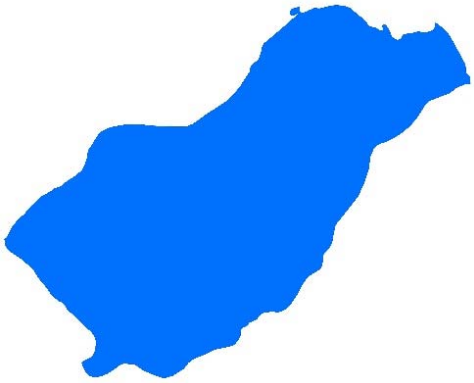
Moosehead

09-0041-00 Carlton County



Moosehead is located within the city limits of Moose Lake, MN in Carlton County. It is a shallow, oval lake covering 279 acres (Table 1).

Moosehead has three inlets and one outlet, which classify it as a drainage lake. Water enters Moosehead from the Moose Horn River and Portage River in the northeast.

Water quality data have been collected on Moosehead from 2002-2003, 2012-2017 (Tables 2 & 3). These data show that the lake is eutrophic (TSI = 55) which is characteristic of a shallow lake with abundant aquatic plants and algae, and bass fisheries.

Table 1. Moosehead location and key physical characteristics.

Location Data

MN Lake ID:	**09-0041-00**
County:	**Carlton**
Ecoregion:	**Northern Lakes and Forests**
Major Watershed:	**Kettle River**
Latitude/Longitude:	**46.446078, -92.767696**
Invasive Species:	**None as of 2018**

Physical Characteristics

Surface area (acres):	**279.24**
Littoral area (acres):	**261**
% Littoral area:	**93.5%**
Max depth (ft), (m):	**18, 5.5**
Inlets:	**3**
Outlets:	**1**
Public Accesses:	**1**

Table 2. Availability of primary data types for Moosehead.

Data Availability

Transparency data	**Fair, 8 years of data with one large gap**
Chemical data	**Good**
Inlet/Outlet data	**Some data available.**
Recommendations	**For recommendations refer to page 15.**

Lake Map

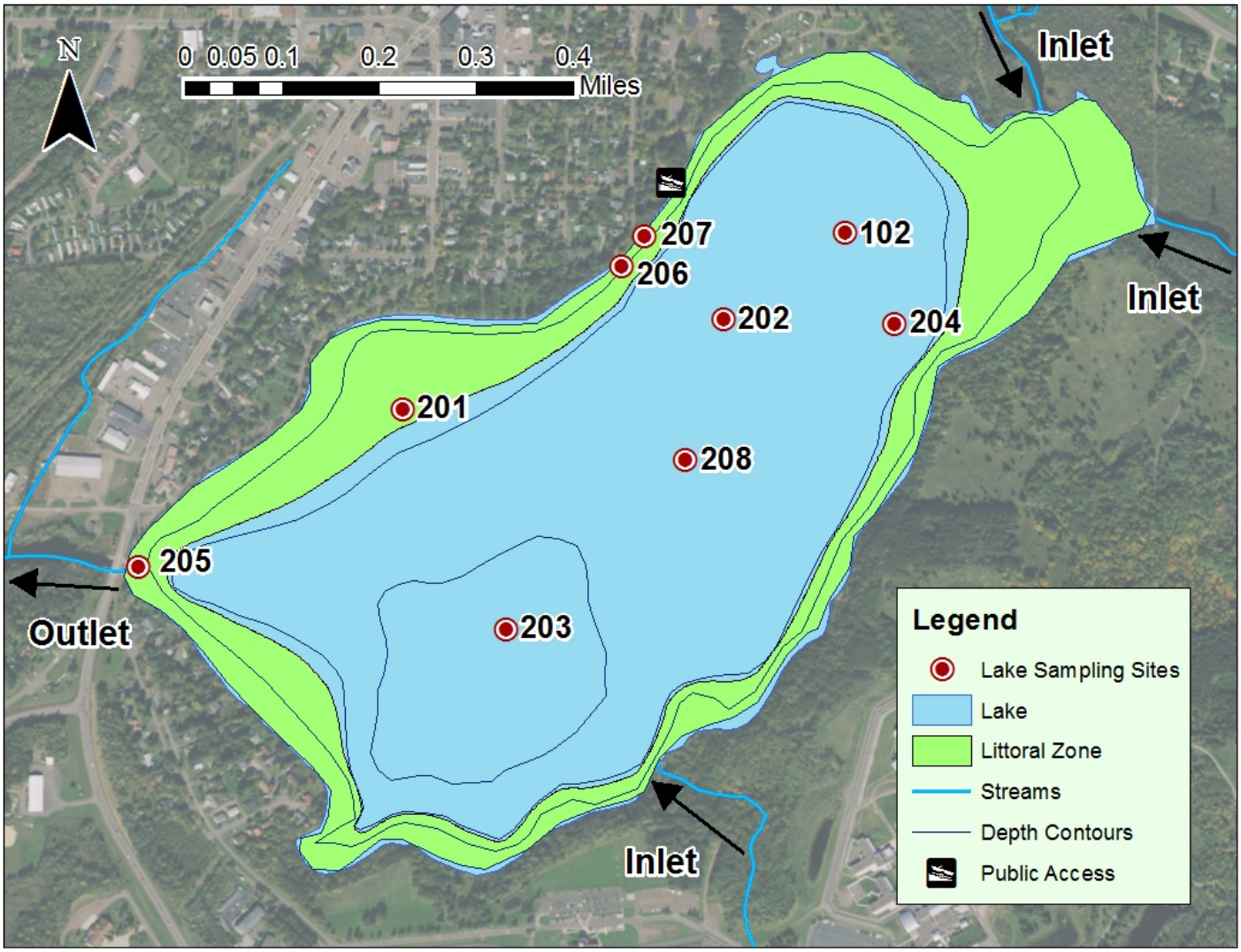


Figure 1. Map of Moosehead Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic plants to grow.

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), Clean Water Legacy Surface Water Monitoring (CWL), Lake Assessment Program (LAP).

Lake Site	Depth (ft)	Monitoring Programs
203* Primary	18	CLMP: 1977, 1986, 2002-2006, 2012-2015; CWL: 2012, 2016; LAP: 2003
202	10	CLMP:1977, 1986, 2002-2006, 2012-2015; CWL: 2012, 2016
102	10	LAP: 2003; CWL: 2012, 2016
201	5	CLMP; 1977, 1986, 2002-2006, 2012-2015
204	10	CLMP; 2002-2003
205, 206, 207, 208	10	CWL: 2012

Average Water Quality Statistics & Comparisons

The information below describes available chemical data for Moosehead through 2017 (Table 4). Data for total phosphorus, chlorophyll *a*, and Secchi depth are from the primary site 203.

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The Minnesota Pollution Control Agency (MPCA) has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion[1] (Table 4). Moosehead is in the Northern Lakes and Forests Ecoregion (Figure 2).

The MPCA has developed Impaired Waters Standards for lakes in each ecoregion to determine if a lake is impaired for excess phosphorus/eutrophication (Table 4). Lakes that are over the impaired waters standards are placed on the state's Impaired Waters List[2].

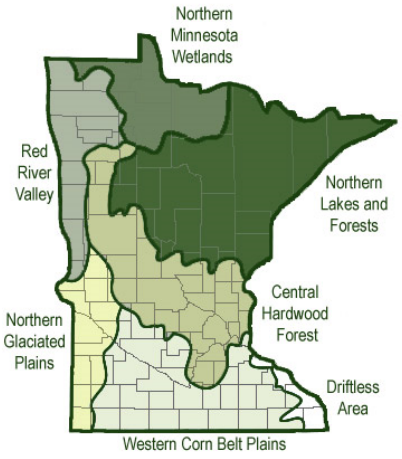


Figure 2. Minnesota ecoregions.

Table 4. Water quality means compared to ecoregion ranges and impaired waters standard.

Parameter	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	33.7	14 – 27	> 30	Results are above the expected range for the Northern Lakes and Forests Ecoregion and the average for the lake is over the impaired waters standard.
[3]Chlorophyll *a* (ug/L)	10.5	4 – 10	> 9	
Chlorophyll *a* max (ug/L)	23.8	< 15		
Secchi depth (ft)	4.4	8 – 15	< 6.5	
Dissolved oxygen	*See page 8*			Dissolved oxygen depth profiles show that the lake mixes periodically in summer.
Total Kjeldahl Nitrogen (mg/L)	0.84	<0.4 – 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	44.2	40 – 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	NA	10 – 35		No data available.
pH	7.3	7.2 – 8.3		Within the expected range for the ecoregion. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water.
Chloride (mg/L)	5.15	0.6 – 1.2		Above the expected range for the ecoregion, but still considered low level.
Total Suspended Solids (mg/L)	3.5	<1 – 2		Above the expected range for the ecoregion, but still considered low level.
Specific Conductance (umhos/cm)	93.4	50 – 250		Within the expected range for the ecoregion.
TN:TP Ratio	40:1	25:1 - 35:1		Shows the lake is phosphorus limited.

[1]The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes: https://www.pca.state.mn.us/quick-links/eda-guide-typical-minnesota-water-quality-conditions
[2]For further information regarding the Impaired Waters Assessment program, refer to http://www.pca.state.mn.us/water/tmdl/index.html
[3]Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

Water Quality Characteristics - Historical Means and Ranges

Table 5. Water quality means and ranges for primary sites.

Parameters	Primary Site 203	Site 202	Site 201	Site 102
Total Phosphorus Mean (ug/L):	33.7	-	-	40.4
Total Phosphorus Min:	18.0			29
Total Phosphorus Max:	50.0			51
Number of Observations:	16			5
Chlorophyll *a* Mean (ug/L):	10.5	-	-	9.8
Chlorophyll-a Min:	4.97			5.1
Chlorophyll-a Max:	23.8			14.2
Number of Observations:	14			4
Secchi Depth Mean (ft):	4.4	4.7	4.6	4.2
Secchi Depth Min:	2.6	2.5	2.5	3.9
Secchi Depth Max:	6.2	6.0	7.5	4.6
Number of Observations:	51	36	38	3

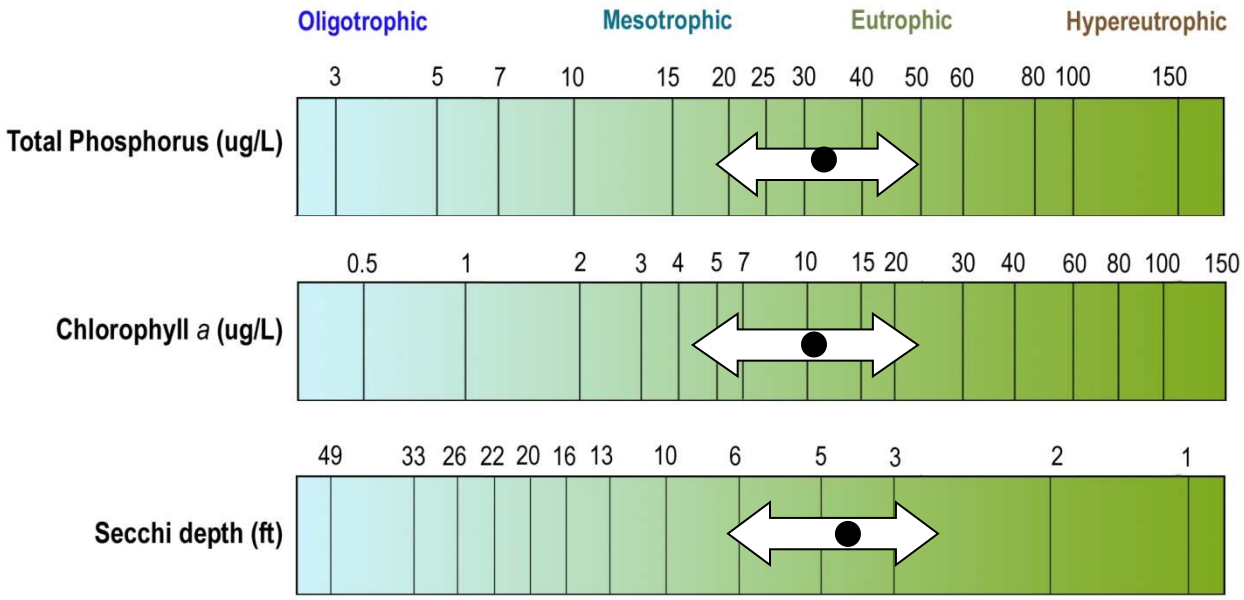


Figure 3. Moosehead Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 203). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. EPA 440/5-88-002)

Transparency (Secchi Depth)

Transparency is how easily light can pass through a substance. In lakes it is how deep sunlight penetrates through the water. Plants and algae need sunlight to grow, so they are only able to grow in areas of lakes where the sun penetrates. Water transparency depends on the number of particles in the water. An increase in particulates results in a decrease in transparency. The transparency varies year to year due to changes in weather, precipitation, lake use, flooding, temperature, lake levels, etc.

The annual mean transparency in Moosehead ranges from 3.5 to 5.5 feet (Figure 3). The annual means hover fairly close to the long-term mean. For trend analysis, see page 10. Transparency monitoring should be continued annually at site 203 in order to track water quality changes.

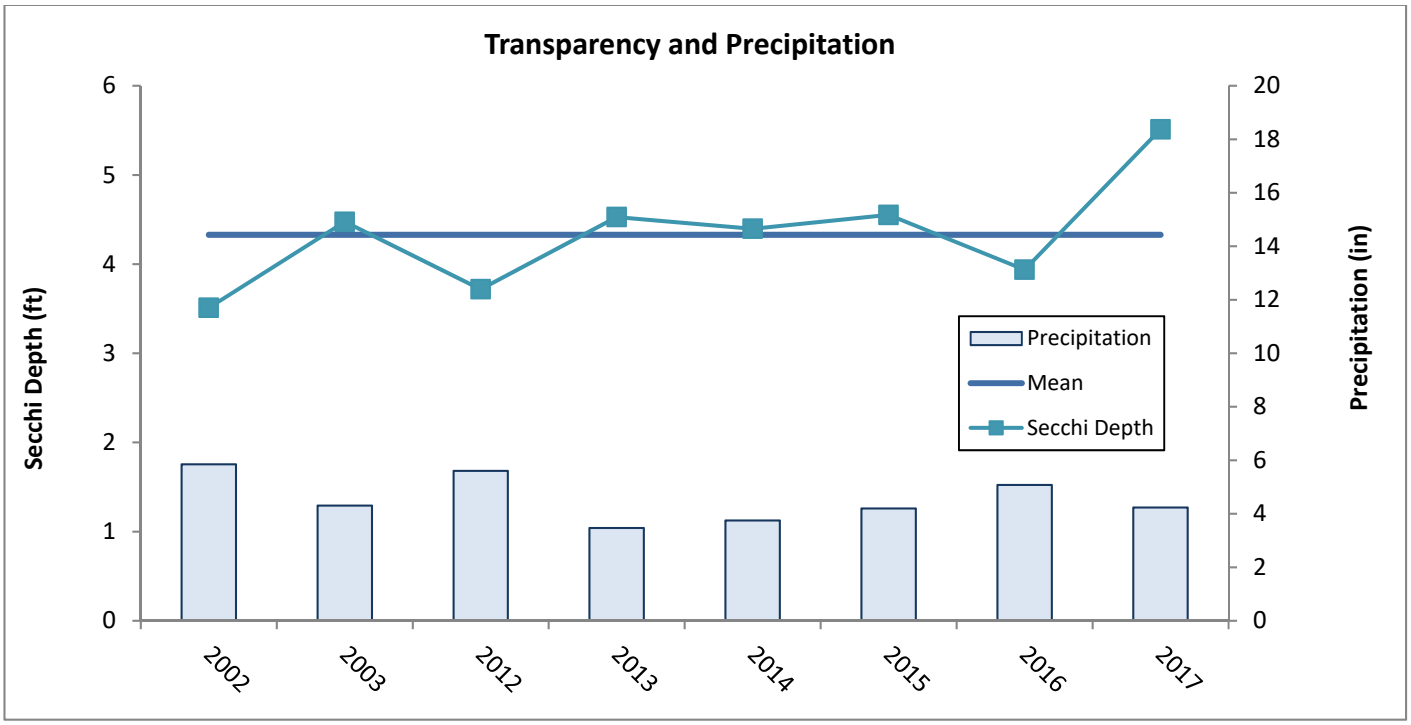


Figure 4. Annual mean transparency compared to long-term mean transparency

Moosehead transparency ranges from 2.6 to 6.2 ft at the primary site (Table 5)). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Moosehead transparency is high in May and June, and then declines through August. The transparency then rebounds in October after fall turnover. This transparency dynamic is typical of a Minnesota lake. The dynamics have to do with algae and zooplankton population dynamics, and lake turnover.

It is important for lake residents to understand the seasonal transparency dynamics in their lake so that they are not worried about why their transparency is lower in August than it is in June. It is typical for a lake to vary in transparency throughout the summer.

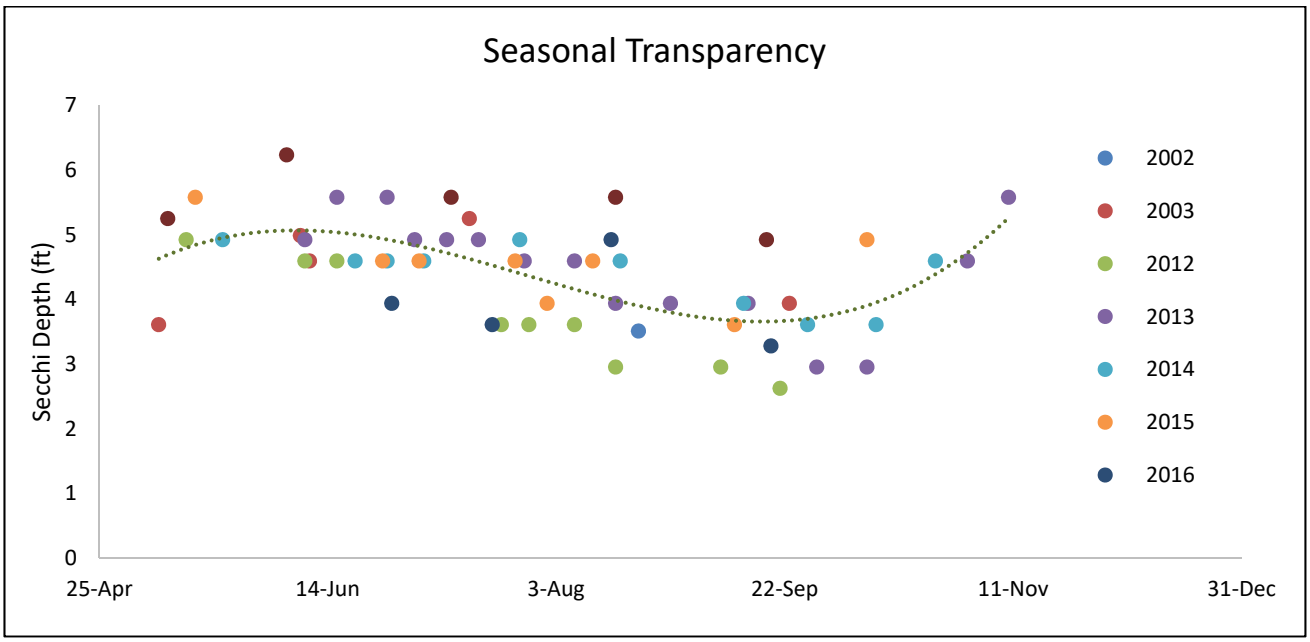


Figure 5. Seasonal transparency dynamics and year to year comparison (Primary Site 203). The black line represents the pattern in the data.

User Perceptions

When volunteers collect Secchi depth readings, they record their perceptions of the water based on the physical appearance and the recreational suitability. These perceptions can be compared to water quality parameters to see how the lake "user" would experience the lake at that time. Looking at transparency data, as the Secchi depth decreases the perception of the lake's physical appearance and recreational suitability decreases (Figures 6-7).

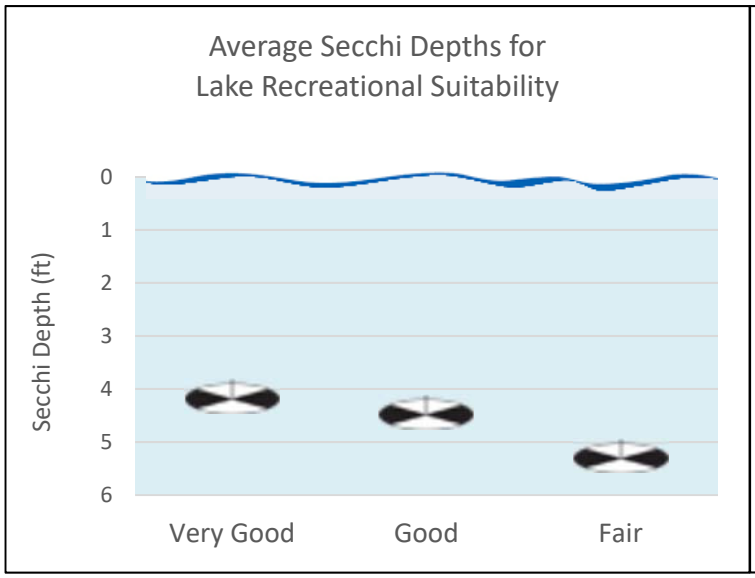


Figure 6. Average Secchi depth (ft) for each lake recreational suitability rating.

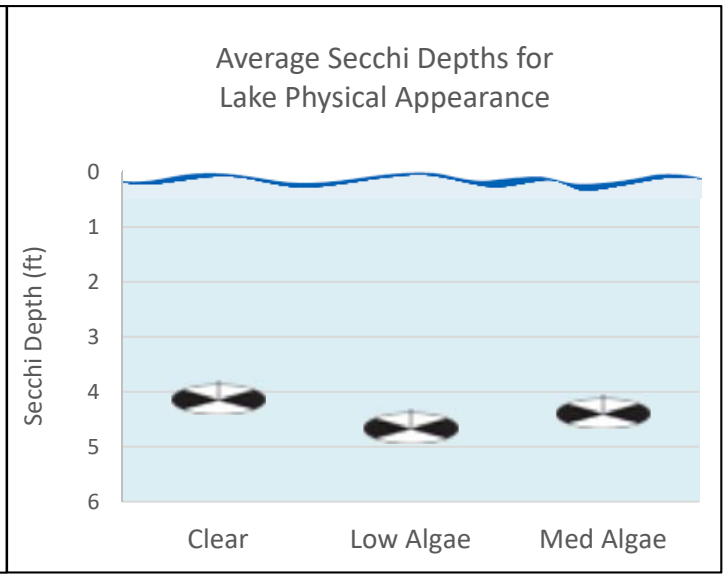


Figure 7. Average Secchi depth for each lake physical appearance rating.

Algae

Chlorophyll *a* is the pigment that makes plants and algae green. Chlorophyll *a* is tested in lakes to determine the algae concentration or how "green" the water is.

Chlorophyll *a* concentrations greater than 10 ug/L are perceived as a mild algae bloom, while concentrations greater than 20 ug/L are perceived as a nuisance.

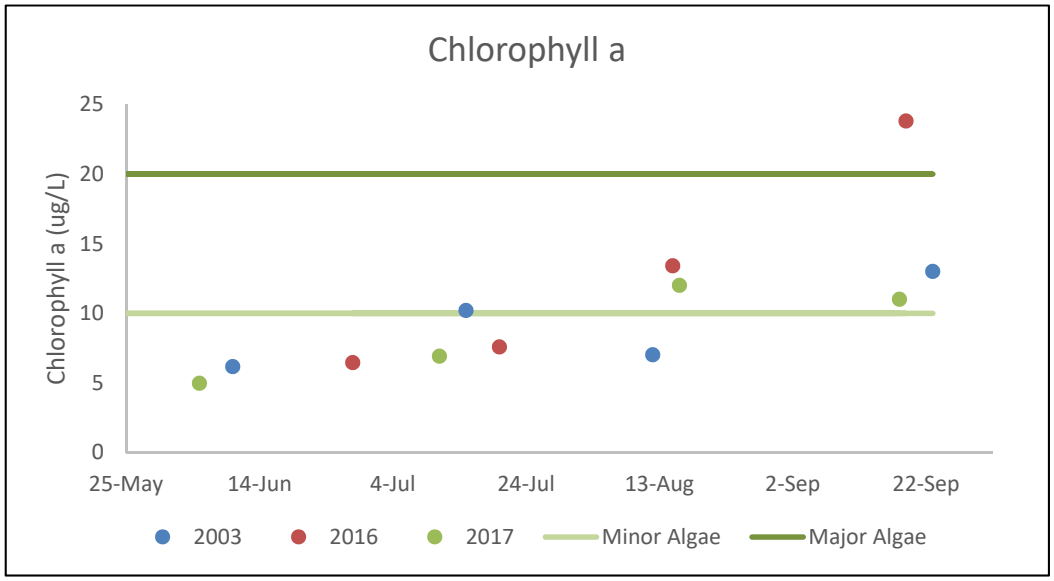


Figure 8. Chlorophyll a concentrations (ug/L) for Moosehead Lake at site 203.

Chlorophyll *a* was evaluated in Moosehead at site 203 in 2003, 2016-2017 (Figure 8). Chlorophyll *a* concentrations went above 10 ug/L in all three years, indicating minor algae blooms.

Phosphorus

Moosehead is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus.

Total phosphorus was evaluated in Moosehead in 2003, 2016-2017. The data are highly variable, which is common for a shallow lake. Most of the data points fall into the mesotrophic/eutrophic border (Figure 7).

Phosphorus should continue to be monitored to track any future changes in water quality.

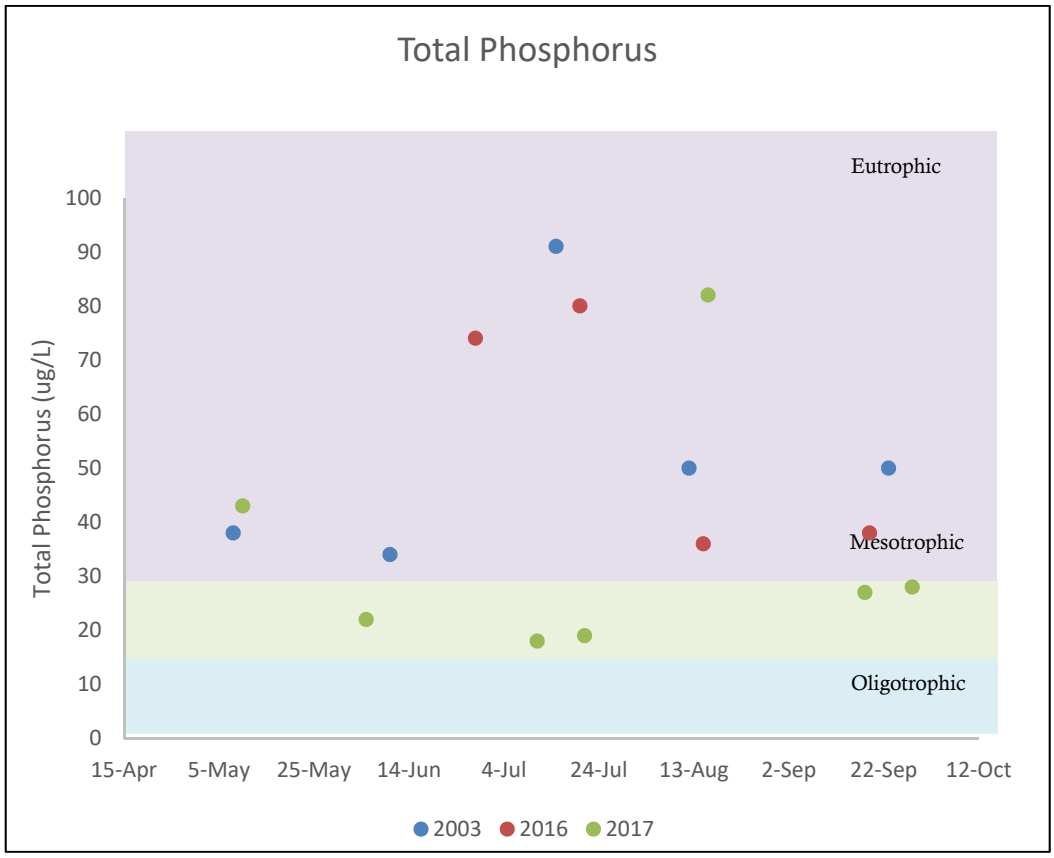
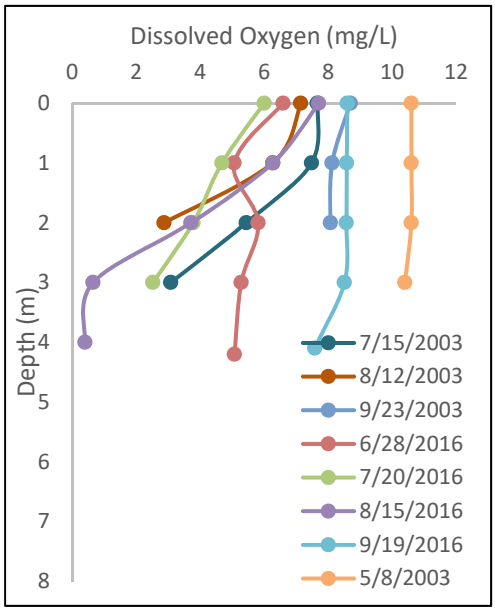


Figure 9. Historical total phosphorus concentrations (ug/L) for Moosehead Lake site 203.

Oxygen



Dissolved Oxygen (DO) is the amount of oxygen dissolved in lake water. Oxygen is necessary for all living organisms to survive except for some bacteria. Living organisms breathe in oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fisheries.

Moosehead is a shallow lake, with a maximum depth of 18 feet. Dissolved oxygen profiles from data collected in 2003 and 2016 at site 203 show periodic mixing (Figure 10). In a shallow lake, the water column never completely stratifies. Any windy day can mix up the water column causing phosphorus from the anoxic lake bottom to re-suspend into the water. This phenomenon is known as internal loading.

Figure 10. Representative dissolved oxygen profiles from 2003 and 2016 in Moosehead Lake.

Trophic State Index (TSI)

TSI is a standard measure or means for calculating the trophic status or productivity of a lake. More specifically, it is the total weight of living algae (algae biomass) in a waterbody at a specific location and time. Three variables, chlorophyll a, Secchi depth, and total phosphorus, independently estimate algal biomass.

If all three TSI numbers are within a few points of each other, they are strongly related. If they are different, there are other dynamics influencing the lake's productivity, and TSI mean should not be reported for the lake. Moosehead falls into the mesotrophic range (Tables 6, 7).

Table 6. Trophic State Index for Moosehead.

Trophic State Index	
TSI Phosphorus	**55**
TSI Chlorophyll-a	**55**
TSI Secchi	**56**
TSI Mean	**55**
Trophic State:	**Eutrophic**

Numbers represent the mean TSI for each parameter.

Table 7. Trophic state index attributes and their corresponding fisheries and recreation characteristics.

Moosehead

Eutrophication

TSI	Attributes	Fisheries & Recreation
<30	**Oligotrophy:** Clear water, oxygen throughout the year at the bottom of the lake, deep cold water.	Trout fisheries dominate.
30-40	Bottom may become anoxic (no oxygen).	Trout fisheries in deep lakes only. Walleye, Cisco present.
40-50	**Mesotrophy:** Water moderately clear most of the summer. May be "greener" in late summer.	No oxygen at the bottom of the lake results in loss of trout. Walleye may predominate.
50-60	**Eutrophy:** Algae and aquatic plant problems possible. "Green" water most of the year.	Warm-water fisheries only. Bass may dominate.
60-70	Blue-green algae dominate, algal scums and aquatic plant problems.	Dense algae and aquatic plants. Low water clarity may discourage swimming and boating.
70-80	**Hypereutrophy:** Dense algae and aquatic plants.	Water is not suitable for recreation.
>80	Algal scums, few aquatic plants.	Rough fish (carp) dominate; summer fish kills possible.

Source: Carlson, R.E. 1997. A trophic state index for lakes. *Limnology and Oceanography*. 22:361-369.

Trend Analysis

For detecting trends, a minimum of 8-10 years of data with 4 or more readings per season are recommended. Minimum confidence accepted by the MPCA is 90%. This means that there is a 90% chance that the data are showing a true trend and a 10% chance that the trend is a random result of the data. Only short-term trends can be determined with just a few years of data, because there can be different wet years and dry years, water levels, weather, etc, that affect the water quality naturally.

Moosehead had enough data to perform a trend analysis on transparency (Table 8). The data was analyzed using the Mann Kendall Trend Analysis.

Table 8. Trend analysis for Moosehead.

Lake Site	Parameter	Date Range	Trend	Probability
203	Total Phosphorus	2003, 2016-2017	Insufficient data	-
203	Chlorophyll *a*	2003, 2016-2017	Insufficient data	-
203	Transparency	2012-2017	Improving	80%

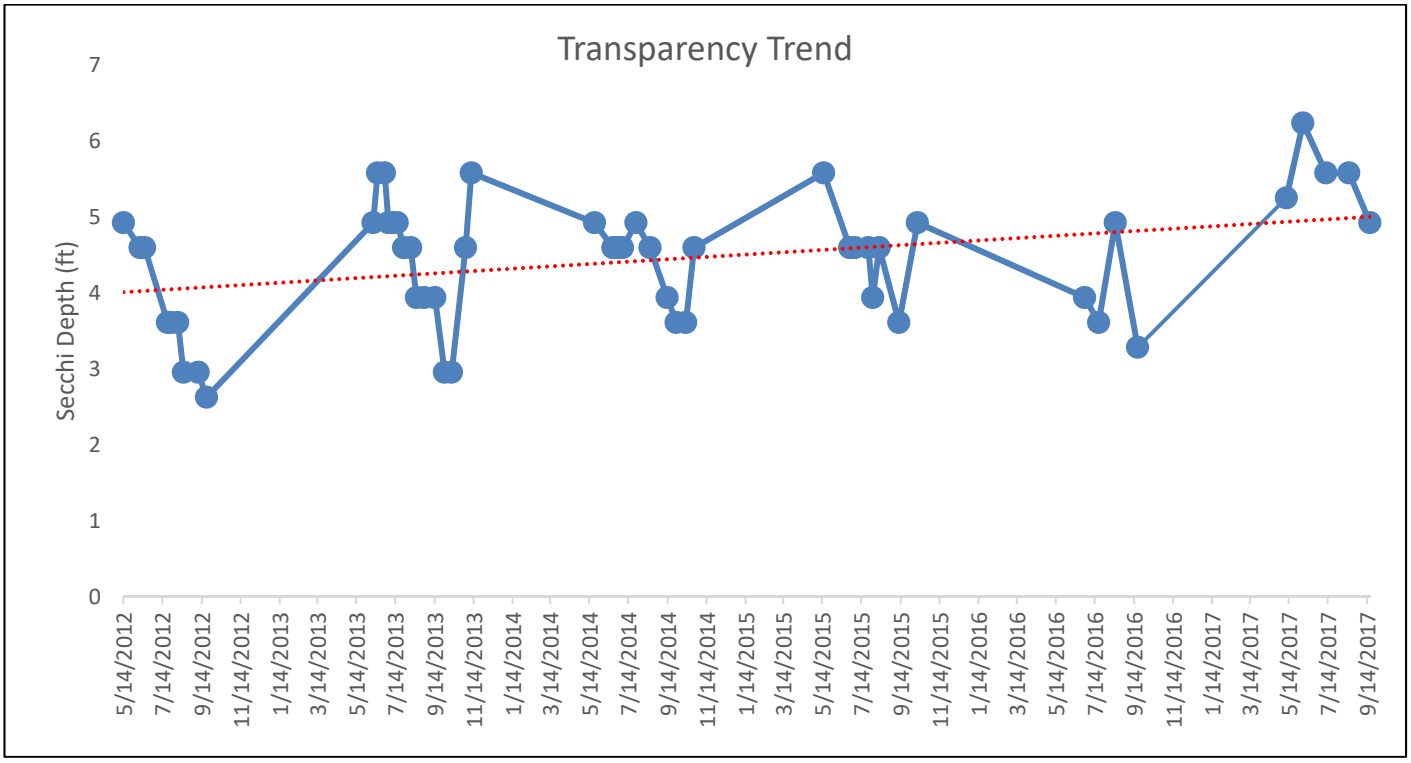


Figure 11. Transparency (feet) trend for site 203 from 2002-2003, 2012-2017.

Moosehead shows weak evidence of an improving transparency trend (Figure 11). Since 2012, the clarity maximums getting higher as well. Transparency monitoring should continue so that this trend can be tracked in future years.

Lakeshed

Understanding a lakeshed requires an understanding of basic hydrology. A watershed is defined as all land and water surface area that contribute excess water to a defined point. The MN DNR has delineated three basic scales of watersheds (from large to small): 1) basins, 2) major watersheds, and 3) minor watersheds.

The Kettle River Watershed is one of the watersheds that make up the St. Croix River Basin, which drains north to Hudson's Bay (Figure 12). Moosehead is located in minor watershed 35022 (Figure 12)

The MN DNR also has evaluated catchments for each individual lake with more than 100 acres surface area. These lakesheds (catchments) are the "building blocks" for the larger scale watersheds. Moosehead falls within lakeshed 35022 (Figure 12). Though very useful for displaying the land and water that contribute directly to a lake, lakesheds are not always true watersheds because they may not show the water flowing into a lake from upstream streams or rivers. While some lakes may have only one or two upstream lakesheds draining into them, others may be connected to a large number of lakesheds, reflecting a larger drainage area via stream or river networks. For further discussion of Moosehead 's watershed, containing all the lakesheds upstream of the Moosehead lakeshed, see page 11. The data interpretation of the Moosehead lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Moosehead.

In an effort to prioritize protection and restoration efforts of fishery lakes, the MN DNR has developed a ranking system by separating lakes into two categories, those needing protection and those needing restoration. Modeling by the DNR Fisheries Research Unit suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes that have watershed with disturbance greater than 25%. Therefore, lakes with watersheds that have less than 25% disturbance need protection and lakes with more than 25% disturbance need restoration (Table 9). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land, public water, wetlands, or conservation easement.

Table 9. Suggested approaches for watershed protection and restoration of DNR-managed fish lakes in Minnesota.

Watershed Disturbance (%)	Watershed Protected (%)	Management Type	Comments
< 25%	> 75%	Vigilance	Sufficiently protected -- Water quality supports healthy and diverse native fish communities. Keep public lands protected.
	< 75%	Protection	Excellent candidates for protection -- Water quality can be maintained in a range that supports healthy and diverse native fish communities. Disturbed lands should be limited to less than 25%.
25-60%	n/a	Full Restoration	Realistic chance for full restoration of water quality and improve quality of fish communities. Disturbed land percentage should be reduced and BMPs implemented.
> 60%	n/a	Partial Restoration	Restoration will be very expensive and probably will not achieve water quality conditions necessary to sustain healthy fish communities. Restoration opportunities must be critically evaluated to assure feasible positive outcomes.

The next step was to prioritize lakes within each of these management categories. DNR Fisheries identified high value fishery lakes, such as cisco refuge lakes. Ciscos (*Coregonus artedi)* can be an early indicator of eutrophication in a lake because they require cold hypolimnetic temperatures and high dissolved oxygen levels. These watersheds with low disturbance and high value fishery lakes are excellent candidates for priority protection measures, especially those that are related to forestry and minimizing the effects of landscape disturbance. Forest stewardship planning, harvest coordination to reduce hydrology impacts and forest conservation easements are some potential tools that can protect these high value resources for the long term.

Moosehead's lakeshed is classified with having 49% of the watershed protected and 32% of the watershed disturbed (Figure 13). Therefore, this lakeshed should have a full restoration focus. Goals for the lake should be to manage water runoff from disturbed land uses and work to limit any increase in disturbed land use. Moosehead has a large watershed, with numerous lakesheds flowing into it (Figure 12).

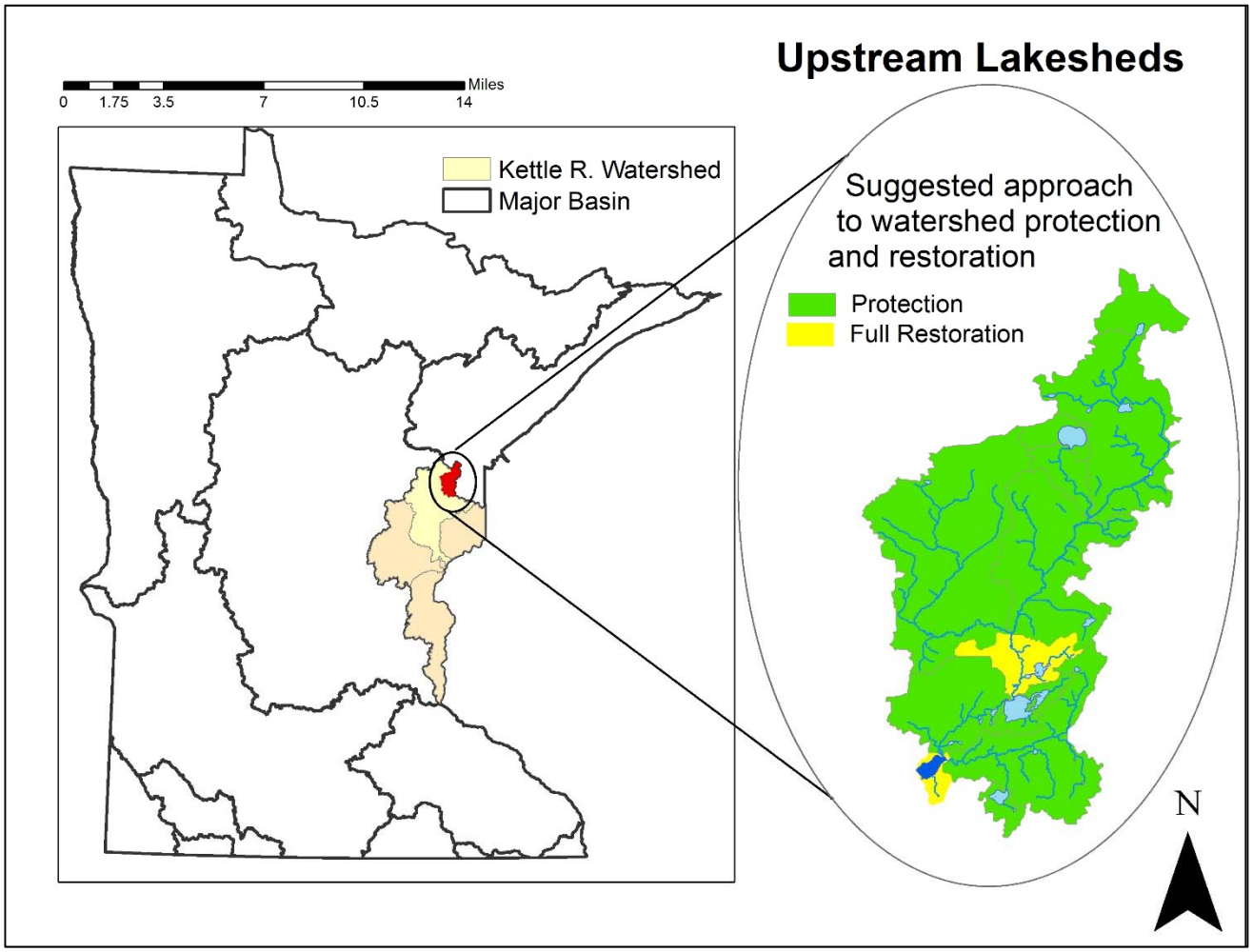


Figure 12. Kettle River major watershed and MN basins (left), and Moosehead Lake lakeshed and upstream catchments with protection suggestions (right).

Land use and Ownership

Activities that occur on the land within the lakeshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed.

Half of the Moosehead Lake lakeshed is protected (Figure 13). This total includes water, wetlands, and publicly owned land. There are two parcels along the lakeshore which have conservation potential. They are both private land over 20 acres which are less than 50% developed or agriculture.

Moosehead lake is within the city of Moose Lake, so there is a lot of concentrated development around the lake and a third of the lakeshed is disturbed (Figure 13). See the recommendations on page 15 for specific project ideas.

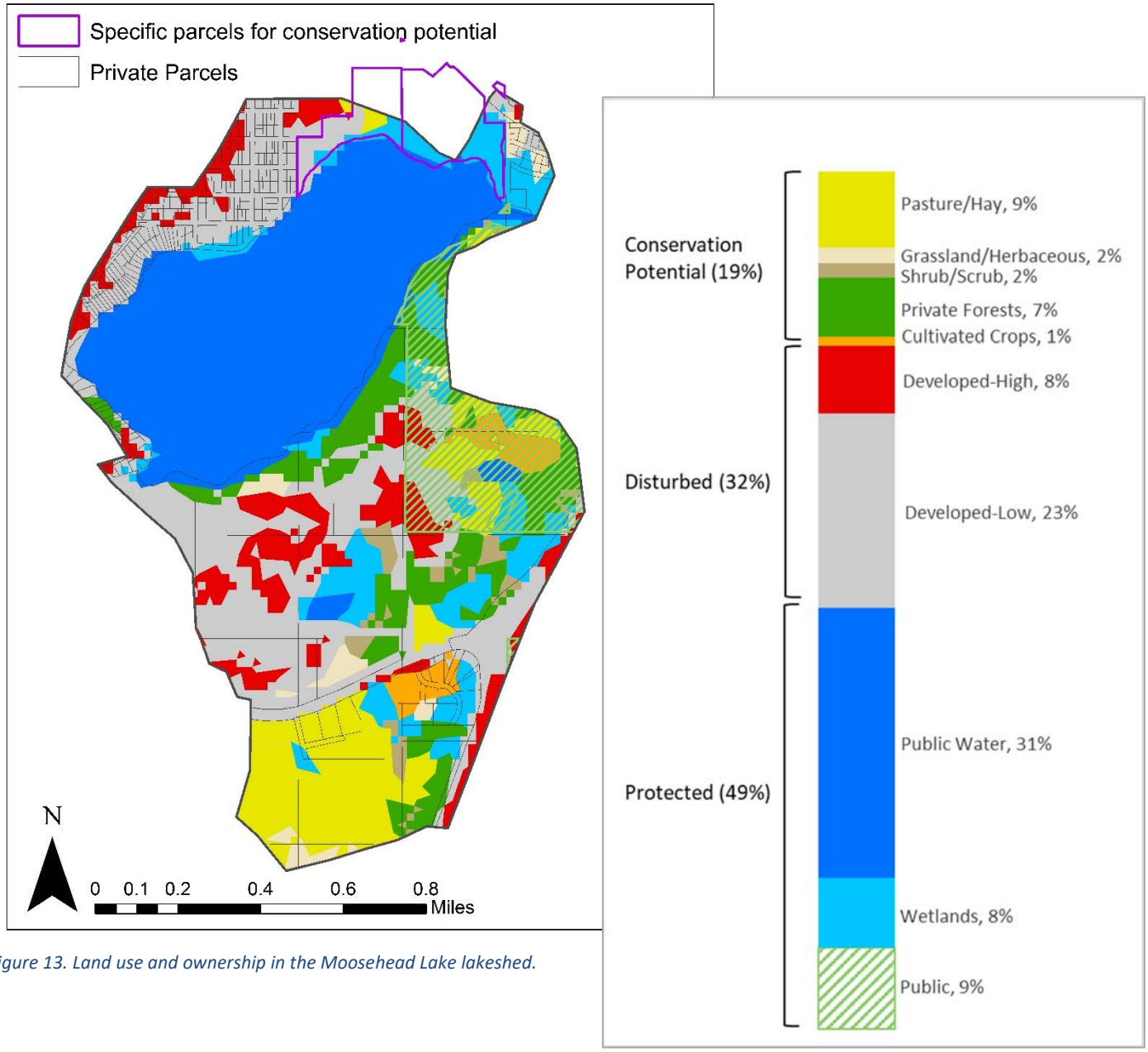


Figure 13. Land use and ownership in the Moosehead Lake lakeshed.

The lakeshed vitals table identifies where to focus organizational and management efforts for each lake (Table 10). Criteria were developed using limnological concepts to determine the effect to lake water quality.

KEY

Possibly detrimental to the lake
Warrants attention
Beneficial to the lake

Table 10. Moosehead Lake lakeshed vitals table.

Lakeshed Vitals		Rating
Lake Area	279.24 acres	descriptive
Littoral Zone Area	261 acres	descriptive
Lake Max Depth	18 ft.	descriptive
Lake Mean Depth	12 ft.	
Water Residence Time	NA	Not available
Miles of Stream	1.1	descriptive
Inlets	3	
Outlets	1	
Major Watershed	35 – Kettle River Watershed	descriptive
Minor Watershed	35022	descriptive
Lakeshed	3502201	descriptive
Ecoregion	Northern Lakes and Forest	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	3:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	255:1	
Wetland Coverage	8%	
Aquatic Invasive Species	None	
Public Drainage Ditches	None	
Public Lake Accesses	1	
Miles of Shoreline	3.18	descriptive
Shoreline Development Index	1.32	
Public Land to Private Land Ratio	1:18	
Development Classification	General Development	
Miles of Road	7.5	descriptive
Municipalities in lakeshed	Moose Lake	
Forestry Practices	None	
Feedlots	None	
Sewage Management	Compliance inspections are required for subsurface sewage treatment systems at point-of-sale or permit application in shoreland areas.	
Lake Management Plan	None	
Lake Vegetation Survey/Plan	DNR, 1997	

Moosehead Lake, Status of the Fishery (DNR, 7/21/2014)

Moosehead is a 292 acre lake with 261 (89%) acres of littoral area and a maximum depth of 18 feet. The lake is located immediately east of Moose Lake, MN and has a city administered, concrete, back-in access. A public swimming beach is adjacent to the access. Moosehead Lake has not been actively managed with fish stocking since 1985. Moosehead Lake was surveyed in 2014 to update information on fish populations and aquatic habitat.

Walleye abundance of 1.7 per gillnet lift was down from 2006 (3.3) but still average compared to other Minnesota lakes of similar type. Walleye abundance has ranged from 2.5 to 3.3 per lift during four previous investigations from 1972 through 2006. Average size was 16.6 inches and growth was average compared to other Duluth Area lakes. Age analysis revealed inconsistent recruitment with six missing year-classes from 2002-2013. Black Crappie abundance of 8.7 per trapnet lift was up from 2006 (1.7) and above average compared to other Minnesota lakes of similar type. Average size of 8.6 inches was large and growth was average compared to other Duluth Area lakes. Age analysis revealed a strong 2010 year-class and consistent recruitment with all year-classes from 2006 through 2012 represented.

Bluegill abundance of 8.4 per trapnet lift was up from 2006 (5.1) and above average compared to other Minnesota lakes of similar type. Average size was 6.7 inches and growth was average compared to other Duluth Area lakes. Age analysis revealed strong 2007 and 2011 year-classes and all year-classes from 2005 through 2012 were represented.

A total of 5 Largemouth Bass were sampled with electrofishing equipment. Bass electrofishing was not attempted in previous investigations but Largemouth Bass were sampled with regular assessment gear in 1977 and 1989. The Largemouth Bass catch rate of 4.1 fish per hour of electrofishing on-time was below average compared to other Duluth Area populations. Largemouth Bass average length was 15.8 inches. Not enough individuals were captured to evaluate stock density or growth, but recruitment appears sporadic with two missing year-classes from 2004-2010.

Northern Pike abundance of 6.0 per gillnet lift was down from 2006 (9.0) and average compared to other Minnesota lakes of similar type. Average size was 21.6 inches. Northern Pike were not aged for this assessment. Yellow Perch abundance of 11.0 was up from 2006 (7.0) but was still average compared to other Minnesota lakes of similar type. Average size was 6.1 inches. Yellow Perch were not aged for this assessment.
Lake Sturgeon have been documented in gillnet samples from investigations conducted in 1989 and 1999. There are also anecdotal reports of spawning activity in the Moosehead River near the Highway #61 Bridge at the outlet of Moosehead Lake. Anglers have reported catching large Lake Sturgeon in Moosehead Lake. No Lake Sturgeon were encountered during this survey.

Other fish species sampled during this investigation include Pumpkinseed Sunfish, Shorthead Redhorse, Silver Redhorse, White Sucker and Yellow Bullhead.

A substantial percentage (31%) of lakeshore homeowners on Moosehead Lake have open yards extending to the shoreline. Lakeshore owners can prevent excessive nutrient loading which leads to excessive plant growth and poor water quality by avoiding lawn fertilization, limiting aquatic vegetation removal, and implementing riparian best management practices. Results of laboratory water analysis indicate Moosehead is a slightly acidic, moderately hard water lake of low fertility.

Information was also collected on aquatic vegetation. Thirty-five aquatic plant species or species groups were identified along 134 sampling points. Water (wild) celery was the most frequently found plant (17% of stations sampled) followed by clasping-leaf pondweed (15%) and bushy pondweed (14%). One invasive plant was identified at low abundance (reed canary grass) but this species is common in emergent wetland plant communities and has become well-established in Minnesota. These data can be compared to future aquatic plant surveys of Moosehead Lake to estimate how the plant community may be changing.

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. http://www.dnr.state.mn.us/lakefind/showreport.html?downum=09004100

Key Findings and Recommendations

Monitoring Recommendations
Transparency monitoring at site 203 should be continued annually. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year-to-year comparisons and trend analyses. Phosphorus and chlorophyll a monitoring should continue at site 203, as the budget allows, to track future water quality trends.

Overall Conclusions
Moosehead Lake is a eutrophic lake (TSI = 55) with weak evidence (80%) of an improving long-term trend in water clarity. The total phosphorus, chlorophyll *a* and transparency ranges are higher than the expected ecoregion ranges and over the impaired waters standard (Figure 4). The Minnesota Pollution Control Agency is currently assessing the Kettle River Watershed and will decide whether to put Mooshead Lake on the Impaired Waters List.

Moosehead's lakeshed lies within the city limits of Moose lake Minnesota and 7% of the lakeshed land area is forested. Almost half of the Moosehead Lakeshed (49%) is protected, which includes public ownership, wetlands and open water. A third (32%) of the lakeshed is disturbed, which includes developed and highly developed land (Figure 13). DNR Fisheries estimates that over 25% disturbance in a lakeshed can affect water quality, and Moosehead Lake is over that threshold.

Moosehead Lake is one of several connected lakes joined via the Moose Horn River. The total watershed area for Hanging Horn Lake is very large (Table 11), therefore disturbances beyond the immediate lakeshed can adversely impact Moosehead's water quality.

Phosphorus Loading and Priority Impacts
Moosehead Lake is at a disadvantage because it has a very large watershed (Table 11). Upstream land use in the watershed is likely the main impact to the lake's water quality.

With the Moose Horn River flowing through the lake, it likely has a short residence time, which means that many of the nutrients flowing into the lake also flush out.

Table 11. Watershed characteristics.

Lakeshed to Lake Area Ratio (lakeshed includes lake area)	3:1
Watershed to Lake Area Ratio (watershed includes lake areas)	255:1
Number of Upstream Lakes	7
Headwaters Lake?	No
Inlets / Outlets	3 / 1
Water Residence Time	NA

In addition to a large watershed, the city of Moose Lake is adjacent to Moosehead Lake. Heavy development and impervious surface change the drainage around the lake to allow more direct runoff. Although the impervious surface area can't be removed in most cases, the storm water can be captured and mitigated. See Table 12 on the next page for specific project ideas.

Best Management Practices Recommendations

The management focus for Moosehead Lake should be to protect the current water quality and restore the lakeshed. Efforts should be focused on managing and/or decreasing the impact caused by current and additional development, including second tier development, and impervious surface area. Project ideas include protecting land with conservation easements, enforcing county shoreline ordinances, shoreline restoration, rain gardens, and septic system maintenance.

Moosehead Lake Goals

1. Protection Focus: minimize disturbed land uses and maintain protected lands
2. Manage phosphorus loading from the **watershed** and **lakeshed**, Table 12
3. Focused BMPs per land type: Table 12

Table 12. Best Management Practices Table specific to Moosehead Lake (refer to Figure 13)

Category	Land use type	Conservation project ideas	Results	Who	Contact for help
Conservation Potential Land	private forests (7%, 66.2 acres)	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives.	Conserve and protect current forest cover.	• Individual Property Owners	Carlton SWCD (218) 384-3891 https://carltonswcd.org
	pasture/hay (9%, 104.0 acres)	Conservation Reserve Program (CRP), maintain vegetative cover, plant trees, conservation easements, grassed waterways, ditch buffers, maintain/restore wetlands.	Reduce water runoff and soil erosion, better water storage.	• Individual Property Owners	Natural Resources Conservation Service 218-720-5209
Disturbed Land	developed, low intensity (23%, 217.5 acres)	Shoreline buffers, rain gardens.	Reduce water runoff and shoreline erosion in lakes and streams.	• Individual Property Owners • Lake Associations	Carlton SWCD (218) 384-3891 https://carltonswcd.org
	Developed, high intensity (8%, 75.6 acres)	Sediment basins, rain gardens, shoreline buffers, stormwater retention.	Reduce water runoff into streams and lakes.	• Individual Property Owners • Cities • Lake Associations	Carlton SWCD (218) 384-3891 https://carltonswcd.org
	cultivated crops (1%, 9.5 acres)	Restore wetlands; Conservation Reserve Program (CRP), Cover Crops.	Reduce water runoff and soil erosion, better water storage.	• Individual Property Owners	Natural Resources Conservation Service 218-720-5209

The current lakeshore homeowners can lessen their negative impact on water quality by installing or maintaining the existing trees on their properties. Forested uplands contribute significantly less phosphorus (lbs/acre/year) than developed land cover (Table 10).

Some of the lakeshed (7%) is privately owned forested uplands (Figure 13). Forested uplands can be managed with Forest Stewardship Planning, 3rd party certification, SFIA, and local woodland cooperatives. Contact the Soil and Watershed Conservation District for options for managing private forests.

The lakeshed still has large undeveloped shoreline parcels (Figure 13). Because a lot of undeveloped private land still exists, there is a great potential for protecting this land with conservation easements and aquatic management areas (AMAs). Conservation easements can be set up easily and with little cost with help from organizations such as the Board of Soil and Water Resources and the Minnesota Land Trust. AMAs can be set up through the local DNR fisheries office.

Native aquatic plants stabilize the lake's sediments and tie up phosphorus in their tissues. When aquatic plants are uprooted from a shallow lake, the lake bottom is disturbed, and the phosphorus in the water column gets used by algae instead of plants. This contributes to "greener" water and more algae blooms. Protecting native aquatic plant beds will ensure a healthy lake and healthy fishery. If a swimming area is necessary in front of people's docks, clear only a small area of plants. Clearing a whole 100 foot frontage is not necessary and can contribute to additional algae blooms.

Table 13. Organizational contacts and reference sites

Organizational contacts and reference sites

Moosehead Lake Association	No contact info.
DNR Fisheries Office	5351 North Shore Drive, Duluth, MN 55804 218-302-3264, duluth.fisheries@state.mn.us
Regional Minnesota Pollution Control Agency Office	525 Lake Avenue South, Suite 400, Duluth, MN 55802 218-723-4660 https://www.pca.state.mn.us/about-mpca/duluth-office
Carlton County Soil and Water Conservation District	808 3rd St, Carlton, MN 55718 (218) 384-3891, https://carltonswcd.org/
Carlton County	301 Walnut Ave, Carlton, MN 55718 http://carltoncountymn.govoffice3.com/