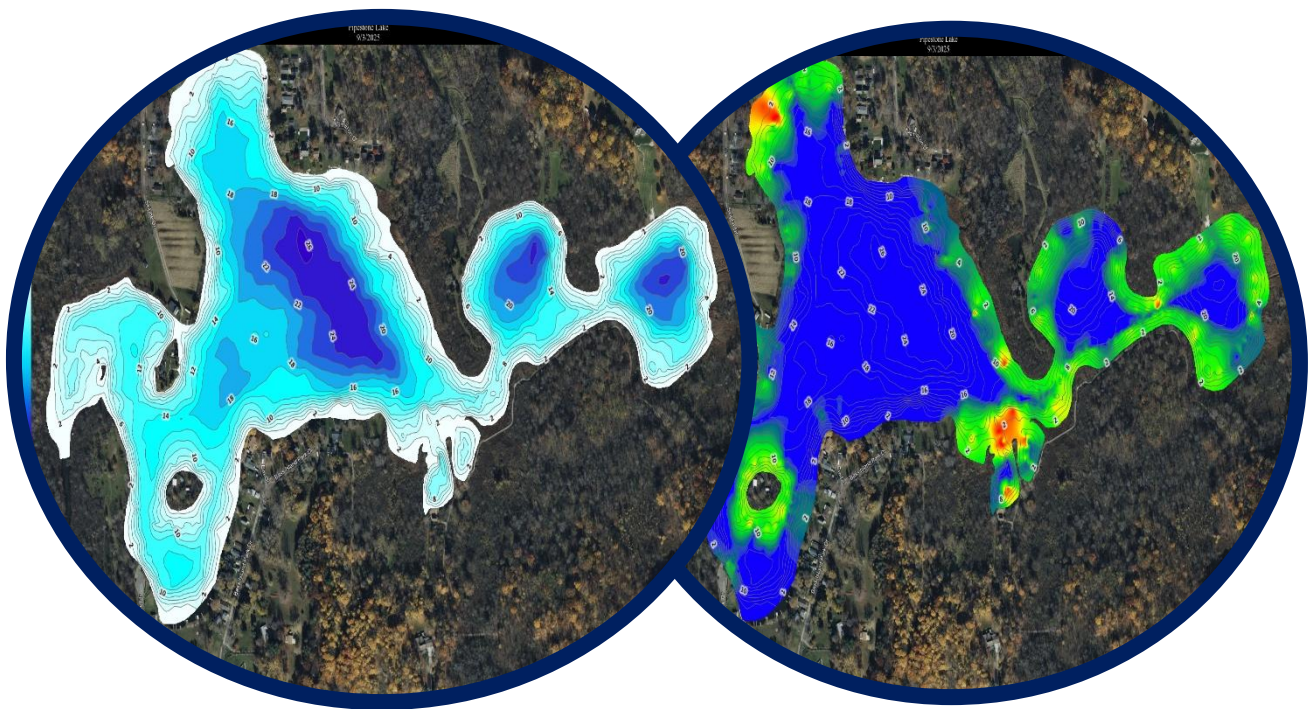




# Pipestone Lake Improvement Study and Management Plan

## Berrien County, Michigan



**Provided for: Pipestone Lake Association Board**

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# Pipestone Lake Improvement Study and Management Plan

## Berrien County, Michigan

October, 2025

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### 1.0 EXECUTIVE SUMMARY

Pipestone Lake is located in Bainbridge Township in Berrien County, Michigan. The lake is comprised of 114.1 acres (RLS, 2025). The lake has five areas of water inflow and thus is considered a drainage lake that receives the majority of its water from surface waters, but it may also contain deeper springs.

The mean depth of the lake is approximately 13.2 feet, and the maximum depth is approximately 26.5 feet (RLS, 2025 bathymetric scan data). The lake also has a fetch (longest distance across the lake) of around 0.5 miles (RLS, 2025), and a shoreline length of 3.8 miles without the island shoreline included and 4.0 miles with the shoreline length included.

Pipestone Lake has an approximate water volume of 1,369 acre-feet (RLS, 2025 bathymetric data). Pipestone Lake lies within the St. Joseph River extended watershed which drains to Lake Michigan. The immediate watershed, which is the area directly draining into the lake, is approximately 2,738 acres which is about 24 times the size of the lake and is considered to be a large-sized immediate watershed.

Based on the current study, Pipestone Lake contains two invasive aquatic plant species including approximately 3.5 acres of submersed Eurasian Watermilfoil (*Myriophyllum spicatum*) and approximately 32 locations where invasive emergent Purple Loosestrife was present around the lake. Both of these species may increase in some years with certain environmental conditions. Recommendations for prevention and treatment of invasives are offered later in this management plan report. Native lily pads are also prevalent around the lake and could be managed with diver-assisted suction harvesting (DASH), mechanical harvesting, or herbicides in beach areas. They should not be removed in undeveloped or areas or those adjacent to wetlands or forests as they offer considerable aquatic life habitat.

Pipestone Lake contained 10 native submersed, 2 floating-leaved, and 6 emergent aquatic plant species, for a total of 18 native aquatic macrophyte species during the lake survey on August 28, 2025 which consisted of a total of geo-referenced 182 sampling locations. This represents a moderately high biodiversity that may increase once the milfoil is effectively reduced.

A detailed, Early Detection- Rapid Response Protocol for future invasives that may enter the lake is recommended to be compiled soon for the lake community. Furthermore, a professional limnologist/lake manager from RLS should perform regular GPS-guided whole-lake surveys each summer/early fall to monitor the growth and distribution of all invasives prior to and after treatments to determine treatment efficacy. Continuous monitoring of the lake for potential influxes of other exotic aquatic plant genera (i.e., *Hydrilla*) that could also significantly disrupt the ecological stability of Pipestone Lake is critical. The lake manager should objectively oversee all management activities and would be responsible for the creation of aquatic plant management survey maps, direction of the herbicide applicator to target-specific areas of aquatic vegetation for removal, independent evaluation of lake management activities, implementation of watershed best management practices, administrative duties such as the review and approval of contractor invoices, and lake management education.

Lake weed treatments should consist only of systemic herbicides for Eurasian Watermilfoil (EWM) with preference for a large spring treatment and seasonal spot-treatments as needed. Purple Loosestrife may be effectively reduced with hand-removal and/or the application of a topical systemic herbicide in early fall. Algal treatments should only be used on very dense filamentous green algae and should consist of chelated copper only to avoid bioaccumulation in lake sediments. RLS should be present in the future to oversee all lake treatments to assure objectivity and evaluate performance.

The lake has an overall moderate abundance of zooplankton that forms the base of the food chain for the lake fishery. It is a biological parameter that should be regularly monitored to evaluate the abundance of food for the lake fishery.

Pipestone Lake is a relatively hard-water lake. Pipestone Lake has moderately high nutrient concentrations, especially at the lake bottom and also receives drainage inputs. Dissolved oxygen declined with depth which could lead to release of TP from the lake bottom that could fuel increased aquatic plant and algae growth with time. Reduction of nutrients should come from proper septic tank maintenance and reduction or cessation of the use of lawn fertilizers.

Lastly, a riparian education program is recommended through the development of this management plan and through holding future educational workshops hosted by RLS professionals. Such workshops may include dispersal of relevant lake information and also identification of local lake biota so that residents know to be vigilant of certain invasives or other lake issues.

## **2.0 LAKE ECOLOGY BACKGROUND INFORMATION**

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### **2.1 Introductory Concepts**

Limnology is a multi-disciplinary field which involves the study of the biological, chemical, and physical properties of freshwater ecosystems. A basic knowledge of these processes is necessary to understand the complexities involved and how management techniques are applicable to current lake issues. The following terms will provide the reader with a more thorough understanding of the forthcoming lake management recommendations for Pipestone Lake.

#### **2.1.1 Lake Hydrology**

Aquatic ecosystems include rivers, streams, ponds, lakes, and the Laurentian Great Lakes. There are thousands of lakes in the state of Michigan, and each possesses unique ecological functions and socio-economic contributions. In general, lakes are divided into four categories:

- Seepage Lakes,
- Drainage Lakes,
- Spring-fed Lakes, and
- Drained Lakes.

Some lakes (seepage lakes) contain closed basins and lack inlets and outlets, relying solely on precipitation or groundwater for a water source. Seepage lakes generally have small watersheds with long hydraulic retention times which render them sensitive to pollutants. Drainage lakes receive significant water quantities from tributaries and rivers. Drainage lakes contain at least one inlet and an outlet and generally are confined within larger watersheds with shorter hydraulic retention times. As a result, they are less susceptible to pollution. Spring-fed lakes rarely contain an inlet but always have an outlet with considerable flow. The majority of water in this lake type originates from groundwater and is associated with a short hydraulic retention time. Drained lakes are similar to seepage lakes yet rarely contain an inlet and have a low-flow outlet.

The groundwater and seepage from surrounding wetlands supply the majority of water to this lake type and the hydraulic retention times are rather high, making these lakes relatively more vulnerable to pollutants. The water quality of a lake may thus be influenced by the quality of both groundwater and precipitation, along with other internal and external physical, chemical, and biological processes. Pipestone Lake is a drainage lake since it has five key areas of drainage and contains an outlet.

### **2.1.2 Biodiversity and Habitat Health**

A healthy aquatic ecosystem possesses a variety and abundance of niches (environmental habitats) available for all of its inhabitants. The distribution and abundance of preferable habitat depends on limiting influence from humans and development, while preserving sensitive or rare habitats. As a result of this, undisturbed or protected areas generally contain a greater number of biological species and are considered more diverse. A highly diverse aquatic ecosystem is preferred over one with less diversity because it allows a particular ecosystem to possess a greater number of functions and contribute to both the intrinsic and socio-economic values of the lake. Healthy lakes have a greater biodiversity of aquatic macroinvertebrates, aquatic macrophytes (plants), fishes, phytoplankton, and may possess a plentiful yet beneficial benthic microbial community (Wetzel, 2001).

### **2.1.3 Watersheds and Land Use**

A watershed is defined as an area of land that drains to a common point and is influenced by both surface water and groundwater resources that are often impacted by land use activities. In general, larger watersheds possess more opportunities for pollutants to enter the ecosystem, altering the water quality and ecological communities.

In addition, watersheds that contain abundant development and industrial sites are more vulnerable to water quality degradation from pollution which may negatively affect both surface and ground water. Since many inland lakes in Michigan are relatively small in size (i.e., less than 300 acres), they are inherently vulnerable to nutrient and pollutant inputs, due to the reduced water volumes and small surface areas. As a result, the living (biotic) components of the smaller lakes (i.e., fishery, aquatic plants, macro-invertebrates, benthic organisms, etc.) are highly sensitive to changes in water quality from watershed influences. Land use activities have a dramatic impact on the quality of surface waters and groundwater.

In addition, the topography of the land surrounding a lake may make it vulnerable to nutrient inputs and consequential loading over time. Topography and the morphometry of a lake dictate the ultimate fate and transport of pollutants and nutrients entering the lake. Surface runoff from the steep slopes surrounding a lake will enter a lake more readily than runoff from land surfaces at or near the same grade as the lake.

Lakes with steep drop-offs may act as collection basins for the substances that are transported to the lake from the land. Land use activities, such as residential land use, industrial land use, agricultural land use, water supply land use, wastewater treatment land use, and storm water management, can influence the watershed of a particular lake. All land uses contribute to the water quality of the lake through the influx of pollutants from non-point sources or from point sources.

Non-point sources are often diffuse and arise when climatic events carry pollutants from the land into the lake. Point-source pollutants are discharged from a pipe or input device and empty directly into a lake or watercourse.

Residential land use activities involve the use of lawn fertilizers on lakefront lawns, the utilization of septic tank systems for treatment of residential sewage, the construction of impervious (impermeable, hard-surfaced) surfaces on lands within the watershed, the burning of leaves near the lakeshore, the dumping of leaves or other pollutants into storm drains, and removal of vegetation from the land and near the water. In addition to residential land use activities, agricultural practices by vegetable crop and cattle farmers may contribute nutrient loads to lakes and streams. Industrial land use activities may include possible contamination of groundwater through discharges of chemical pollutants.

### **3.0 PIPESTONE LAKE PHYSICAL AND WATERSHED CHARACTERISTICS**

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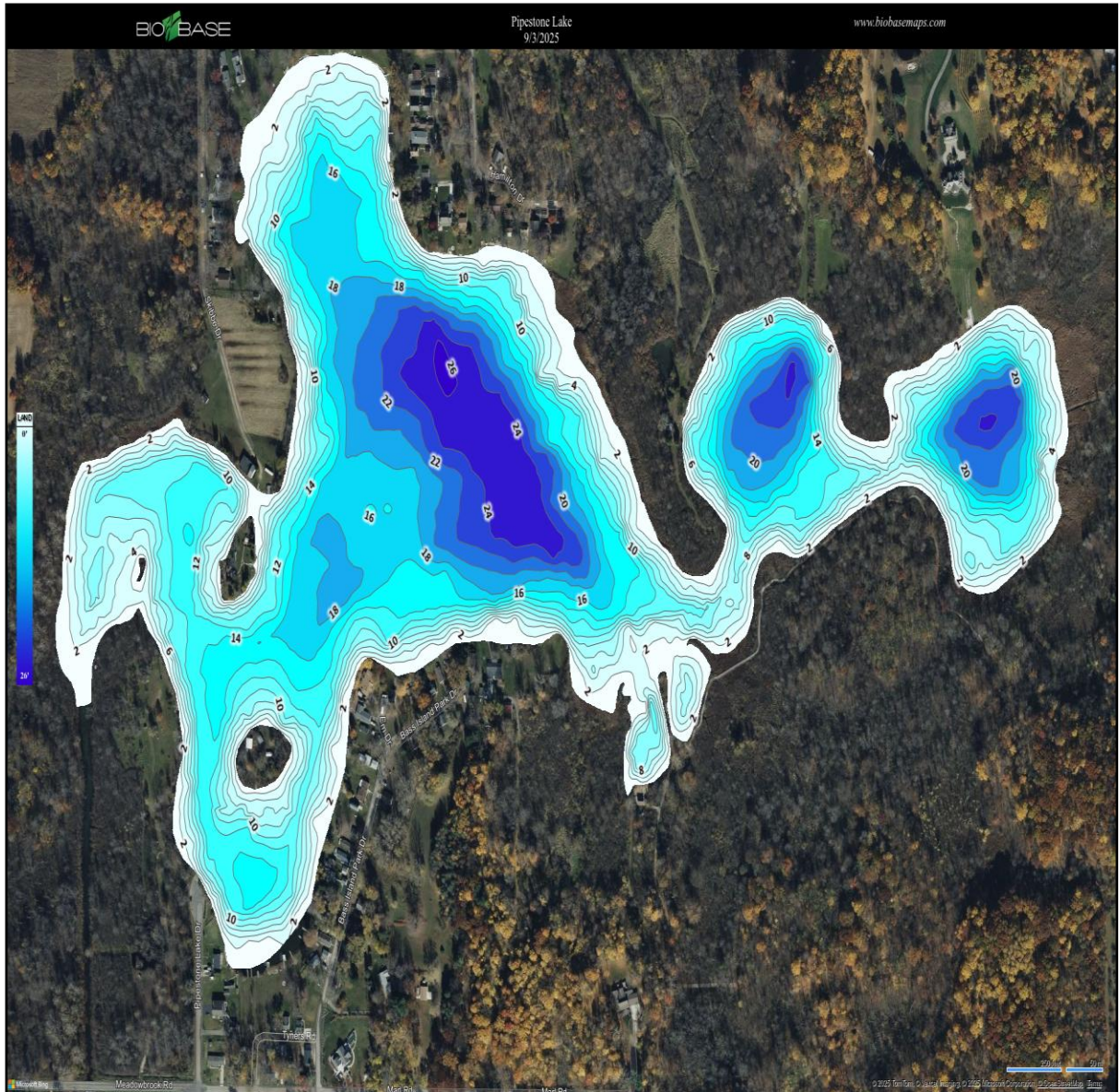
#### **3.1 The Pipestone Lake Basin**

Pipestone Lake is located in Bainbridge Township in Berrien County, Michigan (Figure 1). The lake is comprised of 114.1 acres (RLS, 2025). The lake has five areas of water inflow and thus is considered a drainage lake that receives the majority of its water from surface waters, but it may also contain deeper springs.

The mean depth of the lake is approximately 13.2 feet, and the maximum depth is approximately 26.5 feet (RLS, 2025 bathymetric scan data; Figure 2). The lake also has a fetch (longest distance across the lake) of around 0.5 miles (RLS, 2025), and a shoreline length of 3.8 miles without the island shoreline included and 4.0 miles with the shoreline length included. Pipestone Lake has an approximate water volume of 1,369 acre-feet (RLS, 2025 bathymetric data).



**Figure 1. Pipestone Lake Aerial Photo, Berrien County, Michigan.**



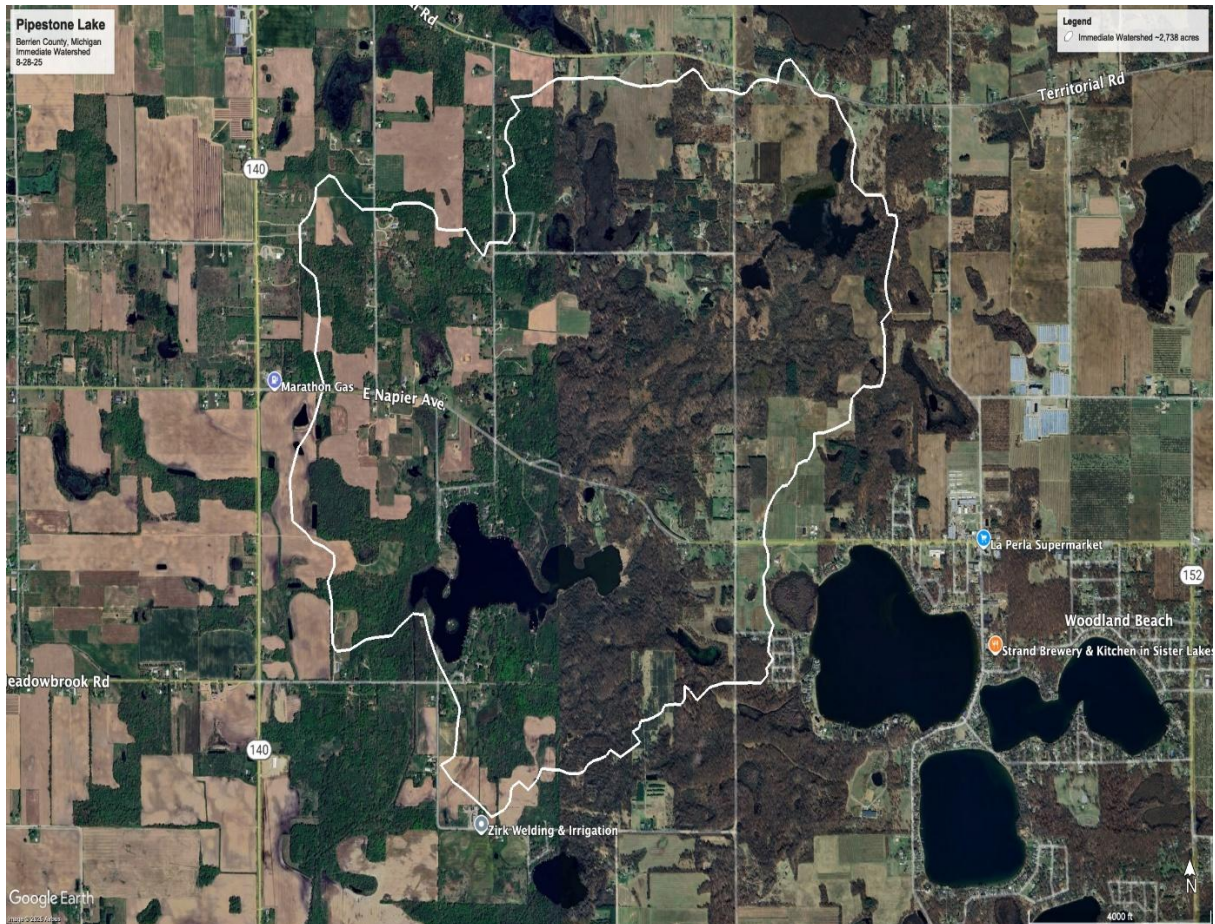
**Figure 2. Pipestone Lake Depth Contour Map, Berrien County, Michigan (September 3, 2025).**

### **3.2 Pipestone Lake Extended and Immediate Watershed and Land Use Summary**

A watershed is defined as a region surrounding a lake that contributes water and nutrients to a waterbody through drainage sources. Watershed size differs greatly among lakes and also significantly impacts lake water quality. Large watersheds with much development, numerous impervious or paved surfaces, abundant storm water drain inputs, and surrounding agricultural lands, have the potential to contribute significant nutrient and pollution loads to aquatic ecosystems.

Pipestone Lake is located within the St. Joseph River extended watershed. The St. Joseph River extended watershed (HUC 04100003) covers an area of approximately 4,685 mi<sup>2</sup> and covers 15 counties in both Michigan and Indiana. The St. Joseph River is approximately 210 miles in length and eventually drains into Lake Michigan near the port of St. Joseph. The watershed is characterized predominately by agriculture, urban land, grasslands, and wetland land uses (current MIRIS data) with the latter being 50% reduced over the past several decades. This information is valuable on a regional scale; however, it is at the immediate watershed scale that significant improvements can be made by the local Pipestone Lake community.

The immediate watershed of Pipestone Lake consists of the area around the lake that potentially directly drains to the lake and measures approximately 2,738 acres in size (Figure 3; RLS, 2025). The immediate watershed is about 24 times the size of the lake, which is considered a large-sized immediate watershed. The lakefront itself has a diverse application of land uses such as riparian waterfront, wetlands, and forested lands. Thus, management options should also consider all of these land uses and preserve their unique functions. Although erosion with high slopes is not an issue around the lake, ponding with abundant mucky soils is a potential issue for nutrient inputs. Best Management Practices (BMP's) for water quality protection are offered in the watershed improvement section of this report.



**Figure 3. Immediate Watershed draining into Pipestone Lake, Berrien County, Michigan (Restorative Lake Sciences, 2025).**

### **3.3 Pipestone Lake Shoreline Soils**

There are 2 major soil types (defined as occupying a greater surface area near the lake shoreline) immediately surrounding Pipestone Lake which may impact the water quality of the lake and may dictate the particular land use activities within the area (Table 1). This denotes a lake with fairly simple geology; Figure 4 (created with data from the United States Department of Agriculture and Natural Resources Conservation Service) demonstrates the precise soil types and locations around Pipestone Lake. Major drainage characteristics of the dominant soil types directly surrounding the Pipestone Lake shoreline are discussed below.

**Table 1. Pipestone Lake Shoreline Soil Types (USDA-NRCS data).**

<b>Soil Series Name</b>	<b>Locations around Lake</b>
Edwards Mucks, 0-1% slopes	north, south, west shores
Houghton Mucks, 0-1% slopes	east, southeast, northeast shores



The majority of the soils around Pipestone Lake are organic mucks which are very deep soils that are very poorly drained. Although most areas around the lake have relatively low slopes (<6%), the mucks are associated with ponding due to poor drainage. These soils are also present on the two lake islands.

Ponding occurs when water cannot permeate the soil and accumulates on the ground surface which then runs off into nearby waterways such as the lake and carry nutrients and sediments into the water. Excessive ponding of such soils may lead to flooding of some low-lying shoreline areas, resulting in nutrients entering the lake via surface runoff since these soils do not promote adequate drainage or filtration of nutrients. The mucks located in the wetlands may become ponded during extended rainfall and the wetlands can serve as a source of nutrients to the lake. When the soils of the wetland are not saturated, the wetland can serve as a sink for nutrients, and the nutrients are filtered by wetland plants.

#### **4.0 PIPESTONE LAKE WATER QUALITY**

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Water quality is highly variable among Michigan's inland lakes, although some characteristics are common among particular lake classification types. The water quality of Pipestone Lake is affected by both 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 2). 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. Pipestone Lake is classified as a eutrophic (nutrient-rich) lake due to moderate to high nutrients, moderate Secchi transparency, and high chlorophyll-*a* concentrations.

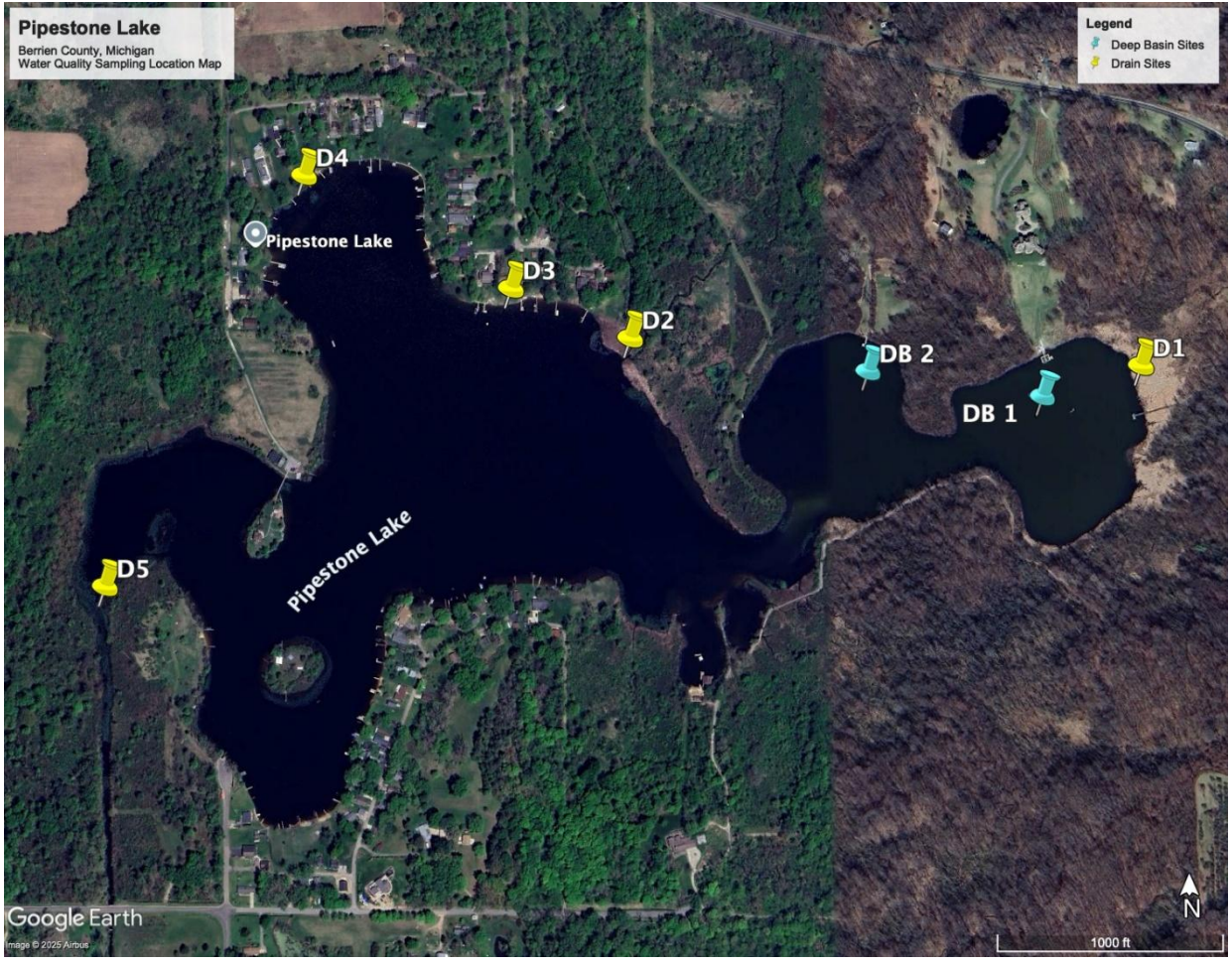
**Table 2. General Lake Trophic Status Classification.**

<i>Lake Trophic Status</i>	<i>Total Phosphorus (mg L<sup>-1</sup>)</i>	<i>Chlorophyll-a (µg L<sup>-1</sup>)</i>	<i>Secchi Transparency (feet)</i>
<b>Oligotrophic</b>	< 0.010	< 2.2	> 15.0
<b>Mesotrophic</b>	0.010-0.025	2.2 – 6.0	7.5 – 15.0
<b>Eutrophic</b>	> 0.025	> 6.0	< 7.5

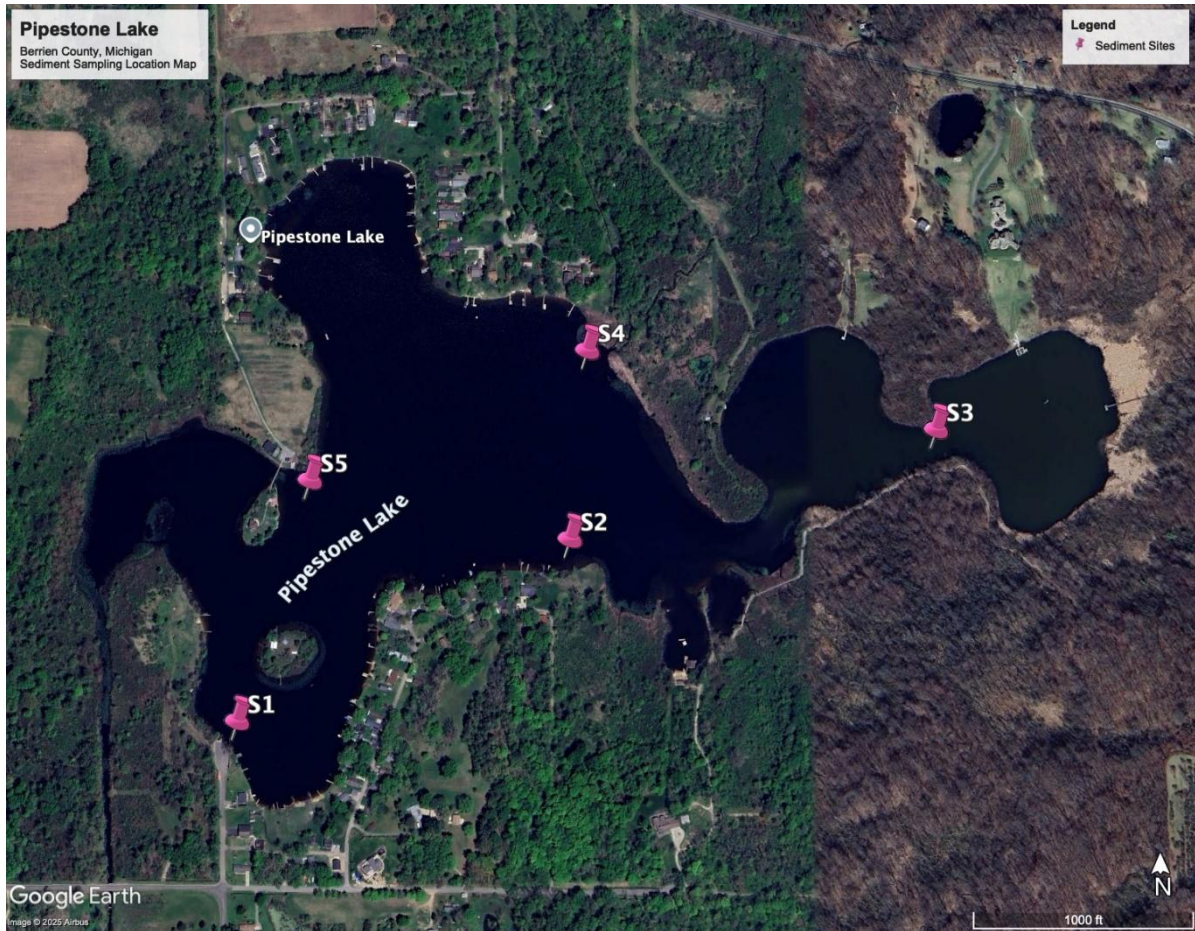
#### **4.1 Water Quality Parameters**

Water quality parameters were measured and included dissolved oxygen (in mg/L), water temperature (in °C), specific conductivity (mS/cm), total suspended solids (mg/L), total dissolved solids (mg/L), pH (S.U.), total alkalinity (mg CaCO<sub>3</sub>/L), total phosphorus and ortho-phosphorus (also known as soluble reactive phosphorus or SRP measured in mg/L), total Kjeldahl nitrogen (in mg/L), total inorganic nitrogen (in mg/L), chlorophyll-a (in µg/L), and Secchi transparency (in feet). All of these parameters respond to changes in water quality and consequently serve as indicators of change over time.

The deep basin results are discussed below and are presented in Tables 5-8 and the results for the incoming drains are displayed in Tables 9-10. A map showing the sampling locations for all water quality samples is shown below in Figure 5. All water samples and readings were collected at the two deepest basins on September 3, 2025 with the use of a Van Dorn horizontal water sampler and calibrated Eureka Manta II® multi-meter probe with parameter electrodes, respectively. All samples were collected with new bottles, placed on ice, and taken to a NELAC (EPA)-certified laboratory for analysis. Chlorophyll-a was measured in the laboratory. Sediment samples were collected with an Ekman hand dredge and placed in glass jars and transported to the laboratory on ice (Figure 6).



**Figure 5. Locations for deep basin and drainage water quality sampling in Pipestone Lake (September 3, 2025).**

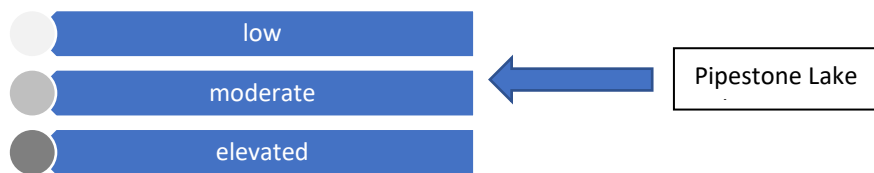


**Figure 6. Locations for sediment organic matter sampling in Pipestone Lake (September 3, 2025).**

#### **4.1.1 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 to sustain a healthy warm-water fishery and even higher around 6 mg/L for trout. 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) with the use of a calibrated Eureka Manta II® dissolved oxygen meter.

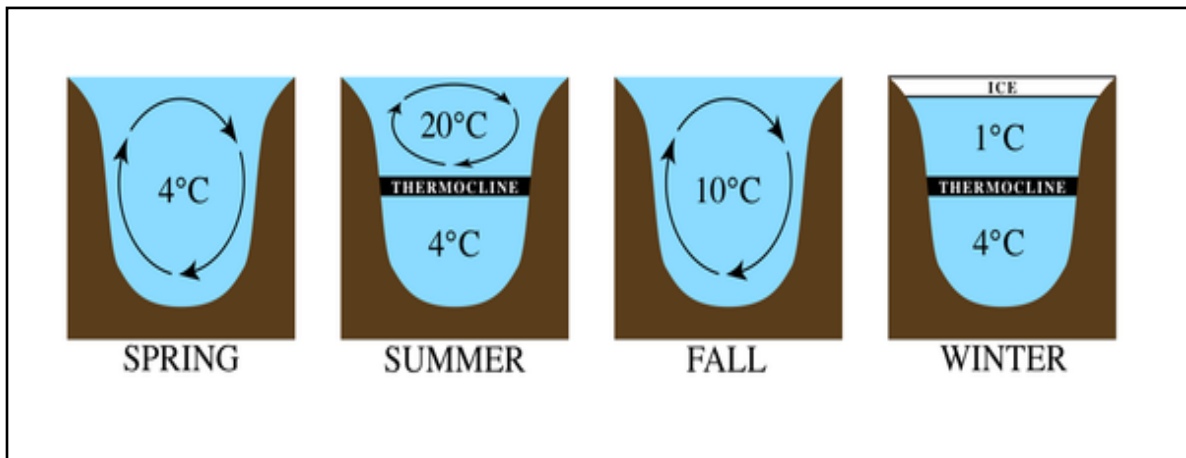
Dissolved oxygen (DO) concentrations in the deep basins ranged from 8.9-0.3 mg/L on September 3, 2025, with the highest values measured at the surface and lowest values near the lake bottom. The bottom of the lake produces a biochemical oxygen demand (BOD) due to microbial activity attempting to break down high quantities of organic plant matter, which reduces dissolved oxygen in the water column at depth. Furthermore, the lake bottom is distant from the atmosphere where the exchange of oxygen occurs. A decline in the dissolved oxygen concentrations to near zero may result in an increase in the release rates of phosphorus (P) from lake bottom sediments. The most recent 2024 CLMP data showed that historical depth and dissolved oxygen data is lacking.



#### **4.1.2 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" (Figure 7). In general, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature was measured in degrees Celsius ( $^{\circ}\text{C}$ ) with the use of a calibrated Eureka Manta II<sup>®</sup> submersible thermometer. The September 3, 2025 water temperatures of Pipestone Lake demonstrated the presence of thermoclines and are indicative of a lake that mixes two times per year due to the presence of deep basins.

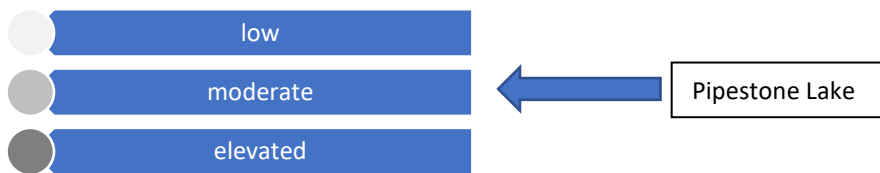
On the day of sampling, water temperatures ranged from 22.8 $^{\circ}\text{C}$  at the surface to 10.3 $^{\circ}\text{C}$  at the bottom of the two deep basins.



**Figure 7. The lake thermal stratification process.**

#### **4.1.3 Specific Conductivity**

Specific conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances that can conduct an electrical current. Specific conductivity generally increases with water temperature and the amount of dissolved minerals and salts in a lake. Specific conductivity was measured in micro Siemens per centimeter ( $\mu\text{S}/\text{cm}$ ) with the use of a calibrated Eureka Manta II<sup>®</sup> specific conductivity probe and meter. Specific conductivity values for Pipestone Lake were variable among depths at the deep basins on September 3, 2025 and ranged from 404-543 mS/cm which are moderate values. The highest specific conductivity values were recorded in deep basin #1. Since these values are moderate for an inland lake, the lake water contains ample dissolved metals and ions such as calcium, potassium, sodium, chlorides, sulfates, and carbonates. Baseline parameter data such as specific conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Pipestone 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. Elevated conductivity values over 800 mS/cm can negatively impact aquatic life. Historical data on this parameter is lacking.



#### 4.1.4 Total Dissolved Solids and Total Suspended Solids

##### 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. Total dissolved solids were measured with the use of a calibrated Eureka Manta II® meter in mg/L. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS in Pipestone Lake on September 3, 2025 ranged from 263-274 mg/L for the deep basins which is moderate for an inland lake and correlates with the measured moderate conductivity.



##### Total Suspended Solids (TSS)

Total suspended solids is a measure of the number of suspended particles in the water column. Particles suspended in the water column absorb heat from the sun and raise the water temperature. Total suspended solids were measured in mg/L and analyzed in the laboratory with Method SM 2540 D-11. The lake bottom contains many fine (flocculent) sediment particles that are easily perturbed from winds and wave turbulence. Spring values would likely be higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TSS concentrations in Pipestone Lake on September 3, 2025 ranged from <10-20 mg/L, with the highest concentrations located throughout deep basin #2. Ideally values should be < 10 mg/L but it is common to have higher values at the lake bottom where sediments are more flocculent. These values are overall good.



#### **4.1.5 pH**

pH is a measure of acidity or basicity 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 7.0 to 9.5 S.U. 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). The pH of Pipestone Lake water ranged from 7.2-8.9 S.U. during the September 3, 2025 sampling event. This range of pH is neutral to alkaline on the pH scale and is ideal for an inland lake but historical data is lacking on this parameter. pH tends to rise when abundant aquatic plants are actively growing through photosynthesis or when abundant marl deposits are present.

#### **4.1.6 Total Alkalinity**

Total alkalinity is a measure of the pH-buffering capacity of lake water. Lakes with high alkalinity (> 150 mg/L of CaCO<sub>3</sub>) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of CaCO<sub>3</sub> and are categorized as having “hard” water. Total alkalinity was measured in milligrams per liter of CaCO<sub>3</sub> through the acid titration Method SM 2320 B-11.

Total alkalinity in the deep basins ranged from 150-220 mg/L of CaCO<sub>3</sub> during the September 3, 2025 sampling event, which represents a moderately high alkalinity (hard water) and may be a characteristic of the lake sediments and geology. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water.

#### **4.1.7 Total Phosphorus and Ortho-Phosphorus (SRP)**

##### ***Total Phosphorus***

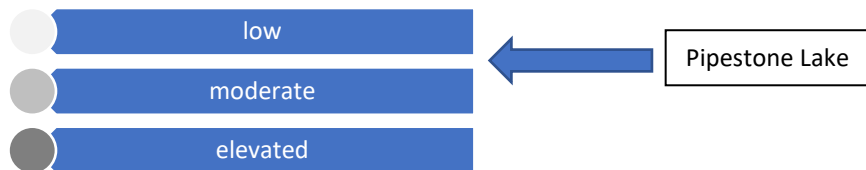
Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. Lakes which contain greater than 0.020 mg/L (or 20 µg/L) of TP are defined as eutrophic or nutrient-enriched. TP concentrations 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 milligrams per liter (mg/L) with the use of Method EPA 200.7 (Rev. 4.4).

The total phosphorus (TP) concentrations in the lake deep basins ranged from 0.012-0.270 mg/L during the September 3, 2025 sampling event. The highest concentration was measured near the bottom of deep basin #1. Both deep basins exhibited internal loading of phosphorus that may exacerbate blue-green algal blooms.



### ***Ortho-Phosphorus***

Ortho-Phosphorus (also known as soluble reactive phosphorus or SRP) was measured with Method SM 4500-P (E-11). SRP refers to the most bioavailable form of P used by all aquatic life. The SRP concentrations ranged from <0.010-0.026 mg/L on September 3, 2025 which is variable and favorable. The highest concentrations were found at the bottom of deep basin #1 but this value is just at the eutrophic threshold.



### **4.1.8 Total Kjeldahl Nitrogen and Total Inorganic Nitrogen**

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate ( $\text{NO}_3^-$ ), nitrite ( $\text{NO}_2^-$ ), ammonia ( $\text{NH}_4^+$ ), and organic nitrogen forms in freshwater systems. TKN was measured with Method EPA 351.2 (Rev. 2.0) and Total Inorganic Nitrogen (TIN) was calculated based on the aforementioned three different forms of nitrogen at Trace Analytical Laboratories, Inc. (a NELAC-certified laboratory). 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 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 groundwater 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. Lakes with a mean TKN value of 0.66 mg/L may be classified as oligotrophic, those with a mean TKN value of 0.75 mg /L may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg/L may be classified as eutrophic. The TKN concentrations for the sampling event ranged from <0.5-1.8 mg/L which is favorable.

Total Inorganic Nitrogen (TIN) is the sum of nitrate (NO<sub>3</sub><sup>-</sup>), nitrite (NO<sub>2</sub><sup>-</sup>), and ammonia (NH<sub>4</sub><sup>+</sup>), nitrogen forms in freshwater systems. TIN was measured with Method EPA 351.2 (Rev. 2.0) and Total Inorganic Nitrogen (TIN) was calculated based on the aforementioned three different forms of nitrogen. 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 groundwater 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, which is correct for Pipestone Lake. 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. Pipestone Lake contained low to moderate concentrations of TIN at all depths (0.100-0.500 mg/L), which is normal for an inland lake of similar size and favorable. In the absence of dissolved oxygen, nitrogen is usually in the ammonia form and will contribute to rigorous submersed aquatic plant growth if adequate water transparency is present. All of the TIN present in the Pipestone Lake samples was in ammonia form and the nitrate and nitrite were both below detection. Historical data for both types of nitrogen has been scarce.



#### **4.1.9 Chlorophyll-*a* and Algal Communities**

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes.

Chlorophyll-*a* concentrations greater than 6 µg/L are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg/L are found in nutrient-poor or oligotrophic lakes.

Chlorophyll-*a* was measured in micrograms per liter (µg/L) with Method SM 10200H. The chlorophyll-*a* concentrations in Pipestone Lake were determined by collecting a composite sample of the algae throughout the water column at the deep basin sites from just above the lake bottom to the lake surface. The chlorophyll-*a* concentrations in the deep basins ranged from 21.4-99.3 µg/L during the September 3, 2025 sampling event which is very high. Historical data on this parameter has been scarce. Chlorophyll-*a* concentrations may significantly fluctuate with changes in air and water temperatures and with storm-driven runoff.

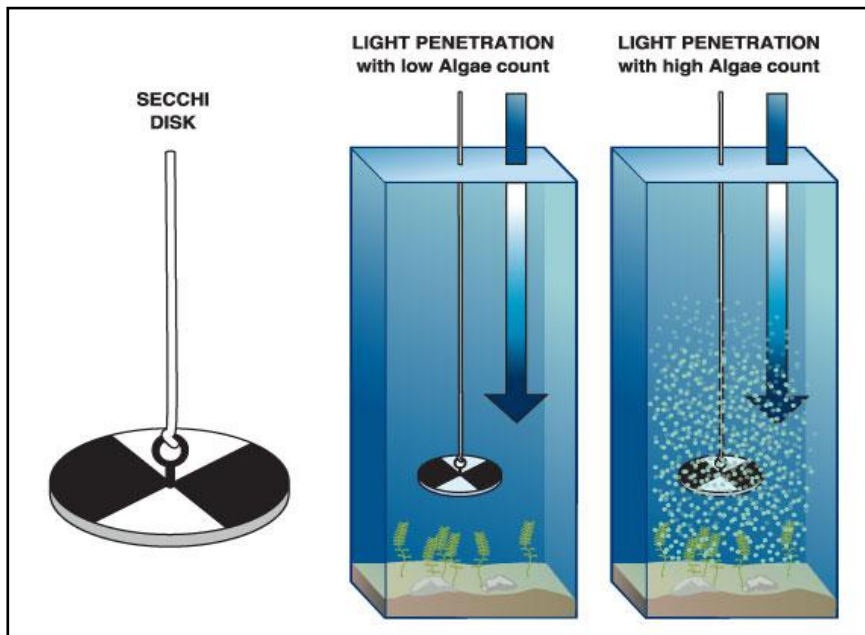
Algal genera from a composite water sample collected from the deep basins of Pipestone Lake were analyzed under a Zeiss® compound brightfield microscope. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Rhizoclonium* sp., *Spirogyra* sp., *Mougeotia* sp., *Staurastrum* sp., *Botryococcus* sp., and *Pediastrum* sp.; the Cyanophyta (blue-green algae): *Microcystis* sp., and *Oscillatoria* sp.; the Bascillariophyta (diatoms): *Navicula* sp., *Synedra* sp., *Fragilaria* sp., *Tabellaria* sp., and *Cymbella* sp. The aforementioned species indicate a moderately diverse algal flora and represent a relatively balanced freshwater ecosystem, capable of supporting a strong zooplankton community in favorable water quality conditions. The blue-green algae were dominant with green algae and diatoms equally prevalent.



#### 4.1.10 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. Secchi disk transparency is measured in feet (ft.) or meters (m) 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 (Figure 8). Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. The Secchi transparency of Pipestone Lake was measured on September 3, 2025 and was 6.4 feet over the deep basins which are fair measurements. Measurements were collected during calm conditions.

This transparency indicates a moderate quantity of suspended particles and algae throughout the water column which would result in reduced water clarity. 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. Secchi transparency has been scarce on the lake and is likely correlated with lake use and wind and storm events as well as the concentrations of algae and solids.



**Figure 8. Measurement of water transparency with a Secchi disk.**

**4.1.11 Sediment Relative Hardness and Sediment Organic Matter**

Organic matter (OM) contains a high amount of carbon which is derived from biota such as decayed plant and animal matter. Detritus is the term for all dead organic matter which is different than living organic and inorganic matter. OM may be autochthonous or allochthonous in nature where it originates from within the system or external to the system, respectively.

A total of five lake sediment samples were collected with an Ekman hand dredge. Sediment OM is measured with the ASTM D2974 Method and is usually expressed in a percentage (%) of total bulk volume. Many factors affect the degradation of organic matter including basin size, water temperature, thermal stratification, dissolved oxygen concentrations, particle size, and quantity and type of organic matter present.

The organic content in the Pipestone Lake sediments ranged from 0.4-53.0% organic matter, which is variable with lower organic carbon nearshore and higher values in deeper water. This indicates that the lake has overall highly variable sediments (Table 3).

**Table 3. Pipestone Lake sediment nutrients (% OM) collected from 5 locations throughout the lake on September 3, 2025.**

<i>Sediment Site</i>	<i>% Organic Matter</i>
1	0.4
2	4.7
3	15.0
4	53.0
5	1.4

A bottom sediment hardness scan with 2,426 GPS soundings was conducted of the entire lake bottom on September 3, 2025. The bottom hardness map shows (Figure 9) that most of the lake bottom consists of a mix of consolidated and softer marl areas throughout the lake. Table 4 below shows the categories of relative bottom hardness with 0.0-0.1 referring to the softest and least consolidated bottom and >0.4 referring to the hardest, most consolidated bottom.

**Table 4. Pipestone Lake relative hardness of the lake bottom on September 3, 2025 by category or hardness and percent cover of each category (relative cover).**

<b>Lake Bottom Relative Hardness Category</b>	<b>% Relative Cover of Bottom by Category</b>
<b>0.0-0.1</b>	7.7
<b>0.1-0.2</b>	14.7
<b>0.2-0.3</b>	31.5
<b>0.3-0.4</b>	40.2
<b>&gt;0.4</b>	5.9

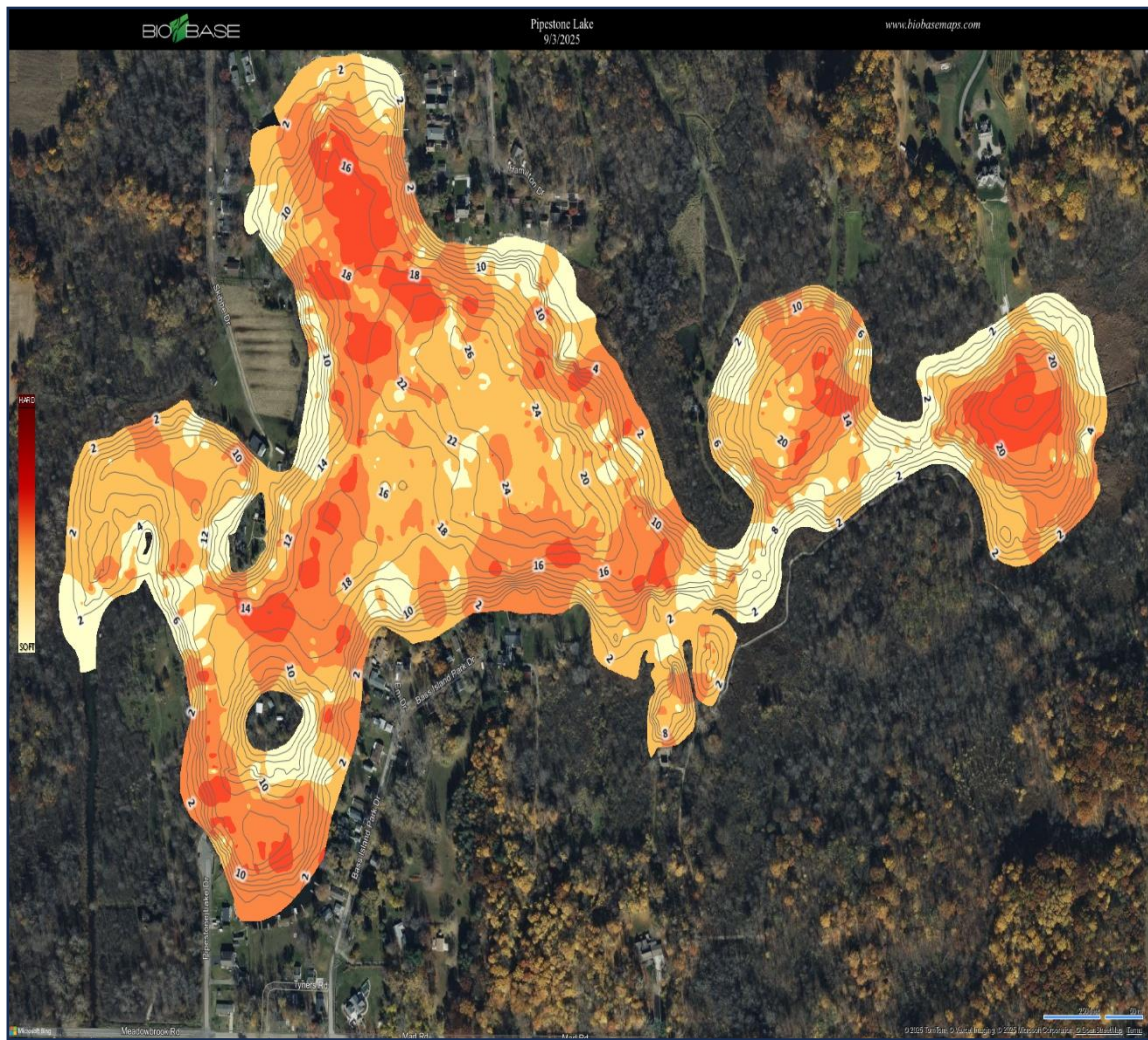


Figure 9. Pipestone Lake sediment relative hardness map. Note: The light colored areas represent less consolidated sediments, and the darker colors represent more consolidated sediments.

**Table 5. Pipestone Lake physical water quality parameter data collected in deep basin #1 (September 3, 2025).**

Depth (m)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Secchi Depth (ft)
0	22.7	8.9	8.9	415	265	6.4
0.5	22.7	8.7	8.9	415	265	
1.0	22.7	8.6	8.9	415	265	
1.5	22.7	8.6	8.9	415	265	
2.0	22.7	8.6	8.8	415	265	
2.5	22.2	8.0	8.5	422	270	
3.0	22.0	7.6	8.4	425	272	
3.5	21.7	6.7	8.2	427	274	
4.0	21.4	5.5	8.1	428	274	
4.5	21.2	3.9	8.0	428	274	
5.0	20.6	3.5	7.9	423	271	
5.5	19.2	1.8	7.7	416	266	
6.0	16.2	1.1	7.4	410	263	
6.5	12.7	0.7	7.2	464	295	
7.0	11.3	0.5	7.2	506	326	
7.5	10.3	0.3	7.4	543	347	

**Table 6. Pipestone Lake chemical water quality parameter data collected in deep basin #1 (September 3, 2025).**

Depth (m)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TIN (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	<0.5	0.012	<0.010	<0.100	<10	21.4	170
3.5	<0.5	0.018	<0.010	<0.100	<10		190
7.5	1.8	0.270	<0.010	<0.500	18		200

**Table 7. Pipestone Lake physical water quality parameter data collected in deep basin #2 (September 3, 2025).**

Depth (m)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Secchi Depth (ft)
0	22.8	8.6	8.9	405	259	6.4
0.5	22.8	8.6	8.9	405	259	
1.0	22.8	8.6	8.9	405	259	
1.5	22.8	8.6	8.9	405	259	
2.0	22.8	8.6	8.9	404	259	
2.5	22.8	8.6	8.8	405	259	

**Table 8. Pipestone Lake chemical water quality parameter data collected in deep basin #2 (September 3, 2025).**

Depth (m)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TIN (mg/L)	TSS (mg/L)	Chl-a (µg/L)	Talk (mg/L)
0	<0.5	0.012	<0.010	<0.100	<10	99.3	190
1.5	<0.5	0.016	<0.010	<0.100	<10		150
2.5	1.8	0.120	<0.010	<0.500	20		220

**Table 9. Pipestone Lake physical water quality parameter data collected in the N=5 drains (September 3, 2025). Note: Drains D2 and D3 were not actively flowing during site visits and thus could not be sampled at those times.**

Drain Site #	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Flow (cfs)
D1	16.2	9.6	9.2	585	375	0.1
D2	NA	NA	NA	NA	NA	NA
D3	NA	NA	NA	NA	NA	NA
D4	13.0	8.0	8.2	478	305	0.1
D5	14.2	7.6	7.9	95.0	60.8	0.01

**Table 10. Pipestone Lake chemical water quality parameter data collected in the N=5 drains (September 3, 2025).**

Drain Site #	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TIN (mg/L)	TSS (mg/L)	Talk (mg/L)
D1	<0.5	0.020	<0.010	<0.100	20	260
D2	NA	NA	NA	NA	NA	NA
D3	NA	NA	NA	NA	NA	NA
D4	<0.5	0.020	<0.010	<0.100	<10	220
D5	1.1	0.018	<0.010	<0.500	<10	160

The drains contained low quantities of nutrients such as phosphorous and nitrogen and thus are not likely large contributors to the lake nutrient status. More high-flow data is needed in the future however to confirm this.

## 4.2 Pipestone Lake Aquatic Vegetation Communities

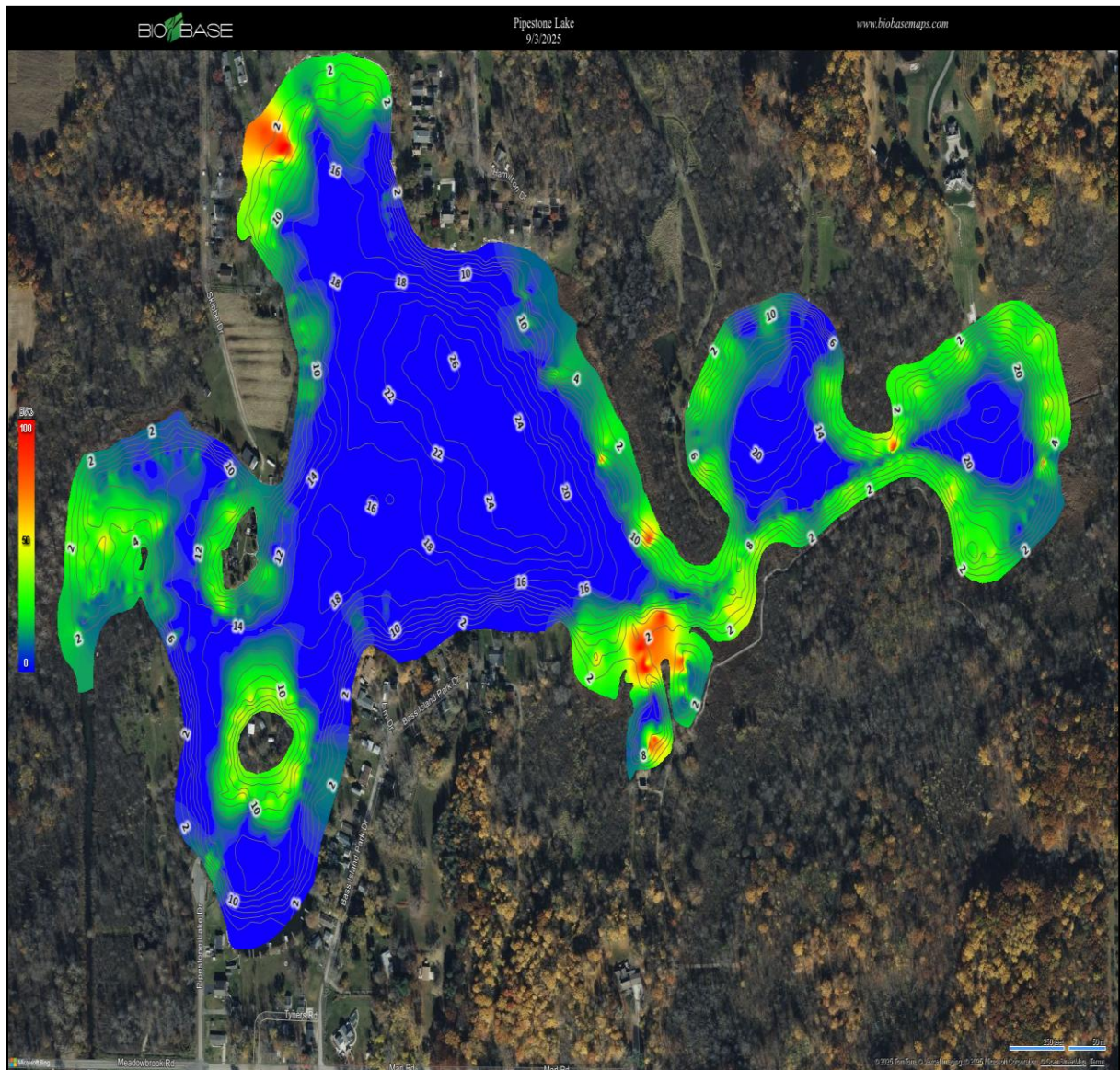
Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as suitable habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients such as phosphorus and nitrogen upon decay. 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, Native Loosestrife) 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., Milfoils, 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. Pipestone Lake currently has a favorable quantity of submersed aquatic vegetation with only one sampling location showing a lack of aquatic vegetation.

A whole-lake scan of the aquatic vegetation biovolume in Pipestone Lake was conducted on September 3, 2025 with a WAAS-enabled Lowrance HDS 9<sup>®</sup> GPS with variable frequency transducer. This data included 2,426 GPS data sounding points which were uploaded to a cloud software program to reveal maps that displayed depth contours, sediment hardness, and aquatic vegetation biovolume. On the biovolume scan map (Figure 10), the color blue refers to areas that lack vegetation. The color green refers to low-lying vegetation. The colors red/orange refer to tall-growing vegetation. There are many areas around the littoral (shallow) zone of the lake that contain low-growing plants like Chara or Naiad. For this reason, the scans are conducted in conjunction with a whole lake GPS Point Intercept survey to account for individual species identification of all aquatic plants in the lake. Table 11 shows the biovolume categories by plant cover on September 3, 2025.

The GPS Point Intercept survey is sometimes used with an Aquatic Vegetation Assessment Site (AVAS) Survey method to assess the relative abundance of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of inland lakes. With this survey method, the littoral zone areas of the lakes are divided into lakeshore sections approximately 100 - 300 feet in length.

Each AVAS segment is sampled using visual observation, dependent on water clarity, and weighted rake tows to verify species identification. The species of aquatic macrophytes present and density of each macrophyte are recorded onto an AVAS data sheet. Each separate plant species found in each AVAS segment is recorded along with an estimate of each plant density. Each macrophyte species corresponds to an assigned number. 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). In addition to the particular species observed (via assigned numbers), density information above was used to estimate the percent cumulative coverage of each species within the AVAS site. Where shallow areas were present in the open waters of the lake, individual AVAS segments were sampled at those locations to assess the macrophyte communities in offshore locations. This is particularly important since exotics often expand in shallow island areas located offshore in many lakes.

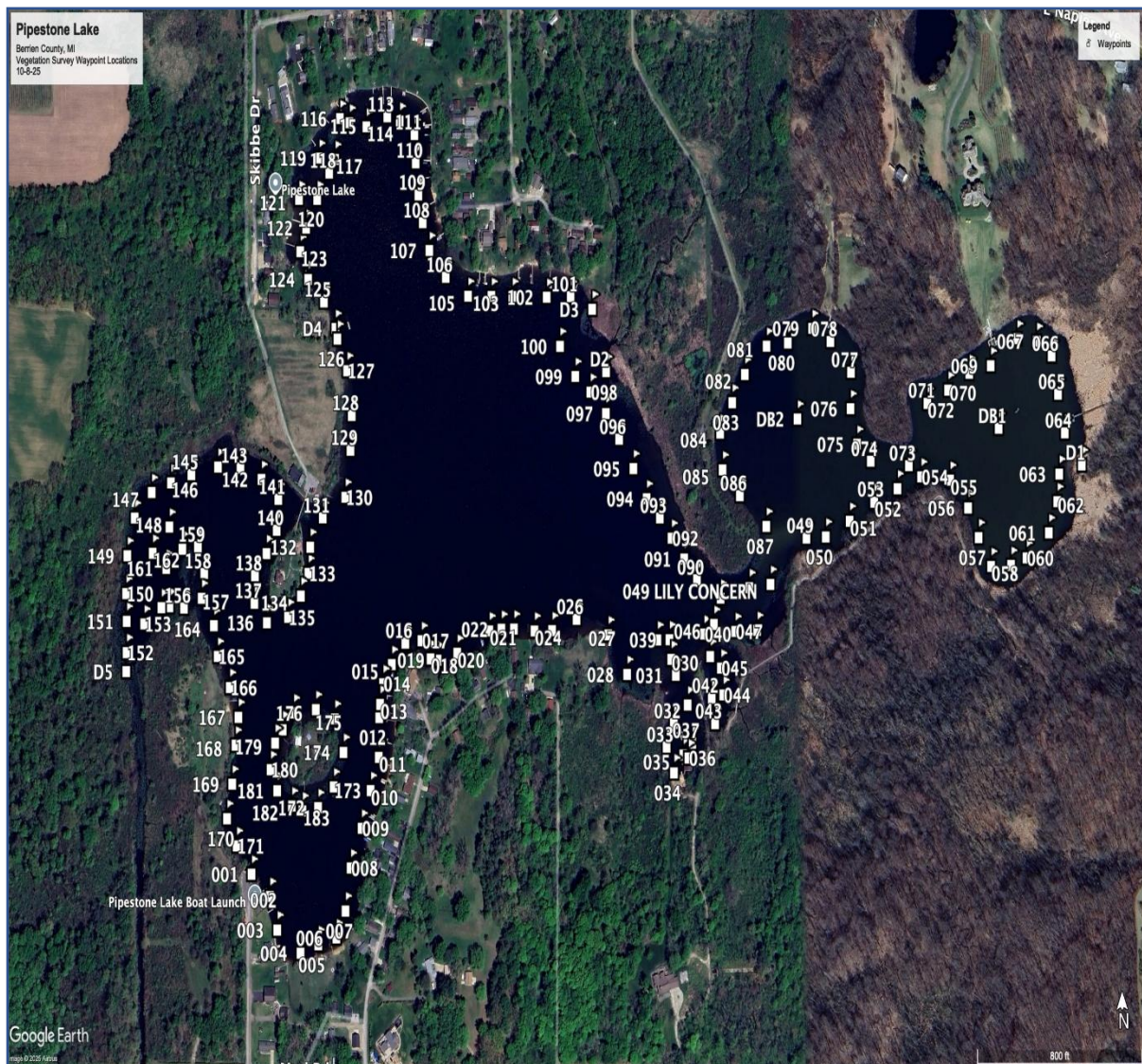
The GPS Point-Intercept/AVAS survey of Pipestone Lake was conducted on August 28, 2025 and consisted of 182 sampling locations around the littoral zone (Figure 11). Data were placed in a table showing the relative abundance of each aquatic plant species found and a resultant calculation showing the frequency of each plant. The majority of the lake contained low-growing aquatic plants that were within the 0-5% cover and 5-20% cover categories.



**Figure 10. Aquatic plant biovolume of all aquatic plants in Pipestone Lake, Pipestone County, Michigan (September 3, 2025). Note: Red denotes high-growing aquatic plants, green color denoted low-growing aquatic plants, and blue color represents a lack of aquatic vegetation.**

**Table 11. Pipestone Lake aquatic vegetation biovolume by bottom cover category (relative cover on September 3, 2025).**

<b>Aquatic Vegetation Biovolume Cover Category</b>	<b>% Relative Cover of Bottom by Category</b>
<b>0-20%</b>	78.6
<b>20-40%</b>	14.5
<b>40-60%</b>	5.6
<b>60-80%</b>	0.4
<b>80-100%</b>	0.8



**Figure 11. Aquatic vegetation sampling locations in Pipestone Lake (August 28, 2025).**

#### **4.2.1 Pipestone 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 (Milfoils). 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.

Pipestone Lake contained 10 native submersed, 2 floating-leaved, and 6 emergent aquatic plant species, for a total of 18 native aquatic macrophyte species (Table 12). Relative abundance for each aquatic plant species is shown in Table 13. Photos of all native aquatic plants are shown below in Figures 12-29. The emergent macrophytes were found along the shoreline areas of the lake. Additionally, the lower-growing species were found throughout the littoral zone, and the higher-growing pondweeds were present in the deeper waters of the littoral zone where they were protected from wave action.

The dominant aquatic plants in the main part of the lake included the White waterlily (91.8% of the sampling locations), the emergent Pickerelweed (51.1% of the sampling locations), and the submersed rootless Coontail (44.0% of the sampling locations). The pondweeds grow tall in the water column and serve as excellent fish cover. Protection of all native aquatic plant species is critical for the lake ecosystem especially since the relative abundance is overall low for most native aquatic plant species.

Rooted aquatic plants (relative to non-rooted plants) utilize nutrients in the sediments and rootless aquatic plants use nutrients in the water column). Pipestone Lake has a good balance of both rooted and non-rooted aquatic vegetation along with an abundance of floating-leaved and emergent aquatic vegetation.

**Table 12. Pipestone Lake native aquatic vascular plants and frequency (August 28, 2025).**

<b><i>Native Aquatic Plant Species Name</i></b>	<b><i>Native Aquatic Plant Common Name</i></b>	<b><i>Growth Form</i></b>	<b><i>% Frequency</i></b>
<i>Chara vulgaris</i>	Muskgrass	Submersed	10.4
<i>Stuckenia pectinatus</i>	Sago Pondweed	Submersed	28.6
<i>Potamogeton zosteriformis</i>	Flat-stem Pondweed	Submersed	14.8
<i>Potamogeton gramineus</i>	Variable-leaf Pondweed	Submersed	4.4
<i>Potamogeton natans</i>	Floating-leaf Pondweed	Submersed	1.6
<i>Potamogeton pusillus</i>	Small-leaf Pondweed	Submersed	0.5
<i>Utricularia vulgaris</i>	Bladderwort	Submersed	1.6
<i>Ceratophyllum demersum</i>	Coontail	Submersed	44.0
<i>Vallisneria americana</i>	Wild Celery	Submersed	13.7
<i>Najas guadalupensis</i>	Southern Naiad	Submersed	0.5
<i>Nymphaea odorata</i>	White Waterlily	Floating-Leaved	91.8
<i>Nuphar advena</i>	Yellow Waterlily	Floating-Leaved	41.7
<i>Schoenoplectus acutus</i>	Bulrushes	Emergent	11.0
<i>Pontedaria cordata</i>	Pickerelweed	Emergent	51.1
<i>Typha latifolia</i>	Cattails	Emergent	29.1
<i>Decodon verticillatus</i>	Swamp Loosestrife	Emergent	28.0
<i>Arrow arum</i>	Arrowhead	Emergent	30.2
<i>Cephalanthus sp.</i>	Buttonbush	Emergent	0.5

**Table 13. Pipestone Lake native aquatic vascular plants and relative abundance (August 28, 2025 ).**

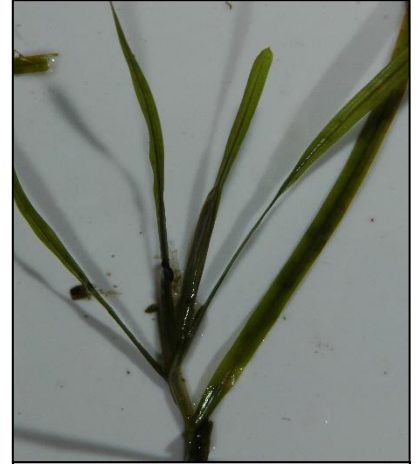
<b><i>Native Aquatic Plant Species Name</i></b>	<b><i>“a” Level</i></b>	<b><i>“b” Level</i></b>	<b><i>“c” Level</i></b>	<b><i>“d” Level</i></b>
<i>Chara vulgaris</i>	0	7	8	4
<i>Stuckenia pectinatus</i>	14	29	9	0
<i>Potamogeton zosteriformis</i>	10	16	1	0
<i>Potamogeton gramineus</i>	1	7	0	0
<i>Potamogeton natans</i>	0	2	1	0
<i>Potamogeton pusillus</i>	0	1	0	0
<i>Utricularia vulgaris</i>	2	1	0	0
<i>Ceratophyllum demersum</i>	22	54	2	2
<i>Vallisneria americana</i>	4	17	4	0
<i>Najas guadalupensis</i>	0	1	0	0
<i>Nymphaea odorata</i>	5	25	108	29
<i>Nuphar advena</i>	0	8	40	28
<i>Schoenoplectus acutus</i>	7	11	2	0
<i>Pontedaria cordata</i>	5	28	55	5
<i>Typha latifolia</i>	10	15	20	8
<i>Decodon verticillatus</i>	2	36	13	0
<i>Arrow arum</i>	7	24	24	0
<i>Cephalanthus sp.</i>	1	0	0	0



**Figure 12. Chara  
(Muskgrass)**



**Figure 13. Sago  
Pondweed**



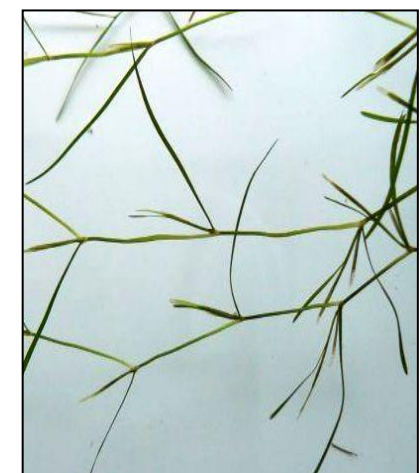
**Figure 14. Flat-stem  
Pondweed**



**Figure 15. Variable-leaf  
Pondweed**



**Figure 16. Floating-leaf  
Pondweed**



**Figure 17. Small-Leaf  
Pondweed**



**Figure 18. Bladderwort**



**Figure 19. Coontail**



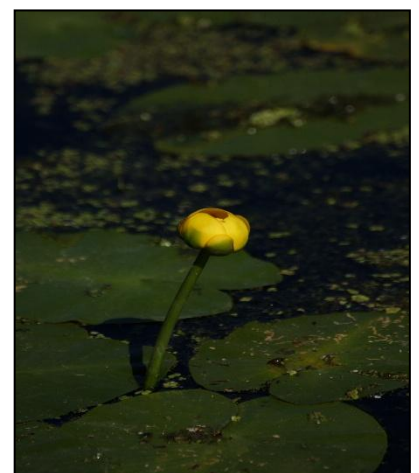
**Figure 20. Wild Celery**



**Figure 21. Southern Naiad**



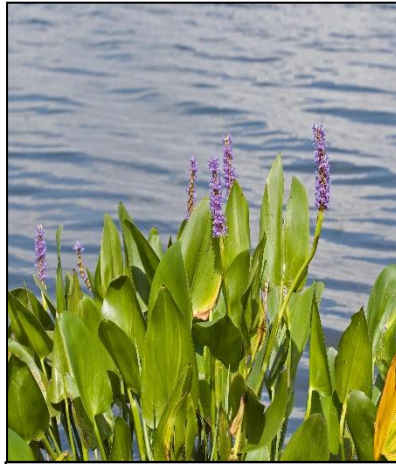
**Figure 22. White Waterlily**



**Figure 23. Yellow Waterlily**



**Figure 24. Bulrushes**



**Figure 25. Pickerelweed**



**Figure 26. Cattails**



**Figure 27. Swamp  
Loosestrife**



**Figure 28. Arrowhead**



**Figure 29. Buttonbush**

#### **4.2.2 Pipestone Lake Exotic Aquatic Macrophytes**

Exotic aquatic plants (macrophytes) are not native to a particular site and 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 30) 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 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).

Approximately 3.5 acres of Eurasian Watermilfoil were found in Pipestone Lake during the August 28, 2025 survey (Figure 31). A precise management program is proposed below. Eurasian Watermilfoil growth in Pipestone Lake is capable of producing dense surface canopies in shallow areas as well as in deeper waters due to the sometimes high light penetration. In addition, it could hybridize with native watermilfoils and create a highly herbicide-resistant strain.

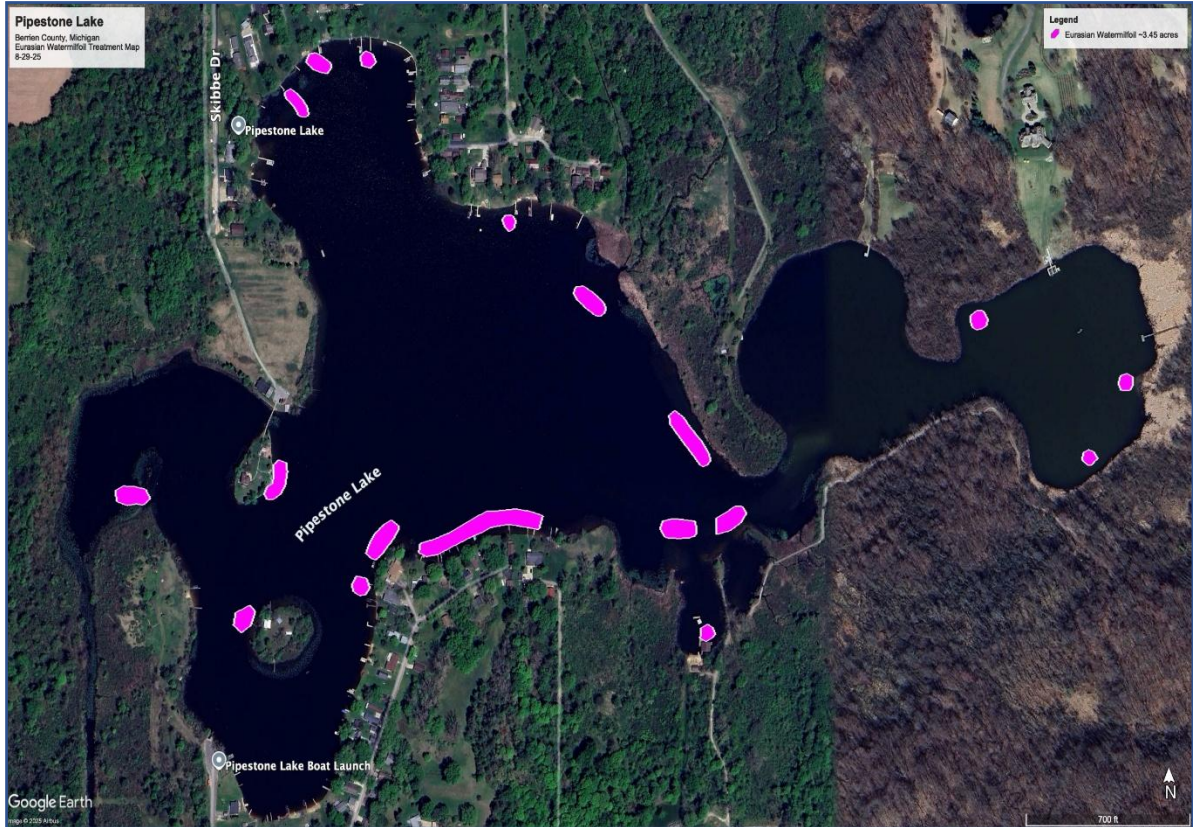
Purple Loosestrife (*Lythrum salicaria*; Figure 32) is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas and was found in 32 locations (Figure 33) around the shoreline of Pipestone Lake. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as Cattails (*Typha latifolia*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity. It should be removed promptly if found (i.e. by hand pulling or using a shovel to remove the roots and then discarding the plant into the garbage) to avoid further infestation.

If the plant is not promptly removed by hand, it could dominate in wetland areas and require larger-scale systemic herbicide treatments.

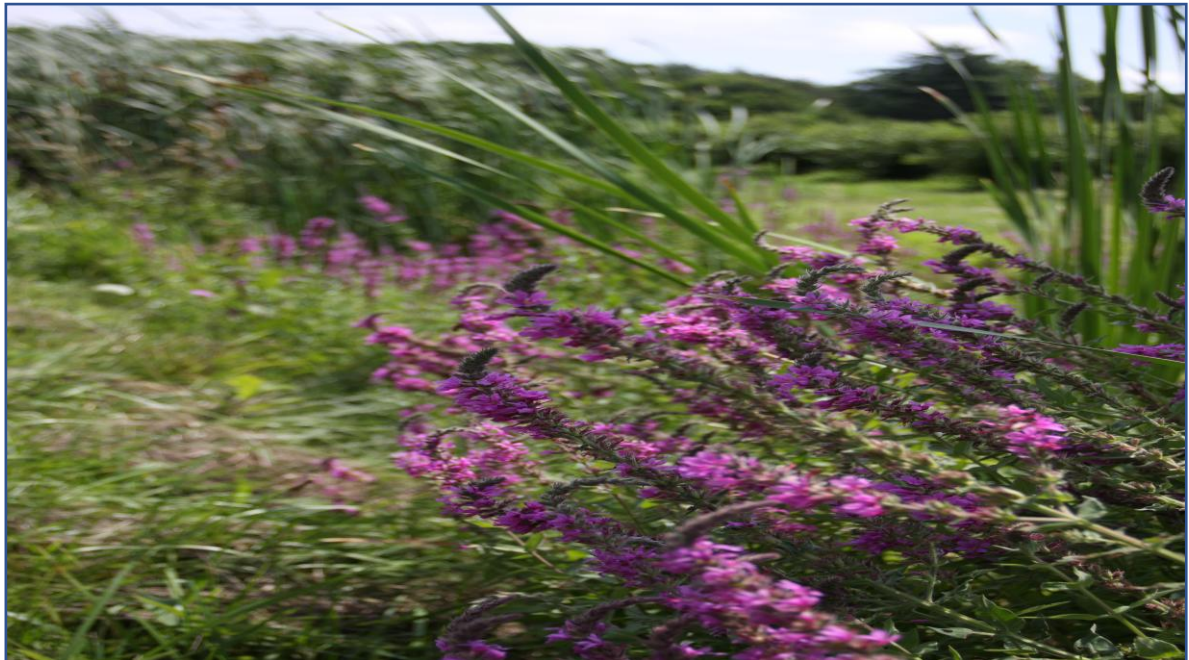
The species of invasive aquatic plants present, and relative abundance of each plant were recorded and then the amount of cover in the littoral zone was calculated. Exotic aquatic plant species that were found in Pipestone Lake on August 28, 2025 are shown in Table 14 below and discussions of key invasives also follow below.



**Figure 30. Hybrid Eurasian Watermilfoil plant with seed head and fragments.**



**Figure 31. EWM distribution in Pipestone Lake (August 28, 2025).**



**Figure 32. The invasive emergent Purple Loosestrife (©RLS).**

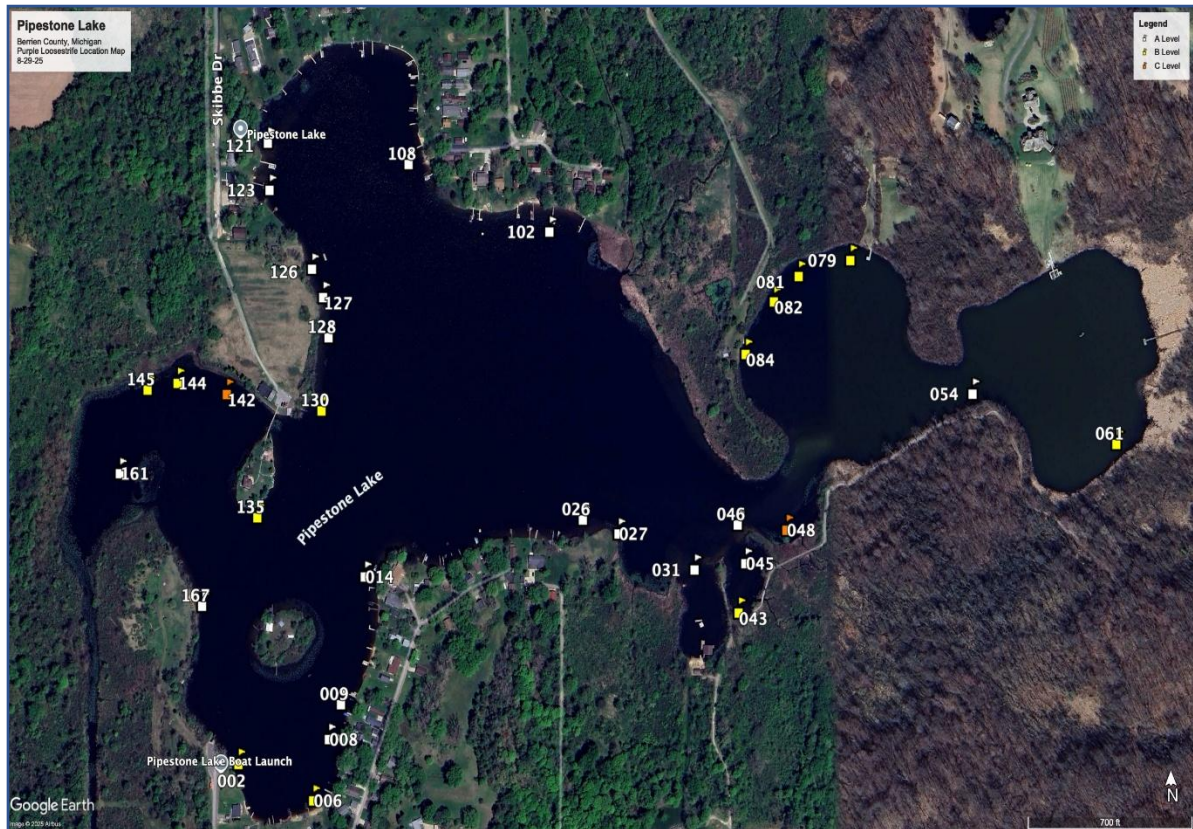


Figure 33. Purple Loosestrife distribution around Pipestone Lake (August 28, 2025).

Table 14. Pipestone Lake exotic aquatic plant species (August 28, 2025).

<i>Exotic Aquatic Plant Species</i>	<i>Exotic Aquatic Plant Common Name</i>	<i>Exotic Aquatic Plant Growth Habit</i>	<i>Abundance in/around Pipestone Lake</i>
<i>Myriophyllum spicatum</i>	Eurasian Watermilfoil	Rooted, Submersed	~3.5 acres
<i>Lythrum salicaria</i>	Purple Loosestrife	Emergent	32 sites

### **4.3 Pipestone Lake Food Chain: Zooplankton**

The zooplankton and macroinvertebrates make up the food chain base in an aquatic ecosystem and thus are integral components. Zooplankton are usually microscopic, but some can be seen with the unaided eye. Macroinvertebrates can be readily seen and are also known as aquatic insects or bugs. The zooplankton migrate throughout the water column of the lake according to daylight/evening cycles and are prime food for the lake fishery. Macroinvertebrates can be found in a variety of locations including on aquatic vegetation, near the shoreline, and in the lake bottom sediments. The biodiversity and relative abundance of both food chain groups are indicative of water quality status and productivity. For this evaluation, zooplankton was sampled and analyzed.

#### ***Lake Zooplankton***

A zooplankton tow using a Wildco® pelagic plankton net (63 micrometer) with collection jar (Figure 34) was conducted by RLS scientists on September 3, 2025 in the 2 deep basins of Pipestone Lake. The plankton net was left at depth for 30 seconds and then raised slowly to the surface at an approximate rate of 4 feet/second. The net was then raised above the lake surface and water was splashed on the outside of the net to dislodge any zooplankton from the net into the jar. The jar was then drained into a 125-mL bottle with a CO<sub>2</sub> tablet to anesthetize the zooplankton. The sample was then preserved with a 70% ethyl alcohol solution. Plankton sub-samples (in 1 ml aliquots) were analyzed under a Zeiss® dissection scope with the use of a Bogorov counting chamber. Taxa were keyed to genus and are shown in Tables 15-16 below.

Overall, the counts were favorable for all categories with highest counts in the cladocerans and rotifers.



Figure 34. A zooplankton collection tow net.

Table 15. Zooplankton taxa and count data from Pipestone Lake Deep Basin #1 (September 3, 2025).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia</i> sp.	29	<i>Cyclops</i> sp.	4	<i>Keratella</i> sp.	19
<i>Chydorus</i> sp.	5	<i>Nauplius</i> sp.	11		
<i>Bosmina</i> spp.	9				

Table 16. Zooplankton taxa and count data from Pipestone Lake Deep Basin #2 (September 3, 2025).

Cladocerans	Count	Copepods	Count	Rotifers	Count
<i>Daphnia</i> sp.	38	<i>Cyclops</i> sp.	2	<i>Keratella</i> sp.	17
<i>Chydorus</i> spp.	2	<i>Mesocyclops</i> sp.	6	<i>Asplanchna</i> sp.	6
<i>Bosmina</i> sp.	7				

## **5.0 PIPESTONE LAKE MANAGEMENT METHODS**

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This section offers methods to reduce the transport as well as the quantity of invasive aquatic plants. Aquatic invasive species (AIS) prevention methods are discussed below along with justifications for specific recommendations.

### **5.1 Pipestone Lake Aquatic Plant Management**

The management of submersed nuisance invasive aquatic plants is necessary in Pipestone Lake due to potential accelerated growth and distribution. Management options should be environmentally and ecologically-sound and financially feasible. Options for control of aquatic plants are limited yet are capable of achieving strong results when used properly. Protection of native aquatic plant species (especially the low growing native plants) in Pipestone Lake to provide for a healthier lake is recommended to maintain and improve lake health. All aquatic vegetation should be managed with solutions that will yield the longest-term results. A detailed Early Detection Rapid Response Protocol (EDRR) is recommended for Pipestone Lake in the future for each invasive species and to prevent others from entering the lake or becoming problematic. The following sections detail invasive species prevention and community education.

#### ***5.1.1 Aquatic Invasive Species Prevention***

An exotic species is a non-native species that does not originate from a particular location. When international commerce and travel became prevalent, many of these species were transported to areas of the world where they did not originate. Due to their small size, insects, plants, animals, and aquatic organisms may escape detection and be unknowingly transferred to unintended habitats.

The first ingredient to successful prevention of unwanted transfers of exotic species to Pipestone Lake is awareness and education (Figures 35 and 36). The exotic species of concern have been listed in this report. Other exotic species on the move could be introduced to the riparians around Pipestone Lake through the use of a professionally developed educational newsletter or through public workshops on the health of the Pipestone Lake ecosystem.

Public boat launches are a primary area of vector transport for all invasive species and thus boat washing stations have become more common. 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 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.

Boat washing stations offer opportunities for collaborative efforts between lake groups, the MDNR, and EGLE. Figures 37-38 demonstrate the use of a boat washing station to prevent the spread of invasives into lakes with public access which is applicable to Pipestone Lake.

Additional educational information regarding these stations and education can be found on the following websites:

- 1) USDA: <https://www.invasivespeciesinfo.gov/us/Michigan>
- 2) Michigan Wildlife Federation Invasive animals, plants list, and native plants/animals list: <https://www.Michiganwildlife.org/wildlife>
- 3) Stop Aquatic Hitchhikers!: [www.protectyourwaters.net](http://www.protectyourwaters.net)

Recently, MSU partnered with EGLE to study the various forms of boat washing stations (including the innovative CD3 units) on lakes to analyze effectiveness of invasive removal, behavior patterns and preference for use, and short and long-term cost effectiveness of each system. This will assist in the placement of specific types of wash stations around specific portals of entry around lakes. Boat washing stations and invasive species prevention signs are recommended at all public entry sites where practical, especially since enforcement is not required and is lacking.



Figure 35. An aquatic invasive prevention sign for public access sites.



Figure 36. An aquatic hitchhiker (milfoil) on a boat trailer.



**Figure 37. A public boat washing station on Higgins Lake, Michigan.**



**Figure 38. A responsible boat owner using a boat washing station.**

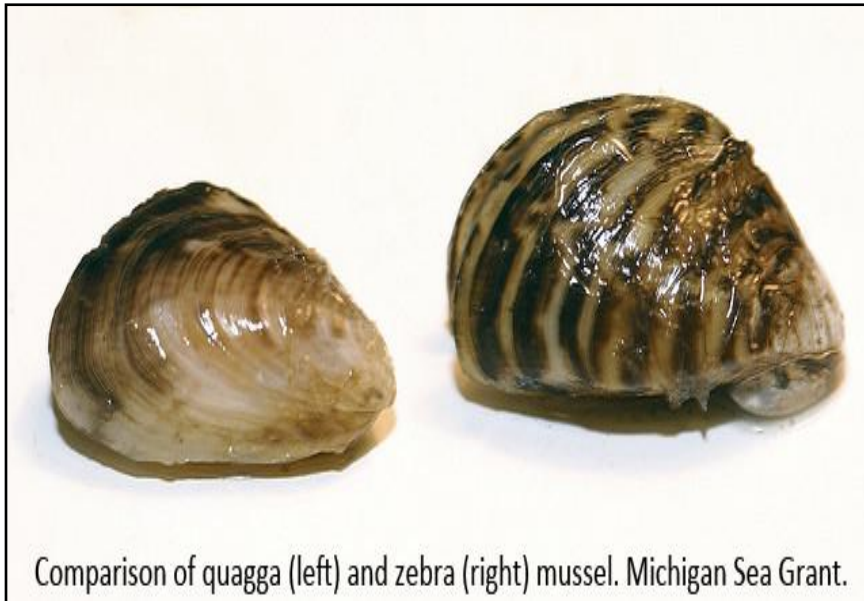
### ***Zebra Mussels and Quagga Mussels***

Although these were not found by RLS in September, 2025, proper protocols for their prevention are offered below.

Zebra Mussels (*Dreissena polymorpha*; Figure 39) were first discovered in Lake St. Clair in 1988 and likely arrived in ballast water or on shipping vessels from Europe (McMahon 1996). They are easily transferred to other lakes because they inherit a larval (nearly microscopic) stage where they can easily avoid detection. The mussels then grow into the adult (shelled) form and attach to substrates (i.e. boats, rafts, docks, pipes, aquatic plants, and lake bottom sediments) with the use of byssal threads. The fecundity (reproductive rate) of female Zebra Mussels is high, with as many as 40,000 eggs laid per reproductive cycle and up to 1,000,000 in a single spawning season (Mackie and Schlosser 1996). Although the mussels only live 2-3 years, they are capable of great harm to aquatic environments. In particular, they have shown selective grazing capabilities by feeding on the preferred zooplankton food source (green algae) and expulsion of the non-preferred blue green algae (cyanobacteria). Additionally, they may decrease the abundance of beneficial diatoms in aquatic ecosystems (Holland 1993). Such declines in favorable algae, can decrease zooplankton populations and ultimately the biomass of planktivorous fish populations. Zebra Mussels are viewed by some as beneficial to lakes due to their filtration capabilities and subsequent contributions to increased water clarity. However, such water clarity may allow other photosynthetic aquatic plants to grow to nuisance levels (Skubinna et al. 1995).

Quagga Mussels (*Dreissena bugensis*; Figure 39) are native the Ukraine and have created an economical burden to the Great Lakes fishery due to their great ability to alter the planktonic food chain in the lakes. They currently outrank the Zebra Mussels in abundance in the Great Lakes and are capable of filtering larger quantities of water and therefore assimilating more plankton. These mussels were shown to be highly selective in choosing naked flagellates such as Rhodomonas as well as larger diatoms (NOAA research; noaa.gov).

Although neither of these were noted during the lake study, the recommended prevention protocols for further introduction of mussels includes steam-washing all boats, boat trailers, jet-skis, and floaters prior to placing them into Pipestone Lake. Fishing poles, lures, and other equipment used in other lakes (and especially the Great Lakes) should also be thoroughly steam-washed before use in Pipestone Lake. Additionally, all solid construction materials (if recycled from other lakes) must also be steam-washed. Boat transom wells must always be steam-washed and emptied prior to entry into the lake. Excessive waterfowl should also be discouraged from the lake since they are a natural transportation vector of the microscopic Zebra Mussel larvae or mature adults.



**Figure 39. Zebra Mussels and Quagga Mussels**  
(Photo courtesy of Michigan Sea Grant).

### ***Invasive Aquatic Plants***

In addition to Eurasian Watermilfoil (*M. spicatum*), many other invasive aquatic plant species have been introduced into waters of the North Temperate Zone. The majority of exotic aquatic plants do not depend on high water column nutrients for growth, as they are well-adapted to using sunlight and minimal nutrients for successful growth but excess nutrients often result in exacerbated growth. These species have similar detrimental impacts to lakes in that they decrease the quantity and abundance of native aquatic plants and associated macroinvertebrates and consequently alter the lake fishery. Such species include *Hydrilla verticillata* (Figure 40) and *Trapa natans* (Water Chestnut; Figure 41). *Hydrilla* was introduced to waters of the United States from Asia in 1960 (Blackburn et al. 1969) and is a highly problematic submersed, rooted, aquatic plant in tropical waters. Many years ago, *Hydrilla* was found in Lake Manitou (Indiana, USA) and the lake public access sites were immediately quarantined in an effort to eradicate it. It has since been discovered in two ponds in southwest Michigan as well as in bordering states such as Ohio, Indiana, and Illinois, among others. *Hydrilla* retains many physiologically distinct reproductive strategies which allow it to colonize vast areas of water and to considerable depths, including fragmentation, tuber and turion formation, and seed production.

Currently, the methods of control for *Hydrilla* include the use of chemical herbicides, rigorous mechanical harvesting, and Grass Carp (*Ctenopharyngodon idella* Val.), with some biological controls currently being researched. Water Chestnut (*Trapa natans*) is a non-native, annual, submersed, rooted aquatic plant that was introduced into the United States in the 1870's yet may be found primarily in the northeastern states. The stems of this aquatic plant can reach lengths of 12-15 feet, while the floating leaves form a rosette on the lake surface. Seeds are produced in July and are extremely thick and hardy and may last for up to 12 years in the lake sediment.

If stepped on, the seed pods may even cause deep puncture wounds to those who recreate on the lakes. Methods of control involve the use of mechanical removal and chemical herbicides. Biological controls are not yet available for the control of this aquatic invasive plant.



**Figure 40. Hydrilla from a Florida lake.**



**Figure 41. Water Chestnut from a northeastern lake.**

### ***5.1.2 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 42). 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. The permit also requires notification of the Loon protection program if nesting Loons are present on the lake. 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 Pipestone Lake, the use of contact herbicides (such as diquat and flumioxazin) would be highly discouraged for native aquatic plants but may be used for temporary reduction of dense lily pads in beach areas. Contact herbicides offer short-term control of plants since they do not kill plant roots.

Algaecides such as copper sulfate should also be avoided on Pipestone Lake as 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. There is also evidence that over-use of algaecides can exacerbate blue-green algae when blooms are present. The reduction of algae usually depends upon long-term nutrient reductions from the immediate watershed (septic tanks) and reduction or cessation of lawn fertilizers.

Systemic herbicides such as ProcellaCOR®, 2,4-D, triclopyr are the 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 scattered but low abundance of milfoil in Pipestone Lake (given its size), the use of fluridone is not recommended. The use of other systemic herbicides such as ProcellaCOR® or triclopyr that may be used for spot-treatments are recommended.



**Figure 42. A boat used to apply aquatic herbicides in inland lakes.**

### **5.1.3 Mechanical Harvesting**

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 43). 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 Eurasian Watermilfoil since the plant may fragment when cut and re-grow on the lake bottom. Due to the distribution of invasives in open water areas, mechanical harvesting is not recommended or needed for Pipestone Lake at this time. It may, however, be used to remove dense lily pad biomass in beach areas as an alternative to the use of herbicides.



**Figure 43. A mechanical harvester used to remove aquatic plants.**

#### 5.1.4 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](http://www.lakemat.com) or [www.lakebottomblanket.com](http://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](http://www.crary.com/marine) or at: [www.lakegroomer.net](http://www.lakegroomer.net). Both methods are useful in recreational lakes such as Pipestone Lake and work best in beach areas and near docks to reduce nuisance aquatic vegetation growth if it becomes prevalent in future years.

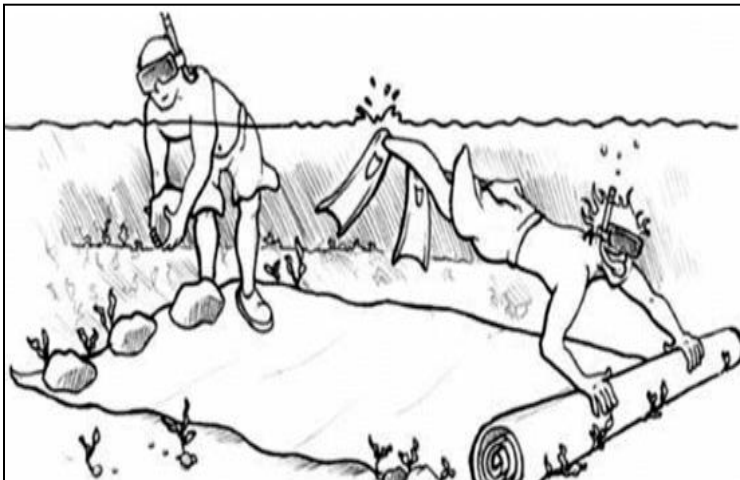


Figure 44. A Benthic Barrier. Photo courtesy of Cornell Cooperative Extension.



Figure 45. A Weed Roller.

### **5.1.5 Diver Assisted Suction Harvesting (DASH)**

Suction harvesting via a Diver Assisted Suction Harvesting (DASH) boat (Figure 46) 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 costly on a large scale and so it is used on a spot-removal basis or in small areas. It has been used to remove nuisance invasive aquatic vegetation in inland lakes and requires a joint permit with EGLE and the U.S. Army Corps of Engineers (USACE).

Because this activity may cause re-suspension of sediments (Nayar et al., 2007), increased turbidity and reduced clarity of the water can occur. Permitting requirements include the use of a turbidity curtain that reduce the transport of solids to locations outside of treatment areas and also help define areas where intensive aquatic vegetation removal efforts are being implemented. This method may be feasible for small areas of dense lily pad removal and result in permanent reduction of them in DASH areas. It is however very costly and costs often range from \$1,500-\$4,000 per acre.



**Figure 46. A DASH boat used in a lake for aquatic plant removal.**

### **5.1.6 Dredging**

Dredging is a lake management option used to remove accumulated lake sediments to increase accessibility for navigation and recreational activities. Dredging is subject to permitting by the U.S. Army Corps of Engineers (USACE), and Michigan Department of Environment, Great Lakes, and Energy (EGLE). The two major types of dredging include hydraulic and mechanical. A mechanical dredge usually utilizes a backhoe and requires that the disposal site be adjacent to the lake (Figure 47). In contrast, a hydraulic dredge removes sediments in aqueous slurry, and the wetted sediments are transported through a hose to a confined disposal facility (CDF).

Selection of a particular dredging method and CDF should consider the environmental, economic, and technical aspects involved. The CDF must be chosen to maximize retention of solids and accommodate large quantities of water from the dewatering of sediments. It is imperative that hydraulic dredges have adequate pumping pressure which can be achieved by dredging in waters greater than 3 foot of depth.

Dredge spoils cannot usually be emptied into wetland habitats; therefore, a large upland area is needed for lakes that are surrounded by wetland habitats. 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. In addition, proposed sediment for removal must be tested for metal contaminants before being stored in a CDF. Dredging is a very costly operation with an average dredging cost of \$28-40 per cubic yard. Dredging is not recommended for any areas in Pipestone Lake at this time but could be used in shallow bays in the future if the water level becomes too low or navigation becomes difficult.



**Figure 47. A mechanical dredge for sediment removal in inland waters.**

### **5.1.7 Aeration, Oxygenation, and Bioaugmentation:**

Aeration systems such as laminar flow (Figure 48) are retrofitted to a particular site and account for variables such as water depth and volume, contours, water flow rates, and thickness and composition of lake sediment. The systems are designed to completely mix the surrounding waters and evenly distribute dissolved oxygen throughout the lake sediments for efficient microbial utilization.

A laminar flow aeration (LFA) system utilizes diffusers which are powered by onshore air compressors. The diffusers are connected via extensive self-sinking airlines which help to purge the lake sediment pore water of gases such as benthic carbon dioxide (CO<sub>2</sub>) and hydrogen sulfide (H<sub>2</sub>S). In addition to the placement of the diffuser units, the concomitant use of bacteria and enzymatic treatments to facilitate the microbial breakdown of organic sedimentary constituents is also used as a component of the treatment. Beutel (2006) found that lake oxygenation eliminates release of NH<sub>3</sub><sup>+</sup> from sediments through oxygenation of the sediment-water interface. Allen (2009) demonstrated that NH<sub>3</sub><sup>+</sup> oxidation in aerated sediments was significantly higher than that of control mesocosms with a relative mean of  $2.6 \pm 0.80$  mg N g dry wt day<sup>-1</sup> for aerated mesocosms and  $0.48 \pm 0.20$  mg N g dry wt day<sup>-1</sup> in controls.

Case studies have shown promise on the positive impacts of laminar flow aeration systems on aquatic ecosystem management with respect to organic matter degradation and resultant increase in water depth, and algal management in shallow eutrophic ecosystems (Jermalowicz-Jones, *in progress*). Toetz (1981) found evidence of a decline in *Microcystis* algae (a toxin-producing blue-green algae) in Arbuckle Lake in Oklahoma. Other studies (Weiss and Breedlove, 1973; Malueg et al., 1973) have also shown declines in overall algal biomass.

Conversely, a study by Engstrom and Wright (2002) found no significant differences between aerated and non-aerated lakes with respect to reduction in organic sediments. This study was however limited to one sediment core per lake and given the high degree of heterogeneous sediments in inland lakes may not have accurately represented the conditions present throughout much of the lake bottom.

### ***Benefits and Limitations of Laminar Flow Aeration***

In addition to the reduction in toxic blue-green algae (such as *Microcystis* sp.) as described by Toetz (1981), aeration and bioaugmentation in combination have been shown to exhibit other benefits for the improvements of water bodies. Laing (1978) showed that a range of 49-82 cm of organic sediment was removed annually in a study of nine lakes which received aeration and bioaugmentation. It was further concluded that this sediment reduction was not due to re-distribution of sediments since samples were collected outside of the aeration “crater” that is usually formed. A study by Turcotte et al. (1988) analyzed the impacts of bioaugmentation on the growth of Eurasian Watermilfoil and found that during two four-month studies, the growth and re-generation of this plant was reduced significantly with little change in external nutrient loading. Currently, it is unknown whether the reduction of organic matter for rooting medium or the availability of nutrients for sustained growth is the critical growth limitation factor and these possibilities are being researched.

A reduction of Eurasian Watermilfoil is desirable for protection of native plant biodiversity, recreation, water quality, and reduction of nutrients such as nitrogen and phosphorus upon decay (Ogwada et al., 1984).

Furthermore, bacteria are the major factor in the degradation of organic matter in sediments (Fenchel and Blackburn, 1979) so the concomitant addition of microbes to lake sediments will accelerate that process. A reduction in sediment organic matter would likely decrease Eurasian Watermilfoil growth as well as increase water depth and reduce the toxicity of ammonia nitrogen to overlying waters. A study by Verma and Dixit (2006) evaluated aeration systems in Lower Lake, Bhopal, India, and found that the aeration increased overall dissolved oxygen, and reduced biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliform counts.

The LFA system has some limitations including the inability to break down mineral sediments such as marl or silt, the requirement of a constant Phase I electrical energy source to power the units, and possible unpredictable response by various species of rooted aquatic plants (currently being researched by RLS) as well as high cost and permitting difficulty. There are some sediments in Pipestone Lake that contain moderate quantities of organic matter so there may be some muck reduction with bioaugmentation in areas with ample dissolved oxygen. The largest benefit of LFA for Pipestone Lake would be the increase in water column dissolved oxygen which would reduce the release of phosphorus and also the reduction in blue-green algae which is critical. Aeration and bio augmentation have also been successfully used to reduce nuisance algal blooms, increase water clarity, and reduce water column nutrients and sedimentary ammonia nitrogen (RLS, 2009-2025, among others).

A newer and more cost-effective alternative to LFA would be the use of hypolimnetic oxygenation which utilizes direct supplementation of concentrated oxygen to the deeper areas of the lake to prevent the release of phosphorus that causes blue-green algal blooms. An advantage of the latter is that it does not destratify the water column which is beneficial to reduce transfer of phosphorus from the bottom layer to the middle and upper water column layers. Both types of aeration require rigorous permitting, testing, and reporting to EGLE.

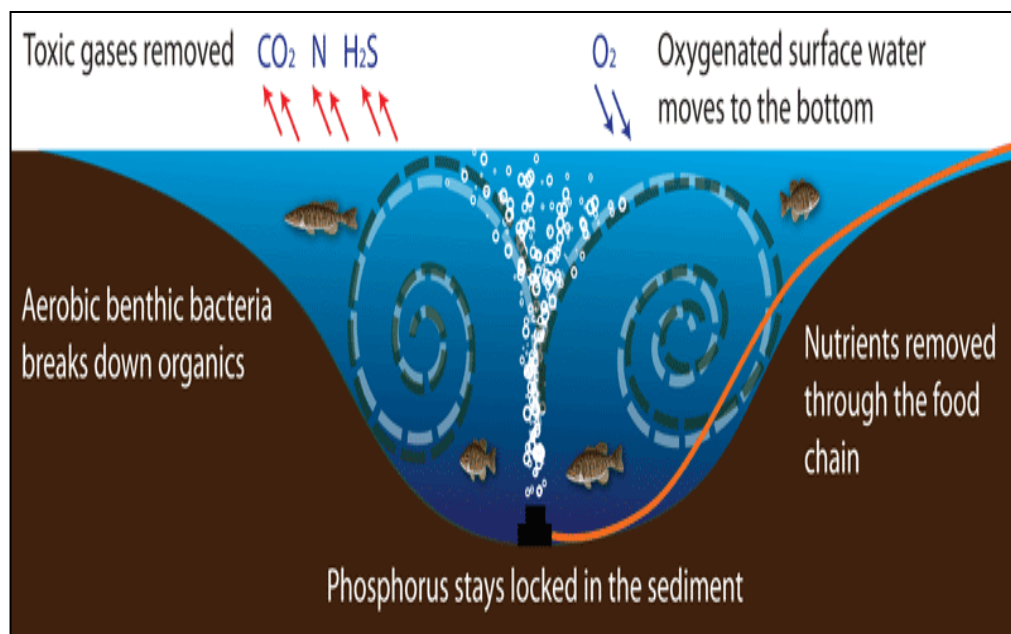


Figure 48. Diagram of lake aeration. ©RLS

### **5.1.8 Nutrient Reduction and Inactivation**

There are a few products on the lake improvement market that aim to reduce phosphorus in the water column and the release of phosphorus from a lake bottom. Such products are usually applied as slurry by a special dose-metered vessel to the water column or just above the lake bottom. Most of these formulas can be applied in aerobic (oxygenated) or anaerobic (oxygen-deficient) conditions. In lakes that lack ample dissolved oxygen at depth, this product may help prevent phosphorus release from the sediments. A few disadvantages include cost, inability to bind high concentrations of phosphorus especially in lakes that receive high external loads of phosphorus (i.e. lakes such as Pipestone Lake with a large catchment or watershed), and the addition of an aluminum floc to the lake sediments which may impact benthic macroinvertebrate diversity and relative abundance (Pilgrim and Brezonik, 2005). Some formulas utilize a clay base with the P-inactivating lanthanum (Phoslock® or EutroSorb G®) which may reduce sediment toxicity of alum.

If this method is implemented, it is highly recommended that sampling the lake sediments for sediment pore water phosphorus concentrations be conducted to determine internal releases of phosphorus pre-alum and then monitoring post-alum implementation. Additionally, external phosphorus loads must be significantly reduced since these inputs would compromise phosphorus-inactivation formulas (Nürnberg, 2017).

Some recent case studies (Brattebo et al., 2017) are demonstrating favorable results with alum application in hypereutrophic waters that are also experiencing high external nutrient loads. At this time, a lake mixing technology would be preferred over application of alum since a higher dissolved oxygen concentration is desired throughout the water column and on the lake bottom to reduce internal release of phosphorus and also decrease blue-green algal blooms and increase water clarity while improving the zooplankton and benthic macroinvertebrate biodiversity.

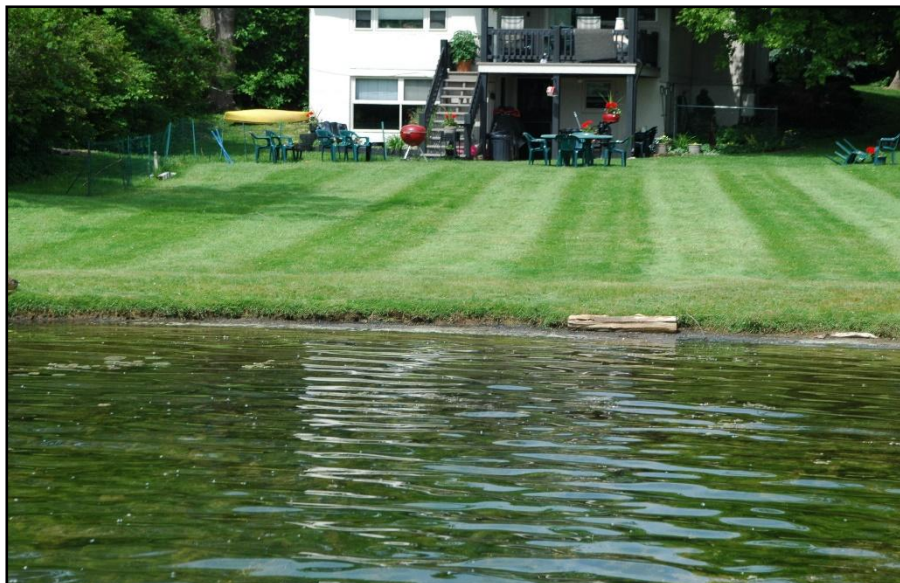
### **5.3 Pipestone Lake Watershed Management**

Protection of the lake watershed is imperative for long-term improvement of water quality in Pipestone Lake. There are many practices that individual riparians as well as the local municipalities can adopt to protect the land from ponding and flooding and reduce nutrient loading to the lake. The following sections offer practical Best Management Practices (BMP's) commonly followed to protect water quality.

### 5.3.1 Pipestone Lake Nutrient Source Control

Any additional inputs of phosphorus to the lake are likely to create additional algal and aquatic plant growth, especially nearshore. Accordingly, RLS recommends the following procedures to protect the water quality of Pipestone Lake:

- 1) **Avoid the use of lawn fertilizers that contain phosphorus (P).** P is the main nutrient required for aquatic plant and algae growth, and plants grow in excess when P is abundant. When possible, water lawns with lake water which usually contains adequate P for successful lawn growth. If you must fertilize your lawn, assure that the middle number on the bag of fertilizer reads “0” to denote the absence of P. If you must fertilize, use low N in the fertilizer or use lake water. Education of riparians on this issue is important as is understanding what they may use for fertilizers and where they are purchased. Figure 49 demonstrates a lawn that is bright green and lacks a buffer and is likely contributing nutrients to the lake.



**Figure 49. A green lawn leading to a lake with absence of emergent vegetation to reduce nutrient runoff into lake.**

- 2) **Have all septic systems annually inspected if possible or at least every two years.** This includes both the tank and the drain field. Septic inputs have been shown to be the second largest contributor of both nitrogen and phosphorus to Pipestone Lake. For more information on septic care, visit the EPA website at: <http://www.epa.gov/septic>

- 3) **Preserve riparian vegetation buffers around the shoreline since they act as a filter to catch nutrients and pollutants that occur on land and may run off into the lake.**

As an additional bonus, Canada geese (*Branta canadensis*) usually do not prefer lakefront lawns with dense riparian vegetation because they are concerned about the potential of hidden predators within the vegetation. Valuable information can be found on the Michigan Natural Shoreline Partnership website at: [www.mishorelinepartnership.org](http://www.mishorelinepartnership.org)

- 4) **Do not burn leaves near the lake shoreline since the ash is a high source of P.** The ash is lightweight and may become airborne and land in the water eventually becoming dissolved and utilized by aquatic vegetation and algae.
- 5) Assure that all areas that drain into the lake from the surrounding land are vegetated and that no fertilizers are used in areas with saturated soils.
- 6) **Never dump any solvents, chemicals, or debris into the lake.** These can all harm fish, wildlife, and humans.
- 7) Never dump leaves or chemicals into storm drains as these often lead to waterways.
- 8) **At a minimum, have annual or bi-annual septic tank and drain field inspections.** Septic systems and drain fields can contribute high nutrient and bacteria loads to the lake which are costly to mitigate.
- 9) Allow trees to grow near the shoreline for erosion control but be sure to rake away leaves in the fall. Do not rake leaves into the lake and instead dispose of leaves as yard waste.
- 10) Preserve all wetlands around the lake as they act as natural filters of runoff nutrients in those areas.
- 11) **Do not feed any waterfowl.** Although this is enjoyable, they have plenty of food in the lake and their feces are high in nutrients and bacteria.
- 12) **Do not allow any rubber from water balloons, firework debris, plastic, Styrofoam, or food containers to enter the lake.** Most of this will require hundreds of years to break down and is harmful to the lake.
- 13) **Be a responsible lake steward!** Attend lake association meetings and learn about issues on the Pipestone Lake Association website at: <https://pipestonelake.org/>

## 6.0 PIPESTONE LAKE MANAGEMENT PLAN CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

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Pipestone Lake is facing significant issues that may degrade water quality, including inputs of nutrients from septic systems and use of lawn fertilizers which leads to a decline in lake health over time. Additionally, invasive species such as Eurasian Watermilfoil (EWM) and Purple Loosestrife are located in or around the lake. These invasives pose a serious risk to the native aquatic plant biodiversity and recreational activities in the lake. Protection of the moderately high biodiversity of native aquatic plants is essential for lake health, especially given the low relative abundance of most native aquatic plant species. **Here are the key conclusions and recommendations for successful management of Pipestone Lake:**

**1. Management of invasive species would be best achieved with aquatic herbicides but could be removed on a smaller scale with DASH technology.** EGLE permits treatment of invasive EWM and Purple Loosestrife with systemic or contact aquatic herbicides. Purple Loosestrife can also be removed by hand without the use of herbicides in areas of low to moderate density. At the current time, there are approximately 3.5 acres of EWM and 32 locations where Purple Loosestrife was located. RLS recommends spot-treating the EWM with systemic ProcellaCOR® or triclopyr. The product types and doses should rotate each year to lessen the occurrence of herbicide tolerance by EWM in Pipestone Lake. The use of copper sulfate for algal control should not be used for Pipestone Lake since it bioaccumulates in the lake sediments and may harm lake benthos and macroinvertebrates. Chelated copper products could be used only on nuisance green filamentous nearshore algae. As stated earlier, blue-green algae can be exacerbated by algaecide treatments. **EGLE and USACE also permit the use of DASH for removal of invasives or dense lily pads. The latter can also be temporarily controlled with mechanical harvesting.**

**2. A detailed, Early Detection-Rapid Response (EDRR) Protocol for future invasives that may enter the lake is recommended to be compiled soon for the Pipestone Lake community.** This would include current identification and treatment protocols and also those for new invasives that have been appearing in our Midwest lakes such as *Hydrilla*.

**3. Each year, an independent professional limnologist/aquatic botanist at RLS should perform regular GPS-guided whole-lake surveys each summer/early fall to monitor the growth and distribution of all invasives prior to and after all treatments to determine treatment efficacy.** Continuous monitoring of the lake for potential influxes of other exotic aquatic plant genera (i.e., *Hydrilla*) that could also significantly disrupt the ecological stability of Pipestone Lake is critical.

The lake manager should oversee all management activities and would be responsible for the creation of aquatic plant management survey maps, direction of the applicators to target-specific areas of aquatic vegetation for removal and reviewing all contractor invoices for accuracy.

**4. A boat washing station is recommended for the public access site and would require some financial investment.** It could consist of a basic sprayer bottle and signs in place of a pricey electronic steam or compressed air wash unit, but the latter is still preferred. These stations have been effective at educating visitors to clean their boats and trailers and at reducing the spread of invasive aquatic plant species.

**5. The lake has a healthy food chain with abundant zooplankton.** All of these organisms are sensitive to high copper use and thus these products should be avoided if possible.

**6. Annual water quality monitoring of the deep basins is recommended to continue to evaluate long-term trends and impacts of management practices.** The water quality parameters measured included physical parameters such as water temperature, dissolved oxygen, pH, conductivity, Secchi transparency, and total dissolved solids. In addition, chemical water quality parameters such as total phosphorus (TP) and ortho-phosphorus (SRP), total Kjeldahl nitrogen (TKN), total inorganic nitrogen (TIN), chlorophyll-*a*, and total suspended solids (TSS) should also be monitored. These should be sampled in the 2 deep basins each summer annually from late May-September. The 2025 water quality data demonstrated elevated phosphorus at the lake bottom which indicates internal loading in the absence of dissolved oxygen at depth.

**7. Pipestone Lake has nutrient concentrations in the deep basins that are near or just below the eutrophic threshold and inputs are likely from septic effluent, lawn fertilizers, or runoff.** A small amount of phosphorus is deposited in lakes from atmospheric deposition. Since a lake-wide sewer may not be feasible, maintenance of individual septic systems and drain fields is critical. This could be encouraged through a community-wide septic pumping period and education of riparians on the importance of proper septic maintenance.

**9. Lastly, a riparian education program is recommended through the development of this management plan and through holding future educational workshops.** Such workshops may include dispersal of relevant lake information and also identification of local lake biota so that residents know to be vigilant of certain invasives. This could be done at annual lake association meetings or at a venue during the summer.

A complete list of recommended lake improvement options for this proposed lake management plan can be found in Table 17 below. It is important to coordinate these methods with objectives so that baseline conditions can be compared to post-treatment/management conditions once the methods have been implemented.

**Table 17. List of Pipestone Lake proposed improvement methods with primary and secondary goals and locations for implementation.**

<b>Proposed Improvement Method</b>	<b>Primary Goal</b>	<b>Secondary Goal</b>	<b>Where to Implement</b>
<b>Maintenance program for septic systems</b>	To reduce nutrients inputs from septic systems	To improve water quality parameters- especially lake bottom nutrients	Lake-wide
<b>Spot-treatment with systemic herbicides for control of EWM and/or Purple Loosestrife</b>	Systemically reduce EWM throughout lake and reduce other invasives	Use less herbicide over time for all invasives	Entire lake where invasive EWM and Purple Loosestrife are present
<b>Bi-annual water quality monitoring of lake</b>	Monitor lake health over time	Use long-term and current data to drive management decisions relative to BMP's	Lake deep basins (n=2)
<b>Development of Early Detection Rapid Response Protocol for new invasives</b>	Generate a clear strategy for dealing with new invasives that may be found in the lake	Allow for less long-term spread of any new invasives with early detection	Entire lake
<b>DASH or Mechanical harvesting for dense lily pad removal</b>	To reduce the density of lily pads in beach areas	To prevent the need for herbicide treatment of dense lily pads	Areas of dense lily pad growth; primarily beach areas
<b>Boat launch washing station</b>	To reduce entry of invasives into Pipestone Lake	To reduce exit of invasives from Pipestone Lake	At public access site
<b>Annual lake surveys pre- and post-treatment</b>	To determine efficacy of all treatments on invasives and nuisance plants	To determine ability of native aquatic vegetation biodiversity to recover post-management implementation	Entire lake

<b>Independent and objective oversight of lake treatments or other contractor work</b>	To objectively evaluate treatments for optimum science and future costs	To work with applicators or contractors for optimum lake management solutions	Through treatment season
<b>Riparian/Community Education</b>	To raise awareness of lake issues and empower all to participate in lake protection	Long-term sustainability requires ongoing awareness and action	Entire lake community and those who frequent the lake; may also include other relevant stakeholders

### **6.1 Proposed Cost Estimates for Pipestone Lake Improvements**

The proposed lake improvement and management program for Pipestone Lake is recommended to begin as soon as possible. A breakdown of estimated costs associated with the various proposed management items in Pipestone Lake is presented in Table 18. 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 herbicide costs). Note that this table is adaptive and is likely to change. Any of these could be conducted during different years of a new or existing SAD program. However, it is highly recommended to perform all of these management methods as soon as possible. The annual cost will decline over time with the boat wash station, early detection rapid response protocol, and reductions in invasive aquatic plant species.

**Table 18. Pipestone Lake proposed lake management program costs. Note: These items could be implemented over a period of years with professional services and treatment of invasives recommended on an annual basis.**

<b>Proposed Pipestone Lake Improvement Item</b>	<b>Estimated Itemized Costs</b>
<sup>1</sup> Treatments for EWM and Purple Loosestrife (Systemic herbicides used for EWM and Purple Loosestrife or herbicides for EWM and removal of dense lily pads by DASH or mechanical harvesting); NOTE: EWM could be removed with DASH as an alternative to herbicides along with dense lily pads	\$22,500
<sup>2</sup> Professional services (limnologist management of lake, aquatic vegetation surveys, deep basin water quality sampling, oversight of treatments, education, development of Rapid Response Protocol, annual professional report)	\$11, 850
<sup>3</sup> Boat washing station-basic	~\$8,000-\$33,000
<sup>4</sup> Lake workshop in late summer with tips for riparians and handouts of Pipestone Lake maps, data, protection info	\$5,000
Contingency	\$6,785
<b>Total Estimated Cost of all Items</b>	<b>\$74,635</b>

<sup>1</sup> This cost is based on an evaluation of previous and current treatments and possible need for higher systemic herbicide doses in the future to adequately control hybrid EWM.

<sup>2</sup> This cost would include all annual professional consulting deliverables from RLS that would include aquatic plant surveys, follow-up surveys, treatment oversights, deep basin water quality sampling, riparian education, data analysis, professional annual report, and attendance at up to 2 lake Association meetings.

<sup>3</sup> This cost includes a professional boat washing station but lower cost versions are available.

<sup>4</sup>This cost would include a three-hour lake workshop at a venue of choice by the Pipestone Lake Association and would include handouts on Pipestone Lake protection and ecology and also booths from informative sources such as RLS, MSU Extension, MDNR, and EGLE, among others.

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