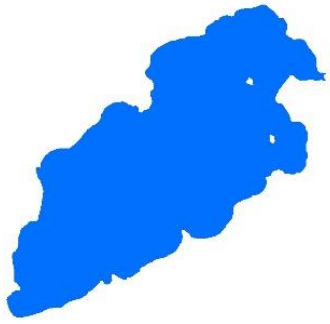
Oak Lake

58-0048-00 Pine County



Oak Lake is located 3 miles West of the town of Duquette, MN in Pine County. It is located relatively close to Interstate 35 and county Highway 23. It is a relatively large lake covering approximately 462 acres (Table 1).

Oak Lake is a headwaters lake with one minor intermittent inlet and two outlets. One outlet flows into Little Oak Lake to the west and one flows south toward Willow Lake. This classifies Oak lake as a groundwater drainage lake. Therefore, land practices have the largest impact on the lake's water quality.

Water quality data have been collected on Oak Lake from 1976 - 2018 at four different sites and with several gap years (Tables 2 & 3). The data show that the lake is mesotrophic (TSI = 54) with moderately clear water conditions most of the summer.

Table 1. Oak Lake location and key physical characteristics.

Location Data		Physical Characteristics	
MN Lake ID:	**58-0048-00**	Surface area (acres):	**462.1**
County:	**Pine County**	Littoral area (acres):	**433**
Ecoregion:	**Northern Lakes and Forests**	% Littoral area:	**93.7%**
Major Watershed:	**Kettle River**	Max depth (ft), (m):	**20, 6.096**
Latitude/Longitude:	**46.386313, -92.595429**	Inlets:	**1**
Invasive Species:	**None as of 2018**	Outlets:	**2**
		Public Accesses:	**1**

Table 2. Availability of primary data types for Oak Lake.

Data Availability		
Transparency data		**Fair, more than 10 years of data; however, it is not consecutive and sampled at various sites.**
Chemical data		**Poor, only 4 years of nonconsecutive data**
Inlet/Outlet data	--	**Not necessary**
Recommendations		**For recommendations refer to page 15.**

Lake Map

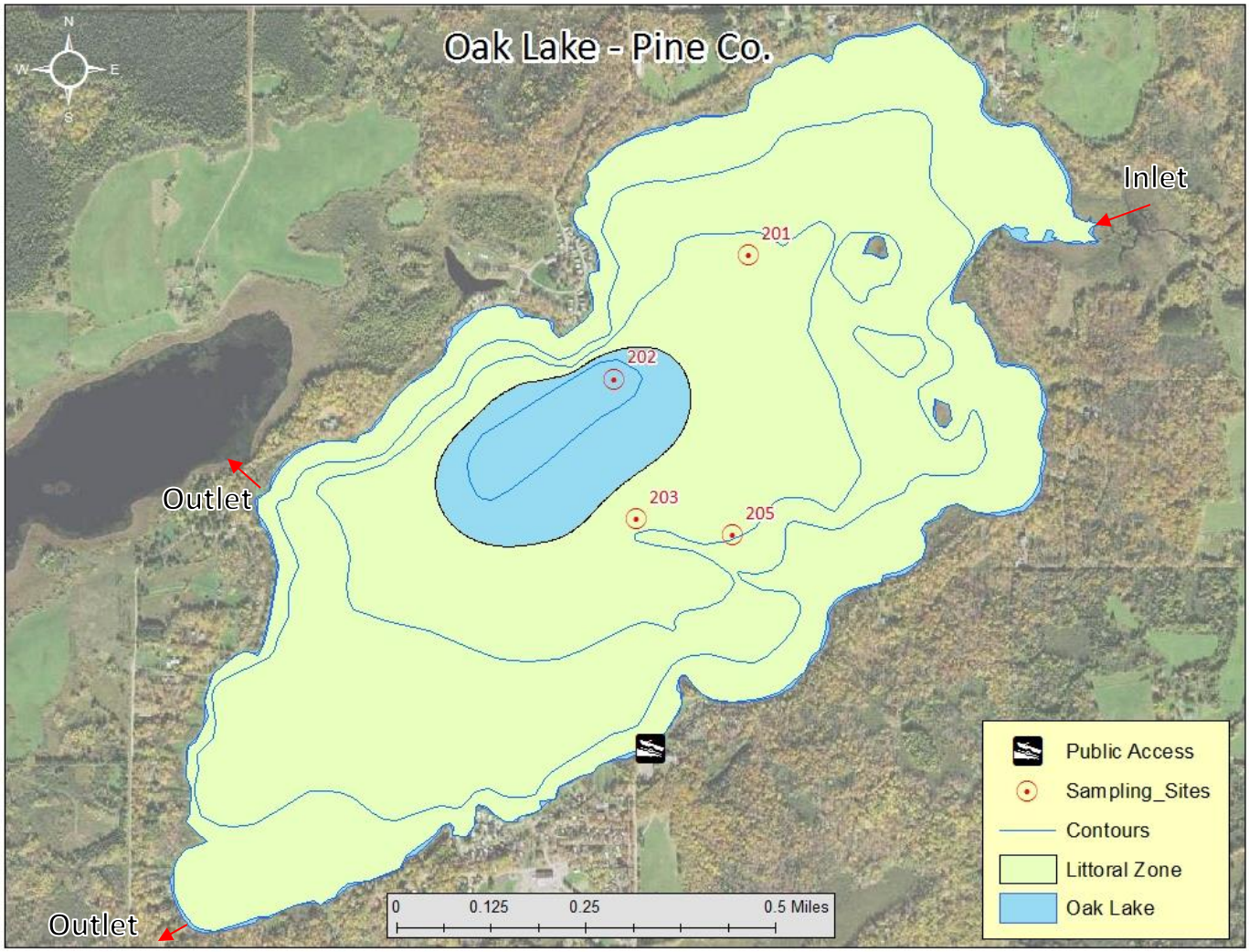


Figure 1. Map of Oak Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic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

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), RMB Environmental Laboratories Lakes Monitoring Program (RMBLMP), North shore Lake Superior Lake and Stream Water Assessment NRRI (NSLSLSWA), and Pine SWCD Surface Water Assessment Grant (SWCD).

Lake Site	Depth (ft)	Monitoring Programs
201	10	CLMP: 1976-1977; SWCD: 2011-2012
202* Primary site	18	CLMP: 2003-2010, 2012, 2016-2018; NSLSLSWA: 2016
203	10	CLMP: 2005
205	10	RMBLMP: 2018

Average Water Quality Statistics & Comparisons

The information below describes available chemical data for Oak Lake through 2018 (Table 4). Data for total phosphorus, chlorophyll *a*, and Secchi depth are from the primary site 202.

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). Oak Lake 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)	29.0	14 – 27	> 30	Results are slightly higher the expected range for the Northern Lakes and Forests Ecoregion. This could have more to do with the depth of the lake than the water quality. The lake is not impaired for excess phosphorus.
[3]Chlorophyll *a* (ug/L)	12.15	4 – 10	> 9	
Chlorophyll *a* max (ug/L)	28.2	< 15		
Secchi depth (ft)	4.5	8 – 15	< 6.5	
Dissolved oxygen	*See page 8*			Dissolved oxygen depth profiles show that the lake mixes in spring and fall (dimictic).
Total Kjeldahl Nitrogen (mg/L)	No Data	<0.4 – 0.75		If a lake has insufficient nitrogen, it can support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	No Data	40 – 140		Determines sensitivity to acid rain and buffering capacity.
Color (Pt-Co Units)	No Data	10 – 35		Indicates water color.
pH	7.04	7.2 – 8.3		Indicates a hard water lake. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water.
Chloride (mg/L)	3.5	0.6 – 1.2		Above the expected range for the ecoregion; however, there is only one data point from 2016. Further testing would give a clearer picture of chloride concentrations in Oak lake.
Total Suspended Solids (mg/L)	No Data	<1 – 2		Shows the concentration of suspended solids within the water column.
Specific Conductance (umhos/cm)	70.3	50 – 250		Within the expected range for the ecoregion.
TN:TP Ratio	N/A	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	Site 201	Primary Site 202	Site 203	Site 205
Total Phosphorus Mean (ug/L):	32.2	29.0	-	40.3
Total Phosphorus Min:	21.0	20.0	-	24.0
Total Phosphorus Max:	53.0	38.0	-	50.0
Number of Observations:	10	6	0	4
Chlorophyll *a* Mean (ug/L):	18.3	12.2	-	29.8
Chlorophyll-a Min:	4.0	1.9	-	3.56
Chlorophyll-a Max:	40.0	28.2	-	62.3
Number of Observations:	10	6	0	4
Secchi Depth Mean (ft):	4.6	4.6	3.7	-
Secchi Depth Min:	2.6	1.5	3.0	-
Secchi Depth Max:	10.0	9.0	5.0	-
Number of Observations:	30	81	6	0

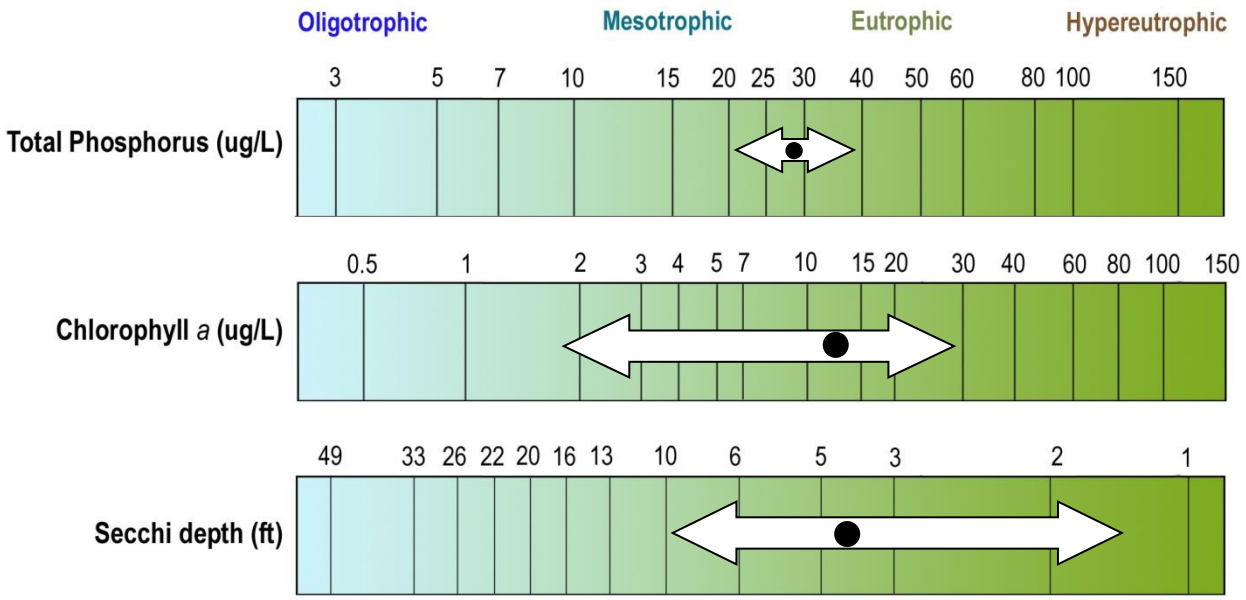


Figure 3. Oak Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 202). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. EPA 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 Oak Lake ranges from 2.4 to 6.6 feet (Figure 4). The annual means hover up and down around the long-term mean of 4.7 feet. For trend analysis, see page 10. Transparency monitoring should be continued annually at site 202 in order to track water quality changes.

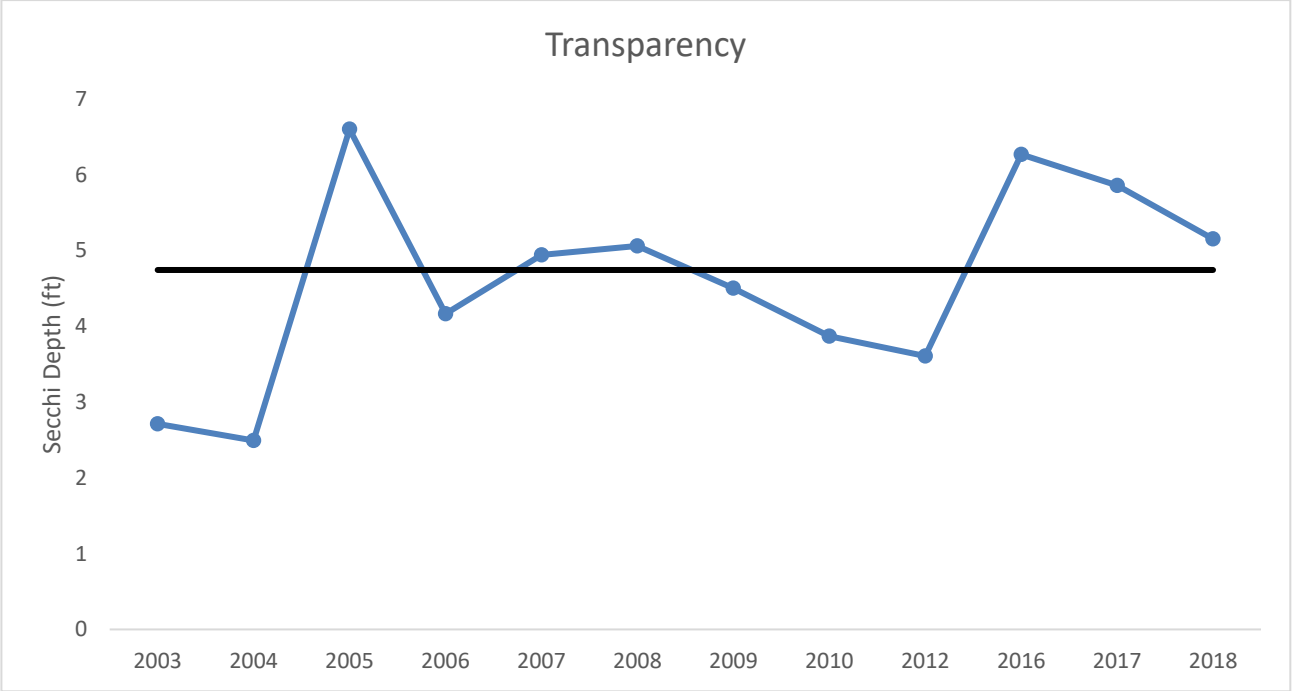


Figure 4. Annual mean transparency compared to long-term mean transparency

Oak Lake transparency ranges from 1.5 to 9.0 ft at the primary site 202 (Table 5). Figure 5 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Oak Lake transparency is high in May and June, and then declines through August. 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.

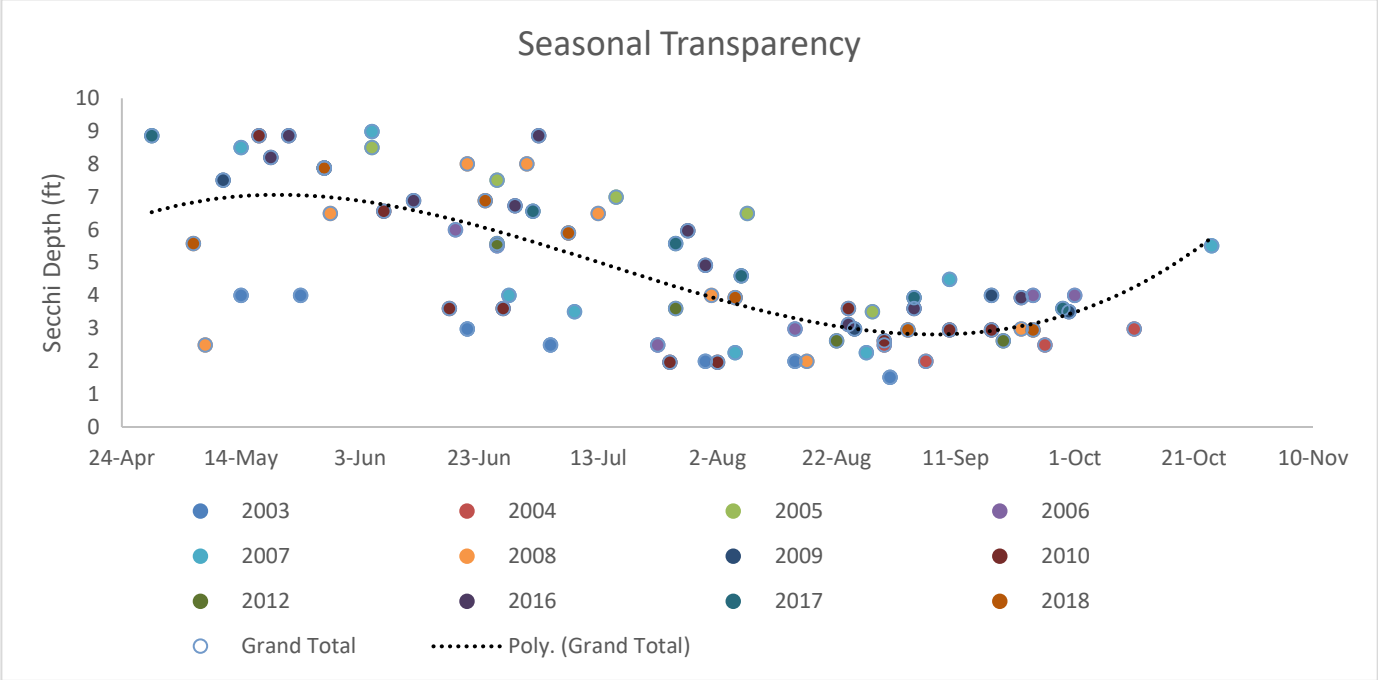


Figure 5. Seasonal transparency dynamics and year to year comparison (Primary Site 202). The black line represents the pattern in the data.

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 (transparency) decreases the perception of the lake's physical appearance and recreational suitability decreases (Figures 6-7).

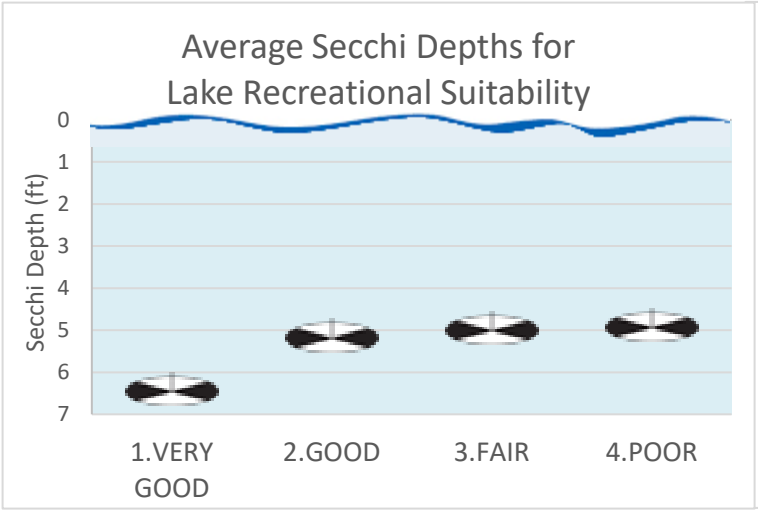


Figure 6. Average Secchi depth (ft) at site 202 for each lake recreational suitability rating.

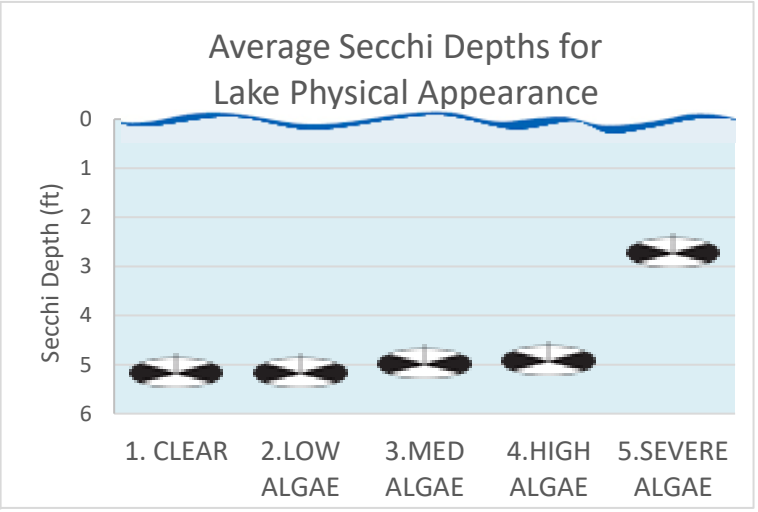


Figure 7. Average Secchi depth (ft) at site 202 for each lake physical appearance rating.

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.

Chlorophyll *a* was evaluated in Oak Lake at site 201* in 2011-2012, site 202* on 2016, and site 205* in 2018 (Figure 8). Chlorophyll *a* concentrations went above 10 ug/L all four years chlorophyll a was monitored, indicating minor algae blooms. Chlorophyll *a* concentrations were above 20 ug/L in 2012, 2016, and 2018 indicating a major algae bloom. Chlorophyll *a* concentrations are usually highest in late summer, this is typical for Minnesota lakes.

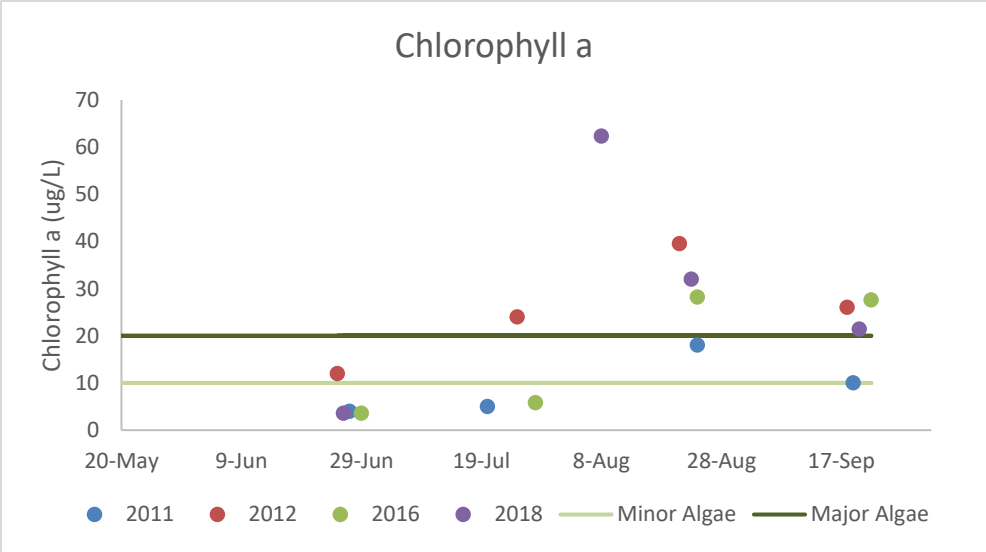


Figure 8. Chlorophyll a concentrations (ug/L) for Oak Lake at site 201.

*Multiple sites were used for this analysis instead of only the primary site 202 because there was more chemical data is needed. In future projects, it is important to be consistent with sites so that all parameters can be looked at when comparing data.

Phosphorus

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

Total phosphorus was evaluated in Oak Lake at site 201* in 2011-201, site 202 on 2016, and site 205 in 2018 (figure 9). The data illustrate the typically lower phosphorus concentrations in early summer with the concentrations reaching a peak in late August or early September.

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

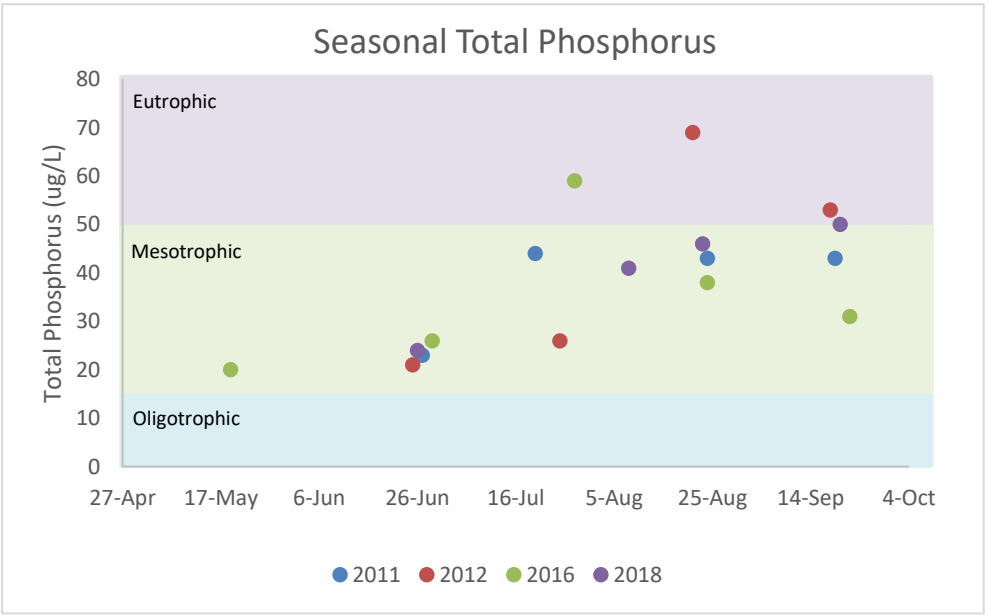


Figure 9. Historical total phosphorus concentrations (ug/L) for Oak Lake site 201.

*Site 201 was used for this analysis instead of the primary site 202 because there was more chemical data at this site. In future projects, it is important to be consistent with sites so that all parameters can be looked at when comparing data.

Oxygen

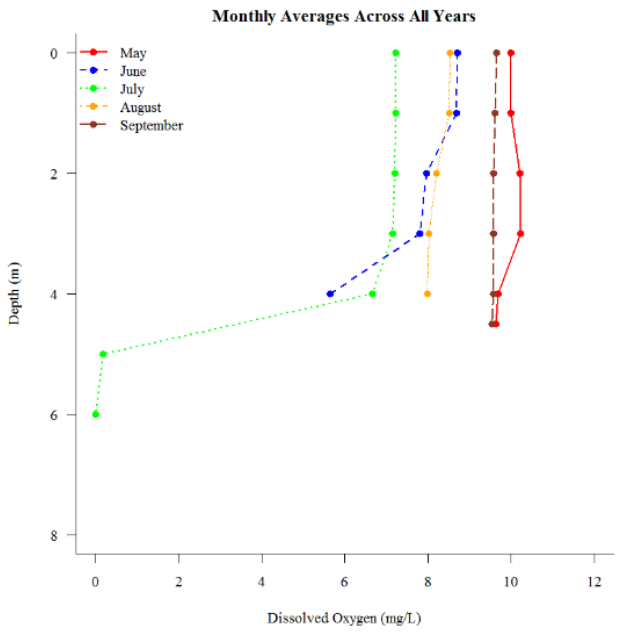


Figure 10. Representative dissolved oxygen profiles from 2016 in Oak Lake.

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.

Oak Lake is a shallow lake, with a maximum depth of 20 feet. Dissolved oxygen profiles from data collected in 2016 at site 202 show stratification developing during the summer (Figure 10). The thermocline in 2016 was around 3 to 4 meters (10 feet). Dissolved oxygen was below 5 mg/L in July meaning gamefish will likely be scarce in the deeper water at that time.

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. Oak Lake falls into the eutrophic range (Tables 6, 7).

Table 6. Trophic State Index for Oak Lake.

Trophic State Index	
TSI Phosphorus	53
TSI Chlorophyll-a	55
TSI Secchi	55
TSI Mean	54
Trophic State:	Eutrophic

Numbers represent the mean TSI for each parameter.

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

Oak Lake

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.

Oak Lake 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 Oak Lake.

Lake Site	Parameter	Date Range	Trend
202	Total Phosphorus	2016	Insufficient Data
202	Chlorophyll *a*	2016	Insufficient Data
202	Transparency	2003-2010, 2012, 2016-2018	No significant trend

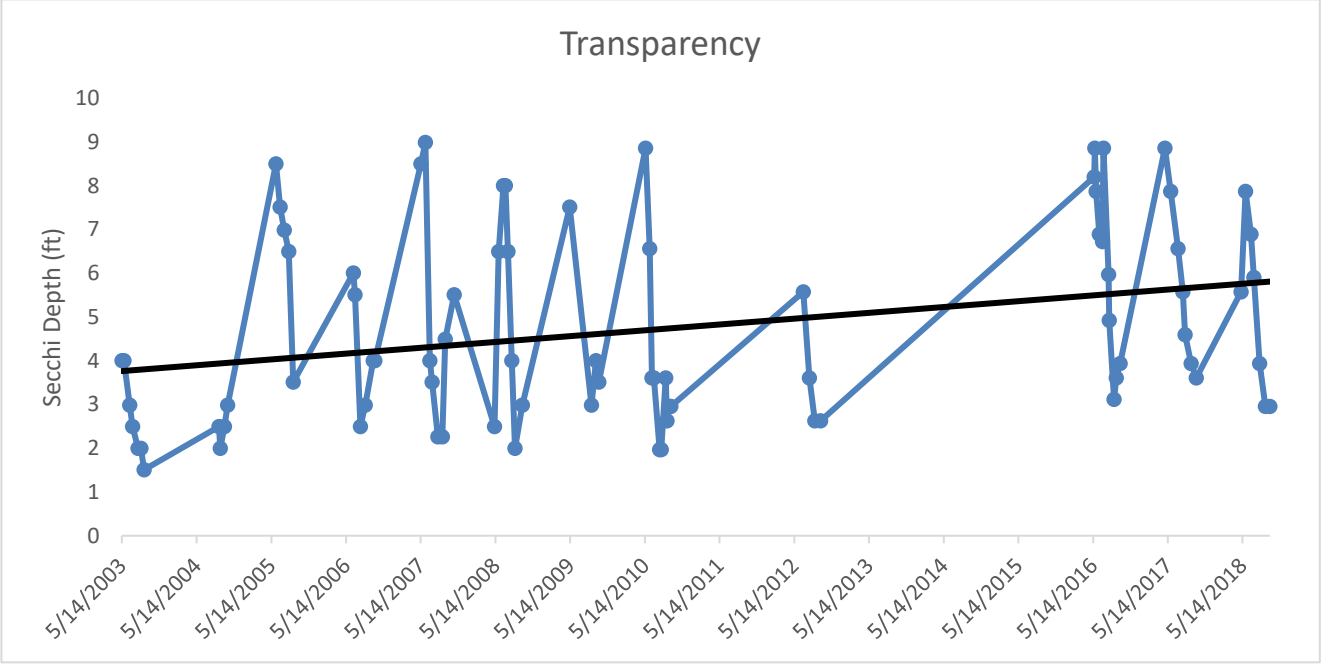


Figure 11. Transparency (feet) trend for site 202 from 2003-2010, 2012, 2016-2018.

Oak Lake shows insufficient evidence for a transparency trend (Figure 11). There was a large gap in data between 2012 and 2016. Even though the figure 11 appears to have increasing transparency trend, when the data was run through the Mann Kendall Statistic Test, there was not a strong enough trend for it to be statistically significant. No significant trend means that the transparency is remaining stable from year to year. See the recommendations section for more explanation (page 15). 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 Major Watershed is one of the watersheds that make up the St. Croix River Basin, which drains south to the Gulf of Mexico (Figure 12).

The MN DNR also has evaluated catchments for each individual lake with greater than 100 acres surface area. These lakesheds (catchments) are the "building blocks" for the larger scale watersheds. Oak Lake falls within lakeshed 3504301 (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.

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 based on their lakeshed, 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 surface waters, 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. Cisco (*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.

Oak Lake's lakeshed is classified with having 60% of the watershed protected and 5% of the watershed disturbed (Figure 13). Therefore, this lakeshed should have a protection focus. Goals for the lake should be to limit any increase in disturbed land use and to maintain current protection levels. Oak Lake is a headwaters lakeshed, which means that no other lakesheds flow into it (Figure 12).

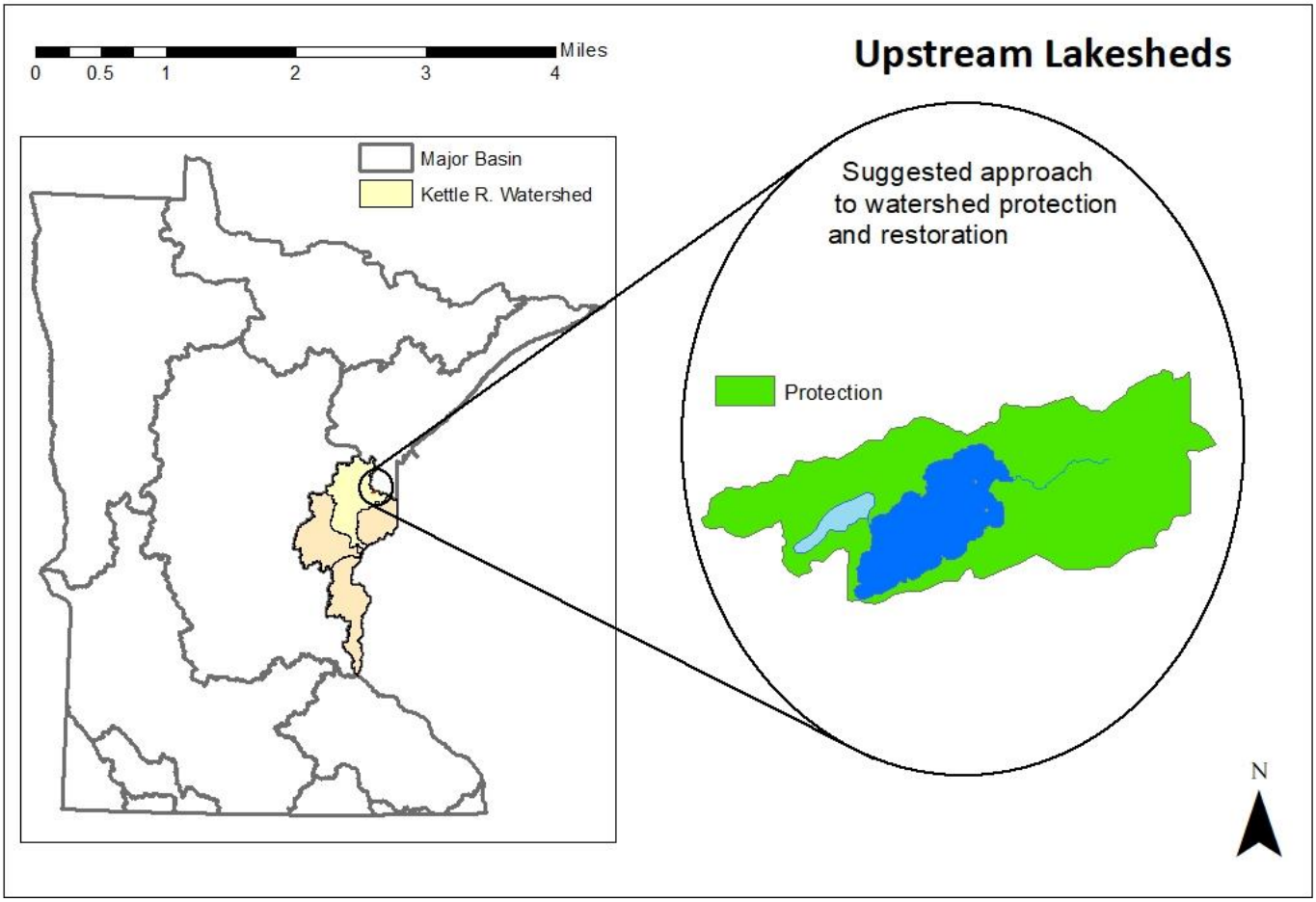


Figure 12. Kettle River major watershed and MN basins (left), and Oak Lake lakeshed and upstream catchments with protection suggestions (right).

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.

Over half (60%) of the Oak Lake lakeshed is protected (Figure 13). This total includes water, wetlands, and publicly owned land. There are several parcel 6 parcels along the lakeshore which have conservation potential. Parcels are considered for conservation potential if, it is private land over 20 acres, with less than 50% developed or agriculture.

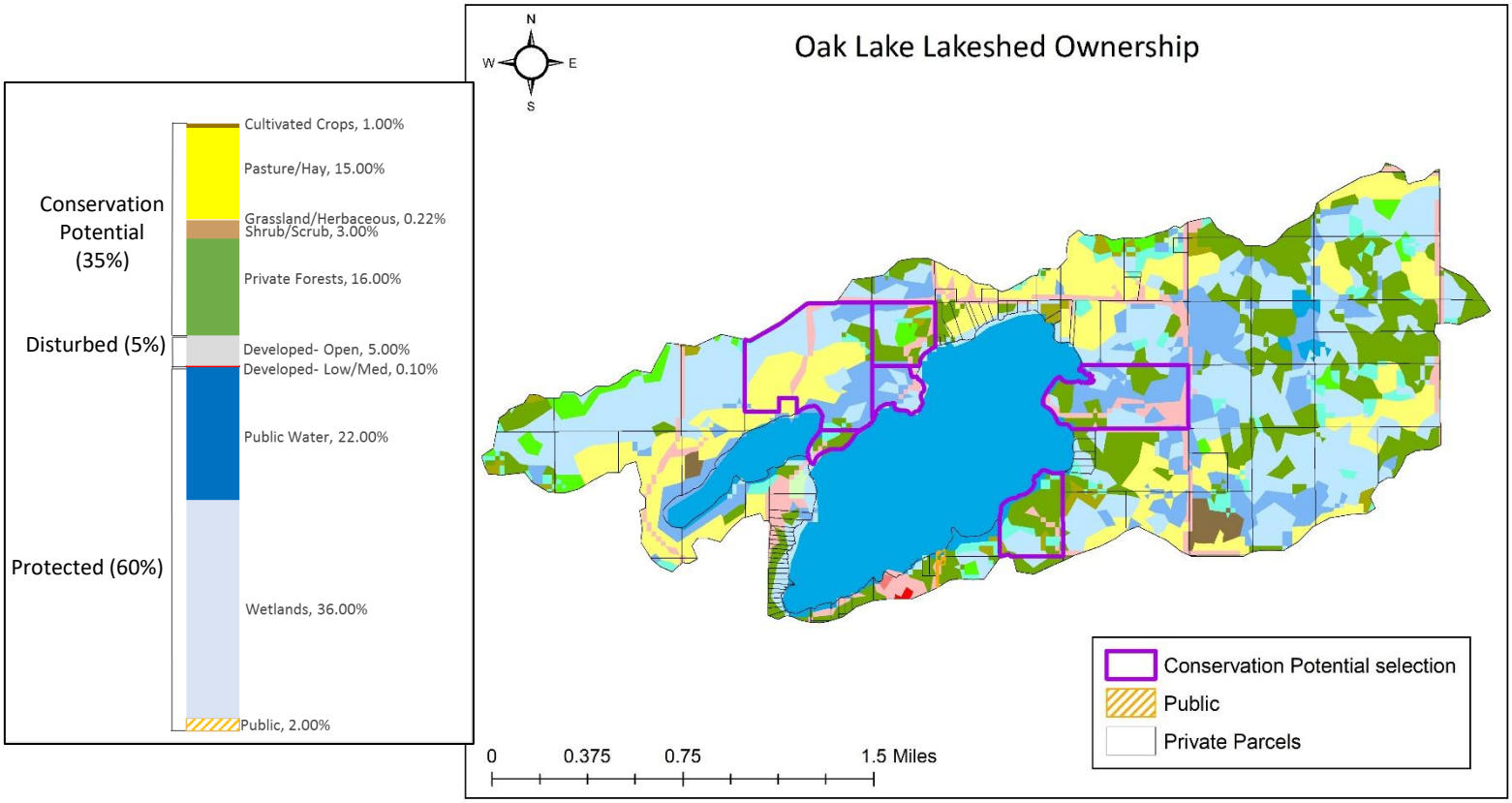


Figure 13. Land use and ownership in the Oak Lake lakeshed.

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. Oak Lake lakeshed vitals table.

Lakeshed Vitals		Rating
Lake Area	462.1	descriptive
Littoral Zone Area	62.5 acres	descriptive
Lake Max Depth	20 ft.	descriptive
Lake Mean Depth	8 ft.	
Water Residence Time	NA	Not available
Miles of Stream	0.98	descriptive
Inlets	1	
Outlets	2	
Major Watershed	35 – Kettle River	descriptive
Minor Watershed	Willow River	descriptive
Lakeshed	3504301	descriptive
Ecoregion	Northern Lakes and Forest	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	5:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	5:1	
Wetland Coverage	36.0%	
Aquatic Invasive Species	None as of 2018	
Public Drainage Ditches	None	
Public Lake Accesses	1	
Miles of Shoreline	0.72	descriptive
Shoreline Development Index	1.54	
Public Land to Private Land Ratio	1.5:1	
Development Classification	Recreational Development	
Miles of Road	5.56	descriptive
Municipalities in lakeshed	None	
Forestry Practices	None	
Feedlots	1	
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, 1998	

Oak Lake, Status of the Fishery (DNR, 8/3/2015)

Oak Lake is a fertile 462.1 acre basin in northern Pine County. In recent years Walleye, the primary management species, have been stocked annually as fingerlings at a rate of 1.5 pounds per littoral acre (300 pounds). A paved public access and a private resort are both located on the south shore of the lake. The lake is fairly remote with moderate levels of development. The shoreline is predominately sand and the water clarity is fairly good despite occasional algae blooms. Lake use is light to moderate for both boating and fishing. Anglers can expect acceptable-size Black Crappie, Walleye, and Largemouth Bass in abundances typical of the lake type.

To assess lake management goals and the current fishery, an assessment was conducted on Oak Lake in 2015. This survey consisted of night electrofishing, gill netting, and trap netting.

Walleye, Yellow Perch, Black Crappie, and Bluegill were all present in size and numbers typical of the lake type. Black Crappie again averaged close to 8 inches with individuals over 10 inches present. Walleye averaged 17 inches and nearly two pounds. Largemouth Bass increased in both size and abundance compared to the previous assessment. Bass averaged over 13 inches and a pound-and-a-third. The Northern Pike quality dipped since the 2010 netting when more than a fifth of the catch exceeded 30 inches. Only one northern in the 2015 assessment exceeded 30 inches.

Development pressure is increasing around the shorelines and within the watersheds of many Minnesota lakes. This development can degrade water quality and impact valuable shoreline habitat. Native shoreline vegetation provides habitat for fish and wildlife, filters harmful nutrients, and protects against shoreline erosion. Lakeshore owners can minimize their impact on the shoreline and maintain a more natural setting while actually decreasing annual maintenance. For more information on how to accomplish this, contact the nearest Area Fisheries office or go to the following website: www.dnr.state.mn.us/shorelandmgmt

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. https://www.dnr.state.mn.us/lakefind/showreport.html?downum=58004800

Key Findings and Recommendations

Monitoring Recommendations
Currently there is not a statistically significant transparency trend at site 202 on Oak lake. It is important to continue transparency monitoring weekly or at least monthly every year to enable year-to-year comparisons and trend analyses. Phosphorus and chlorophyll a monitoring should continue at site 202, as the budget allows, to track future water quality trends. As of 2019, there is not enough data to run any statistical analysis on the data.

Overall Conclusions
Oak Lake is a eutrophic lake (TSI = 54) with insufficient evidence of a long-term trend in water clarity. The total phosphorus, and chlorophyll *a* concentration averages are slightly higher than the ecoregion ranges; however, since Oak lake is a shallow lake and will naturally have more phosphorus and chlorophyll a than a large, deep lake. (Table 4) This allows for more plant growth. The transparency readings are lower than expected for this eco region, again this could be due to the shallow lake depth, with the mean depth of 8 feet.

Over half of the Oak Lakeshed is protected (60%), which includes public ownership, wetlands, and open water, and 16% of the lakeshed land area is forested. Only 5% of the lakeshed is disturbed, which includes high and low levels of development (Figure 13).

Interstate 35 is approximately 20 miles west of Oak Lake. Chloride concentration in the lake was monitored 2016 and is higher than expected for the region (Table 4). The chloride is still under the state standard though; the state standard is 207 mg/L and Oak Lake is 3.5 mg/L. This higher chloride could be due to road salt on I35; however, Oak lake has a fairly protected watershed. More information about chloride monitoring and guidelines can be found at the Minnesota Pollution Control Agency's website here: https://www.pca.state.mn.us/water/chloride-salts. Stormwater from cities and Interstate 35 could be diverted to a sediment basin before running into Oak Lake to protect the lake from chloride runoff.

Phosphorus Loading and Priority Impacts
Oak Lake is at an advantage because it is a headwaters lake and has a well-protected lakeshed, which means no additional water flows into this lake from upstream lakes or rivers. The inlets to the lake are intermittent and groundwater and/or wetland fed. (Figure 1). This means that the land practices around Oak Lake and in it's lakeshed are the main impacts to the lake (Figure 13).

Table 11. Watershed characteristics.

Lakeshed to Lake Area Ratio (lakeshed includes lake area)	5:1
Watershed to Lake Area Ratio (watershed includes lake areas)	5:1
Number of Upstream Lakes	0
Headwaters Lake?	Yes
Inlets / Outlets	1 / 2
Water Residence Time	NA

Oak Lake has insufficient evidence for a strong trend in transparency from 2003-2010, 2012, 2016-2018 (Table 8, Figure 11). The graph shows that the monthly average high readings are staying relatively the same from year to year, whereas the monthly average lows seem to be increasing in depth in more recent years. This causes the overall trend to appear as though it is increasing even though the Mann Kendall statistical test states there is not a significant trend at this time. Currently, there are not any data for water levels on Oak lake. High water can cause shoreline erosion and cause decreased water transparency. Maintaining wetlands in the lakeshed help with water storage and can decrease the impact from high water events. Future monitoring of water levels could help to track the tendencies of Oak lake.

Best Management Practices Recommendations

The management focus for Oak Lake should be to protect the current water quality and 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.

Oak Lake Goals

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

Table 12. Best Management Practices Table specific to Oak Lake (refer to Figure 13 for locations).

Category	Land use type	Conservation project ideas	Results	Who	Contact for help
Conservation Potential Land (35%)	private forests (16%, 444 acres)	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives	Conserve and protect current forest cover	• Individual Property Owners	Pine SWCD 320-216-4240
	pasture/hay (15%, 361 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 123-4567-8910, info@swcd.org
Disturbed Land (5%)	developed, Open (5%, 132 acres)	Shoreline buffers, rain gardens	Reduce water runoff and shoreline erosion.	• Individual Property Owners	Pine SWCD 320-216-4240
	developed, low to Medium intensity (0.10%, 2 acres)	Sediment basins, rain gardens, shoreline buffers, stormwater retention.	Reduce water runoff into streams and lakes.	• Individual Property Owners • Cities • Lake Associations	Pine SWCD 320-216-4240

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 12).

Sixteen percent of the lakeshed is privately owned forested uplands (Table 12). 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 a few of 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

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
Pine County Soil and Water Conservation District	130 Oriole Street East, Sandstone, MN 55072 320-216-4240
Pine County	635 Northridge DR NW Pine City, MN 55063 320-591-1400