Lake Management

Hess Lake Management Plan

Prepared for:
Hess Lake Improvement Board
c/o Newaygo County Drain Commissioner's Office
306 S North Street
PO Box 885
White Cloud, MI 49349

Prepared by:
Progressive AE
1811 4 Mile Road, NE
Grand Rapids, MI 49525-2442
616/361-2664

June 2020

Project No: 83700001

progressive|ae

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Introduction

Hess Lake is located in Sections 31, 32, and 33 of Brooks Township and Sections 4 and 5 of Grant Township (T.11-12N; R.12W) in Newaygo County, Michigan (Figure 1). In November of 2017, Progressive AE was retained by the Hess Lake Improvement Board to develop and define a management plan for Hess Lake. Issues of concern include turbid water, persistent algae blooms, lack of rooted aquatic plants and a declining fishery. In developing the plan, the physical, chemical, and biological characteristics of the lake were evaluated, historical studies were compiled and reviewed, and in-lake and watershed management alternatives were identified. This report contains a summary of study findings, conclusions and recommendations.

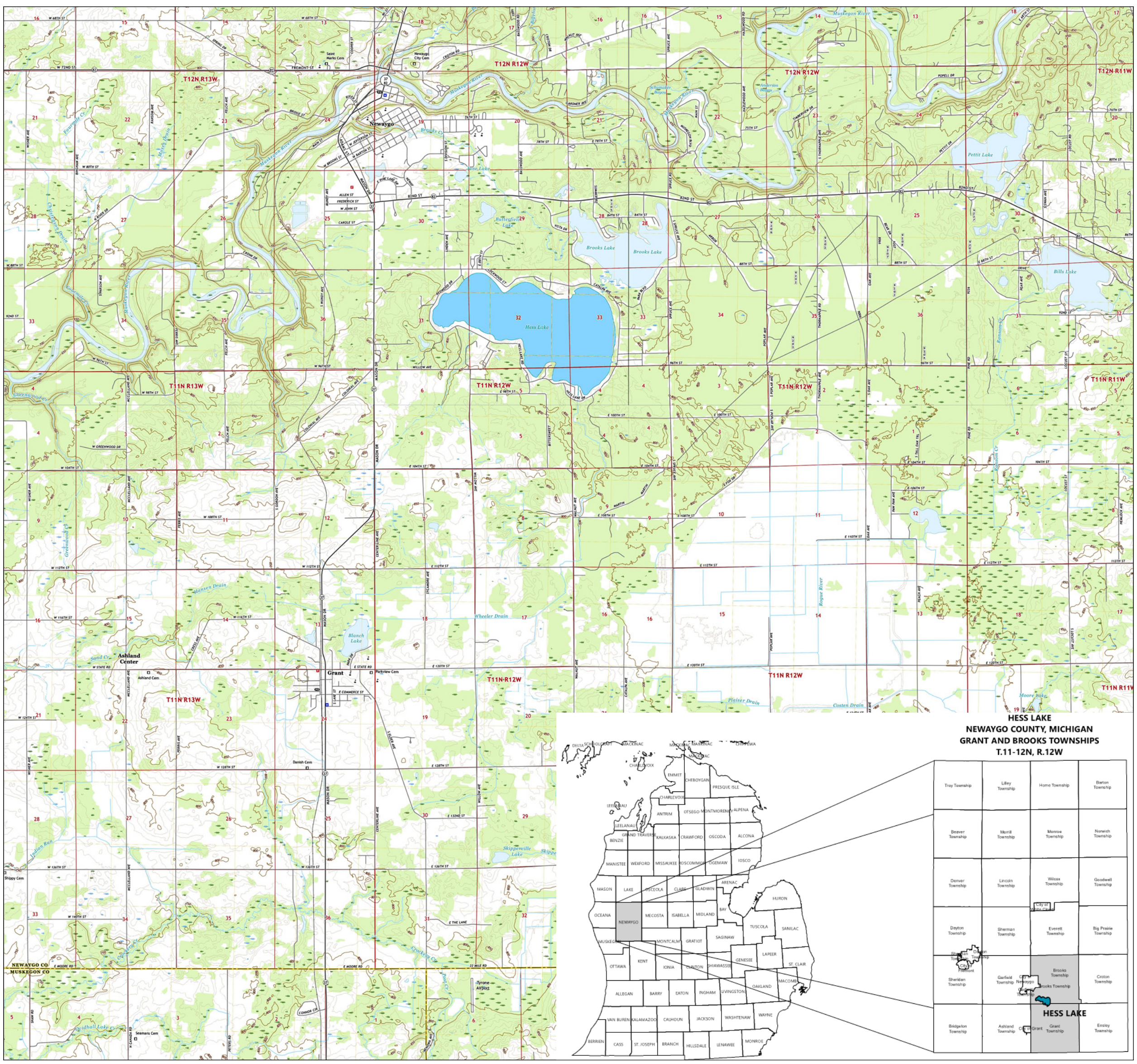


Figure 1. Project location map. Source: US Geological Survey.

Results and Discussion

LAKE AND WATERSHED CHARACTERISTICS

Hess Lake was originally mapped in 1955 by the Michigan Department of Conservation Institute for Fisheries Research (Figure 2). The original map indicated Hess Lake had a surface area of 755 acres. Most of the lake was less than 10 feet and the maximum depths in the three deep basins measured 17 feet, 28 feet and 29 feet, respectively.

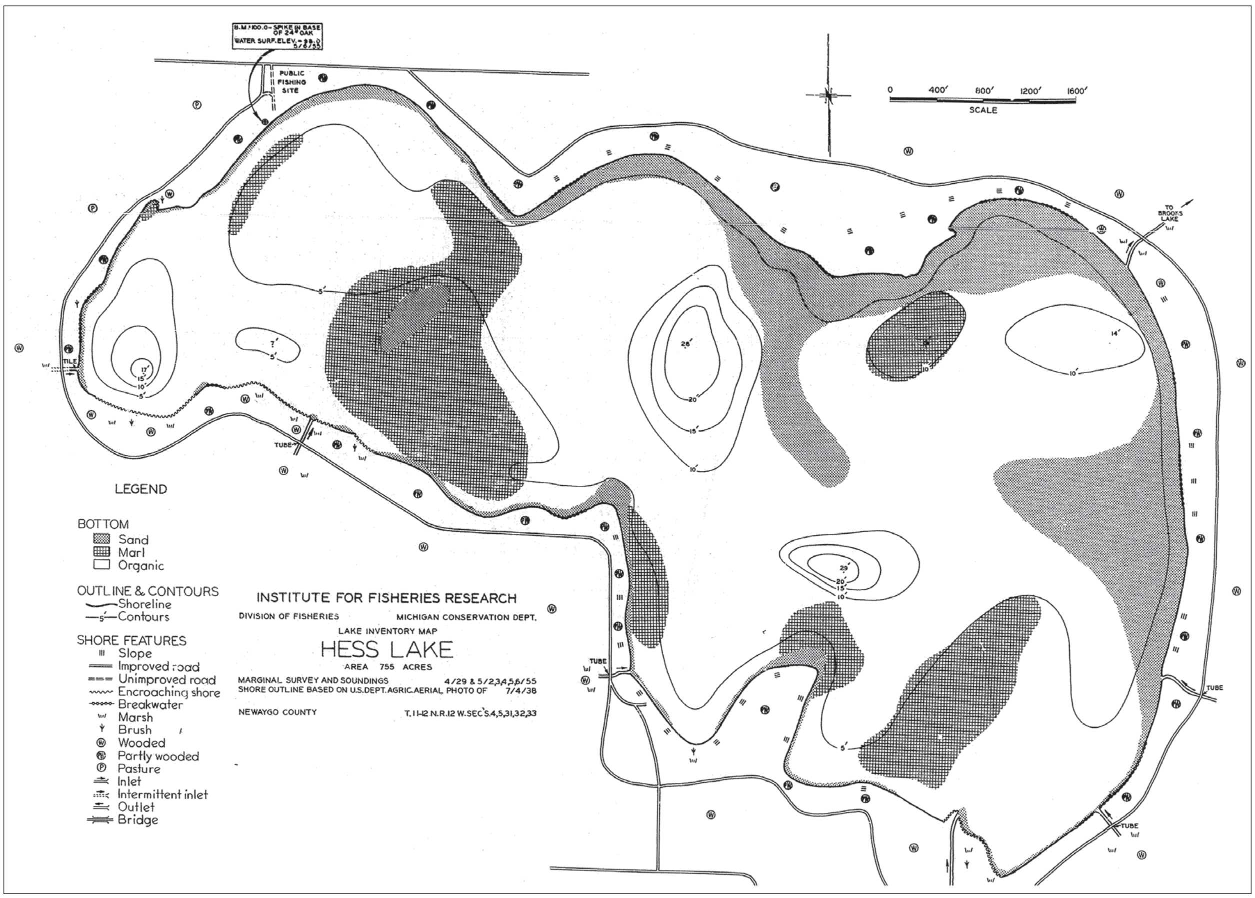


Figure 2. Hess Lake 1955 depth contour map. Source: Michigan Department of Conservation Institute for Fisheries Research.

Mapping conducted during the current study indicates Hess Lake has a surface area of 777 acres; maximum depths in the three deep basins are 14, 25 and 18 feet, somewhat less than the original mapping (Figure 3; Appendix A). Minor modifications in the shoreline over the years likely account for the differences in lake surface area, and shifting sediment may account for the reduced depths measured in the lake. Outside of the deep basins, depths in the lake are shallow and similar to those measured historically. In terms of surface area, Hess Lake is the 137th largest lake in Michigan. A summary of the physical characteristics of the lake is provided in Table 1.

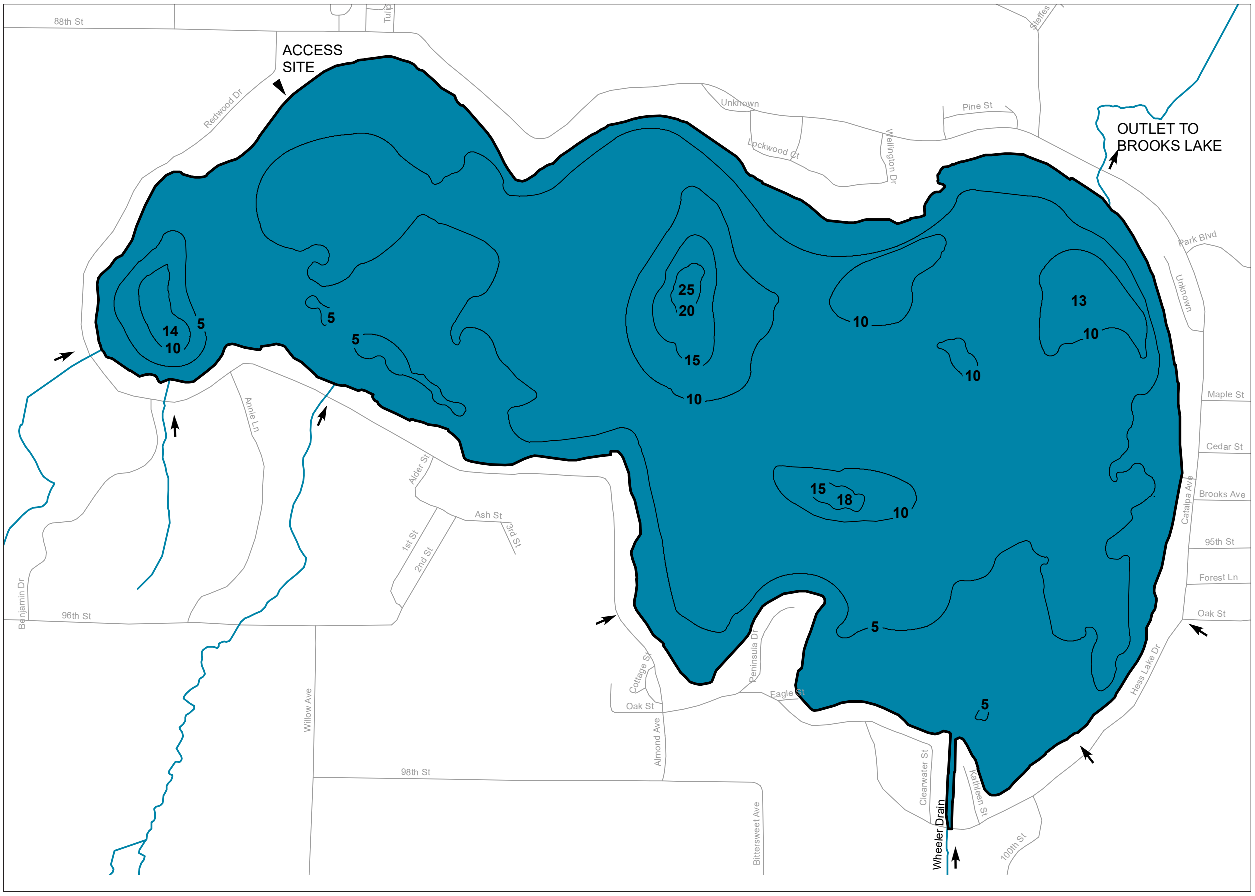


Figure 3. 2019 Hess Lake depth contour map.

TABLE 1
HESS LAKE PHYSICAL CHARACTERISTICS

Lake Surface Area	777 Acres
State Ranking for Surface Area	137
Maximum Depth	25 Feet
Mean Depth	6.4 Feet
Lake Volume	4,949 Acre-Feet
Shoreline Length	6.2 Miles
Shoreline Development Factor	1.6
Shallowness Factor	0.4
Lake Elevation	763.3 Feet
Watershed Area	9,336 Acres
Ratio of Lake Area to Watershed Area	12.0

Watershed Land Uses	Acres	Percent of Total
Residential	459	5%
Agricultural	3,684	39%
Forest	3,672	39%
Open Space	902	10%
Lakes	41	<1%
Wetlands	578	6%
	9,336	100%

Hess Lake has a volume of 4,949 acre-feet which equates to 1.6 billion gallons. The mean or average depth in the lake is 6.4 feet. Only about 2% of Hess Lake is greater than 15 feet deep.

Hess Lake has a shoreline length of 6.2 miles and a shoreline development factor of 1.6. Shoreline development factor is a measure of the irregularity of the shoreline. A lake with a perfectly round shape would have a shoreline development factor of 1.0. With a shoreline development factor of 1.6, the shoreline of Hess Lake is 1.6 times longer than if the lake were perfectly round.

The shallowness ratio compares the area of the lake less than 5 feet deep to the total lake area and indicates the degree to which the lake bottom area is likely to be affected by motorized watercraft. Impacts of primary concern include sediment suspension, turbidity, and destruction of fish habitat. Shallowness ratios range from low (less than 0.10) for lakes unlikely to be impacted to high (greater than 0.50) for lakes with a high potential for impact (Wagner 1991). Hess Lake has a shallowness ratio of 0.4 which indicates that there is a relatively high potential for motorized watercraft to impact the lake.

Except for the north and eastern shores of the lake where relatively hard bottom sediments are found, most of the offshore portions of the lake have soft sediment (Figure 4; Appendix A). In shallow waters less than about 4 feet, sediment depths are generally less than two feet; in deeper offshore areas, sediment depths often exceed six feet (Spicer Group 2010).

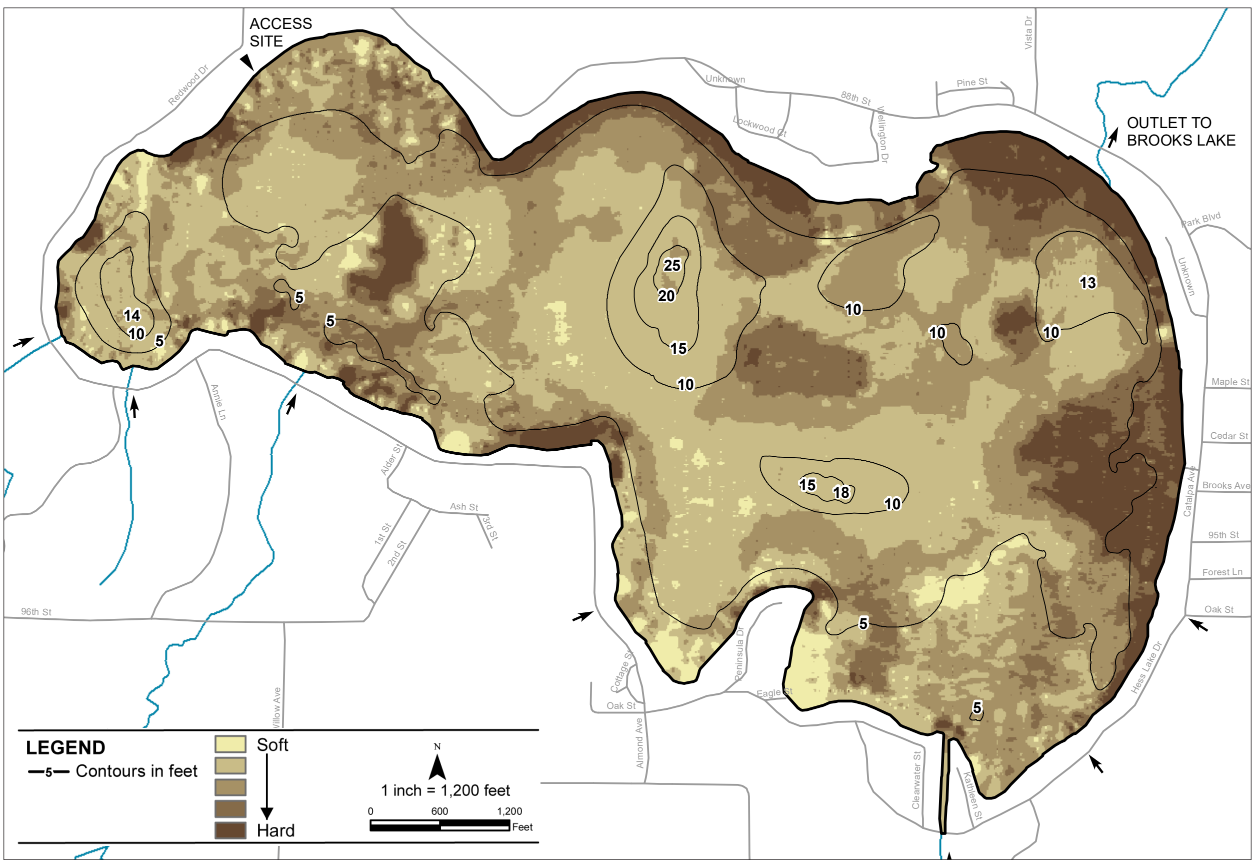


Figure 4. Hess Lake sediment hardness map. Hydro-acoustic depth measurements conducted in September of 2019. Hydro-acoustic data processed by C-MAP. Lake shoreline digitized from aerial orthodigital photography (Source: DigitalGlobe 2018).

Hess Lake has a lake level of 763.3 feet above sea level established in 1965 by circuit court order. Water flows from Hess Lake to Brooks Lake which outlets to Brooks Creek, the Muskegon River and Lake Michigan. The elevation of Hess Lake is approximately 186 feet above Lake Michigan.

A lake watershed is the land area that drains to a lake. The Hess Lake watershed is 9,336 acres, a land area about 12 times larger than the lake (Figure 5). The watershed is drained by Alger Creek and the Wheeler Drain, as well as several small, unnamed tributaries. Wheeler Drain and part of the upper portion of Alger Creek are designated county drains and are regulated under Michigan's Drain Code (PA 40 of 1956). Historical Michigan Department of Conservation records indicate that, at one time, drainage from what is now the upper portion of the Wheeler Drain flowed east and south away from the lake to the headwaters of the Rogue River. In the early 1900s, the drain was diverted to its present course substantially increasing the size of the Hess Lake watershed. Currently, the Wheeler Drain drains approximately 6,270 acres or about two-thirds of the watershed.

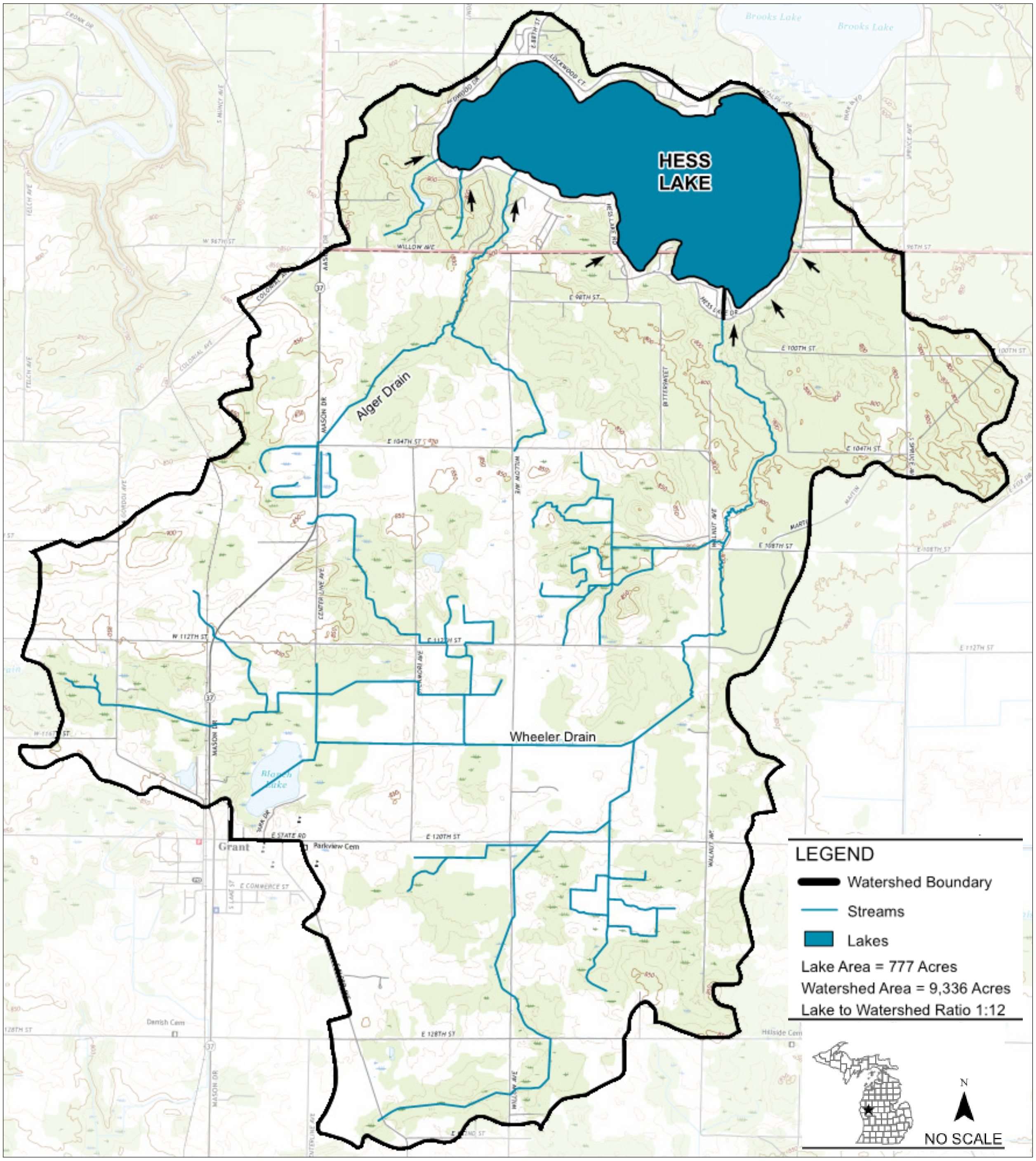


Figure 5. Hess Lake watershed map. Topographic map source: USGS TopoView. Watershed boundary source: USGS and USDA-NRCS.

Much of the upper portion of the watershed is agricultural while forest cover is more prevalent closer to the lake (Figure 6). Most of the development in the watershed occurs in close proximity to the lake and currently nearly 400 homes border directly on the lake. In general, soils near the lake appear to be moderately well drained while the soils in the upper watershed are poorly drained (Figure 7). Many of these poorly drained areas are tiled with under drains to facilitate farming operations.

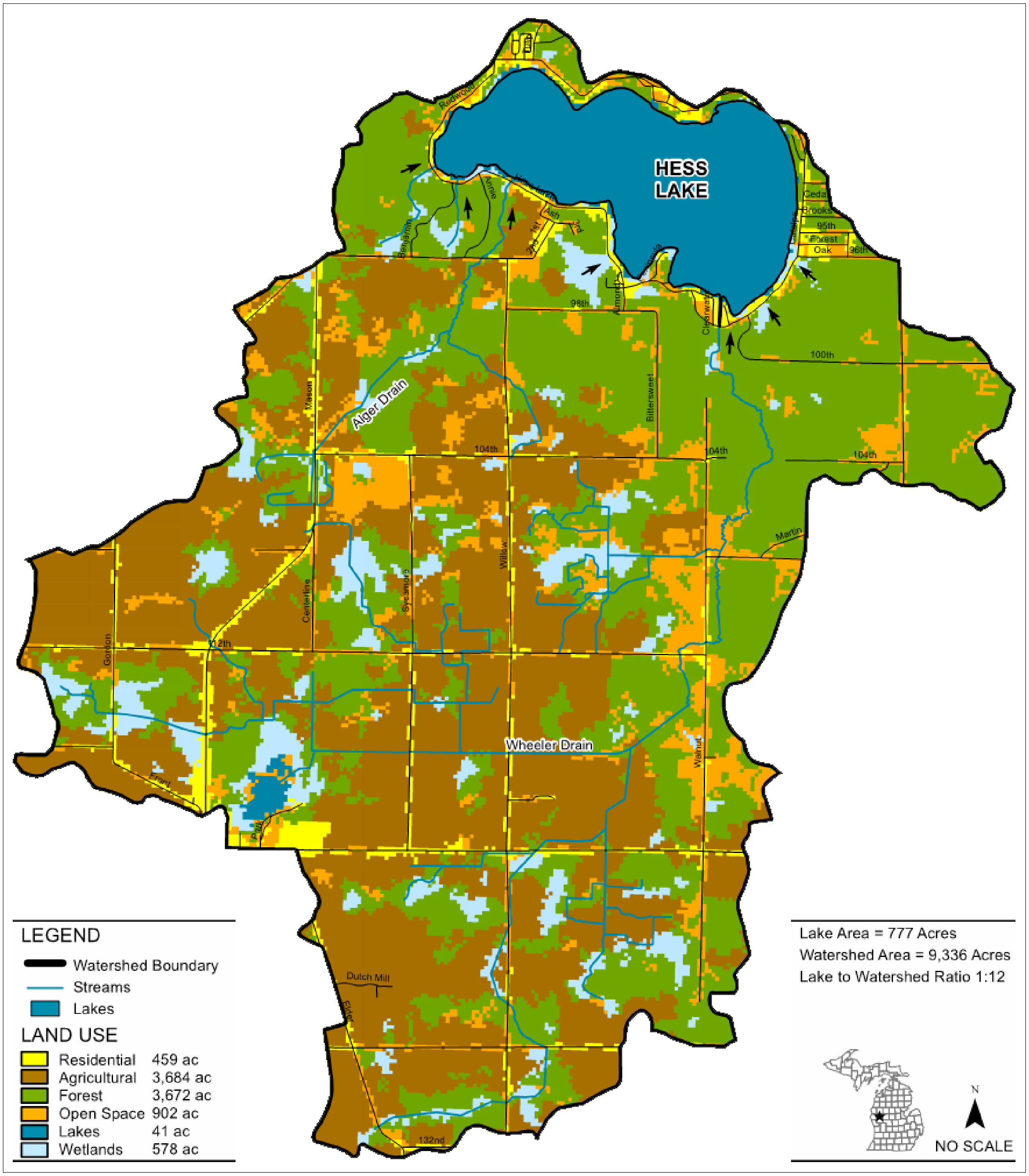
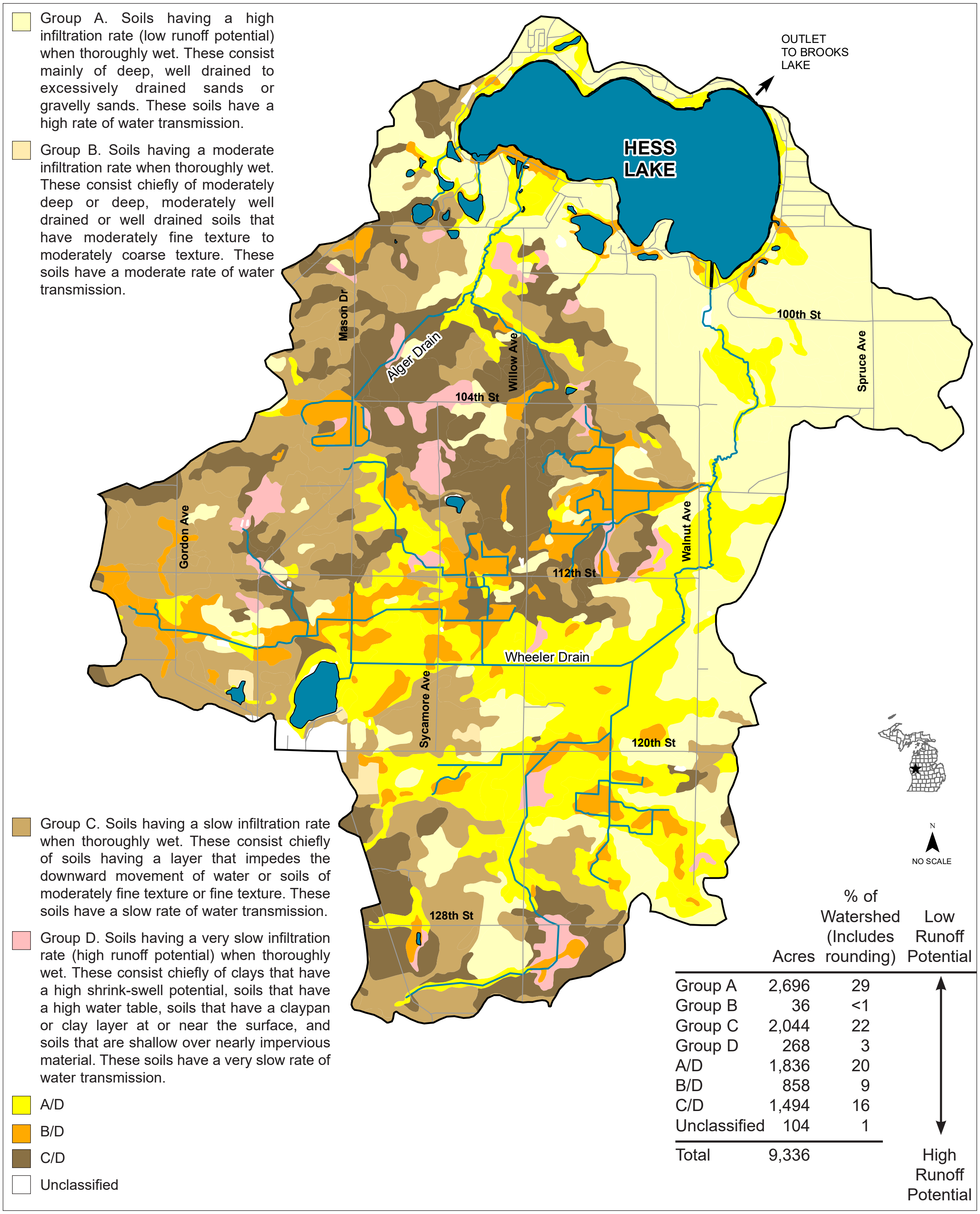


Figure 6. Hess Lake watershed land cover map. Land use source: U.S. Geological Survey, 20140331, NLCD 2011 Land Cover (2011 Edition): U.S. Geological Survey, Sioux Falls, SD. Watershed boundary source: USGS and USDA-NRCS.



	Acres	% of Watershed (Includes rounding)
Group A	2,696	29
Group B	36	<1
Group C	2,044	22
Group D	268	3
A/D	1,836	20
B/D	858	9
C/D	1,494	16
Unclassified	104	1
Total	9,336	

Figure 7. Hess Lake watershed hydrologic soils group map. Soil information source: Soil Survey Staff, Natural Resources Conservation Service, United States Dept of Agriculture. Soil Survey Geographic (SSURGO) Database for Newaygo County, Michigan. Available online at http://soildatamart.nrcs.usda.gov. Accessed April 2018. Watershed boundary source: USGS AND USDA-NRCS. Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Wheeler Drain is the largest single source of water to Hess Lake (Edmunds Engineering, Inc. 1982). Inflows from Wheeler Drain help to maintain summer lake levels in Hess Lake. The drain begins at the extreme south end of the watershed and travels about 6 miles to the lake (Figure 8).

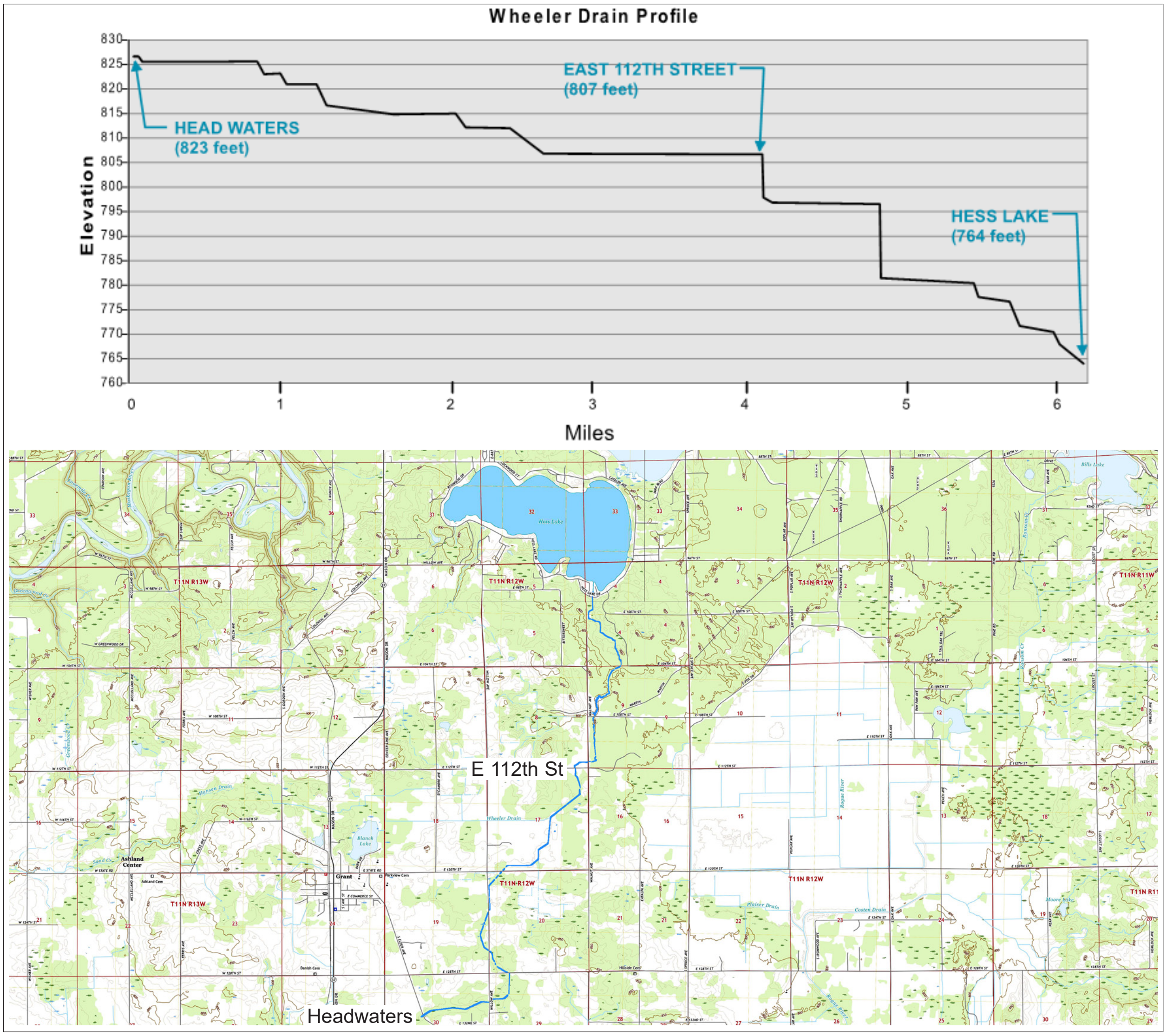


Figure 8. Wheeler Drain profile.

In a federal grant application prepared by the Hess Lake Improvement Board in 1988, Wheeler Drain is described as follows:

> It is important to note that the south (upstream) portion of the Wheeler Drain has a low grade, is mostly runoff fed, and carries mostly fine particulate matter following rain fall events. The northerly portion (downstream) has a steeper grade, is less impacted by immediate runoff, has a significant base flow, and carries a substantial course particle load when flows increase.

Erosion along the lower stretch of Wheeler Drain has been ongoing for decades (Edmunds Engineering, Inc. 1982). In a recent drain inspection report (Spicer Group 2009), it was noted that the lower portion of the drain (north of 112th Street) has high, steeply-sloped banks and no floodplain to slow the water during storm events and control erosion (Spicer Group 2009). The rerouting of Wheeler Drain in the early 1900s along with tiling and drainage alterations in the upper portion of the drain may be exacerbating erosion yet today (Schottler et al. 2013).

WATER QUALITY

Lakes can be classified into three broad categories based on their productivity or ability to support plant and animal life. The three basic lake classifications are “oligotrophic,” “mesotrophic,” and “eutrophic” (Figure 9). Oligotrophic lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient dissolved oxygen in the cool, deep bottom waters during late summer to support coldwater fish such as trout and whitefish. By contrast, eutrophic lakes are generally shallow, turbid, and support abundant aquatic plant growth. In deep eutrophic lakes, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, these lakes can only support warmwater fish such as bass and pike. Lakes that fall between these two extremes are called mesotrophic lakes. In a recent assessment of Michigan’s lakes, the U.S. Geological Survey estimated that statewide about 25% of lakes are oligotrophic, 52% are mesotrophic and 23% are eutrophic (Fuller and Taricska 2012).

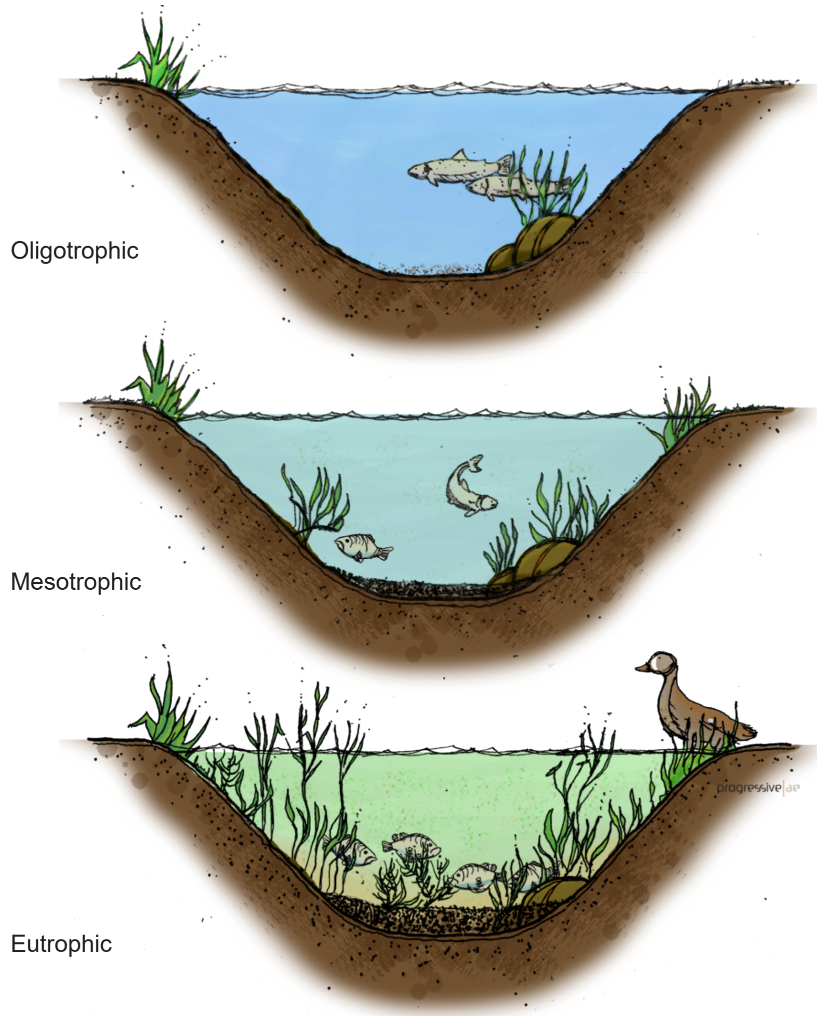


Figure 9. Lake classification.

Under natural conditions, most lakes will ultimately evolve to a eutrophic state as they gradually fill with sediment and organic matter transported to the lake from the surrounding watershed. As the lake becomes shallower, the process accelerates. When aquatic plants become abundant, the lake slowly begins to fill in as sediment and decaying plant matter accumulate on the lake bottom. Eventually, terrestrial plants become established and the lake is transformed to a marshland. The natural lake aging process can be greatly accelerated if excessive amounts of sediment and nutrients (which stimulate aquatic plant growth) enter the lake from the surrounding watershed. Because these added inputs are usually associated with human activity, this accelerated lake aging process is often referred to as *cultural eutrophication*.

There are many ways to measure lake water quality, but there are a few important physical, chemical, and biological parameters that indicate the overall condition of a lake. These measurements include temperature, dissolved oxygen, total phosphorus, chlorophyll-*a*, and Secchi transparency.

Temperature

Temperature is important in determining the type of organisms that may live in a lake. For example, trout prefer temperatures below 68°F. Temperature also determines how water mixes in a lake. As the ice cover breaks up on a lake in the spring, the water temperature becomes uniform from the surface to the bottom. This period is referred to as "spring turnover" because water mixes throughout the entire water column. As the surface waters warm, they are underlain by a colder, more dense strata of water. This process is called thermal stratification. Once thermal stratification occurs, there is little mixing of the warm surface waters with the cooler bottom waters. The transition layer that separates these layers is referred to as the "thermocline." The thermocline is characterized as the zone where temperature drops rapidly with depth. As fall approaches, the warm surface waters begin to cool and become more dense. Eventually, the surface temperature drops to a point that allows the lake to undergo complete mixing. This period is referred to as "fall turnover." As the season progresses and ice begins to form on the lake, the lake may stratify again. However, during winter stratification, the surface waters (at or near 32°F) are underlain by slightly warmer water (about 39°F). This is sometimes referred to as "inverse stratification" and occurs because water is most dense at a temperature of about 39°F. As the lake ice melts in the spring, these stratification cycles are repeated (Figure 10). Shallow lakes do not stratify. Lakes that are 15 to 30 feet deep may stratify and destratify with storm events several times during the year.

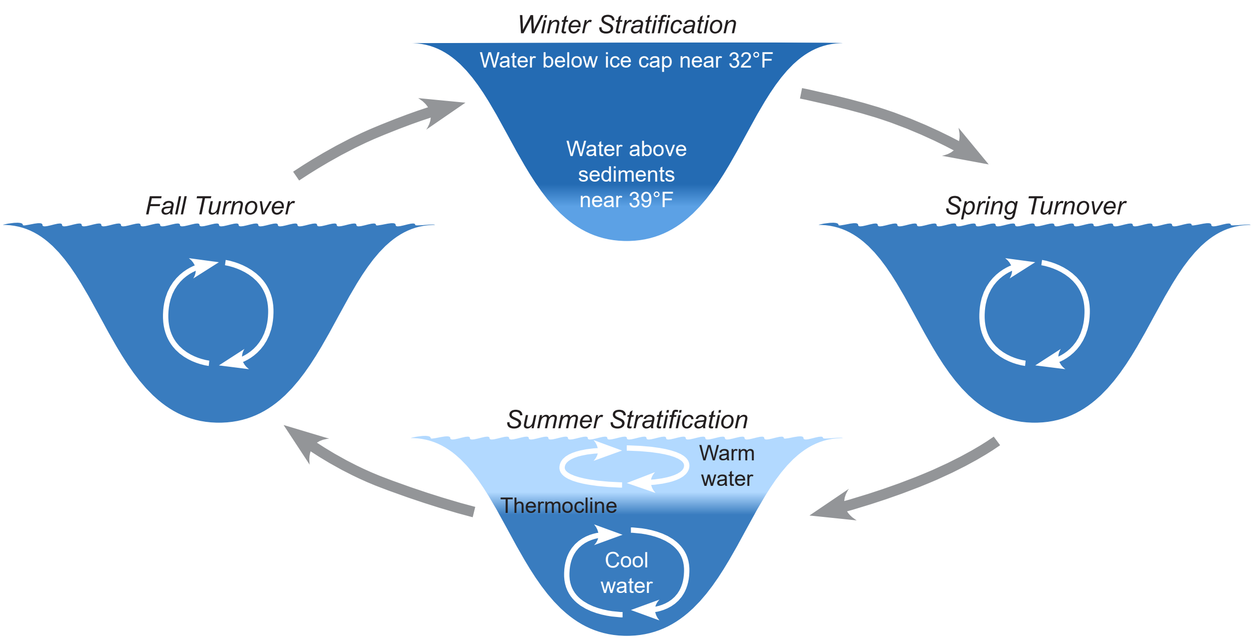


Figure 10. Seasonal thermal stratification cycles.

Dissolved Oxygen

An important factor influencing lake water quality is the quantity of dissolved oxygen in the water column. The major inputs of dissolved oxygen to lakes are the atmosphere and photosynthetic activity by aquatic plants. An oxygen level of about 5 mg/L (milligrams per liter, or parts per million) is required to support warmwater fish. In lakes deep enough to exhibit thermal stratification, oxygen levels are often reduced or depleted below the thermocline once the lake has stratified. This is because deep water is cut off from plant photosynthesis and the atmosphere, and oxygen is consumed by bacteria that use oxygen as they decompose organic matter (plant and animal remains) at the bottom of the lake. Bottom-water oxygen depletion is a common occurrence in eutrophic and some mesotrophic lakes. Thus, eutrophic and most mesotrophic lakes cannot support coldwater fish because the cool, deep water (that the fish require to live) does not contain sufficient oxygen.

Phosphorus

The quantity of phosphorus present in the water column is especially important since phosphorus is the nutrient that most often controls aquatic plant growth and the rate at which a lake ages and becomes more eutrophic. In the presence of oxygen, lake sediments act as a phosphorus trap, retaining phosphorus and, thus, making it unavailable for algae growth. However, if bottom-water oxygen is depleted, phosphorus will be released from the sediments and may be available to promote aquatic plant growth. In some lakes, the internal release of phosphorus from the bottom sediments is the primary source of phosphorus loading (or input).

By reducing the amount of phosphorus in a lake, it may be possible to control the amount of aquatic plant growth. In general, lakes with a phosphorus concentration greater than 20 μg/L (micrograms per liter, or parts per billion) are able to support abundant plant growth and are classified as nutrient-enriched or eutrophic.

Chlorophyll-*a*

Chlorophyll-*a* is a pigment that imparts the green color to plants and algae. A rough estimate of the quantity of algae present in lake water can be made by measuring the amount of chlorophyll-*a* in the water column. A chlorophyll-*a* concentration greater than 6 μg/L is considered characteristic of a eutrophic condition.

Secchi Transparency

A Secchi disk is often used to estimate water clarity. The measurement is made by fastening a round, black and white, 8-inch disk to a calibrated line (Figure 11). The disk is lowered over the deepest point of the lake until it is no longer visible, and the depth is noted. The disk is then raised until it reappears. The average between these two depths is the Secchi transparency. Generally, it has been found that aquatic plants can grow at a depth of approximately twice the Secchi transparency measurement. In eutrophic lakes, water clarity is often reduced by algae growth in the water column, and Secchi disk readings of 7.5 feet or less are common.

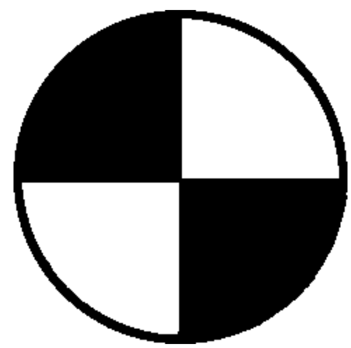


Figure 11. Secchi disk.

Lake Classification Criteria

Ordinarily, as phosphorus inputs (both internal and external) to a lake increase, the amount of algae will also increase. Thus, the lake will exhibit increased chlorophyll-*a* levels and decreased transparency. A summary of lake classification criteria developed by the Michigan Department of Natural Resources (Warbach et al. 1990) is shown in Table 2.

TABLE 2

LAKE CLASSIFICATION CRITERIA

Lake Classification	Total Phosphorus (μg/L)[1]	Chlorophyll-*a* (μg/L)[1]	Secchi Transparency (feet)
Oligotrophic	Less than 10	Less than 2.2	Greater than 15.0
Mesotrophic	10 to 20	2.2 to 6.0	7.5 to 15.0
Eutrophic	Greater than 20	Greater than 6.0	Less than 7.5

1 μg/L = micrograms per liter = parts per billion.

pH and Total Alkalinity

pH is a measure of the amount of acid or base in the water. The pH scale ranges from 0 (acidic) to 14 (alkaline or basic) with neutrality at 7. The pH of most lakes in the Upper Midwest ranges from 6.5 to 9.0 (Michigan Department of Environmental Quality (MDEQ) 2012; Table 3). In addition, according to the Michigan Department of Environment, Great Lakes, and Energy (EGLE 2020):

> While there are natural variations in pH, many pH variations are due to human influences. Fossil fuel combustion products, especially automobile and coal-fired power plant emissions, contain nitrogen oxides and sulfur dioxide, which are converted to nitric acid and sulfuric acid in the atmosphere. When these acids combine with moisture in the atmosphere, they fall to earth as acid rain or acid snow. In some parts of the United States, especially the Northeast, acid rain has resulted in lakes and streams becoming acidic, resulting in conditions which are harmful to aquatic life. The problems associated with acid rain are lessened if limestone is present, since it is alkaline and neutralizes the acidity of the water.
>
> Most aquatic plants and animals are adapted to a specific pH range, and natural populations may be harmed by water that is too acidic or alkaline. Immature stages of aquatic insects and young fish are extremely sensitive to pH values below 5. Even microorganisms which live in the bottom sediment and decompose organic debris cannot live in conditions which are too acidic. In very acidic waters, metals which are normally bound to organic matter and sediment are released into the water. Many of these metals can be toxic to fish and humans. Below a pH of about 4.5, all fish die.

The Michigan Water Quality Standard (Part 4 of Act 451) states that pH shall be maintained within the range of 6.5 to 9.0 in all waters of the state.

Alkalinity, also known as acid-neutralizing capacity or ANC, is the measure of the pH-buffering capacity of water in that it is the quantitative capacity of water to neutralize an acid. pH and alkalinity are closely linked and are greatly impacted by the geology and soil types that underlie a lake and its watershed. According to MDEQ (2012):

> Michigan's dominant limestone geology in the Lower Peninsula and the eastern Upper Peninsula contributes to the vast majority of Michigan lakes being carbonate-bicarbonate dominant [which increases alkalinity and moderates pH] and lakes in the western Upper Peninsula having lower alkalinity and thus lesser buffering capacity.

The alkalinity of most lakes in the Upper Midwest is within the range of 23 to 148 milligrams per liter, or parts per million, as calcium carbonate (MDEQ 2012; Table 3).

TABLE 3
pH AND ALKALINITY OF UPPER MIDWEST LAKES

Measurement	Low	Moderate	High
pH (in standard units)	Less than 6.5	6.5 to 9.0	Greater than 9.0
Total Alkalinity or ANC (in mg/L as $CaCO_3$[1])	Less than 23	23 to 148	Greater than 148

1 mg/L $CaCO_3$ = milligrams per liter as calcium carbonate.

Total Suspended Solids

According to EGLE (2020):

> Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter... Most people consider water with a TSS concentration less than 20 mg/L to be clear. Water with TSS levels between 40 and 80 mg/L tends to appear cloudy, while water with concentrations over 150 mg/L usually appears dirty.

Chloride

Normally, chloride is a very minor component of freshwater systems and background concentrations are generally less than about 10 milligrams per liter (Wetzel 2001; Fuller and Taricska 2012, Figure 12). However, chloride pollution from sources such as road salting, industrial or municipal wastewater, water softeners, and septic systems can increase chloride levels in lakes. Increased chloride levels can reduce biological diversity and, because chloride increases the density of water, elevated chloride levels can prevent a lake from completely mixing during spring and fall. Michigan's water quality standards require that waters designated as a public water supply source not exceed 125 milligrams per liter of chlorides as a monthly average.

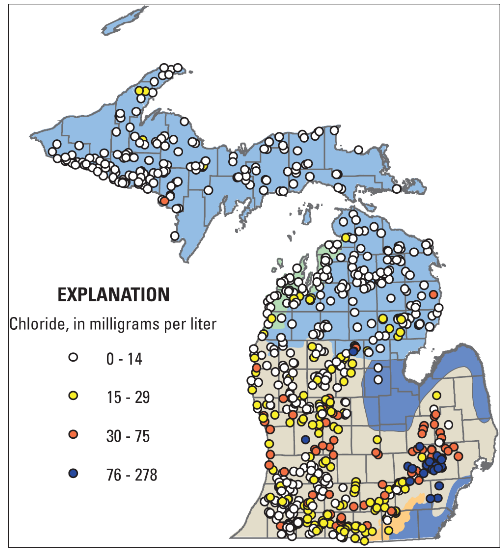


Figure 12. Lake chloride levels (2001–10) in USEPA ecoregions. Fuller and Taricska 2012.

Hess Lake Water Quality

In order to evaluate baseline water quality conditions in Hess Lake, samples were collected at five-foot intervals over the three deep lake basins in April and August of 2018 (Figure 13; Appendix A). In addition to the in-lake sampling locations, samples were collected from each of the five tributaries to the lake. Tributary samples were collected in April and August of 2018 and again in April of 2019.

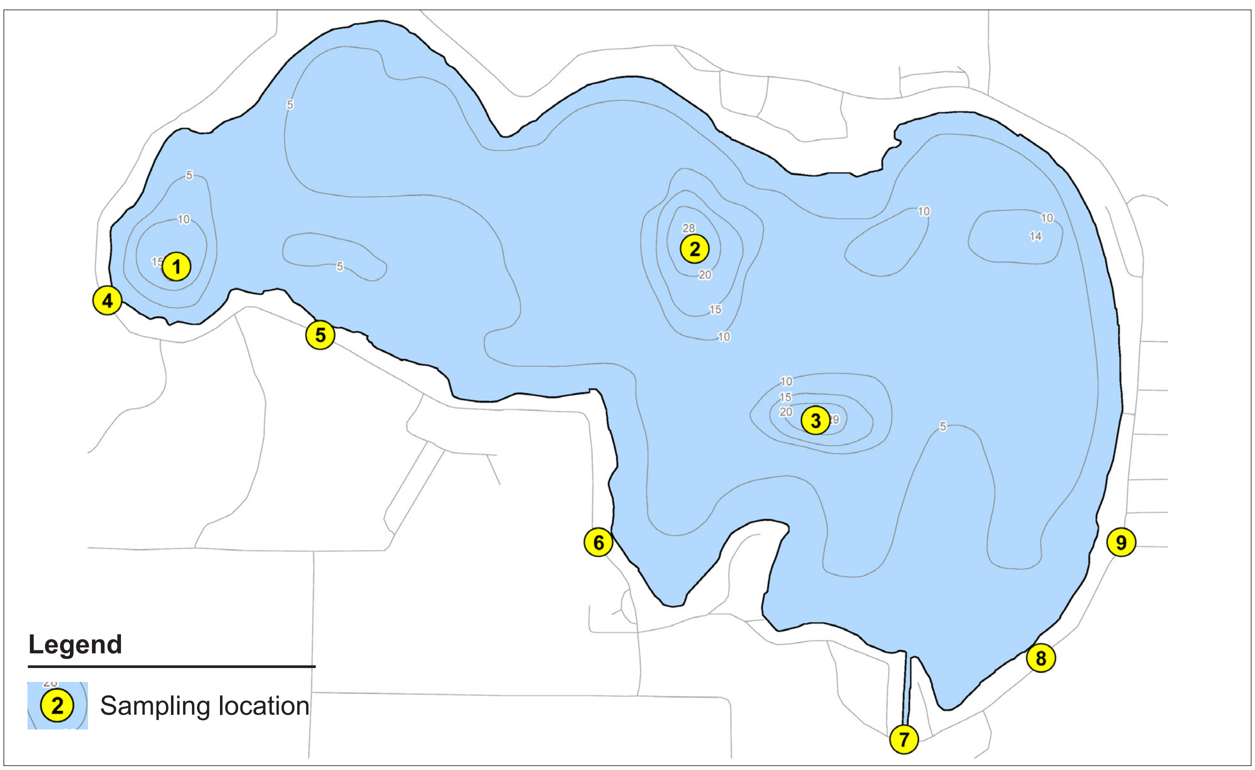


Figure 13. Hess Lake and tributary sampling location map.

RESULTS AND DISCUSSION

Sampling results for Hess Lake indicate the following:

The April sampling occurred during spring turnover when temperature and dissolved oxygen were uniform from the lake surface to bottom (Table 4). During the summer sampling period, thermal stratification was observed over the deep lake basins and the bottom waters were anoxic (i.e., devoid of oxygen). With the exception of the deep basins in Hess Lake, the remainder of the lake is too shallow to stratify and, during ice free periods, most of the lake is mixed and well oxygenated.

While conditions in Hess Lake are suitable for warmwater fish, the cool, deep bottom waters lack oxygen during summer stratification. Thus, the lake is uninhabitable for coldwater fish, and coolwater fish such as northern pike will be stressed (Jude 2020).

Phosphorus levels were moderate in spring and elevated during the summer sampling period, often exceeding the eutrophic threshold concentration. Given the small size of the deep basins, it's unlikely that internal phosphorus release from anoxic deep-water sediments is a primary phosphorus source in Hess Lake.

Secchi transparency readings were low during both sampling periods (Table 5). Chlorophyll-*a* levels were elevated during spring sampling indicating abundant algae growth in the water column at that time. During the summer sampling, algae growth was more moderate. At the times of sampling, total suspended solids levels were low and did not appear to be contributing to the poor transparency in the lake. Reduced transparency in Hess Lake is likely related to a combination of factors including wind-induced sediment resuspension, algae growth, roiling action of common carp, and motorized boat activity.

pH and total alkalinity in Hess Lake were generally within a moderate range for Michigan lakes.

Chloride levels in Hess Lake were low and similar to concentrations found in other rural areas of the state (Table 4).

Tributary data indicate discharge and pollutant loadings (i.e., total phosphorus and total suspended solids) are greatest from Wheeler Drain (Table 6). The relatively high total phosphorus and total suspended solids levels measured in Wheeler Drain in April of 2018 were likely influenced by excavation occurring in the sediment basin upstream of the lake. Discharge rates from all tributaries are greater in spring than summer.

Current and historical water quality data indicate Hess Lake is eutrophic (Table 7 and Appendix B). The lake generally has elevated phosphorus and chlorophyll-*a* levels, and reduced transparency. In a state-wide assessment of lake water quality conducted by the U.S. Geological Survey, Hess Lake was classified as hyper-eutrophic (Fuller and Taricska 2012).

TABLE 4
HESS LAKE 2018 DEEP BASIN WATER QUALITY DATA

Date	Station	Sample Depth (feet)	Temper-ature (°F)	Dissolv. Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]	pH (S.U.)[3]	Total Alkalinity (mg/L as $CaCO_3$)[4]	Total Suspended Solids (mg/L)[1]	Chloride (mg/L)[1]
12-Apr-18	1	1	45	9.5	19	9.0	137	10	13
12-Apr-18	1	5	45	9.8	25	8.9	137	9	13
12-Apr-18	1	10	45	9.8	21	8.9	142	24	15
12-Apr-18	1	13	45	9.4	20	8.9	135	11	13
12-Apr-18	2	1	44	9.2	22	9.4	139	8	13
12-Apr-18	2	5	44	9.6	21	9.3	142	8	13
12-Apr-18	2	10	44	9.6	5	9.4	138	10	13
12-Apr-18	2	15	44	9.3	<5	9.4	137	11	14
12-Apr-18	2	20	44	9.8	16	9.4	137	9	13
12-Apr-18	3	1	45	9.8	12	9.4	138	5	13
12-Apr-18	3	5	44	9.5	16	9.4	136	10	13
12-Apr-18	3	10	44	10.8	<5	9.4	136	14	13
12-Apr-18	3	15	44	11.5	<5	9.3	140	10	13
20-Aug-18	1	1	78	8.9	16	8.7	114	20	16
20-Aug-18	1	5	74	9.7	22	8.6	114	20	16
20-Aug-18	1	10	69	1.3	58	7.0	155	13	31
20-Aug-18	1	13	69	0.0	90	6.8	189	11	15
20-Aug-18	2	1	79		16	8.7	114	15	15
20-Aug-18	2	5	79	9.5	35	8.8	112	20	15
20-Aug-18	2	10	73	10.0	17	8.7	114	19	15
20-Aug-18	2	15	71	6.9	18	8.2	117	16	16
20-Aug-18	2	20	71	0.0	43	6.9	192	20	16
20-Aug-18	3	1	79	8.2	12	8.7	112	12	15
20-Aug-18	3	5	78	7.5	80	8.7	114	26	15
20-Aug-18	3	10	73	9.2	45	8.5	112	14	16
20-Aug-18	3	16	73	0.7	48	6.9	164	18	15

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.
3 S.U. = standard units.
4 mg/L as $CaCO_3$ = milligrams per liter as calcium carbonate.

TABLE 5
HESS LAKE 2018 SURFACE WATER QUALITY DATA

Date	Station	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
12-Apr-18	1	4	2.5
12-Apr-18	2	11	2.5
12-Apr-18	3	12	2.5
20-Aug-18	1	5	2.0
20-Aug-18	2	4	1.5
20-Aug-18	3	3	2.0

TABLE 6
HESS LAKE 2018-2019 TRIBUTARY WATER QUALITY DATA

Date	Station	Stream	Discharge (cfs)	Total Phosphorus (µg/L)[1]	Total Suspended Solids (mg/L)[2]
12-Apr-18	4	West trib	0.1	5	<4
12-Apr-18	5	Alger Creek	1.2	45	21
12-Apr-18	6	South trib	0.3	<5	<4
12-Apr-18	7	Wheeler Drain	10.5	329	194
12-Apr-18	8	Southeast trib	0.4	22	19
12-Apr-18	9	East trib	---	7	9
20-Aug-18	4	West trib	0	---	---
20-Aug-18	5	Alger Creek	---	55	6
20-Aug-18	6	South trib	0	---	---
20-Aug-18	7	Wheeler Drain	1.5	61	8
20-Aug-18	8	Southeast trib	0.1	35	8
20-Aug-18	9	East trib	0.3	64	<4
23-Apr-19	4	West trib	1.6	16	<4
23-Apr-19	5	Alger Creek	3.1	21	<4
23-Apr-19	6	South trib	0.6	<10	<4
23-Apr-19	7	Wheeler Drain	19.3	47	<4
23-Apr-19	8	Southeast trib	0.5	<10	<4
23-Apr-19	9	East trib	1.3	<10	<4

1 µg/L = micrograms per liter = parts per billion.
2 mg/L = milligrams per liter = parts per million.

TABLE 7
HESS LAKE WATER QUALITY SUMMARY STATISTICS (1974-2019)

	Total Phosphorus (µg/L)[1]	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
Mean	33	12	3.3
Standard deviation	19	8	1.9
Median	32	10	2.5
Minimum	5	3	1.5
Maximum	90	35	10.5
Number of samples	65	48	185

AQUATIC PLANTS

Aquatic plants are an important ecological component of lakes. They produce oxygen from photosynthesis, provide food and habitat for fish, and help stabilize shoreline and bottom sediments (Figure 14).

The distribution and abundance of aquatic plants are dependent on several variables including light penetration, bottom type, temperature, water levels, and the availability of plant nutrients. The term "aquatic plants" includes both the algae and the larger aquatic plants or macrophytes. The macrophytes can be categorized into four groups: emergent, floating-leaved, submersed, and free floating (Figure 15). Each plant group provides unique habitat essential for a healthy fishery.

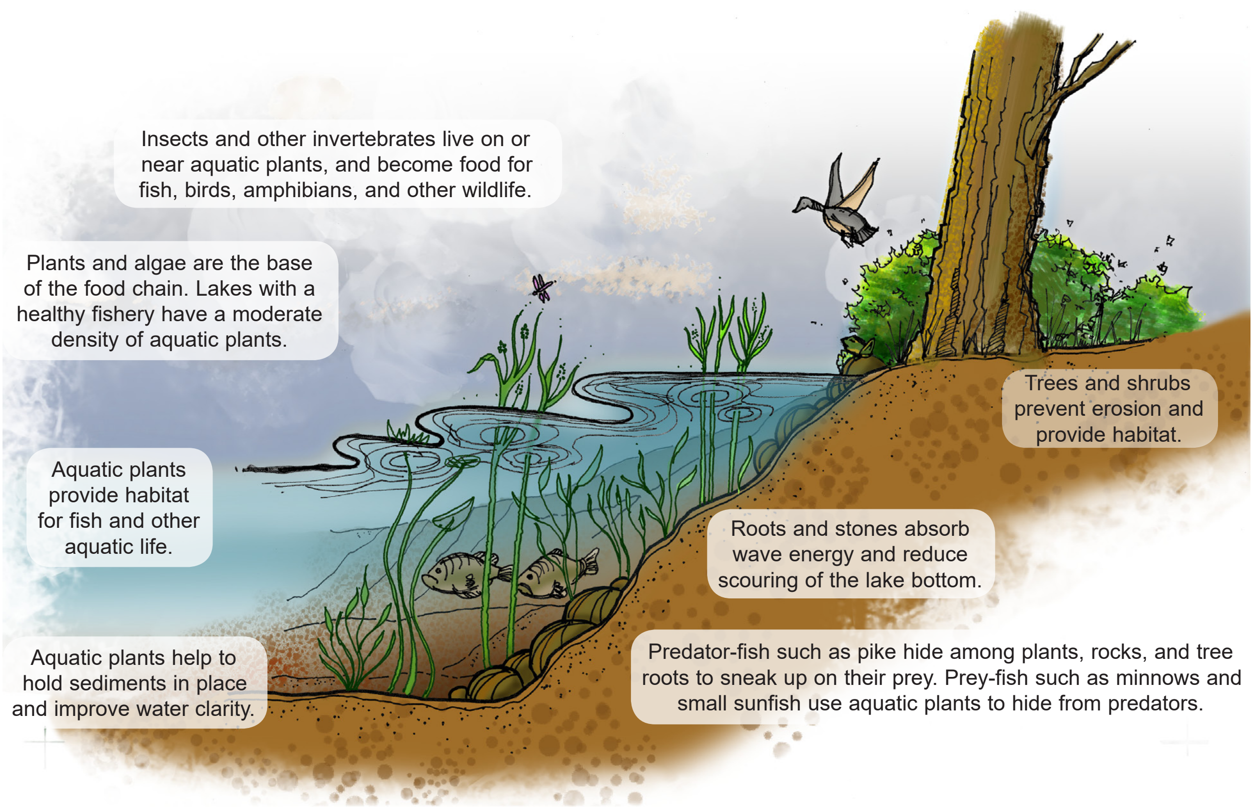


Figure 14. Benefits of aquatic plants.

1 µg/L = micrograms per liter = parts per billion.

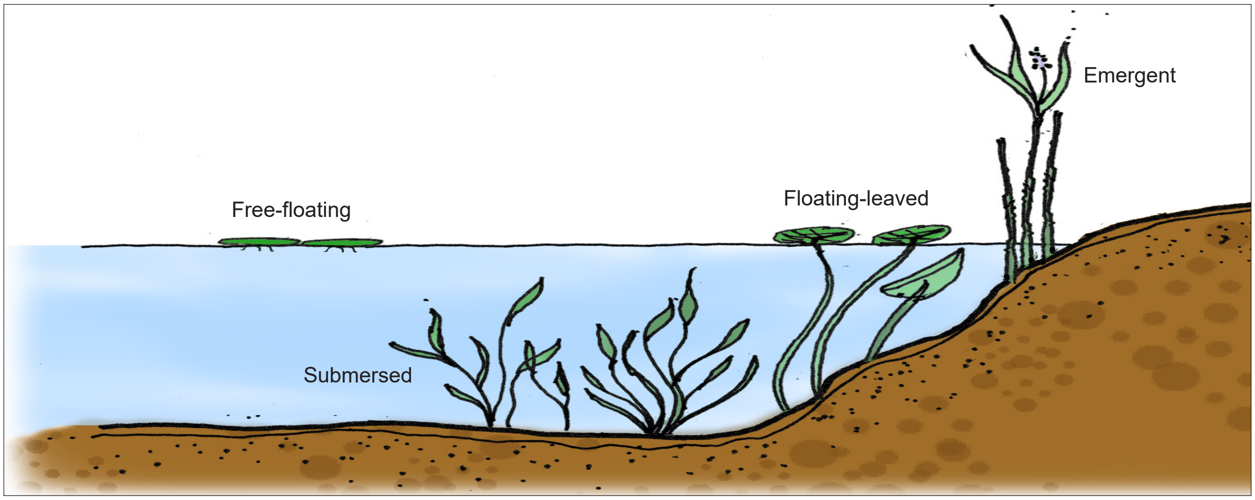


Figure 15. Aquatic plant groups.

While most aquatic plants are beneficial, exotic (i.e., non-native) plant species are a problem in many lakes. Exotic aquatic plants often have aggressive and invasive growth. In some lakes, they quickly out-compete native plants and gain dominance. In Michigan, an exotic plant of primary concern is Eurasian milfoil (*Myriophyllum spicatum*, Figure 16). Eurasian milfoil generally becomes established early in the growing season and can spread rapidly by vegetative propagation (i.e., small pieces of the plant break off, take root, and grow). The plant often forms a thick canopy at the lake surface that can degrade fish habitat and seriously hinder recreational activity. Eurasian milfoil infestations have been a problem on Hess Lake for many years.

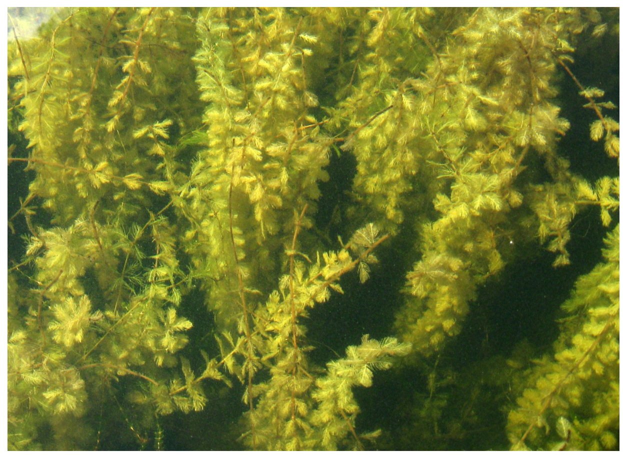


Figure 16. Eurasian milfoil (*Myriophyllum spicatum*).

Hess Lake has the potential to naturally support abundant plant growth, both rooted plants and algae. Historical data indicate that submersed plant growth was common in Hess Lake. A 1937 U.S. Forest Service map shows various plant species across much of the lake, including *Potamogeton* sp. (pondweeds) and Chara, a submersed alga that looks similar to a rooted plant. These plant types are generally considered to be beneficial. Chara in particular is considered a beneficial plant in that it is low-growing, therefore generally does not interfere with recreational activities; forms a net-like mat at the bottom which helps to hold sediments in place; absorbs phosphorus and helps improve water clarity. Abundant rooted plant growth in Hess Lake was also noted in the early 1980s and 1990s (Edmunds Engineering, Inc. 1982, Hess Lake Improvement Board 1995).

To measure current plant cover and bio-volume (i.e., the height of plants in the water column) hydro-acoustic surveys of the lake were conducted in 2018 and 2019 (Figures 17 and 18; Appendix A). When plants grow to the surface, they occupy 100% of the water column, and those areas are shown in red on the maps. When plants are not present, 0% of the water column contains plants, and those areas are shown in blue. When plants grow half-way to the surface, they occupy 50% of the water column, and are shown in yellow. The plant bio-volume maps show very little submersed plant growth currently present in Hess Lake.

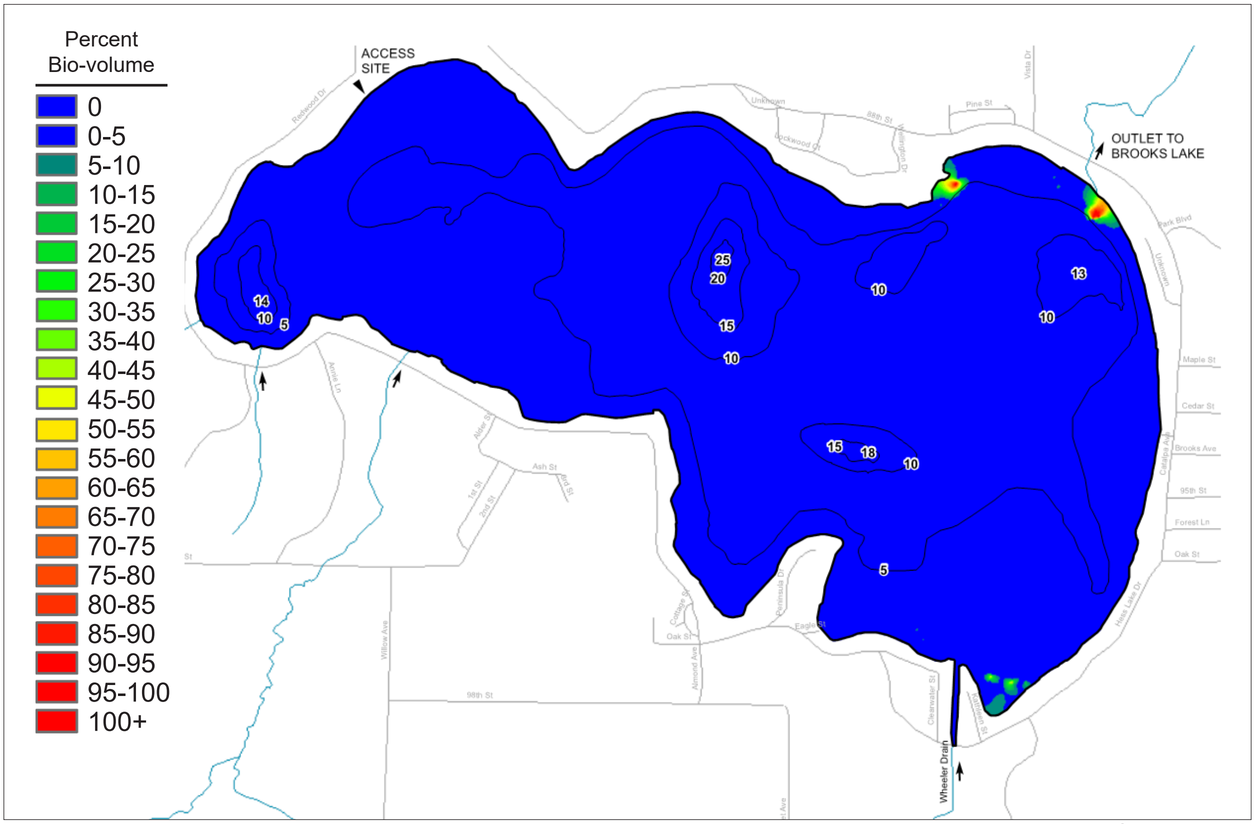


Figure 17. Hess Lake bio-volume map, August 2018. Hydro-acoustic data processed using Biobase by C-Map. Lake shoreline digitized from aerial orthodigital photography (Source: DigitalGlobe 2018).

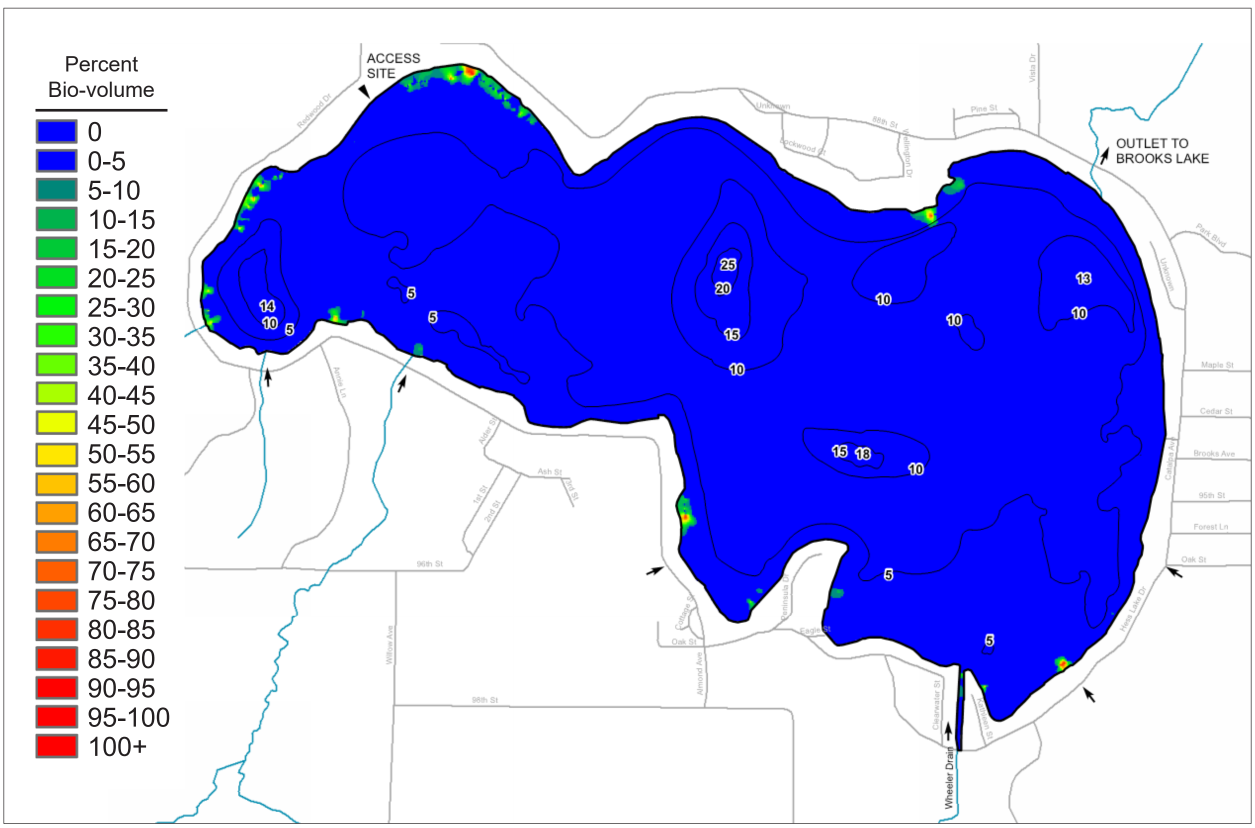


Figure 18. Hess Lake bio-volume map, September 2019. Hydro-acoustic data processed using Biobase by C-Map. Lake shoreline digitized from aerial orthodigital photography (Source: DigitalGlobe 2018).

Both during the current study and by others previously, several assessments of plant growth in Hess Lake have been conducted in accordance with Michigan Department of Environment, Great Lakes and Energy Procedures of Aquatic Vegetation Surveys. With these surveys, the shoreline is divided into individual assessment areas and the type and relative abundance of each plant species is determined at each assessment site. In recent years, native submersed plant growth has been almost non-existent in the lake (Table 8).

TABLE 8
HESS LAKE AQUATIC VEGETATION ASSESSMENT SITE SURVEY RESULTS (1996-2019)

Year	Number of Submersed Native Species	Number of Survey Sites	Percentage of Sites with Native Plants
1996	7	30	23
2000	5	20	25
2001	6	48	13
2002	5	42	12
2003	7	45	16
2005	2	46	4
2006	5	48	10
2007	1	44	2
2008	2	96	2
2009	2	100	2
2013	0	55	0
2015	0	55	0
2016	1	55	2
2016	4	55	7
2017	1	55	2
2018	2	107	2
2019	1	107	1

During the period of study, Eurasian milfoil was the most abundant submersed plant found in Hess Lake (Tables 9 and 10). Floating-leaved species included white waterlily and yellow waterlily and a small portion of the shoreline supported emergent plant species.

In the absence of rooted plants, algae has become dominant in Hess Lake, and algae blooms are common (Figure 19). The lake's reduced water clarity favors algae growth: Rooted plants don't receive enough sunlight to stimulate their growth, while algae cells concentrate near the surface where light is plentiful. Algae growth further reduces water clarity and the cycle is perpetuated. Recent studies show blue-green algae, primarily Microcystis, is the most common type of algae in Hess Lake (Jude 2020, PhytoTech 2019). Blue-green algae (also called cyanobacteria) are generally considered to be nuisance species due to their tendency to form unsightly floating scums at the lake surface. Another concern with cyanobacteria is the potential to cause harmful algal blooms (HABs) by releasing toxins into the water that, at elevated levels, cause health concerns. A recent analysis of water samples from Hess Lake found a high potential for HABs (PhycoTech 2019).

Figure 19. Hess Lake algae.

TABLE 9
HESS LAKE AQUATIC PLANTS
August 20, 2018

Common Name	Scientific Name	Group	Percent of Sites Where Present
Eurasian milfoil	*Myriophyllum spicatum*	Submersed	16
Coontail	*Ceratophyllum demersum*	Submersed	3
Chara	*Chara* sp.	Submersed	1
White waterlily	*Nymphaea odorata*	Floating-leaved	29
Yellow waterlily	*Nuphar* sp.	Floating-leaved	6
Purple loosestrife	*Lythrum salicaria*	Emergent	10
Arrowhead	*Sagittaria latifolia*	Emergent	6
Swamp loosestrife	*Decodon verticillatus*	Emergent	4
Cattail	*Typha* sp.	Emergent	3
Pickerelweed	*Pontederia cordata*	Emergent	3
Phragmites	*Phragmites australis*	Emergent	1

TABLE 10
HESS LAKE AQUATIC PLANTS
October 4, 2019

Common Name	Scientific Name	Group	Percent of Sites Where Present
Eurasian milfoil	*Myriophyllum spicatum*	Submersed	32
Coontail	*Ceratophyllum demersum*	Submersed	3
White waterlily	*Nymphaea odorata*	Floating-leaved	17
Yellow waterlily	*Nuphar* sp.	Floating-leaved	5
Swamp loosestrife	*Decodon verticillatus*	Emergent	3
Cattail	*Typha* sp.	Emergent	3
Arrowhead	*Sagittaria latifolia*	Emergent	2
Phragmites	*Phragmites australis*	Emergent	1
Pickerelweed	*Pontederia cordata*	Emergent	1

FISH

In a recent fishery study of Hess Lake (Jude 2020), the importance of aquatic plants to maintaining a healthy fishery in Hess Lake was noted. The report stated:

> The shallow nature of the lake and high turbidity has resulted in a dearth of macrophytes, sediment buildup in many areas nearshore, and habitat favored by the invasive fish species, common carp, which appear to be abundant. Loss of aquatic plants is a serious problem, since macrophytes are keystone habitats in a lake for fishes; they provide aquatic insects for food, spawning habitat, and probably most importantly, nursery and shelter for smaller fishes. It also anchors the sediment and prevents wind-generated currents from re-suspending bottom sediments. Macrophytes also are important since nutrients in a lake can be tied up in algae or macrophytes, and it is critical that macrophytes predominate and prevent blue-green algae from taking over and shading the plants and increasing turbidity, which appears to now be the case in Hess Lake. Increased turbidity can thwart visual predators from catching prey favoring predators such as black crappies and channel catfish, which can feed in the dark. Loss of macrophytes results in loss of shelter for prey fish, and re-suspended sediments can put more nutrients into the water column, which can fuel algal and macrophyte growth. Some places we seined were relatively macrophyte depauperate and fish catch reflected this with low catches.
>
> It should also be pointed out that with the current situation with dense blue-green algae blooms ongoing in Hess Lake during summer, that at night these algae will respire and use dissolved oxygen instead of producing it in excessive quantities, like it does during the day. This will result in dissolved oxygen sags during the night. We do not know the extent of this phenomenon, but this situation is termed summer kill, when the dissolved oxygen drops so much, it kills fish. This type of situation was probably documented during 2010 when black crappies moved into Wheeler Creek to spawn, then experienced a rain event or possibly summer kill reducing dissolved oxygen so far that a fish kill resulted.

The Jude 2020 fishery also noted:

> Algae are composed of two major groups: macro algae of which Chara is an example and of which much is growing in Hess Lake, and micro algae or phytoplankton, which are mostly microscopic organisms, which can turn the lake to green or brown or cause massive floating mats of filamentous green algae (Cladophora) or blue-green algae, some members (Microcystis) of which have become famous in Lake Erie for closing down the Toledo water intake. We saw Chara in many places during our seining activities. It is an important plant, since it can take up nutrients, provides cover for insects and fish, and because it ties up nutrients, it can modulate algal blooms. Since this plant is an alga, a native species that provides cover for benthos and small fish, and it can tie up phosphorus by complexing phosphorus with calcium carbonate precipitation, it should not be treated chemically and encouraged to grow.

Lake Management Alternatives

INTRODUCTION

The goals of the Hess Lake management plan are to improve water clarity, re-establish beneficial submersed plants, enhance the fishery, and reduce pollutant runoff from the watershed. Hess Lake is naturally nutrient-enriched and has the potential to support abundant rooted plant and algae growth. However, rooted vegetation that was once prevalent in the lake has been replaced by persistent algae blooms and poor water clarity, which are aesthetically displeasing and not conducive to a healthy fishery. The blue-green algae that are currently dominant in the lake have the potential to pose public health concerns.

The following discussion of management alternatives for Hess Lake provides an overview of past management activities and recommendations, referenced in Appendix C, as well as alternatives that may be implemented in the future to improve lake conditions.

AQUATIC PLANT CONTROL

In the 1980s and 1990s, nuisance plant growth was controlled with mechanical harvesting and herbicide treatments (Hess Lake Improvement Board 1995). More recently, rooted plant growth in the lake has been minimal and the lake has become an algae-dominated system. Persistent algae blooms in the lake are commonplace. Currently, poor water transparency and other factors such as carp-roiling appear to be inhibiting the establishment of submersed vegetation in the lake.

For the past several years, herbicide treatments have been the primary method of plant control in Hess Lake (Table 11). In 2013, a large-scale treatment of beneficial native submersed plants was conducted. Since then, the primary plant targeted for control has been Eurasian milfoil, although the type of herbicides used had the potential to impact beneficial native plants also. In order to strike a more natural balance, plant control activities in Hess Lake should minimize impacts to native plant species.

Eurasian milfoil is commonly controlled with herbicides. In general, there are two types of herbicides: systemic and contact. Systemic herbicides are taken up by the plant and translocated to the roots, resulting in more complete control. Contact herbicides only impact the portions of the plant that come into contact with the herbicide. They also tend to be broad-spectrum; they kill both milfoil and desirable native plants. By contrast, systemic herbicides kill milfoil with little or no impact to native plants. Contact herbicides work relatively quickly while systemic herbicides generally take several weeks to kill the targeted plant. However, control with contact herbicides is usually short-lived and milfoil can re-grow within a few weeks. Another consideration with some systemic herbicides is that irrigation restrictions tend to last several weeks as opposed to several days for contact herbicides.

Given the lack of submersed plant growth in Hess Lake, it is recommended that lake treatments focus on the control of invasive and exotic species only with the select use of systemic herbicides, when feasible. Beneficial native plants should be allowed to re-establish. Re-establishment of submersed native plants would help stabilize bottom sediments, improve transparency, create valuable fish habitat, reduce the frequency of algae blooms, and help restore the natural ecological balance in the lake.

TABLE 11
HESS LAKE HERBICIDE TREATMENT HISTORY, 2013-2019

Date	Acres Treated	Herbicide Type	Target Plant
6/6/2019	21	Contact	Eurasian Watermilfoil, Curly Leaf Pondweed
7/10/2019	18	Contact	Eurasian Watermilfoil
8/13/2019	19	Contact	Eurasian Watermilfoil
6/4/2018	10	Contact	Eurasian Watermilfoil, Curly Leaf Pondweed
7/9/2018	5	Contact	Eurasian Watermilfoil
8/7/2018	8	Contact	Eurasian Watermilfoil
6/5/2017	10	Contact	Eurasian Watermilfoil, Curly Leaf Pondweed
9/5/2017	8	Contact	Eurasian Watermilfoil
6/1/2016	13	Contact	Eurasian Watermilfoil, Curly Leaf Pondweed
7/25/2016	5	Contact	Eurasian Watermilfoil
8/23/2016	8	Contact	Eurasian Watermilfoil
6/2/2015	8	Contact	Eurasian Watermilfoil, Curly Leaf Pondweed
6/2/2015	120	Algaecide	Planktonic Algae, Filamentous Algae
7/15/2015	120	Algaecide	Planktonic Algae, Filamentous Algae
8/25/2015	5	Contact	Eurasian Watermilfoil
8/25/2015	120	Algaecide	Planktonic Algae, Filamentous Algae
6/12/2014	5	Contact	Eurasian Watermilfoil
6/12/2014	38	Algaecide	Planktonic Algae, Filamentous Algae
7/9/2014	120	Algaecide	Planktonic Algae, Filamentous Algae
8/12/2014	120	Algaecide	Planktonic Algae, Filamentous Algae
5/29/2013	122	Contact	Eurasian Watermilfoil
5/29/2013	122	Algaecide	Planktonic Algae, Filamentous Algae
5/29/2013	122	Contact	Broad Leaf, Clasping Leaf
6/19/2013	122	Contact	Eurasian Watermilfoil
6/19/2013	122	Algaecide	Planktonic Algae, Filamentous Algae
7/31/2013	122	Algaecide	Planktonic Algae, Filamentous Algae
8/2/2013	122	Algaecide	Planktonic Algae, Filamentous Algae

If native submersed plants are re-established in Hess Lake, there is the potential that native plants could become abundant, and possibly grow to nuisance densities. In that event, control should be limited to near-shore areas and only where plant growth poses an extreme nuisance condition. Currently, Michigan Department of Environment, Great Lakes and Energy (EGLE) permits only allow herbicide treatments for nuisance native plants within 100 feet of developed shorelines. By contrast, a permit would not be required for mechanical harvesting of nuisance plants, and harvesting could be used to create boating pathways. However, if Eurasian milfoil were present, it would need to be removed early in the growing season with systemic herbicides, since harvesting can cause Eurasian milfoil to fragment and spread.

Copper sulfate and various chelated copper-based products are often used to control algae growth. Following treatment, copper does not remain in the water column but instead deposits rapidly in the sediment (Johnson 2015). Thus, the effects of copper treatments are generally short-lived. Unlike most aquatic herbicides, copper is persistent in the aquatic environment and, over time, accumulates in the sediment. According to the Environmental Protection Agency (EPA):

> Copper is an abundant naturally occurring trace element found in the earth's crust that is also found in surface waters. Copper is a micronutrient at low concentrations and is essential to virtually all plants and animals. At higher concentrations copper can become toxic to aquatic life.

As such, EPA allows only partial treatment of a water body and 10-14 days between treatments to reduce risk. Additionally, the EPA has imposed maximum annual rates for treatment (Johnson 2015). Given the potential for copper to accumulate in the sediments and the limited efficacy of copper treatments for algae control, treatments with copper-based algaecides in Hess Lake should be limited or curtailed.

In Michigan, aquatic herbicide use is regulated under Part 33 (Aquatic Nuisance Control) and Part 31 (Water Resources Protection) of the Natural Resources and Environmental Protection Act, PA 451 of 1994. Prior to herbicide treatments, a permit must be acquired from the Michigan Department of Environment, Great Lakes and Energy (EGLE). EGLE regulates which herbicides can be applied, dose rates, and areas of the lake where treatments are allowed.

LAKE ALUM TREATMENT

Alum (aluminum sulfate) is a chemical that has been used successfully in lakes to reduce phosphorus levels and algae blooms, primarily by preventing phosphorus release from lake sediments (Cooke et al. 2005, Huser el al. 2015, Wagner 2017, Kuster et al. 2020). Once applied, alum binds with phosphorus in the water column and settles to the bottom as a floc. The floc inhibits the release of phosphorus from lake sediments. Alum is commonly used to treat wastewater and drinking water and, over the last half-century, there have been hundreds of lake alum treatments (Kuster et al. 2020).

In lakes, alum is typically used to reduce internal phosphorus loading which occurs when lake sediments release phosphorus under anoxic conditions, which does not appear to be substantial in Hess Lake. However, alum can also be used to bind and remove phosphorus and suspended solids from the water column, temporarily reduce algae growth, and improve water clarity. In Hess Lake, improved clarity may help to re-establish rooted plants, which would, in turn, help to reduce algae growth and enhance fishery habitat.

An alum treatment of Hess Lake would strip phosphorus from the water column and make it temporarily unavailable for algae growth. The effectiveness of an alum treatment of Hess Lake in reducing phosphorus and algae levels and improving water clarity would likely be less than five years (Huser et al. 2015). Continued nutrient loading from the watershed, roiling activity by carp and wind- and boat-induced mixing of the water column would limit the longevity of the treatment. However, the alum treatment may help to shift the lake from being algae-dominated to a more natural balance of desirable algae and rooted aquatic plants.

Alum is typically applied at a specified dose over a designated portion of the lake with a specialized application barge (Figure 20). In the case of Hess Lake, alum would be applied at a dose of about 8 milligrams per liter over the entire surface of the lake, would likely take about two weeks to complete. Once applied, the alum would strip phosphorus from the water column and settle to the lake bottom. The phosphorus stripped from the water column would remain bound to the alum and become biologically inactive. If applied properly, the alum should not impact lake biota.

Figure 20. Alum application barge.

In Michigan, the application of alum to surface waters requires a Rule 97 Certification of Approval from EGLE. State approval would likely require monitoring of lake conditions before, during and after the alum treatment.

FISHERIES MANAGEMENT

Historical data on file with the Michigan Department of Natural Resources (MDNR) indicate concerns with the Hess Lake fishery go back many years. In 1969, the MDNR considered whole-lake fish removal but abandoned the effort due to opposition from lake residents. More recently, many lake residents have expressed concern about a declining fishery, a primary issue being the prevalence of carp in Hess Lake. Feeding activity by carp can increase turbidity, reduce rooted aquatic plants and cause lakes to shift from relatively clear to turbid conditions (Weber and Brown 2009).

In a recent assessment of the fishery in Hess Lake, Jude (2020) noted:

> This fish community is suboptimal and a reflection of the current degraded water quality conditions in the lake. Channel catfish, which are not native to the lake, are common, eating insects, and eventually will create a substantial appetite/demand for prey fish and since they feed efficiently at night, will have a big impact on nearshore fishes. Whether the fishers on the lake regard this as a good outcome, remains to be seen. Catfish are certainly good eating. There are three minnows in the lake, two are great prey fish (bluntnose minnows and golden shiners) while the third is the curse of many lakes, the common carp. Common carp appear to be common based on our catches and reports from lake residents. They are well known for rooting up sediments, consuming fish eggs, and creating turbid conditions. They need to be controlled by any means possible by residents (via hook and line and bow and arrow fishing). We are aware of efforts to control this species with awards given out during summer as designated times for killing this species. This should be continued, and we can make two additional recommendations, that if the MDNR supports these efforts, could also contribute to lowering of their populations. One would be to do some trammel netting during the spawning season in known spawning areas of the lake, which has been given support by MDNR…

In order to reduce the number of carp in Hess Lake it is recommended that an annual carp netting and removal program be considered. This approach would involve the use of trammel nets (Figure 21) that would be placed in select locations during the spring spawning season to capture and remove carp from the lake.

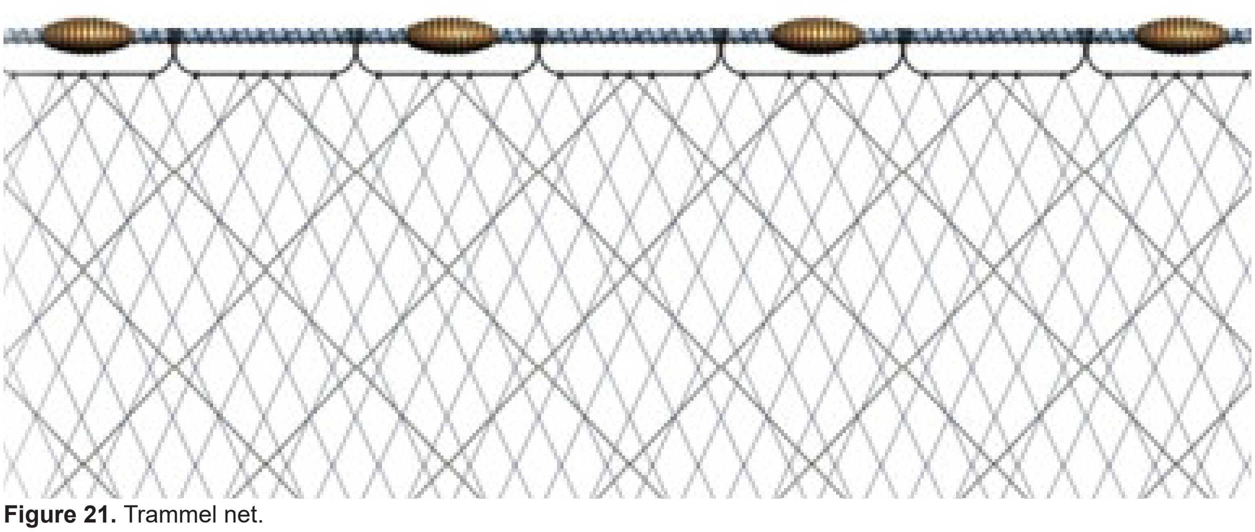


Figure 21. Trammel net.

DREDGING

Given the shallowness of Hess Lake, dredging to deepen the lake has been discussed frequently over the years (Edmunds Engineering, Inc. 1982, Wade-Trim/Granger 1990, Spicer Group 2010). There are two major dredging methods: mechanical and hydraulic. While both methods involve removing sediment from the water, the operations are quite different. Mechanical dredging involves removing lake sediments with an excavator operating from shore or from a floating barge. Dredged material is disposed on shore or contained on the barge and off-loaded for final disposal. By contrast, material excavated with a hydraulic dredge is pumped in a slurry through a floating pipeline to the point of disposal (Figure 22).

Figure 22. Hydraulic dredge.

In a prior dredging feasibility evaluation (Edmunds Engineering, Inc. 1982), it was estimated that to deepen about 30% of Hess Lake to a depth of 15 feet would require the removal of about 3.5 million cubic yards of material at a cost (in 1982 dollars) of 6 to 7 million dollars. This estimate assumed that lands near the lake would be available to dispose of dredge materials. Assuming a project of this scope could be completed today for $10 to $15 per cubic yard, the cost of dredging and disposal would be between 35 and 52 million dollars. While dredging would help to improve conditions in Hess Lake, the costs of a project would likely be prohibitive.

LAKE AERATION

Aeration (also called “artificial circulation” or “artificial de-stratification”) is a lake management technique that involves pumping air into a lake or pond to circulate and oxygenate waters. In some situations, aeration can reduce the potential for fish-kills, improve water quality or help control algae growth (Cooke et al. 2005, Welch and Gibbons 2009, Osgood 2015). Over the years, there have been claims that aeration will “eat muck” or will reduce the amount of lake-bottom sediment, either alone or in combination with bacteria and/or enzymes. However, these claims remain unproven.

In a Minnesota study of five non-aerated lakes and five lakes aerated for between 8 and 18 years, Engstrom and Wright (2002) collected multiple sediment cores from each lake and evaluated the effects of aeration on sediment accumulation. The sediment cores were widely spaced at different depths within each of the respective study lakes to encompass a range of depositional environments. There was no evidence that aeration reduced lake-bottom muck. The researchers concluded “results from this study do not support claims that aeration-induced circulation will enhance the removal of organic sediments from lake basins either by mineralization or offshore transport,” and “there is little to recommend aeration as a method for improving the sedimentary environment of urban lakes.”

In a recent assessment of methods to control muck accumulation in lakes (Hoyer et al. 2017), it was noted:

> Keeping muck under control requires fairly arduous and unpleasant effort, and many people understandably seek an approach that requires less or no work. There is no such work-free approach, unfortunately, but if you keep searching, sooner or later somebody will suggest you try using aeration and bacterial additions—beneficial bacteria, they say, will “eat up the muck.” Proceed with caution if you try this approach, and be prepared for unimpressive to disastrous results: although this approach is supported by testimonials, as yet there is little scientific evidence to suggest it is effective.

Aeration is a crucial component of this approach and promoters point out that addition of oxygen to a water body stimulates the aerobic bacteria that are added. It is true that the addition of oxygen to a pond or lake can be good for animals like fish, but there will already be plenty of aerobic bacteria in any water body with normal levels of oxygen. The few scientific studies on the role of aeration in treatment of muck seem to show that any muck reduction is likely related to the redistribution of the bottom material, and not bacterial metabolism. The redistribution of bottom muck is related to water currents generated by the aerators, which move material to deep water.

The failure of added bacteria to remove deep muck deposits is related to the inability of oxygen to penetrate deep below the sediment surface. Deeper oxygen penetration will only occur if the muck is stirred and re-suspended into the water column, an undesirable side effect because it makes the water murky. Furthermore, massive re-suspension of anaerobic sediments can consume oxygen in the overlying water column, with predictable negative consequences for fish and other aquatic fauna.

There is also a fundamental problem regarding how much of the muck is biodegradable. The most readily decomposed material in a water body is the organic matter produced by algae. Most muck sediments have an organic content less than 50%. For waters that do not receive substantial inputs of treated municipal wastewater, sediment accumulation on the bottom is on the order of millimeters per year. Even if 90% of the material were biodegradable, the thickness of the muck would only decrease by a few millimeters, making it very difficult to measure any loss. More importantly, some muck will remain even under the best decomposition scenario because not all the organic material will decompose. Thus, purchase of bacterial pellets or solutions for muck control is likely not the wisest possible investment.

Given that Hess Lake is naturally well-mixed and oxygenated by wind and wave action, it does not appear that aeration would have any beneficial impact in Hess Lake. A similar conclusion was reached in a previous study of Hess Lake (Edmunds Engineering, Inc. 1982). Aeration is not recommended as a lake management technique for Hess Lake.

SHORELANDS MANAGEMENT

In the first-ever National Lakes Assessment conducted by the U.S. Environmental Protection Agency, researchers found that lakes lacking natural shoreland habitat were three times more likely to be in poor biological condition (USEPA 2010). With the onset of development, many of the natural areas around Hess Lake were replaced by roof tops, roads, driveways and other impervious surfaces. As such, rainwater no longer infiltrates into the ground to the degree that it once did. Precipitation now has a greater potential to run off into the lake, carrying with it fertilizers, oil, gas and other pollutants. Currently, much of the Hess Lake shoreline is armored with seawalls, and very little natural shoreline exists around the lake. Seawalls are problematic in that they can deflect wave energy and increase the potential for shoreline scouring and erosion, both of which can increase turbidity in the lake. Successful long-term management of Hess Lake will require that lake residents preserve and restore as much natural shoreline as possible. Currently, the Brooks Township zoning ordinance requires properties bordering the lake to maintain a 25-foot vegetative buffer strip along the shoreline.

Properties around Hess Lake are served by on-site septic systems. The impact of septic systems can be expected to increase over time as more homes are converted from seasonal to year-round use and the limited capacity of area soils to bind septic pollutants is exceeded. Until such time as public sewer service is available for the Hess Lake area, lake residents should be vigilant in the management of their on-site septic systems. The Brooks Township septic system time-of-property-transfer ordinance is useful in promoting proper septic system maintenance (Brooks Township 2005).

As part of the management plan for Hess Lake, shoreland management guidelines should be created and distributed to all lake residents.

WHEELER DRAIN

Over the years, several projects have been proposed to reduce the impact of Wheeler Drain on Hess Lake. In 1982, a bypass pipe was proposed to convey flows from Wheeler Drain to a discharge point downstream of Brooks Lake (Edmunds Engineering, Inc. 1982). State regulators raised several concerns with this proposal and the project was never constructed. Another proposal to reduce nutrient loading from Wheeler Drain was to divert water from the drain to a sand filtration system that would remove phosphorus from the drain water (Progressive Architects Engineers Planners 1989). However, due to prohibitive costs and potential construction difficulties, the project was deemed infeasible.

In 1986, a sediment basin was constructed on the drain immediately upstream of the lake (Figure 23). In the mid-1990s, additional sediment basins were constructed, check dams were installed, streambanks were stabilized, and a number of conservation practices were implemented all designed to reduce the impact of Wheeler Drain on Hess Lake (FTC&H 1996). Maintenance of existing structural controls on Wheeler Drain is essential to optimizing their effectiveness.

Figure 23. Wheeler Drain sediment basin south of Hess Lake Drive.

Although several improvements have been installed, erosion along Wheeler Drain still occurs. Since the installation of sedimentation basins and other improvements, new stream assessment methods have emerged that focus on the stream “geomorphology,” that is, the shape of the stream and the way the stream interacts with the surrounding landscape. By assessing a stream’s geomorphology, more effective and sustainable erosion control methods can be devised. The Michigan Nonpoint Source Best Management Practices Manual (Michigan Department of Environmental Quality 2017) describes the assessment process:

> Channel erosion control should always begin with a stream channel evaluation using geomorphological methods, to determine if the erosion is a natural stream process, or if not, to identify the causes of the erosion.

> Unnatural or excessive stream channel erosion is not always obvious. Channel erosion that appears to be excessive could still be a natural process. The causes of channel erosion are often due to watershed-wide influences that must also be addressed for any channel restoration to be successful. Controls applied to natural erosion processes, or that fail to address the root cause of the erosion, can be a waste of money, be prone to failure, or cause additional channel instabilities in other parts of the stream.
>
> Stream instability is characterized by failure of a channel to maintain its pattern, dimension, and profile, resulting in either aggradation (deposition) or degradation (scouring). Localized channel instabilities have causes that are generally easily identified, such as channel misalignment, obstructions, improperly designed crossings, livestock access, or All-Terrain Vehicle access. Localized erosion is limited to a single site, or at most a small number of sites.
>
> Examples of systemic causes of instability include increases in runoff volume or rate due to urban development, channelization, loss of stream bank vegetation, or increases in sediment load from construction or farming. System-wide stream instability is manifested through numerous erosion sites distributed throughout a stream reach, or through dramatic, large-scale erosion resulting in significant channel widening or down-cutting, and downstream deposition.

In order to best address continuing erosion, Wheeler Drain should be assessed to further evaluate the causes of stream instability and to identify possible corrective actions.

Recommended Management Plan

Current and historical water quality data indicated the lake is nutrient-enriched, i.e., eutrophic. Drainage from the watershed is likely contributing to this nutrient-enriched condition. Hess Lake naturally supports abundant plant growth. However, for the past several years, rooted aquatic vegetation in the lake has been nearly non-existent and the lake is plagued by frequent blooms of blue-green algae. Turbidity caused by the algae growth, resuspension of bottom sediments, roiling activity by carp, and other factors limit submersed plant growth. Despite minimal growth of rooted plants, the plants that do occur in the lake are not native and are treated with herbicides to control their growth. The goals of the Hess Lake management plan are to improve water clarity, re-establish beneficial submersed plants, enhance the fishery, and reduce pollutant runoff from the watershed.

In order to improve conditions in Hess Lake, the following management plan is recommended:

- Aquatic Plant Control: Plant control activities in Hess Lake should focus primarily on the control of invasive and exotic plant species with the select use of systemic herbicides, where feasible. The use of copper-based algaecides to control algae growth should be limited or stopped.
- Re-establish submersed vegetation: Submersed aquatic vegetation should be re-established to stabilize bottom sediments, improve transparency, create valuable fish habitat, reduce the frequency of algae blooms, and help restore the natural ecological balance in Hess Lake. If native submersed plants re-establish and grow to nuisance densities, control should be limited to near-shore areas where plants pose an extreme nuisance condition.
- Lake Alum Treatment: To provide an opportunity for submersed aquatic plants to reestablish in the lake, an alum treatment should be conducted to bind phosphorus and temporarily reduce algae growth and improve water clarity.
- Fisheries Management: This management alternative will involve the physical netting and removal of carp from the lake and re-establishment of vegetative cover and habitat.
- Shorelands Management: To address water quality issues over the long term, a shorelands management program focused on preserving and restoring natural shoreline, minimizing impacts of sea walls, and septic system maintenance.
- Wheeler Drain: To reduce nutrient and sediment loading from Wheeler Drain, the upstream sediment basin should be inspected and cleaned annually to optimize removal of sediments and nutrients. In addition, Wheeler Drain should be assessed to identify causes of stream instability and possible corrective actions.

Project Financing

Lake improvements in Hess Lake are financed in accordance with Part 309 (Inland Lake Improvements) of the Natural Resources and Environmental Protection Act, PA 451 of 1994. Under provisions of the act, a special assessment district was established for Hess Lake that includes all properties within 500 feet of the lake. Assessment apportionment criteria for Hess Lake are outlined in Table 12.

TABLE 12
HESS LAKE SPECIAL ASSESSMENT APPORTIONMENT CRITERIA

Parcel Type	Assessment Rate (# of Units)
Waterfront	1.00
Back Lots	0.50
3rd Tier	0.25
Commercial	2.00

Costs for the recommended lake management plan for Hess Lake and approximate annual assessments are presented in Table 13. In order to determine if lake residents support proceeding with the recommended plan, the Hess Lake Improvement Board must hold a public hearing to receive public comment on the practicability (necessity) of the project. If public support exists for the project, the lake board may resolve to proceed with the recommended management plan and hold a separate hearing on the special assessment roll for the project.

TABLE 13
HESS LAKE MANAGEMENT PLAN PROPOSED BUDGET (2021 – 2025)

Plan Component	Annual Cost	Approximate Annual Unit Assessment
Aquatic Plant Control	$64,500	$135
Lake Alum Treatment	$150,000	$313
Fisheries Management	$6,000	$13
Watershed Management:	$6,000	$13
• Wheeler Drain Maintenance and Stream Stability Assessment		
• Shorelands Management		
Administration and Contingency	$20,000	$42
Total	$246,500	$516

Annual plant control activities in Hess Lake are proposed to be coordinated under the direction of the lake board's environmental consultant. The consultant would be responsible for preparing contract documents for the plant control program, conducting GPS-guided surveys of the lake to identify treatment areas, and conducting follow-up surveys to evaluate treatment impacts. The consultant would report to the lake board and maintain a written record of the timing, scope and cost of plant control activities. The consultant would conduct an annual whole-lake vegetation survey to evaluate the type and distribution of plants and prepare an annual report of findings. The $64,500 earmarked for aquatic plant control would include $12,000 for professional services, annual monitoring of aquatic plants and plant control activities.

The alum treatment would be financed over five years with an annual assumed interest rate of 6%. The alum treatment cost includes the preparation of technical specifications and bid documents for the project and the alum treatment application (estimated at $525,000), financing costs ($100,000), and annual monitoring and reporting required by state permit conditions ($125,000).

Fisheries management would focus on the netting and removal of carp from Hess Lake during the spring spawning period annually over the five-year duration of the project.

Watershed management would include regular inspections and clean-outs of the Wheeler Drain sediment basin, a drain stability analysis, and an information and education program to disseminate information on shorelands management practices to lake residents. Costs associated with clean-outs of the sediment basin would be assessed to the Wheeler Drain Drainage District.

Project administration and contingency would include costs related to public hearing proceedings, permitting fees, legal, postage, mailings, meetings, copies, general administration and contingent expenses.

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Appendix A
Study Methods

PHYSICAL

The Hess Lake shoreline was digitized from DigitalGlobe 2018 aerial orthodigital photography using ArcMap software. In September of 2019, a GPS-guided hydro-acoustic survey was conducted at 100-foot intervals across Hess Lake. Hydro-acoustic data were uploaded to C-MAP BioBase for a kriging analysis to create interpolated mapping. Lake volume was calculated using the conical frustrum method (Wetzel and Likens 2010). Lake volume was divided by surface area to calculate mean depth. Shoreline development factor was calculated from shoreline length and surface area (Wetzel and Likens 2010). Shallowness ratio was calculated from the area less than five feet in depth divided by the total lake area (Wagner 1991).

CHEMICAL

Water quality samples were collected in the spring and summer of 2018 from the surface to the bottom at 5-foot intervals over the three deep basins of Hess Lake (Figure 13). Temperature was measured using a YSI Model 550A probe. Samples were analyzed for dissolved oxygen, total phosphorus, pH, total alkalinity, total suspended solids, and chloride. Dissolved oxygen samples were fixed in the field and then transported to Progressive AE for analysis using the modified Winkler method (Standard Methods procedure 4500-O C). pH was measured in the field using an Oakton pH2+ EcoTestr. Total alkalinity, total phosphorus, total suspended solids, and chloride samples were placed on ice and transported to respective laboratories for analysis. Total alkalinity was titrated at Progressive AE using Standard Methods procedure 2320 B. Total phosphorus, total suspended solids, and chloride were analyzed at Prein and Newhof[1] using Standard Methods procedure 4500-P E and A2540D, and EPA method 300.0, respectively. Secchi transparency was measured and a composite chlorophyll-*a* sample was collected from the surface to a depth equal to twice the Secchi transparency. Chlorophyll-*a* samples were analyzed using Standard Methods procedure 10200H by Prein and Newhof.

Samples were collected and discharge was measured in spring and late summer in the six major tributaries to Hess Lake, the west tributary, Alger Creek, south tributary, Wheeler Drain, southeast tributary, and the east tributary (Sites 4 through 9, respectively; Figure 13). Tributary stream discharge was estimated using the U.S. Geological Survey midsection method (Buchanan and Somers 1969). Stream velocity was measured with a Pygmy Gurley flow meter. Samples were analyzed for total phosphorus and total suspended solids at Prein and Newhof Laboratory.

BIOLOGICAL

Aquatic plant species were surveyed at GPS reference points at 300-foot intervals along the shoreline of Hess Lake (Figure A1; Michigan Department of Environmental Quality (MDEQ) 2005). At each reference point, plant densities were estimated as follows: (a) = found: one or two plants of a species found at a site, equivalent to less than 2% of the total site surface area; (b) = sparse: scattered distribution of a species at a site, equivalent to between 2% and 20% of the total site surface area; (c) = common: common distribution of a species where the species is easily found at a site, equivalent to between 21% and 60% of the total site surface area; (d) = dense: dense distribution of a species where the species is present in considerable quantities throughout a site, equivalent to greater than 60% of the total site surface area. Data was compiled and tabulated to evaluate the relative abundance of all plant species in Hess Lake.

1 Prein and Newhof, 3260 Evergreen Drive, NE, Grand Rapids, MI 49525.

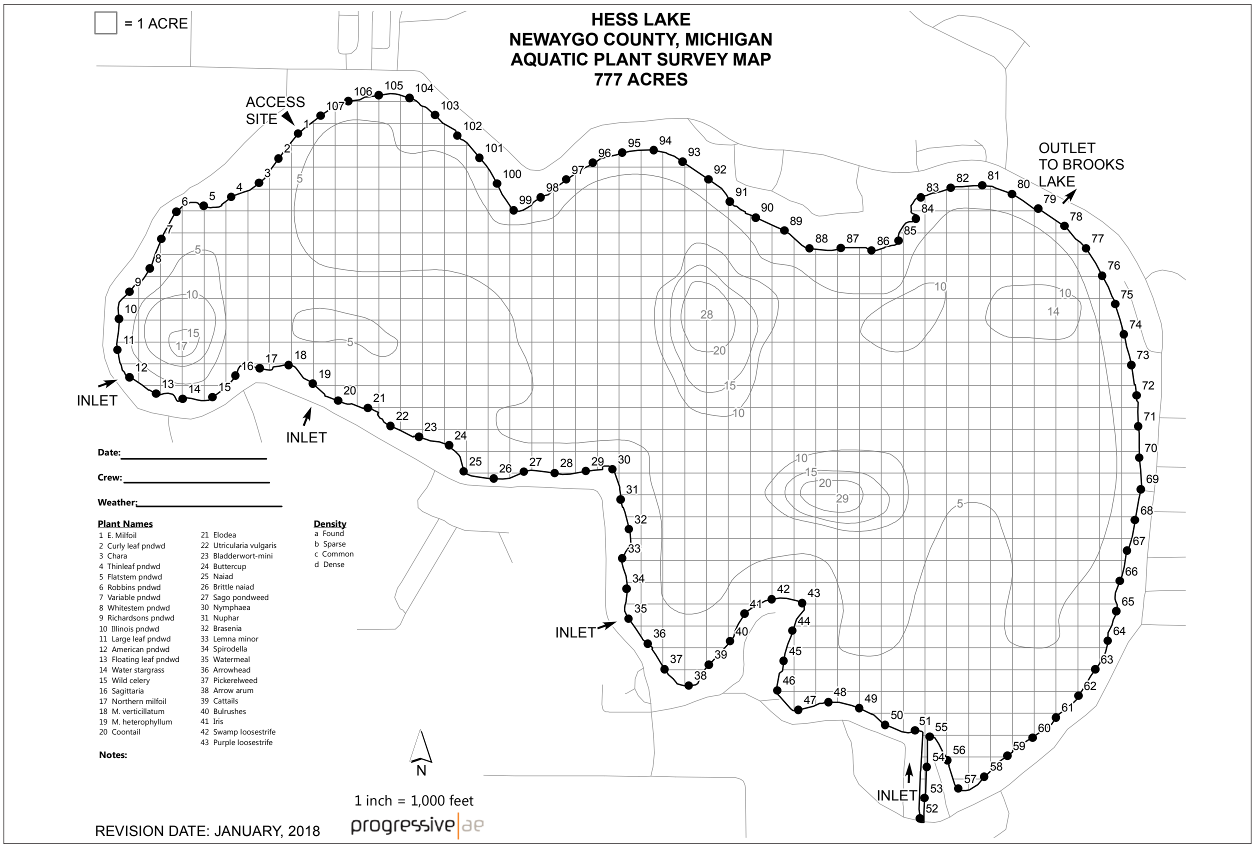

Figure A1. Hess Lake aquatic plant survey map.

Appendix B

Hess Lake Historical Water Quality Data

TABLE B1
HESS LAKE MDEQ DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temper-ature (°F)	Dissolv. Oxygen (mg/L)[1]	pH (S.U.)[2]	Total Alkalinity (mg/L as $CaCO_3$)[3]	Total Phosphorus (µg/L)[4]	Chloride (mg/L)[1]
15-Sep-74	0	68	8.2	9.1	122	20	12
15-Sep-74	28	66	7.2	8.8	123	20	12
16-Apr-80	0	41	12.3	8.7	132	30	
16-Apr-80	15	41	12.2	8.7	132	32	
16-Apr-80	24	41	12.2	8.7	130	31	
17-Apr-85	0	50	12.1	8.6	123	20	10.3
17-Apr-85	15	50	9.2	8.0	126	27	10.3
17-Apr-85	26	46	9.2	8.0	125	5	10.3
9-Sep-85	0	75	8.5	9.5		21	
9-Sep-85	10	75	8.6	9.5			
9-Sep-85	15	71	7.8	9.5		18	
9-Sep-85	20	70	2.0	8.8			
9-Sep-85	24	69	0.9	8.7		22	
14-Sep-88	0	68	9.9	9.0		58	
14-Sep-88	15	66	9.6	9.0		84	
14-Sep-88	22	65	4.0	8.6			
14-Sep-88	24	65	3.4	8.2		82	
14-Sep-88	26	65					

1 mg/L = milligrams per liter = parts per million.
2 S.U. = standard units.
3 mg/L as $CaCO_3$ = milligrams per liter as calcium carbonate.
4 µg/L = micrograms per liter = parts per billion.

TABLE B2
HESS LAKE MDEQ/USGS DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temper-ature (°F)	Dissolv. Oxygen (mg/L)[1]	pH (S.U.)[2]	Total Alkalinity (mg/L as $CaCO_3$)[3]	Total Phosphorus (µg/L)[4]	Chloride (mg/L)[1]
12-Apr-06	1	53	11.0	8.3			
12-Apr-06	3	53	11.0	8.3		52	
12-Apr-06	5	52	11.1	8.3			
12-Apr-06	7	52	11.2	8.3			
12-Apr-06	9	52	11.0	8.3			
12-Apr-06	11	52	11.1	8.3			
12-Apr-06	12				116	34	14
12-Apr-06	13	52	11.1	8.3			
12-Apr-06	15	52	11.1	8.3			
12-Apr-06	17	52	11.1	8.3			
12-Apr-06	19	52	11.1	8.3			
12-Apr-06	21	52	11.1	8.3			
12-Apr-06	22					44	
12-Apr-06	23	52	11.0	8.3			
12-Apr-06	25	51	8.4	7.8			
9-Aug-06	2	79	8.5	8.0			
9-Aug-06	3					38	
9-Aug-06	4	79	8.2	8.1			
9-Aug-06	6	79	8.3	8.1			
9-Aug-06	8	78	8.2	8.1			
9-Aug-06	10	78	7.7	8.0			
9-Aug-06	12	78	7.7	8.0		39	
9-Aug-06	14	78	6.4	7.8			
9-Aug-06	16	77	3.8	7.6			
9-Aug-06	18	74	1.2	7.2			
9-Aug-06	20	72	0.7	6.9			
9-Aug-06	21					56	
9-Aug-06	22	69	0.6	6.6			

1 mg/L = milligrams per liter = parts per million.
2 S.U. = standard units.
3 mg/L as $CaCO_3$ = milligrams per liter as calcium carbonate.
4 µg/L = micrograms per liter = parts per billion.

TABLE B3
HESS LAKE MDEQ/USGS SURFACE WATER QUALITY DATA

Date	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
15-Sep-74	7.1	4.2
16-Apr-80	17	3.5
17-Apr-84	11	
17-Apr-85		5.5
9-Sep-85	4.4	6.5
14-Sep-88	28	1.5
12-Apr-06	19	3.6
9-Aug-06	9.1	2.6

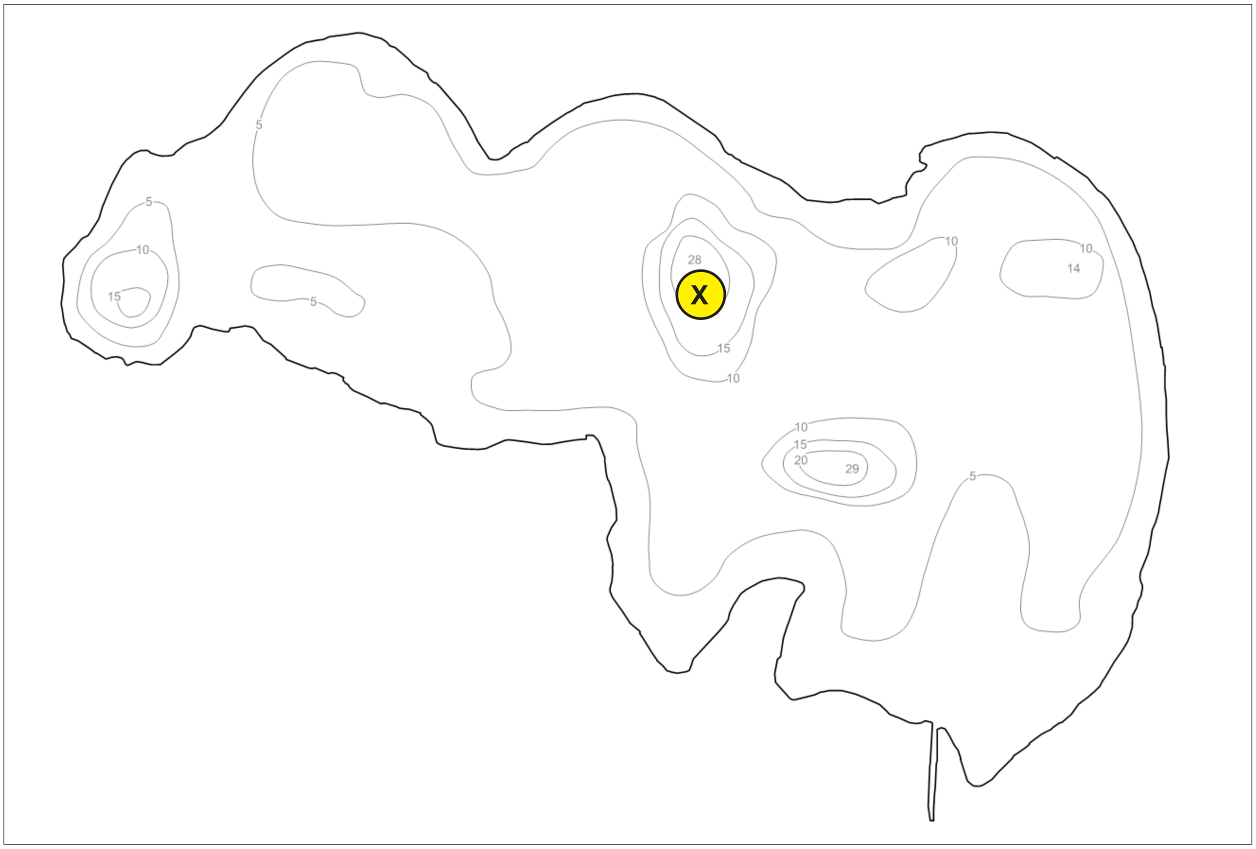

Figure B1. Sampling location map, U.S. Geological Survey and Michigan Department of Environmental Quality.

1 µg/L = micrograms per liter = parts per billion.

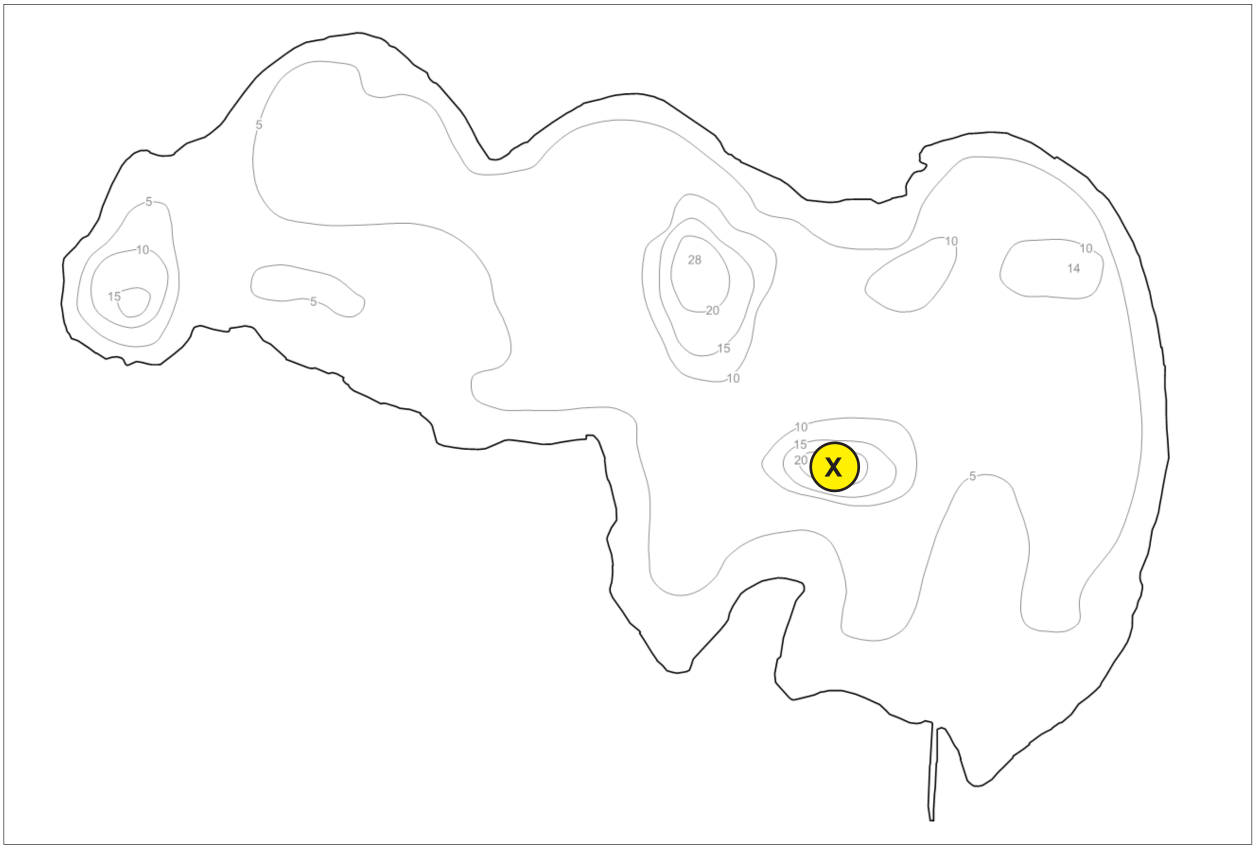

Figure B2. Sampling location map, Cooperative Lakes Monitoring Program.

TABLE B4
HESS LAKE COOPERATIVE LAKES MONITORING PROGRAM
SUMMARY STATISTICS (1980-2010)

	Total Phosphorus (µg/L)[1]	Chlorophyll-a (µg/L)[1]	Secchi Transparency (feet)
Mean	38.1	11.3	3.3
Standard deviation	7.7	7.3	1.9
Median	38.0	9.5	2.5
Minimum	27.0	2.6	1.5
Maximum	54.0	35.0	10.5
Number of samples	19	48	177

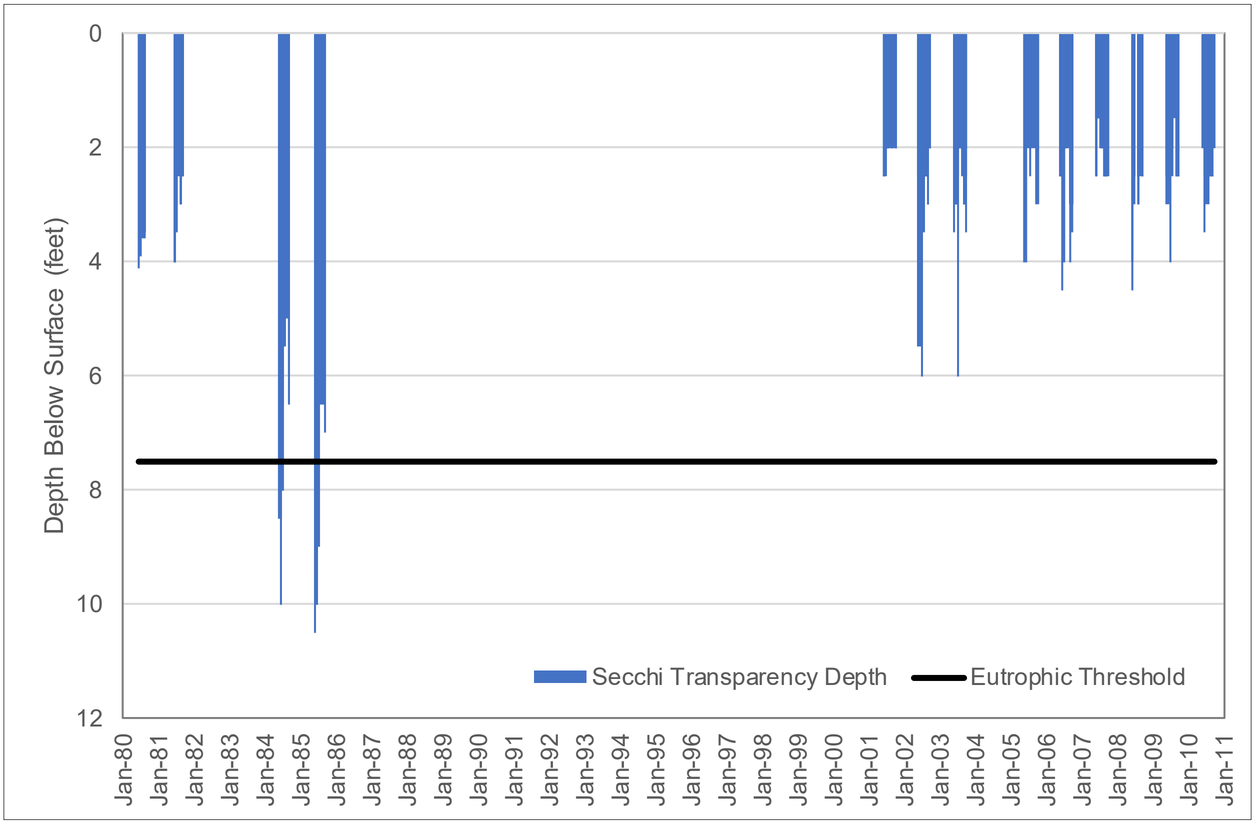

Figure B3. Hess Lake Cooperative Lakes Monitoring Program Secchi transparency, 1980-2010.

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Misc, Wheeler Sediment Basin Cleanouts cost, Hess Lake Depth Map.

Hess Lake Tributaries map.