	Hometown
9	land owner below lake
10	Former resident
11	Community member
12	I live on the Waupaca River
13	Former resident
14	former resident
15	Grew up in weyauwega. No longer live there.



In a typical year, how many days per month do you use the lake during the open water months, approximately May - September? Enter numbers only.	
Answer Options	Response Count
	112
answered question	112
skipped question	20

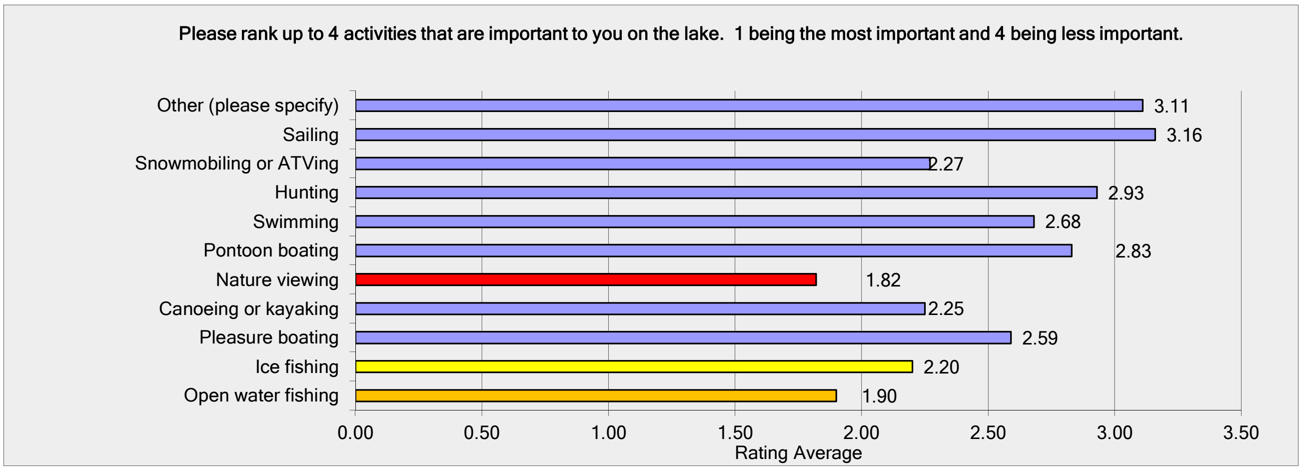


In a typical year, how many days per month do you use the lake during winter months when the lake is frozen, approximately November - March? Enter numbers only.	
Answer Options	Response Count
	112
answered question	112
skipped question	20

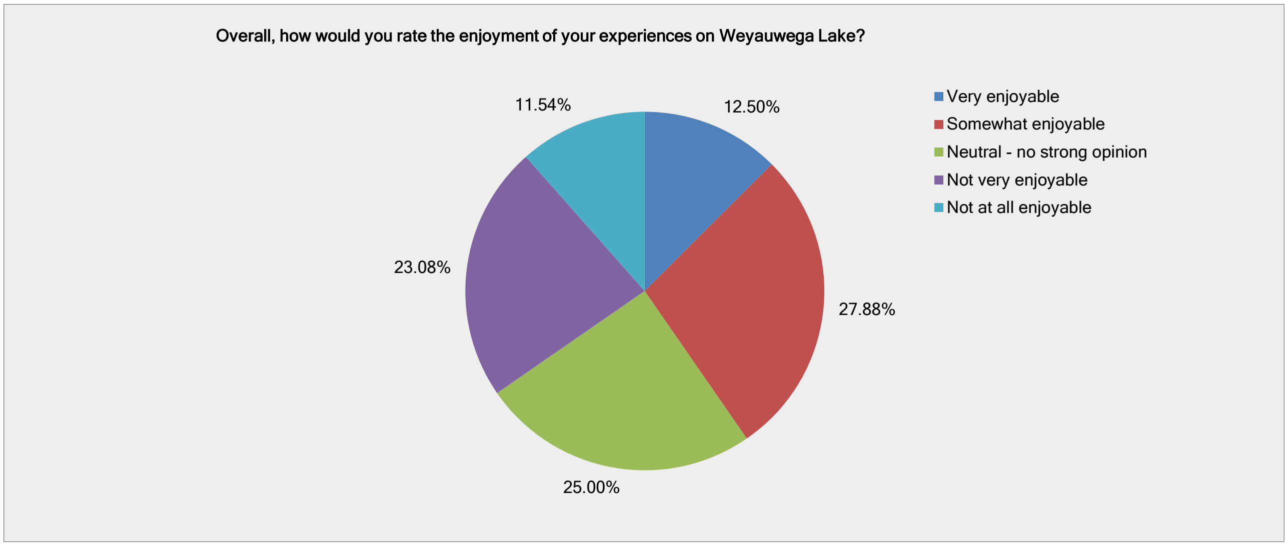


Please rank up to 4 activities that are important to you on the lake. 1 being the most important and 4 being less important.						
Answer Options	1	2	3	4	Rating Average	Response Count
Open water fishing	58	9	12	18	1.90	97
Ice fishing	36	15	13	20	2.20	84
Pleasure boating	23	18	9	31	2.59	81
Canoeing or kayaking	35	18	13	22	2.25	88
Nature viewing	48	22	8	12	1.82	90
Pontoon boating	15	12	13	30	2.83	70
Swimming	19	15	16	28	2.68	78
Hunting	13	13	14	34	2.93	74
Snowmobiling or ATVing	30	17	9	21	2.27	77
Sailing	13	6	6	43	3.16	68
Other (please specify)	8	0	1	19	3.11	28
Other (please specify)						1
					answered question	106
					skipped question	26

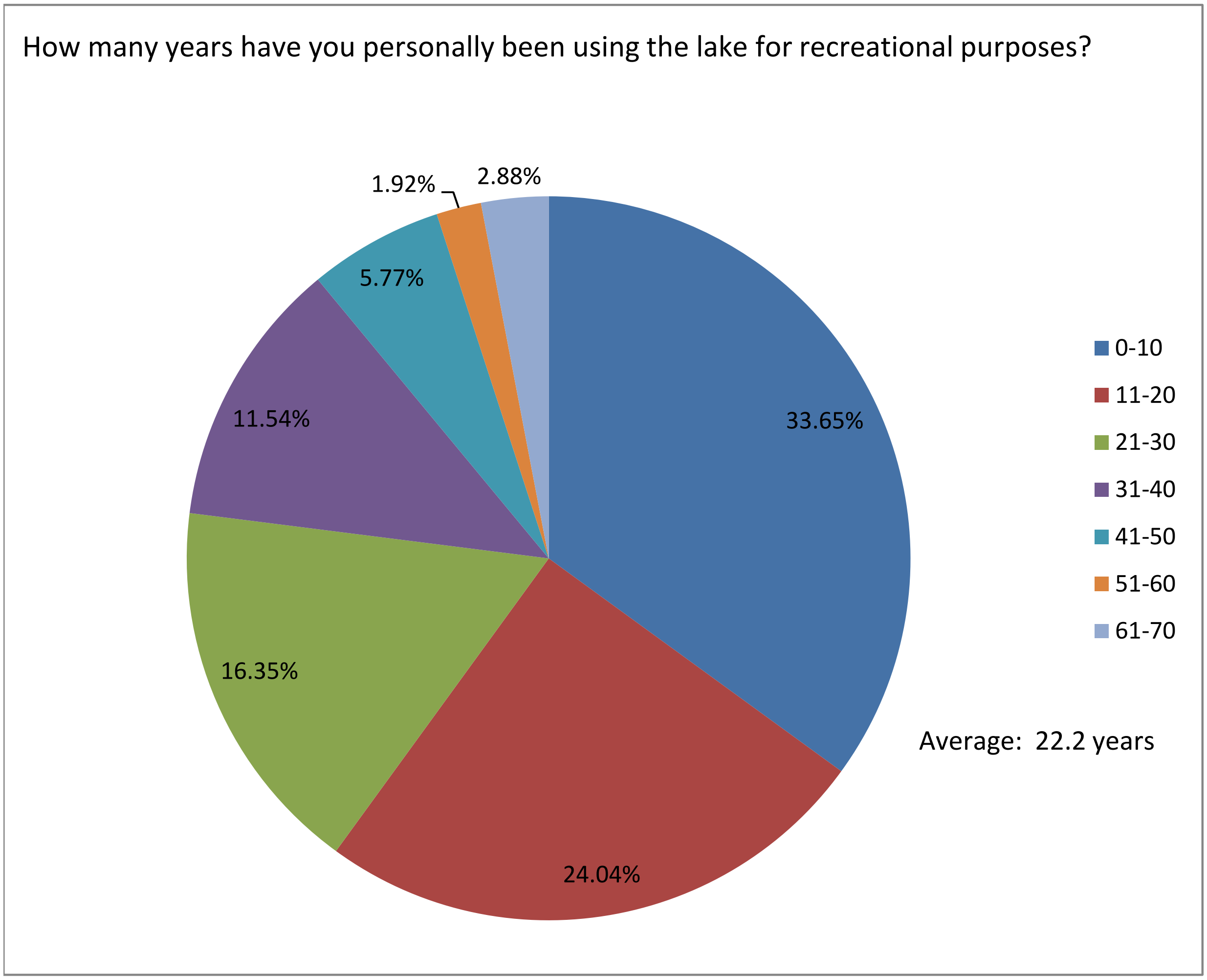
Number	Other (please specify)
1	Keeping the Waupaca River intact



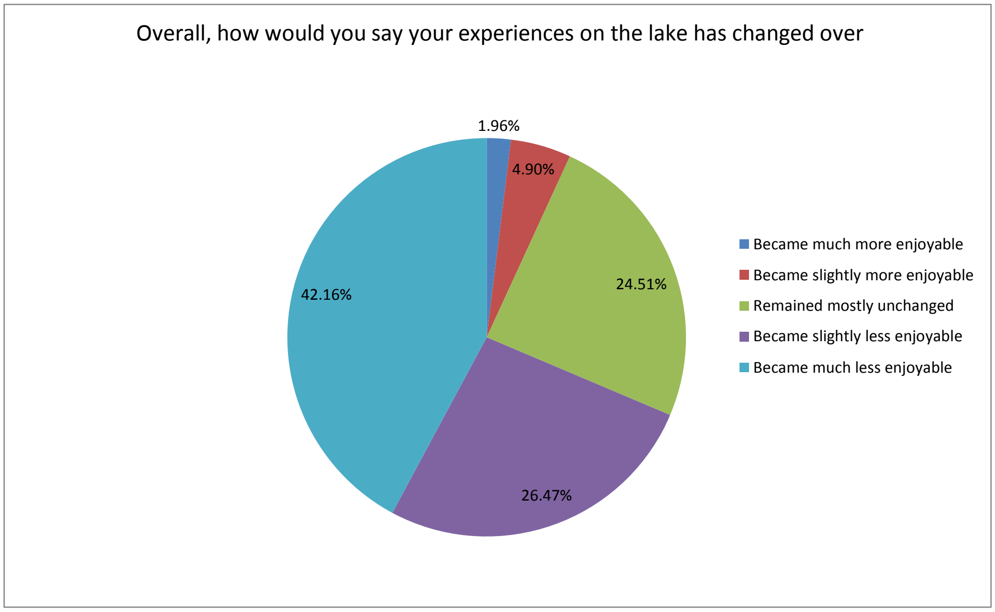
Overall, how would you rate the enjoyment of your experiences on Weyauwega Lake?							
Answer Options	Very enjoyable	Somewhat enjoyable	Neutral - no strong opinion	Not very enjoyable	Not at all enjoyable	Rating Average	Response Count
	13	29	26	24	12	2.93	104
Percent	12.50%	27.88%	25.00%	23.08%	11.54%		
						answered question	104
						skipped question	28



How many years have you personally been using the lake for recreational purposes? (Enter	
Answer Options	Response Count
	104
answered question	104
skipped question	28



Overall, how would you say your experiences on the lake has changed over that period of time? (please select only one)							
Answer Options	Became much more enjoyable	Became slightly more enjoyable	Remained mostly unchanged	Became slightly less enjoyable	Became much less enjoyable	Rating Average	Response Count
	2	5	25	27	43	4.02	102
Percent	1.96%	4.90%	24.51%	26.47%	42.16%		
						answered question	102
						skipped question	30



If your experience using the lake over time has become less enjoyable, what do you consider the two main factors contributing to your decrease in enjoyment? (please select up to two)

Choice 1

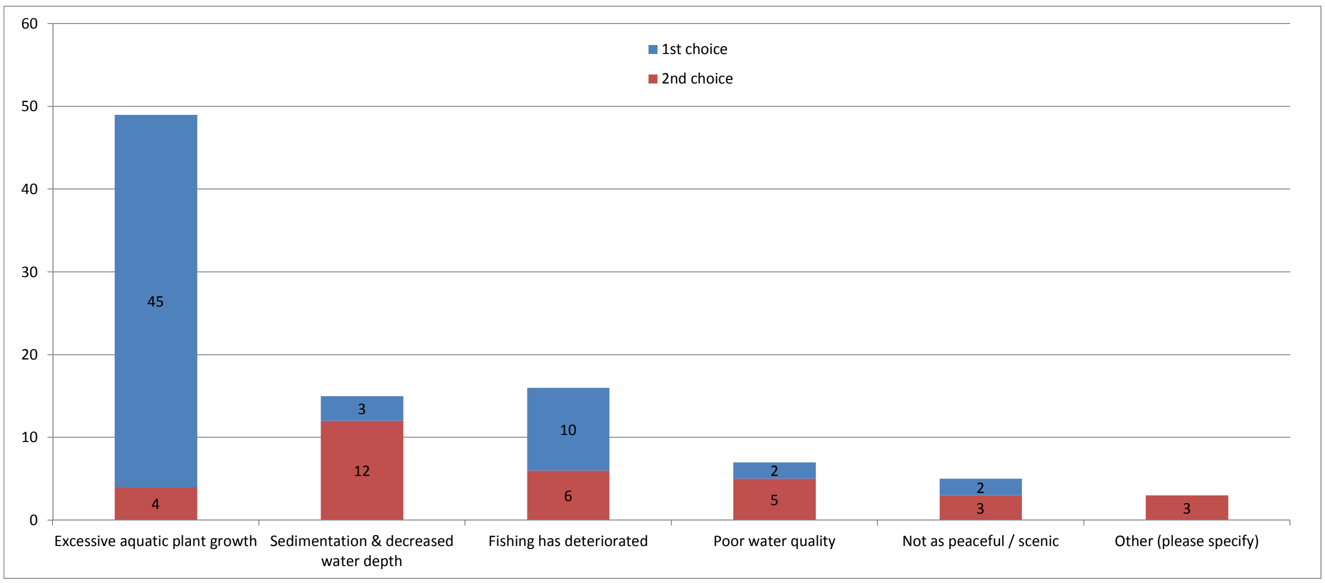
Answer Options	Excessive aquatic plant growth	Sedimentation & decreased water depth	Overcrowding of lake users	Increased shoreline development	Fishing has deteriorated	Poor water quality	Not as peaceful / scenic	Other (please specify)	Response Count
Factors	45	3	0	0	10	2	2	0	62

Choice 2

Answer Options	Excessive aquatic plant growth	Sedimentation & decreased water depth	Overcrowding of lake users	Increased shoreline development	Fishing has deteriorated	Poor water quality	Not as peaceful / scenic	Other (please specify)	Response Count
Factors	4	12	0	0	6	5	3	3	33

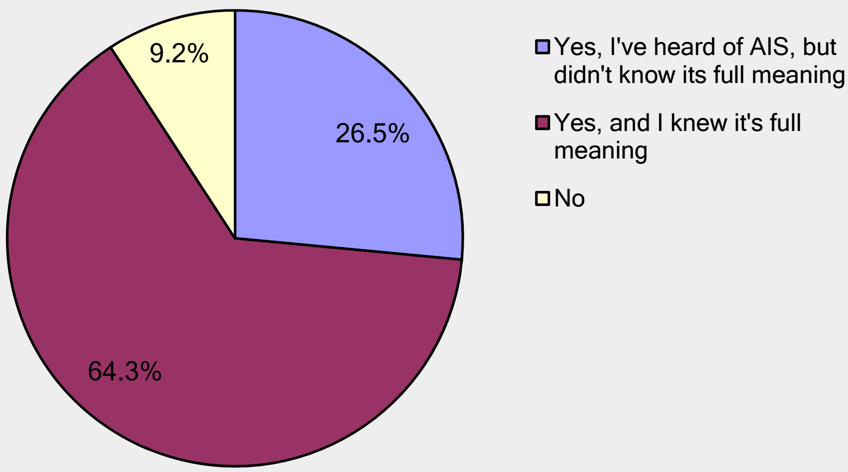
	Question Totals
Other (please specify)	10
answered question	62
skipped question	70

Number	Other (please specify)
1	Smelly,not pretty
2	lake did not have any water for over a year
3	Fish was great. When it was drained it was destroyed.
4	getting to shallow
5	Smell
6	Excess of weeds and muck bottom
7	weeds
8	I think the dumping of cheese factory waste water is contributing to the plant growth problem
9	sedument
10	homeowners who believe they own the waters and yell for you to get off the lake

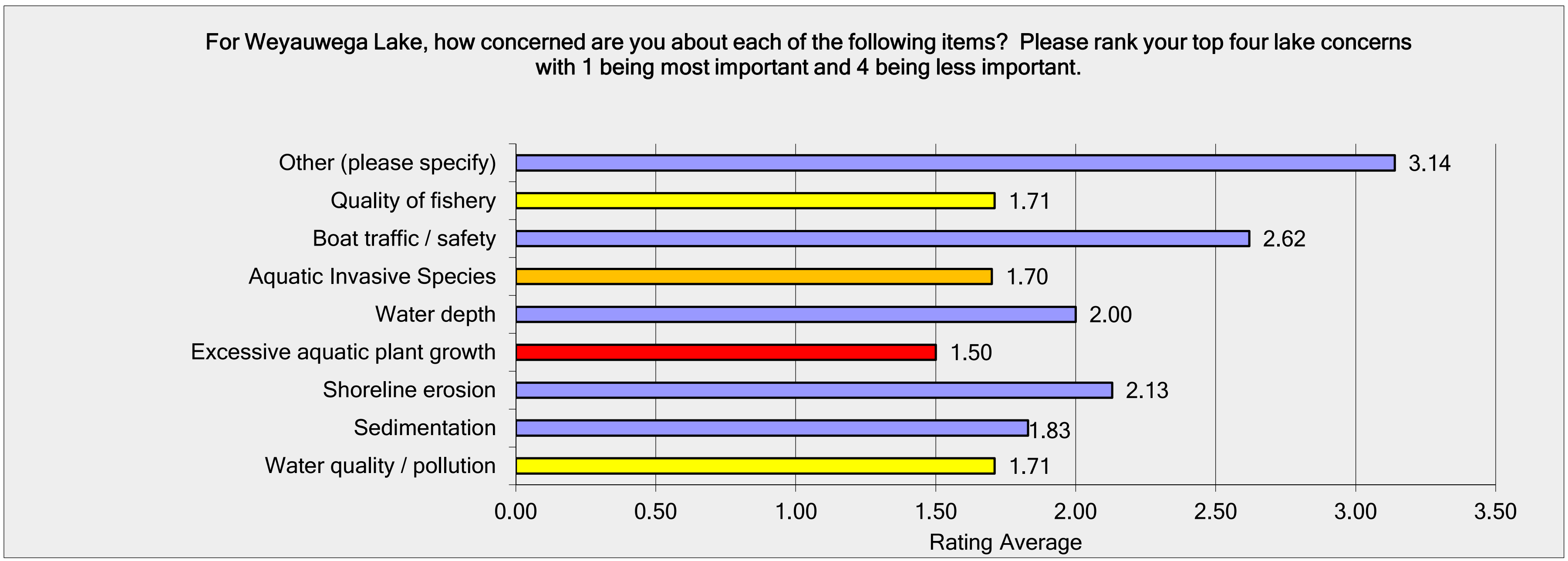


Aquatic Invasive Species (AIS) are non-native plants or animals that can out-compete their natives counterparts and potentially cause many problems within the lake and/or and ecosystem. Prior to this survey, have you heard the therm Aquatic Invasive Species and did you know that it meant?		
Answer Options	Response Percent	Response Count
Yes, I've heard of AIS, but didn't know its full meaning	26.5%	26
Yes, and I knew it's full meaning	64.3%	63
No	9.2%	9
	answered question	98
	skipped question	34

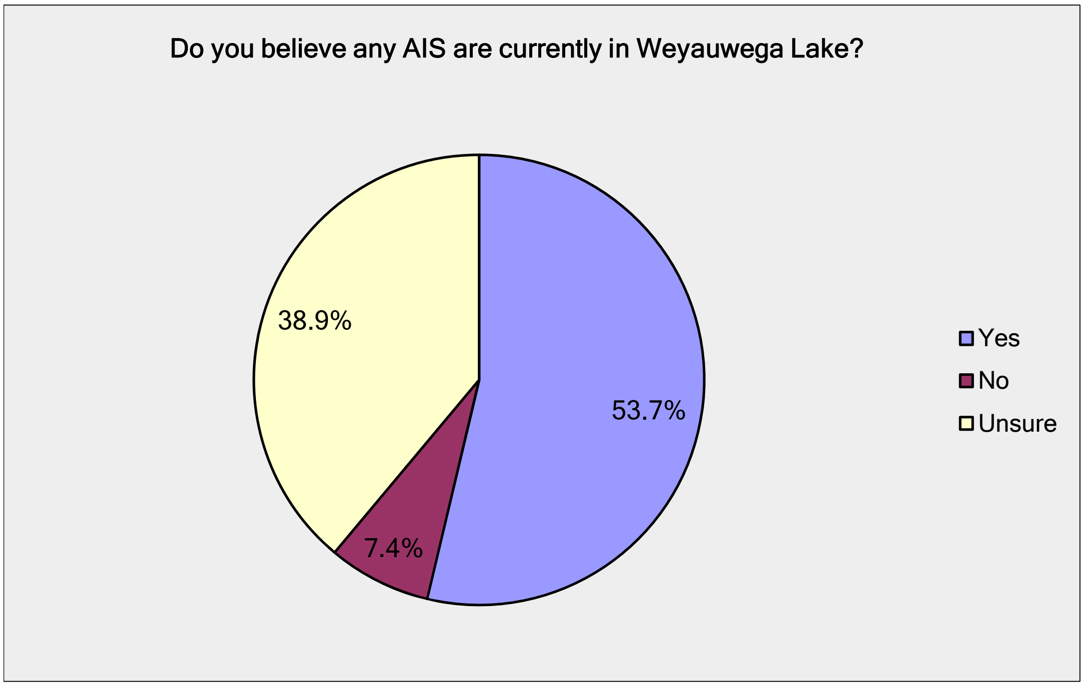
Have you heard the term Aquatic Invasive Species and did you know what it meant?



For Weyauwega Lake, how concerned are you about each of the following items? Please rank your top four lake concerns with 1 being most important and 4 being less important.						
Answer Options	1	2	3	4	Rating Average	Response Count
Water quality / pollution	50	20	7	9	1.71	86
Sedimentation	40	17	11	8	1.83	76
Shoreline erosion	27	17	14	11	2.13	69
Excessive aquatic plant growth	62	19	6	5	1.50	92
Water depth	33	25	11	11	2.00	80
Aquatic Invasive Species	53	15	11	8	1.70	87
Boat traffic / safety	10	21	15	17	2.62	63
Quality of fishery	52	13	8	10	1.71	83
Other (please specify)	2	0	0	5	3.14	7
Other (please specify)						0
					answered question	96
					skipped question	36

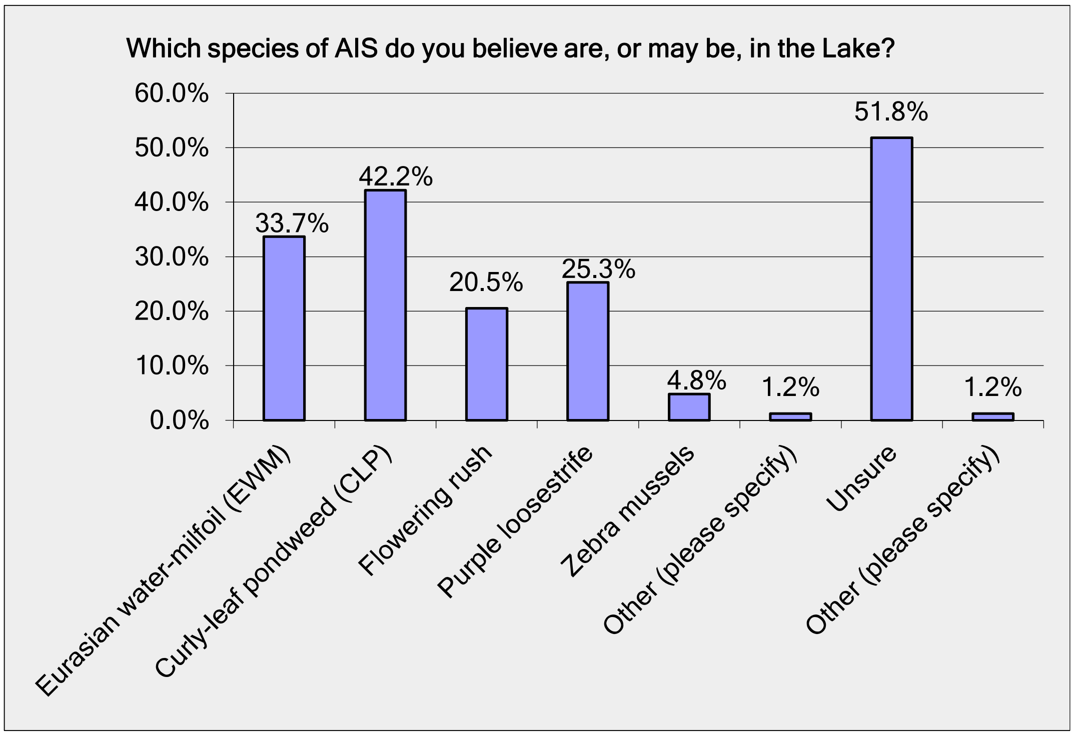


Do you believe any AIS are currently in Weyauwega Lake?		
Answer Options	Response Percent	Response Count
Yes	53.7%	51
No	7.4%	7
Unsure	38.9%	37
	answered question	95
	skipped question	37

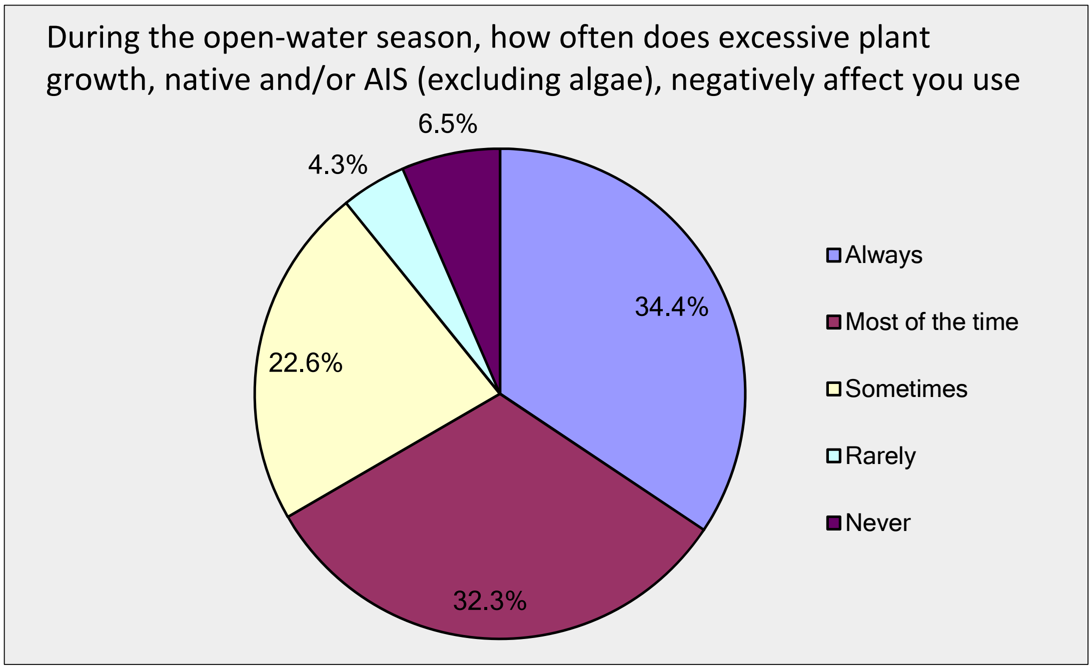


Which species of AIS do you believe are, or may be, in the Lake?		
Answer Options	Response Percent	Response Count
Eurasian water-milfoil (EWM)	33.7%	28
Curly-leaf pondweed (CLP)	42.2%	35
Flowering rush	20.5%	17
Purple loosestrife	25.3%	21
Zebra mussels	4.8%	4
Other (please specify)	1.2%	1
Unsure	51.8%	43
Other (please specify)	1.2%	1
	answered question	83
	skipped question	49

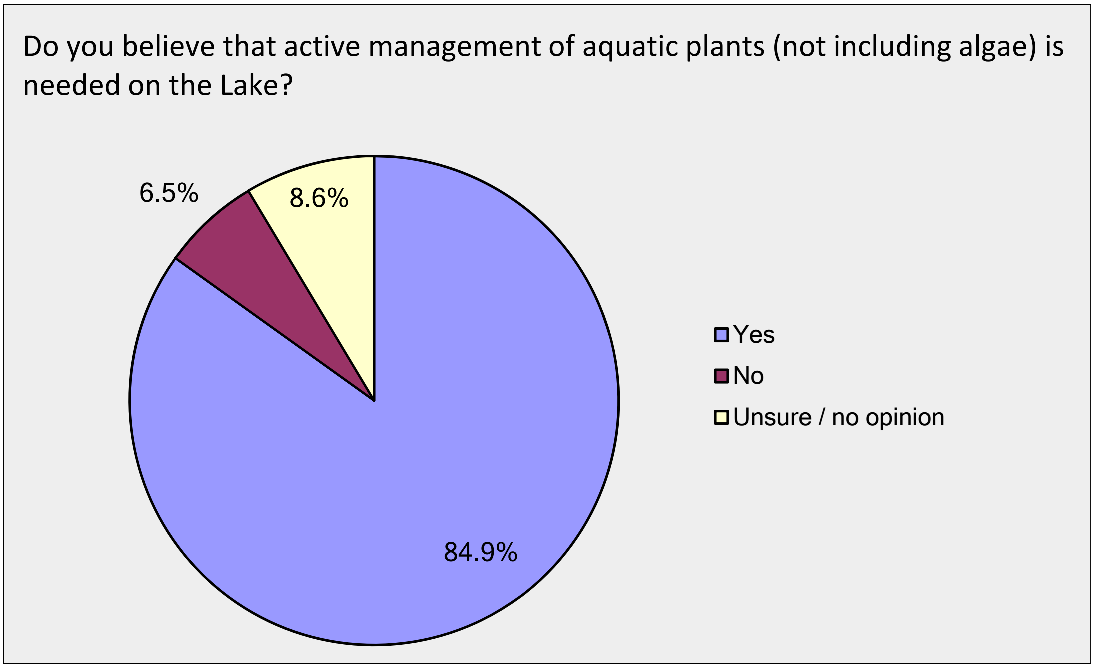
Number	Other (please specify)
1	Blogs and cat tails



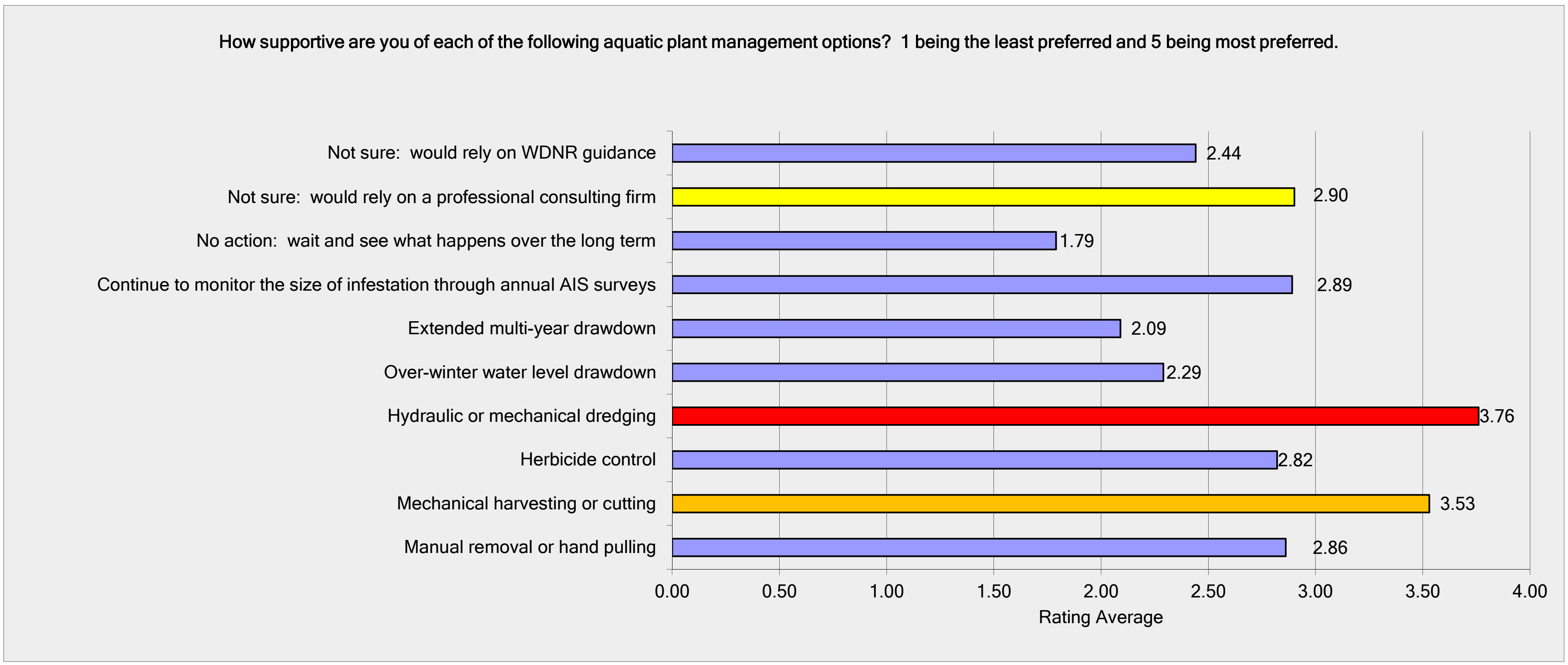
During the open-water season, how often, if at all, does excessive plant growth, native and/or AIS (excluding algae), negatively affect your use of the lake?		
Answer Options	Response Percent	Response Count
Always	34.4%	32
Most of the time	32.3%	30
Sometimes	22.6%	21
Rarely	4.3%	4
Never	6.5%	6
	answered question	93
	skipped question	39



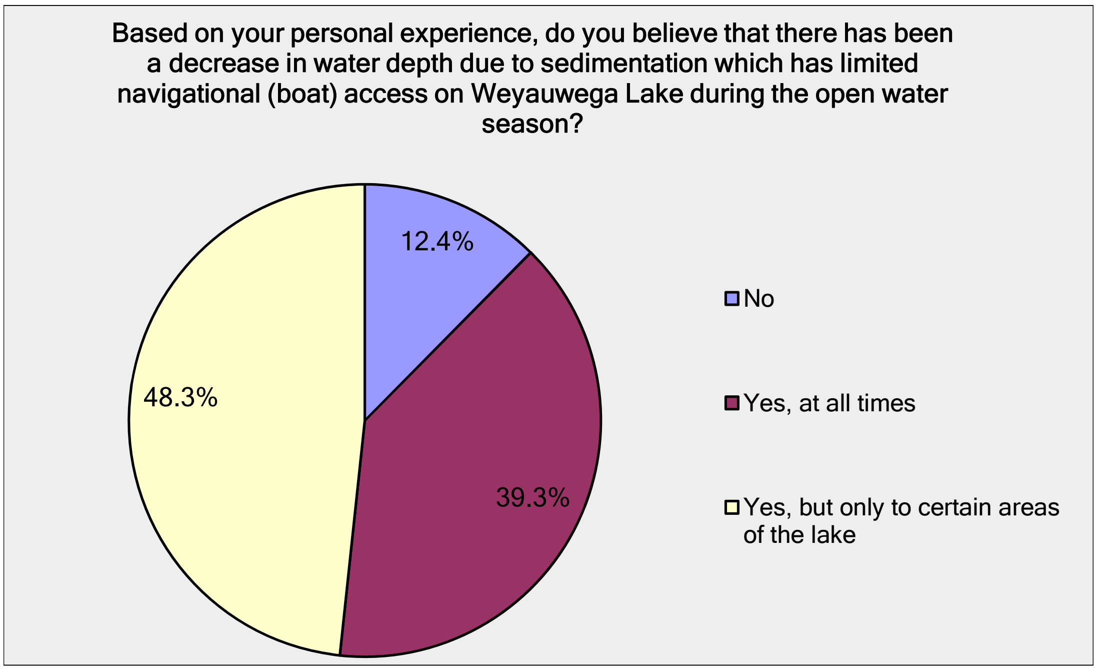
Do you believe that active management of aquatic plants (not including alage) is needed on the Lake?		
Answer Options	Response Percent	Response Count
Yes	84.9%	79
No	6.5%	6
Unsure / no opinion	8.6%	8
	answered question	93
	skipped question	39



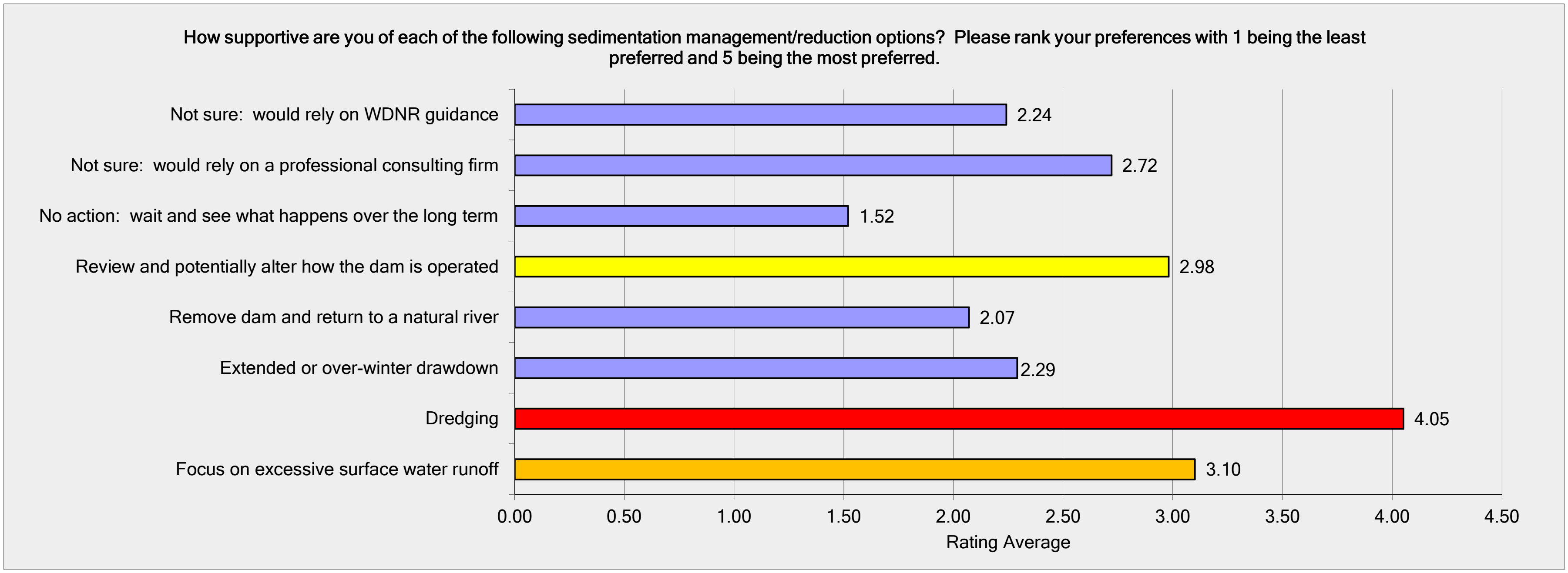
How supportive are you of each of the following aquatic plant management options? 1 being the least preferred and 5 being most preferred.								
Answer Options	Not supportive - 1	Slightly not supportive - 2	Neutral - 3	Mildly supportive - 4	Highly Supportive - 5	Unsure - Need more information	Rating Average	Response Count
Manual removal or hand pulling	27	6	15	15	17	1	2.86	81
Mechanical harvesting or cutting	15	5	16	15	32	0	3.53	83
Herbicide control	21	14	20	6	18	2	2.82	81
Hydraulic or mechanical dredging	9	6	16	13	36	2	3.76	82
Over-winter water level drawdown	34	13	15	9	8	3	2.29	82
Extended multi-year drawdown	40	10	17	9	4	3	2.09	83
Continue to monitor the size of infestation through annual	22	7	24	10	16	2	2.89	81
No action: wait and see what happens over the long term	48	8	14	6	2	1	1.79	79
Not sure: would rely on a professional consulting firm	18	10	16	19	10	2	2.90	75
Not sure: would rely on WDNR guidance	31	7	18	11	8	2	2.44	77
							answered question	89
							skipped question	43



Based on your personal experience, do you believe that there has been a decrease in water depth due to sedimentation which has limited navigational (boat) access on Weyauwega Lake during the open water season?		
Answer Options	Response Percent	Response Count
No	12.4%	11
Yes, at all times	39.3%	35
Yes, but only to certain areas of the lake	48.3%	43
	answered question	89
	skipped question	43

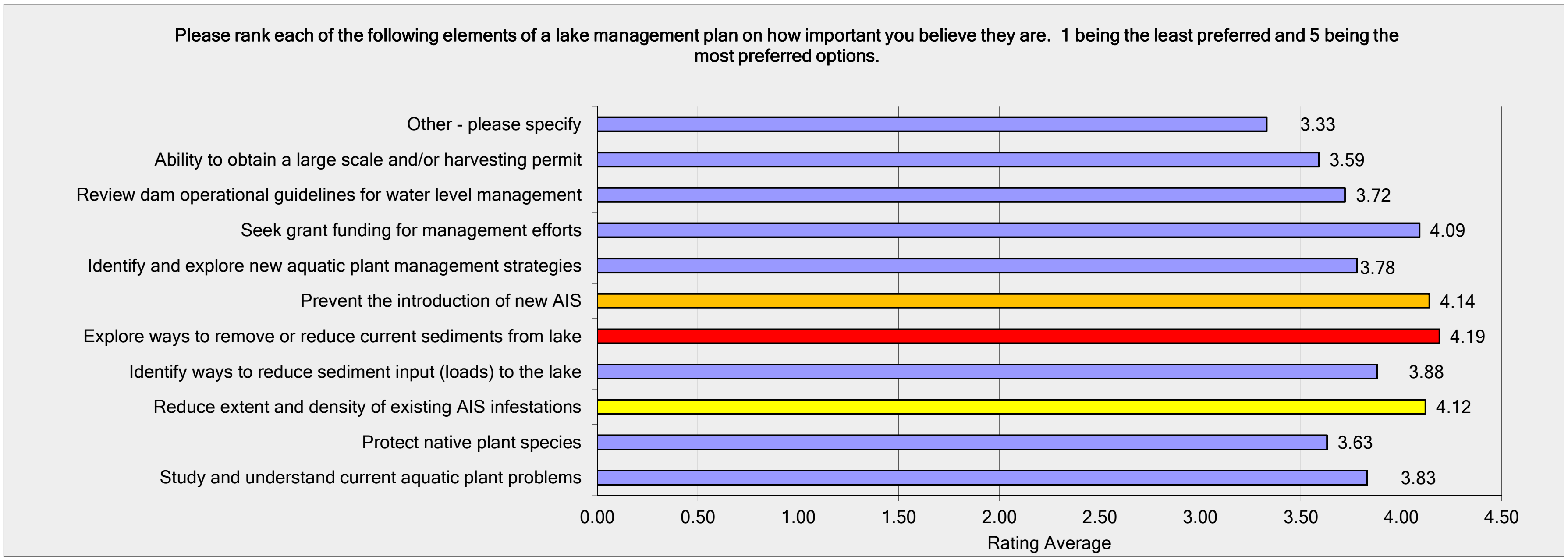


How supportive are you of each of the following sedimentation management/reduction options? Please rank your preferences with 1 being the least preferred and 5 being the most preferred.								
Answer Options	Not supportive - 1	Slightly not supportive - 2	Neutral - 3	Mildly supportive - 4	Highly Supportive - 5	unsure - Need more information	Rating Average	Response Count
Focus on excessive surface water runoff	9	4	24	14	7	4	3.10	62
Dredging	6	3	7	13	34	4	4.05	67
Extended or over-winter drawdown	22	9	18	6	3	5	2.29	63
Remove dam and return to a natural river	33	2	11	7	4	7	2.07	64
Review and potentially alter how the dam is operated	11	6	17	15	6	5	2.98	60
No action: wait and see what happens over the long term	43	8	9	2	0	0	1.52	62
Not sure: would rely on a professional consulting firm	21	5	16	8	11	1	2.72	62
Not sure: would rely on WDNR guidance	29	4	14	4	7	3	2.24	61
							answered question	69
							skipped question	63

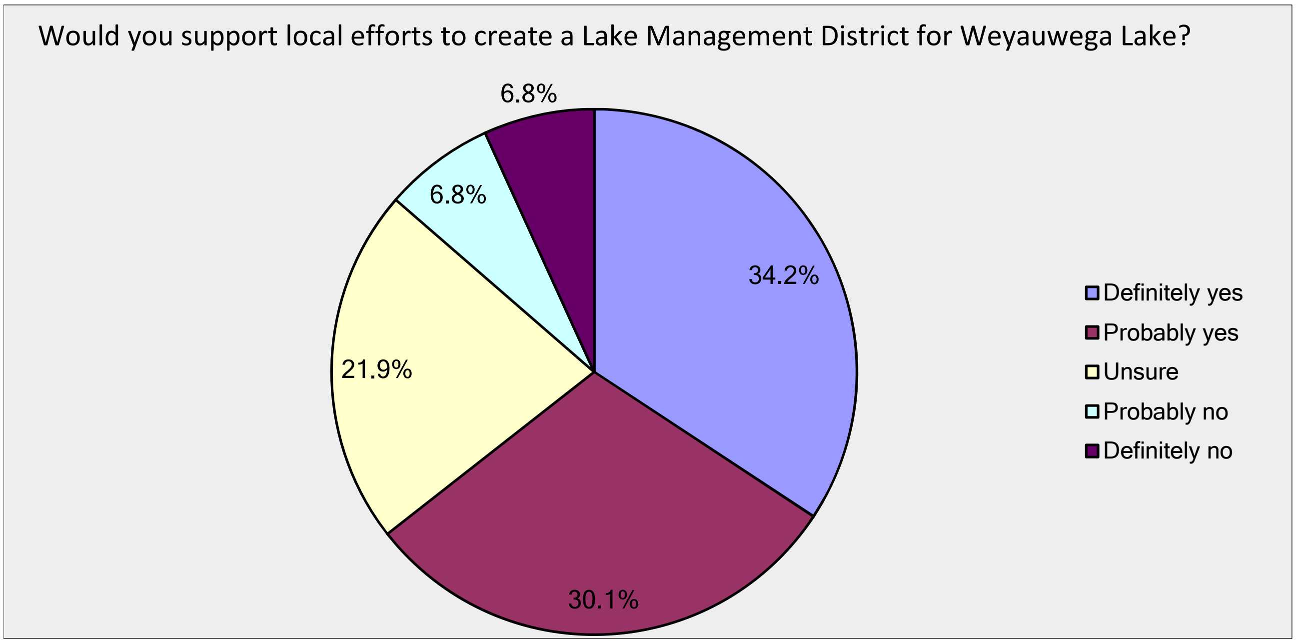


Please rank each of the following elements of a lake management plan on how important you believe they are. 1 being the least preferred and 5 being the most preferred options.								
Answer Options	Not Supportive - 1	Slightly not supportive - 2	Neutral - 3	Mildly supportive - 4	Supportive - 5	Unsure - need more information	Rating Average	Response Count
Study and understand current aquatic plant problems	8	2	15	14	31	2	3.83	72
Protect native plant species	8	3	17	21	21	2	3.63	72
Reduce extent and density of existing AIS infestations	3	2	11	21	32	5	4.12	74
Identify ways to reduce sediment input (loads) to the lake	8	1	12	18	30	5	3.88	74
Explore ways to remove or reduce current sediments from	5	1	10	13	40	4	4.19	73
Prevent the introduction of new AIS	3	3	9	18	33	7	4.14	73
Identify and explore new aquatic plant management	6	4	16	15	27	5	3.78	73
Seek grant funding for management efforts	7	1	9	14	38	4	4.09	73
Review dam operational guidelines for water level	6	4	17	12	25	7	3.72	71
Ability to obtain a large scale and/or harvesting permit	10	4	12	13	24	9	3.59	72
Other - please specify	1	0	5	1	2	3	3.33	12
Other (please specify)								1
							answered question	77
							skipped question	55

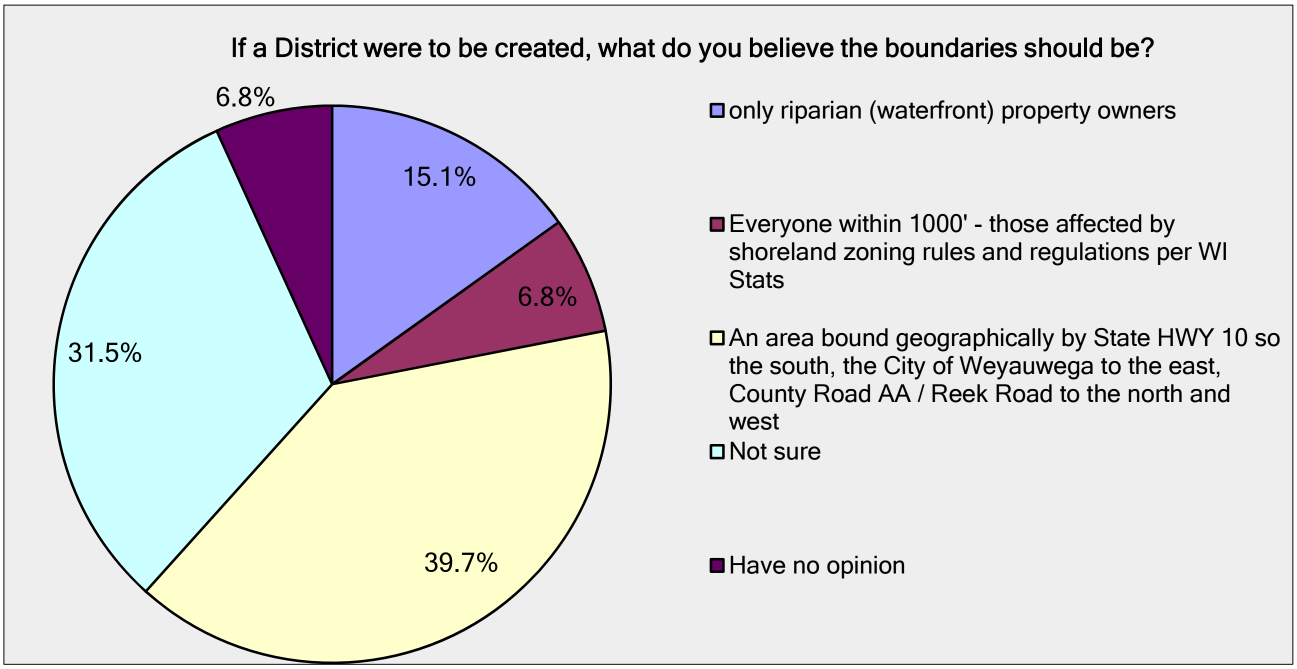
Number	Other (please specify)
1	Get the cheese factories that are dumping waste water in the Mill Pond to STOP.



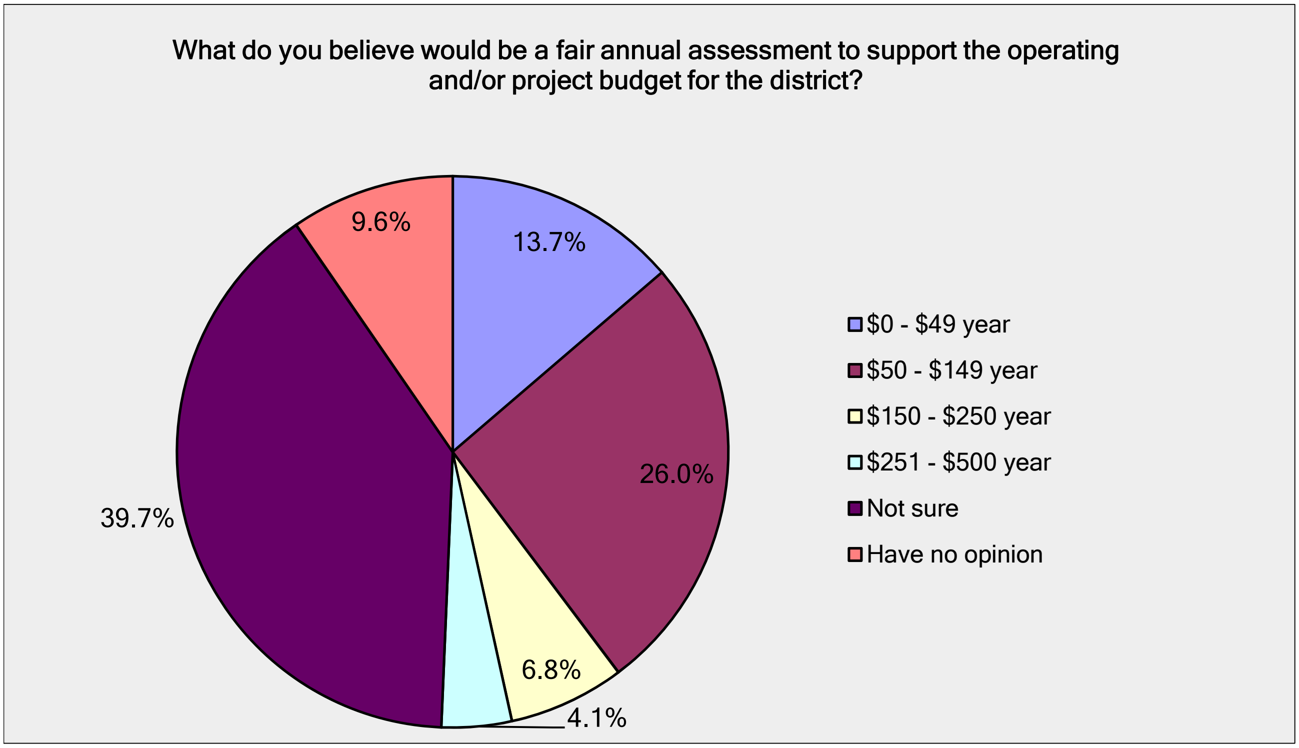
Would you support local efforts to create a Lake Management District for Weyauwega Lake?		
Answer Options	Response Percent	Response Count
Definitely yes	34.2%	25
Probably yes	30.1%	22
Unsure	21.9%	16
Probably no	6.8%	5
Definitely no	6.8%	5
	answered question	73
	skipped question	59



If a District were to be created, what do you believe the boundaries should be?		
Answer Options	Response Percent	Response Count
only riparian (waterfront) property owners	15.1%	11
Everyone within 1000' - those affected by shoreland zoning rules and regulations per WI Stats	6.8%	5
An area bound geographically by State HWY 10 so the south, the City of Weyauwega to the east, County Road AA / Reek Road to the north and west	39.7%	29
Not sure	31.5%	23
Have no opinion	6.8%	5
	answered question	73
	skipped question	59



What do you believe would be a fair annual assessment to support the operating and/or project budget for		
Answer Options	Response Percent	Response Count
$0 - $49 year	13.7%	10
$50 - $149 year	26.0%	19
$150 - $250 year	6.8%	5
$251 - $500 year	4.1%	3
Not sure	39.7%	29
Have no opinion	9.6%	7
	answered question	73
	skipped question	59



If you have any additional comments or concerns about Weyauwega Lake, please enter them here.

Answer Options	Response Count
	15
answered question	15
skipped question	117

Number	Response Text
1	If addressing the problem doesn't include solving the problem (as opposed to putting on a band-aid, like weed cutting), I would be against wasting money. It's about stopping fertilizer, sediment inflo.
2	The lake is a valuable resource for the township, but only if properly managed. We are new to the area but feel the lake could add a lot of value to the community.
3	Bring back Lake Weyauwega like it was before the 1960s. Quit fooling around with mother nature. The town dried up when the city first drained the lake in the 70S. Bring back the lake and the town will revitalize like it once was. .
4	residents who don't live on the water should not pay for the back yard of those who do
5	This is a 100 year old catch basin, not a natural lake, which is due to the dam. There once were ski shows on this lake and hydroplane boat racing . Also, there was a paddle wheel boat that cruised the lake from Mellon park . The only way you can get to Mellon Park now is with a pair of marsh ski's . You can not even get to the Hitching Post by boat! This is sad.
6	If this lake is to be saved it needs to be drained down, have it dredged, and then you you will have boating, swimming, fishing, and hunting again. Dredge the "mill pond". Let nature do what nature does after that. No good can come from forming a lake district. The goal should be to get more people on the pond using it year round. Many good ideas in the community for its use and improvements.
7	I used to go fishing as much as i possible could when i was younger(10-15 years ago) catch and release. Now i will not waste my time fishing here. I will drive by it and go else where now
8	Why not ask how the land owners down river from the dam have been impacted!!
9	When it was drained down the first time should have let faulks brothers come in and take out sediment screw the DNR now we r back to where we started
10	I am concerned that although the lake is important...the downriver property owners are greatly impacted by what happens with lake issues. Sediment and water quality are issues that affect many people.
11	The fish management sucks no carp in the river because of what has been done. Stop putting in Northerns
12	Waist some more grant money on useless surveys spend the money painting the barn next to the painted silo that no one can see that might help the lake!
13	Very excited to see action being taken to help make this a beautiful body of water in our community. Let's bring back a healthy lake with native species. The health of the lake and its native plant and animal communities should be the number one concern above all else (including recreation such as boating). Let's make this project and lake a model for other small communities!
14	Why are there no reports on fish stocking. My guess is that since the beginning of this process is that no additional fish have been stocked.
15	Do not remove the dam!! fishing below it brings alot of enjoyment to many people.

APPENDIX B

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Appendix B – Supporting Aquatic Plant Documentation

The point intercept method was used to evaluate the existing emergent, submergent, floating-leaf and free-floating aquatic plants. If a species was not collected at a specific point, the space on the datasheet was left blank. For the survey, the data for each sample point was entered into the WDNR "Worksheets" (i.e., a data-processing spreadsheet) to calculate the following statistics:

Taxonomic richness (the total number of taxa detected)

- **Maximum depth of plant growth**
- **Community frequency of occurrence** (number of intercept points where aquatic plants were detected divided by the number of intercept points shallower than the maximum depth of plant growth)
- **Mean intercept point taxonomic richness** (the average number of taxa per intercept point)
- **Mean intercept point native taxonomic richness** (the average number of native taxa per intercept point)
- **Taxonomic frequency of occurrence within vegetated areas** (the number of intercept points where a particular taxon (e.g., genus, species, etc.) was detected divided by the total number of intercept points where vegetation was present)
- **Taxonomic frequency of occurrence at sites within the photic zone** (the number of intercept points where a particular taxon (e.g., genus, species, etc.) was detected divided by the total number of intercept points which are equal to or shallower than the maximum depth of plant growth)
- **Relative taxonomic frequency of occurrence** (the number of intercept points where a particular taxon (e.g., genus, species, etc.) was detected divided by the sum of all species' occurrences)
- **Mean density** (the sum of the density values for a particular species divided by the number of sampling sites)
- **Simpson Diversity Index (SDI)** is an indicator of aquatic plant community diversity. SDI is calculated by taking one minus the sum of the relative frequencies squared for each species present. Based upon the index of community diversity, the closer the SDI is to one, the greater the diversity within the population.

Floristic Quality Index (FQI) (This method uses a predetermined Coefficient of Conservatism (C), that has been assigned to each native plant species in Wisconsin, based on that species' tolerance for disturbance. Non-native plants are not assigned conservatism coefficients. The aggregate conservatism of all the plants inhabiting a site determines its floristic quality. The mean C value for a given lake is the arithmetic mean of the coefficients of all native vascular plant species occurring on the entire site, without regard to dominance or frequency. The FQI value is the mean C times the square root of the total number of native species. This formula combines the conservatism of the species present with a measure of the species richness of the site.

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Table 1: Taxa Detected During 2015 Aquatic Plant Survey, Weyauwega Lake, Waupaca County, WI			
Genus	**Species**	**Common Name**	**Category**
Aglae	*sp.*	Filamentous algae	Algae
Botumus	***umbaltus***	**Flowering rush**	**Emergent AIS**
Ceratophyllum	*demersum*	Coontail	Submersed
Elodea	*canadensis*	Common waterweed	Submersed
Heteranthera	*dubia*	Water star-grass	Submersed
Lemna	*minor*	Small duckweed	Free-floating
Phalaris	***arundinacea***	**Reed canary grass**	**Emergent AIS**
Potamogeton	***crispus***	**Curly-leaf pondweed**	**Submersed AIS**
Potamogeton	*nodosus*	Long-leaf pondweed	Submersed
Potamogeton	*praelongus*	White-stem pondweed	Submersed
Potamogeton	*pusillus*	Small pondweed	Submersed
Potamogeton	*zosteriformis*	Flat-stem pondweed	Submersed
Spirodela	*polyrhiza*	Large duckweed	Free-floating
Salix	*sp.*	Willow shrub	Emergent
Stuckenia	*pectinata*	Sago pondweed	Submersed
Typha	*angustifolia*	Narrow-leaved cattail	Emergent

Table 3: 2015 Aquatic Plant Taxa-Specific Statistics, Weyauwega Lake, Waupaca County, WI					
Common Name	**Percent Frequency of Occurrence within vegetated areas**	**Percent Frequency of Occurrence at sites shallower than max depth of plants**	**Percent Relative Frequency of Occurrence**	**Number of Intercept Points Where Detected**	**Average Density**
Curly-leaf pondweed	31.97	29.89	10.60	78	1.00
Flowering rush	53.69	50.19	18.90	131	1.06
Coontail	77.46	72.41	25.70	189	1.38
Common waterweed	47.54	44.44	15.80	116	1.09
Water star-grass	4.92	4.60	1.60	12	1.00
Small duckweed	26.23	24.52	8.70	64	1.00
Reed canary grass	0.82	0.77	0.30	2	2.00
Long-leaf pondweed	3.28	3.07	1.10	8	1.00
White-stem pondweed	0.41	0.38	0.10	1	1.00
Small pondweed	0.82	0.77	0.30	2	1.00
Flat-stem pondweed	1.64	1.53	0.50	4	1.00
Large duckweed	30.33	28.35	10.10	74	1.00
Sago pondweed	0.41	0.38	0.10	1	1.00
Narrow-leaved cattail	2.46	2.30	0.80	6	1.00
Filamentous algae	34.43	32.18	---	84	1.01
Willow species	2.05	1.92	0.70	5	1.00

APPENDIX C

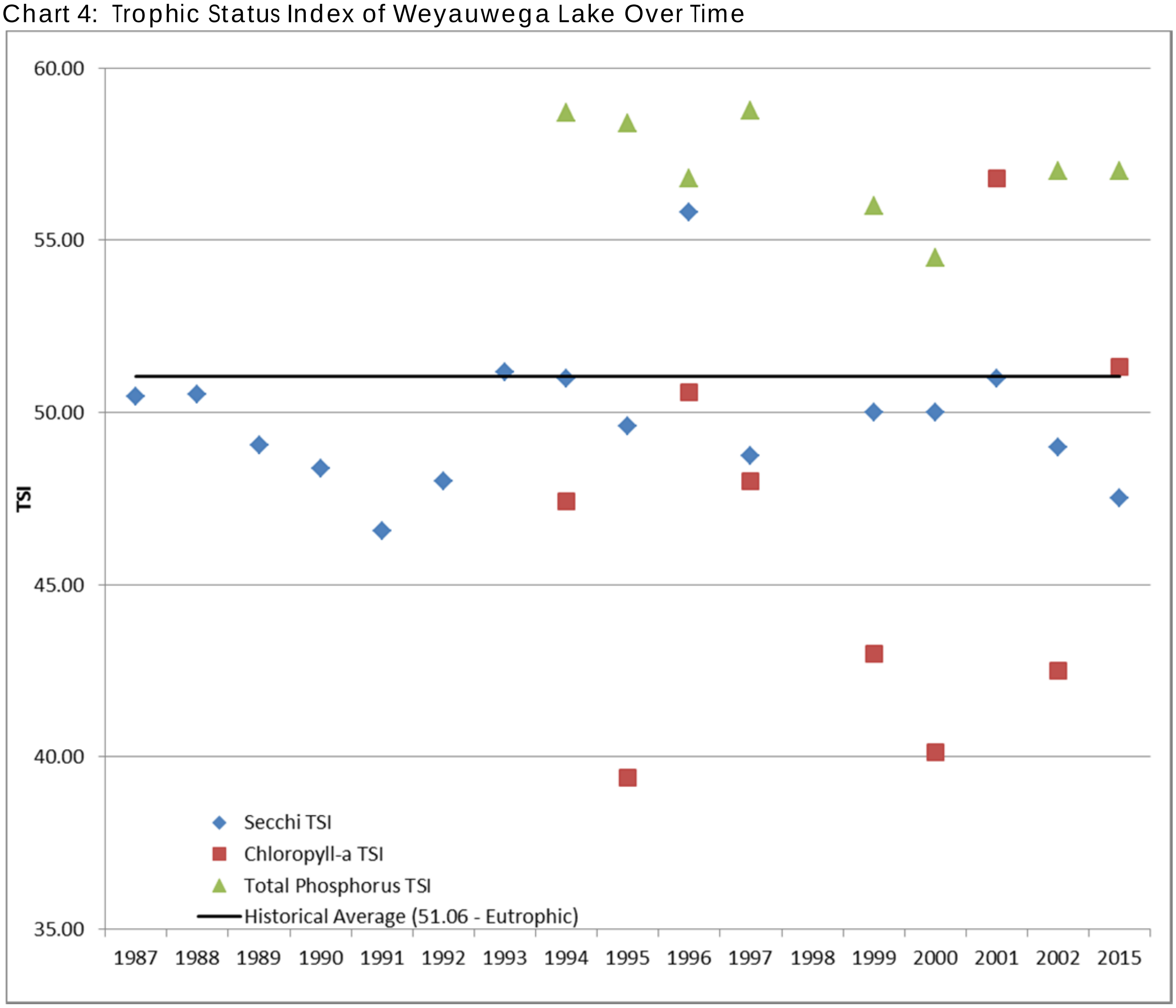
Appendix C – Supporting Water Quality Documentation

Chart 3: Trophic Status Index of Weyauwega Lake Compared to TSI Rankings

Category	TSI	Lake Characteristics	Total P *(ug/l)*	Chlorophyll a *(ug/l)*	Water Clarity *(feet)*
Oligotrophic	1-40	Clear water; oxygen rich at all depths, except if close to mesotrophic border; then may have low or no oxygen; cold-water fish likely in deeper lakes.	< 12	<2.6	>13
Mesotrophic	41-50	Moderately clear; increasing probability of low to no oxygen in bottom waters.	12 to 24	2.6 to 7.3	13 to 6.5
Eutrophic	51-70	Decreased water clarity; probably no oxygen in bottom waters during summer; warm-water fisheries only; blue-green algae likely in summer in upper range; plants also excessive.	> 24	>7.3	<6.5
Weyauwega Lake	**51.6**	**Eutrophic**	**49.8**	**11.96**	**6.92**

Adopted from Carlson 1977, Lillie and Mason, 1983, and Shaw 1994 et al

Chart 4: Trophic Status Index of Weyauwega Lake Over Time



APPENDIX D

Appendix D – Supporting Watershed Documentation

Watershed and land use evaluation is a necessary component of a management plan. The land use within the watershed is the primary sources of nutrient into the ecosystem. Slight changes in land use watershed can create major impacts on the receiving water body. For instance, if a large land area is disturbed runoff will have a greater sediment and nutrient load. The opposite can occur if major areas that were disturbed are now vegetated with trees or native plants. Land use within the watershed is from WISCLAND – WI DNR data.

Watershed evaluation includes a presentation of the data gathered as part of this project and modeling programs used to predict land use changes and watershed impacts. The Wisconsin Lake Modeling Suite (WiLMS), a screening level and water quality evaluation toll, was used to model the lake's watershed. Using this model, estimates of nutrient and sediment runoff from various land cover types was analyzed for potential impact to the lake. In conjunction with WiLMS, the Lake Eutrophication Analysis Procedure (LEAP) was used to model internal phosphorus loading and eutrophication indices of Weyauwega Lake based on watershed land cover, creating a nutrient budget.

Table 9: Phosphorus input by land use type. Weyauwega Lake, Waupaca County, WI

		Phosphorus Loading	
Land Use	**Acres**	**kg / year**	**Average kg / acre / year**
Mixed Agricultural	75416.47	24417	0.32
Open Water	2837.18	344	0.12
Forest	59746.09	2176	0.04
Pasture / Grassland	26209.18	3182	0.12
Lake Surface	253	31	0.12
High Density Urban	278.93	169	0.61
Medium Density Urban	894.57	181	0.20
Rural Residentail	3014.56	122	0.04
Wetlands	11697.6	473	0.04
TOTAL	**180347.58**	**31095**	**1.61**

♬Weyauwega Lake

Date: 1/13/2016 Scenario: 2

Lake Id: Weyauwega Lake
Watershed Id: 0

Hydrologic and Morphometric Data

Tributary Drainage Area: 180094.6 acre
Total Unit Runoff: 10.50 in.
Annual Runoff Volume: 157582.8 acre-ft
Lake Surface Area <As>: 253.0 acre
Lake Volume <V>: 1259.1 acre-ft
Lake Mean Depth <z>: 5.0 ft
Precipitation - Evaporation: 3.8 in.
Hydraulic Loading: 157662.9 acre-ft/year
Areal Water Load <qs>: 623.2 ft/year
Lake Flushing Rate <p>: 125.22 1/year
Water Residence Time: 0.01 year
Observed spring overturn total phosphorus (SPO): 11.4 mg/m^3
Observed growing season mean phosphorus (GSM): 49.8 mg/m^3
% NPS Change: 0%
% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		|---- Loading (kg/ha-year) ----|				|----- Loading (kg/year)----		
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0
Mixed AG	75416.5	0.30	0.80	1.40	78.5	9156	24417	42729
Pasture/Grass	26209.2	0.10	0.30	0.50	10.2	1061	3182	5303
HD Urban (1/8 Ac)	278.9	1.00	1.50	2.00	0.5	113	169	226
MD Urban (1/4 Ac)	894.6	0.30	0.50	0.80	0.6	109	181	290
Rural Res (>1 Ac)	3014.6	0.05	0.10	0.25	0.4	61	122	305
Wetlands	11697.6	0.10	0.10	0.10	1.5	473	473	473
Forest	59746.1	0.05	0.09	0.18	7.0	1209	2176	4352
Open Water	2837.2	0.10	0.30	1.00	1.1	115	344	1148
Lake Surface	253.0	0.10	0.30	1.00	0.1	10	31	102

POINT SOURCE DATA

Point Sources	Water Load (m^3/year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %

SEPTIC TANK DATA

Description		Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)		0.30	0.50	0.80	
# capita-years	0.0				
% Phosphorus Retained by Soil		98.0	90.0	80.0	
Septic Tank Loading (kg/year)		0.00	0.00	0.00	0.0

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	27131.8	68554.1	121097.7	100.0
Total Loading (kg)	12306.9	31095.9	54929.5	100.0
Areal Loading (lb/ac-year)	107.24	270.96	478.65	
Areal Loading (mg/m^2-year)	12020.18	30371.44	53649.75	
Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0
Total NPS Loading (lb)	27109.3	68486.4	120871.9	100.0
Total NPS Loading (kg)	12296.7	31065.2	54827.2	100.0

LEAP - Lake Eutrophication Analysis Procedure

Lake Name:	Weyauwega Lake	**Ecoregion:**	North Central Hardwood Forests
Watershed Area:	180094.6 Acres	**Surface Area:**	253 Acres
Mean Depth:	5 ft	**TP Load:**	14053 kg/yr
Lake Outflow:	95 AF/yr	**Avg TP Inflow:**	148 ug/L
Residence Time:	0.0 years		
Areal Water Load:	92.58 m/yr	**P Retention Coef:**	0.15

Variable	Observed	Predicted	Std Error	Residual	T-test
TP (ug/L)	50	126	25	-0.40	-3.62
Chlr a (ug/L)	12.0	77.4	35.4	-0.81	-3.53
Secchi (m)	2.1	0.6	0.2	0.55	3.51

Note: Residual = Log10(Observed/Predicted)

T-test for signifigant difference between observed & predicted

Chlrophyll A Interval Frequencies (%)

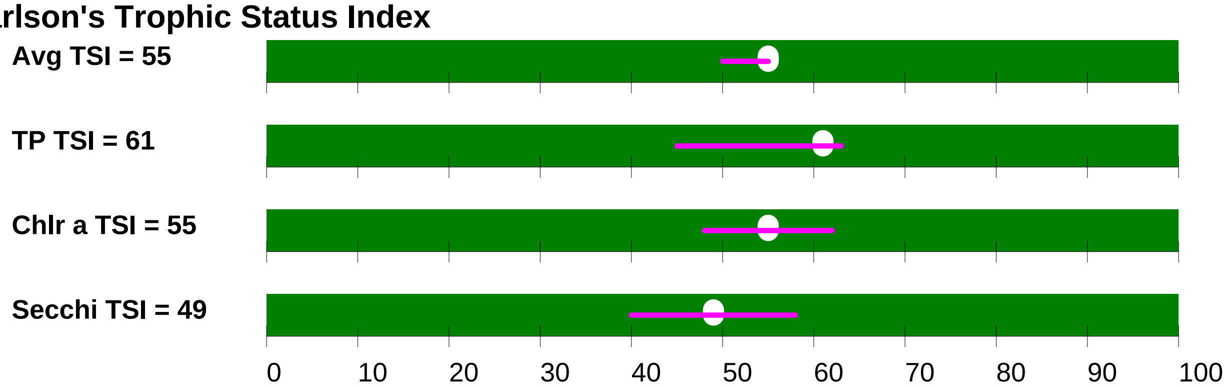
ppb	Observed	Case A	Case B	Case C
10	55%	100%	100%	100%
20	9%	100%	99%	96%
30	2%	96%	95%	89%
60	0%	62%	61%	58%

Case A = within year variation considered

Case B = within year + year-to-year variation

Case C = Case B + Model Error

Carlson's Trophic Status Index



APPENDIX E

Management Options for Aquatic Plants

Option	Permit Needed	How it Works	Pros	Cons
No Management	No	No active plant management	Possible protects native species that can enhance water quality and provide habitat for aquatic fauna: • No financial cost • No system disturbance • No harmful effects of chemicals • Permit not required	May allow small populations of invasive plants to become larger and more difficult to control later • Requires intensive monitoring
Mechanical Control	Required under NR 109	Plants reduced by mechanical means	Flexible control	Must be repeated, often more than once per season, sometimes weekly
		Wide range of techniques from manual to mechanized	Can balance habitat and recreational needs	Can suspend sediments and increase highly turbidity and nutrient release
a. Handpulling/ Manual raking	Yes/No	Scuba divers or snorkelers remove plants are removed with a rake	Little to no damage done to lake or to native plant species	Very labor intensive and costly by hand or plants
		Works best in soft sediments	Can be highly selective Can be done by shoreline property owners within an area <30 ft wide or removing EWM or CLP Can be very effective at removing problems particularly following early detection of an invasive specie	Needs to be carefully monitored Roots, runners and even fragments of some without permits species (including EWM) will start new where selectively planted, so all of plant must be removed Small scale control only plants Can be very costly if subcontracted
b. Harvesting	Yes	Plants are "mowed" at depths of 2-5 ft., collected with a conveyor and off loaded onto shore	Immediate results	Not selective in species removed
		Harvest invasives only if invasive is already present throughout the lake	Good for CLP management if cut prior to turion production and is then cut to be kept in check through its growth cycle Usually minimal impact to the lake Harvested lanes through dense weed beds can increase growth and forage ability of some fish Can remove some nutrients from the lake	Fragments of EWM can re-root Difficulty in finding disposal sites Can remove some small fish and reptiles from lake Initial cost of harvester expensive High transport, maintenance and operational costs Liability if owned
Biological Control	Yes	Living organisms (e.g. insects or fungi) eat or infect plants	Self sustaining organism will over winter resume eating its host the next year Lowers density of problem plant to allow growth of natives	Effectiveness will vary as control agent's population fluctuates Provides moderate control – complete control unlikely Control response may be slow. Must have enough control agent to be effective

Management Options for Aquatic Plants

a. Weevils on EWM	Yes	Native weevil prefers EWM to other native water milfoil	Native to Wisconsin: Weevil cannot "escape" and become a problem Selective control of target species Longer term control with limited management	Excessive cost need to stock large numbers, even if some already present and are costly **$1.00/each** Need good habitat for over wintering on shore (leaf litter) associated with undeveloped shorelines High Panfish populations decrease densities through predation
b. Pathogens	Yes	Fungal/bacterial/viral pathogen introduced to target species to induce mortality	May be species specific May provide long term control Few dangers to humans or animals	Largely experimental; effectiveness and longevity unknown Possible side effects not understood
c. Allelopathy	Yes	Aquatic plants release chemical compounds that inhibit other plants from growing	May provide long term, maintenance free control Spikerushes (*Eleocharis* spp.) appear to inhibit Eurasian watermill foil growth	Initial transplanting slow and labor intensive Spikerushes native to Wisconsin and have not effectively limited EWM growth Wave action along shore makes it difficult to establish plants; plants will not grow in deep or turbid water
d. Restoration of native plants	Possibly, strongly recommend plan and consultation with DNR	Diverse native plant community established to help repel invasive species	Native plants provide food and habitat for aquatic fauna Diverse native community more repellant to invasive species Supplements removal techniques	Initial transplanting slow and labor intensive Nuisance invasive plants may outcompete plantings Largely experimental; few well documented successful cases and very costly
Physical Control	Required under Ch. 30/NR 107	Plants are reduced by altering variables that affect growth, such as water depth or light levels		
a. Drawdown	Yes, may require Environmental Assessment	Lake water lowered; plants killed when sediment dries, compacts or freezes	Can be effective for EWM, especially when done over winter, provided drying and freezing occur. Sediment compaction is possible over winter.	Plants with large seed bank or propagules that survive drawdown may become more abundant upon refilling
		Must have a water level control or device or siphon	Summer drawdown can restore large portions of shoreline and shallow areas as well as provide sediment compaction	Species growing in deep water (e.g. EWM) that survive may increase, particularly if desired native species are reduced
		Season or duration of drawdown can change effects	Emergent plant species often rebound near shore providing fish and wildlife habitat, sediment stabilization and increased water quality Successful for EWM	May impact attached wetlands and shallow wells near shore Not a good control measure for CLP

Management Options for Aquatic Plants

				Low cost if not a hydroelectric dam Restores natural water fluctuation important for all aquatic ecosystems	Can affect fish, particularly in shallow lakes if oxygen levels drop or if water levels are not restored before spring spawning Winter drawdown must start in early fall or will kill hibernating reptiles and amphibians Controversial
b.	**Dredging**	Yes	Plants are removed along with sediment	Increases water depth	Expensive
			Most effective when soft sediments overlay harder substrate	Removes nutrient rich sediments	Increases turbidity and releases nutrients
			For extremely impacted systems	Removes soft bottom sediments that may have high oxygen demand	Exposed sediments may be recolonized by invasive species
			Extensive planning and permitting required		Sediment testing is expensive Removes benthic organisms Dredged materials must be disposed if Severe impact on lake ecosystem
c.	**Dyes**	Yes	Colors water, reducing light and reducing plant and algal growth	Impairs plant growth without increasing turbidity Usually non-toxic, degrades naturally over a few weeks	Appropriate for very slam water bodies Should not be used in pond or lake with outflow Impairs aesthetics Affects to microscopic organisms unknown
d.	**Mechanical circulation (Solarbees)**	Yes	Water is circulated and oxygenated	Reduces blue green algae	Method is experimental; no published studies have been done
			Oxygenation of water decreases ammonium-nitrogen, which is a preferred nutrient source of EWM, theoretically limiting EWM growth (has not been demonstrated scientifically)	May reduce levels of ammonium-nitrogen in the water and at the sediment interface, which could reduce EWM growth Oxygenated water may reduce phosphorus release from sediments if mixing is complete Reduces chance of fish kills by aerating water	Although EWM prefers ammonium-nitrogen to nitrate, it will uptake nitrate efficiently, so EWM growth may not be affected Units are aesthetically unpleasing Units could be a navigational hazard
e.	**Non-point source nutrient control**	No	Runoff of nutrients from the watershed are reduced (e.g. by controlling construction erosion or reducing fertilizer use)	Attempts to correct source of problem, not treat symptoms Could improve water clarity and reduce occurrences of algal blooms	Results can take years to be evident due to internal recycling of already resent lake nutrients Expensive

Management Options for Aquatic Plants

			Native plants may be able to compete invasive species better in low nutrient conditions	Requires landowner cooperation and regulation Improved water clarity may increase plant growth
Chemical Control	Required under NR 107	Granules or liquid chemicals kill plants or cease plant growth; some chemicals used primarily for algae	Some flexibility for different situations	Possible toxicity to aquatic animals or humans, especially applicators
		Results usually within 10 days of treatment, but repeat treatments usually needed	Some can be selective if applied correctly Can be used for restoration activities	May kill desirable plant species, e.g. native water milfoil or native pondweeds Treatment set back requirements from potable water sources and/or drinking water use restrictions after application, usually based on concentration May cause severe drop in dissolved oxygen causing fish kill, depends on plant biomass killed, temperatures and lake size and shape Controversial
a. 2,4-D (DMA-4; Sculpin	Yes	Systemic[1] herbicide selective to broadleaf[2] plants that inhibit cell division in new tissue	Moderately to highly effective; especially on EWM	May cause oxygen depletion after plants die and decompose
		Applied as liquid or granules during early growth phase	Monocots, such as pondweeds (e.g. CLP) and many other native species not affected Can be used in synergy with endotholl for early season CLP and EWM treatments Widely used aquatic herbicides	Cannot be used in combination with copper herbicides (used for algae) Toxic to fish
b. Endothall (Aquathol)	Yes	Broad-spectrum[3], contact [4] herbicide that inhibits protein synthesis	Especially effective on CLP and also effective on EWM	Kills many native pondweeks
		Applied as liquid or granules	May be effective in reducing reestablishment of CLP if reapplied several years in a row in early spring Can be selective depending on concentration and seasonal timing Can be combined with 2,4-D for early season CLP and EWM treatments, or with copper compounds	Not as effective in dense plant beds Not to be used in water supplies Toxic to aquatic fauna (to varying degrees)
c. Diquat (Reward)	Yes	Broad-spectrum, contact herbicide that disrupts cellular functioning	Mostly used for water-milfoil and duckweed	May impact non-target plants, especially native pondweeds, coontail, elodea, naiads
		Applied as liquid, can be combined with copper treatment	Rapid action Limited direct toxicity on fish and other animals	Toxic to aquatic invertebrates Needs to be reapplied several years in a row

Management Options for Aquatic Plants

					Ineffective in muddy or cold water (<50ºF)
d.	**Fluridone (Sonar)**	Yes	Broad-spectrum, systemic pigment bleaching herbicide that inhibits photosynthesis, some reduction in non target effects can be achieved by lowering dosage	Effective on EWM for 2 to 4+ years Applied at very low concentration typically on lake wide basis of less than 8 PPB Specific granular formulation release over extended periods of time 30 – 60 days eliminating peaks and lessening impacts to non targets (natives)	Affects some non-target plants, particularly native milfoils, coontails, elodea and naiads, even at low concentrations. These plants are important to combat invasive species Requires long contact time: 60-90 + days Requires residual monitoring
				Slow decomposition of plants may limit decreases in dissolved oxygen Low toxicity to aquatic animals	Demonstrated herbicide resistance in hydrilla subjected to repeat treatments Unknown effect of repeat whole lake treatments on lake ecology
e.	**Glyphosate (Rodeo)**	Yes	Broad spectrum, systemic herbicide that disrupts enzyme formation and function	Effective on floating and emergent plants such as purple loosestrife	Effective control for 1-5 years
			Usually used for purple loosestrife stems or cattails	Selective if carefully applied to individual plants	Ineffective in muddy water
			Applied as liquid spray or painted on loosestrife stems	Non-toxic to most aquatic animals at recommended dosages	Cannot be used near potable water intakes No control of submerged plants
f.	**Triclopyr (Renovate)**	Yes	Systemic herbicide selective to broadleaf plants that disrupts enzyme function	Effective on many emergent and floating plants	Impacts may occur to some native plants at higher does (e.g. coontail)
			Applied as liquid spray or liquid	More effective on dicots, such as purple loosestrife; may be more effective than glyphosate Results in 3-5 weeks Low toxicity to aquatic animals No recreational use restrictions following treatment	May be toxic to sensitive invertebrates at higher concentrations Retreatment opportunities may be limited due to maximum seasonal rate (2.5 ppm) Sensitive to UV light; sunlight can break herbicide down prematurely Relatively new management option for aquatic plants (since 2003)
g.	**Copper compounds (Cutrine, Captain)**	Yes	Broad-spectrum, systemic herbicide that prevents photosynthesis	Reduces algal growth and increases water clarity	Elemental copper accumulates and persists in sediments
			Used to control planktonic and filamentous algae	No recreational or agricultural restrictions on water use following treatment Herbicidal action on hydrilla, an invasive plant not yet present in Wisconsin	Short term results Small-scale control only, because algae are easily windblown

Management Options for Aquatic Plants

					Toxic to invertebrates, trout and other fish, depending on the hardness of the water Long-term effects of repeat treatments to benthic organism unknown Clear water may increase plant growth
h.	**Lime slurry**	Yes	Applications of lime temporarily raise water pH, which limits the availability of inorganic carbon to plants, preventing growth	Appears to be particularly effective against EWM and CLP Prevents release of sediment phosphorus, which reduces algal growth Increases growth of native plants beneficial as fish habitat	Relatively new technique, so effective dosage levels and exposure requirements are not yet known Short-term increase in turbidity due to suspended lime particles High pH detrimental to aquatic invertebrates May restrict growth of some native plants
i.	**Alum (aluminum sulfate)**	Yes	Remove phosphorus from water column and creates barrier on sediment to prevent internal loading of phosphorus	Most often used against algal problems Lasts up to 5 years	Most not eat fish for 30 days from treatment area
			Dosage must consider pH, hardness and water volume	Improves water clarity	Minimal effect on aquatic plants, or increased light penetration may increase aquatic plants Potential ecosystem toxicity issues for aquatic animals, including fish at some concentrations
j.	**Phoslock**	yes	Remove/sequesters phosphorus from water column and creates barrier on sediment to prevent internal loading of phosphorus	Most often used against algal problems/blooms Improves water quality	Higher cost than Alum
			Dosing based on water quality parameters and volumes	Lasts up to 5 years Made from natural materials/carriers and tends to be more environmentally friendly than alum	

***EWM** - Eurasian water-milfoil
***CLP** - Curly-leaf pondweed

[1]**Systemic herbicide -** Must be absorbed by the plant and moved to the site of action. Often slower-acting than contact herbicides.

[2]**Broadleaf herbicide -** Affects only dicots, one of two groups of plants. Aquatic dicots include waterlilies, bladderworts, watermilfoils, and coontails.

[3]**Broad-spectrum herbicide -** Affects both monocots and dicots.

[4]**Contact herbicide -** Unable to move within the plant; kills only plant tissue it contacts directly

Techniques for Aquatic Plant Control Not Allowed in Wisconsin

Option	How it Works	Pros	Cons
Biological Control			
a. Carp	Plants eaten by stocked carp	Effective at removing aquatic plants Involves species already present in Madison lakes	Illegal to transport or stock carp in Wisconsin Carp cause resuspension of sediments, increased water temperature, lower dissolved oxygen levels and reduction of light penetration Widespread plant removal deteriorates habitat for other fish and aquatic organisms Complete alteration of fish assemblage possible Dislodging of plants such as EWM or CLP turions can lead to accelerated spreading of plants
b. Crayfish	Plants eaten by stocked crayfish	Reduces macrophyte biomass	Illegal to transport or stock crayfish in Wisconsin Control not selective and may decimate plant community Not successful in productive, soft-bottom lakes with many fish predators Complete alteration of fish assemblage possible
Mechanical Control			
a. Cutting (no removal)	Plants are “mowed” with underwater cutter	Creates open water areas rapidly Works in water up to 25 ft	Root system remains for regrowth Fragments of vegetation can re-root and spread infestation throughout the lake Nutrient release can cause increased algae and bacteria and be a nuisance to riparian property owners Not selective in species removed small-scale control only
b. Rototilling	Sediment is tilled to uproot plant roots and stems	Decreases stem density, can affect entire plant	Creates turbidity
	Works in deep water (up to 17 ft)	Small scale control May provide long-term control	Not selective in species removed Fragments of vegetation can re-root Complete elimination of fish habitat

Techniques for Aquatic Plant Control Not Allowed in Wisconsin

			Releases nutrients Increased likelihood of invasive species recolonization
c. Hydroraking	Mechanical rake removes plants from lake	Creates open water areas rapidly	Fragments of vegetation can re-root
	Works in deep water (14 ft)		May impact lake fauna Creates turbidity Plants regrow quickly Requires plant disposal
Physical Control			
a. Fabrics/Bottom Barriers	Prevents light from getting to lake bottom	Reduces turbidity in soft substrate areas Useful for small areas	Eliminates all plants, including native plants important for a healthy lake ecosystem May inhibit spawning by some fish Need maintenance or will become covered in sediment and ineffective Gas accumulation under blankets can cause them to dislodge from the bottom Affects benthic invertebrates Anaerobic environment forms that can release excessive nutrients from sediment