WENCK File #4476-0001
June 2017

Pine County Aquatic Vegetation Management Plan DRAFT: Pokegama, Cross, Sand and Sturgeon Lakes




Prepared for:

Pine County Planning and Zoning

635 Northridge Dr. NW,
Suite 250
Pine City, MN 55063

WENCK

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Prepared by:
Tom Langer
Jeff Strom

WENCK
1800 Pioneer Creek Center
Maple Plain, MN 55359
Phone: 763-479-4200
Fax: 763-479-4242

Table of Contents

Table of Contents (Cont.)

TABLES

FIGURES

APPENDICES

1.0 Introduction

1.1 PROJECT PUROPOSE

In early 2017 Wenck Associates, Inc. staff met with Pine County Planning and Zoning staff, representatives from the Pokegama, Cross, and Windemere Lake Associations and the Minnesota Department of Natural Resources (MnDNR). The purpose of the meeting was to discuss management strategies to address concerns of AIS and promote growth of healthy submerged aquatic vegetation (SAV) communities within county lakes. It was agreed upon that establishing an aquatic vegetation management plan (AVMP) that targeted four lakes within Pine County with known AIS infestations and ongoing management activities (Pokegama, Cross, Sand, and Sturgeon Lakes) would be addressed in 2017 with the ability to expand the plan to other county lakes in proceeding years. At this meeting, mentioned parties expressed four main objectives for managing vegetation in the county lakes:

- Organize a unified concerted effort among parties and data collection efforts
- Limit the growth and spread of non-native AIS
- Determine the effectiveness of vegetation management activities
- Promote and restore growth of native vegetation in AIS infested areas

The Lake Associations have recently managed AIS on their lakes through herbicide treatments and, in the case of Pokegama Lake, mechanical harvesting equipment. However, the County and the Lake Associations believe a plan which focuses on long-term sustainable management will better address the objectives for these lakes. Thus, the goal of this plan is to present an adaptive approach to managing existing SAV and AIS in these four lakes through:

- Understanding historic and current vegetation community conditions (AIS and native plants) within each lake
- Review and evaluate potential drivers that affect AIS and native plant growth within each lake (i.e. water quality, lake level, sediment, fish community, etc.)
- Establish recommended treatment strategies and monitoring protocols for each lake to track success of management activities and the vegetation community response
- Adapt future management actions, applying a *lessons learned* mentality to best facilitate AIS management and native SAV restoration within the lakes.

We address and discuss these topics in proceeding sections of this document. Section 2.0 of this plan provides an overview of major factors affecting AIS and SAV growth in lakes throughout Minnesota. Section 3.0 discusses the rules and management options for controlling AIS and SAV in lakes. Sections 4.0 through 7.0 provide detailed management plans for the four lakes covered in this plan. These sections include a discussion of the status of AIS and SAV within each lake, individual review of the major factors affecting SAV growth, recommended treatment options, and a follow-up monitoring plan.

1.2 PINE COUNTY OVERVIEW

Pine County is in east-central Minnesota along the Minnesota-Wisconsin boarder (Figure 1-1). There are five major river watersheds (also referred to as HUC8 watersheds) that have a portion of their boundary in Pine County: Lower St. Croix River, Snake River, Kettle River, Upper St. Croix River, and the Nemadji River. Most of Pine County is situated in the

Northern Lakes and Forest Ecoregion. The Snake River watershed, which covers the southwest corner of the County is the only part of the County located in the North Central Hardwood Forests Ecoregion. The northern part of the county has higher elevation and is more forested, while the southern part of the county is lower in elevation and has more land devoted to agriculture (Pine County SWCD, 2015). Per the MnDNR, Pine County contains 142 lakes with many of these lakes being shallow and unnamed and having little to no development along the shoreline. Many of the larger deep lakes exist along the western half of the County and are heavily navigated by recreators and fisherman and have active Lake Associations and involvement from state and private entities.

1.3 PINE COUNTY AIS PROGRAM

In 2014, the State of Minnesota passed a county tax bill that designates funds for AIS control, prevention, awareness and outreach. Each year $10 million is distributed to counties throughout the State based on the number of watercraft accesses and trailer slips within each county. There are approximately 2,174 public access locations and 19,793 trailer slips throughout the state of Minnesota. Pine County has 30 public watercraft launch sites located on lakes and rivers throughout the County and approximately 244 parking slips. Based on these numbers, Pine County receives approximately $130,635 per year from the State AIS tax bill.

The Pine County Aquatic Invasive Species Program was established in 2014. The goal of the program is to implement new methods for AIS control and educate the public on AIS prevention. Since 2014, the Pine County AIS program has administered and funded efforts to accomplish the goals of their program through watercraft inspection and decontamination, youth programs, and public education. To date, the County has funded over $300,000 worth of AIS related projects. The Pine County website contains annual AIS plans that summarize all AIS funded projects since 2014 (link to website). Many of these projects have involved partnerships with lake associations, local townships, 4-H Clubs, MnDNR and other local government units and agencies.

The county has documented occurrences of two non-native SAV species, curlyleaf pondweed (*Potamogeton crispus*: CLP) and Eurasian watermilfoil (*Myriophilum spicatum*: EWM) which are the focused AIS of this plan. Pokegama and Cross lakes currently contain both CLP and EWM, Sand only contains EWM and Sturgeon has EWM and a potential small population of CLP. Pokegama and Cross Lakes are located on or adjacent to the mainstem of the Snake River and are strongly influenced by the hydrology of the river and its watershed. Sand and Sturgeon Lakes are relatively isolated basins with small drainage areas situated in the far northern portion of Pine County in the Kettle River Watershed. Sand and Sturgeon Lakes exhibit good water quality and fully support state water quality standards, while Pokegama and Cross Lakes were placed on the State of Minnesota’s 303(d) list of impaired waters for nutrients (total phosphorus) in 2004 and TMDL studies were completed for these lakes in 2013 (MPCA, 2013). Each of these lakes and the major factors influencing SAV growth is discussed in more detail in Sections 4.0 through 7.0.

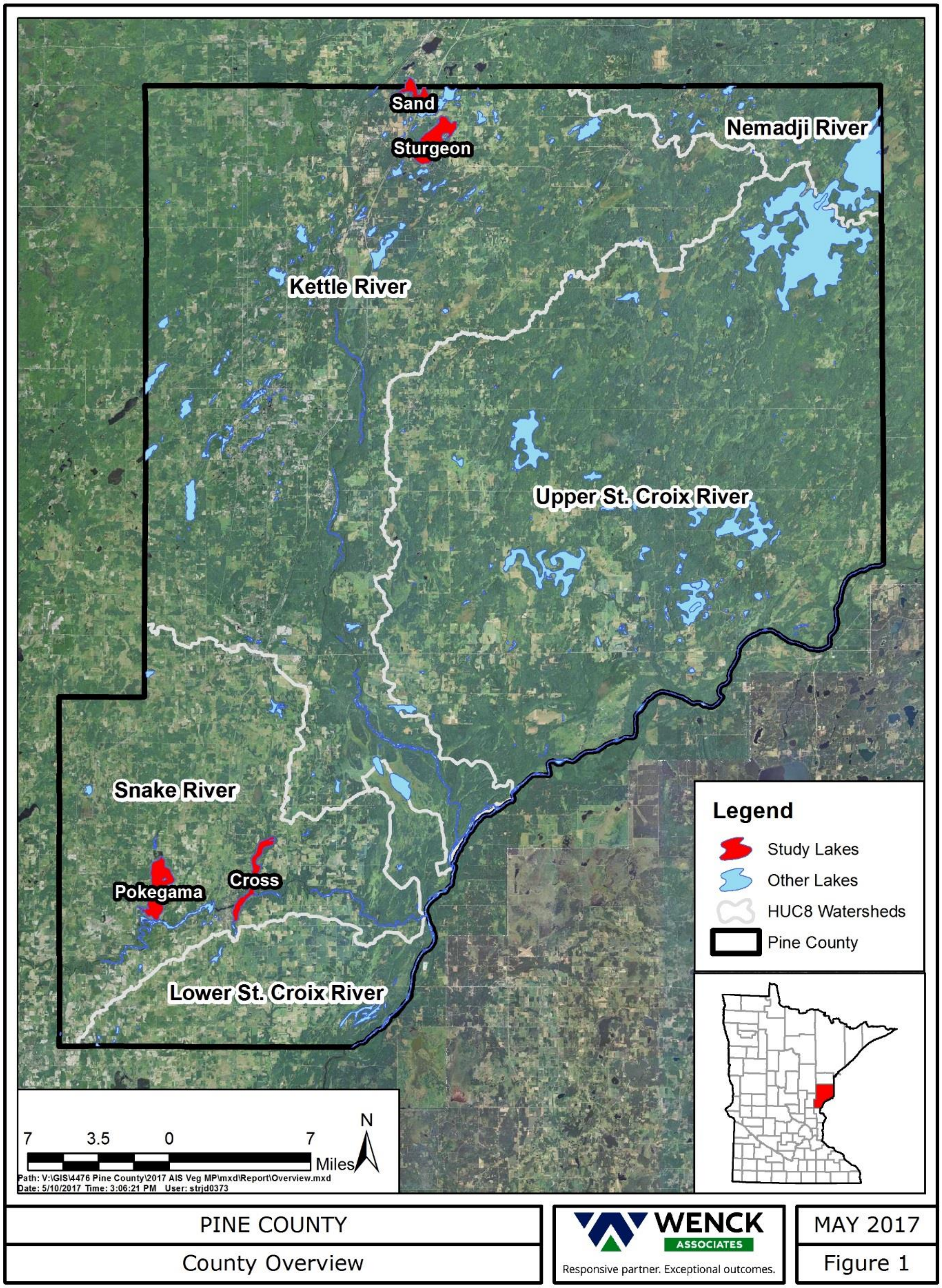


Figure 1-1. Pine County overview and lakes included in this plan.

2.0 Overview of Submerged Aquatic Vegetation

Lakes are common throughout the state of Minnesota and are often perceived as waterbodies that people can fish, swim and recreate with shorelines that are suitable for building homes and cabins along. A Minnesota lake is expected to be fishing and swimming from the dock, speed boats pulling water skiers from the shoreline out into the clear blue waters where ducks, loons and other wildlife swim and call out wilderness cries. This image can be true to many lakes or certain shoreline areas of lakes within Minnesota, however, not all lakes are the same and unique characteristics to each plays an important role in shaping what a healthy lake looks like. Adjusting our perception of all lakes being all things to some lakes are good at some things while other lakes are better at other things is important and will assist in understanding the actions that will restore, enhance and promote healthy submerged aquatic vegetation (SAV) communities and lake ecosystems within the County.

SAV communities perform numerous ecosystem services in our lakes providing foraging, spawning and nursery habitats for fish, macroinvertebrates, and waterfowl, they stabilize lake bottom sediments, sequester and recycle nutrients and carbon, among many more services. Despite all the benefits SAV communities provide to humans and the environment, many people perceive SAV as "weeds" and portray a negative connotation to the vegetation. In many cases, a healthy SAV community goes unnoticed to many lake recreators. Growing under the water's surface, in relatively high diversity stands, with no single species reaching abundances great enough to become a nuisance. At high abundances and densities, SAV often becomes 'noticed' by lake users and property owners. When SAV does reach high abundances and densities, it begins to limit recreational enjoyment, aesthetic pleasures and wildlife habitat services. Further exaggerating this negative connotation are aquatic invasive species (AIS). It is common for AIS to grow in large monodominant stands across a lake basin, completely choking out the entire water column. Submerged AIS often grow to the surface and can spread rapidly throughout a lake catching the eye of many lake recreators and property owners. While nuisance levels of AIS and other SAV can cause harm to a lake, acknowledging the importance of SAV and understanding SAV performs essential services provides meaning to restoration, enhancement and/or protection initiatives.

Lakes in Minnesota are generally classified into two categories: deep or shallow lakes. Deep lakes are classified as 20% or more of the lake area being greater than 15 feet in depth. Shallow lakes are typically classified as having 80-100% of the basin persisting in 15 feet or less. Without further explanation to these lake difference, the importance to the SAV community is that deep lakes often persist across a continuum of vegetation health, from a clear highly diverse SAV-dominated ecosystem to a turbid algal-dominated ecosystem with little to no SAV, while shallow lakes often persist at one end of this continuum or the other with little in between (Figure 2.1). Most SAV-dominated lakes tend to have clear or bluish water, high water clarity, diverse plant growth and little to no noticeable algae. In contrast, algal-dominated lakes tend to have green water, poor water clarity, and support SAV and fish that are adapted to tolerate disturbance and degraded water quality conditions.

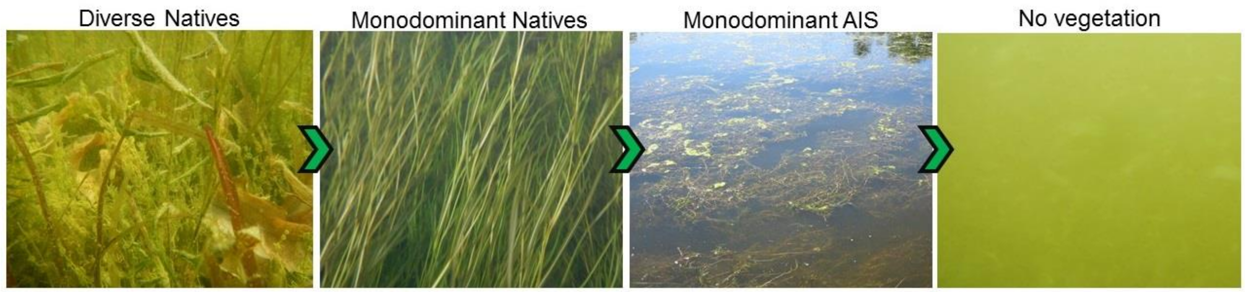
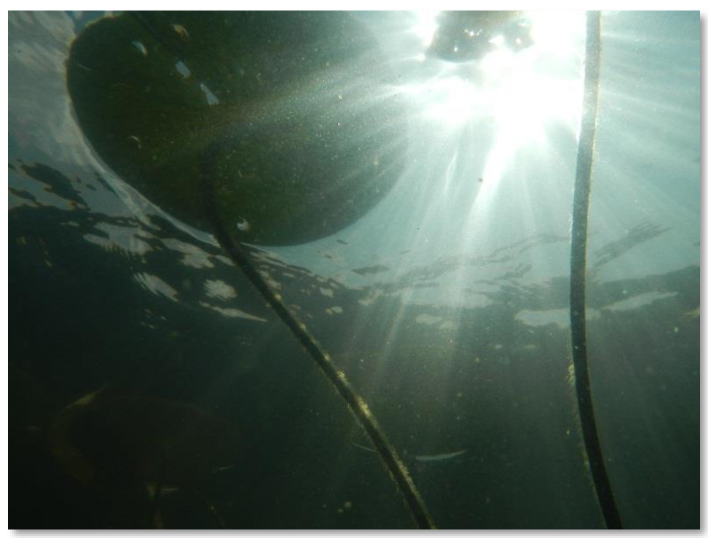


Figure 2-1. Continuum of a healthy submerged aquatic vegetation community and associated ecosystem services.

The purpose of this section is to introduce the potential factors driving lake state and how the types of plant species growing in a lake can be used to determine the health of the community and provide insight to the direct management activities that are influencing the SAV community.

2.1 FACTORS INFLUENCING SUBMERGERED AQUATIC VEGETATION GROWTH



Light, nutrients and disturbances are the primary components influencing SAV growth. Does the vegetation have the nutrients it needs to grow? Does light reach the vegetation? Is something disrupting/ impeding the vegetation from growing? These are rudimentary questions that quickly become complex when beginning to assess how the current SAV community has been shaped by these factors. Light can be directly influenced by water levels and water clarity, nutrients can be influenced by sediment composition, water column nutrients and watershed loading, disturbances can be the result of fish communities, human activities and hydrologic events. The combined and cumulative influence of these major factors stress and shape the SAV community that persists within a lake. Through understanding the current conditions of each of these factors we can begin to understand how the community reflects these conditions and what efforts can be used to begin improving SAV community health. We described each of these factors in proceeding subsections.

2.1.1 Water Clarity

Plant abundance, while related to several factors, is primarily determined by light availability (Cooke et al., 1993). It is a common misconception that excess nutrients in the water column cause nuisance aquatic plant growth. In fact, high water column nutrient concentrations can trigger algae blooms reducing light penetration which limits plant growth. Thus, lakes with high water column nutrient concentrations tend to be algal-dominated systems with lower plant biomass. In these systems, plant growth is typically limited to shallow depths where light can still penetrate the water column, favors species that grow quickly and earlier in the season and favors species that grow to the water's surface.

2.1.2 Water Level

Lake level fluctuation is a natural phenomenon that is unique to each lake due to its water source and watershed but all lakes in a region are influenced by both climate and weather patterns. Seasonally, spring rains and snow melt runoff result in increased water levels during spring that slowly decline over the course of the open water season as rain events become less frequent and spring runoff is no longer present. Through the course of the open water season sporadic weather events can have sudden and significant influence on water levels depending on the waterbody. It is not the direct increase of water volume that influences the plant community, rather the sediment and nutrient loads that are washed in during these events results in a decreased ability of light to penetrate the water column due to increased turbidity and distance light needs to penetrate to reach the vegetation. Therefore, sudden and large fluctuations can directly alter the SAV community in lakes with a greater impact on lakes with current water quality impairments. Through decreased light penetration and a large input of water column nutrients sensitive plant species that cannot handle these changes in the environment are susceptible and often die off. Repeated occurrence of this type of disturbance can ultimately lead to lower species diversity within a lake and result in single-species stands of vegetation.

2.1.3 Water Quality

Water column conditions in Minnesota lakes are often evaluated using three parameters: total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth. These parameters are interrelated and serve as surrogates to describe lake water quality and lake productivity. Total phosphorus is typically the nutrient that limits algal growth in lakes. Chlorophyll-a is the primary pigment in aquatic algae and has been shown to have a positive correlation with algal biomass. Secchi depth is a physical measurement of water clarity in which a black and white disk is lowered into the water until it can no longer be seen from the surface. Therefore, as water clarity decreases we typically see an increase in TP and chl-a concentrations and a decrease in Secchi depth readings which results in a decrease in light penetration and a shading effect on the SAV community.

2.1.4 Sediment Composition

Nutrient demands for SAV are largely supplied through root uptake from the lake sediments. A few SAV species, such as coontail, are not rooted in the sediment obtaining their nutrients from the water column. For rooted SAV, nutrient content, organic matter (carbon) content, sediment bulk density, and particle size all influence aquatic plant growth and abundance. SAV is typically nitrogen limited, therefore managing plant abundance through sediment nutrients would require a focus on reducing watershed and in-lake sources of nitrogen. However, even if these sources were reduced, there may not be an immediate response in plant abundance due to historic loading and long-term buildup of nitrogen in the sediments. Sediment bulk density and particle size are also very difficult to manage without drastic measure such as whole lake drawdown, sediment amendments and/or other engineering measures.

2.1.5 Fisheries

Biological communities (zooplankton, invertebrates, and fish) play an important role in maintaining water quality and a healthy SAV community. Though a more pronounced influence in shallow lakes, the influence of fisheries in deep water lakes has been observed and warrants consideration in managing SAV. In deep lakes, the fish community can affect plant growth through an imbalanced fishery that lacks abundant top predator species, and/or, through the presence of large populations of highly disruptive species, such as common carp.

The lack of large top predators (i.e. northern pike) can create various mechanisms that ultimately lead to increased turbidity or select SAV overgrowth. Bluegill have been shown to be effective predators of a native weevil species that are effective at controlling dense EWM stands, therefore a lack of large top predators can lead to an overabundance of Bluegill, thus increasing predation on native weevils and alleviating EWM from heavily weevil control. In promoting large game fish within a lake has the potential to moderate bluegill and similar species abundances so that weevils and other macroinvertebrates can suppress and overabundance of EWM. Catch and release or selective harvesting practices and following fishing regulations and slot limits can help correct imbalances and promote healthy and balanced fish communities. These practices encourage the release of larger fish while allowing the harvest of more abundant smaller fish. Releasing medium to large fish will help restore and maintain fish community balance, as well as increase opportunities to catch large fish in the future.

High densities of certain fish species (i.e. common carp, fathead minnow, gizzard shad, black bullhead) can also be determinantal to a lake’s SAV community both directly uprooting plants and indirectly increasing water column turbidity which decreases light penetration to more sensitive plant species. The control and management of these fish populations has demonstrated promise in restoring and enhancing the SAV community. Specifically, fish enclosure assessments in lakes have demonstrated the impact common carp have on aquatic vegetation (Johnson 2010, Johnson & Havranek 2013). At high densities, common carp alter the vegetation community by directly uprooting SAV and indirectly by decreasing water clarity and impeding sun light penetration to SAV.

2.1.6 Human Activities

The MnDNR acknowledges recreational activities and allows certain SAV removal to improve swimming and boating activities. There are limits in place as recreation and aesthetic related activities can have both indirect and direct influences on the SAV community. Swimming, boat props/jets, beach grooming, plant cutting, etc. can uproot and/or displace SAV leaving an area void of vegetation or promoting species that tolerate this type of disturbance. Indirectly, some SAV (mainly AIS) species can sprout new growth through plants fragments created through these activities further increasing undesired vegetation grow in areas nearby. The development of swimming areas typically eradicates SAV from a select area and can also lead to a change in substrate that reduces vegetation growth. These are examples of very localized disturbances that cumulatively have the potential to impact much of the shoreline area within a lake. Caution and careful consideration by landowners is important at altering the SAV community.

Large scale influence on SAV communities resulting from human activities can vary and may be applicable to select lakes. Commercial SAV harvesting, shoreline riprap or seawall development, reservoir damming, lake drawdowns are some examples of disturbances that can drastically alter the vegetation community and are often conducted with the direct goal of SAV management.

2.1.7 Interaction of Factors

In summary, many factors control and shape the vegetation community within a lake. Management activities that are planned, documented and carried out can have significant influences on improving the vegetation community and restoring a healthy lake ecosystem. In 2016, efforts by the University of Minnesota and Riley Purgatory Bluff Creek Watershed District documented a multi-year management assessment and the numerous steps taken to improve the vegetation community with Lake Susan. This assessment documented the impact of selective control of vegetative AIS, fisheries management through the removal of common carp, and water clarity improvements through an alum treatment before significant and noticeable results were achieved in the SAV community. The infancy of recent management activities has yet to demonstrate long-term sustained restoration but have shown promise and demonstrated an adaptive step-wise progression to achieving desired responses in the SAV community.

2.2 AQUATIC INVASIVE SPECIES IN MINNESOTA

The only known infestations of AIS in Pine County are EWM and CLP, which are the most common managed AIS in Minnesota lakes. EWM can dominate a lake's SAV community, limiting native plant growth and the ecological value of the plant community. Curlyleaf pondweed is an invasive, like EWM, that can easily outcompete native SAV species. It also presents a unique concern that it may contribute to algal blooms due to its early summer senesce which would facilitate decreased water clarity and light attenuation in the lake. Curlyleaf pondweed begins growing in late fall, continues growing under the ice, and dies back relatively early in summer, releasing nutrients into the water column as it decomposes, possibly contributing to algal blooms.

It is important to evaluate and monitor the presence and abundance of these species in a lake as the impacts of these species degrade the SAV community. Lakes that have nuisance populations of either species should consider controlling those populations. Below is a brief description of EWM and CLP and other AIS found in Minnesota.

2.2.1 Eurasian Watermilfoil

Scientific Name: *Myriophyllum spicatum*
Similar to: Northern Watermilfoil (Native)

Key identifiers:

- 12-20 pairs of leaflets
- Grows in large monodominant stands
- Stems may appear reddish brown to pink and are limp

Eurasian watermilfoil is a prominent AIS found in many lakes in Minnesota. EWM can grow in dense stands and fill the entire water column outcompeting and blocking many native species from light. It can also hybridize with native milfoils making it difficult to manage.

2.2.2 Curlyleaf Pondweed

Scientific Name: *Potamogeton crispus*
Similar to: Clasping Leaf Pondweed (Native) and White Stem Pondweed (Native)

Key identifiers:

- Begins to grow early spring before other plants
- Leaf are crinkly with fine toothed leaf edges and a blunt tip
- Leaf does not wrap around stem (Clasping Leaf Pondweed)
- Develops large turions for reproduction

Curlyleaf pondweed (CLP) is common through Minnesota lakes. The plant senesces in early summer releasing nutrients into the water column and leaving previously inhabited areas vacant of vegetation. CLP often grows in dense mats to the surface in disturbed areas causing recreational and aesthetic concerns.

2.2.3 Other Submerged AIS Species in Minnesota

The list of threatening and merging AIS continues to grow as we begin to understand and investigate our nation's waterbodies. To-date EWM and CLP are the only SAV AIS documented within Pine County and have been the focus of management activities to date with County lakes. We have listed additional SAV AIS that currently pose the greatest threat to Pine County due to the proximity of these species to Minnesota and Pine County waters.

Common Name	Scientific Name
starry stonewort	*Nitellopsis obtusa*
hydrilla	*Hydrilla verticillata*
Brazilian waterweed	*Egeria densa*
brittle naiad	*Najas minor*
parrot feather	*Myriophylum aquaticum*

Currently the MnDNR has listed Cross, Sand, Sturgeon and Pokegama as impaired waters for AIS. With 138 additional MnDNR classified lakes existing within Pine County, continued monitoring and surveying efforts will assist in understanding the location and spread of AIS within the County.

All new or suspected AIS occurrences should be reported to the MnDNR and regional AIS specialist: http://www.dnr.state.mn.us/invasives/aquatic/index.html

3.0 Managing Submerged Aquatic Vegetation

Although nuisance AIS growth and other SAV problems often result from excessive nutrient and sediment inputs, control of their growth and biomass cannot be expected to result from reduction in lake nutrient concentrations. This is because their nutrient demands are largely supplied through root uptake from the sediment. Therefore, more direct methods are employed to deal with excessive aquatic plant biomass. While other techniques exist, the two most common plant management techniques are herbicide treatments and mechanical harvesting. This section describes the rules, regulations and current methods for managing aquatic plants in Minnesota lakes and a description of common management techniques.

3.1 MANAGEMENT REGULATIONS

The management of aquatic plants in public waters in Minnesota is regulated by Minnesota Statute, Section 103G.615, Chapter 6280 and is enforced by the Minnesota Department of Natural Resources (MnDNR). Public waters are described by the state as body of water 2.5 acres or larger within a city limit or 10 acres or larger in a rural setting. Aquatic plant management activities in public waters may or may not require an Aquatic Plant Management (APM) permit, based on the nature of the activity.

APM permits may be issued to provide riparian access, enhance recreational use, control AIS, manage water levels, and protect or improve habitat. Separate permits are required for controlling natives for recreational access and controlling AIS. A specific list of criteria is considered to determine if a permit should be granted. A permit will not be issued to improve the appearance of undeveloped shoreline or for aesthetic reasons alone. A permit also cannot be issued in areas given special designations, such as Scientific and Natural Areas or in areas posted as protected fish spawning areas.

There are several permit fees associated with the control of vegetation in Minnesota lakes. For recreational access, the fee for offshore (>150 feet from shore) mechanical control of submerged aquatic vegetation is $35.00 for the first acre, plus $2.00 for each additional acre up to a maximum fee of $2,500.00. The fee for offshore mechanical control of rooted vegetation on lakes 20 acres or less in size is $17.50 for the first acre plus $1.00 per acres for each additional acre. To control rooted aquatic vegetation with pesticides, the fee is $35 for each contiguous parcel of shoreline up to a maximum of $2,500. If multiple methods are used, only the larger of the fees applies. There is typically no fee for a permit to control AIS.

3.2 ACTIVITIES NOT REQUIRING A PERMIT

Chapter 6280.0250 allows certain activities without an APM permit. Specifically, mechanical control of submerged aquatic plants is allowed by individual property owners in an area not to extend along more than 50 feet or one-half the length of the owner's total shoreline, whichever is less, and not to exceed 2,500 sq. ft. plus the area needed to extend a channel no wider than 15 feet to open water.

These rules also allow for the mechanical control of floating-leaf aquatic plants to obtain a channel extending to open water with the provisions that the channel is no more than 15 feet wide and follows the most direct route to open water, the channel is maintained by cutting or pulling, and the channel remains in the same location from year to year.

The skimming of duckweed or filamentous algae from the surface of a water body is also allowed without a permit.

3.3 ACTIVITIES REQUIRING A PERMIT

An APM permit is required for all other activities below the Ordinary High Water (OHW) level not mentioned above, including all herbicide control of aquatic plants, relocating or removing vegetation, and installing or operating an automated aquatic plant control device (weed roller).

3.4 HERBICIDE TREATMENT

A permit is required for all chemical control of aquatic plants. Herbicide control of aquatic plants is limited to an area that does not exceed 15% of the littoral area (typically ≤15 feet) of a lake. Only specific pesticides that are labeled for use in aquatic sites can be used, and they must be applied per the label instructions. Application can occur as frequently as the applicant desires; however, the frequency must be approved by the DNR. In herbicide applications, timing, concentration, herbicide used, target species, wind, water flow and water temperature are among the many factors to consider when applying an herbicide to control AIS and SAV.

Selective herbicide treatment is most common in herbicide treatments as the chemical compounds are applied at specific timings, dosages or areas of infestation to control specific SAV. Herbicides are meant to target specific biological pathways of a plant or a group of plants (i.e. monocots) allowing selective treatments of SAV. Efforts are continuing to determine the most effective methods and measure to treat a given aquatic plant, however, we provide the current state and recommendations in chemical treatment of CLP and EWM.

Herbicide treatment of CLP is typically conducted in the early spring when water temperatures are between 50-60°F and warming. At this period in the growing season there is typically little to no native SAV growth, therefore, chemical treatments are meant to target CLP only. To have effective chemical concentrations of endothall need to be sustained in target areas and can be greatly influenced by wind and water currents. Treatments are documented at being most effective when large (>5 acres) vegetation stands of CLP can be targeted with dosage concentrations persisting at 0.75 to 1.5 ppm for 12 – 24 hours. If large treatable plots do not exist small areas may be treated but typically require greater concentrations (1.5 to 2.0 ppm or more) to have effective results (MnDNR 2013). Treatment of CLP appears to have the greatest result at lowering reproductive success with repeated treatment for 2-3 years. Johnson *et al.* (2012) found that curlyleaf frequency, biomass and turion density were drastically reduced with repeated treatments, however, complete eradication of viable turions was not achieved suggesting that the population was at least short term controlled. Efforts by Jones *et al.* (2012) demonstrated that though CLP treatment was effective at controlling CLP there was little change in the native vegetation community. Only select species were observed to increase in biomass after treatments, suggesting that other factors (i.e. water clarity, fish community, viable seed bank) were limiting the establishment and increase in native species and biomass.

Herbicide treatment of EWM is typically conducted in mid summer when EWM areas have been delineated. At this period in the growing season there can be many other SAV growing within the body of water, therefore, chemical treatments need to be careful that dosing is conducted in a method that reduces the potential of negatively influencing non-targeted areas and species. EWM is typically treated with an auxin-mimic, usually triclopyr or 2,4-D herbicides. Similar to CLP treatments effective chemical concentrations need to be sustained in target areas for 12-24 hours and can be greatly influenced by wind and water flows. Treatments are most effective when large vegetation stands are dosed at concentrations persisting at 2 to 4 ppm. Dissipation of herbicides in small plots is common making effective treatment ineffective, while increasing dosage to achieve sustained concentrations can drift and harm non-target species (such as waterlilies); (Nault *et al*. 2014, MnDNR 2013). A growing concern among EWM infested waterbodies is the ability of the species to hybridize with native milfoil species. Hybridized milfoil has been shown to grow faster and may be more resilient to herbicides (LaRue *et al.* 2013) and hybridized milfoil is speculated to occur more frequently in herbicide treated lakes (Thum *et al.* 2017). This growing concern warrants consideration in the use of herbicide treatment in EWM infested waters, as ineffective treatment may foster hybridization and greater difficultly in long-term management.

Treatment of areas with both CLP and EWM are conducted in early spring when water temperatures are between 50-60°F and warming. Dosing and target concentrations of endothall are ~ 1.0 ppm and 0.25 to 1.0 ppm for triclopyr or 2,4-D (MnDNR 2013).

Selective treatment using fluoridone is less common and typically not utilized in CLP and EWM treatments. Fluridone is typically pursued as a non-selective method and encompasses the entire lay or embayment area, requiring close monitoring and occasion follow up dosings to achieve desired effects.

In general, long-term control of EWM and CLP has not been well studied to date. It is uncertain if the species are completely killed or undergo seasonal injury, rebounding later in the year or if proceeding years. In addition, there is little information on the long-term effect and recolonization of native or desired SAV species after herbicide treatments. The collection of quality data is an essential objective to assess and inform future management techniques, however, follow up monitoring is not required and often not pursued due to logistical constraints or treatment goals.

3.5 MECHANICAL TREATMENT

Mechanical control of aquatic vegetation typically involves the cutting, pulling, raking or otherwise removing or altering aquatic plants by physical means. Removal can occur as frequently as the applicant desires; however, the frequency must be approved by the MnDNR. Some of the conditions of permitted mechanical control of aquatic plants include:

- the vegetation must be immediately and permanently removed from the water;
- the mechanical control may not exceed 50% of the total littoral area of the lake
- control methods must not change the course of the water; and
- mechanical control for recreational access must be conducted in the same location year after year; locations can vary year to year for AIS control based on pre-control surveys.

The combination of herbicide and mechanical removal is not to exceed a total littoral area of 50%. Therefore, if 15% of the littoral area is treated with herbicide only 35% can be harvested by mechanical methods.

Technologies and research into mechanical harvesting are growing as the need and desire of lake managers continues to grow. Mechanical harvesting typically occurs when vegetation reaches the water's surface and is visible. A project piloted by Minnehaha Creek Watershed

District in 2013, assessed the effectiveness of cutting methods on CLP populations and found that the timing and depth at which the vegetation is cut had a significant influence on the amount of turions observed in the sediment. Turions are a seed like structure in which new CLP stems can sprout. The conclusions of this assessment acknowledge that traditional cutting methods likely will not control populations of CLP, rather they provide lake managers a method to improve recreation on infested waterbodies. This research also highlighted that conducting cuttings deeper and earlier may be more effective at controlling the population and turion densities but continued research is needed.

3.6 TRANSPLANTING

A permit is required for the relocation and transplanting of all native SAV. The transport and relocation of any AIS is illegal and is not permitted by the MnDNR. Transplanting is an effective technique when lake conditions are suitable for plant growth when the seed bank and/or abundance of native species in a lake has been depleted. The native vegetation species used in transplanting is typically acquired from areas within the lake and/or from neighboring lakes.

Current research is underway at the University of Minnesota that is monitoring transplanting success of various species through time. Preliminary results are promising, yet, controlling other limiting factors (i.e. light availability, nutrient loading, fisheries management) may need to occur in conjunction with transplanting activities. Transplanting alone has been shown to have little to no improvement in the SAV community. Verhfstad et al. (2017) suggested that once light is no longer limiting, seed propagules or the seed bank within a lake has a greater influence on which species will come back rather than lake sediment chemistry. Therefore, continued efforts to promote and facilitate seed bank restoration and/or transplanting of SAV may produce favorable SAV communities during water quality restoration efforts.

3.7 FISHERIES

The use of barriers, exclosure or enclosures or any methods that capture and collect fish in public waters requires permitted approval by the MnDNR. Since common carp are a pervasive fish within much of Minnesota waterbodies extensive research has been conducted to reduce the negative impacts these fish have on SAV communities and water quality. Survey methods have been developed by the University of Minnesota to determine the population density of common carp through boat electrofishing surveys. At densities of 89 lbs/acre, common carp begin to have significant impacts on the SAV communities and water quality with severely degraded conditions persistent at densities of 450 lbs/acre or greater. Exclosure experiments have been used to document the in lake impacts common carp have on the SAV community and/or to restore native and desired SAV within a waterbody. Exclosures are meant to be temporary with more permanent structures and removal processes needed to have sustained longer term impacts.

3.8 SEDIMENT ALTERATION

Alteration of benthic sediment with the goal to change bulk density, sediment particle size, and/or nutrient content has the potential to influence plant growth and the types of plants growing in a specific area. However, identifying the target sediment parameters for the desired condition is difficult and needs further research. There are several techniques that can be used to alter sediment composition including the addition of sand or engineered soils to the lake. However, these techniques are typically not feasible due to high costs of treating large areas of a lake and the uncertainty of the outcomes.

The most common approach to altering sediment bulk density is whole and/or partial lake drawdowns. Lake drawdowns are a rare but in some cases effective method at vegetation management. Lake drawdowns expose shallow areas of the lake and typically alter sediment bulk density and the viable seed bank within the benthic sediments. Exposing lake sediment to the atmosphere results in sediment drying and consolidation and loss of nitrogen from increased denitrification.

3.9 SPECIALIZED TREATMENT OPTIONS

There are additional forms of plant management (i.e. dredging, hydrovacing, biomats) that exist, however, these methods are only approved by the MnDNR in very rare and special cases. These methods attempt to alter or block the sediment with the goal to reset the seed bank and substrate conditions. These methods can be cost prohibitive, require extensive permitting and research assessments, therefore we do not provide further insight or literature review of these methods.

4.0 Pokegama Lake

4.1 LAKE DESCRIPTION

Pokegama Lake is a 1,515 acre lake located about three miles east of Pine City. Pokegama Lake has a maximum depth of 25 feet with 60% of the lake at or less than 15 feet in depth. The lake is connected to the Snake River via surface flow through a channel that runs beneath County Road 53 on the south end of the lake. Pokegama Lake is subject to water level fluctuations and watershed inputs due to its proximity to the River.

Land use and land cover in Pokegama Lake's 50,630 acre drainage area is predominately hay/pasture (33%), wetland (30%), and forestland (29%) (MPCA, 2013). A large portion of Pokegama Lake's inflow comes from Pokegama Creek which drains approximately 42,811 acres and enters the lake through a wide channel on the north end of the lake. Direct drainage to Pokegama Lake accounts for approximately 15% (7,819 acres) of the lake's total watershed and is made up of several small tributaries that drain directly to the lake.

4.2 VEGETATION COMMUNITY

Historic vegetation assessments have been conducted by the MnDNR (1946, 71, 81, 90, 98, 2000, 08 and 09) and Wenck (2016). These assessments documented a total of 25 species of aquatic vegetation that have been observed within Pokegama Lake at some point in time since 1946. Species observed varied from 7 to 16 species observed at any given point in time. The 2008, 2009 and 2016 efforts were early season efforts when the abundance and presence of some native SAV species are not commonly surveyed but the presence of CLP is at peak densities. The 2008 and 2009 reports do not contain full species lists, therefore, information about the entire SAV community is limited (Table 4.1).

The most recent full lake survey was conducted on June 23rd, 2016. This assessment collected frequency of occurrence information for each observed species and found that three species dominated the vegetation community. Two of the three species were AIS suggesting that the current vegetation community is largely impaired and reflective of a degraded vegetation community. CLP and EWM growth was restricted to the depths of 10 feet or less. In general, Pokegama Lake has a relatively quick drop-off from the shoreline to 10 feet in depth with most of this depth change occurring within 150 feet of the shoreline. Without a late season survey inference about species abundances and occurrences outside of CLP should be minimal, however, inference about what species are present within the lake can be made.

Table 4-1. Historic submerged and floating leaf vegetation summary for Pokegama Lake.

Common name	Scientific name	1946	1971	1981	1990	1998	2000	2016
Berchtold's pondweed	*Potamogeton Berchtoldii*		x	x				
Bushy pondweed	*Najas flexilis*				x	x	x	
Canada waterweed	*Elodea canadensis*	x			x	x	x	49
Claspingleaf pondweed	*Potamogeton Richardsonii*	x			x			1
Coontail	*Ceratophyllum demersum*	x	x	x	x	x	x	2
Curlyleaf pondweed	*Potamogeton crispus*				x		x	66
Eurasian Watermilfoil	*Myriophyllum spicatum*							38
Flatstem pondweed	*Potamogeton zosteriformis*	x			x	x	x	6
Floatingleaf pondweed	*Potamogeton natans*	x	x	x	x			
Greater bladderwort	*Utricularia vulgaris*				x	x		
Greater duckweed	*Spirodela polyrhiza*		x		x	x		1
Lesser duckweed	*Lemna minor*	x	x	x	x		x	1
Muskgrass	*Chara sp.*							5
Narrowleaf pondweed	*Potamogeton sp.*	x						
Northern watermilfoil	*Myriophyllum sibiricum*	x		x				2
River pondweed	*Potamogeton nodosus*	x			x			
Sago pondweed	*Stuckenia pectinata*	x			x		x	
Star duckweed	*Lemna trisulca*	x			x	x		1
Turion duckweed	*Lemna turionifera*					x		
Water meal	*Wolffia columbiana*					x	x	
White waterlily	*Nymphaea tuberosa*	x	x	x	x	x	x	1
Whitestem pondweed	*Potamogeton praelongus*						x	
Water celery	*Vallisneria americana*					x	x	6
Yellow water stargrass	*Zosterella dubia*				x	x	x	
Yellow waterlily	*Nuphar variegatum*	x	x	x	x	x	x	1

*An 'x' corresponds to the species being observed. Values correspond to reported frequency of occurrence.

Historic records documented the first CLP observation to be in 1990, with the first documented record for EWM in the lake occurring in 2005. Pokegama Lake Association has activity managed CLP since 1999, when they began mechanical harvesting. Since then they have harvested CLP annually and conducted small herbicide applications in 2008 and in the spring of 2017. No documented efforts have been conducted to control EWM within the lake. We are unable to make conclusions about the success of treatment activities to date due to the lack of efforts to track, monitor and quantify results pre- and post- treatment. It is likely that treatment had seasonal success as long term success does not appear to have occurred with wide spread occurrence of CLP within the lake.

4.3 POTENTIAL FACTORS INFLUENCING VEGETATION COMMUNITY

4.3.1 Water Quality

Annual monitoring of lake water quality on Pokegama Lake has been conducted periodically over the past 10 years. Most of the data was collected by the MPCA in support of the Snake River Watershed TMDL Study (MPCA, 2013) and through the Citizen Assisted Monitoring Program (CAMP). Average annual total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth for the past 10 years is summarized in Figure 4-1. Average annual Secchi depth measurements and TP and chl-a concentrations for Pokegama Lake have failed to meet state waters quality standards every year in which these parameters were monitored over the past 10 years.

Due to the poor water quality conditions described above, Pokegama Lake was placed on Minnesota's 303(d) list of impaired waters in 2004 and a TMDL study for the lake was completed in 2013 (MPCA, 2013). Results of this study indicate nutrient (TP) loading to Pokegama will need to be decreased by 24,617 pounds per year for the lake to meet state water quality standards. Modeling done to develop the TMDL suggests TP load reductions will need to come from a combination of watershed (11,962 pounds per year) and internal (11,847 pounds per year) sources.

Appendix A provides figures showing how water quality conditions change in Pokegama Lake throughout the summer growing season. In general, all three water quality parameters are at or near water quality standards during the early growing season (May to early June). However, by late June, phosphorus concentrations begin to increase significantly which results in increased algae growth and reduced water clarity. Chlorophyll-a concentrations and Secchi depth measurements in Pokegama Lake consistently fail to meet water quality standards from mid-June through September (Appendix A).

Water clarity was relatively good in Pokegama Lake at the time of the June 2, 2016 vegetation survey as Secchi depth measured 2.2 meters (state standard = 1.4 meters). During this survey, vegetation growth was noted at 79% of the surveyed points, however no vegetation was observed growing at depths greater than 10 feet and the vegetation community was dominated by AIS (CLP and EWM). While a late summer follow-up survey was not performed in 2016, local lake residents indicated vegetation growth and coverage decreased significantly by mid-summer after CLP died off and water clarity declined. These observations suggest that water quality conditions within the lake, particularly poor water clarity, likely have a significant impact on vegetation growth, life cycle, and the types of AIS and native vegetation species growing in the lake.

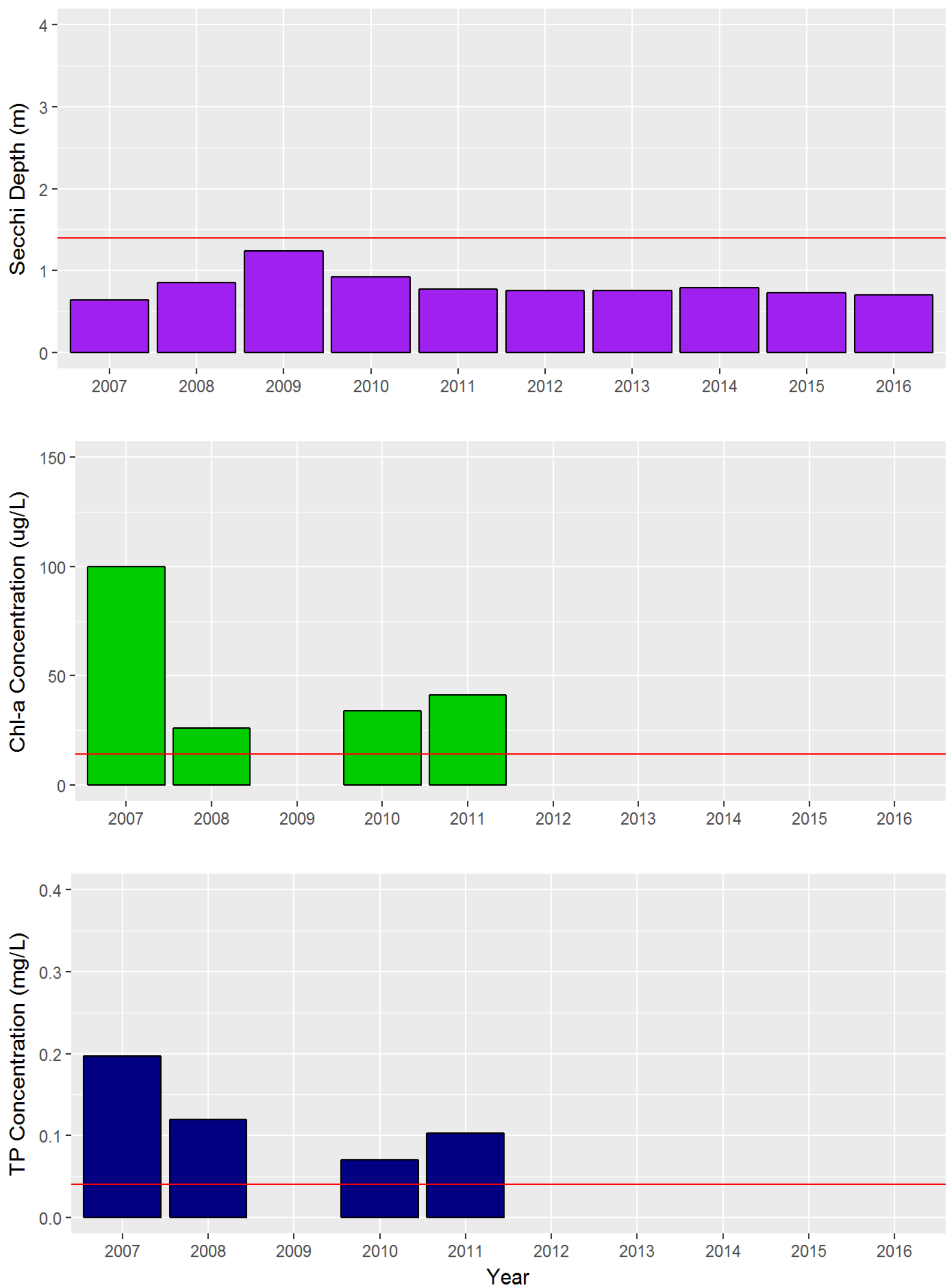


Figure 4-1. Pokegama Lake average annual Secchi depth, chlorophyll-a and total phosphorus concentrations. Note: Red line indicates state water quality standard for deep lakes in the North Central Hardwood Forest Ecoregion.

4.3.2 Water Level

Lake level data has been collected periodically in Pokegama Lake since 1940 (See Appendix A). These data show that prior to 2002, average annual lake level did not exceed the lake's OHW level (933.4 ft). Since 2002, average annual lake levels have exceeded the OHW level six times. While no statistical analysis has been performed on the lake level dataset, these results show that lake levels have generally increased over the past 20 years.

It is difficult to assess what impact the long-term changes in lake levels have had on SAV communities in Pokegama Lake. Often, SAV can adjust to long-term changes in lake levels, however they are not as well suited at adapting to abrupt, short-term increases (bounces) in lake level when water clarity is poor. In Pokegama Lake, lake level bounces greater than 2.0 feet within a 7-day period are common in response to 7-day rainfall totals greater than 2.0 inches. Since 2007, there have been 15 occasions in which lake levels bounced more than 2.0 feet within 7 days. The largest 7-day bounce occurred in 2016 when lake levels increased approximately 5.5 feet between July 10 and July 17 (Figure 4-2). This bounce was in response to 7-day rainfall totals of approximately 7.5 inches. Local knowledge indicates significant decreases in SAV abundance following these large lake level fluctuations.

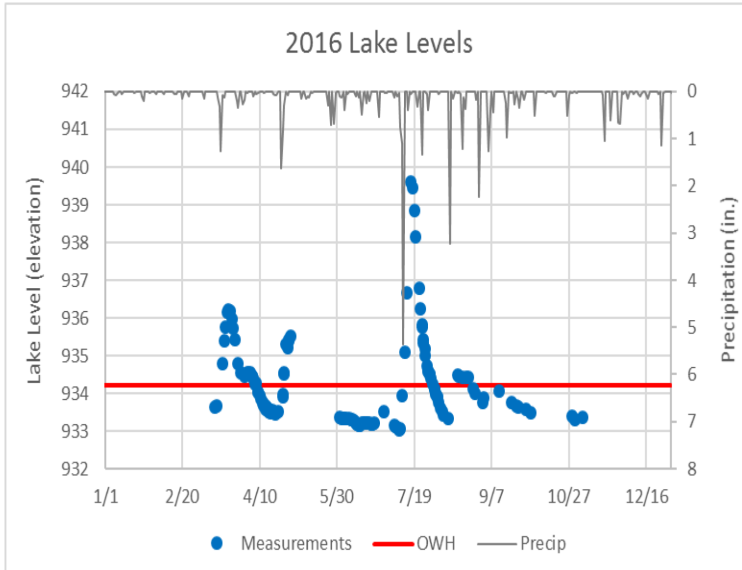


Figure 4-2. 2016 Pokegama Lake levels.

Pokegama Lake currently outlets through a 60-foot-wide channel located on the southeast corner of the lake. The outlet channel flows a short distance beneath County Road 53 (Tigura Road) and then discharges directly to the Snake River. Due to its proximity to the Snake River, Pokegama lake levels are strongly influenced by water levels in the river which are ultimately controlled by the Cross Lake dam five miles downstream of Pokegama Lake. Installation of an outlet control structure on Pokegama Lake could prevent backflow from the Snake River into Pokegama Lake during high flow events.

Water level bounce in Pokegama lake could also be mitigated through modifications to the existing dam at Cross Lake. The dam currently consists of a 331-foot-long concrete weir with an outlet elevation of 932.6 feet. Increasing the length of the spillway would result in higher flow rates over the dam which would reduce the water level bounce in the Snake River, Pokegama Lake, Cross Lake, and other upstream waterbodies.

4.3.3 Sediment

No sediment information or data is currently available within the littoral areas of Pokegama Lake. In 2012, sediment cores were collected at the lake's long-term water quality monitoring station near the deepest part of the lake, approximately 25 feet. These cores were analyzed for various chemical and physical parameters in support of the TMDL study. These analyses included phosphorus content, phosphorus release, organic matter content, and bulk density. Results showed that sediment in this part of the lake has relatively high bulk density, high phosphorus and organic matter content, and high phosphorus release. Since sediment conditions in deep lakes vary drastically between littoral areas (<15 feet) and deep areas, it is difficult to use these results to make any firm conclusions about the littoral sediment in Pokegama Lake. However, given the eutrophic nature of the lake and the high sediment phosphorus content in the deep part of the lake, it is very likely that phosphorus, nitrogen, and organic matter has accumulated in the sediment throughout the littoral areas. Thus, while they have not been assessed in Pokegama Lake, sediment conditions are likely favorable to support excessive plant growth.

4.3.4 Fish Community

Pokegama receives moderate fishing pressure and is actively stocked for walleye by the MnDNR. The most recent fisheries assessment was conducted in 2014 by the MnDNR and demonstrated a decrease in overall fish numbers across species from recent surveys with the largest group of fish caught existing in the invertivore species (excluding sunfish species) grouping. Piscivorous fish, including the walleye and northern pike were below historic catch rates while bluegill, crappie and freshwater drum were species that achieved normal status for either catch rate or average length during the survey. Long-term records demonstrate a cyclical trend were abundances of all fish increase and decrease over a decade, therefore, fish populations maybe expected to increase by the next fish survey event (Figure 4-3).

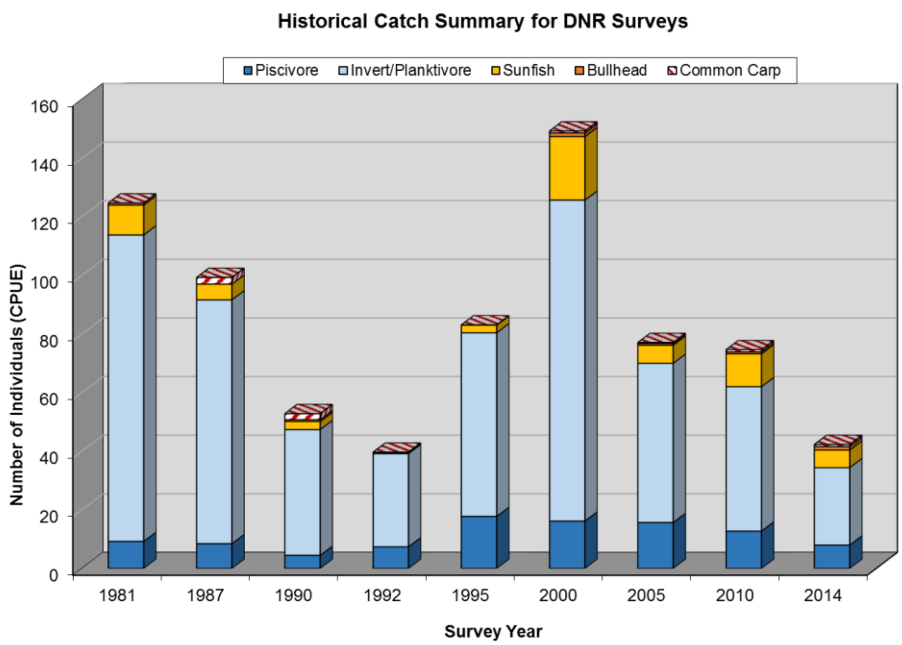


Figure 4-3. Pokegama Lake fisheries summary.

Common carp are present within Pokegama Lake, however their population size, density and influence on the vegetation community is unknown. Traditional MnDNR trap and gill net methodology is poor at capturing and representing the common carp population due to their size and learned avoidance of the gear. We recommend utilizing traditional survey methods in terms of presences and absence when assessing common carp existence in a lake and when present, further assessment may be warranted. Since Pokegama is connected to a large river network, long-term sustained carp management may be difficult without significant structural engineering. The presence of lake sturgeon within the lake system may present permitting issues for structures as the fish species is a fish closely monitored by MnDNR researchers. Regardless, common carp population assessment or exclosure experiments would allow inferences to be made in regards to the influence fish are having on the current SAV community.

Sunfish species comprised a normal percentage of the fish catch which may be promising for natural weevil control of EWM within the lake. Declining catch rates of top predator (walleye and northern pike) maybe a potential concern, however, there appears to be greater water quality concerns impeding vegetation growth. Fish management activities should continue to follow MnDNR fishing regulations.

4.4 MANAGEMENT RECOMMENDATIONS

4.4.1 Development of Monitoring Plots

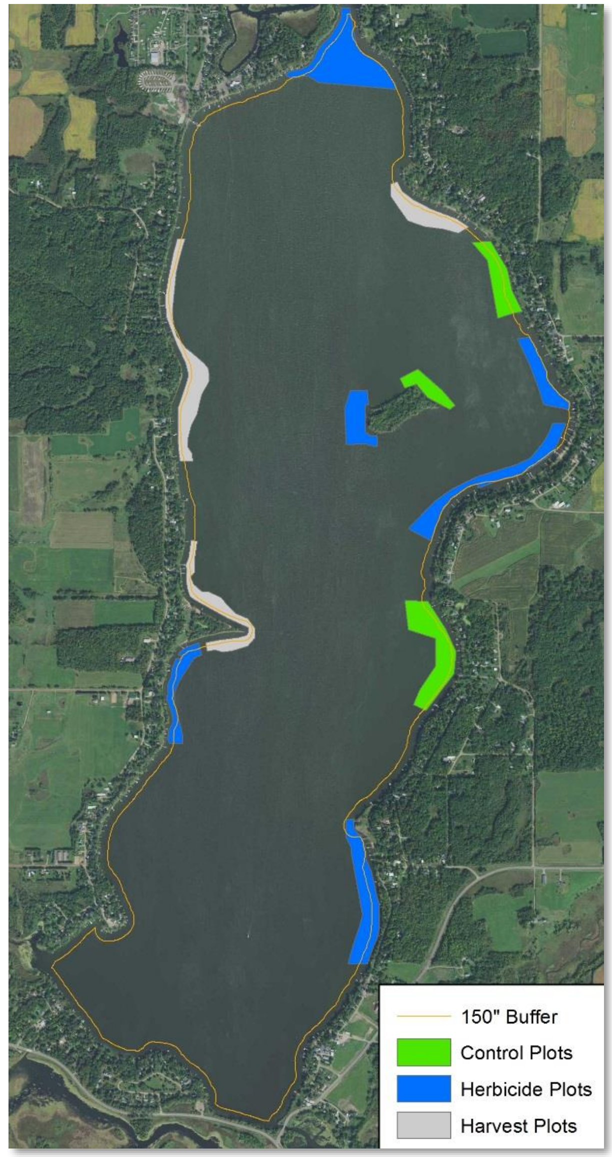
The intention of developing monitoring plots within Pokegama Lake is to document and quantify the changes in the SAV community following specific management activities to 1) better understand the success of a given management activities and 2) adapt management activities to best control and reduce the impact AIS and restore a healthy SAV community. For a detailed standard operating procedure and equipment to establish and conduct SAV monitoring for this management plan please consult Appendix B.

Review of previous early season vegetation survey efforts by Wenck Associates, Inc. (2016) and the MnDNR (2009) suggest wide spread proliferation of CLP and EWM across the Pokegama Lake shoreline area. Using ciBiobase sonar processing and recent (2016) point intercept survey efforts, we could outline and propose treatment and control plots. The MnDNR conducted a field delineation and vetted proposed areas, ultimately approving 58 herbicide treatment acres and permitting 86 acres of mechanical harvesting (permit number 16F-3B367) within the lake.

Chemical treatment plots were randomly selected in locations across the lake and occurred where large (>5 acre) CLP stands could be treated. MnDNR regulations require landowner written approval for any chemical treatment of submerged aquatic vegetation within 150 feet of the shoreline. Since, most of the lake’s CLP growth occurs within the 150-shoreline buffer area there were limited areas in the lake where the water depth change is more gradual and vegetation growth was observed in areas beyond the 150-foot buffer area. Receiving landowner approval was viewed as critical to develop effective treatment plots. Therefore, Pokegama Lake Association acquired needed landowner signatures for permit approval by the MnDNR to conduct treatment within the 150-foot buffer. The ability to treat CLP across the entire depth profile in which it grew is believed to have a greater probability of creating a core habitat void of CLP, thus allowing desired SAV an opportunity to recolonize treated areas. In limiting chemical treatment to specific depth and distance from shoreline, treatment plots have a great probability of being replenished with CLP turions that drift in from neighboring untreated areas.

Current literature recommends that chemical treatment of CLP growth areas may need to be treated annually for 3 years to reduce the turion density within a given area to levels where desired SAV can establish. Thus, it is recommended that treatment plots be closely monitored and likely treated in proceeding years until turion densities are reduced and desired SAV recolonize the plots.

Much like chemical treatment plots the mechanical harvest plots were randomly selected in areas that large CLP stands could be targeted. Mechanical harvesting is approved to occur from 100-feet from shoreline towards open waters. It is our recommendation that CLP mechanical harvesting plots cut prior to dense surface growth to reduce turion densities and increase the likelihood of long-term sustained reduction form mechanical harvesting. We did not propose treatment plot monitoring for all 86 acres of harvestable CLP. Rather we propose select areas to monitor in 2017 and leave the remaining acreage and locations up to the Association's discretion (avoiding control plots) to harvest. Documentation by the Association of the timing and location of additional mechanically harvested areas is recommended to aid future adaptive management decisions.



Control plots were proposed and were designed to be of similar size to treatment plots. No management activity should occur in control plots as they are intended to be surveyed and used in comparison to treatment plots to quantify treatment effectiveness. The location of control plots should remain constant annually to ensure that no remnant management activity is influencing the SAV community. Without knowing the exact location of historic management activities, we cannot conclude that current control plots are persisting outside of remnant influences, however, due to the presence of CLP growth throughout the lake remnant influences are not suspected.

Monitoring throughout the SAV growing season within monitoring plots will continue to inform and update effective management strategies. Monitoring and management activities should occur in these same plots in following growing seasons to assess short and long-term success of treatment. A more detailed SOP of recommended monitoring procedures is outlined in Appendix B.

4.4.2 Conclusions

Reduced light penetration due to poor water quality and large lake level bounces are the most prominent factors impeding the restoration of a healthy SAV community within Pokegama Lake. If light availability increases, the SAV will likely respond to improved growing conditions with increased biomass and the number of species persisting within the lake. The Snake River TMDL assessments identified both watershed loading and internal lake processes as contributing factors to decreased water quality and clarity in Pokegama Lake, therefore efforts targeting both areas will improve water quality.

Siting and installation of watershed BMPs to target high nutrient loading areas will help reduce watershed loads to Pokegama Lake. Application of a product such as aluminum sulfate (alum) would help permanently bind what would otherwise become mobile phosphorus during mid- to late summer months, which would greatly decrease internal load and improve water quality and light penetration within the lake. An internal load feasibility would need to be conducted to determine the location(s) and amount of alum (or other product) needed and the associated costs.

Water level feasibility assessments for one or both water level control methods described above would determine effects on upstream and downstream flooding, as well as outlet design and construction costs associated with modifications. The goal with outlet modifications is to decrease the amount of water level bounce observed in the lake, which should help maintain the area light reaches SAV.

Recommended actions to consider for Pokegama Lake:

- ▲ Internal load feasibility assessment
  - Alum treatment
- ▲ Water level stabilization feasibility assessment
  - Outlet structure modification
  - Cross Lake dam lengthening
- ▲ Watershed BMPs
  - Agriculture practices
  - Wetland restorations

Light may not be the only factor limiting the SAV community within Pokegama Lake. It is possible that the fish community (i.e. common carp) are directly uprooting and displacing desired SAV. If fish are having a strong influence on the vegetation community improvements in water quality may not result in any changes to the SAV community and/or no noticeable changes to the presence or abundance of desired SAV species. Common carp population assessment or conducting fish exclosure experiments would allow inference and conclusions to be drawn to the impacts fish are having on the SAV community. Efforts to transplant SAV to recolonize a lake and develop a viable seed bank of desired SAV can be impeded by the fish community, therefore, negating restoration efforts.

Recommended actions to consider:

- Common carp population assessment
- Fish exclosure experiment

Vegetative AIS pose another biological concern to enhancing the SAV community. Though AIS are more valuable to lake health than no vegetation, improving growth conditions for SAV may promote extensive growth of all SAV, including AIS, in the lake. The monitoring efforts beginning in 2017 will quantify the effectiveness of treatment activities provide research opportunities aimed at reducing their presence and restoring diverse native stands of vegetation. Should growing conditions improve and limited desired SAV recolonize areas within the lake, management activities may need to consider transplanting species. Vegetation transplanting, if done correctly and in favorable conditions, has been beginning to show promise at restoring the SAV community in areas within a lake.

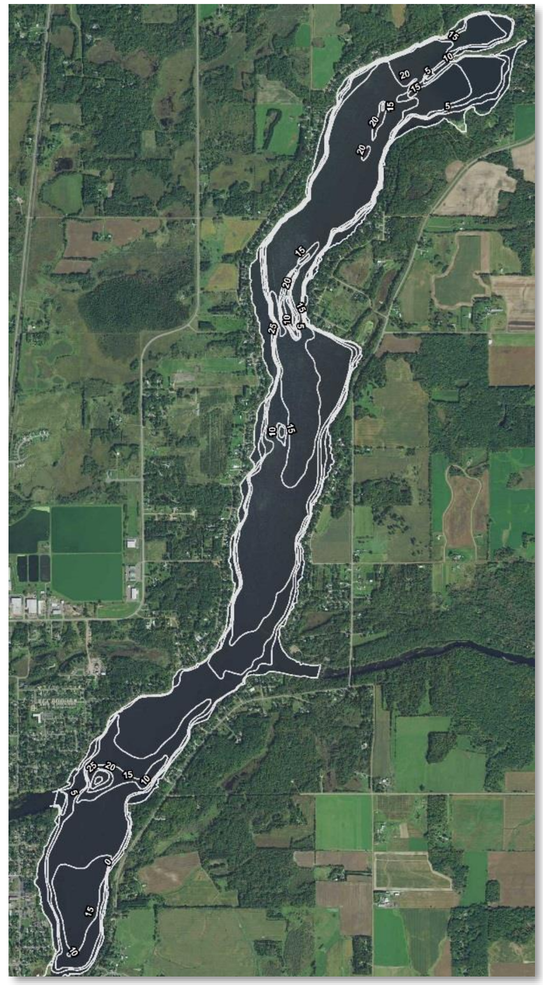
Recommended actions to consider:

- Update late season SAV survey
- Monitor vegetation management activities
- Determine and locate potential waterbodies were transplants can come from
- Adapt management activities as new technologies and methodologies as they become available

In summary, the vegetation community in Pokegama Lake is degraded and restoration should be the focus of management activities. Improving water quality conditions across the lake and/or controlling the water level fluctuation present a large challenge but perhaps the best chance in enhancing and restoring the SAV community in Pokegama Lake. Beginning to track and monitor changes in the SAV community will allow insight to management activities and assist in adapting management decisions to combating AIS and promoting a healthy lake ecosystem.

5.0 Cross Lake

5.1 LAKE DESCRIPTION



Cross Lake is a 925 acre lake located on the northeast edge of Pine City, MN. Cross Lake has a long narrow shape, generally running north-south. Cross Lake has three primary basins that display different physical and limnological characteristics. All three basins are moderately deep with maximum depths ranging from 22-30 feet. Littoral area (<15 feet deep) ranges from 18% in the south basin to 63% and 73% in the north and central basins, respectively.

The general flow pattern for Cross Lake is from the north basin to the central basin and eventually to the lake's outlet between the central and south basins. Direct drainage to Cross Lake is approximately 7,102 acres and includes Cross Creek, which enters the lake on the north side of the north basin, and several smaller tributaries and intermittent streams. The Snake River, which enters and exits the lake through the south basin, drains approximately 611,704 acres of land that includes several smaller streams and upstream lakes. Average residence times for the north and central basins is typically 1-2 years whereas residence time in the south basin is less than 10 days due to influence of the Snake River.

Land use and land cover in Cross Lake's 7,102 acre direct drainage area is predominately hay/pasture (35%), forestland (20%), and wetland (16%) (MPCA, 2013). Land use in the Snake River watershed upstream of Cross Lake is primarily forestland (36%), wetland (31%), and hay/pasture (22%).

5.2 VEGETATION COMMUNITY

Historic vegetation assessments have been conducted by the MnDNR (1955, 71, 81, 90, 2000, 07 and 14) and Wenck (2017). These assessments documented a total of 27 species of aquatic vegetation that have been observed within Cross Lake at some point in time since 1955. Species observed varied from 6 to 20 species observed at any given point in time (Table 5.1). The 2007, 2014 and 2017 efforts are confirmed early season surveys when the abundance and presence of some native SAV species are not commonly surveyed. Without a late season survey inference about species abundances and occurrences outside of CLP should be cautioned.

The most recent full lake point intercept survey was conducted on May 31st 2017. This assessment collected frequency of occurrence information for each observed species and found that the most common species were coontail and curlyleaf pondweed. CLP and EWM were observed in the lake. The growth of vegetation within Cross Lake appears limited to depth less than 10 feet. The depth of plant growth and the quick drop off in depth across the entire lake results in a very limited amount of vegetation growth across the basin.

Historic records documented the first CLP observation to be in 1981, with the first documented record for EWM in the lake occurring in 2004 (non-survey year). Cross Lake Association began chemical herbicide treatment of CLP in 2014 and EWM in 2016 and have continued management activities since. We are unable to make conclusions about the success of treatment activities to date due to the lack of efforts to track, monitor and quantify results pre- and post- treatment. It is likely that treatment had seasonal success as long term success does not appear to have occurred with re-occurrence of CLP and EWM in the same locations over proceeding years.

Table 5-1. Historic submerged and floating leaf vegetation summary for Cross Lake.

Common name	Scientific name	1955	1971	1981	1990	2000	2007	2014	2017
Berchtold's pondweed	*Potamogeton Berchtoldii*				x	x			
Bushy pondweed	*Najas flexilis*	x				x		1	
Canada waterweed	*Elodea canadensis*				x	x			5
Claspingleaf pondweed	*Potamogeton Richardsonii*		x		x	x			2
Coontail	*Ceratophyllum demersum*	x	x	x	x	x	x	49	27
Curlyleaf pondweed	*Potamogeton crispus*			x	x	x	x	5	20
Eurasian watermilfoil	*Myriophyllum spicatum*								7
Flatstem pondweed	*Potamogeton zosteriformis*					x	x	1	9
Floatingleaf pondweed	*Potamogeton natans*	x	x	x					
Greater duckweed	*Spirodela polyrhiza*					x		2	
Lesser duckweed	*Lemna minor*		x	x	x	x		10	1
Little yellow waterlily	*Nuphar microphyllum*							8	
Narrowleaf pondweed	*Potamogeton sp.*						x	3	
Northern watermilfoil	*Myriophyllum sibiricum*	x				x	x		
River pondweed	*Potamogeton nodosus*				x	x			
Robbins' pondweed	*Potamogeton Robbinsii*						x		

Common name	Scientific name	1955	1971	1981	1990	2000	2007	2014	2017
Sago pondweed	*Stuckenia pectinata*				x	x			
Star duckweed	*Lemna trisulca*					x			
Stonewort	*Nitella sp.*					x			
Water meal	*Wolffia columbiana*					x		5	
Water moss	*Drepanocladus sp.*					x			
Water stargrass	*Zosterella dubia*				x	x		1	
White water buttercup	*Ranunculus aquatilis*								1
White waterlily	*Nymphaea tuberosa*	x	x	x	x	x	x	12	5
Whitestem pondweed	*Potamogeton praelongus*							1	1
Water celery	*Vallisneria americana*	x	x		x	x	x	60	4
Yellow waterlily	*Nuphar variegatum*		x	x			x	1	

*An 'x' corresponds to the species being observed. Values correspond to reported frequency of occurrence.

5.3 POTENTIAL FACTORS INFLUENCING VEGETATION COMMUNITY

5.3.1 Water Quality

Annual monitoring of lake water quality on Cross Lake has been conducted periodically over the past 10 years. Most of the data was collected by the MPCA in support of the Snake River Watershed TMDL Study (MPCA, 2013) and by the Lake Association and Pine Soil and Water Conservation District (SWCD). Average annual total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth at the long-term monitoring station (central basin) since 2000 is summarized in Figure 5-1. Average annual Secchi depth measurements and TP and chl-a concentrations have failed to meet state waters quality standards every year in which these parameters were monitored over the past 10 years.

Due to the poor water quality conditions described above, Cross Lake was placed on Minnesota's 303(d) list of impaired waters in 2004 and a TMDL study for the lake was completed in 2013 (MPCA, 2013). Results of this study indicate nutrient (TP) loading to Pokegama will need to be decreased by 5,749 pounds per year in order for the lake to meet state water quality standards. Modeling done to develop the TMDL suggest TP load reductions will need to focus on internal (5,355 pounds per year) and watershed (1,136 pounds per year) sources.

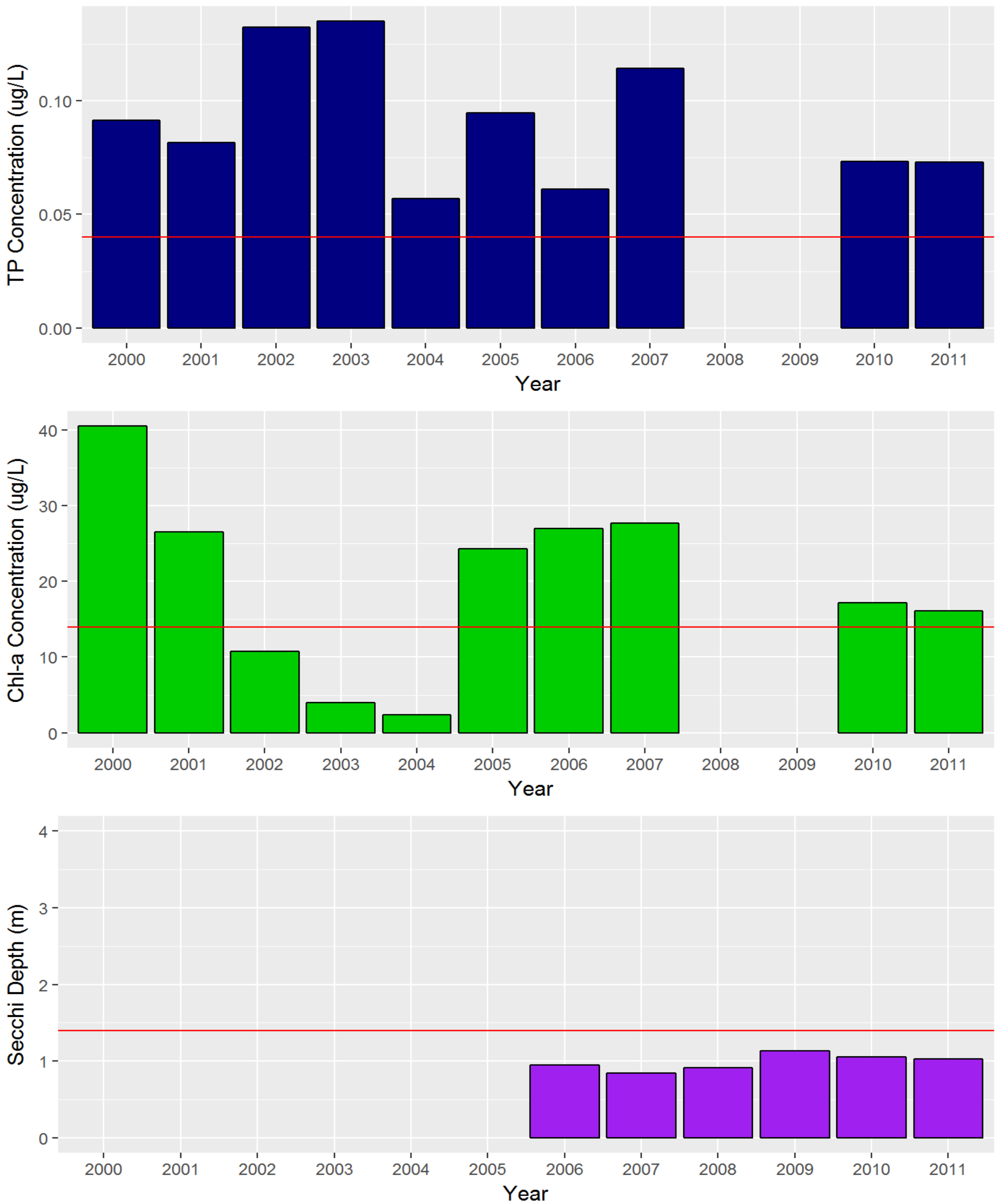


Figure 5-1. Cross Lake (central basin) average annual Secchi depth, chlorophyll-a and total phosphorus concentrations.

Appendix A provides figures showing how water quality conditions change in Cross Lake throughout the summer growing season. In general, all three water quality parameters are at or near water quality standards during the early growing season (May to early June). However, by late June, phosphorus concentrations begin to increase significantly which results in increased algae growth and reduced water clarity. Chlorophyll-a concentrations and Secchi depth measurements in Cross Lake consistently fail to meet water quality standards from mid-June through September (Appendix A). This suggests that water quality conditions within the lake, particularly poor water clarity, likely have a significant impact on vegetation growth, life cycle, and the types of AIS and native vegetation species growing in the lake.

5.3.2 Water Level

Lake level data was collected periodically in Cross Lake between 1962-1993, however very few measurements have been recorded since 1993. The United States Geologic Survey (USGS) operates a flow monitoring station on the Snake River just downstream of the Cross Lake dam (link to website). This station has continuously monitored river discharge and gage height on the Snake River since 1951. Discharge measurements from the USGS station were used to estimate surface water elevations in Cross Lake using the following weir equation:

$$H = (Q/2.8L)^{2/3}$$

Where H is the height above the dam, Q is discharge in the river, and L is the length of the weir. Estimated lake levels in Cross Lake according to this equation are presented in Appendix A. While no statistical analysis has been performed on this dataset, these results do not show any clear long-term trends over the past 65 years.

As discussed in Section 2.1.2, vegetation in lakes is not well suited at adapting to abrupt, short-term increases (bounces) in lake levels. Similar to Pokegama Lake, lake level bounces in Cross Lake greater than 2.0 feet within a 7-day period are common in response to 7-day rainfall totals greater than 2.0 inches. Since 2007, there have been 9 occasions in which lake levels bounced more than 2.0 feet within 7 days. The largest 7-day bounce occurred in 2016 when lake levels increased approximately 4.5 feet between July 10 and July 17 (Figure 5-2). This bounce was in response to 7-day rainfall totals of approximately 7.5 inches. Local knowledge indicates significant decreases in SAV abundance following these large lake level fluctuations.

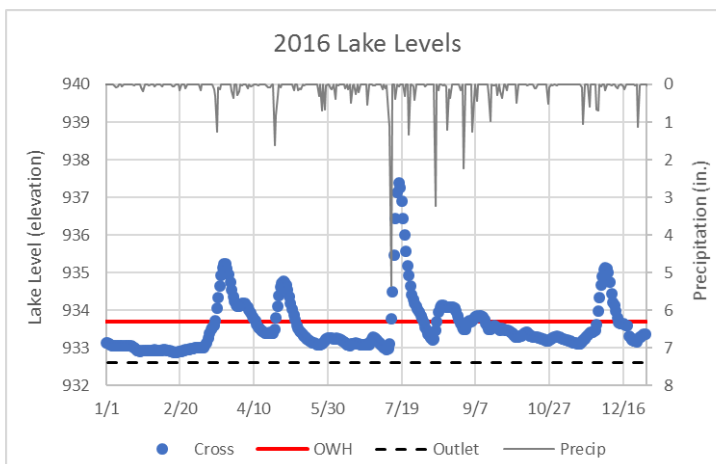


Figure 5-2. 2016 Cross Lake water levels

Water level bounce in Cross Lake could potentially be mitigated through modifications to the existing outlet structure. As discussed in Section 4.3.2., increasing the length of the spillway would result in higher flow rates over the dam which would reduce the water level bounce in the Snake River, Cross Lake, Pokegama Lake and other upstream waterbodies. A feasibility analysis would need to be conducted to determine effects on upstream and downstream flooding, as well as outlet design and construction costs.

5.3.3 Sediment

No sediment information or data is currently available within the littoral areas of Cross Lake. In 2012, sediment cores were collected near the deepest part of the north, central, and south basins. These cores were analyzed for various chemical and physical parameters in support of the TMDL study (MPCA, 2013). These analyses included phosphorus content, phosphorus release, organic matter content, and bulk density. Results showed that sediment in the all three basins has moderate bulk density and organic matter content, high phosphorus levels, and extremely high phosphorus release. Since sediment conditions in deep lakes vary drastically between littoral areas (<15 feet) and deep areas, it is difficult to use the deep-water sediment core results to make any firm conclusions about the littoral sediment in Cross Lake. However, given the eutrophic nature of the lake and the high sediment phosphorus content in all three basins, it is very likely that phosphorus, nitrogen, and organic matter has accumulated in the sediment throughout the littoral areas and sediment conditions are likely favorable to support excessive plant growth.

5.3.4 Fish Community

Cross Lake receives moderate to high fishing pressure and is actively stocked for walleye and muskellunge on an annual basis by the MnDNR. The most recent fisheries assessment was conducted in 2014 by the MnDNR and relatively average abundances of fish overall. Suggesting that fish opportunities and a potentially balanced fishery is in place within the lake. Walleye did appear to be at relatively low catch rates while bluegill catch rate was the highest recorded for the lake. Long-term records demonstrate the current state of fish abundances and fish groupings are relatively average to long term assessments (Figure 5-3).

Common Carp are present within Cross Lake, however their population size, density and influence on the vegetation community is unknown at this time. Traditional MnDNR trap and gill net methodology is poor at capturing and representing the common carp population due to their learned avoidance of the gear. We recommended utilizing traditional survey methods in terms of presences and absence when assessing common carp existence in a lake. Further assessment is warranted to determine their impact on the SAV community. Since Cross Lake is connected to a large river network, long-term sustained carp management may be difficult without significant structural engineering. The presence of lake sturgeon within the lake system may present permitting issues for structures as the fish species is a fish closely monitored by MnDNR researchers. Regardless, common carp population assessment or exclosure experiments would allow inferences to be made in regards to the influence fish are having on the current SAV community.

Sunfish species comprised a high percentage of the fish catch which may pose concerns for natural weevil control of Eurasian Watermilfoil within the lake. Declining catch rates of top predator (walleye) may also be a potential concern. Fish management activities should continue to follow MnDNR fishing regulations and practice selective fishing or catch release fishing, to maintain a balanced fishery.

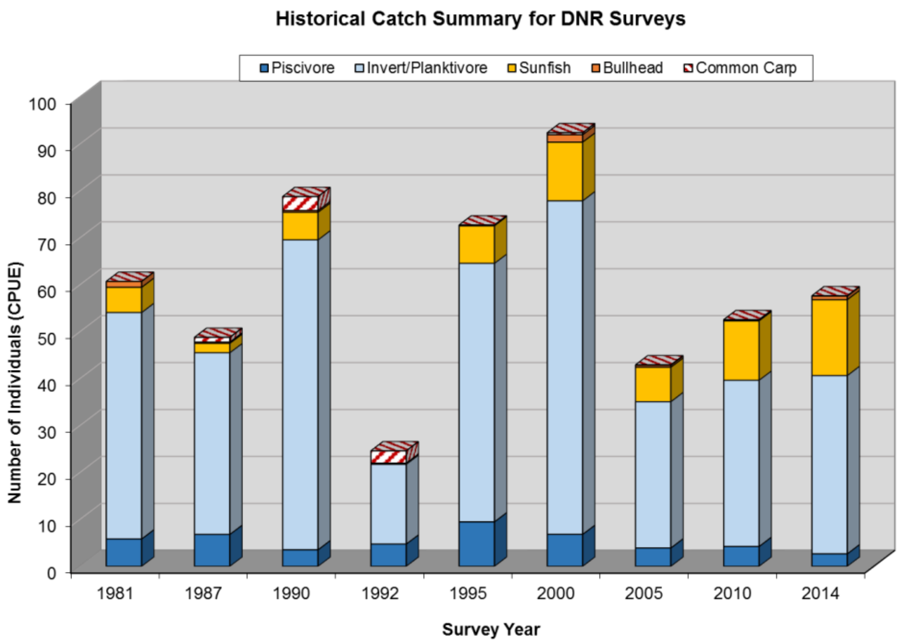


Figure 5-3. Cross Lake fisheries summary.

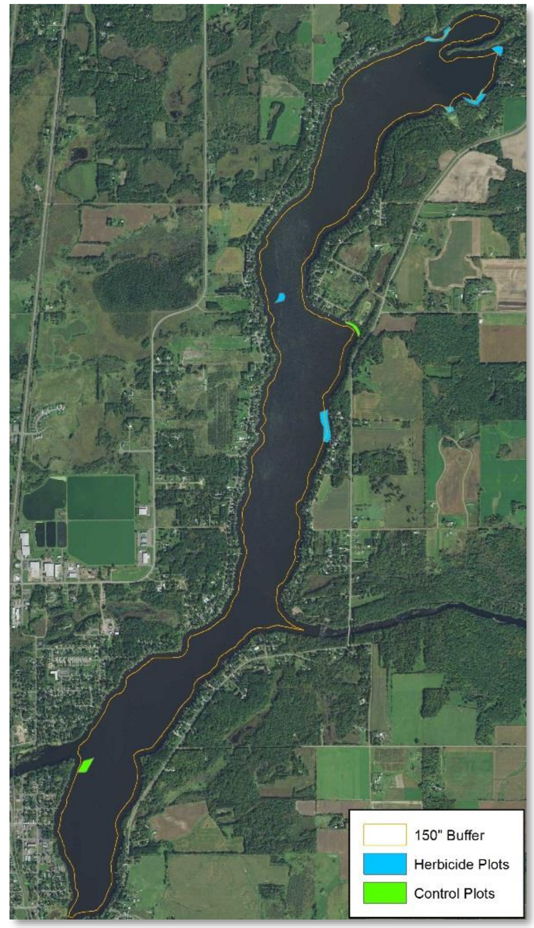
5.4 MANAGEMENT RECOMMENDATIONS

5.4.1 Development of Monitoring Plots

The intention of developing monitoring plots within Cross Lake is to document and quantify the changes in the SAV community following specific management activities to 1) better understand the success of a given management activities and 2) adapt management activities to best control and reduce the impact AIS and restore a healthy SAV community. For a detailed standard operating procedure and equipment to establish and conduct SAV monitoring for this management plan please consult Appendix B.

The Cross Lake Association had proposed areas to the MnDNR in previous years in which they would like to chemically treat CLP and expressed for similar treatment to occur in 2017. Without a recent point intercept survey and ciBiobase assessment we utilized previous CLP delineation efforts conducted by the MnDNR to select location for chemical treatment and continued post treatment monitoring. The MnDNR conducted a field delineation and vetted proposed areas, ultimately approving 8.57 chemical treatment acres within the lake.

Wenck and Pine County conducted a full lake point intercept survey on Cross Lake (May 31st, 2017). The survey was conducted post chemical treatment; therefore, no additional treatment plots would be proposed in 2017 based on these efforts. During the survey, additional CLP plots were identified and will serve as control plots. No management activity should occur in control plots as they are intended to be surveyed and used in comparison to treatment plots to quantify treatment effectiveness. The location of control plots should remain constant annually to ensure that no remnant management activity is influencing the SAV community.



We recommend continued monitoring throughout the SAV growing season to document changes in the SAV communities in all monitoring plots. Continued monitoring and management activities should occur in these same plots in subsequent years to assess short and long-term success of treatment. Continuing to adaptive and evolve management activities will be important as results and treatment success is quantified. A more detailed SOP of recommended monitoring procedures is outlined in Appendix B.

5.4.2 Conclusions

Reduced light penetration due to poor water quality and large lake level bounces are the most prominent factors impeding the restoration of a healthy SAV community within Cross Lake. If light availability increases, the SAV will likely respond to improved growing conditions with increased biomass and the number of species persisting within the lake. The Snake River TMDL assessments identified both watershed loading and internal lake processes are contributing to decreased water quality and clarity in Cross Lake, therefore efforts targeting both areas will improve water quality.

Siting and installation of watershed BMPs to target high nutrient loading areas will help reduce watershed loads to Cross Lake. Application of a product such as aluminum sulfate (alum) would help permanently bind what would otherwise become mobile phosphorus during mid- to late summer months, which would greatly decrease internal load and improve water quality and light penetration within the lake. An internal load feasibility would need to be conducted to determine the location(s) and amount of alum (or other product) needed and the associated costs.

Water level feasibility assessments for water level control methods would determine effects on upstream and downstream flooding, as well as outlet design and construction costs associated with modifications. The goal with outlet modification is to decrease the amount of water level bounce observed in the lake, therefore, maintaining the area light reaches SAV

Recommended actions to consider:

- ▲ Internal load feasibility assessment
  - Alum treatment
- ▲ Water level stabilization feasibility assessment
  - Outlet structure modification
  - Cross Lake dam lengthening
- ▲ Watershed BMPs
  - Agriculture practices
  - Urban stormwater practices (Pine City)
  - Wetland restorations

Light may not be the only factor limiting the SAV community within Cross Lake. It is possible that the fish community (i.e. Common Carp) are directly uprooting and displacing desired SAV. If fish are having a strong influence on the vegetation community improvements in water quality may not result in any changes to the SAV community and/or no noticeable changes to the presence or abundance of desired SAV species. Common carp population assessment or conducting fish exclosure experiments would allow inference and conclusions to be drawn to the impacts fish are having on the SAV community. Efforts to transplant SAV to recolonize a lake and develop a viable seed bank of desired SAV can be impeded by the fish community, therefore, negating restoration efforts. Recommended actions to consider:

- ▲ Common carp population assessment
- ▲ Fish exclosure experiment

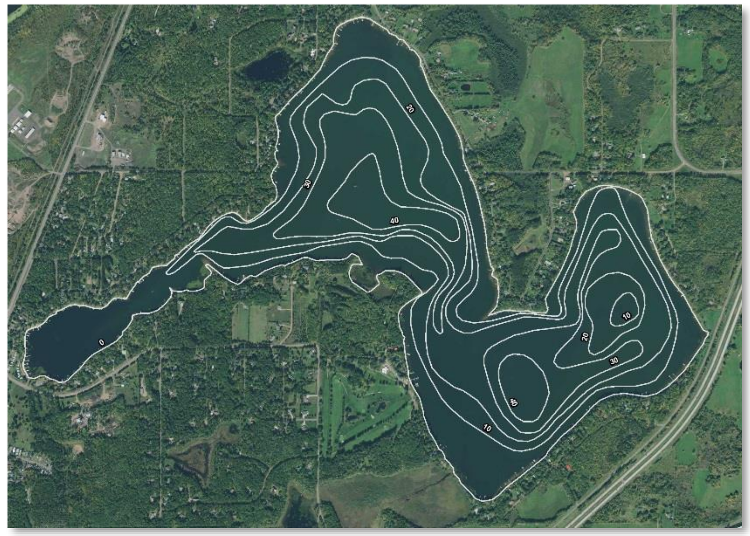
Vegetative AIS pose another biological concern to enhancing the SAV community. Though AIS are more valuable to lake health than no vegetation, improving growth conditions for SAV may promote extensive growth of CLP and EWM in the lake. The monitoring efforts beginning in 2017 will quantify the effectiveness of treatment activities provide research opportunities aimed at reducing their presence and restoring diverse native stands of vegetation. Should growing conditions improve and limited desired SAV recolonize areas within the lake, management activities may need to consider transplanting species. Vegetation transplanting, if done correctly and in favorable conditions, has been beginning to show promise at restoring the SAV community in areas within a lake. Recommended actions to consider:

- ▲ Update late season SAV survey
- ▲ Monitor vegetation management activities
- ▲ Determine and locate potential waterbodies were transplants can come from
- ▲ Adapt management activities as new technologies and methodologies as they become available

In summary, the vegetation community on Cross Lake is poor and restoration should be the focus of management activities. Improving water quality conditions across the lake and/or controlling the water level fluctuation present a large challenge but perhaps the best chance in enhancing and restoring the SAV community in Cross Lake. Beginning to track and monitor changes in the SAV community will allow insight to management activities and assist in adapting management to combat AIS and promote a healthy lake ecosystem.

6.0 Sand Lake

6.1 LAKE DESCRIPTION



Sand Lake is a 527 acre lake located two miles south of Moose Lake, Minnesota. Sand Lake has a maximum depth of 47 feet and approximately 40% of the lake is 15 feet or less in depth. Compared to Pokegama and Cross Lake, Sand Lake has a relatively small direct drainage area (2,758 acres) that is made up of small tributaries and wetlands that discharge directly to the lake. Land use and land cover within Sand Lake's direct drainage area is predominately forest land with some development occurring around the shoreline of the lake and the outer edges of Moose Lake. Sand Lake also receives outflow from Island Lake and its 4,000 acre watershed which is located directly east of Sand Lake. Sand Lake outflows to the Moose Horn River, a major tributary to the Kettle River, via surface flow through a channel on the northwest corner of the lake.

6.2 VEGETATION COMMUNITY

Historic vegetation assessments have been conducted by the MnDNR (1949, 57, 72, 82, 92, 98, 2002, 08, 09 and 10). These assessments documented a total of 39 species of aquatic vegetation that have been observed within Sand Lake at some point in time since 1949. Species observed varied from 8 to 26 species observed at any given point in time (Table 6-1).
All surveys are believed to occur in late summer when EWM and native vegetation species were near peak growth. No record of early season survey efforts exist.

The most recent full lake point intercept survey was conducted on July 7th 2010. This assessment collected frequency of occurrence information for each observed species and found that the most common species were all native SAV species. The most recent survey did not detect either CLP or EWM within the lake, however, more recent EWM delineation efforts conducted by the MnDNR have documented EWM in the lake. The 2010 survey report noted that the observed vegetation community was relatively healthy, supporting a diverse mixture of SAV species.

Historic records documented the first EWM in the lake occurring in 2003 (non-survey year), CLP has not been documented in Sand Lake. The Windemere Lake Association (Sand Lake and others) began chemical herbicide treatment of EWM in 2006 and has continued management activities through 2016 with planned treatment in 2017. No EWM was treated in 2004, 05, 09, 10, or 11. 2010 point intercept survey reported small stands of EWM existed outside of survey point locations. It is likely that the low density and occurrence of

EWM, resulted in no pursued management activities by the Lake Association during previously mentioned years. We are unable to make conclusions about the success of treatment activities to date due to the lack of efforts to track, monitor and quantify results pre- and post- treatment. It is likely that treatment had seasonal success and possible short-term annual success, however, EWM appears to have recovered in Sand Lake in recent years.

Table 6-1. Historic submerged and floating leaf vegetation summary for Sand Lake.

Common name	Scientific name	1949	1957	1972	1982	1992	1998	2002	2008	2009	2010
Bladderwort sp.	*Utricularia sp.*							x			
Bushy pondweed	*Najas flexilis*	x	x			x	x	x		x	10
Canada waterweed	*Elodea canadensis*			x	x	x	x	x	x	x	15
Claspingleaf pondweed	*Potamogeton Richardsonii*	x	x	x	x	x	x		x	x	4
Coontail	*Ceratophyllum demersum*			x	x	x	x	x	x	x	4
Creeping spearwort	*Ranunculus flammula*									x	
Eurasian watermilfoil	*Myriophyllum spicatum*								x		
Flatstem pondweed	*Potamogeton zosteriformis*					x	x	x	x	x	4
Floatingleaf pondweed	*Potamogeton natans*	x	x	x	x	x		x	x		
Greater bladderwort	*Utricularia vulgaris*									x	1
Greater duckweed	*Spirodela polyrhiza*					x				x	
Illinois pondweed	*Potamogeton illinoensis*										
Largeleaf pondweed	*Potamogeton amplifolius*					x	x	x	x	x	11
Leafless water milfoil	*Myriophyllum tenellum*						x			x	2
Leafy pondweed	*Potamogeton foliosus*								x		
Lesser duckweed	*Lemna minor*			x	x	x					
Little yellow waterlily	*Nuphar microphyllum*										1
Muskgrass	*Chara sp.*									x	2
Narrowleaf pondweed sp.	*Potamogeton sp.*							x	x	x	7
Northern watermilfoil	*Myriophyllum sibiricum*			x	x	x		x			
Quillwort	*Isoetes echinospora*										1
Ribbon leaved pondweed	*Potamogeton epihydrus*						x			x	1

Common name	Scientific name	1949	1957	1972	1982	1992	1998	2002	2008	2009	2010
Robbins' pondweed	*Potamogeton Robbinsii*	x	x	x	x	x	x	x	x	x	61
Sago pondweed	*Stuckenia pectinata*			x	x	x					
Slender waterweed	*Elodea nuttallii*									x	
Small pondweed	*Potamogeton pusillus*			x	x					x	
Snailseed pondweed	*Potamogeton spirillus*						x				
Star duckweed	*Lemna trisulca*								x		
Stonewort	*Nitella sp.*								x	x	14
Variable pondweed	*Potamogeton gramineus*	x	x				x		x	x	9
Vasey's pondweed	*Potamogeton vaseyi*	x					x				
Very small pondweed	*Potamogeton pusillus*						x				
Water marigold	*Bidens beckii*						x				
Water shield	*Brasenia schreberi*			x	x	x	x		x	x	2
Water stargrass	*Zosterella dubia*						x				
White waterlily	*Nymphaea tuberosa*	x	x	x	x	x	x	x	x		2
Whitestem pondweed	*Potamogeton praelongus*						x	x	x	x	9
Water celery	*Vallisneria americana*			x	x	x	x	x	x	x	23
Yellow waterlily	*Nuphar variegatum*	x	x	x	x	x	x	x	x	x	2

*An 'x' corresponds to the species being observed. Values correspond to reported frequency of occurrence.

6.3 POTENTIAL FACTORS INFLUENCING VEGETATION COMMUNITY

6.3.1 Water Quality

Annual monitoring of lake water quality on Sand Lake has been conducted periodically over the past 10 years. Most of the data has been collected by the Lake Association, Pine SWCD, and the MPCA in support of the Kettle River Watershed's Monitoring and Assessment Study. Average annual total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth for the past 10 years is summarized in Figure 6-1. Average annual Secchi depth measurements and TP and chl-a concentrations for Sand Lake have met state waters quality standards every year in which these parameters were monitored over the past 10 years.

The MPCA is currently completing the Kettle River Watershed Monitoring and Assessment Report which will identify lakes and streams within the watershed that are currently meeting state water standards, and those that are considered impaired (not meeting standards). Waterbodies that are considered impaired will be included in the Kettle River Watershed TMDL study which has a target completion date of 2019 (link to MPCA's Kettle River

Watershed page). As described above, Sand Lake is currently meeting state water quality standards for all three parameters and therefore is not impaired. Strategies to protect water quality in Sand Lake and its watershed will be developed as part of the MPCA's Watershed Restoration and Protection Strategy (WRAPS) report for the Kettle River. This report will be done at the same time as the watershed-wide TMDL study and therefore also has a target completion date of 2019.

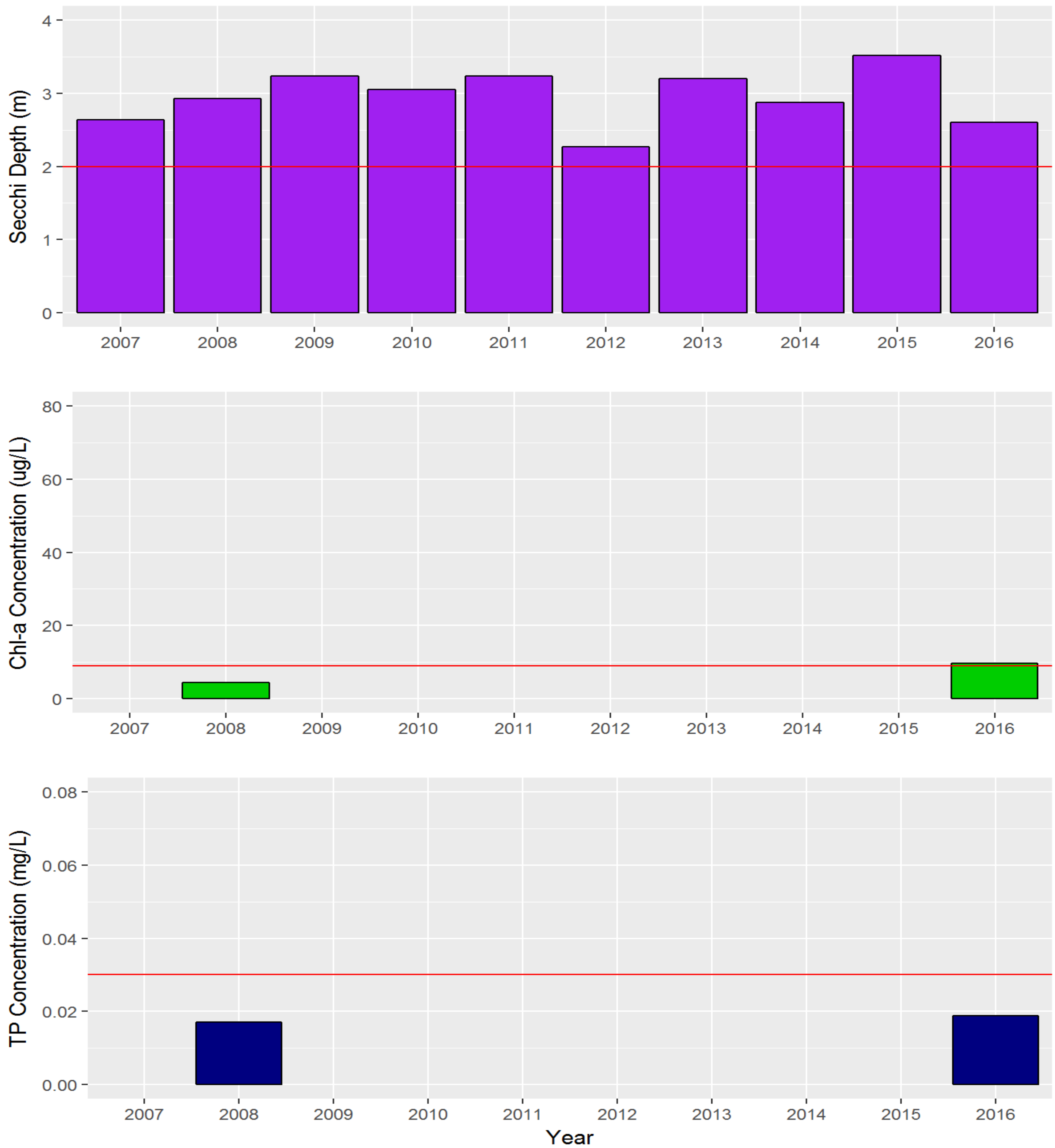


Figure 6-1. Sand Lake average annual Secchi depth, chlorophyll-a and total phosphorus concentrations.

6.3.2 Water Level

Lake level data has been collected periodically in Sand Lake since 1972 (See Appendix A). These data show that four of the five highest average annual lake levels on record have occurred within the last 10 years. While no statistical analysis has been performed on this dataset, these results suggest that lake levels in Sand Lake may be increasing.

SAV communities can often adjust to long-term changes in lake levels but are not well suited at adapting to abrupt, short-term increases (bounces) in lake levels. Due to Sand Lake's watershed size and limited downstream controls, water level response to larger storm events is slower and more gradual than Pokegama and Cross Lakes. The largest monitored 7-day lake level bounce in Sand Lake occurred in 2012 when lake levels increased approximately one foot in response to 7-day rainfall totals of approximately five inches (Figure 6-2)

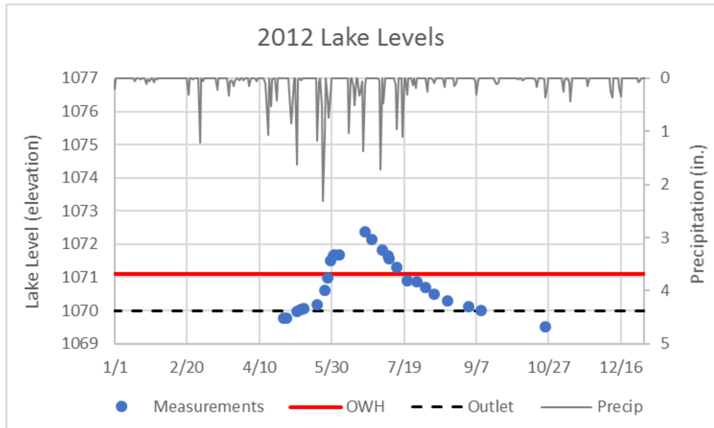


Figure 6-2. 2012 Sand Lake water levels

Since lake bounce in Sand Lake is not a major concern, lake level management should not be considered a priority at this time for managing vegetation. However, it is recommended that the DNR and/or lake association continue monitoring lake levels in Sand Lake to evaluate the potential increasing trend in average annual lake levels. Also, the lake association should periodically inspect the lake's outlet and outlet channel to make sure it is free of debris, tree downfalls, and other obstructions.

6.3.3 Sediment

There are currently no sediment data/surveys available to assess sediment conditions in Sand Lake.

6.3.4 Fish Community

Sand Lake has a variety of targeted game fish species and is actively stocked for walleye on an annual basis by the MnDNR. A period of greater fish catch rates appeared in the late 90s and early 2000s, however the most recent survey documented similar catch rates to thus observed in the 80s and early 90s (Figure 6-3).

In the most recent survey, Bluegill comprised 47% of the catch and limited large piscivorous fish species (i.e. Northern Pike) were observed. The large proportion of bluegill likely has the potential to limit significant weevil control of EWM within the lake. Weevil control will not eradicate EWM but has the potential to reduce nuisance level growth of EWM in systems where their abundance is high. It is noted by the MnDNR that catch rates of Bluegill are around average for lakes with similar characteristics, however, it is unclear if this is most appropriate condition for the lake. It is unclear whether an imbalanced fishery currently exists within Sand Lake and efforts to practice selective harvesting or catch and release may prove beneficial at protecting large piscivorous fish species.

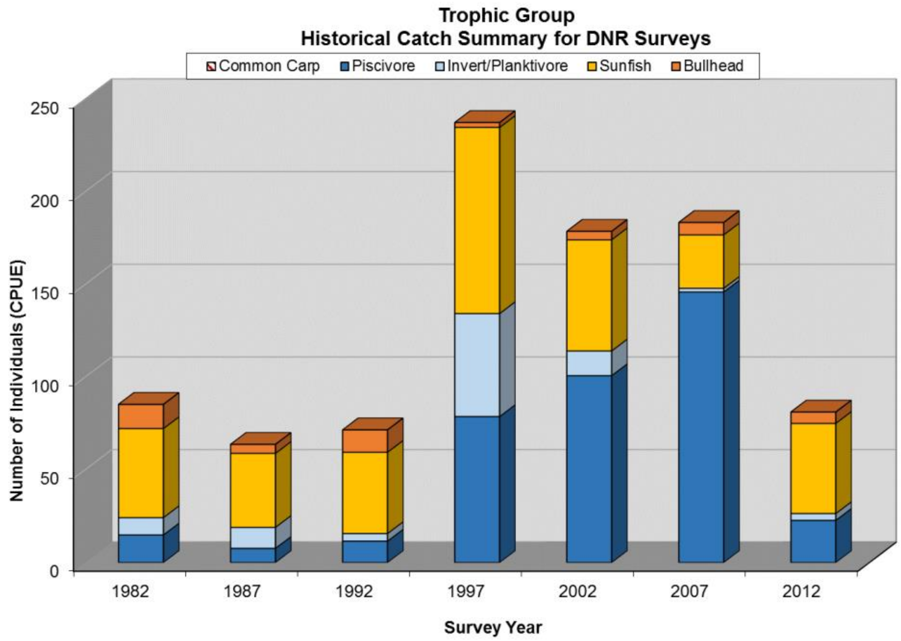


Figure 6-3. Sand Lake fisheries summary.

Common Carp do not appear to be present within Sand Lake. Further assessment is not warranted at this time to determine if common carp exist in the system or are densities that could cause degradation to the SAV community and water quality.

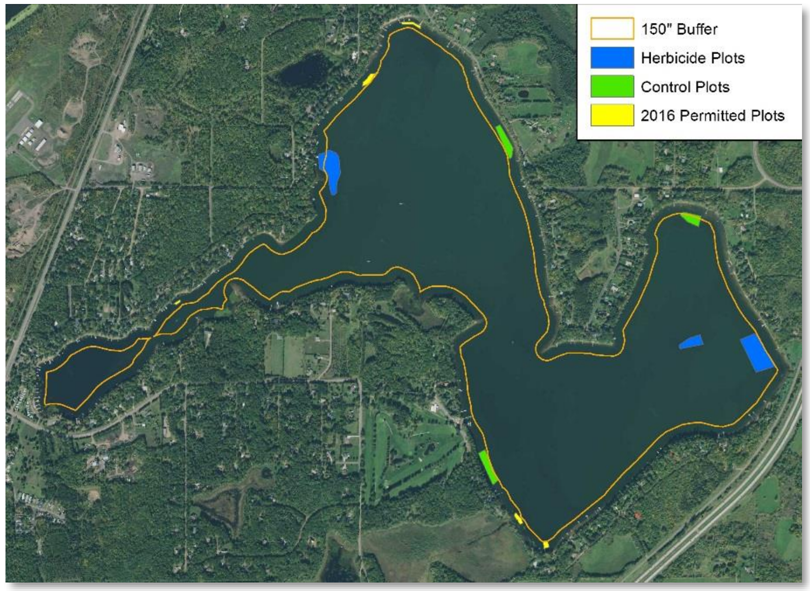
6.4 MANAGEMENT RECOMMENDATIONS

6.4.1 Development of Monitoring Plots

The intention of developing monitoring plots within Sand Lake is to document and quantify the changes in the SAV community following specific management activities to 1) better understand the success of a given management activities and 2) adapt management activities to best control and reduce the impact AIS and restore a healthy SAV community. For a detailed standard operating procedure and equipment to establish and conduct SAV monitoring for this management plan please consult Appendix B.

The Windermere Lake Association is planning to chemically treat up to 10 acres of EWM on Sand Lake. Without a recent point intercept survey and ciBiobase assessment we utilized 2016 EWM delineation efforts conducted by the MnDNR to select location for chemical treatment and continued post treatment monitoring. The MnDNR will conduct field delineations this summer to field delineate and vet proposed areas. No large (>5 acres) stands of EWM were documented to exist in Sand Lake, with the largest areas ~2.7 acres in size. We have previously described concerns to small scale treatment efficiency, therefore, have minimized the amount of areas recommended for chemical treatment within Sand Lake until effectiveness of application can be quantified or large EWM stands are observed. In total 6 areas delineated in 2016 were observed to be 0.7 acres or larger in size, we randomly selected three to serve as treatment plots (5.8 acres) and three to serve as control plots (2.6 acres).

No management activity should occur in control plots as they are intended to be surveyed and used in comparison to treatment plots to quantify treatment effectiveness. The location of control plots should remain constant annually to ensure that no remnant management activity is influencing the SAV community. Without knowing the exact location of historic management activities, we cannot conclude that current control plots are persisting outside of remnant influences.



Five additional areas were delineated in 2016 and were observed to be 0.35 acres or less in size. Additional areas can be chemically treated at the discretion of the Association and efforts to document the location, timing and treatment related information would be beneficial for further use. Due to the relatively small size, decreased efficiency of chemical treatment and growing concerns of hybridized milfoil resistance to herbicide pursuing small scale harvesting (i.e. hand pulling, mechanical weed cutting) may prove beneficial at control EWM in small infested areas. Due to the location of vegetation permits may be required to conducted said harvesting and should be vetted with the MnDNR as a management option on Sand Lake. Should this option be pursued similar monitoring efforts should be practiced to assist in quantifying the short and long term success of management activities.

We recommend continued monitoring throughout the SAV growing season to document changes in the SAV communities in all monitoring plots. Continued monitoring and management activities should occur in these same plots in subsequent years to assess short and long-term success of treatment. Continuing to adaptive and evolve management activities will be important as results and treatment success is quantified. A more detailed SOP of recommended monitoring procedures is outlined in Appendix B.

6.4.2 Conclusions

Light limitation does not appear to be a current restoration concern for Sand Lake. No internal loading or water level control feasibility assessment are warranted at this time; however, watershed BMP could be an option for ensuring the maintenance of a high-water clarity standard is maintained within the lake. Recommended actions to consider:

- ▲ Watershed BMPs
  - Agriculture practices
  - Wetland restorations

The fish community within Sand Lake may be having an influence on the SAV community. The presence of native weevil populations within the lake are unknown, but if present, may present a natural control (not eradicate) to reducing the presence of EWM within the lake.

Weevils are very susceptible to sunfish predation, therefore large sunfish populations within the lake have the potential to limit large weevil populations. Weevil population assessment and fish exclosure experiments would allow inference and conclusions to be drawn to the impacts fish are having on the EWM populations within the lake. However, long-term sustained management of the fishery may be difficult and would require coordination with the MnDNR to instill fishing regulations to reduce sunfish populations within the lake. Recommended actions to consider:

- Weevil population assessments
- Fish exclosure experiment
- Promote large piscivorous catch and release

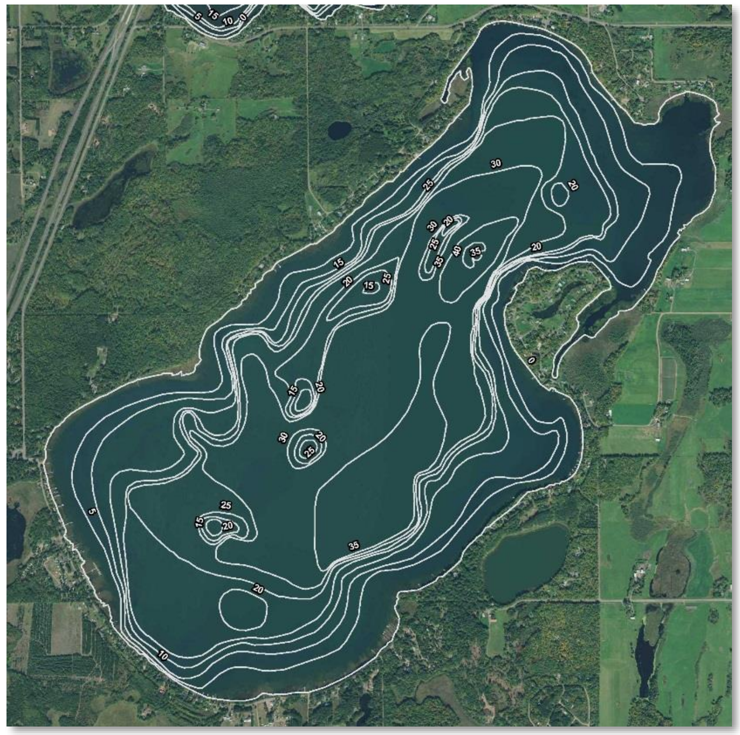
EWM poses a threat to protecting the SAV community within Sand Lake due to its ability to outcompete native vegetation and spread throughout a lake. Local conditions (i.e. substrate, sediment nutrient) within the lake are unknown and are a potential mechanism that would explain the occurrence and distribution of SAV species and EWM across the lake. Investigation into local site conditions (i.e. sediment chemistry and composition) in areas where EWM exists and where native SAV grows may allude mechanisms that promote EWM growth. In understanding these mechanisms, management activities can look to remediate local conditions to reduce the presence of EWM and promote native SAV growth. Recommended actions to consider:

- Update late season SAV survey
- Monitor vegetation management activities
- Adapt management activities as new technologies and methodologies as they become available
- Develop and conduct localized assessments to understand site specific conditions within the lake

In summary, the vegetation community on Sand Lake is healthy with concerns of AIS spreading throughout the lake. Protection initiatives and efforts to begin to understand conditions that promote EWM within the lake will prove beneficial to both the lake and surrounding lakes in limiting the spread of AIS. Beginning to track and monitor changes in the SAV community will allow insight to management activities and assist in adapting management decisions to combating AIS and maintain a healthy lake ecosystem.

7.0 Sturgeon Lake

7.1 LAKE DESCRIPTION



Sturgeon Lake is a 1,706 acre lake located four miles south of Moose Lake, Minnesota and two miles east of Sturgeon Lake, Minnesota. Sturgeon Lake has a maximum depth of 40 feet and approximately 29% of the lake is 15 feet or less in depth. Similar to Sand Lake, Sturgeon Lake has a relatively small direct drainage area (4,843 acres) that is made up of small tributaries and lakes that discharge directly to the lake. The smaller lakes within the Sturgeon Lake drainage area include Dago, Turtle, Rush and Johnson. Land use and land cover within Sturgeon's drainage area is predominately forest land with some agriculture east of the lake and development occurring around the shoreline of the lake. Sturgeon Lake is considered a landlocked basin and therefore it does not discharge to any downstream waterbodies.

7.2 VEGETATION COMMUNITY

Historic vegetation assessments have been conducted by the MnDNR (1955, 67, 75, 86, 96, 98, and 2009). These assessments documented a total of 31 species of aquatic vegetation that have been observed within Sturgeon Lake at some point in time since 1955. Species documented during surveys varied from 8 to 26 species (Table 7-1). All surveys are believed to occur in late summer when EWM and native vegetation species were near peak growth. No record of early season survey efforts exist.

The most recent full lake point intercept survey was conducted on several dates between July 1- 10th, 2009. This assessment collected frequency of occurrence information for each observed species and found that the most common species were all native SAV species. Vegetation was observed grow to depths around 20 feet. The most recent survey documented both CLP and EWM within the lake. The 2009 survey report noted that the observed vegetation community was relatively healthy, supporting a diverse mixture of SAV species.

Historic records documented the first CLP observation to be in 1986, with the first documented record for EWM in the lake occurring in 2008 (non-survey year). The

Windemere Lake Association (Sturgeon Lake and others) began chemical herbicide treatment of EWM in 2009 and has continued management activities through 2016 with planned treatment in 2017. Each year the amount of EWM treated has increased as the presence of EWM continues to spread across the lake. We are unable to make conclusions about the success of treatment activities to date due to the lack of efforts to track, monitor and quantify results pre- and post- treatment. It is likely that treatment had seasonal success as long term success does not appear to have occurred with re-occurrence of EWM in the same locations over proceeding years.

CLP was observed within Sturgeon Lake in 1986 and again in 2009, however, without early season assessments frequency of occurrence information does not accurately depict its occurrence within the lake. Since CLP has not been a concern with the Lake Association the growth of CLP in the lake is likely limited and occurs infrequently.

Table 7-1. Historic submerged and floating leaf vegetation summary for Sturgeon Lake.

Common name	Scientific name	1955	1967	1975	1986	1996	1998	2009
Braun's quillwort	*Isoetes echinospora*						x	4
Bushy pondweed	*Najas flexilis*					x	x	15
Canada waterweed	*Elodea canadensis*		x	x	x	x	x	11
Claspingleaf pondweed	*Potamogeton Richardsonii*		x			x	x	4
Coontail	*Ceratophyllum demersum*	x	x	x	x	x	x	27
Creeping spearwort	*Ranunculus flammulus*							4
Curlyleaf pondweed	*Potamogeton crispus*				x			1
Eurasian watermilfoil	*Myriophyllum spicatum*							2
Filamentous algae						x		
Flatstem pondweed	*Potamogeton zosteriformis*		x			x	x	6
Floatingleaf pondweed	*Potamogeton natans*		x	x	x		x	1
Fries' Pondweed	*Potamogeton friesii*						x	
Greater bladderwort	*Utricularia vulgaris*					x	x	1
Greater duckweed	*Spirodela polyrhiza*					x	x	
Illinois pondweed	*Potamogeton illinoensis*							11
Largeleaf pondweed	*Potamogeton amplifolius*		x			x	x	8
Leafless watermilfoil	*Myriophyllum tenellum*						x	6

Common name	Scientific name	1955	1967	1975	1986	1996	1998	2009
Leafy pondweed	*Potamogeton foliosus*					x		
Little yellow waterlily	*Nuphar microphylla*							1
Muskgrass	*Chara sp.*	x	x			x		28
Narrowleaf pondweed	*Potamogeton sp.*		x			x		14
Northern watermilfoil	*Myriophyllum sibiricum*		x	x	x	x	x	9
Nuttall's waterweed	*Elodea nuttallii*						x	
Guadalupe Island naiad	*Najas guadalupensis var. olivacea*						x	
Ribbon leaved pondweed	*Potamogeton epihydrus*						x	
Robbins' pondweed	*Potamogeton Robbinsii*		x			x	x	40
Snailseed pondweed	*Potamogeton spirillus*						x	
Star duckweed	*Lemna trisulca*				x		x	
Stonewort	*Nitella sp.*							9
Turion duckweed	*Lemna turionifera*						x	
Variable pondweed	*Potamogeton gramineus*		x			x	x	11
Vasey's pondweed	*Potamogeton vaseyi*						x	
Very small pondweed	*Potamogeton pusillus*						x	
Water buttercup	*Ranunculus sp.*							0.4
Water marigold	*Bidens beckii*						x	3
Water moss	*Drepanocladus sp.*					x		1
Water shield	*Brasenia shcreberi*							0.2
Water smartweed	*Polygonum amphibium*			x	x	x	x	2
Water stargrass	*Zosterella dubia*						x	
White water crowfoot	*Ranunculus aquatilis*						x	
White waterlily	*Nymphaea tuberosa*		x	x	x	x	x	2
Whitestem pondweed	*Potamogeton praelongus*						x	17
Water celery	*Vallisneria americana*	x				x	x	1
Yellow waterlily	*Nuphar variegatum*		x			x	x	2

*An ‘x’ corresponds to the species being observed. Values correspond to reported frequency of occurrence.

7.3 POTENTIAL FACTORS INFLUENCING VEGETATION COMMUNITY

7.3.1 Water Quality

Annual monitoring of lake water quality on Sturgeon Lake has been conducted periodically over the past 10 years. Most of the data has been collected by the Lake Association, Pine SWCD, and the MPCA in support of the Kettle River Watershed's Monitoring and Assessment Study. Average annual total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth for the past 10 years is summarized in Figure 7-1. Average annual Secchi depth measurements and TP and chl-a concentrations for Sturgeon Lake have met state waters quality standards every year in which these parameters were monitored over the past 10 years.

The MPCA is currently completing the Kettle River Watershed Monitoring and Assessment Report which will identify lakes and streams within the watershed that are currently meeting state water standards, and those that are considered impaired (not meeting standards). Waterbodies that are considered impaired will be included in the Kettle River Watershed TMDL study which has a target completion date of 2019 (link to MPCA's Kettle River Watershed page). As described above, Sturgeon Lake is currently meeting state water quality standards for all three parameters and therefore is not impaired. Strategies to protect water quality in Sturgeon Lake and its watershed will be developed as part of the MPCA's Watershed Restoration and Protection Strategy (WRAPS) report for the Kettle River. This report will be done at the same time as the watershed-wide TMDL study and therefore also has a target completion date of 2019.

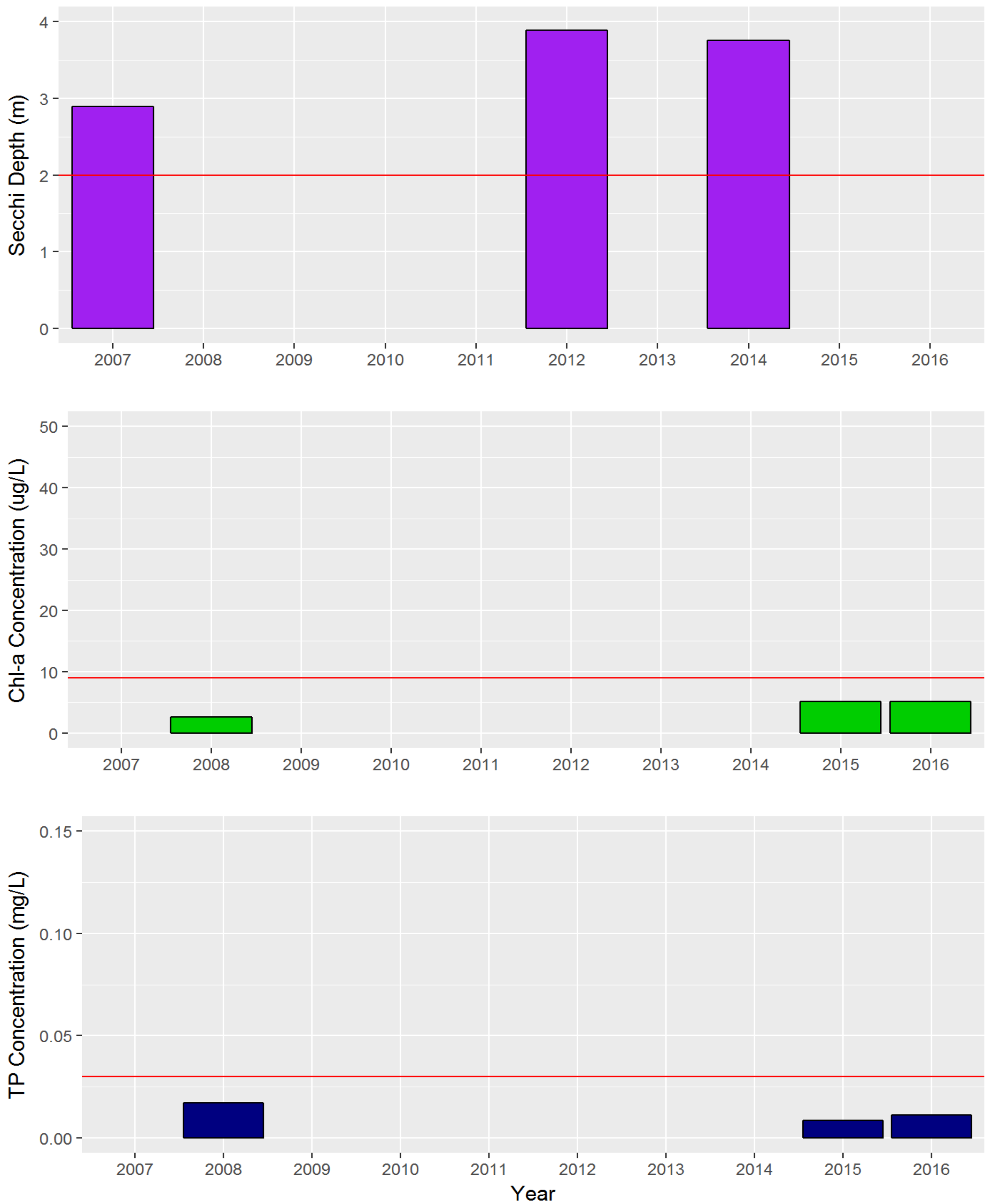


Figure 7-1. Sturgeon Lake average annual Secchi depth, chlorophyll-a and total phosphorus concentrations.

7.3.2 Water Level

Lake level data has been collected periodically in Sturgeon Lake since the late 1960s (See Appendix A). These data show no clear trends, however average annual lake levels have been up approximately one foot over the past five years (2011-2016) compared to lake level data from 2006-2010.

SAV communities can often adjust to long-term changes in lake levels but are not well suited at adapting to abrupt, short-term increases (bounces) in lake levels. Due to Sturgeon Lake's watershed size and limited downstream controls, water level response to larger storm events is slower and more gradual than Pokegama and Cross Lakes. The largest monitored 7-day lake level bounce in Sturgeon Lake occurred in 2016 when lake levels increased approximately 0.6 feet in response to 7-day rainfall totals of approximately five inches (Figure 7-2)

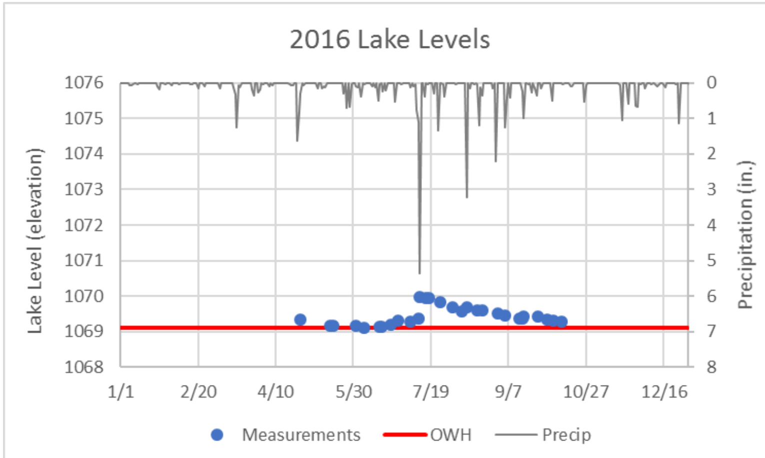


Figure 7-2. 2016 Sturgeon Lake water levels

Since lake bounce in Sturgeon Lake is not a major concern, lake level management should not be considered a priority at this time for managing vegetation. However, it is recommended that the DNR and/or lake association continue monitoring lake levels in Sturgeon Lake to evaluate the increased lake levels noted over the past five years.

7.3.3 Sediment

There is currently no sediment data/surveys available to assess sediment conditions in Sand Lake.

7.3.4 Fish Community

Sturgeon Lake has a variety of targeted game fish species and is actively stocked for walleye on an annual basis by the MnDNR. Recent fish surveys have demonstrated considerable variability in the catch rate of all fish with the most recent survey having a relatively high catch rate compared to historic records (Figure 7-3). The MnDNR has instilled a slot limit regulations on northern pike within the lake since 1997 with a change to the regulation in 2008 to an effort increase the size and number of the species within the lake. It appears that the size structure of the population has declined since the regulation change, possibly suggesting an imbalance in the fishery.

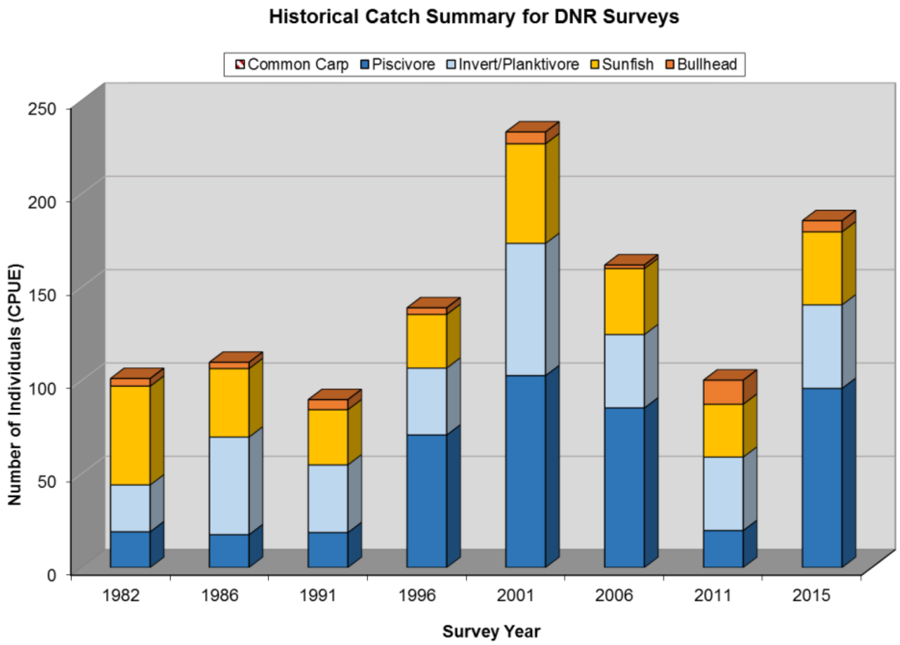


Figure 7-3. Sand Lake fisheries summary.

Common Carp do not appear to be present within Sand Lake. Further assessment is not warranted (at this time) to determine if common carp exist in the system or are densities that could cause degradation to the SAV community and water quality.

In the most recent survey, Bluegill comprised 35% of the catch, other sunfish species comprising another 16% of the total catch and limited large (30+ inch) piscivorous fish species (i.e. Northern Pike) were observed. A large abundance of small piscivorous fish exists within the lake, suggesting the potential of greater sunfish control as these fish grow. The large proportion of bluegill (and other sunfish) has the potential to limit significant weevil control of EWM within the lake. Weevil control will not eradicate EWM but has the potential to reduce nuisance level growth of EWM in systems where their abundance is high. It is noted by the MnDNR that catch rates of Bluegill are around average for lakes with similar characteristics, however, it is unclear if this is most appropriate condition for the lake. It is possible an imbalanced fishery currently exists within Sand Lake and efforts to practice selective harvesting or catch and release on large piscivorous fish (30+ inches) may prove beneficial to the northern pike population which may indirectly aid in natural weevil control of EWM.

7.4 MANAGEMENT RECOMMENDATIONS

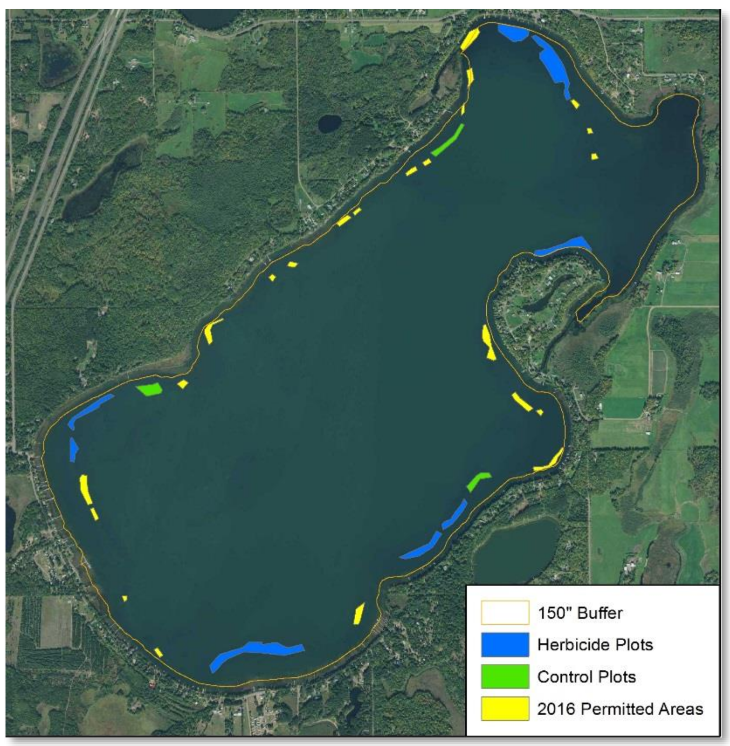
7.4.1 Development of Monitoring Plots

The intention of developing monitoring plots within Sturgeon Lake is to document and quantify the changes in the SAV community following specific management activities to 1) better understand the success of a given management activities and 2) adapt management activities to best control and reduce the impact AIS and restore a healthy SAV community. For a detailed standard operating procedure and equipment to establish and conduct SAV monitoring for this management plan please consult Appendix B.

The Windermere Lake Association is planning to chemically treat up to 40 acres of EWM on Sand Lake. Without a recent point intercept survey and ciBiobase assessment we utilized 2016 EWM delineation efforts conducted by the MnDNR to select location for chemical treatment and continued post treatment monitoring. The MnDNR will conduct field delineations this summer to field delineate and vet proposed areas. Two large (>5 acres) stands of EWM were documented to exist in Sturgeon Lake, with many delineated areas existing in small stands across the lake. Since its original location in the lake, EWM has continued to spread across the lake result in small stands. Some of the stands are closely located to each other almost acting as a large stand. We have previously described concerns to small scale treatment efficiency, therefore, we have minimized the amount of standalone small areas recommended for chemical treatment within Sturgeon Lake until effectiveness of application can be quantified. In total 8 areas delineated in 2016 were observed to be 1.0 acres or larger in size and are being proposed for chemical treatment and monitoring in 2017.

We randomly selected three control plots from remaining stands that were at least 1.0 acres in size. No management activity should occur in control plots as they are intended to be surveyed and used in comparison to treatment plots to quantify treatment effectiveness. The location of control plots should remain constant annually to ensure that no remnant management activity is influencing the SAV community. Without knowing the exact location of historic management activities, we cannot conclude that current control plots are persisting outside of remnant influences.

Additional areas can be chemically treated at the discretion of the Association and efforts to document the location, timing and treatment related information would be beneficial for further use. Due to the relatively small size, decreased efficiency of chemical treatment and growing concerns of hybridized milfoil resistance to herbicide pursuing small scale harvesting (i.e. hand pulling, mechanical weed cutting) may prove beneficial at control EWM in small infested areas. Due to the location of vegetation permits may be required to conducted said harvesting and should be vetted with the MnDNR as a management option on Sturgeon Lake. Should this option be pursued similar monitoring efforts should be practiced to assist in quantifying the short and long term success of management activities.



We recommend continued monitoring throughout the SAV growing season to document changes in the SAV communities in all monitoring plots. Continued monitoring and management activities should occur in these same plots in subsequent years to assess short and long-term success of treatment. Continuing to adaptive and evolve management activities will be important as results and treatment success is quantified. A more detailed SOP of recommended monitoring procedures is outlined in Appendix B.

7.4.2 Conclusions

Light limitation is not a current restoration concern for Sturgeon Lake. No internal loading or water level control feasibility assessment are warranted at this time; however, watershed BMP could be an option for ensuring the maintenance of a high-water clarity standard is maintained within the lake. Recommended actions to consider:

- ▲ Watershed BMPs
  - Agriculture practices
  - Wetland restorations

The fish community within Sturgeon Lake may be having an influence on the SAV community. The presence of native weevil populations within the lake are unknown, but if present, may present a natural control (not eradicate) to reducing the presence of EWM within the lake. Weevils are very susceptible to sunfish predation, therefore large sunfish populations within the lake are likely reducing weevil populations. Weevil population assessment and fish exclosure experiments would allow inference and conclusions to be drawn to the impacts fish are having on the EWM populations within the lake. However, long-term sustained management of the fishery may be difficult. Current fishing regulation exist on Sturgeon Lake to promote game fish opportunities. Follow up with the MnDNR to evaluate and possibly update slot limits to promote sunfish control by large piscivorous fishes may prove beneficial to controlling EWM with the lake. Recommended actions to consider:

- ▲ Weevil population assessments
- ▲ Fish exclosure experiment
- ▲ Promote large piscivorous catch and release
- ▲ Fisheries discussions with the MnDNR

Concerns that EWM is outcompeting native vegetation and spreading across the lake pose a great threat to maintaining a healthy SAV community. EWM has been spreading annually across Sturgeon Lake since its first observation in 2008 with limited sustained herbicide treatment success. Local conditions within the lake are unknown and are one potential factor that could explain the occurrence and distribution of SAV species and EWM across the lake. Investigation into local site conditions (i.e. sediment chemistry and composition) in areas where EWM exists and where native SAV grows may allude mechanisms that promote EWM growth. In understanding these mechanisms, management activities can look to remediate local conditions to reduce the presence of EWM and promote native SAV growth. Recommended actions to consider:

- ▲ Update late season SAV survey
- ▲ Conduct early season CLP assessment
- ▲ Monitor vegetation management activities
- ▲ Adapt management activities as new technologies and methodologies as they become available
- ▲ Develop and conduct localize assessments to understand site specific conditions within the lake

In summary, the vegetation community on Sturgeon Lake is healthy with concerns degradation through the spread of EWM throughout the lake. Protection initiatives and efforts to begin to understand conditions that promote EWM within the lake may prove beneficial to both the lake and surrounding lakes in limiting the spread of AIS. Beginning to track and monitor changes in the SAV community will allow insight to management activities and assist in adapting management decisions to combating AIS and maintain a healthy lake ecosystem.

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Appendix A

Water Quality Data

Appendix B

Monitoring Plot Standard Operating Procedure

Appendix C

Vegetation Survey Data Sheet

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