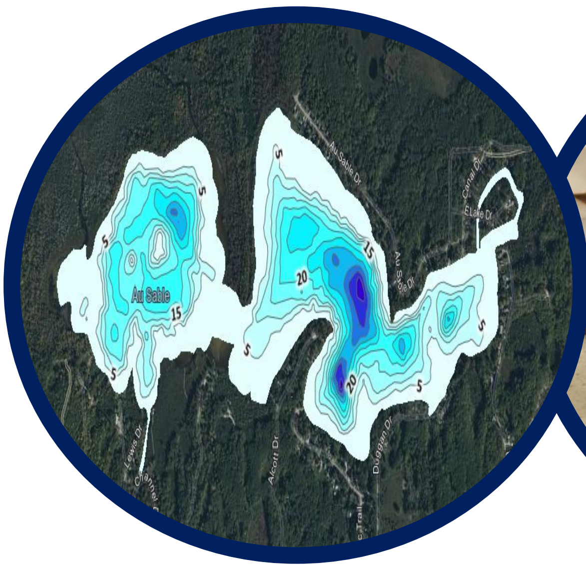
Au Sable Lake Aquatic Vegetation Management Plan with Professional Management Recommendations Ogemaw County, Michigan



Provided for: Au Sable Lake Association

Prepared by: Restorative Lake Sciences
Dr. Jennifer L. Jermalowicz-Jones, CLP, CLM
www.restorativelakesciences.com

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Au Sable Lake Aquatic Vegetation Management Plan with Professional Management Recommendations

July, 2025

1.0 EXECUTIVE SUMMARY

Au Sable Lake is a 271-acre lake located in Ogemaw County, Michigan (MDNR). The lake has two distinct deep basins separated by a large marl shoal (Figure 1). The maximum depth of the lake was measured at 49 feet (RLS, 2025; Figure 2). There is legal lake level established in 1974 with the summer level set at 898.1 feet and the winter level at 897.6 feet. There is an inlet from Au Sable Creek and an outlet with a control structure that drains into Little Au Sable Lake via a channel. The surrounding land use is primarily wetlands (44%) and forest (37%) followed by 6% developed land and other minor land uses. There is a public access site created in 1962.

A whole-lake aquatic plant survey and scan of aquatic vegetation biovolume was conducted on June 23, 2025. The lake scan consisted of thousands of GPS sounding points and the aquatic vegetation sampling survey utilized 198 GPS sampling stations in the lake where at least two rake tosses were conducted at each site. Based on this data, Au Sable Lake contains 17 native submersed, 4 native floating-leaved, and 6 native emergent aquatic plant species. This represents a very high and healthy biodiversity of native aquatic plants with 27 native aquatic plant species. The most dominant native aquatic plants were the submersed Variable Watermilfoil and Chara. There were 3 exotic invasive aquatic plant species found and included Eurasian Watermilfoil (EWM), Curly-leaf Pondweed (CLP), and Starry Stonewort (SS). These invasives were low in relative abundance (<1 acres each except for 6.3 acres of SS) and were found scattered in single locations throughout the lake basins and thus treatment should be prioritized to reduce further spread.

Management recommendations are included later in this report but the recommended approach for Eurasian Watermilfoil, Curly-leaf Pondweed, and Starry Stonewort is the use of DASH. Curly-leaf Pondweed tends to die off on its own by late July of each season but may necessitate treatment if dense canopies threaten safe navigation and recreation.

The following conclusions and recommendations can be made based on this evaluation:

1. Protect the robust and healthy native aquatic plant biodiversity in the lake.
2. Reduce invasive species such as Eurasian Watermilfoil and Starry Stonewort and monitor Curly-leaf Pondweed distributions.

Although Curly-leaf Pondweed is an invasive aquatic plant, it will not likely take over the lake as there are so many other native pondweeds that are successfully outcompeting the Curly-leaf Pondweed and this plant naturally decays by late July of each season. This could be accomplished with DASH in place of chemicals.

3. A licensed contractor (DASH or other) should be retained for removal of the invasives. To avoid any conflicts of interest, an independent consulting limnologist (Restorative Lake Sciences) should be retained to oversee all lake treatments and make objective treatment recommendations.
4. In nearshore areas, especially beaches, the use of benthic mats and weed rollers can reduce aquatic plant germination and growth without the use of chemicals.
5. Consider future purchase of a boat washing station when the invasives are reduced. The systems are costly (usually ≥$30,000 per unit) but are worth the investment. Periodic grants are available.

The overall water quality of Au Sable Lake was measured as very good with moderately low nutrients such as phosphorus and nitrogen and good water clarity with moderate chlorophyll-*a* concentrations. The pH of the lake indicates that it is a neutral lake. The specific conductivity and total dissolved solids were both low and favorable. Often, this is due to the position of the lake in more rural areas.

Restorative Lake Sciences recommends an annual whole-lake GPS survey and scan to determine the relative abundance of all native and invasive aquatic plant species, their relative abundance, and the percent cover of the lake surface area as well as follow up surveys in key areas. This data will be used each year to make management decisions about where to treat and what method(s) to use as these may change with time and results. Survey data can also be used to determine treatment efficacy.

Restorative Lake Sciences recommends continued education of lake riparians on nutrient reduction to the lake and lake protection Best Management Practices (BMP's) such as proper shoreline stewardship and protection of the immediate watershed surrounding the lake.

Figure 1. Au Sable Lake aerial map (RLS, 2025).

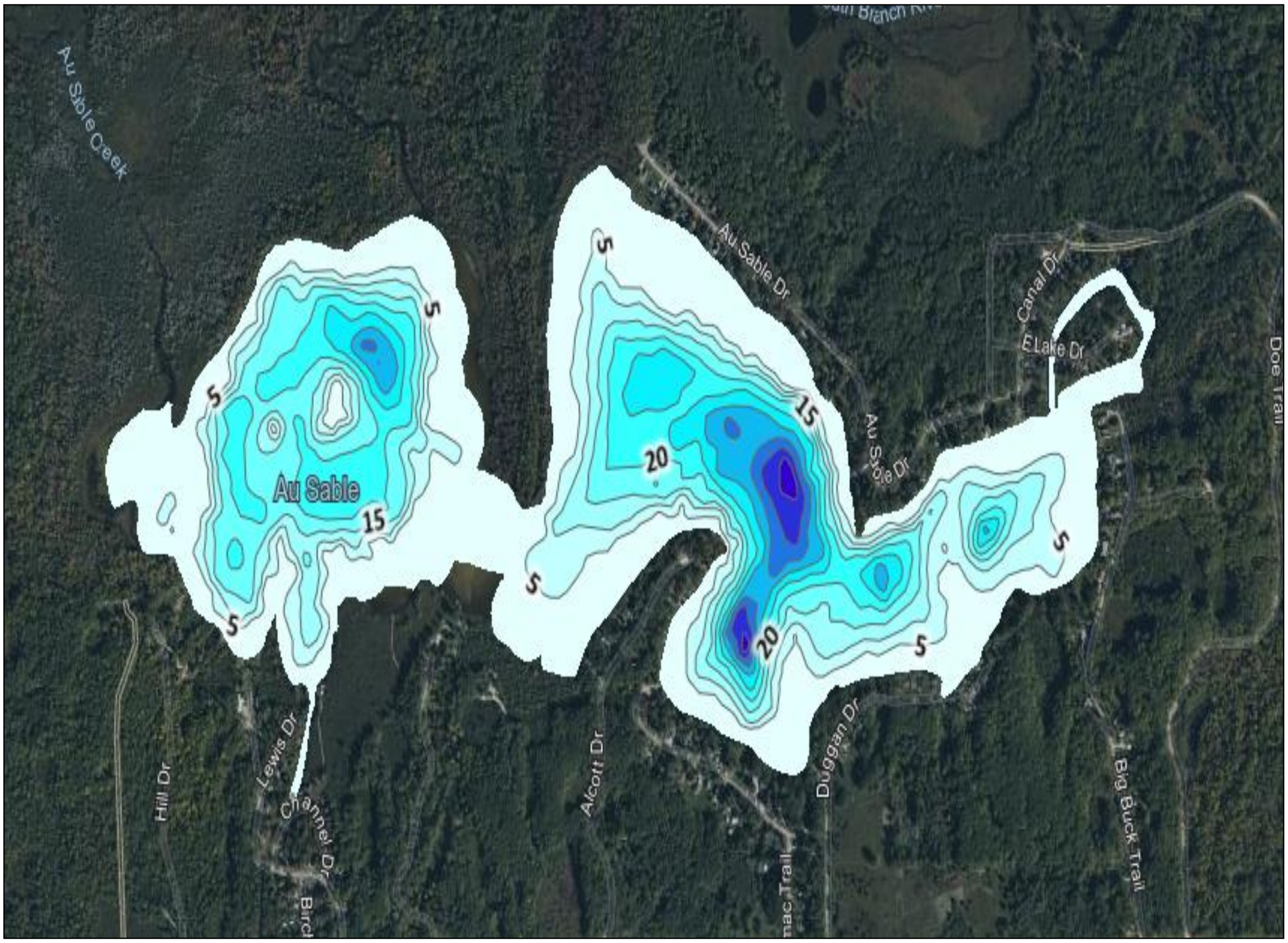


Figure 2. Au Sable Lake depth contour map (June 23, 2025).

2.0 AU SABLE LAKE WATER QUALITY

Water quality is highly variable among Michigan's inland lakes, although some characteristics are common among particular lake classification types. The water quality of each lake is affected by geology, land use practices, and climatic events. Climatic factors (i.e. spring runoff, heavy rainfall) may alter water quality in the short term; whereas, anthropogenic (man-induced) factors (i.e. shoreline development, lawn fertilizer use) alter water quality over longer time periods. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 1).

Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as eutrophic; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as oligotrophic.

Lakes that fall in between these two categories are classified as mesotrophic. **Au Sable Lake is classified as meso-eutrophic which means it contains moderate nutrient concentrations and favorable clarity and algae.**

Table 1. Lake Trophic Status Classification Table

Lake Trophic Status	***Total Phosphorus ($\mu g\ L^{-1}$)***	***Chlorophyll-a ($\mu g\ L^{-1}$)***	***Secchi Transparency (feet)***
Oligotrophic	< 10.0	< 2.2	> 15.0
Mesotrophic	10.0 – 20.0	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 20.0	> 6.0	< 7.5

2.1 Water Quality Parameters

Parameters such as, but not limited to, dissolved oxygen, water temperature, conductivity, total dissolved solids, pH, total phosphorus total Kjeldahl nitrogen, chlorophyll-*a*, and Secchi transparency, are critical indicators of water quality. On July 1, 2025, Restorative Lake Sciences collected water samples from within the deepest basin in Au Sable Lake. The results are discussed below and are presented in Table 2. A map showing the sampling locations for all water quality samples collected from the deep basins is shown below in Figure 3. All water samples and readings were collected on July 1, 2025 with the use of a Van Dorn horizontal water sampler and calibrated Eureka Manta II® multi-meter probe with parameter electrodes, respectively. Chlorophyll-*a* was measured *in situ* with a calibrated chlorophyll-*a* meter from Turner Designs®. All other water quality samples were analyzed at NELAC-certified Trace Analytical Laboratories in Muskegon, Michigan.

Figure 3. Location for water quality sampling of the deepest basin in Au Sable Lake (July 1, 2025).

2.1.1 Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters. Dissolved oxygen was measured in milligrams per liter (mg L^{-1}) with the use of a calibrated Eureka Manta II® dissolved oxygen meter. During the summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity.

Dissolved oxygen concentrations during the July 1, 2025 sampling event ranged from 8.0-0.0 mg L^{-1}, with concentrations of dissolved oxygen higher at the surface and slightly lower at the bottom. There was a significant decline after a depth of 18 feet.

2.1.2 Water Temperature

A lake's water temperature varies within and among seasons, and is nearly uniform with depth under the winter ice cover because lake mixing is reduced when waters are not exposed to the wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover". In general, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature was measured in degrees Celsius (ºC) with the use of a calibrated Eureka Manta II® submersible thermometer. **The July 1, 2025 water temperatures of Au Sable Lake demonstrated a strong thermocline in the deep basin and ranged from a high of 26.2°C to a low of 8.6°C. This is a favorable water temperature difference given the time of year when many shallow lakes can exceed water temperatures of 17.6°C.**

2.1.3 Specific Conductivity

Specific conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. It increases under anoxic (low dissolved oxygen) conditions. Conductivity generally increases with the amount of dissolved minerals and salts in a lake. Specific conductivity was measured in micro Siemens per centimeter (µS cm^{-1}) with the use of a calibrated Eureka Manta II® conductivity probe meter. **The specific conductivity for the Au Sable Lake deep basin ranged from 266-299 mS cm^{-1} during the July 1, 2025 sampling event. These values are moderately low for an inland lake and favorable.** Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Au Sable Lake over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading.

2.1.4 Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. TDS was measured with the use of a calibrated Eureka Manta II® TDS probe in mg L^{-1}. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. **The TDS in Au Sable Lake ranged from 170-192 mg L^{-1} for the deep basin on July 1, 2025, which is favorable. The preferred range for TDS in surface waters is between 0-1,000 mg L^{-1}.**

2.1.5 pH

pH is the measure of acidity or alkalinity of water. pH was measured with a calibrated Eureka Manta II® pH electrode and pH-meter in Standard Units (S.U). The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). pH changes on a daily basis due to changes in aquatic plant photosynthesis which actively grow during the daytime and respire at night. Generally speaking, the pH is usually lower in the hypolimnion (bottom depths) of a lake. **The pH of Au Sable Lake ranged from 7.6-8.5 S.U. during the July 1, 2025 sampling event. This range is ideal for an inland lake.**

2.1.6 Total Kjeldahl Nitrogen

Total Inorganic Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+) nitrogen and organic nitrogen forms in freshwater systems. TIN was analyzed in the laboratory with Method EPA 300. Rev 2.1 and Method EPA 350.1, Rev 2.0. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e. burning of fossil fuels), wastewater sources from developed areas (i.e. runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings.

It also enters lakes through ground or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. **The TKN concentrations in Au Sable Lake during the July 1, 2025 sampling event ranged from 0.6-0.9 mg L^{-1}, which is moderately low for an inland lake.**

2.1.7 Total Phosphorus

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. TP is measured in the laboratory with Method Lakes which contain greater than 20 µg L^{-1} of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to the higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Total phosphorus was measured in the laboratory in micrograms per liter (µg L^{-1}) with the use of a chemical auto analyzer and Method EPA 200.8, Rev. 5.4. **The TP concentrations in the deep basin of Au Sable Lake ranged from 10-20 µg L^{-1} on July 1, 2025. These concentrations are moderate and indicative of mesotrophic waters.**

2.1.8 Chlorophyll-a and Algae

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, typically in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Concentrations greater than 6 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg L^{-1} are found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* was measured in situ in micrograms per liter (µg L^{-1}) with the use of a calibrated Turner Designs® fluorimeter.

The chlorophyll-*a* concentrations in Au Sable Lake were determined by collecting composite samples of the algae throughout the water column at the deepest basin from just above the lake bottom to the lake surface. **The chlorophyll-*a* concentration in the deep basin was 3.0 µg L^{-1} on July 1, 2025.** This value indicates that a moderate amount of planktonic algae were prominent in the water column. It is likely that these values are higher in the spring after spring runoff or in late summer when water temperatures increase and lead to the growth of algae in the water column (planktonic form) or on the surface (filamentous form).

2.1.9 Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk (Figure 4). Secchi disk transparency is measured by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk. Elevated Secchi transparency readings are usually correlated with increased aquatic plant and algae growth and higher suspended solids. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. Further, elevated phytoplankton and turbidity, also are associated with decreased Secchi transparency. **The Secchi transparency of Au Sable Lake was measured at 12.5 feet during the day of sampling.** This transparency is adequate to allow abundant growth of algae and aquatic plants in the majority of the littoral (shallow) zone of the lake and is likely higher when the water temperatures are cooler and less algae is present. Secchi transparency is variable and depends on the amount of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement.

Figure 4. A Secchi disk

Table 2. Au Sable Lake water quality parameter data collected in the deepest basin on July 1, 2025.

Depth m	*Water Temp °C*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*TKN mg L^{-1}*	*Chl-a µg L^{-1}*	*Secchi ft.*
0	26.2	8.0	8.5	266	170	0.010	0.6	3.0	12.5
1.0	26.2	8.2	8.5	266	170	--	--	--	--
2.0	26.2	8.2	8.5	266	170	--	--	--	--
3.0	24.8	8.2	8.4	270	173	--	--	--	--
4.0	19.9	7.7	8.3	282	180	--	--	--	--
5.0	15.3	7.3	8.2	287	183	--	--	--	--
6.0	12.8	3.2	8.0	287	183	--	--	--	--
7.0	11.4	0.8	7.8	290	186	0.014	0.7	--	--
8.0	10.5	0.4	7.6	292	187	--	--	--	--
9.0	9.7	0.1	7.6	294	188	--	--	--	--
10.0	9.0	0.0	7.6	296	189	--	--	--	--
11.0	8.7	0.0	7.6	297	190	--	--	--	--
12.0	8.6	0.0	7.6	298	190	--	--	--	--
13.0	8.6	0.0	7.6	298	191	--	--	--	--
14.0	8.6	0.0	7.6	299	192	0.020	0.9	--	--

3.0 AU SABLE LAKE AQUATIC VEGETATION COMMUNITIES

3.1 Overview of Aquatic Vegetation and the Role for Lake Health

The overall health of Au Sable Lake is strongly connected to the type and density of aquatic vegetation present in the lake. Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients. In addition, decaying aquatic plants contribute organic matter to lake sediments which further supports healthy growth of successive aquatic plant communities that are necessary for a balanced aquatic ecosystem. An overabundance of aquatic vegetation may cause organic matter to accumulate on the lake bottom faster than it can break down.

Aquatic plants generally consist of rooted submersed, free-floating submersed, floating-leaved, and emergent growth forms. The emergent growth form (i.e., cattails) is critical for the diversity of insects onshore and for the health of nearby wetlands. Submersed aquatic plants can be rooted in the lake sediment (i.e., pondweeds), or free-floating in the water column (i.e., Coontail). Nonetheless, there is evidence that the diversity of submersed aquatic macrophytes can greatly influence the diversity of macroinvertebrates associated with aquatic plants of different structural morphologies (Parsons and Matthews, 1995). Therefore, it is possible that declines in the biodiversity and abundance of submersed aquatic plant species and associated macroinvertebrates, could negatively impact the fisheries of inland lakes. Alternatively, the overabundance of aquatic vegetation can compromise recreational activities, aesthetics, and property values. Similarly, an overabundance of exotic aquatic plant species can also negatively impact native aquatic plant communities and create an unbalanced aquatic ecosystem. **The biodiversity present in Au Sable Lake is optimum and ideal for a healthy lake fishery, but it is threatened by invasive aquatic plants.**

3.2 Aquatic Vegetation Sampling Methods

The aquatic plant sampling methods used for lake surveys of aquatic plant communities commonly consist of shoreline surveys, visual abundance surveys, transect surveys, AVAS surveys, and Point-Intercept Grid surveys. Such surveys are conducted on most inland lakes to assess the changes in aquatic vegetation structure and to record the relative abundance and locations of native aquatic plant species. Due to the great mean depth of Au Sable Lake, a whole-lake GPS Point-Intercept grid matrix survey and AVAS survey (Figure 5) were conducted from July 1, 2025 to assess all aquatic plants, including submersed, floating-leaved, and emergent species. **The lake scan consisted of thousands of GPS points and the aquatic vegetation sampling survey utilized over 198 sampling location assessment stations within the lake.** The lake bottom was scanned with the use of a side-scan sonar GPS device to scan the aquatic plant biovolume, bathymetric contours, and sediment bottom hardness of the lake (using a Lowrance® HDS 8 unit with BioBase® software). Figure 6 below shows the aquatic vegetation biovolume in Au Sable Lake. Table 3 below displays the actual aquatic vegetation biovolume data that corresponds to the map.

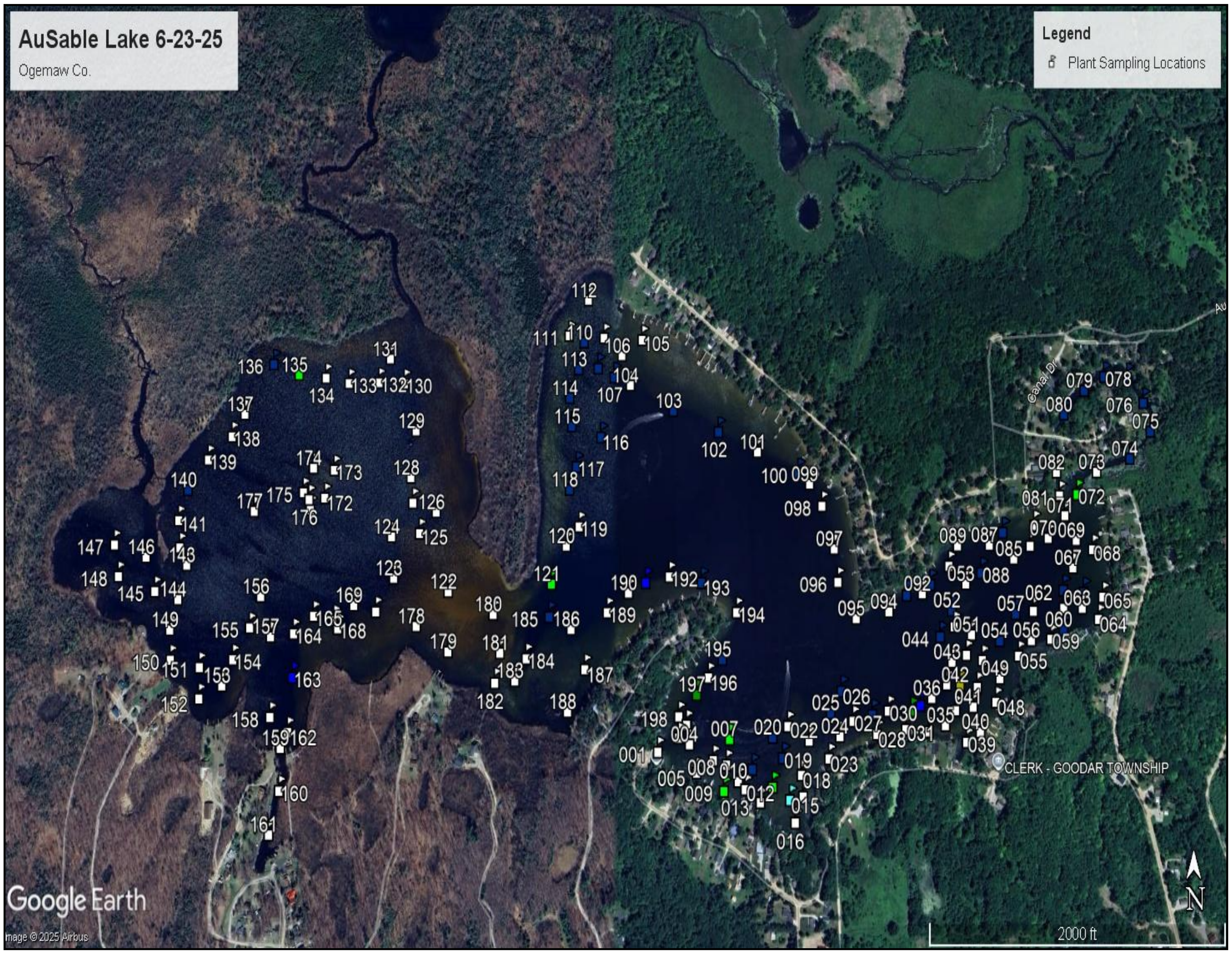


Figure 5. Aquatic vegetation sampling point locations in Au Sable Lake (June 23, 2025).

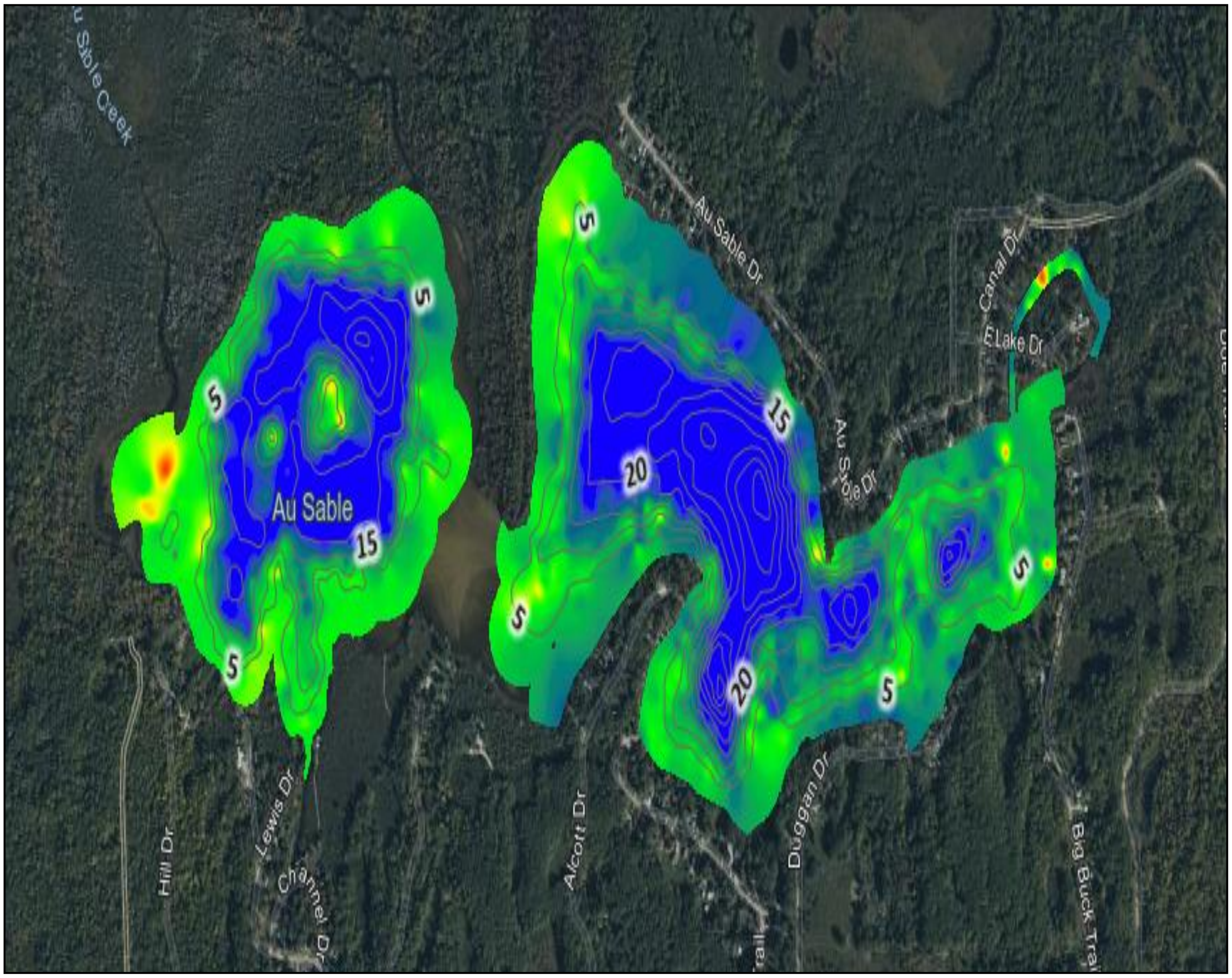


Figure 6. Aquatic vegetation biovolume scan map of Au Sable Lake (June 23, 2025). Note: The blue color represents areas that are not covered with aquatic vegetation. The green color represents low-growing aquatic vegetation, and the red colors represent high-growing aquatic vegetation. This scan does not differentiate between invasive and native aquatic vegetation biovolume which is why the GPS-point intercept survey is also executed in concert with the whole-lake scan.

Table 3. Au Sable Lake aquatic vegetation biovolume by category percent cover of each category (relative cover on June 23, 2025).

Biovolume Cover Category	% Relative Cover of Bottom by Category
0-20%	69.5
20-40%	28.3
40-60%	2.1
60-80%	0.1
>80%	0.0

3.3 Au Sable Lake Exotic Aquatic Macrophytes

Exotic aquatic plants (macrophytes) are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem.

Exotic aquatic plants (macrophytes) are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. **An aquatic exotic species may have profound impacts on the aquatic ecosystem.** Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 7) is an exotic aquatic macrophyte first documented in the United States in the 1880's (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was first found in the 1940's. In recent years, this species has hybridized with native milfoil species to form hybrid species. Eurasian Watermilfoil has since spread to thousands of inland lakes in various states through the use of boats and trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. Eurasian Watermilfoil is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation within lakes (Madsen et *al*. 1991), in that it forms dense canopies (Figure 8) and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et *al*. 1979). Additionally, Eurasian Watermilfoil can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

Eurasian Watermilfoil was found in 7 locations of Au Sable Lake during the survey (Figure 9) and urgent management is recommended to prevent further spread. Eurasian Watermilfoil growth in Au Sable Lake is capable of producing dense surface canopies in shallow areas.

The species of invasive aquatic plants present and relative abundance of each plant are recorded and then the amount of cover in the littoral zone is calculated.

Figure 7. Hybrid Eurasian Watermilfoil plant with seed head and fragments (©RLS).

Figure 8. Hybrid Eurasian Watermilfoil Canopy on an inland lake (©RLS).

Figure 9. Eurasian Watermilfoil distribution in Au Sable Lake (June 23, 2025).

Curly-leaf Pondweed (*Potamogeton crispus*; Figure 10) is an exotic, submersed, rooted aquatic plant that was introduced into the United States in 1807 but was abundant by the early 1900's. It is easily distinguished from other native pondweeds by its wavy leaf margins. It grows early in the spring and as a result may prevent other favorable native aquatic species from germinating. The plant reproduces by the formation of fruiting structures called turions. The plant does not reproduce by fragmentation as milfoil does; however, the turions may be deposited in the lake sediment and germinate in following seasons. Fortunately, the plant naturally declines around mid-July in most lakes and thus is not likely to be prolific throughout an entire growing season. **Curly-leaf Pondweed is a pioneering aquatic plant species and specializes in colonizing disturbed habitats. It is highly invasive in aquatic ecosystems with low biodiversity and unique sediment characteristics. It was present in 11 single locations of the lake and was not abundant at the time of the survey (Figure 11). It's presence is likely higher in the spring when the growth is most active.**

Figure 10. Curly-leaf Pondweed, *Potamogeton crispus*.

Figure 11. Locations of CLP in Au Sable Lake (June 23, 2025).

Starry Stonewort (*Nitellopsis obtusa*; Figure 12) is an invasive macro alga that has invaded many inland lakes and was originally discovered in the St. Lawrence River. The "leaves" appear as long, smooth, angular branches of differing lengths. The alga has been observed in dense beds at depths beyond several meters in clear inland lakes and can grow to heights in excess of a few meters. **It prefers clear alkaline waters and has been shown to cause significant declines in water quality and fishery spawning habitat. Individual fragments can be transported to the lake via waterfowl or boats. These conditions make the lake vulnerable to its growth. It was found in 35 single locations throughout Au Sable Lake (Figure 13).**

Figure 12. Starry Stonewort, a macro algae.

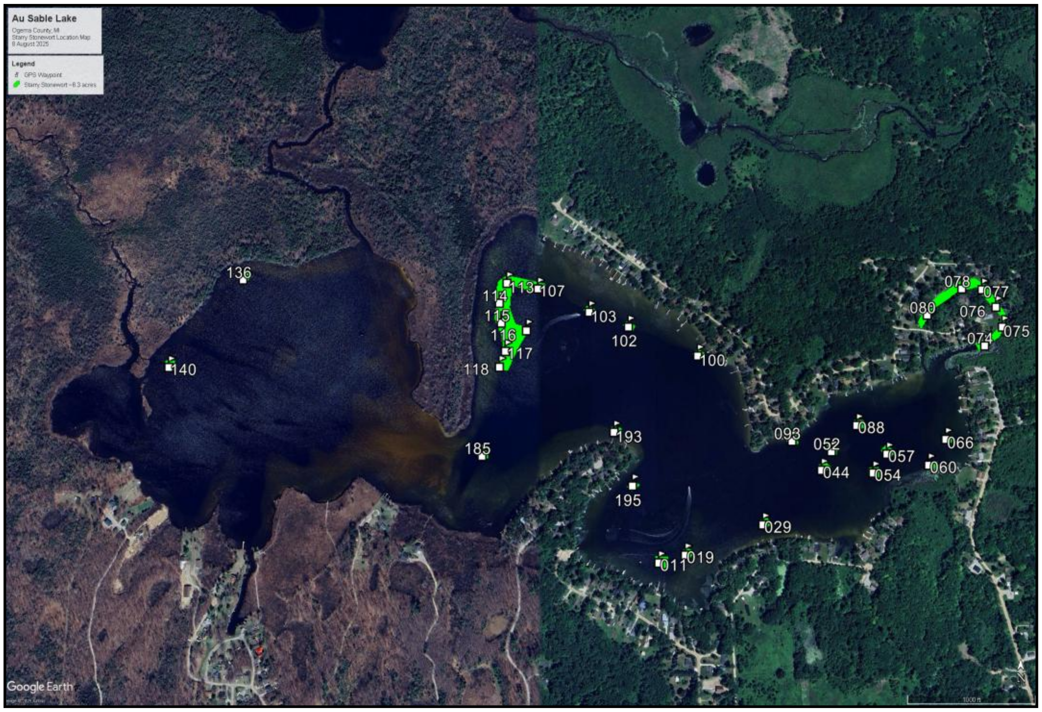


Figure 13. Locations of Starry Stonewort in Au Sable Lake (June 23, 2025).

3.4 Au Sable Lake Native Aquatic Macrophytes

There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (Pondweeds) and the Haloragaceae (Watermilfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) such as phosphorus, and in sites with high water transparency. The diversity of native aquatic plants is essential for the balance of aquatic ecosystems, because each plant harbors different macroinvertebrate communities and varies in fish habitat structure.

Au Sable Lake contained 17 native submersed, 4 floating-leaved, and 6 emergent aquatic plant species, for a total of 27 native aquatic macrophyte species (Tables 4 and 5). This is considered a highly diverse aquatic vegetation community. There are designated density codes for the aquatic vegetation surveys, where a = found (occupying < 2% of the surface area of the lake), b = sparse (occupying 2-20% of the surface area of the lake), c = common, (occupying 21-60% of the surface area of the lake), and d = dense (occupying > 60% of the surface area of the lake). Photos of all native aquatic plants are shown below in Figures 14-40. The majority of the emergent macrophytes may be found along the shoreline of the lake. The majority of the floating-leaved lily pads can be found near the shoreline and near wetlands.

The most dominant aquatic plant in the main part of the lake included the submersed Variable Watermilfoil (60.6%) and Chara (53%). Variable Watermilfoil has robust reddish stems and may grow in dense patches. It is considered excellent fishery habitat and should be preserved. The macro alga, Chara, serves as excellent bottom cover and also favorable fishery spawning habitat. Chara keeps sediments from being resuspended and also carpets the lake bottom making is difficult for any invasive aquatic plant species to root and become established. It should also be preserved.

The emergent plants, such as (Cattails), and *Scirpus acutus* (Bulrushes) are critical for shoreline stabilization as well as for wildlife and fish spawning habitat. The latter is particularly prevalent and serves as favorable wave energy dispersion in nearshore areas. Additionally, the floating-leaved aquatic plants such as yellow and white water lilies are excellent fishery cover and house numerous snails and aquatic macroinvertebrates that are critical for the fishery food chain.

Table 4. Au Sable Lake native aquatic plant species relative abundance (June 23, 2025).

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***A Level***	***B Level***	***C Level***	***D Level***
Chara vulgaris	Muskgrass	5	33	49	18
Stuckenia pectinatus	Thin-leaf Pondweed	6	10	2	0
Potamogeton zosteriformis	Flat-stem Pondweed	8	44	29	1
Potamogeton gramineus	Variable-leaf Pondweed	15	19	2	0
Potamogeton praelongus	White-stem Pondweed	2	1	0	0
Potamogeton richardsonii	Clasping-leaf Pondweed	4	1	1	0
Potamogeton illinoensis	Illinois Pondweed	12	56	11	1
Potamogeton amplifolius	Large-leaf Pondweed	5	1	1	0
Potamogeton pusillus	Small-leaf Pondweed	1	0	0	0
Vallisneria americana	Wild Celery	6	1	0	0
Myriophyllum sibiricum	Northern Watermilfoil	5	0	0	0
Myriophyllum heterophyllum	Variable Watermilfoil	39	55	26	0
Ceratophyllum demersum	Coontail	3	3	0	0
Elodea canadensis	Common Waterweed	17	41	6	8
Utricularia vulgaris	Common Bladderwort	36	27	4	0
Drepanocladus revolvens	Scorpion Moss	1	0	0	0
Najas guadalupensis	Southern Naiad	15	19	2	0
Nymphaea odorata	White Waterlily	10	45	6	0
Nuphar variegata	Yellow Waterlily	12	15	4	0
Spirodela sp.	Common Duckweed	1	0	0	0
Lemna minor	Lesser Duckweed	1	0	0	0
Typha latifolia	Cattails	6	8	0	0
Schoenoplectus acutus	Bulrushes	4	39	6	0
Arrow arum	Arrowhead	16	16	1	0
Iris sp.	Wild Iris	10	3	0	0

Decodon verticillatus	Swamp Loosestrife	9	20	5	0
Sparganium americanum	Bur reed	1	0	0	0

Table 5. Au Sable Lake native aquatic plant species frequency (June 23, 2025).

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***Frequency (% Sampling Locations Found)***
Chara vulgaris	Muskgrass	53.0
Stuckenia pectinatus	Thin-leaf Pondweed	9.1
Potamogeton zosteriformis	Flat-stem Pondweed	41.4
Potamogeton gramineus	Variable-leaf Pondweed	18.2
Potamogeton praelongus	White-stem Pondweed	1.5
Potamogeton richardsonii	Clasping-leaf Pondweed	3.0
Potamogeton illinoensis	Illinois Pondweed	40.4
Potamogeton amplifolius	Large-leaf Pondweed	3.5
Potamogeton pusillus	Small-leaf Pondweed	0.5
Vallisneria americana	Wild Celery	3.5
Myriophyllum sibiricum	Northern Watermilfoil	2.5
Myriophyllum heterophyllum	Variable Watermilfoil	60.6
Ceratophyllum demersum	Coontail	3.0
Elodea canadensis	Common Waterweed	36.4
Utricularia vulgaris	Common Bladderwort	33.8
Drepanocladus revolvens	Scorpion Moss	0.5
Najas guadalupensis	Southern Naiad	18.2
Nymphaea odorata	White Waterlily	30.8
Nuphar variegata	Yellow Waterlily	15.7
Spirodela sp.	Common Duckweed	0.5
Lemna minor	Lesser Duckweed	0.5
Typha latifolia	Cattails	7.1
Schoenoplectus acutus	Bulrushes	24.7
Arrow arum	Arrowhead	16.7
Iris sp.	Wild Iris	6.6

Decodon verticillatus	Swamp Loosestrife	17.2
Sparganium americanum	Bur reed	0.5

Figure 14. Chara (Muskgrass) ©RLS

Figure 15. Thin-leaf Pondweed ©RLS

Figure 16. Flat-stem Pondweed ©RLS

Figure 17. Variable-leaf Pondweed ©RLS

Figure 18. White-stem Pondweed ©RLS

Figure 19. Clasping-leaf Pondweed ©RLS

Figure 20. Illinois Pondweed ©RLS

Figure 21. Large-leaf Pondweed ©RLS

Figure 22. Small-leaf Pondweed ©RLS

Figure 23. Wild Celery ©RLS

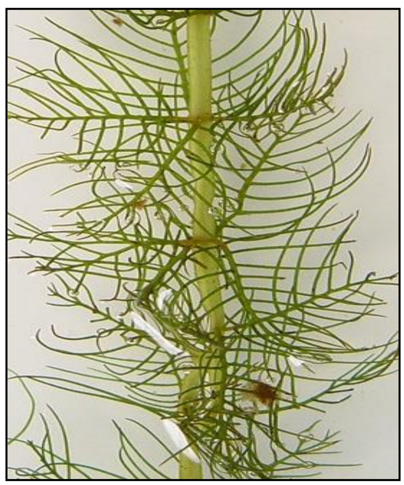


Figure 24. Northern Watermilfoil ©RLS

Figure 25. Variable Watermilfoil ©RLS

Figure 26. Coontail ©RLS

Figure 27. Elodea ©RLS

Figure 28. Bladderwort ©RLS

Figure 29. Scorpion moss ©RLS

Figure 30. Southern Naiad ©RLS

Figure 31. White Waterlily ©RLS

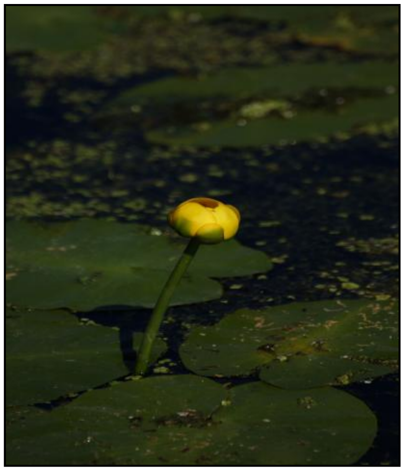


Figure 32. Yellow Waterlily ©RLS

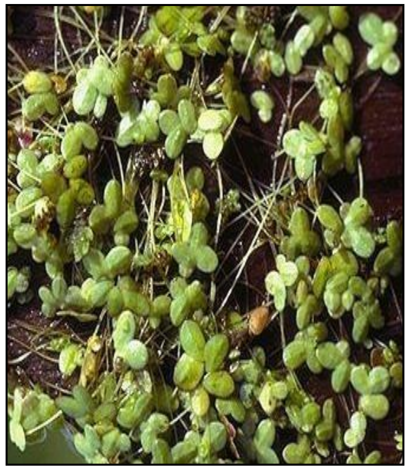


Figure 33. Common Duckweed ©RLS

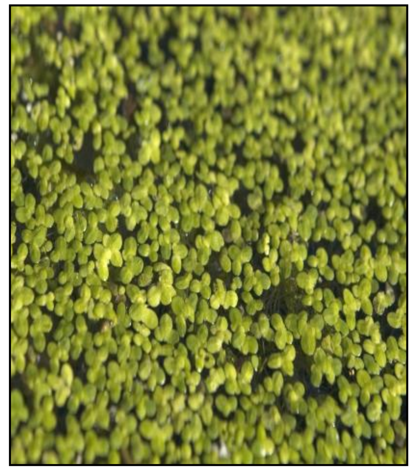


Figure 34. Lesser Duckweed ©RLS

Figure 35. Cattails ©RLS

Figure 36. Bulrushes ©RLS

Figure 37. Arrowhead ©RLS

Figure 38. Iris ©RLS

Figure 39. Swamp Loosestrife ©RLS

Figure 40. Bur reed ©RLS

4.0 AU SABLE LAKE MANAGEMENT IMPROVEMENT METHODS

4.1 Au Sable Lake Aquatic Plant Management Methods

Improvement strategies, including the management of only invasive aquatic plants, control of land and shoreline erosion, and further nutrient loading from external sources, are available for the various problematic issues facing Au Sable Lake. Long-term lake management components involve both within-lake (basin) and around-lake (watershed) solutions to protect and restore complex aquatic ecosystems. **The goals of a lake improvement program are to improve aquatic vegetation biodiversity, improve water quality and wildlife habitat, protect recreational use of a water resource and protect waterfront property values.** Regardless of the management goals, all management decisions must be site-specific and should consider the socio-economic, scientific, and environmental components of the lake management plan.

The management of nuisance level exotic aquatic plants is necessary in Au Sable Lake due to accelerated growth and distribution. Management options should be environmentally and ecologically sound and financially feasible. Options for control of aquatic plants are limited yet some are capable of achieving strong results when used properly. Exotic aquatic plant species should be managed with solutions that will yield long-term results. The sections below discuss the individual lake management methods (tools) and then ultimately lead to a section with specific recommendations using those methods.

4.1.1 Aquatic Herbicides and Applications

The use of aquatic chemical herbicides is regulated by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) and requires a permit. Aquatic herbicides are generally applied via an airboat or skiff equipped with mixing tanks and drop hoses (Figure 41). The permit contains a list of approved herbicides for a particular body of water, as well as dosage rates, treatment areas, and water use restrictions. **Contact and systemic aquatic herbicides are the two primary categories used in aquatic systems.**

Contact herbicides such as diquat, flumioxazin, and hydrothol cause damage to leaf and stem structures; whereas systemic herbicides are assimilated by the plant roots and are lethal to the entire plant. **Wherever possible, it is preferred to use a systemic herbicide for longer-lasting aquatic plant control of invasives. In Au Sable Lake, the use of contact herbicides (such as diquat and flumioxazin) would be highly discouraged since those offer short-term control of plants and are most commonly used on nuisance native aquatic plant species. The native aquatic plants within Au Sable Lake are critical for the lake fishery and should all be protected. They also assist with preventing further infestations from invasives. Contact herbicides could be used for the Starry Stonewort, however, but they are often used in combination with chelated copper or SeClear G®.**

Algaecides such as copper sulfate should also be avoided on Au Sable Lake. **Copper accumulates in lake sediments and bio-persists over time. It is harmful to sediment biota and can be released into the water column with sediment perturbations. Chelated products may be necessary though for Starry Stonewort.**

Systemic herbicides such as ProcellaCOR® and triclopyr are the two primary systemic herbicides used to treat milfoil that occurs in a scattered distribution. Fluridone (trade name, SONAR®) is a systemic whole-lake herbicide treatment that is applied to the entire lake volume in the spring and is used for extensive infestations. The objective of a fluridone treatment is to selectively control the growth of milfoil in order to allow other native aquatic plants to germinate and create a more diverse aquatic plant community. **Due to the cost and potential impacts of fluridone on native aquatic plants in Au Sable Lake, the use of fluridone is not recommended.**

Systemic herbicides such as triclopyr and ProcellaCOR® are the primary systemic herbicides used to treat Eurasian Watermilfoil. This approach has been very successful on other lakes with large treatment areas and minimal impacts to native aquatic plant species. Paradise Lake in Emmet County, Michigan and Lake St. Helen in Roscommon County are excellent recent examples. Aquatic herbicides are not necessary for the invasives in Au Sable Lake since DASH can also be considered given the sparse distribution.

Figure 41. An herbicide treatment airboat and crew preparing for a lake treatment.

4.1.2 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 42). The mechanical harvester collects numerous loads of aquatic plants as they are cut near the lake bottom. The plants are off-loaded onto a conveyor and then into a dump truck. Harvested plants are then taken to an offsite landfill or farm where they can be used as fertilizer. Mechanical harvesting is preferred over chemical herbicides when primarily native aquatic plants exist, or when excessive amounts of plant biomass need to be removed**. Mechanical harvesting is usually not recommended for the removal of watermilfoil since the plant may fragment when cut and re-grow on the lake bottom. This technology would have the most efficacy on very large weed beds but is still not needed at this time. It could be used to thin dense areas of pondweed once all of the EWM is reduced and only if the pondweeds prohibit recreation and navigation on the lake.**

Figure 42. A mechanical harvester.

4.1.3 Diver Assisted Suction Harvesting (DASH)

Suction harvesting via a Diver-Assisted Suction Harvesting (DASH) boat (Figure 43) involves hand removal of individual plants by a SCUBA diver in selected areas of lake bottom with the use of a hand-operated suction hose. Samples are dewatered on land or removed via fabric bags to an offsite location. **This method is generally recommended for small (less than 10 acres) spot removal of vegetation since it is usually cost-prohibitive on a larger scale.** The advantage it has is that it can be selective in what species it removes since a diver is guiding the suction hose to targeted plants. This process may remove either plant material or sediments and may require a USACE bottomlands permit.

Furthermore, this activity may cause re-suspension of sediments (Nayar et *al*., 2007) which may lead to increased turbidity and reduced clarity of the water. **It can be used to remove invasives in Au Sable Lake as an alternative to herbicides.**

Figure 43. A DASH boat for hand-removal of watermilfoil or other nuisance vegetation. ©Restorative Lake Sciences, LLC

4.1.4 Benthic Barriers and Nearshore Management Methods

The use of benthic barrier mats (Figure 44) or Weed Rollers (Figure 45) have been used to reduce weed growth in small areas such as in beach areas and around docks. The benthic mats are placed on the lake bottom in early spring prior to the germination of aquatic vegetation. They act to reduce germination of all aquatic plants and lead to a local area free of most aquatic vegetation. Benthic barriers may come in various sizes between 100-400 feet in length. They are anchored to the lake bottom to avoid becoming a navigation hazard. The cost of the barriers varies among vendors but can range from $100-$1,000 per mat. Benthic barrier mats can be purchased online at: www.lakemat.com or www.lakebottomblanket.com. The efficacy of benthic barrier mats has been studied by Laitala et *al.* (2012) who report a minimum of 75% reduction in invasive milfoil in the treatment areas. Lastly, benthic barrier mats should not be placed in areas where fishery spawning habitat is present and/or spawning activity is occurring.

Weed Rollers are electrical devices which utilize a rolling arm that rolls along the lake bottom in small areas (usually not more than 50 feet) and pulverizes the lake bottom to reduce germination of any aquatic vegetation in that area. They can be purchased online at: www.crary.com/marine or at: www.lakegroomer.net.

Both methods are useful in lakes such as Au Sable Lake and work best in beach areas and near docks to reduce nuisance aquatic vegetation growth. These technologies could be used in beach areas on the lake if the bottom substrate is consolidated (firm).

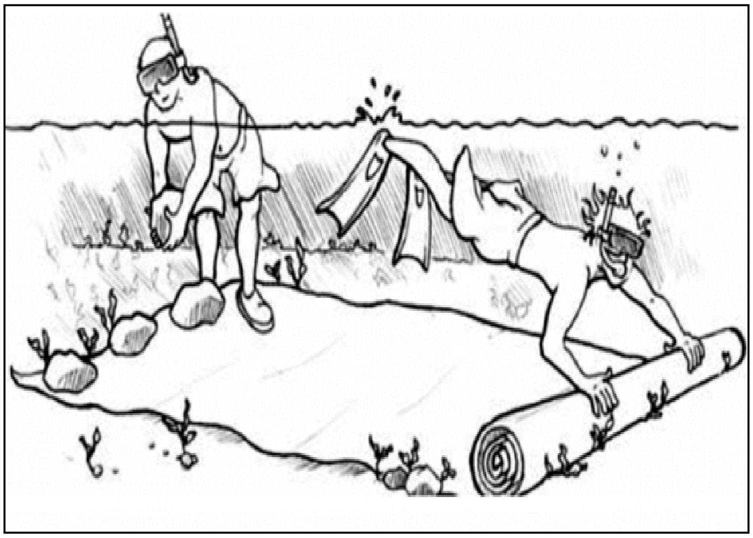


Figure 44. A Benthic Barrier. Photo courtesy of Cornell Cooperative Extension.

Figure 45. A Weed Roller.

4.1.5 Boat Washing Stations

In 2019, the Michigan Natural Resources Environmental Protection Act (PA 451 of 1993, Part 413) was amended with new boating and fishing laws that aim to prevent the introduction and spread of invasive aquatic species. Due to this amendment, technologies such as boat washing stations (Figure 46) are becoming prevalent and necessary.

With over 13 million registered boaters in the U.S. alone, the need for reducing transfer of aquatic invasive species (AIS) has never been greater. The Minnesota Sea Grant program identifies five major boat wash scenarios which include: 1) permanent washing stations at launch sites, 2) Portable drive-thru or transient systems, 3) Commercial car washes, 4) Home washing, and 5) Mandatory vs. volunteer washing. Boat washing stations are voluntary for incoming and exiting boaters. Boat washing stations promote the Clean Waters Clean Boats volunteer education program by educating boaters to wash boating equipment (including trailers and bait buckets) before entry into every lake. Critical elements of this education include: 1) how to approach boaters, 2) demonstration of effective boat and trailer inspections and cleaning techniques, 3) the recording of important information, 4) identification of high-priority invasive species, and 5) sharing findings with others. **Once a boat washing station is in place on Au Sable Lake, the Association should work together to educate the public and lake users on proper cleaning techniques and other invasive species information.**

A "Landing Blitz" can be held once the station is in place and the public can be invited to a field demonstration of how to use the washing station.

Figure 46. A boat washing station on an inland lake.

5.0 AU SABLE LAKE IMPROVEMENT CONCLUSIONS & RECOMMENDATIONS

The information given in the aforementioned sections for the long-term management of Au Sable Lake should be considered for effective management and ultimate protection of the lake water quality, balance of native aquatic plants, and protection of waterfront property values. **The overall goals of this proposed management program are listed in Table 6 along with where the proposed improvements should be implemented in and around the lake. The proposed aquatic vegetation management program conclusions and recommendations include the following:**

1. Protect the robust and healthy native aquatic plant biodiversity
2. Reduce invasive species such as Eurasian Watermilfoil and Starry Stonewort
3. Although Curly-leaf Pondweed is an invasive aquatic plant, it will not likely take over the lake as there are so many other native pondweeds that are successfully outcompeting the Curly-leaf Pondweed. It should be monitored each spring/summer however.
4. A licensed contractor should be retained for removal of all invasives. To avoid any conflicts of interest, an independent consulting limnologist (Restorative Lake Sciences) should be retained to oversee all lake improvements and/or make objective treatment recommendations.
5. In nearshore areas, especially beaches, the use of benthic mats and weed rollers can reduce aquatic plant germination and growth without the use of chemicals.
6. The use of DASH is a suitable alternative to herbicides for invasive removal.
7. Consider future purchase of a boat washing station when the invasives are reduced. The systems are costly (usually ≥$30,000 per unit) but are worth the investment. Periodic grants are available.

If the improvement methods described above are implemented, the balance of the Au Sable Lake ecosystem will improve over time. Such improvements will take considerable time and financial investment. RLS has prepared the optimum herbicide options for cost and responsibility to the ecosystem below in Table 6.

Table 6. Proposed lake improvement methods for Au Sable Lake's aquatic vegetation management plan.

Lake Management Activity	Primary Goal	Secondary Goal	Best Locations to Use
DASH for Eurasian Watermilfoil	To reduce % cover of EWM throughout lake	To protect native aquatic plant biodiversity	ONLY where EWM is located
DASH Starry Stonewort control	To stop it from spreading to other areas of the lake	To protect native aquatic plant biodiversity	ONLY where SS is located
Benthic Barriers/Weed Rollers	To prevent germination of nuisance weeds in beach areas	To reduce dependency on chemicals in nearshore areas	Beach areas only
Lake Vegetation Surveys/Scans	To determine % cover by invasives and use as data tool	To compare year to year reductions in nuisance vegetation areas	Entire lake, annually and follow-ups as needed
Water Quality Monitoring	To determine trophic status of the lake annually	To compare trend in water quality parameters with time	Main Lake deepest basin or both deep basins

5.1 Cost Estimates for Au Sable Lake Aquatic Vegetation Management:

The proposed aquatic vegetation management program for Au Sable Lake is recommended to begin as soon as possible. A breakdown of estimated costs associated with the various proposed treatments in Au Sable Lake is presented in Table 7. It should be noted that proposed costs are estimates and may change in response to changes in environmental conditions (i.e., increases in aquatic plant growth or distribution, or changes in removal costs). Note that this table is adaptive and is likely to change.

Table 7. Au Sable Lake proposed lake improvement program costs (2026-2028).

Proposed Au Sable Lake Improvement Item	Year 1 Costs	Years 2-5 (Annual) Costs
Professional services (limnologist management of lake, oversight, water quality, processing, education)[1]	$8,500	$9,000
EWM and SSW treatment with DASH[2] (other methods available)	$15,500	$15,500
Contingency[3]	$2,400	$2,450
Total Annual Estimated Cost	$26,400	$26,950

[1] Professional services includes comprehensive management of the lake with two annual GPS-guided, aquatic vegetation surveys, pre and post-treatment surveys for aquatic plant control methods, oversight and management of the aquatic plant control program and all management activities, all water quality monitoring and evaluation of all improvement methods, review of all invoices from contractors and others billing for services related to the improvement program, education of local riparians and attendance at up to two regularly scheduled annual board or Association meetings. Meetings may also be held by Zoom if necessary.

[2] DASH scope may change annually due to changes in the distribution and/or abundance of aquatic plants.

[3] Contingency is 10% of the total project cost, to assure that extra funds are available for unexpected expenses. Note: Contingency may be advised and/or needed for future treatment years.

6.0 SCIENTIFIC LITERATURE CITED

Anderson, E. 1948. Hybridization of the habitat. *Evolution* 2:1-9.

Harley, K.L.S., and I.W. Forno. 1992. Biological control of weeds: a handbook for practitioners and students. 74 pp. Inkata Press.

Halstead, J.M., J. Michaud, and S, Hallas-Burt. 2003. Hedonic analysis of effects of a non-native invader (*Myriophyllum heterophyllum*) on New Hampshire (USA) lakefront properties. *Envrion. Manage* 30 (3): 391-398.

Les, D.H., and C.T. Philbrick. 1993. Studies of hybridization and chromosome number variation in aquatic angiosperms: Evolutionary implications. *Aquatic Botany* 44: 181-228.

Parsons, J.K., and R.A. Matthews. 1995. Analysis of the camps between macroinvertebrates and macrophytes in a freshwater pond. *Northwest Science*, 69: 265-275.

Madsen, J.D., J.A. Bloomfield, J.W. Sutherland, L.W. Eichler, and C.W. Boylen. 1996. The aquatic plant community of Onondaga Lake: Field survey and plant growth bioassays of lake sediments, *Lake and Reservoir Management* 12:73-79.

Madsen, J.D. G.O. Dick, D. Honnell, J. Schearer, and R.M. Smart. 1994. Ecological assessment of Kirk Pond, Miscellaneous Paper A-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Moody, M.L., and D.H. Les. 2007. Geographic distribution and genotypic composition of invasive hybrid watermilfoil (*Myriophyllum spicatum* x *M. sibiricum*) populations in North America. *Biological Invasions* 9: 559-570.

Nayar, S., DJ Miller, A. Hunt, BP Goh, and LM Chou. 2007. Environmental effects of dredging on sediment nutrients, carbon, and granulometry in a tropical estuary. *Environmental Monitoring and Assessment,* 127(1-3):1-13.

Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press, 1006 pgs.