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

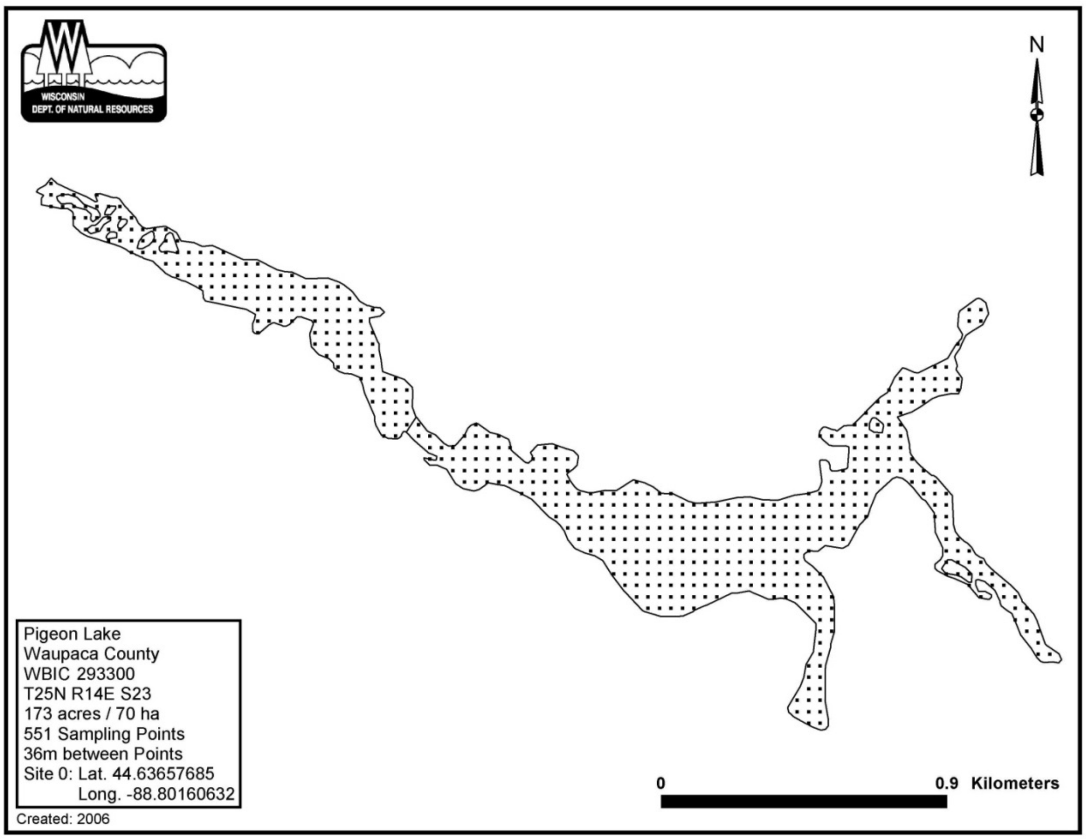
Management actions carried out for aquatic plant growth within the Lake have concentrated on aquatic plant harvesting. Issues still persisted in Pigeon Lake after several plans were created and some management actions enacted to the level feasible, as evidenced by the concerns raised in the user questionnaire.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

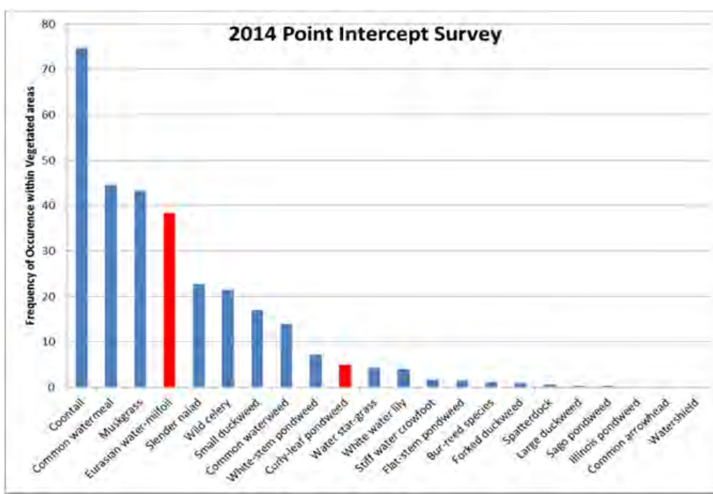
Table 2: 2014 Aquatic Plant Community Statistics, Pigeon Lake, Waupaca County, WI

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.

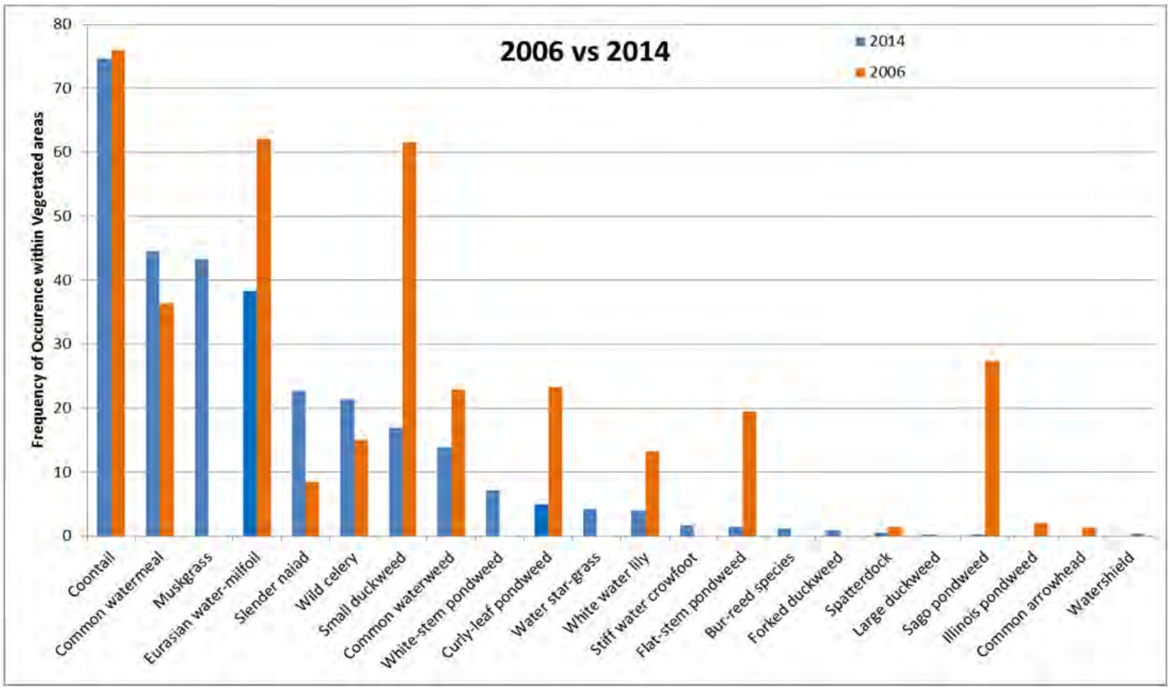
Though the survey methods have changed, the relative plant community within the lake has remained stable in abundance and diversity throughout the surveys. As this happens, species diversity, average coefficient of conservatism and FQI are relatively stable over time as the Lake ecosystem ages. These 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

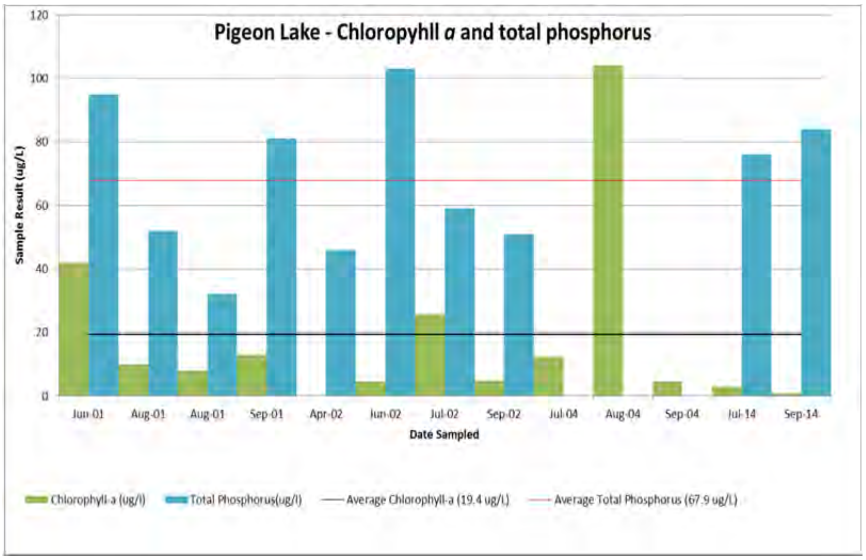
Water Quality Index	Total Phosphorus (mg/L)	
Very Poor	0.150+	
Poor	0.053 – 0.149	← Pigeon Lake
Fair	0.031 – 0.052	
Good	0.016 – 0.030	
Very Good	0.002 – 0.015	
Excellent	0.001 or less	

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.

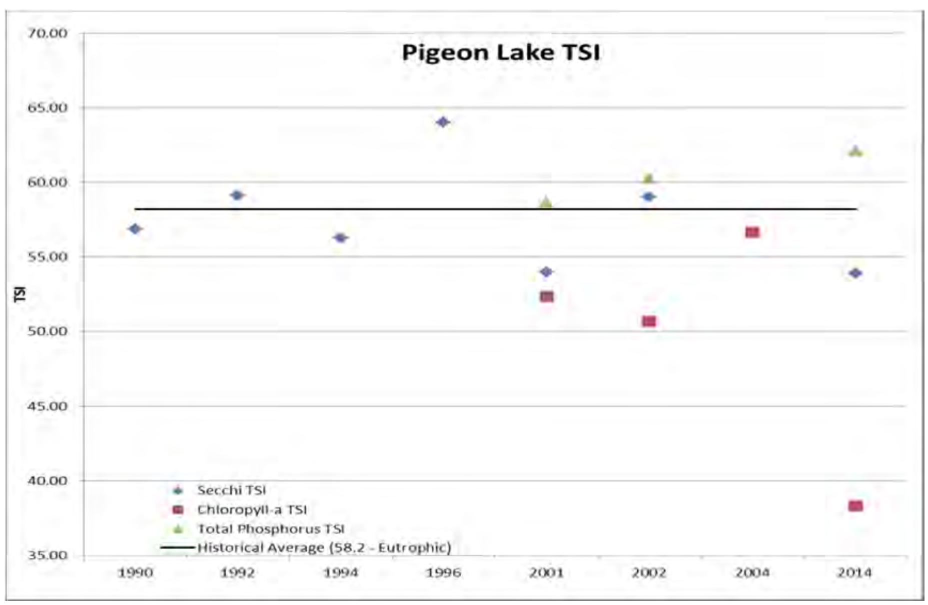
Total nitrogen for Pigeon Lake averaged 1.92 mg/L. Nitrogen levels on their own are typically not tracked in comparison to other lakes, such as with phosphorus above. Instead, they are compared with the phosphorus concentration of the lake to establish a ration between nitrogen and total phosphorus present 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.

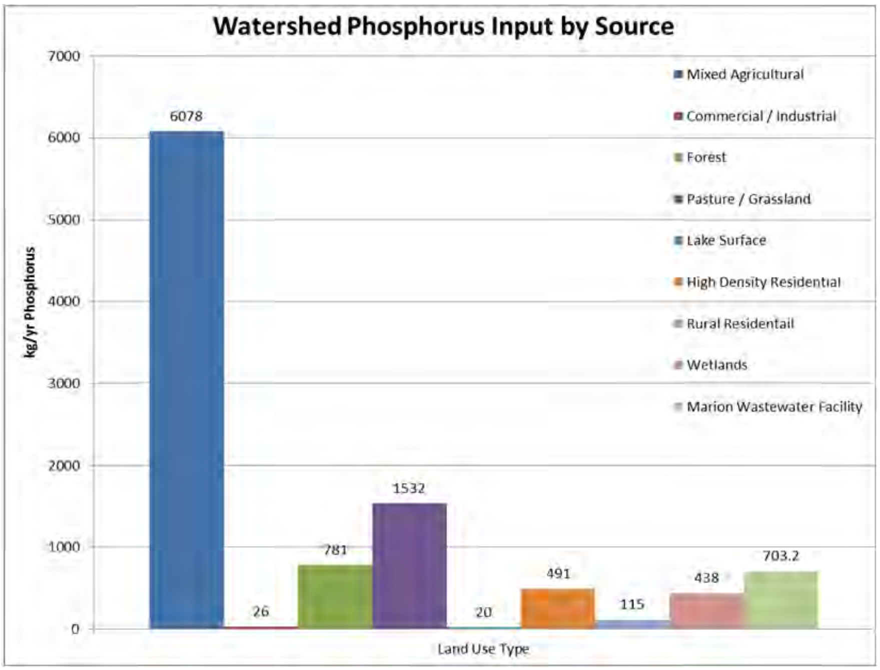
LEAP is a program within WiLMS that predicts lake trophic status indices based on watershed area, lake depth and lake ecoregion. For Pigeon Lake, the watershed without the lake itself is 67,337 acres while the Lake has a mean depth of 4.2 feet and total surface area of 162.7 acres within the watershed 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.

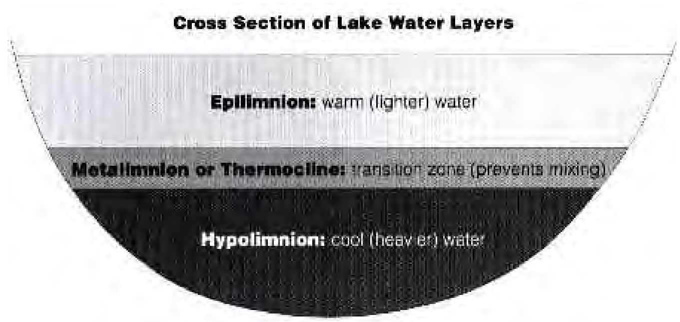
7.0 IN-LAKE RESTORATION OPTIONS

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
Brian Haase – County Conservationist
(715) 258-6482
Brain.haase@co.waupaca.wi.us

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

12.0 REFERENCES

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

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