Pigeon Lake - Lake Management Plan

Pigeon Lake Protection & Rehabilitation District (PLPRD)

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Sign-off Sheet

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Executive Summary

Pigeon Lake is the name of the impoundment created 160 years ago when a Dam was built on the Pigeon River at Clintonville, WI. As the impoundment ages, it has experienced decreasing water depths due to inorganic and organic sediment accumulation, presence and expansion of aquatic invasive species (AIS), and an overall very dense aquatic community being the main issues of concern for Lake users. These problems hamper navigation throughout the Lake, limit enjoyment, and cause increased expenditure on actions, such as aquatic plant harvesting, 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 is focused solely on aquatic plant harvesting. Though this provides immediate relief for navigational nuisance, it is labor intensive and does not address the presence of AIS within the system or issues related to increased sedimentation. Additionally, as an impoundment, water level manipulation is an inexpensive and viable management alternative that has not yet been adequately explored for use on Pigeon Lake, though it can many times also be controversial.

This management plan provides a multi-faceted approach to alleviate issues and recommend management options based on best fit and desire with direct input from lake users. 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 a continuation of aquatic plant harvesting, an already accepted and in place management technique, 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, aeration, 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

Pigeon Lake (the Lake) is a shallow, 163 acre man-made drainage lake (impoundment), created by damming the Pigeon River with an average depth of 4 feet. Located in northern Waupaca County (the County) and adjacent to the City of Clintonville, the Lake provides ample year-round recreational opportunities. The Pigeon Lake Protection & Rehabilitation District (PLPRD; the District) is a group with a strong tradition in conservation and resource management within the Lake to protect and enhance these opportunities. The District has been active in a number of lake management activities on Pigeon Lake including: aquatic plant management, water quality sampling and management, aeration, invasive species sampling and fisheries management through stocking. The PLPRD contracted Stantec Consulting Services Inc. (Stantec) to help develop a comprehensive lake management (CLM) plan for Pigeon Lake.

2.0 LAKE USER SURVEY AND PRIMARY CONCERNS

Any management plan can only be successful if accepted by the users it impacts the most. If options are laid out that are not warranted 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 PLPRD and made available to any interested Lake user, as this is the direct audience, and was also made available online. Results of the questionnaire are included in Appendix A. This questionnaire gives us a unique look at all Lake users and a strong 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, 192 responses to the survey were completed across an array of users with a majority (79%) residing away from the water, 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 Pigeon Lake and to create an average user profile. Overall, the average user looks like this:

- 66% have used the lake for 10+ years
    - Average of 22+ year history with the lake
- Spend an average time on the water of
    - 6.2 days per month during open water
    - 3.9 days per month during ice cover
- 47% find their time enjoyable with low impact activities their top choice, including:
    - Fishing (#1)
    - Nature viewing
    - Canoeing and kayaking
    - Pontoon boating

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

- 34.6% indicated no change
- 53.5% indicated their use has become less enjoyable, due to:
    - Excessive aquatic plant growth
        - Negatively impacted users of the 82.7% of the time
        - Due to dense growth of native AND invasive species
    - Increased sedimentation leading to decreased water depths
        - Negatively impacted users 62.4% of the time, but not evenly within the lake
        - 46.1% chose the whole lake to be impacted by sedimentation
        - Upstream of Lakeshore Road boat landing and Fairway Lake most-impacted individual areas
- Main concerns on lake health
    - Quality of fishery
    - Excessive aquatic plant growth
    - Water quality

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

- Users very knowledgeable about AIS and potential harm, 90.7% responded in kind
- 82.7% of respondents want action to reduce aquatic plant and sedimentation impacts with top options being:
  - Mechanical harvesting (currently in place)
  - Dredging
  - Herbicide management

The Pigeon 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 the 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 northern Waupaca County in the Town of Larabee and City of Clintonville, the Lake was created by damming of the Pigeon River in 1855 by an earthen and timber dam. Originally used to power a grist mill, the dam has gone through various reconstructions over the years. The dam now in place was constructed in 1913.

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 Pigeon 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:

- **Pigeon Lake Management Plan – 1977**: Creation of this plan was driven by continued dense aquatic plant growth and a concern for increasing depths of soft organic sediment within the Lake, causing issues with use of the Lake. This plan was the initial management document for the Lake and recommended to begin aquatic plant harvesting.
- **Pigeon Lake Management Study – 1997**: This plan identified increasing sedimentation since the 1977 study, poor water quality attributed to high phosphorus levels in tributaries, and dense aquatic plant growth which has been reduced slightly since the past study. In-lake management recommendations limited to continuing aquatic plant harvesting.
- **Aquatic Plant Survey and Comprehensive Lake Management Plan – 2006**: Work for this plan included an updated aquatic plant survey that found continued, dense aquatic plant growth including Eurasian water-milfoil (EWM) and curly-leaf pondweed (CLP), both AIS. Water quality remained poor with high phosphorus levels. Sedimentation, both inorganic and organic, again was a problem. Recommendations focused on controlling AIS growth through limited harvesting and water level manipulation (drawdowns). Sediment control was touched on, with hydraulic dredging a listed possible approach.
- **Pigeon Lake Drawdown Potential – 2007**: This plan was done to assess the soft organic sediment within the Lake and potential affect from a drawdown for increasing the depth of these sediment areas. The project took sediment samples, analyzed them and came to a conclusion that a drawdown could potentially increase depth from 2 - 5 inches under ideal conditions.
- **Lake Management Report Review and Priority Recommendations – 2009:** A review of past management plans to summarize priority recommendations was conducted to complete this plan. It referenced all of the above and concluded that dredging was the top priority project combined with agricultural land controls within the watershed to alleviate inorganic sedimentation problems. Continued mechanical harvesting for

aquatic vegetation issues was a primary recommendation, along with water level control.

As an impoundment, Pigeon River's watershed upstream of the dam has an immense impact on the water quality of the 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:

- **Mid 1990s**: Waupaca County Land and Water Conservation Department (LWCD) identifies Pigeon Lake's watershed as a potential Priority Watershed (PWS) project for non-point source issues. However, final funding was never received and only minimal work done on properties within the watershed
- **2002-2004**: Natural Resources Conservation Services (NRCS), a division of the United States Department of Agriculture, designates special Environmental Quality Incentives Program (EQIP) funding for the Pigeon River Watershed. The focus of EQIP funding was on conservation tillage and nutrient management planning for various agricultural operations.
- **2013-present**: NRCS presents a new funding opportunity; National Water Quality Initiative (NWQI). Waupaca County LWCD applied on behalf of the Pigeon Lake watershed and are one of only three statewide project requests to receive NWQI funding. Since being awarded funding, nearly 2 million dollars have been allocated towards non-point source work. From 2014 – 2015, the following projects have been installed and up to 90% cost sharing:
    - 5 manure storage systems, 1 more set for 2016
    - 5 total containment barnyard runoff systems, more set for 2016
    - 6 roof runoff systems
    - 2 clean water diversions
    - 1 sediment control basin

  In addition to the above projects, land use practices have also been initiated, including:

    - 24.6 acres converted to grass waterways
    - 103 acres enrolled in conservation tillage incentives
    - 1957 acres covered under nutrient management plans
    - Additional acreage anticipated to begin in 2016

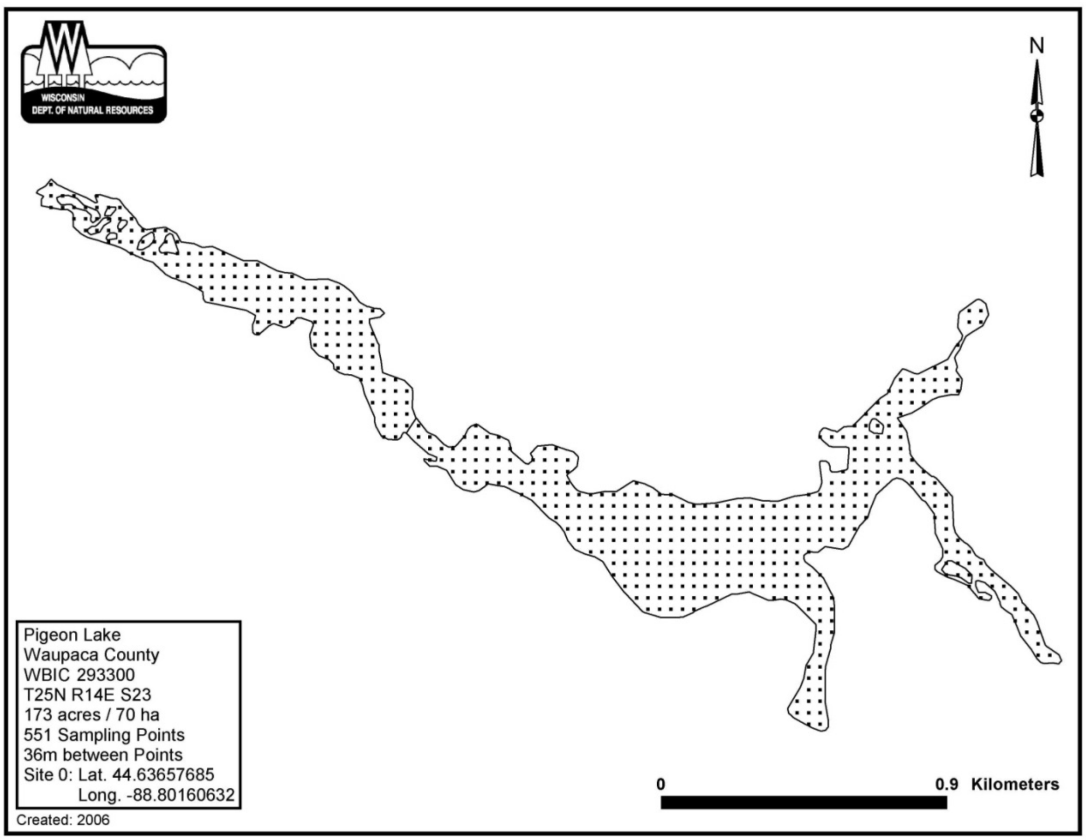
Management actions carried out for aquatic plant growth within the Lake have concentrated on aquatic plant harvesting. Issues still persisted in Pigeon Lake after several plans were created and some management actions enacted to the level feasible, as evidenced by the concerns raised in the user questionnaire. 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.

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 EWM, 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 10, 2014 following all WDNR survey protocol. The survey included sampling at 551 pre-determined locations uniformly spaced 36 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.

4.1 2014 POINT INTERCEPT SURVEY

In 2014, the aquatic plant survey identified a moderately diverse community with large sections of dense growth. In total, 19 species were identified, two of them being AIS – Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) (Table 1). All species identified are common of such systems in Wisconsin and tolerant of disturbance.

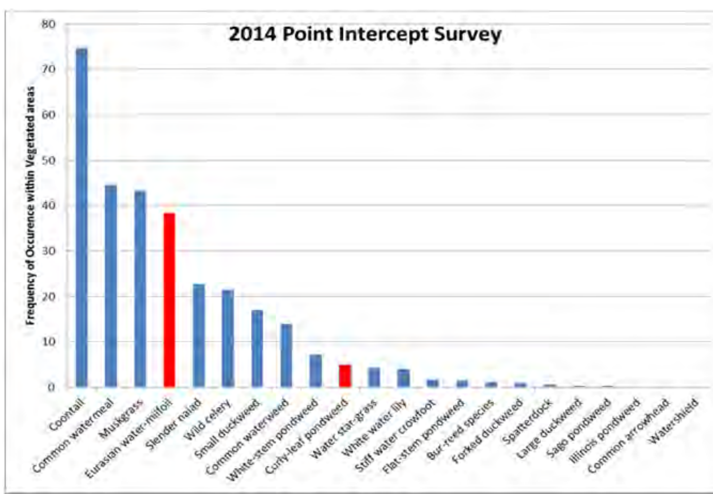
Table 2: 2014 Aquatic Plant Community Statistics, Pigeon Lake, Waupaca County, WI

Aquatic Plant Community Statistics	2014
Frequency of occurrence at sites shallower than maximum depth of plants	95.94%
Simpson Diversity Index	0.86
Maximum Depth of Plants (Feet)	9
Taxonomic Richness (Number Taxa)	19
Average Number of Species per Site (sites less than max depth of plant growth)	2.89
Average Number of Species per Site (sites with vegetation)	3.02
Average Number of NATIVE Species per Site (sites less than max depth of plant growth)	2.48
Average Number of NATIVE Species per Site (sites with vegetation)	2.62

Species sampled in Pigeon Lake were present in four 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 (bur-reed - *Sparganium sp.);* submersed species which root on the Lake bottom and remain below the water's surface (wild celery - *Vallisneria americana*); and floating-leaf species which root on the lake bottom with vegetation growing to and floating on the surface (white water lily – *Nymphaea odorata*).

With nearly the entire Lake within the photic zone, <9.0 feet deep, plant growth was locally dense with 96% of the waterbody vegetated. The soft, rich sediment provides ideal conditions for aquatic plants. Species richness was about average at 19, but exhibited good diversity per sample point averaging over 3 species per site with a moderately good spread throughout the system, as exhibited by a Simpson Diversity Index (SDI) of 0.86. A SDI value closer to 1.0 indicates a healthier, more evenly spread plant community. Coontail and common watermeal (*Wolffia columbiana*) were the most dominant species present (Tables 3, Figures 1.1 – 1.3).

Eurasian water-milfoil (EWM) was sampled during the 2014 at 154 locations and approximately 72 acres. Though it's one of the most common plants in Pigeon Lake, EWM coverage within the Lake has decreased since the previous survey (2006) from 62.1% of vegetated areas to 38.3% as surveyed by Stantec in 2014 (Figure 2).



Curly-leaf pondweed (CLP), also an invasive species, is present within the Lake. CLP occurred at 20 locations, covering approximately 12 acres during the 2014 survey. Due to CLP's life cycle, the best time to gauge distribution of the plant is in spring before it dies off in mid-summer and the 2014 survey may not be a true representation of AIS due to timing (Figure 3).

4.2 FLORISTIC QUALITY INDEX

To compare changes in the plant community over time within Pigeon 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 plants 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 species found in systems of higher water quality. Intermediate C values (4-6) indicate plant species that can tolerate moderate disturbance.

Table 4: 2014 Floristic Quality Index, Pigeon Lake, Waupaca County, WI

Genus	Species	Common Name	Coefficient of Conservatism C
Ceratophyllum	*demersum*	Coontail	3
Chara	*sp.*	Muskgrass	7
Elodea	*canadensis*	Common waterweed	3
Heteranthera	*dubia*	Water star-grass	6
Lemna	*minor*	Small duckweed	4
Lemna	*trisulca*	Forked duckweed	6
Najas	*flexilis*	Slender naiad	6
Nuphar	*variegata*	Spatterdock	6
Nymphaea	*odorata*	White water lily	6
Potamogeton	*praelongus*	White-stem pondweed	8
Potamogeton	*zosteriformis*	Flat-stem pondweed	6
Ranunculus	*aquatilis*	Stiff water crowfoot	8
Spirodela	*polyrhiza*	Large duckweed	5
Stuckenia	*pectinata*	Sago pondweed	3
Vallisneria	*americana*	Wild celery	6
Wolffia	*columbiana*	Common watermeal	5
		Total Species	16
		Mean C	5.31
		Floristic Quality Index (FQI)	**21.25**

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. Pigeon 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. Pigeon Lake is found near the heart of the ecoregion within the upper Wolf River stagnation moraine 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 of these lakes leads to more disturbance 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.

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 Pigeon Lake and though AIS is present, there is a moderately diverse native plant community still present. 17 native species were found during the 2014 survey with an average of 2.62 native species per sample point with vegetation present with many sample points having more than this and up to six 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 EWM due to potential management. Many lakes with EWM growth, especially within this region, lack a native community to do so.

Table 5: FQI and Average Coefficient of Pigeon 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
Pigeon Lake - 2014	5.31			21.25		

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

The FQI calculated from the 2014 aquatic plant survey data was 21.25 with an average C of 5.31. These values, when compared to the North Central Hardwood Forests Eco-region means of 20.9 and 5.6 respectively, are above average for FQI and slightly below average for average C.

4.3 HISTORICAL COMPARISON

The aquatic plant community of Pigeon Lake has been sampled numerous times throughout its history, providing a unique opportunity to gauge changes over the years. Beginning with line transect surveys in 1977 and 1997, protocol was changed to be more repeatable with point intercept surveys. Full point intercept surveys have been completed in 2006 and 2014. Data from the original, 1977 line-transect survey is not available.

Though the survey methods have changed, the relative plant community within the lake has remained stable in abundance and diversity throughout the surveys. As this happens, species diversity, average coefficient of conservatism and FQI are relatively stable over time as the Lake ecosystem ages. These trends play out and are shown to be stable for all metrics over time when comparing historical survey data.

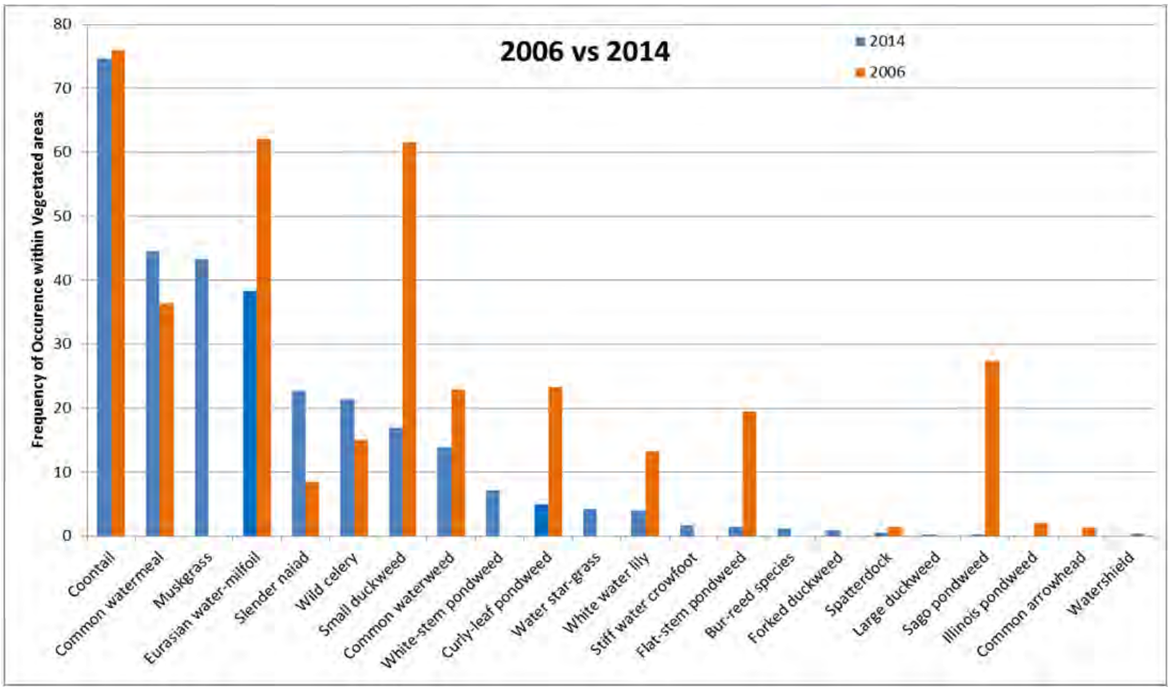
Table 6: Historical Aquatic Plant Community Statistics, Pigeon Lake, Waupaca County, Wisconsin.

	1977	1997	2006	2014
F.o.o. at sites shallower than maximum depth of plants	---*	---	97.09	95.94
Most Dominant Species	Coontail	Coontail	Coontail	Coontail
	White-stem pondweed	Curly-leaf pondweed	Eurasian water-milfoil	Comon watermeal
	Northern water-milfoil	Common waterweed	Small duckweed	Muskgrass / Chara
	Flat-stem pondweed	Eurasian water-milfoil	Common watermeal	Eurasian water-milfoil
	Eurasian water-milfoil	Flat-stem pondweed	Sago pondweed	Slender naiad
Maximum Depth of Plants	---	---	11.9	9
Species Richness	17	17	20	19
Community FQI	---	---	20.51	21.25
Average Coeffecient of Conservatism	---	---	4.83	5.31

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

From the two most recent full aquatic plant surveys a few changes are evident. The five most common species in these surveys are variable, as expected for a waterbody with active vegetation management. EWM was present in higher numbers in 2006 (2^{nd} most common) and sago pondweed, fifth most common in 2006, was found at only one location in 2014. Free-floating plant species were once again very common in 2014, with common watermeal the second most common species found and small duckweed the seventh most common. These species thrive in nutrient-rich environments with the ability to absorb them directly from the water.

Over the two most recent surveys (2006 and 2014) as shown below, the aquatic plant community has seen some minor changes while remaining relatively stable. Species sampled in 2006 but not present in 2014 include common arrowhead, Illinois pondweed and watershield. Five additional species were noted as visual only in 2006 with no statistics calculated. These were near-shore emergents, and still present during the 2014 survey and include; sweetflag, pickerelweed, water plantain, softstem bulrush and broad-leaf cattail. However, the 2014 survey had seven species sampled that were not in 2006, including; muskgrass, white-stem pondweed, water star-grass, stiff water crowfoot, bur-reed, forked duckweed and large duckweed. Both white-stem pondweed and water star-grass were once prevalent in the system, but were noted to decrease from 1977 to 1997 with neither found during the 2006 survey.



Data comparison between years on the Lake shows that the Lake exhibits a healthy although 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.

Even as the community of the Lake matures, AIS are an ever increasing threat. EWM is the most prevalent AIS present and has decreased from the 2006 survey. However, this species was found growing in dense, often monotypic colonies matting on 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 most of the 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 only green plants while under ice cover. This makes it very opportunistic in nutrient rich environments and is one of the first plants to begin growth once ice cover leaves.

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 give off differing amounts of nutrient and sediment loads through 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 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 Pigeon Lake. Information on methods and all referenced tables or charts is included in Appendix C.

5.1 WATER QUALITY

Pigeon 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.

Pigeon Lake water quality data has been collected sparingly as part of various projects since 1990, including:

- Water clarity (Secchi depth) - 1990, 1992, 1994, 1996, 2001-2002 & 2014
- Total phosphorus – 2001-2002 & 2014
- Chlorophyll *a* – 2001-2002, 2004 & 2014
- Nitrogen – 2014

Due to the lack of recent data, all three parameters were again collected and tested for during this project period (2014).

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 4.16 feet, indicating marginal clarity, while lakes in Wisconsin average approximately 10 feet (Chart 1). This can be impacted by a high nutrient load for the Lake and turbid water, due to its watershed.

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

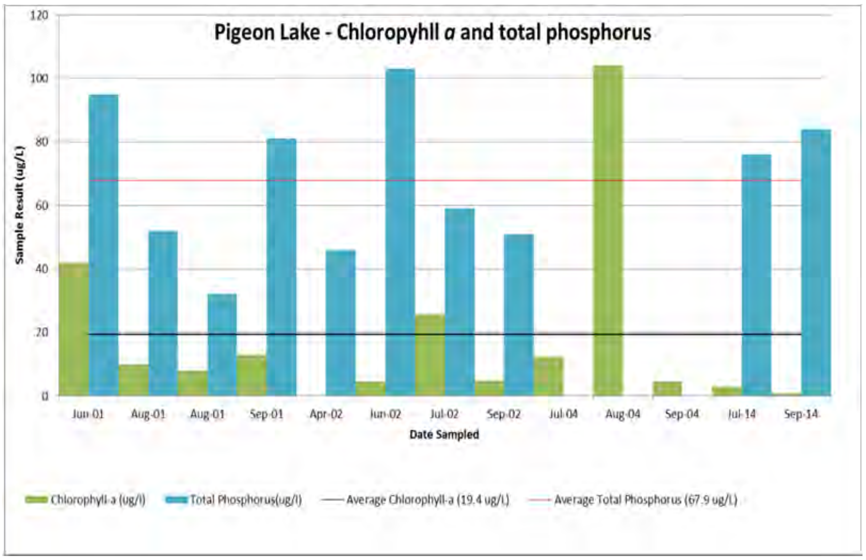
Water Quality Index	Total Phosphorus (mg/L)	
Very Poor	0.150+	
Poor	0.053 – 0.149	← Pigeon Lake
Fair	0.031 – 0.052	
Good	0.016 – 0.030	
Very Good	0.002 – 0.015	
Excellent	0.001 or less	

All samples averaged 0.0679 mg/L for total phosphorus, indicating poor water quality and high availability of nutrients (Chart 2). Though high, it is not unexpected in a flowing system with agricultural use and is only slightly above average for impoundments in Wisconsin. Many factors could have led to high readings, including recent runoff and land use 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.

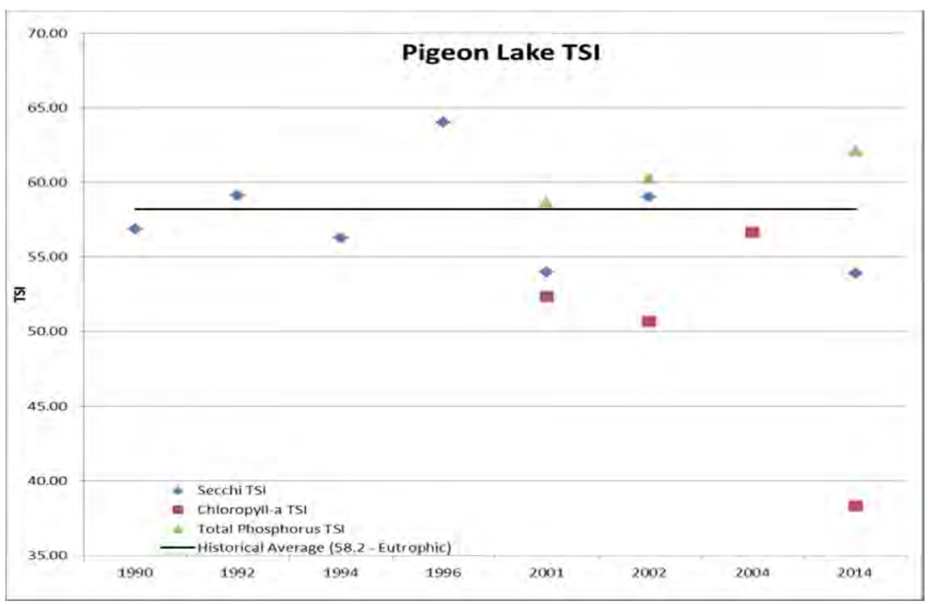
Total nitrogen for Pigeon Lake averaged 1.92 mg/L. Nitrogen levels on their own are typically not tracked in comparison to other lakes, such as with phosphorus above. Instead, they are compared with the phosphorus concentration of the lake to establish a ration between nitrogen and total phosphorus present 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. Pigeon Lake has an average nitrogen level of 1.92 mg/l and an average phosphorus level of 0.0679 mg/L. These values give the Lake a ratio of approximately 28.3:1, indicating that phosphorus is the limiting nutrient for plant growth. This is common for most lakes within 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, especially in the presence of high nutrient loads. Pigeon Lake has experienced algae blooms in the past, particularly noted by residents in Fairway Lake, with an overall average value of 19.4 ug/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 all three values and is 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 Pigeon Lake is a eutrophic lake with an average TSI rating of 58.2. This is expected due to the large watershed contributing to the relatively small water volume of Pigeon Lake with large nutrient inputs from primarily agricultural lands.

5.2 WATERSHED

All above factors are impacted by the lake's watershed. To gauge the watershed's effect on the water quality of Pigeon 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 Pigeon Lake. Information on methods and all referenced tables or charts and direct model outputs is included in Appendix D.

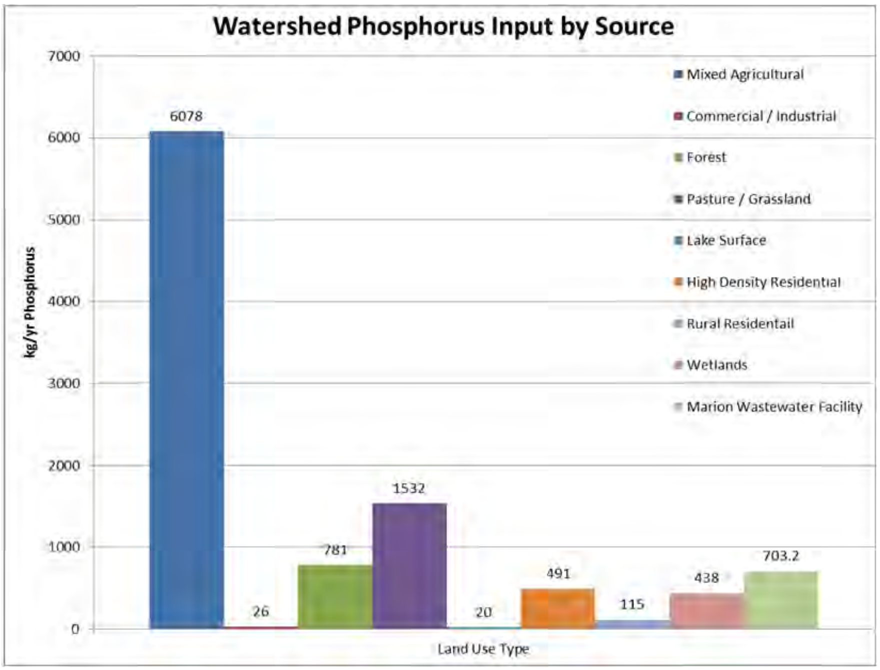
LEAP is a program within WiLMS that predicts lake trophic status indices based on watershed area, lake depth and lake ecoregion. For Pigeon Lake, the watershed without the lake itself is 67,337 acres while the Lake has a mean depth of 4.2 feet and total surface area of 162.7 acres within the watershed and it belongs in the North Central Harwood Forests ecoregion. Previous reports stopped the watershed at the Marion Millpond dam, cutting it short at approximately 33,600 acres. Area above the dam should be included since it all drains into the North Branch Pigeon River, which directly feeds Pigeon Lake; therefor anything affecting Marion Millpond will also affect the Lake (Figure 4).

The LEAP program 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, resulting in increased amounts and leading to soupy, green colored water with reduced water clarity and recreational value associated with chlorophyll a readings of >20.0 ug/L. 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. This is directly in line with measured chlorophyll *a*, which averaged 19.4 ug/L.

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 is one point-source for phosphorus introduction to Pigeon Lake, the City of Marion wastewater treatment facility.

The LTPP predicted a total phosphorous amount of 9481 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 7). Agricultural land inputs the most annually at approximately 6078 kg/year while internal loading or recycling of phosphorus already in the Lake accounts for 20 kg of the lake's budget per year based on the model. There is one known direct, point source for phosphorus loading into the Lake as mentioned above.



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 27.8% of the total watershed, attributes 59.7% of the annual phosphorus load into the lake (Table 8).

Point sources within a watershed allow a nearly direct measurement of input into the system, especially when permitted. This allows documented averages to be extrapolated throughout the year. The City of Marion wastewater treatment facility discharges directly into the Pigeon River, downstream of the Marion Millpond dam. Data for this discharge is available back to 1999 (Table 9). By using average daily flow and total phosphorus concentration, its input can be expanded to an expected annual input of 703.2 kg/year of phosphorus. Which, when calculated over the lakes' surface, is a fairly significant load. Marion's wastewater discharge permit expires in 2014 and is currently up for renewal. It may behoove the District to offer comments on the approved phosphorous discharge limits as part of the public comment permit review and approval process. The City of Clintonville's wastewater treatment facility discharges downstream of the Pigeon Lake dam and does not affect the watershed or nutrient loading above the dam.

Currently, water quality is poor within the Lake, though higher than predicted when comparing with model data. All three trophic status indices are below predicted values for its ecoregion.

Pigeon Lake TSI - Observed vs. Model Predicted Values

Parameter	Observed	Predicted
Total Phosphorus (ug/L)	67.9	123
Chlorophyll-a (ug/L	19.4	74
Secchi (m)	1.3	0.6

Though agricultural land covers 27.8% of the watershed, it contributes approximately 59.7% of nutrient input into the Lake. Some best-management practices may already be currently use within the watershed. The County recently completed an update to their Farmland Preservation Plan, which was originally written in 1982. The new plan provides an avenue for monetary assistance through tax incentives for maintain good water quality practices. However, the expected impact on the Pigeon River watershed is low, as only the Town of Matteson has participated. The Towns of DuPont, Larabee and Wyoming, all within the Pigeon River watershed, opted out of participation in the updated plan.

6.0 DAM HISTORY, DESIGN AND CURRENT OPERATION

The dam impounding Pigeon Lake, commonly called the Clintonville Dam, is owned and operated by the City of Clintonville, Wisconsin. Only 17% of Wisconsin's 3800 permitted dams are owned by a municipality, making this dam somewhat unique.

The WDNR classifies the Clintonville 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 20 feet, the impoundment (Pigeon Lake) is large with an estimated volume of 688 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 first dam was built in 1855 to power a grist mill and has been repaired and reconstructed several times over its history. The picture below from 1910 illustrates the dam that existed before the present dam was built.

The current dam was constructed in 1913 and according to WDNR records has the following physical characteristics:

- Age: 102 years
- Structural Height: 20 feet
- Hydraulic Height: 12 feet
- Crest Length: 240 feet
- Maximum Storage Volume: 1020 acre-feet
- Normal Storage Volume: 688 acre-feet
- Spillway: Three operable gates and fixed crest weir, total capacity 4700 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 remainder of the spillway is a fixed concrete weir approximately 40 feet in length. Most recent dam repairs occurred in 2010 when the gate's operating system was attended to. The dam no longer produces power, and its sole function is regulating the water levels of Pigeon Lake.

The Clintonville Dam provides a unique and only recently recognized service. It serves as a barrier to upstream migration of fish and other aquatic organisms. As such, it may provide value to hinder the spread of diseases such as viral hemorrhagic septicemia (VHS) and invasive plant and animals (mussels, Asian carp, etc.). The value of this function must be considered when management plans are developed.

According to City of Clintonville staff, the City operates the dam to manage lake elevation and safely pass flood flows. The City monitors water levels electronically and manually manipulates the gates to stabilize water levels to the extent practical. Under normal flow conditions, all water passes over the fixed weir that composes the north half of the dam, gates are opened to pass high flows. The City does not attempt to modulate downstream flood flows or augment low, dry weather flow. Reportedly, the dam does not foul with debris and no special action is needed to manage this common problem. Similarly, sediment is not known to have shoaled upstream of the gates to an extent that would influence gate operation. No increase in water turbidity is noted when gates are opened and no dredging has ever been done just upstream of the gates.

Reservoir Sedimentation and Channel Morphology

The dam and Pigeon Lake are 160 years old and have therefore been present essentially throughout the State's history. The Pigeon River's watershed underwent dramatic change during this time period, including removal of primeval forest and conversion of the land to agriculture. This process yielded tremendous volumes of sediment, and Pigeon Lake, being a quiescent water body, served as a settling basin. This process continues to this day, although likely at a reduced rate.

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 agricultural, 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.

The 163 acre lake presently has an average depth of 4 feet, and a maximum depth of approximately 10 feet. The deepest water areas are located just upstream of the dam, a narrow channel area with higher water velocity. Significant inorganic sedimentation was recently noted in Fairway Lake, a man made portion of the lake off the main channel which receives runoff from a drainage creek serving a northern portion of the watershed and significant storm sewer water discharged from adjacent urbanized street areas. Particularly heavy sedimentation was reportedly noted after construction and landscaping of the local school. According to available 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.

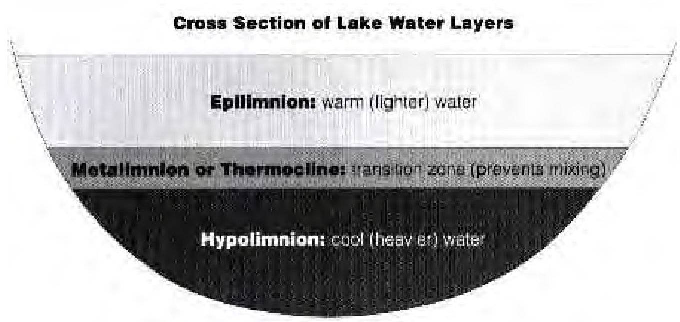
7.0 IN-LAKE RESTORATION OPTIONS

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.

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. Pigeon 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.

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.

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 MANAGEMENT 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 Stantec.

AQUATIC PLANT MANAGEMENT ALTERNATIVES

A combination of management alternatives may be used on a lake in which a healthy aquatic plant community exists and invasive and non-native plant species are 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 2014 full point-intercept survey. In order to monitor existing populations of current AIS and for new AIS in the future, a strong Pigeon Lake monitoring program that 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 Pigeon 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 Pigeon Lake has been limited, though participation in this program is strongly encouraged. Especially when considering the amount of AIS within the system and relatively high number of boat landings (5) for a lake its size. The CB/CW participation on Pigeon Lake is low, only 14.25 hours in 2012 and 11 hours in 2013. Increased joint participation of this program is recommended and should be promoted within the District, 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 and 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 PLPRD 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 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.

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.

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.

8.0 MECHANICAL AQUATIC PLANT 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. 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.

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. In Pigeon Lake, both coontail and EWM create a canopy, shading out high-quality species as wild celery and white-stem pondweed. Use of a top cut only in areas of dense AIS growth, such as the middle of the main portion of the Lake, can provide additional sunlight for growth, increasing diversity and available fisheries habitat quality. Also added to this technique, a slightly deeper top cut of 2' in depth of high-density EWM and coontail areas adjacent to beds of high quality species can provide lateral habitat for them to expand.

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.

Additionally, if AIS levels are decreased, it is possible for native plants to grow dense enough in their place to cause a nuisance and impede navigation, especially in shallow, soft-sediment bays. Currently, this impedance exists in various locations of the Lake. Most of his impedance is caused by dense, submergent species growth, especially coontail, in shallow water and options to maintain common, navigational access channels within problem areas has been permitted in the past for mechanical harvesting.

As water temperatures decline prior to freeze-up, aquatic plants begin to die back. As the plants die back and decay under ice cover, dissolved oxygen is consumed. In shallow waterbodies or during harsh winters with thick ice and snow cover this process can use enough of the available oxygen to deplete it to the point of starving fish and other organisms of oxygen, leading to a winter kill. Lakes with large volumes of dense aquatic vegetation, such as Pigeon Lake, can experience a winter kill more often. To alleviate the issue, harvesting of remaining vegetation during the die-back period can help. This removes excess vegetation from the system, limiting the amount left to decay while not harming native species or spreading AIS as they have already stopped growing for the year. Typically, this occurs at or below a water temperature of 55° F. As a secondary effect, this approach can delay nuisance growth the following spring by removing excess coontail, the largest cause of nuisance issues on Pigeon Lake.

Current management practices for navigational relief are well received and desired by the users of Pigeon Lake as witnessed in the public questionnaire. Mechanical harvesting has been doing an adequate job in addressing the problem and should continue to be used. Most of the navigational impedance is currently caused by a combination of coontail and EWM and options to maintain a common, navigational access channel will likely still be warranted even after potentially successful large scale EWM herbicide management action, though the frequency and severity may be substantially reduced.

With infrastructure for harvesting already in place and the practice widely accepted among lake users, continuation of this action for navigation nuisance relief and AIS management should be continued. Prior to finalization, all harvesting areas and methods were reviewed and approved by the PLPRD, creating guidance for continuing harvesting operations. Any harvesting operations should follow the guideline below for future permitting.

- EXCEPT FOR NAVIGATIONAL ACCESS LANES, ONLY CUT IN DEPTHS MORE THAN THREE FEET
- PRIORITIZE HARVESTING AREAS TO FOCUS ON GREATEST NEED – Highest priority should be on maintaining navigation access lanes to/from boat landings and common navigational lanes. In these areas, you must leave 12 inches of plant on the lake bottom. Individual areas by priority are included in the table below.
- BOATING ACCESS LANES – These areas are for riparian access to the main lake. Harvesting should be done from pier heads out to a width of 50' and depth up to four feet, leaving 12" of plant material on the bottom. Areas between shore and pier heads should be manually harvested only.
- TOP CUT IN AREAS FOR EWM and CLP for SPECIFIC AIS MANAGEMENT – These areas are specific to AIS harvest management under NR 109. Restrict cutting to 2 feet below the water's surface, leaving a minimum of 12 inches of plant growth on the lake bottom in areas shallower than 5 feet prior to May 31 only. These maybe further limited based on time of year and WDNR permit conditions and are subject to change.
- LATE FALL HARVESTING – Final harvesting of excessive plant growth throughout the main body of Pigeon Lake to reduce winter kill potential and remove excess nutrients caused by decay. This is to occur only post turn-over when water temperatures have declined below 55° F, cutting to a depth of 4' and leaving 12" of plant material on the bottom. This is currently not approved by WDNR. Future approval would likely be considered experimental and would be subject to annual approval and may require more intensive Point Intercept surveys to show no harm to the native plant community.
- HARVESTING OF HIGH VALUE NATIVE PONDWEEDS AND FLOATING-LEAF VEGETATION (WATER LILIES) IS PROHIBITED.
- ALL CUT MATERIAL SHOULD BE INSPECTED FOR FISH AND ANIMALS. ANY ORGANISMS FOUND SHOULD BE IMMEDIATELY RETURNED TO THE WATER.

- ALL CUT MATERIALS SHOULD BE COLLECTED AND DEPOSITED AT THE DESIGNATED DISPOSAL SITE.
- Maps of all harvesting locations are included in Appendix A.

Area	Description	Instructions
NAVIGATIONAL ACCESS AREAS		
A_1	Common access navigation lane	Cut a lane 75' wide - must leave 12" of plant growth on the bottom
A_2	Boating access lane	Cut a lane 50' wide - must leave 12" of plant growth on the bottom
AIS MANAGEMENT AREAS		
B_1	AIS management areas	Top cut 2' to control surface matting of AIS and promote native species growth - prior to May 31 only.

9.0 INVAISIVE PLANT MANAGEMENT ALTERNATIVES

9.1 AQUATIC INVASIVE PLANT SPECIES HERBICIDE TREATMENT

An 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 whole-lake plant survey and will likely require a pre-treatment AIS survey. Along with the above mentioned surveys, pre and post treatment monitoring 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 being updated. Currently EWM is the most common aquatic invasive plant species targeted for chemical treatment in Wisconsin. 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 are less costly and 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 EWM, treatments are completed in the spring when native plant growth is minimal, typically prior to 70˚ 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 Pigeon 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 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. The presence of hybrid EWM on Pigeon Lake has not been tested nor confirmed.

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. 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).

Many times the amount of herbicide used in this type of whole lake treatment can be further reduced by timing the treatment as close as possible to lake stratification. After the thermocline develops in the lake, typically between 60 – 70 degrees surface temperature, this may effectively eliminate the area of the water column below the thermocline from the treatment, reducing the amount of herbicide needed for a whole lake treatment by 20 - 40%. Where this technique can be utilized, on deeper lakes that stratify, it should in order to reduce the amount of herbicide used within the lake and to more effectively target the whole lake treatment within the littoral area.

Currently CLP is considered 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 of turions.

Similar to EWM treatments, granular based formulations are 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. CLP seems to prefer and flourish in mucky or highly flocculent substrate, which is generally not present in most of Pigeon Lake. Given the lack of appropriate substrate and the limited expansion of this invasive within Pigeon Lake, monitoring may be the best option for management.

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 Pigeon 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 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.

9.2 WATER LEVEL DRAWDOWN FOR AIS CONTROL

Having a dam on this waterway presents unique opportunities to potentially manage sediment, water quality and aquatic plants. Over winter drawdowns typically from September through May 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. Longer multiyear drawdowns typically over 2 growing seasons can provide sediment compaction of 1' to 3' to exposed sediment that has the ability to thoroughly dry out during this time. To have maximum effectiveness throughout the reservoir it should be drawdown as far as possible, which 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 typically associated with 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 in 2015, which may provide additional information to assist in making a decision if this management option is one that may be right for the Lake.

Drawdown of water level can be a very effective tool in managing EWM if an available option. During a drawdown the water level is lowered to expose the lake bed where EWM is present, allowing winter temperatures to fatally freeze and dry plants and associated root systems. Drawdowns have drastically reduced EWM frequencies in some lakes, although populations typically rebound after several years. Drawdowns do impact native plants, but not to the extent that it does EWM. 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. Certain emergent plants that need lowered water levels to germinate and reproduce, such as bulrush, benefit from drawdowns.

Periodic 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 of a few inches, up to 12 inches after a drawdown. These two actions, reduction of plant biomass and soil compaction, deepen the lake, which creates a “youthful” trophic condition.

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.

A drawdown in conjunction with fall herbicide control of AIS has also shown to successfully control EWM on similar impoundments and reduce costs due to less herbicide being used. This provides not only AIS reduction, but nuisance, navigational relief and reduced expenses for mechanical harvesting for several years after completion. If chosen, a recommend schedule of an over-winter drawdown every four to five years can be maintained to prolong the life of the impoundment, and a single drawdown permit can be issued for up to 5 years.

The amount of the drawdown as measured at the face of the dam should likely be in the 4 foot range this would expose approximately 120 acres of the reservoir to freezing (see Figure 5) while still maintaining an average water depth of 2.25' and a maximum depth of 6' and affecting 35.5 acres (50.6%) of EWM present.

9.3 BIOLOGICAL EWM CONTROL THROUGH MILFOIL WEEVILS

The milfoil weevil (*Euhrychiopsis lecontei)* has shown promise as an eco-friendly solution with potential for long-term sustainable control of lake-wide EWM infestations. Typically adult weevils are naturally occurring within localized lakes and are collected from those nearby lakes to rear them to produce offspring in a laboratory facility. The offspring (in the form of eggs and larvae) are then re-introduced into dense milfoil stands often over 2-3 seasons and are monitored throughout the stocking programs.

The goal of biological control is to build a sustainable population that is capable of maintaining the milfoil at low levels. As the natural predator of this invasive species, the weevil spends its entire life cycle feeding on the leaves and tunneling through the main stem of the plant, damaging the vascular system which slowly kills the plant. This process takes three-five+ years, depending on the extent of the infestation and how aggressive the stocking program is.

Benefits:

1. The beetles simply utilizing a nature-based predator-prey relationship already found occurring in North American lakes. The benefit is using an environmentally-safe and eco-friendly approach for milfoil control.
2. Because weevil populations naturally exist in the Wisconsin lakes, they sustain their own population and can continue to control the milfoil year after year.
3. Weevils are highly selective – All of the peer-reviewed scientific literature confirms that weevils only live on certain types of milfoils: Eurasian, Northern and/or a hybrid of the two with virtually no possibility of negative impacts to other plants, animals or humans.

Costs:

Weevils are sold in units of 1,000 and 1 unit = $1,000 or $1.00/weevil. Because it is live organism, weevils are not stocked on a per acre basis but rather on the size of the milfoil infestation, and to some extent how rapidly control is desired. Each water body is different, but once a self-sustaining population is achieved, management costs can drop sometimes only requiring occasional monitoring and enhancement of weevil populations if milfoil levels warrant it. Long-term monitoring is an important component for any milfoil management program and should be considered when deciding on a management strategy.

There is a surveying component expense in addition to the weevil cost. This is dependent on the size of the program and can typically range from $1,500 to $5,000 in most cases. A typical three year project for a 200 acre lake with approximately 50 acres of milfoil could be $45,000 - $55,000 ($15,000 - $18,000 per year average). Larger lakes or higher infestations could implement a longer program at that same rate. The purpose is to treat high problem areas while allowing the weevils to get established with the idea that less and less (or no) herbicide will be used as the weevils move throughout the Lake.

Potential disadvantages:

1. The cost of the program is high at least initially, several times higher than herbicide and/or harvesting.

2. For the best results lakes with good naturally occurring native weevil populations seem to be best suited and experience the best results.
3. Weather and potential climate change issues affect the effectiveness of the weevils. Early long, hot and dry summers can negatively affect weevil populations and more so their ability to "eat through" the bumper crop of EWM that accompanies these types of increasingly more common growing seasons. Also dramatic water level fluctuations can negatively affect weevil populations.
4. High populations of stunted panfish without adequate food supplies can prey on the weevils, while not a preferred food source it can become one as other sources are diminished, typically present where stunted panfish population exists.
5. Length of time to see results, most times it takes a minimum of 3 years to see any results, sometimes 5 to 10 years is not uncommon with a possible commitment to stocking each year, and some lakes they never really seem to establish themselves without constant stocking.
6. The success of weevil control projects has been very unpredictability; it is difficult to determine where they are going to work well and where they may not, what lake types, water quality, near shore and shoreland habitats. It has been very difficult to pinpoint which lakes make the best candidates and have the highest likelihood of success. This risk factor alone is too much for many groups.

Please Note: *Unfortunately, milfoil weevils are no longer commercially available and, as such, are not a current option. It is possible that if they again become available in the future this option be further explored if desired and current milfoil abundance warrants. At the time of this report the company that previously produced the weevils, has been in discussions with the State of Wisconsin and other non-profits at potentially taking over this discontinued portion of their business.*

10.0 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 Pigeon 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 District'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 PLPRD 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 PLPRD.

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 PLPRD. See the following table.

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.

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

11.0 OVERALL LAKE MANGEMENT GOALS

Pigeon 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 District with high likelihood of subsequent approval from the WDNR will be selected to help accomplish management goals.

As an impoundment, Pigeon 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: Mechanically harvest following guidance in section 8.0 and Figure 6.

Possible Action: For riparian landowner access areas that are too shallow for harvester access, herbicide application of a mixture of liquid diquat and copper algaecide at a 2:3 ratio may be necessary. If desired, application should be restricted from the pier head to nearest harvester access at a width of 30'.

Goal: Reduce Sediment

Primary Action: Engage the WDNR and District 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 City of Clintonville to improve water quality and better manage sediment and storm loads to the system.

Possible Action: Engage aeration manufactures to look at problem areas on the lake for aeration type and sizing for water quality improvement and soft sediment reduction.

Possible Action: Large scale fall harvesting after lake turn over, or less than 55 degrees water temperature, to reduce biomass of dead and dying plants causing an increased sediment load within the system

Goal: Improve Water Quality

Primary Action: Engage the County Conservation Department and riparian property owners to implement watershed controls and buffer establishment and restoration.

Primary Action: Contact landowners within the watershed with large agricultural lands currently not enrolled in County or NRCS conservation programs to outline the issues caused by non-point sources in the form of a letter describing the current lake issues and encouraging the landowners to participate while funding (up to 90%) is available.

Primary Action: Work with City of Marion and/or WDNR on phosphorus discharge standards for the upstream wastewater treatment plant, the largest point source discharge limits.

***Possible Action*:** Discuss the ability to alter dam operation with the City of Clintonville to improve water quality, better manage sediment and storm loads to the system.

***Possible Action*:** Engage aeration manufactures to look at problem areas on the lake for aeration type and sizing for water quality improvement and sediment reduction.

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 CLP to 2.5% and/or EWM to 5% frequencies of occurrence within the littoral zone.

Primary Action: Begin harvesting in areas where CLP growth has been documented prior to turion production, typically before 65 degree water temperatures, and continue to harvest these areas to prevent turion formation until the plants die, typically in late July

Possible Action: Have at least 3 separate EWM plant specimens from different locations throughout the lake sent to a laboratory (such as Grand Valley State) to verify if the plants are genetic hybrids through eDNA analysis. Cost for this is roughly $50-$80 per plant.

***Possible Action*:** Each year direct AIS management is to take place, continue to complete pre and post-treatment 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. Comparison of data between years allows calculating reduction of targeted species in relation to established frequency of occurrence goals.

***Possible Action*:** Complete an over-winter drawdown of 4'. Water should begin to be lowered beginning in September just after Labor Day at a daily rate 4" until desired depth is achieved. Water level should be returned to normal the following spring. This will have a direct effect on both nuisance aquatic plant growth and AIS, reducing the need for harvesting in conjunction. Consider a fall post drawdown herbicide application for EWM applied at lake wide concentrations due to possible herbicide loss off of treated areas in a flowing system.

Possible Action: If an over winter draw down is not feasible or palatable, consider a spring large scale (> 10 acres) herbicide treatment targeting EWM and/or CLP. This will require a WDNR permit which would be applied for in late winter with the PI 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 reduction in harvesting need and cost on an annual basis.

Goal: Resume and establish a comprehensive water quality monitoring within Pigeon 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, and 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 below.

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
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12.0 REFERENCES

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

Borman, Susan, Robert Korth, and Jo Temte, *Through the Looking Glass, A Field Guide to Aquatic Plants*, Wisconsin Lakes Partnership, 1997

Carlson, R. E., A trophic state index for lakes. Limnology and Oceanography, 22:361-369, 1977

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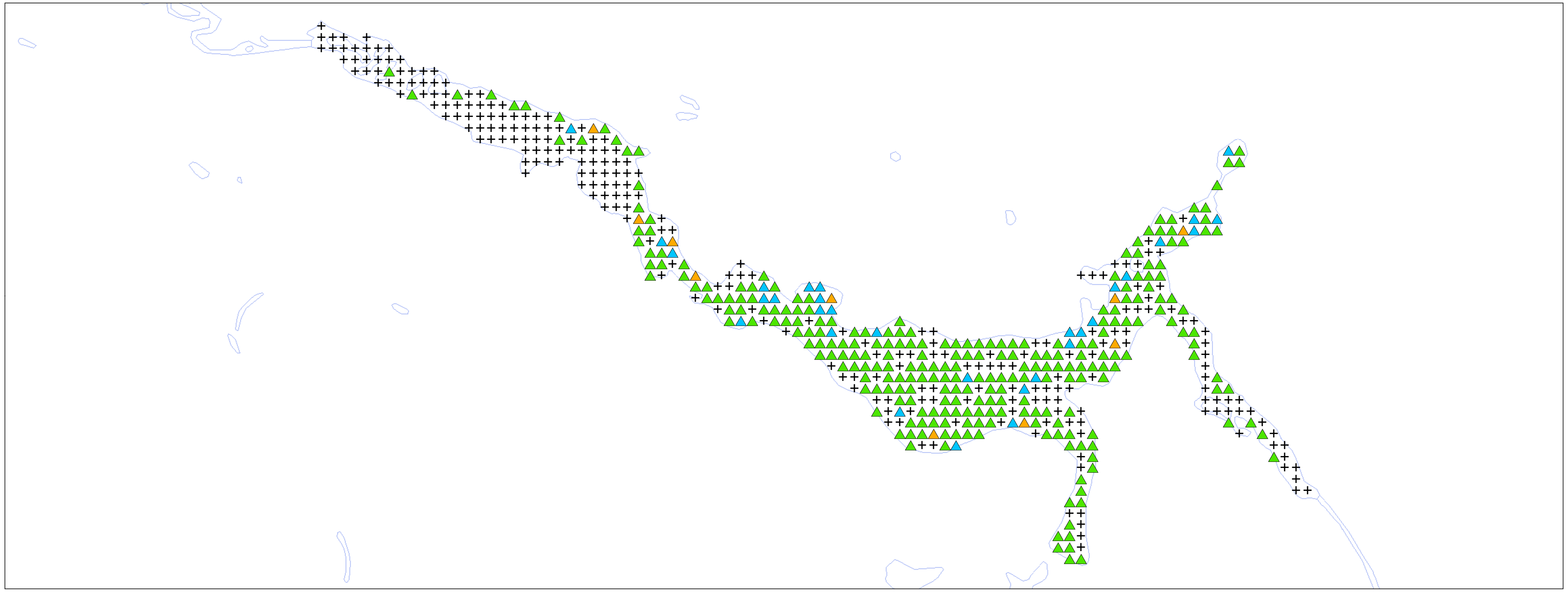
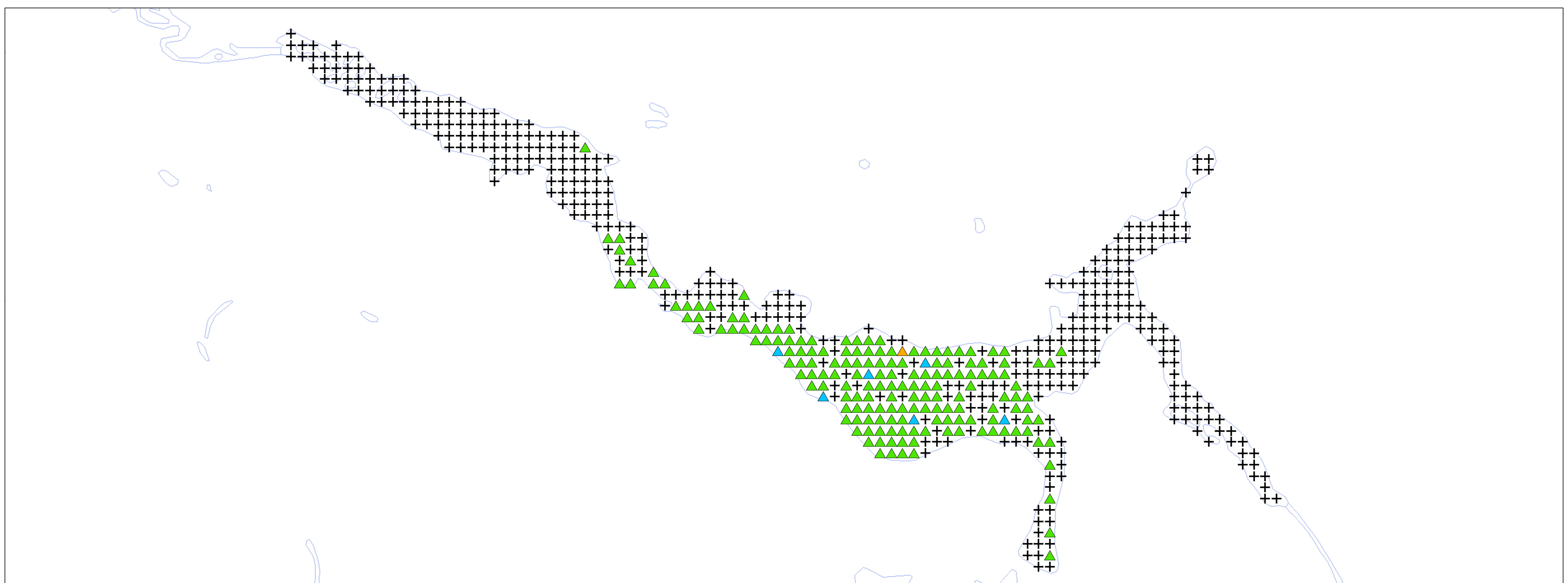
Wisconsin Department of Natural Resources, *Wisconsin Lakes,* Publication # PUB-FH-800, 2005

FIGURES

Coontail *(Ceratophyllum demersum)*





Muskgrass *(Chara sp.)*

Figure No.
1.1

Title

2014 PI Survey - Pigeon Lake Coontail and Chara

Client/Project

Pigeon Lake Protection & Rehabilitation District

Project Location
Waupaca Co., WI

193702900
Prepared by KAS on 2014-09-03
Technical Review by AB on 2014-09-03
Independent Review by JS on 2015-02-05

N

0 700 1,400 Feet

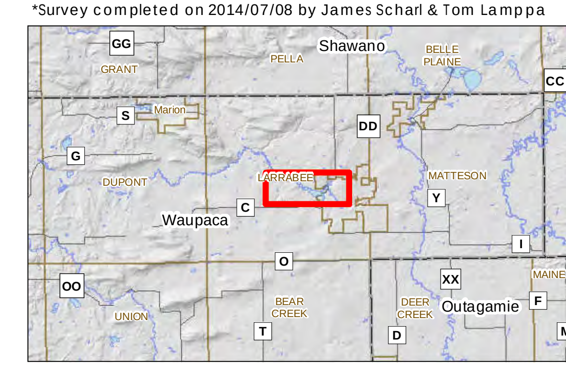
1:16,000 (At original document size of 11x17)

Legend

- + GPS Sample Points*
- ▲ Fullness Rating of 1
- ▲ Fullness Rating of 2
- ▲ Fullness Rating of 3

Fullness Rating	Coverage	Description
1		Only 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 on 2014/07/08 by James Scharl & Tom Lamppa

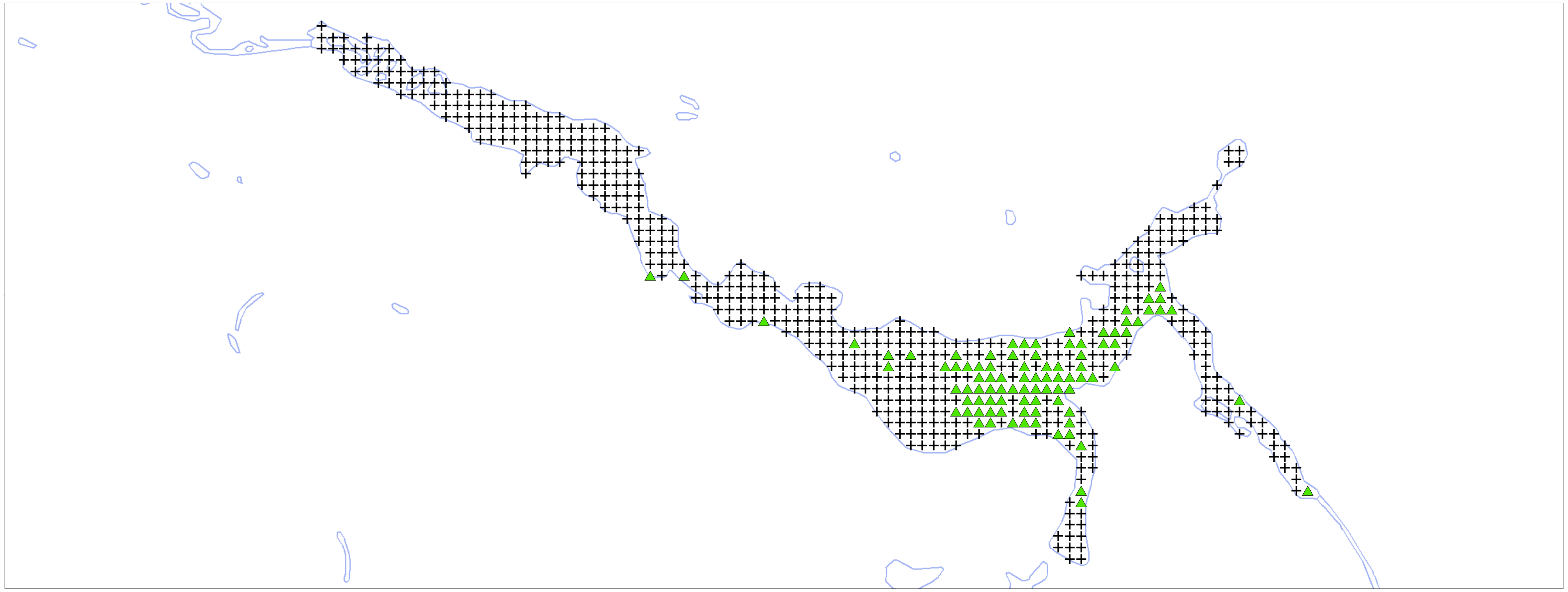


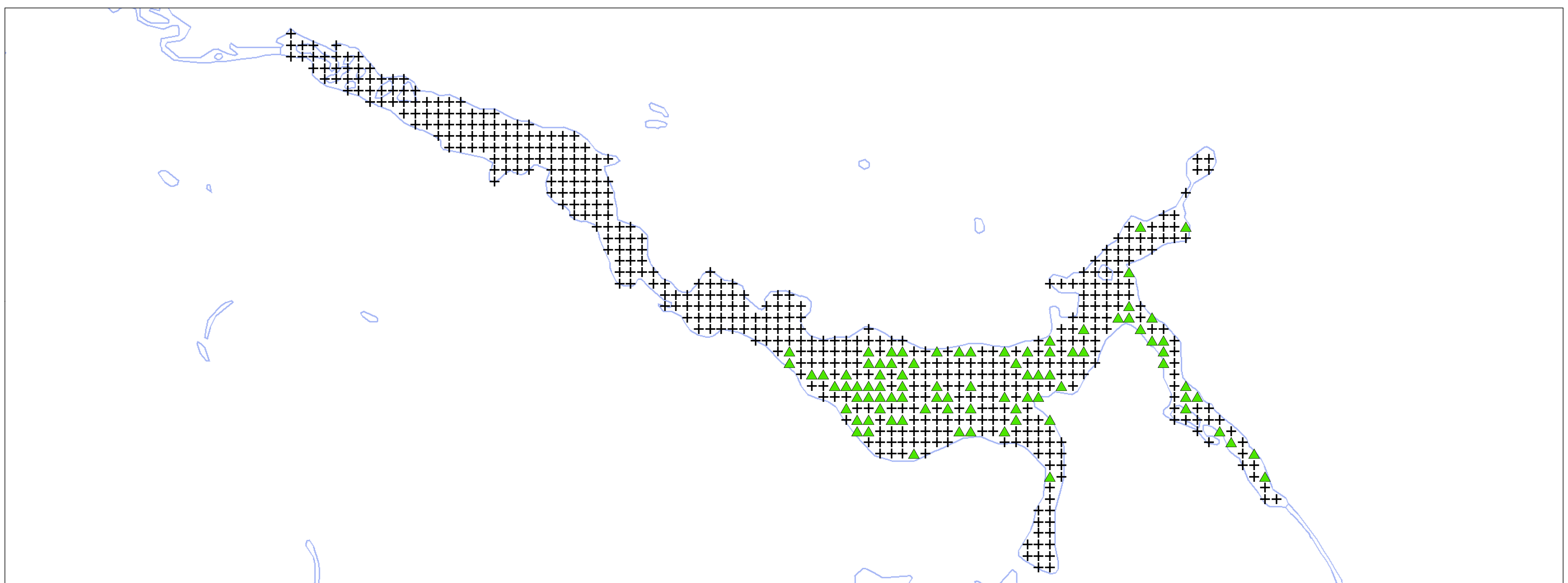
Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec and WDNR

Stantec

R:\gis\other_PCs\193702713_AIS_PigeonLake\07_gis\mxds\PigeonLake_AquaPlantSurvey_Halves_CoonChara.mxd Revised: 2015-02-06 By: ksoltau

Slender Naiad *(Najas flexilis)*





Wild Celery *(Vallisneria americana)*

Figure No.
1.2

Title

2014 PI Survey - Pigeon Lake Slender Naiad and Wild Celery

Client/Project
Pigeon Lake Protection & Rehabilitation District

Project Location
Waupaca Co., WI

193702900
Prepared by KAS on 2014-09-03
Technical Review by AB on 2014-09-03
Independent Review by JS on 2015-02-06

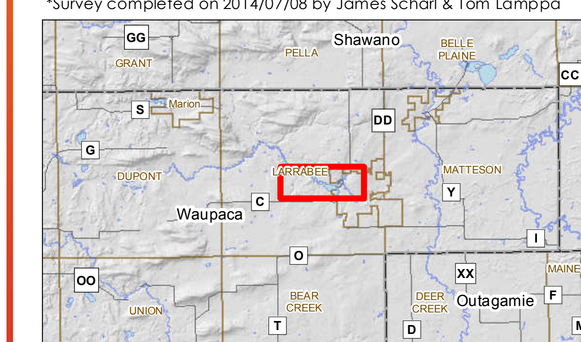
0 700 1,400 Feet
1:16,000 (At original document size of 11x17)

N

Legend
+ GPS Sample Points*
▲ Fullness Rating of 1

Fullness Rating	Coverage	Description
1		Only 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.

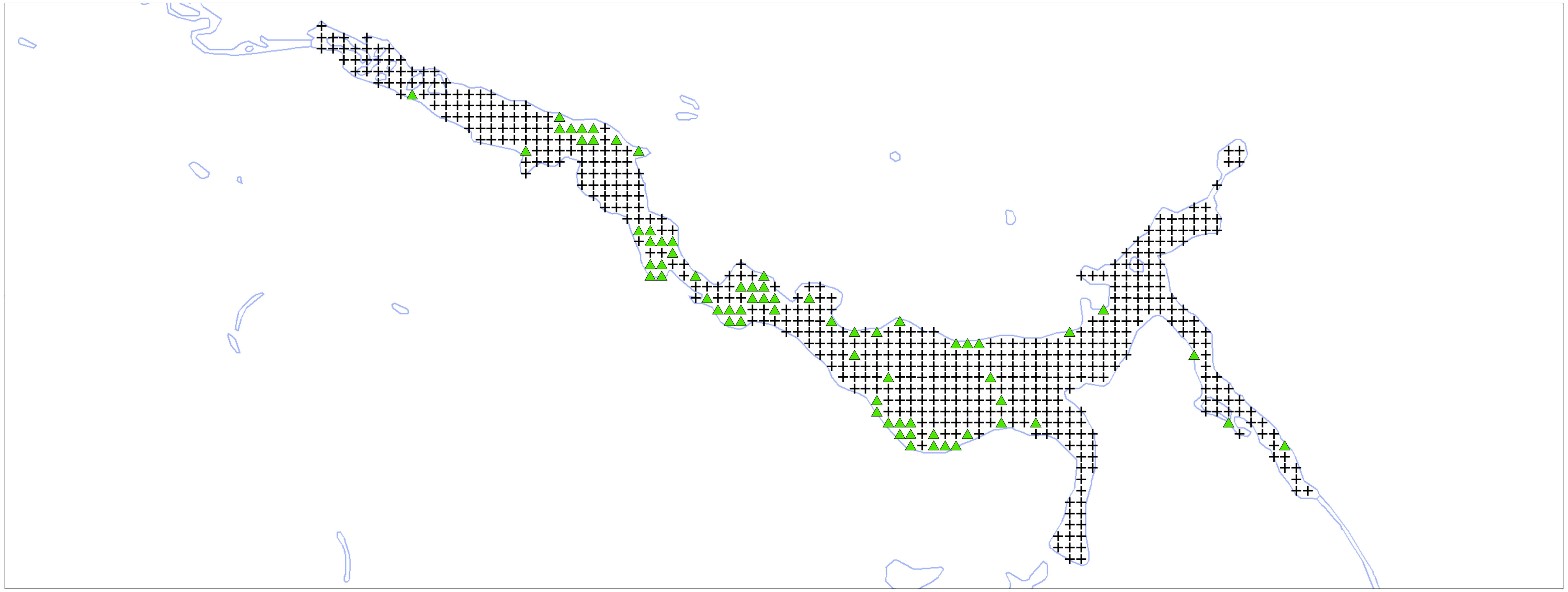
*Survey completed on 2014/07/08 by James Scharl & Tom Lamppa



Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec and WDNR

Stantec

Small Duckweed *(Lemna minor)*



Common Watermeal *(Wolffia sp.)*

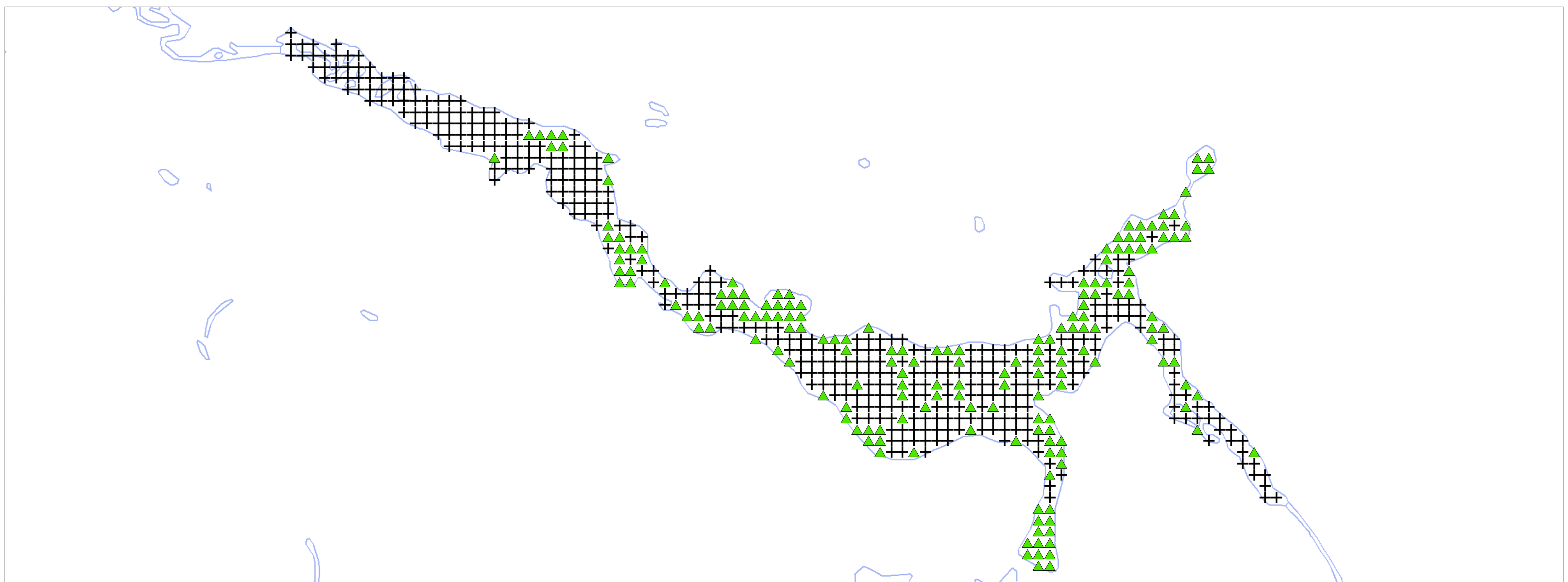


Figure No.
1.3

Title
2014 PI Survey - Pigeon Lake Small Duckweed and Common Watermeal

Client/Project
Pigeon Lake Protection & Rehabillitation District

Project Location
Waupaca Co., WI

193702900
Prepared by KAS on 2014-09-03
Technical Review by AB on 2014-09-03
Independent Review by JS on 2015-02-06

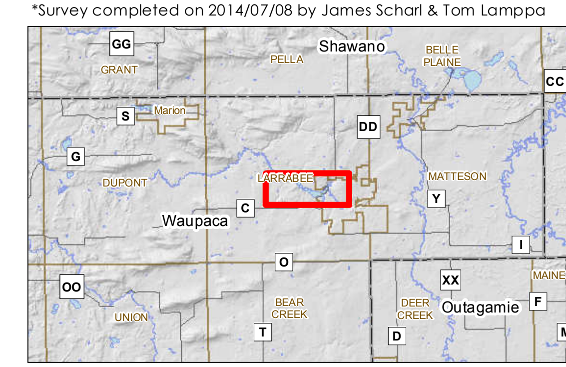
0 700 1,400 Feet
1:16,000 (At original document size of 11x17)

N

Legend
- + GPS Sample Points*
- ▲ Fullness Rating of 1

Fullness Rating	Coverage	Description
1		Only 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 on 2014/07/08 by James Scharl & Tom Lamppa



Notes
1. Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet
2. Data Sources Include: Stantec and WDNR

Stantec

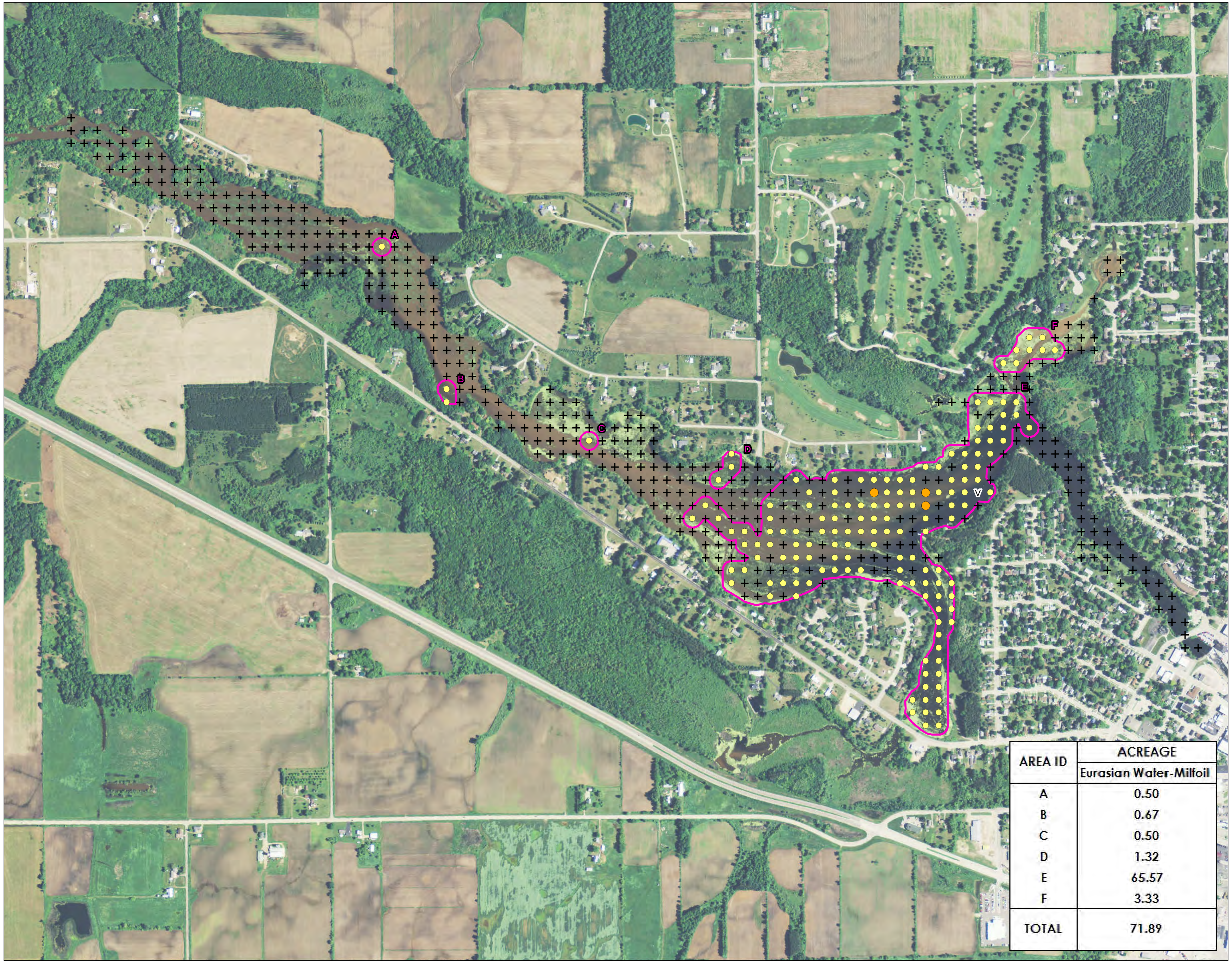
Figure No.
2

Title
2014 PI Survey - Pigeon Lake Eurasian Water-Milfoil

Client/Project
Pigeon Lake Protection & Rehabillitation District

Project Location
Waupaca Co., WI

193702713
Prepared by KS on 2014-09-11
Technical Review by AB on 2014-09-11
Independent Review by JS on 2015-02-05



AREA ID	ACREAGE
	Eurasian Water-Milfoil
A	0.50
B	0.67
C	0.50
D	1.32
E	65.57
F	3.33
TOTAL	71.89

0 450 900 Feet
1:11,000 (At original document size of 11x17)

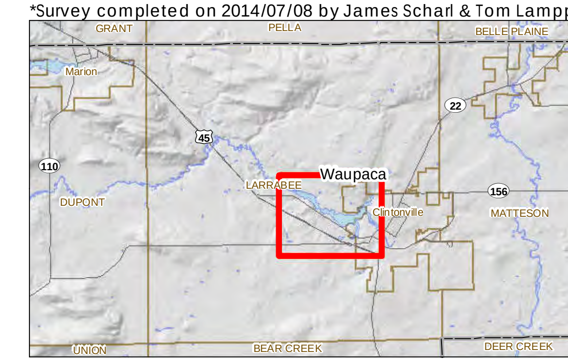
N

Legend

- \+ GPS Sample Points*
- Eurasian Water-Milfoil *(Rake Fullness of 1 Only)*
- Eurasian Water-Milfoil *(Rake head is about half full)*
- V Eurasian Water-Milfoil *(Visual)*
- Invasive Aquatic Plant Area

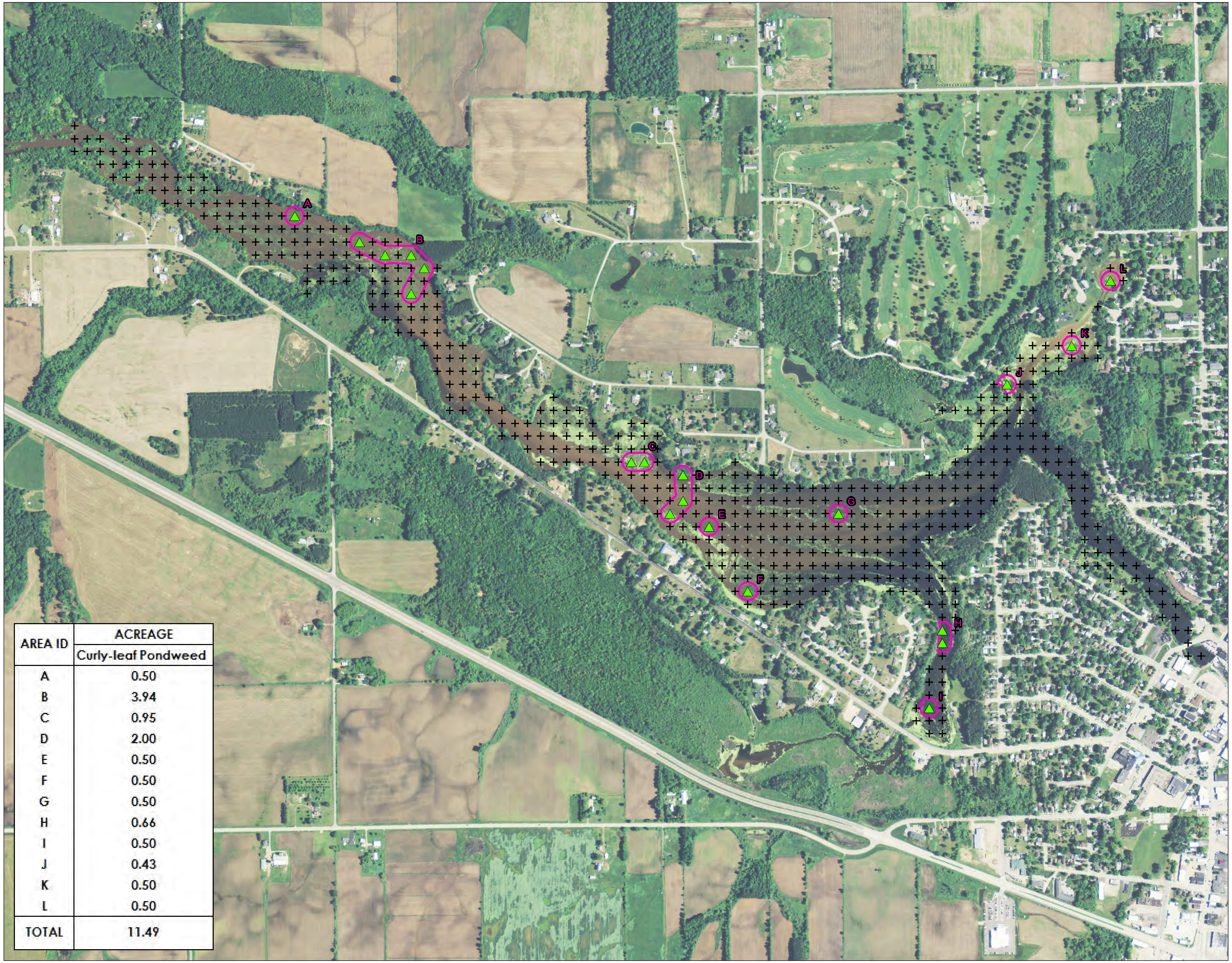
Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered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

*Survey completed on 2014/07/08 by James Scharl & Tom Lamppa



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

Stantec



AREA ID	ACREAGE
	Curly-leaf Pondweed
A	0.50
B	3.94
C	0.95
D	2.00
E	0.50
F	0.50
G	0.50
H	0.66
I	0.50
J	0.43
K	0.50
L	0.50
TOTAL	11.49

Figure No.
3

Title
2014 PI Survey - Pigeon Lake Curly-leaf Pondweed

Client/Project
Pigeon Lake Protection & Rehabilitation District

Project Location
Waupaca Co., WI

193702713
Prepared by KS on 2014-09-11
Technical Review by AB on 2014-09-11
Independent Review by JS on 2015-02-05

0 450 900 Feet
1:11,000 (At original document size of 11x17)

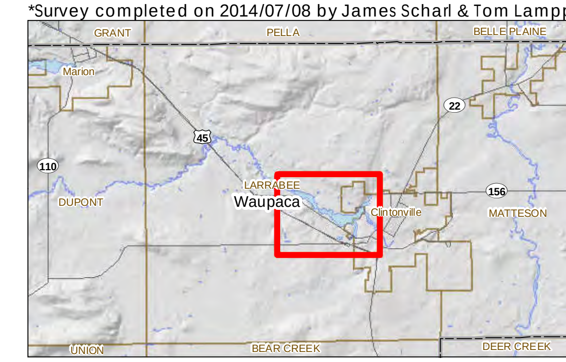
N

Legend

- + GPS Sample Points*
- Curly-leaf Pondweed *(Rake Fullness of 1 Only)*
- Invasive Aquatic Plant Area

Fullness Rating	Coverage	Description
1		Only 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 on 2014/07/08 by James Scharl & Tom Lamppa



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

Stantec

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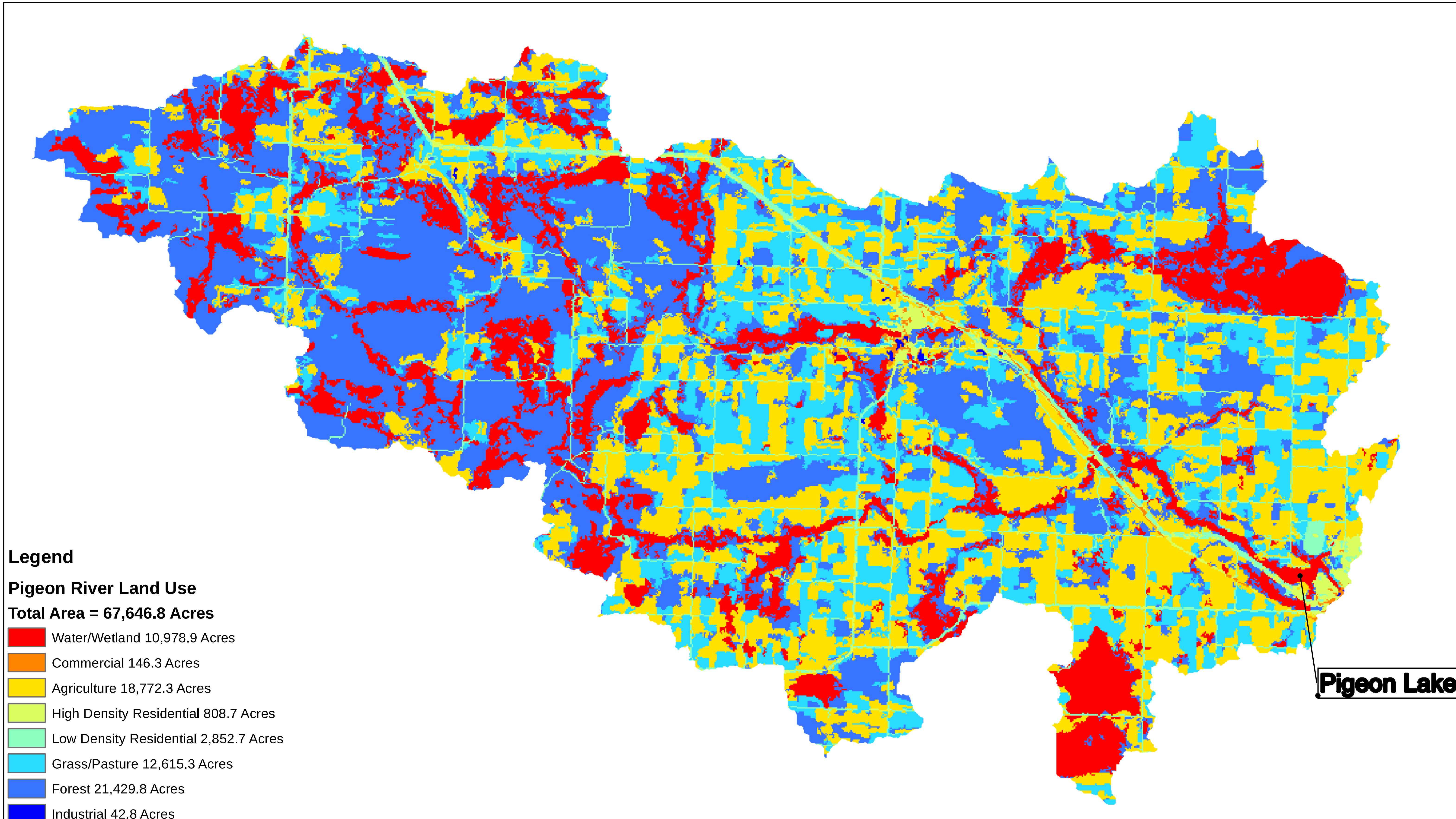


PIGEON RIVER WATERSHED LAND USE MAP
WAUPACA COUNTY, WI

DATE: 2014-03-13
Project Path: V:\1937\active\193702713\07_gis\mxds\Pigeon River.mxd

N

Stantec

Design With Community In Mind

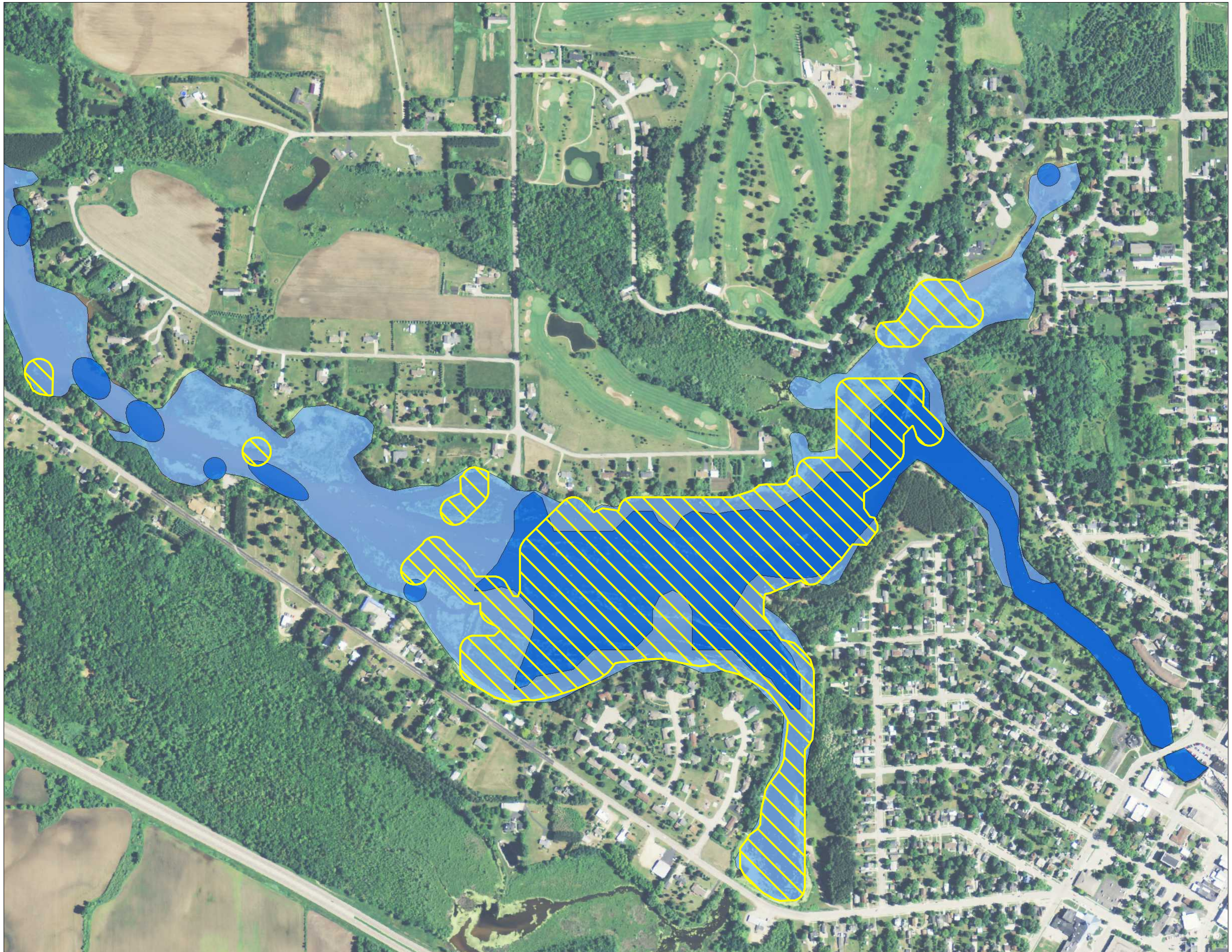


Figure No.
5

Title
Pigeon Lake
2015 Drawdown Plan

Client/Project
Pigeon Lake Protection &
Rehabillitation District

Project Location
Waupaca Co., WI

193702713
Prepared by KAS on 2015-03-13
Technical Review by BT on 2015-03-13
Independent Review by JS on 2015-03-13

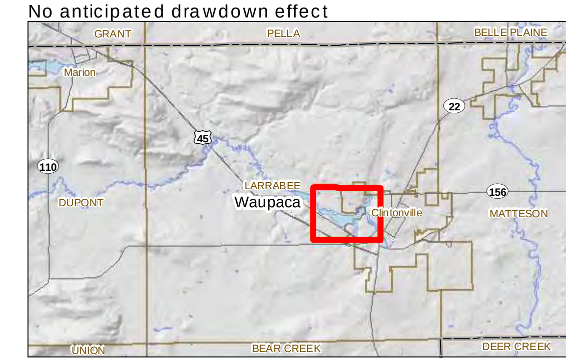
0 300 600 Feet
1:7,200 (At original document size of 11x17)

N

Legend
- Depth Less Than 4'
- Depth Greater Than 4'
- Eurasian Water-Milfoil

Drawdown Impact	
Depth Greater Than 4'	53.14 ac
Depth Less Than 4'	120.09 ac
AIS Impact	
Eurasian Water-Milfoil	35.54 ac

*Portions upstream of map extents are river channel only; No anticipated drawdown effect



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

Stantec

R:\gis\other PCs\193702713 AIS PigeonLake\07 gis\mxds\PigeonLake AquaPlantSurvey drawdown.mxd Revised: 2015-03-13 By: ksoltau

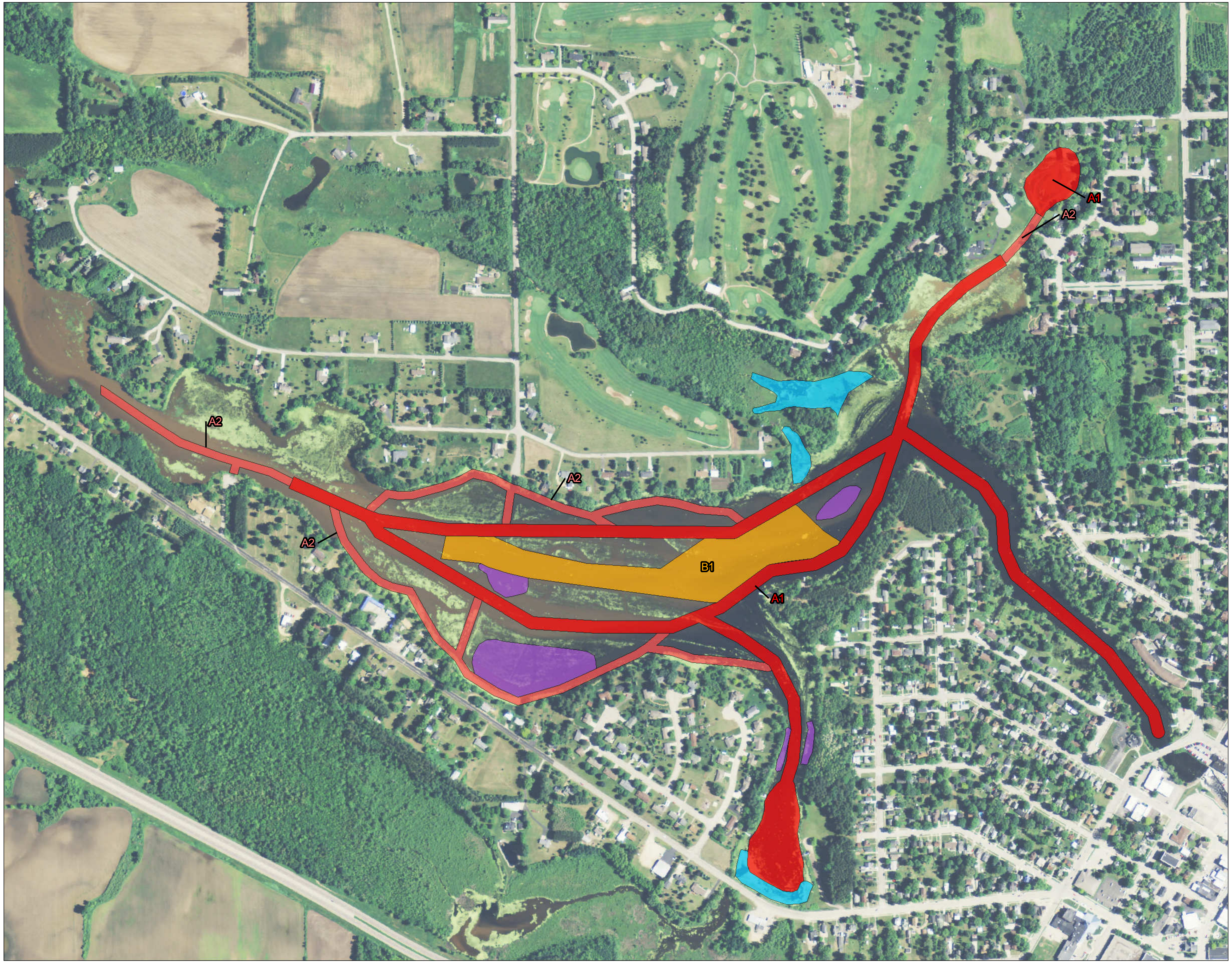


Figure No.
6

Title
Pigeon Lake 2015 Harvest Plan

Client/Project
Pigeon Lake Protection & Rehabilitation District

Project Location
Waupaca Co., WI

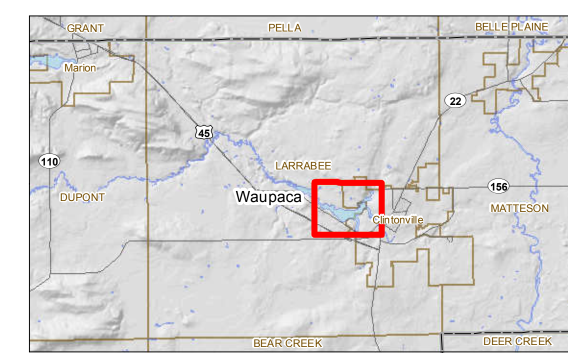
193702713
Prepared by KAS on 2015-03-10
Technical Review by MP on 2015-03-10
Independent Review by MK on 2015-03-11

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

N

Area	Instructions
NAVIGATIONAL ACCESS AREAS - 36.52 ac	
A_1	Cut a lane 75' wide - Must leave 12" of plant growth on the bottom
A_2	Cut a lane 50' wide - Must leave 12" of plant growth on the bottom
AIS MANAGEMENT AREAS - 11.32 ac	
B_1	Top cut 2' to control surface matting of AIS and promote native species growth - Prior to May 31Only

DO NOT HARVEST	
	Floating Leaf Vegetation
	High Value Vegetation



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

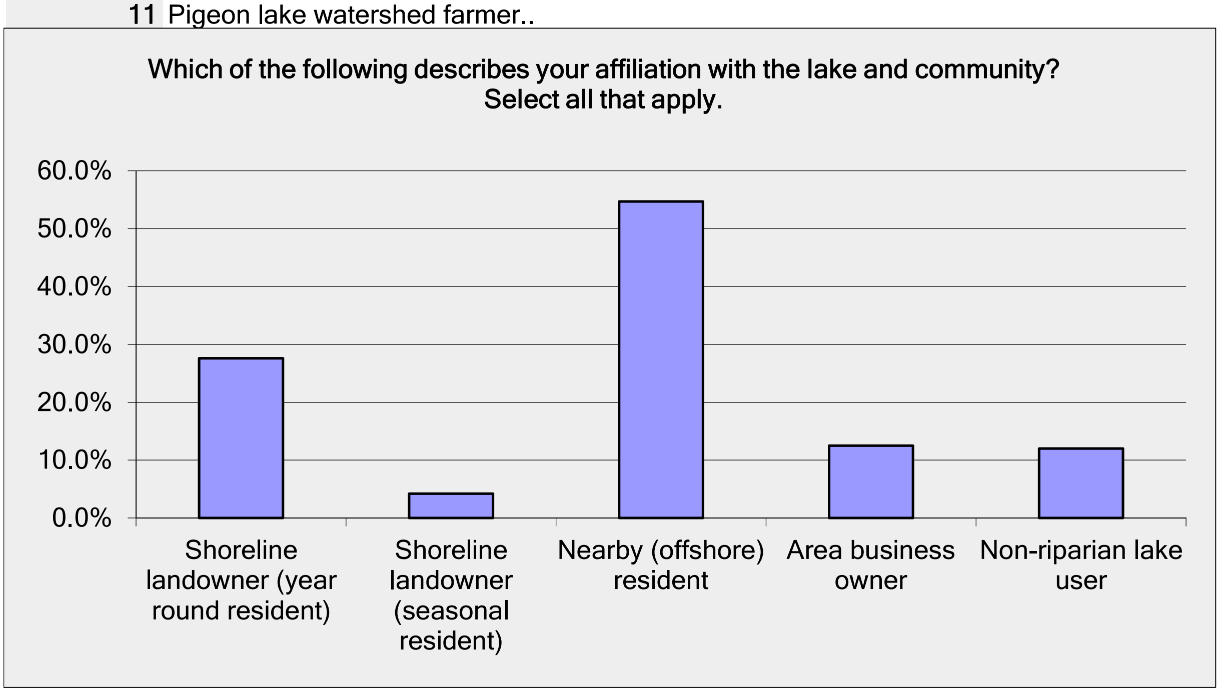
Stantec

APPENDIX A

Pigeon Lake Comprehensive Lake Management Plan Update

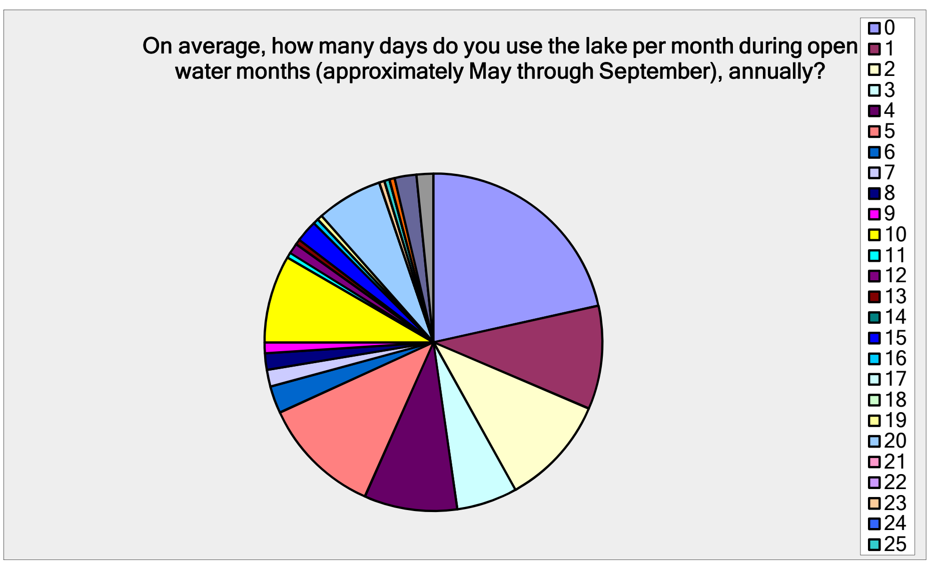
Which of the following describes your affiliation with the lake and community? Select all that apply.		
Answer Options	Response Percent	Response Count
Shoreline landowner (year round resident)	27.6%	53
Shoreline landowner (seasonal resident)	4.2%	8
Nearby (offshore) resident	54.7%	105
Area business owner	12.5%	24
Non-riparian lake user	12.0%	23
Other (please specify)		11
	answered question	192
	skipped question	0

Number	Other (please specify)
1	Area business executive
2	land-owner in drainage area
3	Live on Pigeon River upstream from lake
4	shoreline landowner - vacant lot
5	Own the property but are not there often
6	South branch of the pigeon
7	Surrounding Area Landowner
8	pay the tax for this lake
9	Landowner in the watershed area
10	Pigeon river runs past my property
11	Pigeon lake watershed farmer..



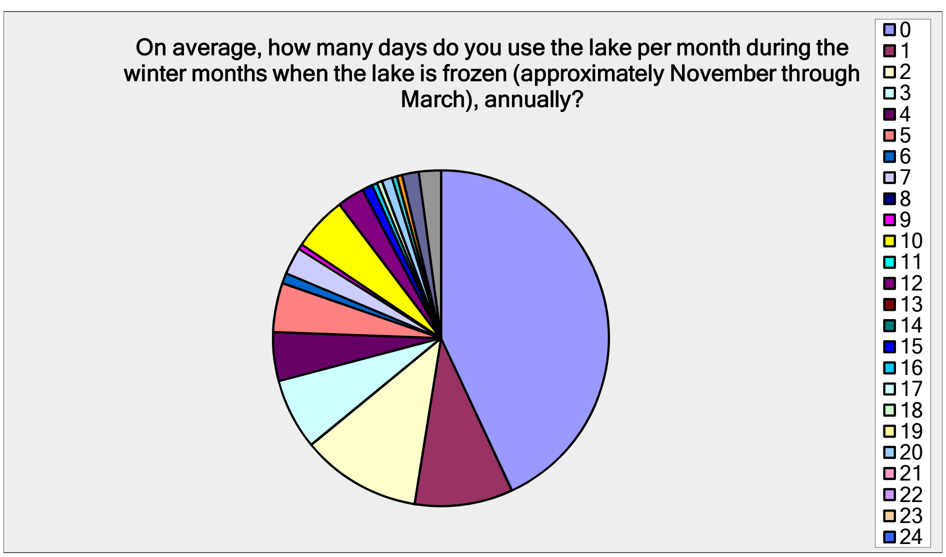
Question 2

On average, how many days do you use the lake per month during open water months (approximately May through September), annually?		
Answer Options	Response Percent	Response Count
0	21.5%	41
1	9.9%	19
2	10.5%	20
3	5.8%	11
4	8.9%	17
5	11.5%	22
6	2.6%	5
7	1.6%	3
8	1.6%	3
9	1.0%	2
10	8.4%	16
11	0.5%	1
12	1.0%	2
13	0.5%	1
14	0.0%	0
15	2.1%	4
16	0.5%	1
17	0.0%	0
18	0.0%	0
19	0.5%	1
20	6.3%	12
21	0.0%	0
22	0.0%	0
23	0.5%	1
24	0.0%	0
25	0.5%	1
26	0.0%	0
27	0.0%	0
28	0.0%	0
29	0.5%	1
30	2.1%	4
31	1.6%	3
	answered question	191
	skipped question	1



Question 3

On average, how many days do you use the lake per month during the winter months when the lake is frozen (approximately November through March), annually?		
Answer Options	Response Percent	Response Count
0	42.9%	82
1	9.4%	18
2	11.5%	22
3	6.8%	13
4	4.7%	9
5	4.7%	9
6	1.0%	2
7	2.6%	5
8	0.0%	0
9	0.5%	1
10	5.2%	10
11	0.0%	0
12	2.6%	5
13	0.0%	0
14	0.0%	0
15	1.0%	2
16	0.5%	1
17	0.0%	0
18	0.5%	1
19	0.0%	0
20	1.0%	2
21	0.0%	0
22	0.0%	0
23	0.0%	0
24	0.0%	0
25	0.5%	1
26	0.0%	0
27	0.0%	0
28	0.5%	1
29	0.0%	0
30	1.6%	3
31	2.1%	4
	answered question	191
	skipped question	1

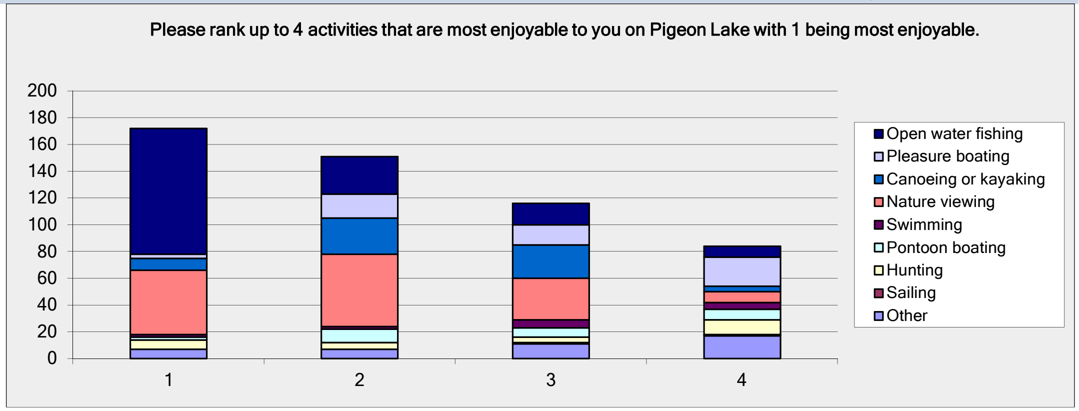


Question 4

Please rank up to 4 activities that are most enjoyable to you on Pigeon Lake with 1 being most enjoyable.

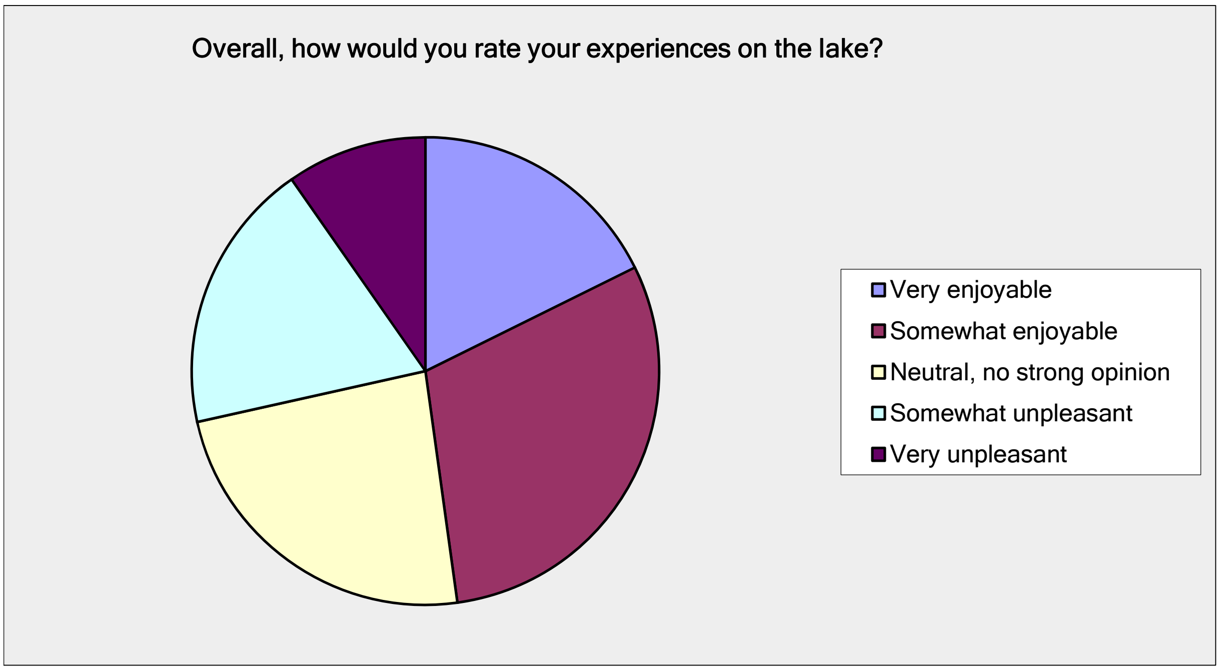
Answer Options	Open water fishing	Pleasure boating	Canoeing or kayaking	Nature viewing	Swimming	Pontoon boating	Hunting	Sailing	Other	Response Count
1	94	3	9	48	2	2	7	0	7	172
2	28	18	27	54	2	10	5	0	7	151
3	16	15	25	31	6	7	4	1	11	116
4	8	22	4	8	5	8	11	1	17	84
Average Ranking	**1.58**	2.97	**2.37**	**1.99**	2.93	2.78	2.70	3.50	2.90	
									Answered Question	175

Number	Other (please specify)
1	ice fishing
2	Ice fishing
3	walking the trail
4	ice walking
5	ice fishing
6	Ice fishing
7	walking the nature trail along the lake
8	we are on the river and our activities also involvbe the lake
9	Ice Skating or Snow shoe hiking
10	Encouraging ducks and geese during migration
11	walking/hiking adjacent trails
12	none
13	you cant enjoy any of these activities on the pond...to weedy, shallow etc.
14	snowmobiling
15	Snowmobiling
16	Trapping
17	letting dog run
18	Sorry, I grew up on Lake Michigan Pigeon Lake is really a pond and not large enough for recreation.
19	ice fishing
20	I do not use the pond at all
21	none
22	Do not use the lake
23	Ice fishing
24	Strictly business owner, do not use the lake
25	no activities
26	ICE FISHING
27	Ice fishing
28	Ice Fishing
29	walking
30	Showshoeing
31	ice fishing/ walking on ice during winter
32	ice fishing
33	Jet ski
34	ice fishing



Question 5

Overall, how would you rate your experiences on the lake?		
Answer Options	Response Percent	Response Count
Very enjoyable	17.7%	33
Somewhat enjoyable	30.1%	56
Neutral, no strong opinion	23.7%	44
Somewhat unpleasant	18.8%	35
Very unpleasant	9.7%	18
	answered question	186
	skipped question	6

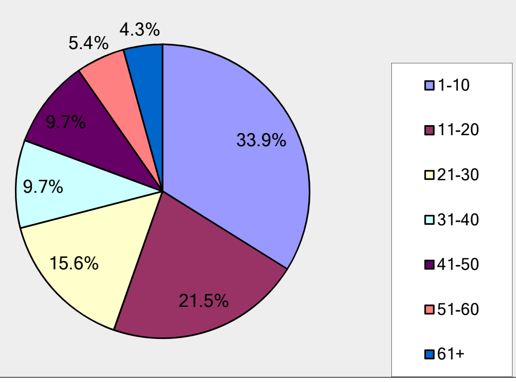


Question 6

How many years have you personally been using the lake for recreational purposes? (if less than one, please select "1")		
Answer Options	Response Percent	Response Count
1	16.1%	30
2	1.6%	3
3	2.7%	5
4	3.2%	6
5	1.6%	3
6	1.1%	2
7	1.1%	2
8	0.5%	1
9	0.5%	1
10	5.4%	10
11	0.5%	1
12	2.7%	5
13	1.6%	3
14	2.7%	5
15	5.4%	10
16	1.1%	2
17	1.1%	2
18	0.5%	1
19	0.5%	1
20	5.4%	10
21	0.0%	0
22	1.1%	2
23	0.0%	0
24	0.5%	1
25	5.9%	11
26	0.5%	1
27	0.0%	0
28	1.1%	2
29	1.1%	2
30	5.4%	10
31	1.1%	2
32	0.5%	1
33	0.5%	1
34	0.0%	0
35	2.7%	5
36	0.5%	1
37	0.0%	0
38	1.1%	2
39	0.5%	1
40	2.7%	5
41	0.0%	0
42	1.1%	2
43	1.1%	2
44	0.0%	0
45	1.6%	3

46	1.1%	2
47	0.5%	1
48	0.0%	0
49	0.0%	0
50	4.3%	8
51	0.5%	1
52	1.1%	2
53	0.0%	0
54	0.0%	0
55	2.2%	4
56	0.0%	0
57	0.0%	0
58	0.5%	1
59	0.0%	0
60	1.1%	2
61	0.0%	0
62	0.0%	0
63	0.0%	0
64	0.0%	0
65	1.6%	3
66	0.0%	0
67	0.5%	1
68	0.0%	0
69	0.0%	0
70	1.6%	3
71	0.0%	0
72	0.0%	0
73	0.0%	0
74	0.0%	0
75	0.5%	1
76	0.0%	0
77	0.0%	0
78	0.0%	0
79	0.0%	0
80	0.0%	0
81	0.0%	0
82	0.0%	0
83	0.0%	0
84	0.0%	0
85	0.0%	0
86	0.0%	0
87	0.0%	0
88	0.0%	0
89	0.0%	0
90	0.0%	0
91	0.0%	0
92	0.0%	0
93	0.0%	0
94	0.0%	0
95	0.0%	0
96	0.0%	0
97	0.0%	0
98	0.0%	0
99	0.0%	0
100	0.0%	0
	answered question	186
	skipped question	6

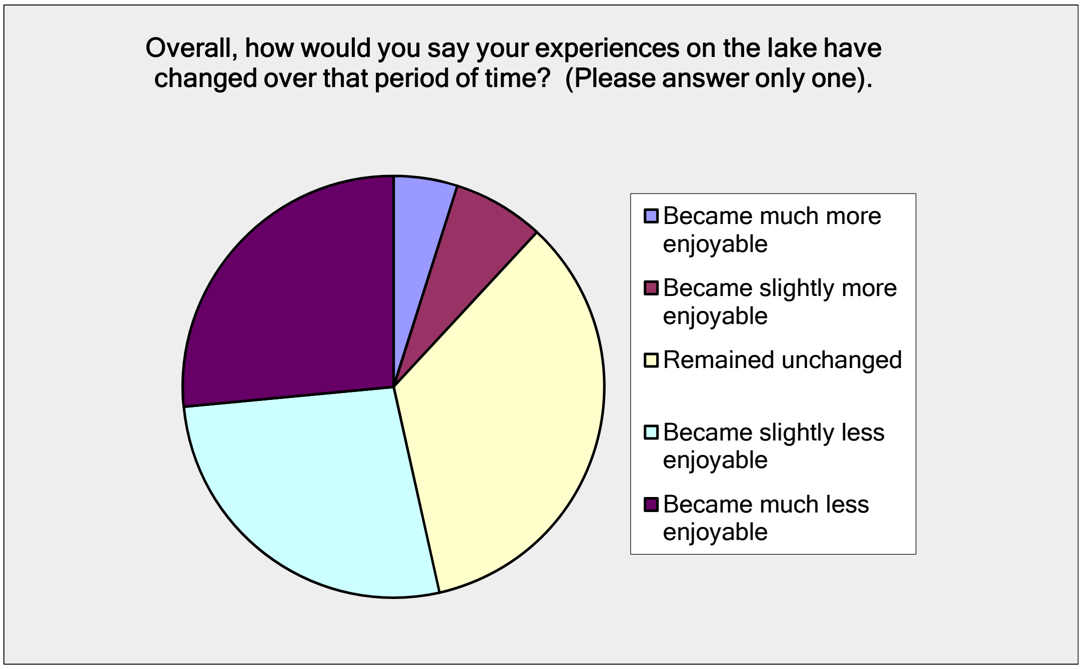
How many years have you personally been using the lake for recreational purposes? (if less than one, please select "1")



Question 7

Overall, how would you say your experiences on the lake have changed over that period of time? (Please answer only one).

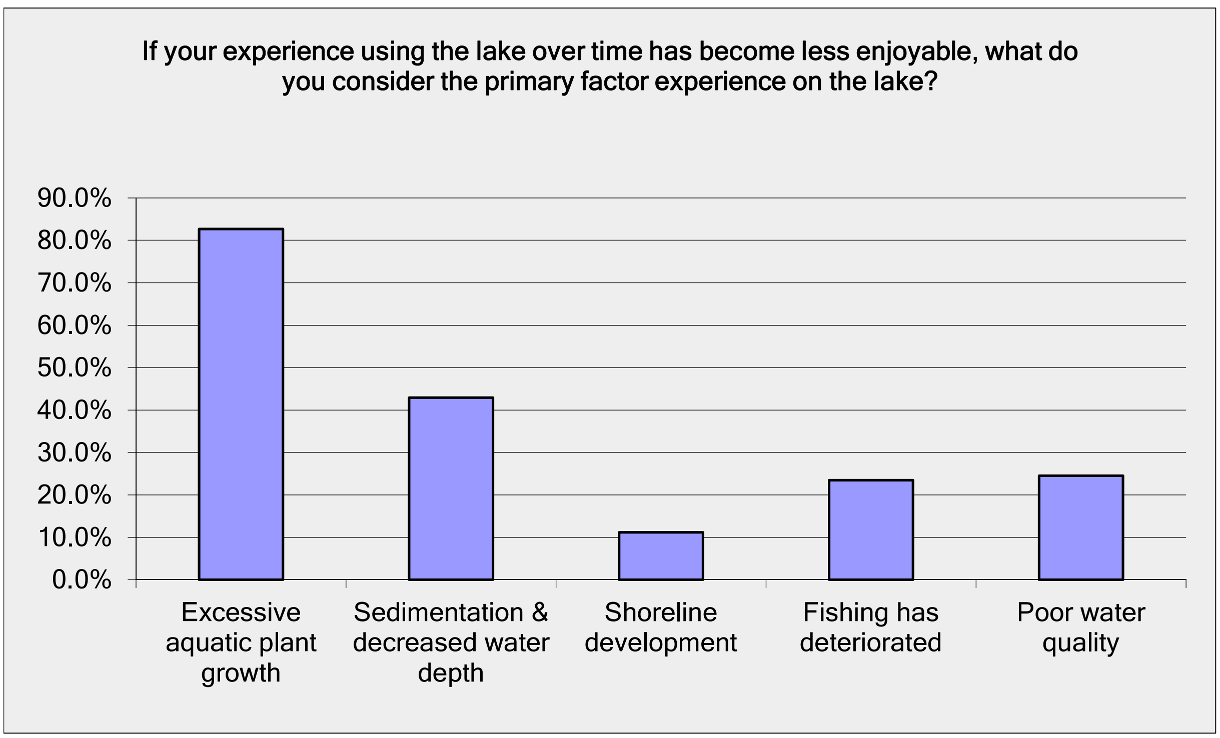
Answer Options	Response Percent	Response Count
Became much more enjoyable	4.9%	9
Became slightly more enjoyable	7.0%	13
Remained unchanged	34.6%	64
Became slightly less enjoyable	27.0%	50
Became much less enjoyable	26.5%	49
	answered question	185
	skipped question	7



Question 8

If your experience using the lake over time has become less enjoyable, what do you consider the primary factor experience on the lake?		
Answer Options	Response Percent	Response Count
Excessive aquatic plant growth	82.7%	81
Sedimentation & decreased water depth	42.9%	42
Shoreline development	11.2%	11
Fishing has deteriorated	23.5%	23
Poor water quality	24.5%	24
Other (please specify)		8
	answered question	98
	skipped question	94

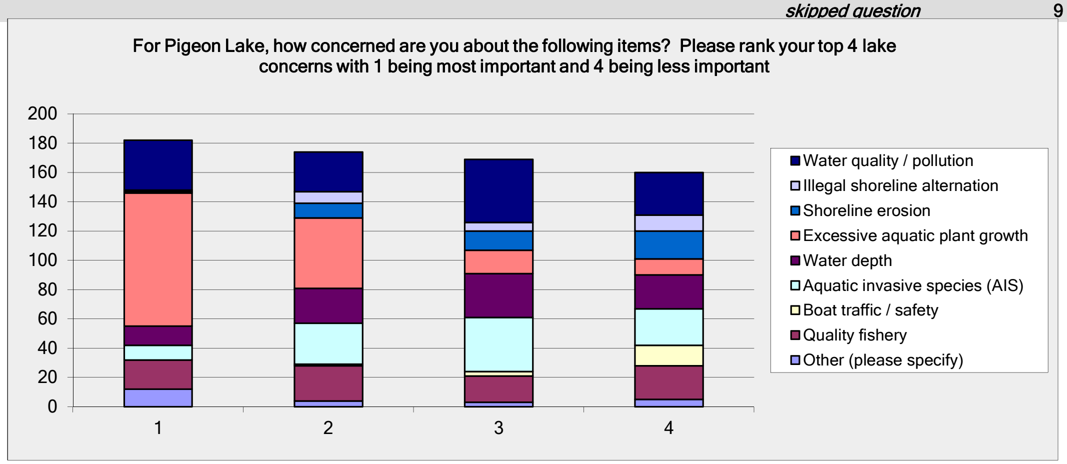
Number	Other (please specify)
1	weeds
2	ice vehicle traffic
3	Loss of clean firm bottom for spawning beds.
4	less water to fish because of the plants in the lake.!!!!
5	all of the above
6	putting rip rap along the point shore has ruined the fishing and trapping there
7	More fishing dock's also for the disabled and elderly (Maybe like gaurd rails)
8	The green slime that floats on the top of the lake....I believe it may be duck weed????



Question 9

For Pigeon Lake, how concerned are you about the following items? Please rank your top 4 lake concerns with 1 being most important and 4 being less important										
Answer Options	Water quality / pollution	Illegal shoreline alternation	Shoreline erosion	Excessive aquatic plant growth	Water depth	Aquatic invasive species (AIS)	Boat traffic / safety	Quality fishery	Other (please specify)	Response Count
1	34	1	1	91	13	10	0	20	12	182
2	27	8	10	48	24	28	1	24	4	174
3	43	6	13	16	30	37	3	18	3	169
4	29	11	19	11	23	25	14	23	5	160
AVERAGE RANK	1.85	2.46	2.07	1.59	2.00	2.06	2.22	1.78	2.42	
									answered question	183
									skipped question	9

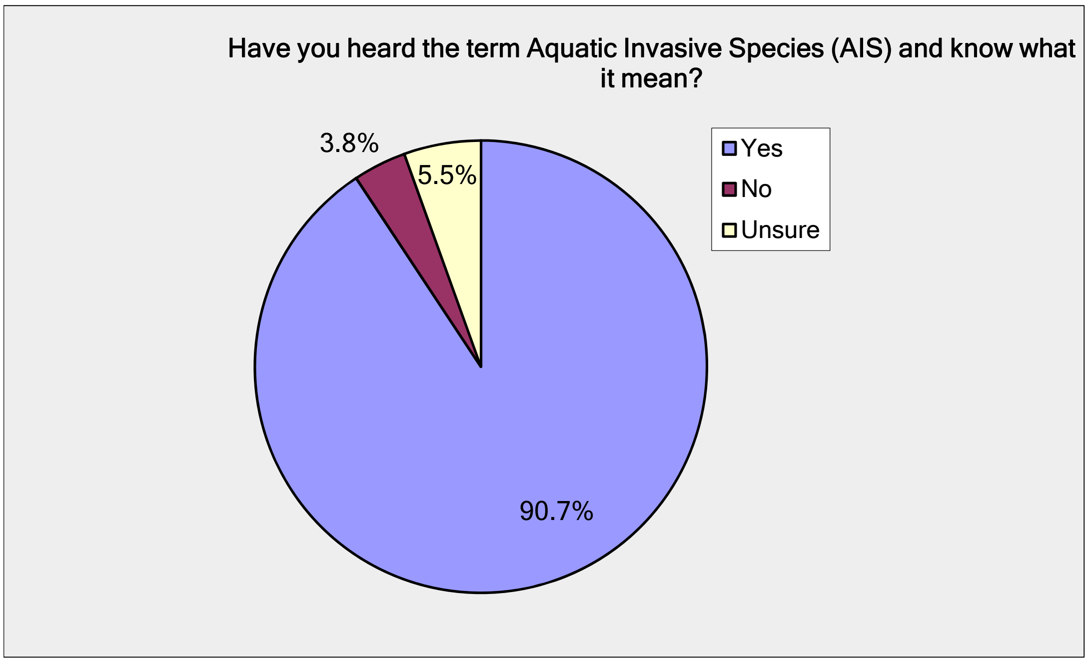
Number	Other (please specify)
1	sedimentation
2	sedimentation
3	sedimentation
4	sedimentation
5	shorelinwe developement
6	sedimentation
7	sedimentsation
8	SEDIMENTATION
9	SEDIMENTATION
10	SEDIMENTATION
11	sedimentation
12	sedimentation
13	sedimentstion
14	high speed traffic boat-water--race cars-ice
15	Hunting ducks and geese. Very dangerous. Bullet holes through my garage.
16	Upstream erosian filling the lake
17	time lost studying and NOT taking action!!
18	the cutter isnt out early enough
19	I dont think it helps, that people living on the lake using fertilizer on their yards(run off into lake)
20	fishing
21	The shoreline should have been left alone, natural and undisturbed. PLD ruined the shoreline.
22	waste of money on a pond that does not need to exist
23	Draw down lake to help reduce sediment .increase depth of lake add rip rap to shore line.
24	Sediment
25	Open hunting area's
26	Loon shit (muck)



Question 10

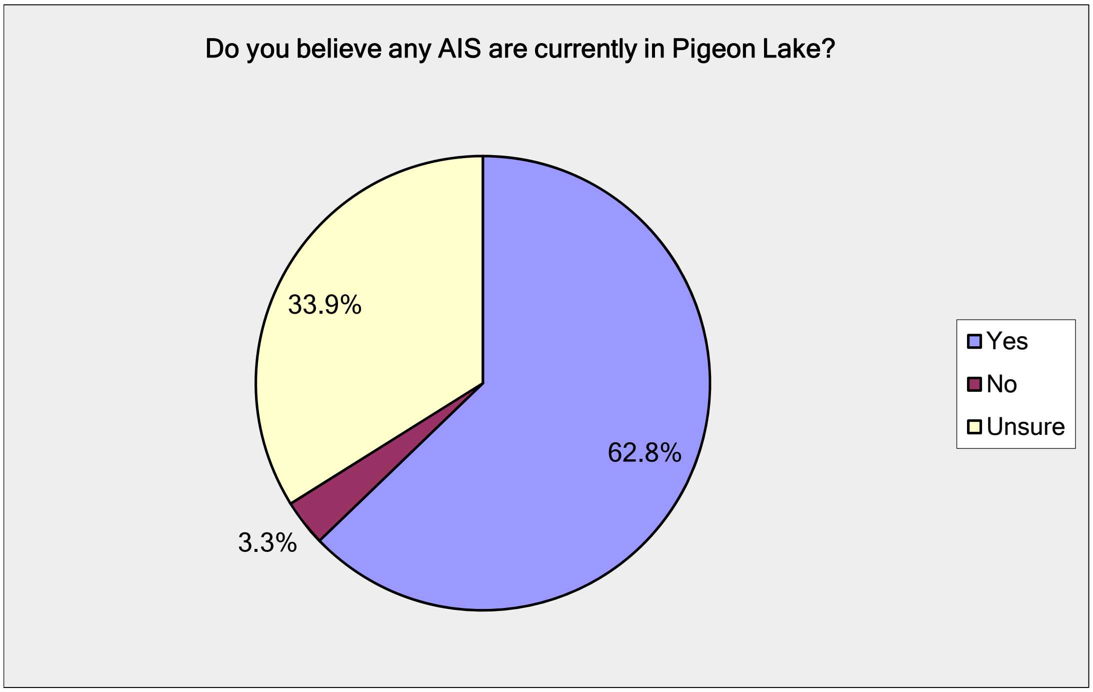
Aquatic Invasive Species (AIS) are non-native plants or animals that can out-compete their native counterparts and potentially cause a myriad of problems within the lake and/or ecosystem. Prior to this survey, have you heard the term Aquatic Invasive Species and did you know what it meant?

Answer Options	Response Percent	Response Count
Yes	90.7%	166
No	3.8%	7
Unsure	5.5%	10
	answered question	183
	skipped question	9



Question 11

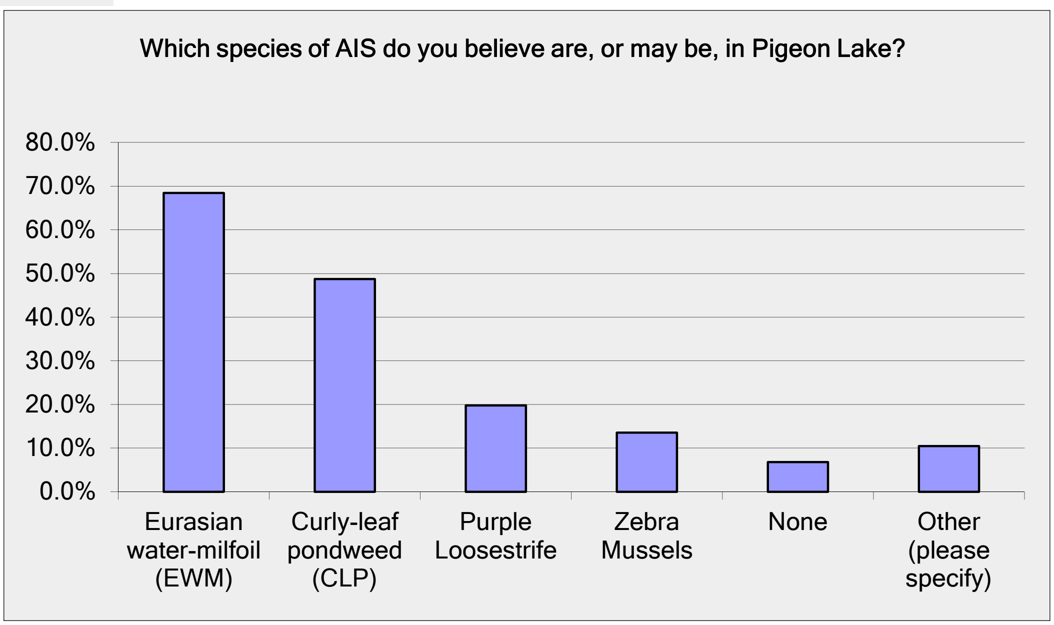
Do you believe any AIS are currently in Pigeon Lake?		
Answer Options	Response Percent	Response Count
Yes	62.8%	115
No	3.3%	6
Unsure	33.9%	62
	answered question	183
	skipped question	9



Question 12

Which species of AIS do you believe are, or may be, in Pigeon Lake?		
Answer Options	Response Percent	Response Count
Eurasian water-milfoil (EWM)	68.5%	111
Curly-leaf pondweed (CLP)	48.8%	79
Purple Loosestrife	19.8%	32
Zebra Mussels	13.6%	22
None	6.8%	11
Other (please specify)	10.5%	17
	answered question	162
	skipped question	30

Number	Other (please specify)
1	do't know
2	unsure
3	I must be one of the few residents that did not graduate with a degree in Marine Science or Biology. I would just be guessing....
4	blue-green algae
5	Don't know
6	I have no knowledge of any, but believe any are possible with some more likely than others.
7	Don't know
8	I don't know.
9	I honestly don't know
10	don't know
11	Unsure
12	unsure
13	not sure what is in the pond
14	Not sure
15	No clue
16	unknown
17	do not know

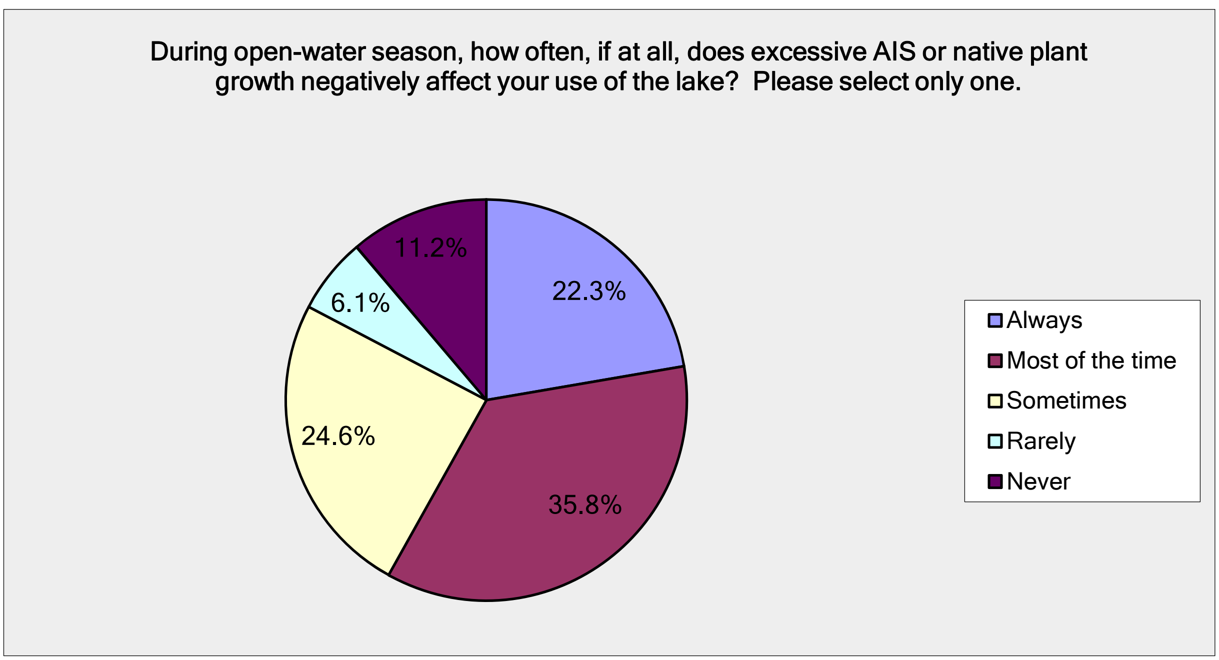


Question 13

During open-water season, how often, if at all, does excessive AIS or native plant growth negatively affect your use of the lake? Please select only one.

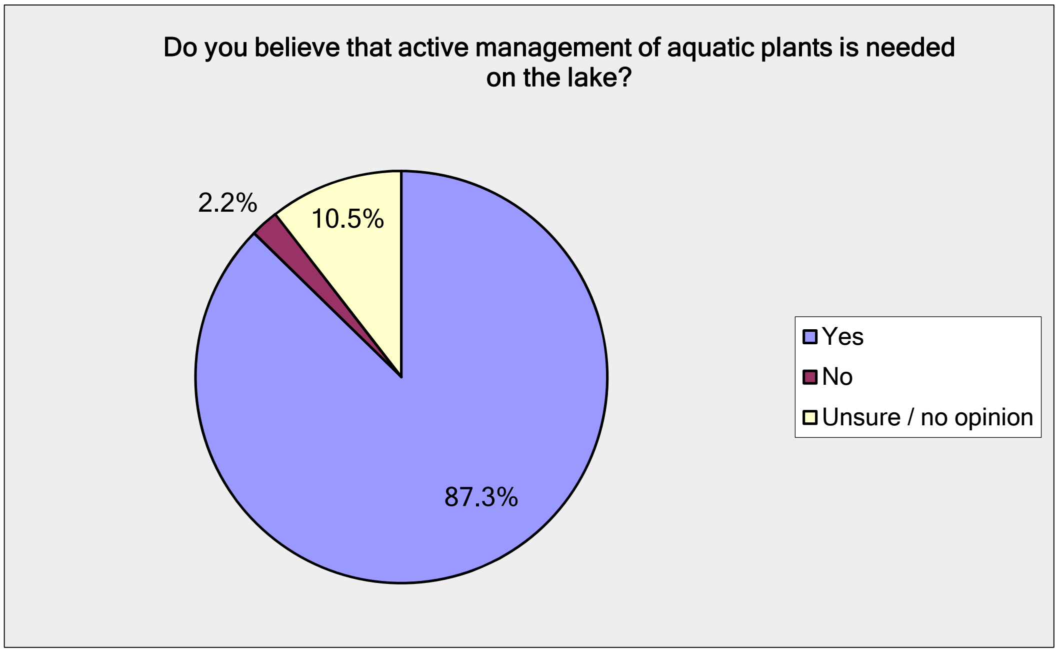
Answer Options	Response Percent	Response Count
Always	22.3%	40
Most of the time	35.8%	64
Sometimes	24.6%	44
Rarely	6.1%	11
Never	11.2%	20
Comments		9
	answered question	179
	skipped question	13

Number	Comments
1	I have used the lake for 38 years for nature viewing and boating and have lived on the Pigeon River for 30 years. The plant growth is worse now than 30 years ago. It used to "green up" so we could not use our boat the first part of June. Now it is too weedy already the first part of May. It seems to be getting worse each year. We have to go to another body of water if we want to use our boat.
2	green algae/weeds on top of water makes fishing difficult from docks
3	WEfish the river and open water
4	Hard to fish with hook and line
5	The pond needs to be drained, dredged down 8-12 feet and refilled and re-stocked.
6	I don't use Pigeon Lake, a few times a year I will walk by Pigeon lake.
7	I do not use the pond
8	Boat landing full of floating weeds.
9	quality of fishing



Question 14

Do you believe that active management of aquatic plants is needed on the lake?		
Answer Options	Response Percent	Response Count
Yes	87.3%	158
No	2.2%	4
Unsure / no opinion	10.5%	19
	answered question	181
	skipped question	11

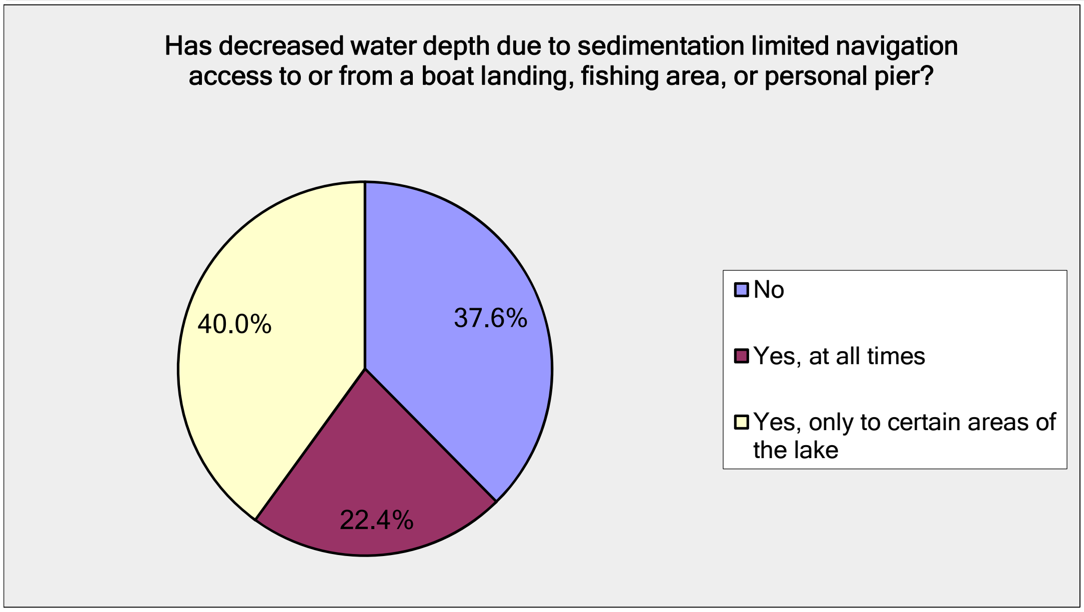


Question 15

Which of the following aquatic plant management options would you support? Please rank your top 4 preferences with 1 being the most preferred and 4 being the least preferred option.										
Answer Options	Manual removal or hand pulling	Mechanical harvesting or cutting	Herbicide control	Hydraulic or mechanical dredging	Over winter water level drawdown	Continue to monitor the size of infestation through annual AIS surveys	No action; wait and see what happens over the long term	Not sure; would rely on a professional consulting firm	Not sure; would rely on the WDNR guidance	Response Count
1	6	60	22	41	8	4	2	14	11	168
2	21	34	29	27	17	8	3	12	13	164
3	17	22	23	29	11	11	5	15	13	146
4	10	7	13	14	16	7	3	17	20	107
AVERAGE RANK	2.57	1.80	2.31	2.14	2.67	2.70	2.69	2.60	2.74	
										Question Totals
									answered question	169
									skipped question	23

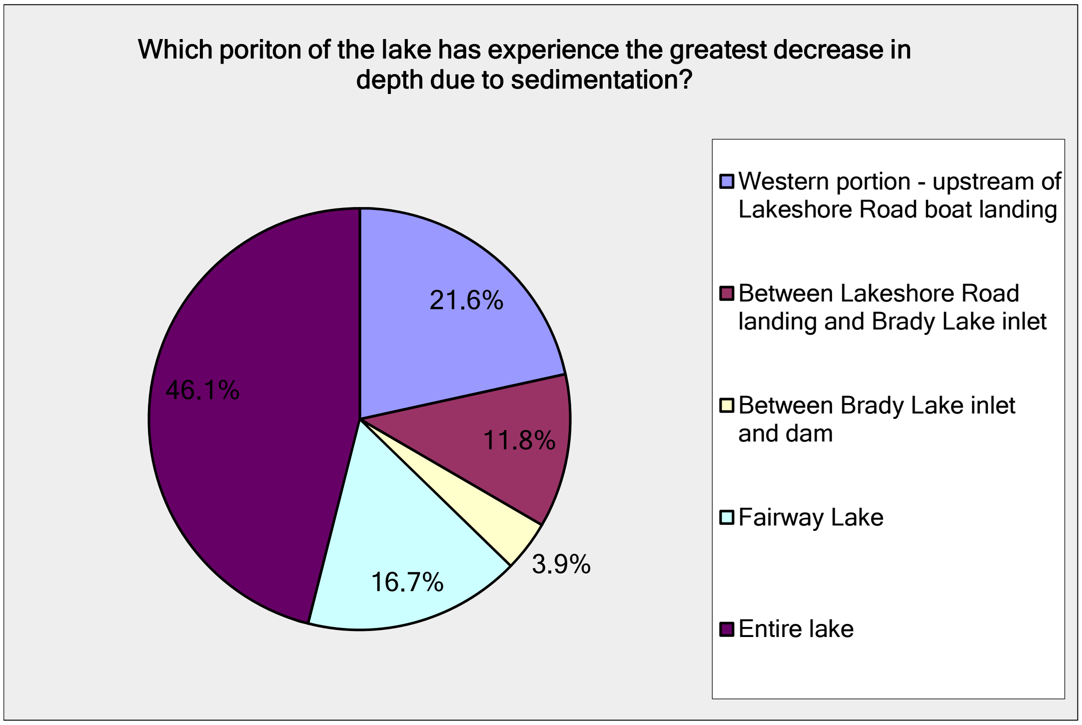
Question 16

Has decreased water depth due to sedimentation limited navigation access to or from a boat landing, fishing area, or personal pier?		
Answer Options	Response Percent	Response Count
No	37.6%	64
Yes, at all times	22.4%	38
Yes, only to certain areas of the lake	40.0%	68
	answered question	170
	skipped question	22



Question 17

Which poriton of the lake has experience the greatest decrease in depth due to sedimentation?		
Answer Options	Response Percent	Response Count
Western portion - upstream of Lakeshore Road boat	21.6%	22
Between Lakeshore Road landing and Brady Lake inlet	11.8%	12
Between Brady Lake inlet and dam	3.9%	4
Fairway Lake	16.7%	17
Entire lake	46.1%	47
	answered question	102
	skipped question	90



Question 18

Which of the following sedimentation management/reduction options would you support? Please rank your top 4 preferences with 1 being the most preferred and 4 being the lesser preferred option

Answer Options	Focus on agricultural runoff / sedimentation	Dredging	Extended or over winter drawdown	Remove dam and return to natural river	Review and potentially alter how the dam is operated	No action: wait and see what happens over the long term	Not sure; would rely on a professional consulting firm	Not sure; would rely on WDNR guidance	Response Count
1	25	45	3	8	3	0	16	5	105
2	26	23	10	3	17	0	7	9	95
3	14	10	14	3	15	1	16	9	82
4	9	7	8	5	10	2	17	12	70
AVERAGE RANKING	2.09	1.75	2.77	2.26	2.71	3.67	2.61	2.80	
									Question Totals
								answered question	105
								skipped question	87

Question 19

Please rank up the importance of the following elements of the Comprehensive Lake Management Plan update with 1 being most important and 4 being less important.

Answer Options	Study and understand current aquatic plant problems	Protect native plant species	Reduce extent and density of existing AIS infestations	Identify ways to reduce sediment input (loads) into the lake	Explore ways to remove or reduce current sediments from the lake	Prevent the introduction of new AIS	Identify and explore new aquatic plant management strategies	Seek grant funding for management efforts	Review dam operational guidelines for water level management	Ability to obtain a large scale an/or harvesting permits	Other	Response Count
1	22	8	25	17	46	4	11	13	4	8	2	160
2	15	17	22	30	22	8	7	22	4	8	1	156
3	19	11	19	17	24	10	18	12	8	11	1	150
4	7	7	7	23	6	13	14	23	12	12	0	124
AVERAGE	2.17	2.40	2.11	2.53	1.90	2.91	2.70	2.64	3.00	2.69	1.75	6
											answered question	161
											skipped question	31

Number	Other (please specify)
1	identify, publicly shame, and resolve any chronic "bad actor" landowners upstream
2	you have studied the problem for 45 years now it is time for action
3	stop the politics and get some action going in a positive direction
4	The pigeon lake is discusting to look at and smell. There is a geat recreational potential here and nothing is done to clean it up. I personally wouldn't let my dog swim in that lake. It is an eyesore in Clintonville and an embarrassment to the area. The DNR dam study that was done in the past clearly stated the dam is to be kept at 5.0 to the max of 5.2.. The dam is always above 5.2 and has been for years. Why put this survey out, no one listens to the public any way. .
5	Unless someone is an expert in this area, we should not abide by these comments. Opinions from those who are not experts are not going be the the best course of action to follow
6	Why not just drain the lake and quit wasting our money?

Question 20

Any additional comments or concerns?		
Answer Options		Response Count
		60
	answered question	60
	skipped question	132

Number	Response
1	will have more time to use lake, live in marion and know of your problems like marions
2	need to cut weeds deeper and need to remove sediments
3	sediment needs to be removed and weeds will alweays need to be harvested, we have learned from other lakes
4	hunting on the lake, spring and fall don't have weeds, it's beutiful
5	It is always difficult to make a lake from a pond. Too much runoff feeding the river from farm;and and no deep holes for water turnover
6	Don't drain the lake, where this was done on other lakes it didn't help
7	I WOULD LIKE TO THANK THIS COMMITTEE AND YOPUR CONTINUED STRIVING TO BEKNOWLEDGEABLE ABOUT THIS LAKE
8	MY NEIGHBOR HAS A HUGE TREE FALLEN DOWN CREATING BACKUP OF WEEDS WHAT CAN BE DONE ABOUT THAT?
9	Would like to see the lake become an attraction to both citizens and outsiders. Fishing, recreational boating, swimming.
10	I like what Iola and weyauwega did. Deeper with reduced plants.
11	yes please put more portable potty in the park that stop the litter in park
12	talk is cheap we all know the flipside
13	Lake Needs help/clean up is needed
14	I am AGAINST making any permanent alterations to the dam or its operation. A winter or temporary drawdown could have benefits. Perhaps the experiences of the Marion Millpond up river could assist in future planning. I have lived on the river for 30 years, paid many taxes and seen many plans brought forward to manage the river, however the thick plants deny me the use of the river for recreational boating. On some summer days the plants are so thick that it seems you could walk across them to get to the other side of the river. The harvesting machine gives temporary relief. On a positive note, the shoreline plants, fish, birds and animals that inhabit the river seem to be healthy and thriving. It is my one reason for owning property here.
15	publicize the root causes, and responsible parties, for the Marion dam fiasco
16	Excess nutrient load from, application of fertilizers, manure pits or excessive manure application to fields which ends up in the Marion or Clintonville pond.
17	Need to get rid of Green Slime on Pond
18	Please find a way to get rid of some of the plant life in the lake so people can be able to go out in a boat and fish, Thank You!!!
19	Bottom adacent to my property has been changing from sand to muck over the last 7 years. I've noticed that fish spawning activity is greatly reduced.
20	enjoying the lake with grandchildren. would like less "green slime" if possible
21	We need to save this Lake for future generations! Do what needs to be done to make this a nice recreational spot for everyone to enjoy! This would help our local economy if this lake was in decent shape.
22	no
23	Since when is it called Pigeon "Lake"? Thought it was the Pigeon "Pond".
24	we understand this is an old water system and we would like to enjoy it as much as we can!!!!
25	There are many issues that many of us are not well enough educated on to pass judgement upon, so we must trust in the stewardship and common sense of those who are educated enough to make decisions regarding the future health and well being of the Pigeon pond.
26	The aquatic plant growth in this body of water is out of control. However I would rather deal with the weeds than to have the body of water drained. Draining the water out does not work, take a look at the Marion pond, no fish & lots of weeds only a year or two after the lake was drained.

27	no
28	do something to return the lake to an acceptable state for swimming, shoreline beaches,remove sedament and weeds
29	Please don't drain the pond like Marion do, it will not work. The pond needs to be dredged out from 10 to 20 feet deep. That would make a nice pond.
30	Get the process going before there is no lake.
31	Was unable to answer several questions in this survey due to lack of knowledge - should have been an option answer stating "do not know"
32	you have studied the problem fo,r 45 years now it is time for action
33	None
34	it has jurrasically improved the last year compared to the following for ais
35	control the boats ripping up the weeds
36	would be a shame to see this lake go to waste,had lots of good times fishing withmy dad on the pond
37	Do not drane the pond for the fish poplasn is grate
38	I would strongly oppose a draw down of the lake. It has proven unsuccessful in area lakes and only harms all the living things that call it home.
39	Tell Scott Walker to get the money from his slush fund
40	With a golf course upstream at Marion and one in Clintonville, both on the lake fronts...their fertilizer is feeding the weeds...in my opinion.
41	Someting needs to be done with the current condition of this lake. It is unuseable most of the summer months and smells bad when it is hot. That in itself cannot be healthy. Thank You
42	Once again the Pond is a eyesore and detriment to the community. We could have a wonderful lake with sand swimming areas, but instead we have a green smelly slime hole. better to drain it and turn it into a river, at least it won't look so bad nor smell.
43	Purchase Canadian carp to eat the weeds (they are sterilized)
44	I think we should gather expert advice -- consulting firm and/or WDNR. I also think we should talk to the people who oversaw the management of the Marion pond. What are their thoughts on the results of the draining? We should listen to the opinions of those who are familiar with the pond by living by it and/or using it, but we need to balance that with expert opinion. People who professionally manage ponds are the ones who will have the most important opinion.
45	remove the sediment and weeds, and control there reentery to the Lake
46	You can't change the fact that an artificial lake will always confront the same problems sooner or later. Why not stop wasting my money on a body of water that is doomed from the outset?
47	smell
48	mid summer you cant even fish anymore, too many weeds
49	Not sure...
50	1997 put in pier 4.5 feet deep today's depth is maybe 2inches
51	Limit weed cutting to main body. Not in no wake areas.
52	scheduled cutting by map layout
53	Look for new methods and try new things to help control the AIS and not things that have been proven ineffective, Thanks for the survey!
54	I would like to see some emplasis given to the clean up on Fairway Lake
55	get rid of the green lake!
56	get rid og the sediment
57	I think the properrty values of homes on Pigeon will sart declining and the city tax base will suffer unless something is done to turn this into a usable lake again
58	As someone who has been on the pond most falls hunting over the last 30 yrs, it is sad to see how bad it has gotten.
59	Get rid of the muck, weeds and dnr.
60	I think that last years water quality was a lot better then past years. Whatever the lake district did in the 2013 season worked. It could use a little more work but it is a great start. I personally dont think we should get rid of all the invasive weeds completely, but find a wayto maintain them. I am very much against putting in a chemical to kills the weeds. If that is done it will kill everything in the lake and make enjoying the lake a huge disappointment. Thanks

APPENDIX B

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.

Table 1: Taxa Detected During 2014 Aquatic Plant Survey, Pigeon Lake, Waupaca County, WI

Genus	Species	Common Name	Category
Ceratophyllum	*demersum*	Coontail	Submersed
Chara	*sp.*	Muskgrass	Submersed [algal]
Elodea	*canadensis*	Common waterweed	Submersed
Heteranthera	*dubia*	Water star-grass	Submersed
Lemna	*minor*	Small duckweed	Free-floating
Lemna	*trisulca*	Forked duckweed	Free-floating
Myriophyllum	*spicatum*	Eurasian water-milfoil	Submersed AIS
Najas	*flexilis*	Slender naiad	Submersed
Nuphar	*variegata*	Spatterdock	Floating-leaf
Nymphaea	*odorata*	White water lily	Floating-leaf
Potamogeton	*crispus*	Curly-leaf pondweed	Submersed AIS
Potamogeton	*praelongus*	White-stem pondweed	Submersed
Potamogeton	*zosteriformis*	Flat-stem pondweed	Submersed
Ranunculus	*aquatilis*	Stiff water crowfoot	Submersed
Sparganium	*sp.*	Bur-reed species	Emergent
Spirodela	*polyrhiza*	Large duckweed	Free-floating
Stuckenia	*pectinata*	Sago pondweed	Submersed
Vallisneria	*americana*	Wild celery	Submersed
Wolffia	*columbiana*	Common watermeal	Free-floating

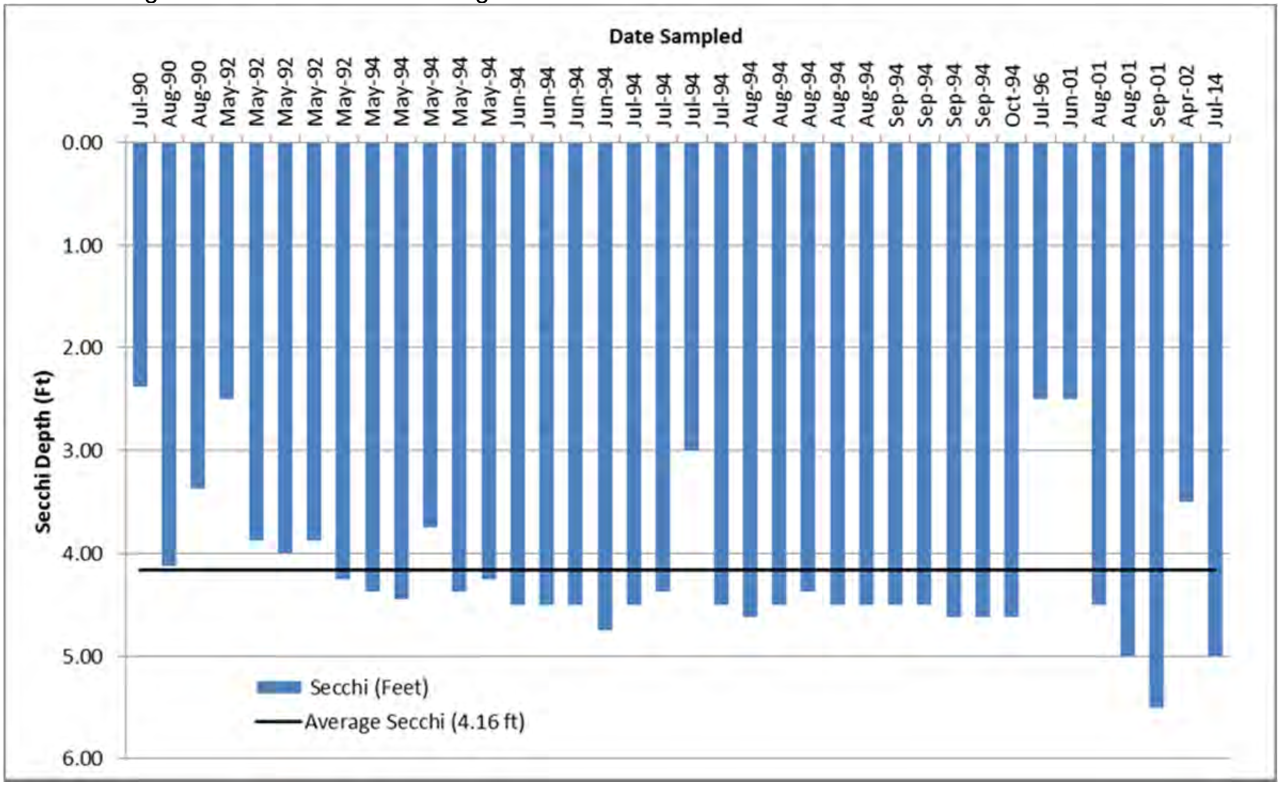
Table 3: 2014 Aquatic Plant Taxa-Specific Statistics, Pigeon Lake, Waupaca County, WI

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
Coontail	74.63	71.60	24.67	300	1.17
Common watermeal	44.53	42.72	14.72	179	1.00
Muskgrass	43.28	41.53	14.31	174	1.05
Eurasian water-milfoil	38.31	36.75	12.66	154	1.02
Slender naiad	22.64	21.72	7.48	91	1.00
Wild celery	21.39	20.53	7.07	86	1.00
Small duckweed	16.92	16.23	5.59	68	1.00
Common waterweed	13.93	13.37	4.61	56	1.11
White-stem pondweed	7.21	6.92	2.38	29	1.00
Curly-leaf pondweed	4.98	4.77	1.64	20	1.00
Water star-grass	4.23	4.06	1.40	17	1.00
White water lily	3.98	3.82	1.32	16	1.00
Stiff water crowfoot	1.74	1.67	0.58	7	1.00
Flat-stem pondweed	1.49	1.43	0.49	6	1.00
Bur-reed species	1.24	1.19	0.41	5	1.00
Forked duckweed	1.00	0.95	0.33	4	1.00
Spatterdock	0.50	0.48	0.16	2	1.00
Large duckweed	0.25	0.24	0.08	1	1.00
Sago pondweed	0.25	0.24	0.08	1	1.00

APPENDIX C

Appendix C – Supporting Water Quality Documentation

Chart 1: Pigeon Lake Secchi Readings



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
Pigeon Lake	**58.2**	**Eutrophic**	**67.9**	**19.4**	**4.16**

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

APPENDIX D

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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 Pigeon Lake based on watershed land cover, creating a nutrient budget.

Table 7: Phosphorus input by land use type. Pigeon Lake, Waupaca County, WI

		Phosphorus Loading	
Land Use	**Acres**	**kg/year**	**Average kg / acre / year**
Mixed Agricultural	18772.3	6078	0.32
Commercial / Industrial	42.8	26	0.61
Forest	21429.8	781	0.04
Pasture / Grassland	12615.3	1532	0.12
Lake Surface	162.7	20	0.12
High Density Residential	808.7	491	0.61
Rural Residential	2852.7	115	0.04
Wetlands	10816.2	438	0.04
Marion Wastewater Facility	---	703.2	---
TOTAL	**67500.5**	**10184.2**	**1.90**

Table 8: Percent phosphorus loading by source. Pigeon Lake, Waupaca County, WI

Land Use	Acres	Percent of Watershed	Percent of Phosphorus Loading
Mixed Agricultural	18772.3	27.81%	59.68%
Commercial / Industrial	42.8	0.06%	0.26%
Forest	21429.8	31.75%	7.67%
Pasture / Grassland	12615.3	18.69%	15.04%
Lake Surface	162.7	0.24%	0.20%
High Density Residential	808.7	1.20%	4.82%
Rural Residential	2852.7	4.23%	1.13%
Wetlands	10816.2	16.02%	4.30%
Marion Wastewater Facility	---	---	6.90%
TOTAL	**67500.5**	**100.00%**	**100.00%**

Table 9: Marion Wastewater Treatment Facility Point-Source Discharge Data

Marion Wastewater Treatment Facility		
Year	**Avg. Flow (MGD)**	**Avg. TP Concentration (mg/L)**
1999	0.246	---
2000	0.222	---
2001	0.235	---
2002	0.26	---
2003	0.306	1.75
2004	0.36	1.75
2005	0.294	1.75
2006	0.236	1.75
2007	0.226	2.2
2008	0.244	2.2
2009	0.217	2.2
2010	0.279	2.2
2011	0.312	2.2
2012	0.209	2.45
2013	0.225	1.25
AVERAGE	**0.258**	**1.97**

Date: 11/17/2014   Scenario: 3

Lake Id: Pigeon Lake
Watershed Id: 0

Hydrologic and Morphometric Data

Tributary Drainage Area: 67337.8 acre
Total Unit Runoff: 10.50 in.
Annual Runoff Volume: 58920.6 acre-ft
Lake Surface Area <As>: 162.7 acre
Lake Volume <V>: 688.0 acre-ft
Lake Mean Depth <z>: 4.2 ft
Precipitation - Evaporation: 3.8 in.
Hydraulic Loading: 59261.1 acre-ft/year
Areal Water Load <qs>: 364.2 ft/year
Lake Flushing Rate <p>: 86.14 1/year
Water Residence Time: 0.01 year
Observed spring overturn total phosphorus (SPO): 46.0 mg/m^3
Observed growing season mean phosphorus (GSM): 70.33 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	18772.3	0.30	0.80	1.40	59.7	2279	6078	10636
Pasture/Grass	12615.3	0.10	0.30	0.50	15.0	511	1532	2553
HD Urban (1/8 Ac)	808.7	1.00	1.50	2.00	4.8	327	491	655
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	2852.7	0.05	0.10	0.25	1.1	58	115	289
Wetlands	10816.2	0.10	0.10	0.10	4.3	438	438	438
Forest	21429.8	0.05	0.09	0.18	7.7	434	781	1561
Commercial / Industrial	42.8	1.00	1.50	2.00	0.3	17	26	35
Lake Surface	162.7	0.10	0.30	1.00	0.2	7	20	66

POINT SOURCE DATA

Point Sources	Water Load (m^3/year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %
Marion Wasterwater Facility	356471.1	445.6	703.2	873.4	6.9

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)	9955.0	22449.3	37708.7	100.0
Total Loading (kg)	4515.6	10182.9	17104.5	100.0
Areal Loading (lb/ac-year)	61.19	137.98	231.77	
Areal Loading (mg/m^2-year)	6858.12	15465.63	25978.03	
Total PS Loading (lb)	982.3	1550.3	1925.4	6.9
Total PS Loading (kg)	445.6	703.2	873.4	6.9
Total NPS Loading (lb)	8958.1	20855.4	35638.1	93.1
Total NPS Loading (kg)	4063.4	9460.0	16165.3	93.1

LEAP - Lake Eutrophication Analysis Procedure

Lake Name:	Pigeon Lake	**Ecoregion:**	North Central Hardwood Forests
Watershed Area:	67337.8 Acres	**Surface Area:**	162.7 Acres
Mean Depth:	4.2 ft	**TP Load:**	5263 kg/yr
Lake Outflow:	35 AF/yr	**Avg TP Inflow:**	148 ug/L
Residence Time:	0.0 years		
Areal Water Load:	53.84 m/yr	**P Retention Coef:**	0.17

Variable	Observed	Predicted	Std Error	Residual	T-test
TP (ug/L)	68	123	25	-0.26	-2.28
Chlr a (ug/L)	19.4	74.0	34.0	-0.58	-2.52
Secchi (m)	1.3	0.6	0.2	0.32	2.04

Note: Residual = Log10(Observed/Predicted)

T-test for signifigant difference between observed & predicted

Chlrophyll A Interval Frequencies (%)

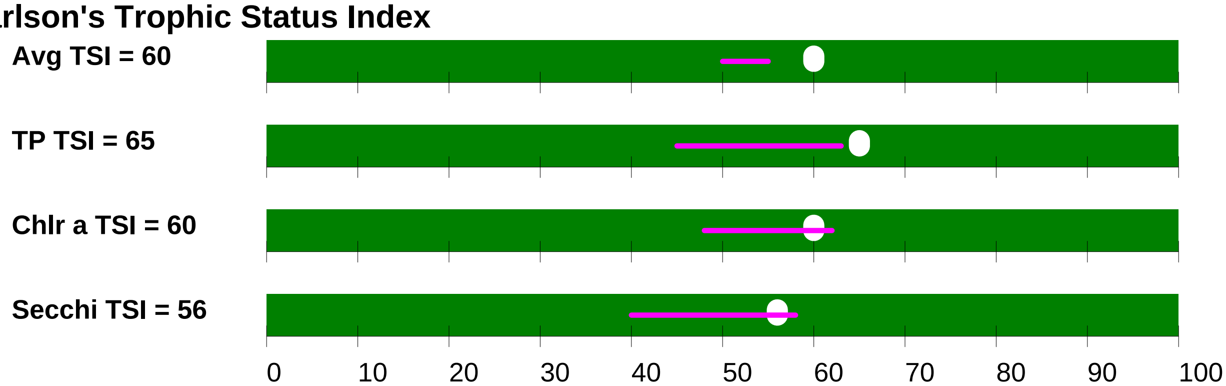
ppb	Observed	Case A	Case B	Case C
10	87%	100%	100%	100%
20	38%	99%	99%	96%
30	13%	95%	94%	87%
60	0%	58%	57%	55%

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