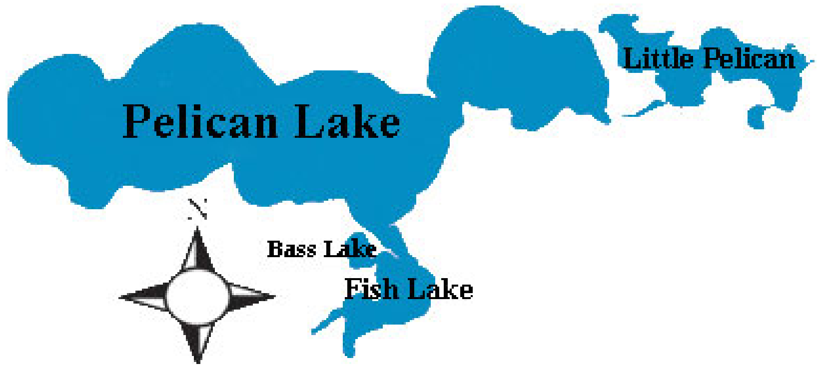
# Chapter 3. Lake Assessments

## Introduction




The Pelican Group of Lakes encompasses 4 lakes: Pelican, Little Pelican, Bass, and Fish. Although these lakes have somewhat different characteristics, they are all considered to have good water quality for northwest Minnesota.

Little Pelican Lake is the first of the PGOLID lakes when considering water flow. The Pelican River drains into Little Pelican Lake on the northeast side and provides the majority of the phosphorus entering the lake. Little Pelican Lake is considered a shallow lake because the majority of the area of the lake is 15 feet deep or less, and it is ringed with emergent vegetation (bulrush, cattails, wild rice, etc). Therefore, because Little Pelican Lake is a shallow lake and the Pelican River drains directly into it, it has the highest phosphorus and lowest clarity of the PGOLID lakes. It is still considered a very healthy shallow lake as the water quality and fishery characteristics are in the range of what is to be expected for a lake of this size and depth.

Pelican, Bass and Fish Lakes are all very similar in water quality and lake condition. In fact, they are all one large system of water. They are fairly deep (33-69 ft), have excellent fisheries, and are good for recreation. These characteristics make them a top tourist destination in northwest Minnesota. The Pelican River exits at the southwest end of Fish Lake.

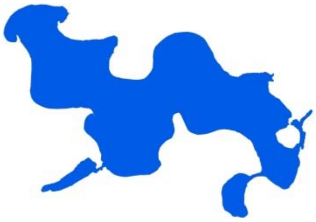
These four lakes must be protected by preserving aquatic habitat and plants, restoring natural shoreline conditions, minimizing impervious surface, working with neighbors upstream of the Pelican River for good watershed management practices, proper maintenance of waste water treatment systems, and education of lakeshore property owners.

### PGOLID Lake Vitals

| | Pelican | Little Pelican | Bass | Fish |
|---|---|---|---|---|
| Size (acres) | 3,986 | 345 | 48 | 261 |
| Mean depth (ft) | 22 | 12 | 18 | 27 |
| Littoral area (%) | 41 | 74 | 50 | 48 |
| Maximum depth (ft) | 55 | 25 | 33 | 69 |
| Volume (acre ft) | 87,692 | 4,140 | 864 | 7,047 |
| Watershed Area (acres) | 164,092 | 96,538 | 138 | 162,190 |
| Trophic State Index (TSI) | 41 | 46 | 42 | 40 |
| Total Phosphorus Mean (ug/L) | 14 | 24 | 17 | 12 |
| Chlorophyll *a* Mean (ug/L) | 5 | 10 | 5 | 4 |
| Chlorophyll *a* Maximum (ug/L) | 17 | 31 | 17 | 9 |
| Transparency (Secchi depth, ft) | 12.6 | 8.3 | 12.0 | 12.4 |

# Little Pelican Lake 56-0761-00 OTTER TAIL COUNTY

## Summary



Little Pelican Lake is the first lake (water flow-wise) in the Pelican Group of Lakes. The Pelican River flows into Little Pelican Lake on the east side and exits on the south central side.

Little Pelican Lake is considered a shallow lake, meaning the majority of its area is less than 15 feet deep. Shallow lakes provide some of the most important wildlife habitat. Aquatic plants in and around the lake are home to nearly all aquatic animals such as waterfowl, muskrats, otters, fish, insects, frogs and turtles. These lakes are also important resting areas for migrating waterfowl. A healthy shallow lake has clear water and dense aquatic plant growth. Many shallow lakes, such as Little Pelican, have large stands of bulrush and/or wild rice. The plants in these shallow lakes lock up a lot of the nutrients in their tissues so that there is not as much algae growth, and they produce oxygen throughout the water as a byproduct of photosynthesis. These plants also keep the sediments stable at the bottom of the lake and not mixed up into the water column.

Currently, the main threats to Little Pelican Lake include the removal of aquatic plants, unnatural shorelines (manicured lawns by the lake), any new development that clears vegetation, and boats with large motors speeding around in the lake.

Water quality data have been collected in Little Pelican Lake since 1997. These data show that the lake is mesotrophic (TSI 48), which is characteristic of a dense aquatic plant population and clear water most of the summer.

## Vitals

| | |
|---|---|
| MN Lake ID: | 56-0761-00 |
| County: | Otter Tail |
| Ecoregion: | North Central Hardwood Forest |
| Major Drainage Basin: | Red River |
| Latitude/Longitude: | 46.70833333 / -95.94950000 |
| Water Body Type: | Public |
| Monitored Sites: | 201, 202 |
| Invasive species present: Zebra Mussels (confirmed September 2009), Curly-leaf pondweed | |

## Physical Characteristics

| | | |
|---|---|---|
| Surface area (acres): | 345 | |
| Littoral area (acres): | 256 | |
| % Littoral area: | 74% | |
| Max depth (ft): | 25 | (m): 7.6 |
| Mean depth (ft): | 12 | (m): 3.7 |
| Lakeshed size (acres): | 1,899 | |
| Lakeshed : lake area ratio | 5.5 : 1 | |
| Inlets | Pelican River | |
| Outlets | Pelican River | |
| Public Accesses | 1 shared with Pelican Lake | |

## Data Availability

Transparency data  Data exist from the MPCA CLMP program from 1997-2015, and RMB Labs from 2003-2015.

Chemical data  Data exist from RMB Labs from 2003-2015.

Inlet/Outlet data  The Pelican River has been monitored by RMB Lab from 2002-2015.

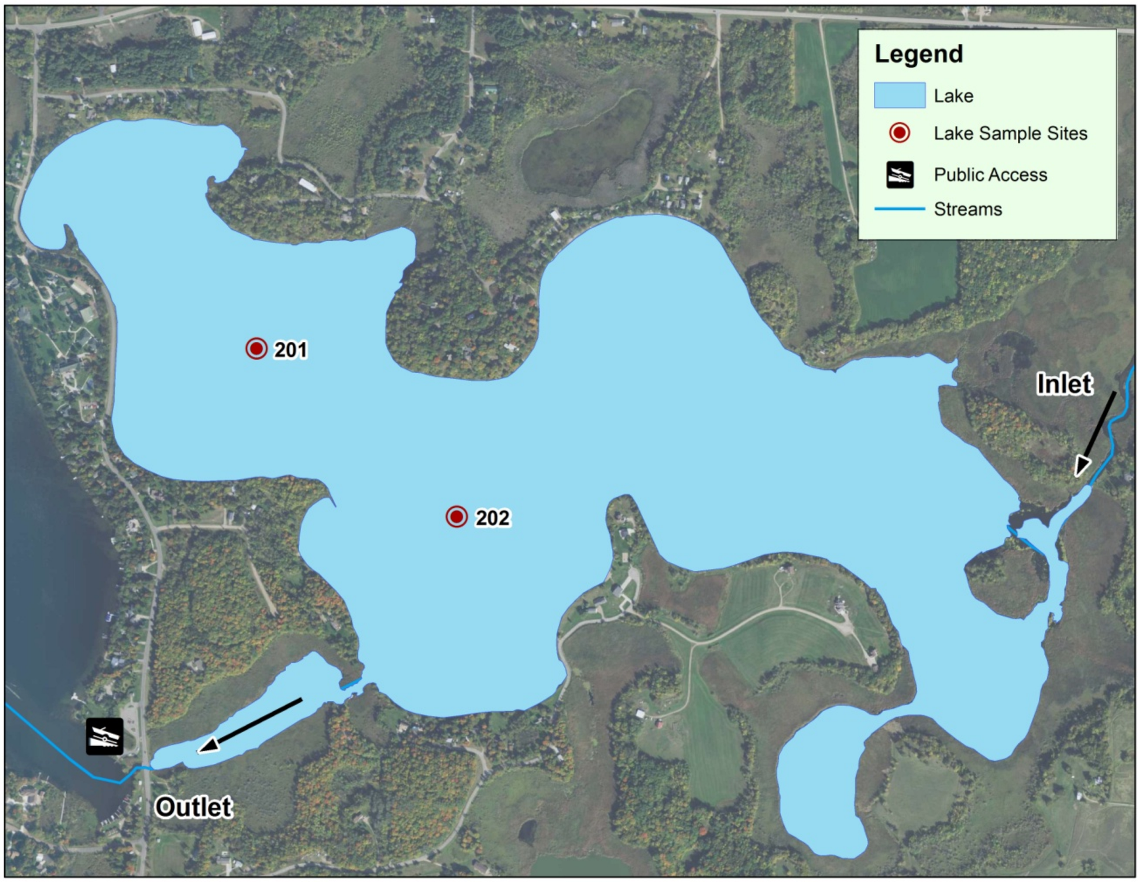



Figure 3.1 Map of Little Pelican Lake illustrating lake sample site locations, stream inlets and outlets and aerial land use. The pink shaded areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic plants to grow.

| Lake Site | Depth (ft) | Monitoring Programs |
|---|---|---|
| 201 | 25 | CLMP: 1997-2015 |
| 202 | 20 | PGOLID: 2003-2015 |

KEY:
CLMP (MPCA Citizens Lake Monitoring Program)
PGOLID (Pelican Group of Lakes Improvement District)

The information below describes available chemical data for Little Pelican Lake through 2015. Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion.

Below are typical measurements one might find for lakes in this ecoregion.

| Parameter | Mean | Ecoregion Range[1] | Interpretation |
|---|---|---|---|
| Total phosphorus (ug/L) | 23.9 | 23 – 50 | Results are within the expected range for the ecoregion. See page 42 for more details. |
| Chlorophyll *a* (ug/L) [2] | 9.5 | 5 – 22 | |
| Chlorophyll *a* max (ug/L) | 31 | 7 – 37 | |
| Secchi depth (ft) | 8.2 | 4.9 – 10.5 | |
| Dissolved oxygen | *See page 41* | | Dissolved oxygen depth profiles show that the lake mixes throughout most of the summer. |
| Total Kieldahl Nitrogen (mg/L) | 0.6 | 0.62 – 1.2 | Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms. |
| Ortho phosphorus (surface, ug/L) | 5.7 | NA | Indicates that all available ortho-phosphorus is taken up by plants and algae living in the lake. |
| Alkalinity (mg/L) | 181 | 75 – 150 | Indicates a low sensitivity to acid rain and a good buffering capacity. |
| Color (Pt-Co Units) | 12.7 | 10-20 | Indicates moderately clear water with little to no tannins (brown stain). |
| Total Suspended Solids (mg/L) | 2.8 | 2 – 6 | Within the ecoregion average range indicating mostly clear water with some algae. |
| Total Nitrogen : Total Phosphorus | 25:1 | 25:1 – 35:1 | The lake is most likely phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake. |
| Calcium (mg/L) | 34.9 | NA | Indicates a hard water lake with sufficient calcium for Zebra mussel survival. |
| Magnesium (mg/L) | 27.3 | NA | Indicates a hard water lake. |

*Data Source: 2003-2015 PGOLID Monitoring Program*

[1]The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes
[2]Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

## Water Quality Characteristics - Historical Means

Years monitored: 1997-2015

| Parameters | Site 201 | Site *202 |
|---|---|---|
| **Total Phosphorus Mean (ug/L):** | | **23.9** |
| Total Phosphorus Min: | | 10 |
| Total Phosphorus Max: | | 48 |
| Number of Observations: | | 93 |
| **Chlorophyll *a* Mean (ug/L):** | | **9.5** |
| Chlorophyll *a* Min: | | 1 |
| Chlorophyll *a* Max: | | 31 |
| Number of Observations: | | 93 |
| **Secchi Depth Mean (ft):** | **8.1** | **8.5** |
| Secchi Depth Min: | 3.9 | 3.9 |
| Secchi Depth Max: | 18.0 | 19.0 |
| Number of Observations: | 208 | 93 |

*primary site

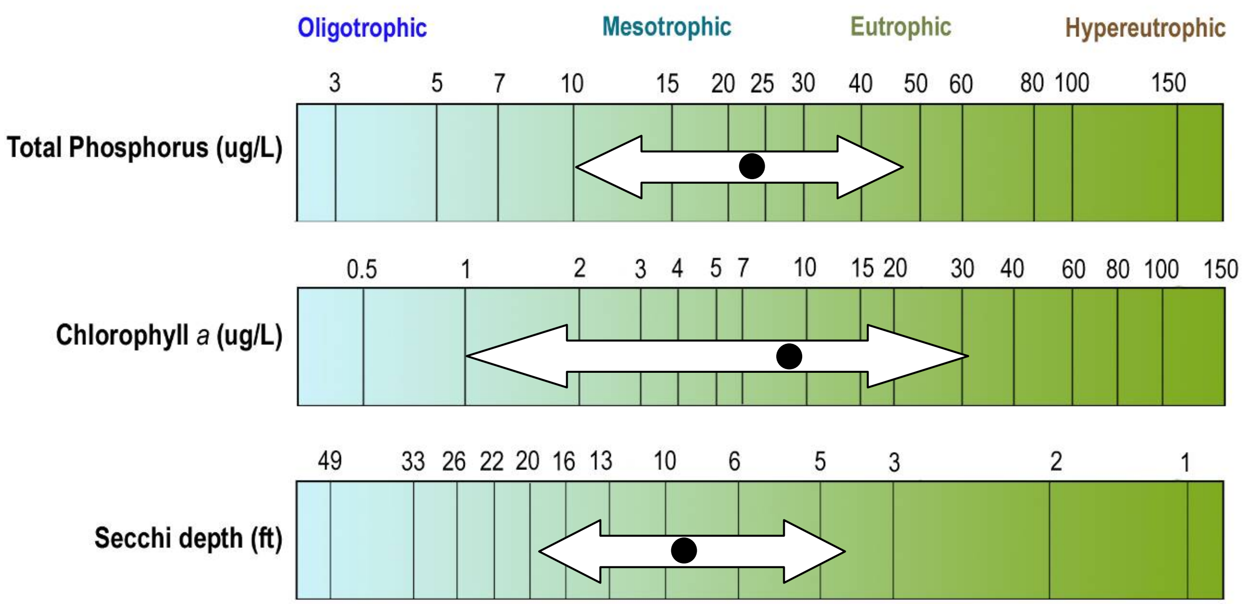



Figure 3.2 Little Pelican Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 202). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (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 amount 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. Site 201 in Little Pelican Lake has been monitored from 1997-2015 by a volunteer living on the lake. The annual means for Little Pelican Lake range from 5.5-10.4 ft (Figure 3.3). The annual mean transparency hovers right around the historical mean with not much digression except for 2005. Transparency was highest in 2010 and lowest in 2005.

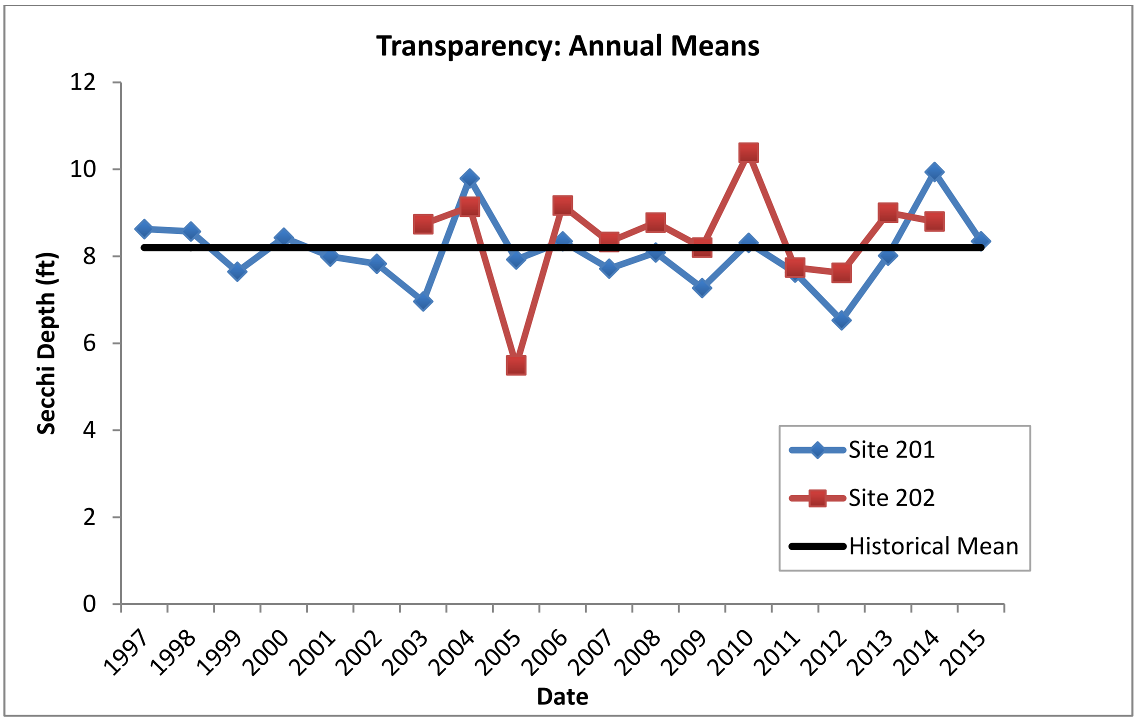



Figure 3.3 Little Pelican Lake annual mean transparency for site 201.

Little Pelican Lake transparency ranges from 4 to 18 feet throughout the summer. Figure 3.4 shows the seasonal transparency dynamics. Little Pelican Lake transparency is highest in May and early June and then declines throughout the summer. After the lake turns over in September the transparency improves in October. This pattern is typical for a lake of this depth in Minnesota. The transparency dynamics have to do with algae population dynamics and lake turnover.

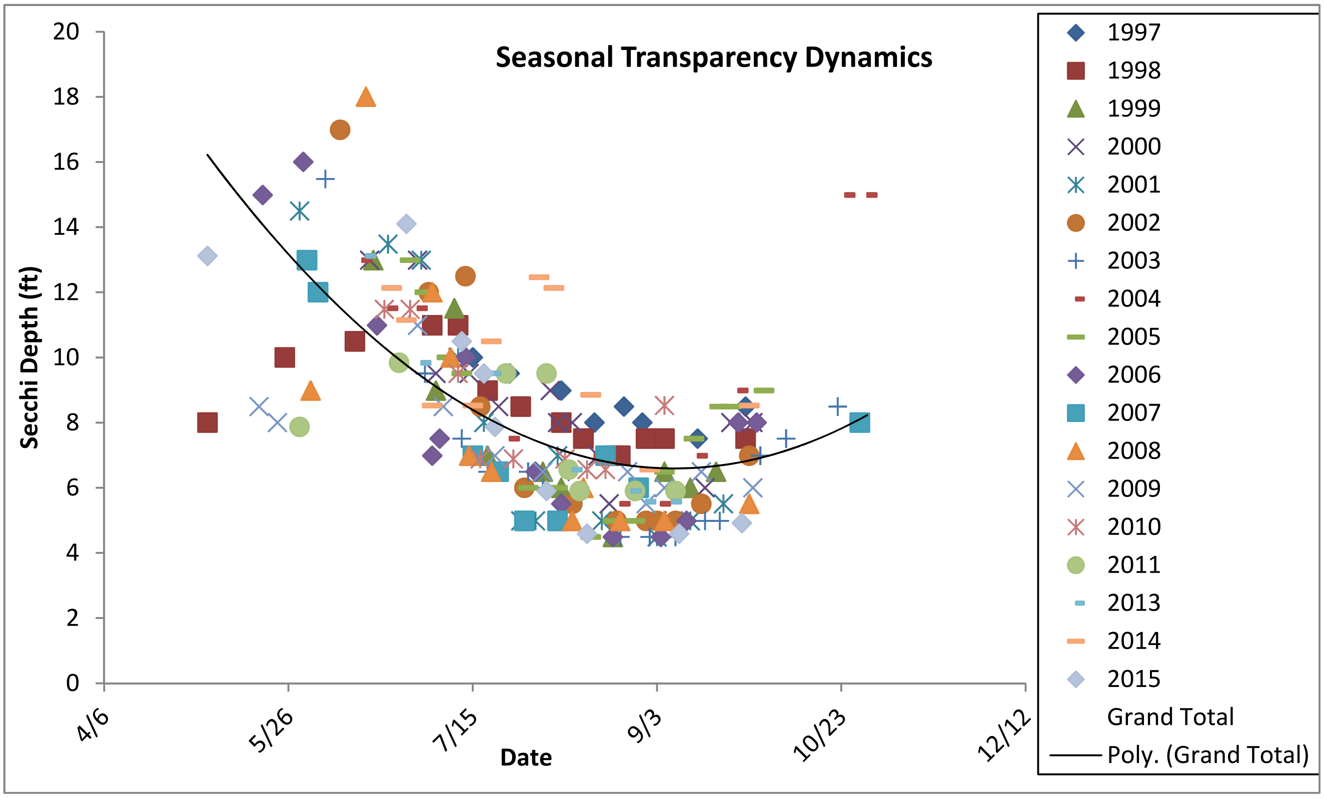
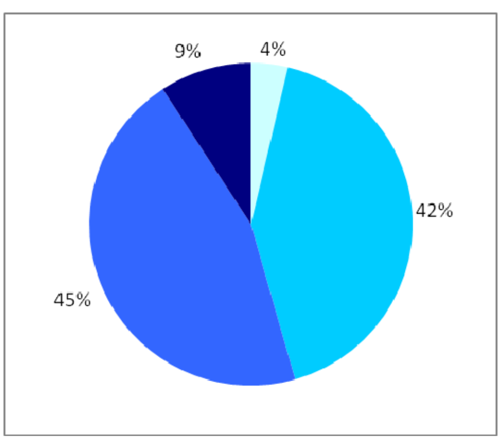



Figure 3.4 Seasonal transparency dynamics and year-to-year comparison.

# User Perceptions

When Secchi depth readings are collected, the perceptions of the water based on the physical appearance and the recreational suitability is recorded. 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 rating decreases. Little Pelican Lake was rated as having "definite algae" 45% of the time between 1997-2015 (Figure 3.5).




**Physical Appearance Rating**

| | |
|---|---|
| 4% | Crystal clear water |
| 42% | Not quite crystal clear – a little algae visible |
| 45% | Definite algae – green, yellow, or brown color apparent |
| 9% | High algae levels with limited clarity and/or mild odor apparent |
| 0% | Severely high algae levels |

Figure 3.5. Physical appearance rating, as rated by the lake monitor (1997-2015).

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Little Pelican Lake was rated as having "swimming and aesthetic enjoyment of the lake slightly impaired because of algae levels" 37% of the time from 1997-2015 (Figure 3.6). For 88% of the time, Little Pelican Lake was rated as being swimmable.

**Recreational Suitability Rating**

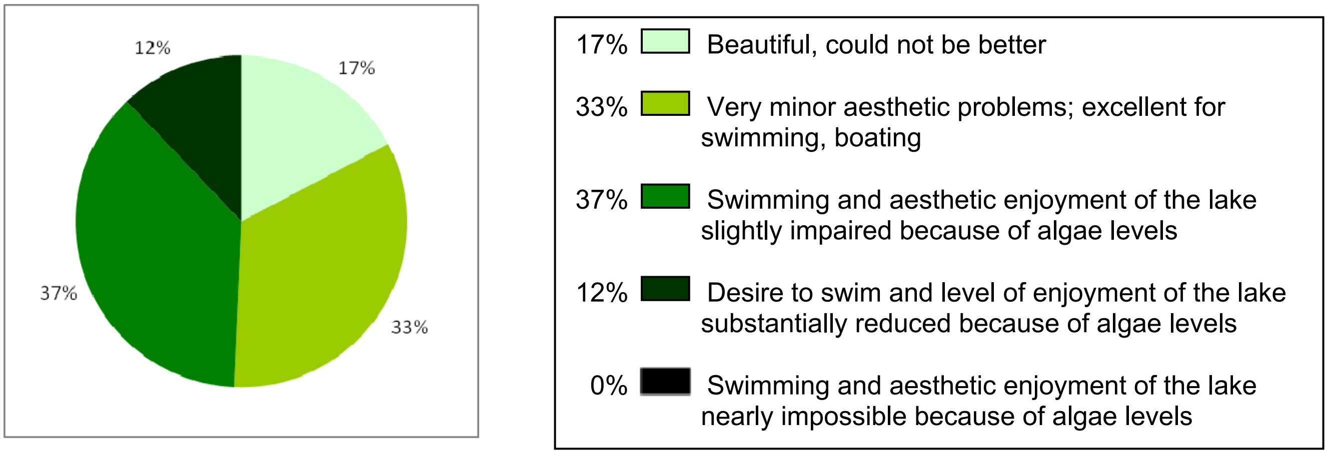



Figure 3.6. Recreational suitability rating, as rated by the lake monitor (1997-2015).

# Total Phosphorus

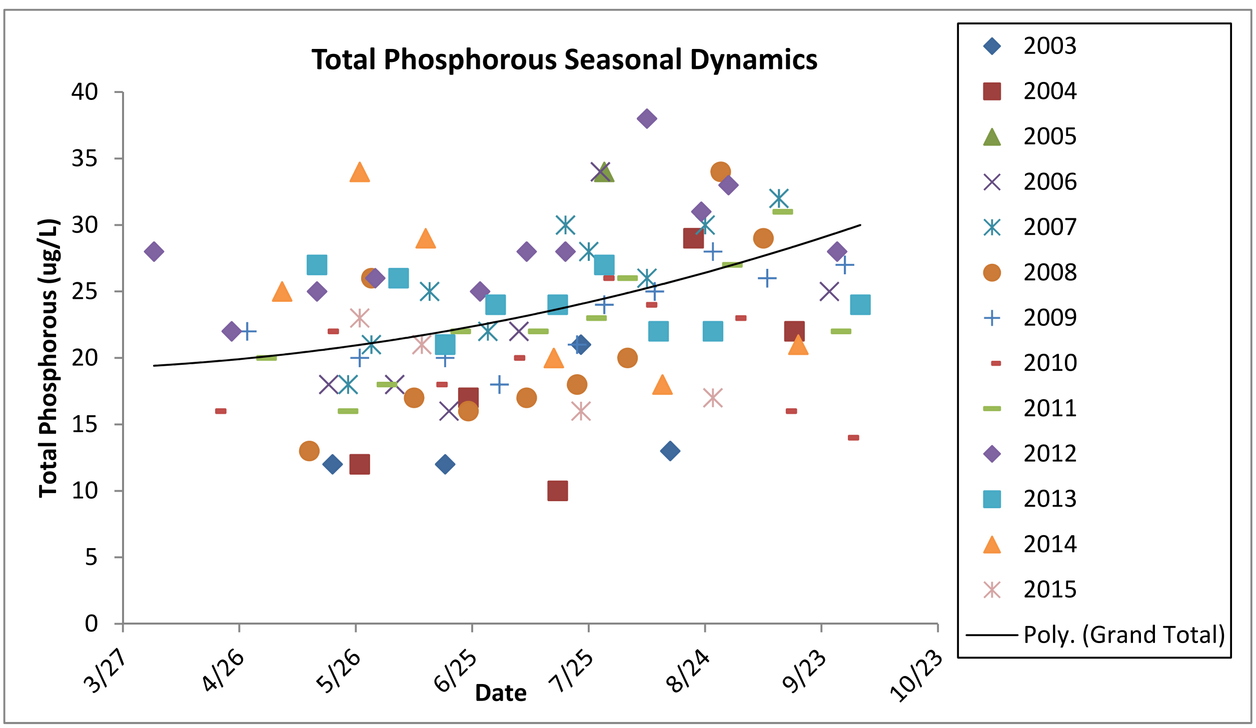



Figure 3.7 Historical total phosphorus concentrations (ug/L) for Little Pelican Lake site 202 (data set from 2003-2015). The black line is the best fit line to show the seasonal pattern.

Little Pelican Lake is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus. The total phosphorus concentration starts out low in the spring and gradually increases throughout the summer (Figure 3.7). There are two possible explanations to this pattern. One is that it follows the pattern in the Pelican River since that is a very large inlet to Little Pelican Lake. The other possible explanation is internal loading.

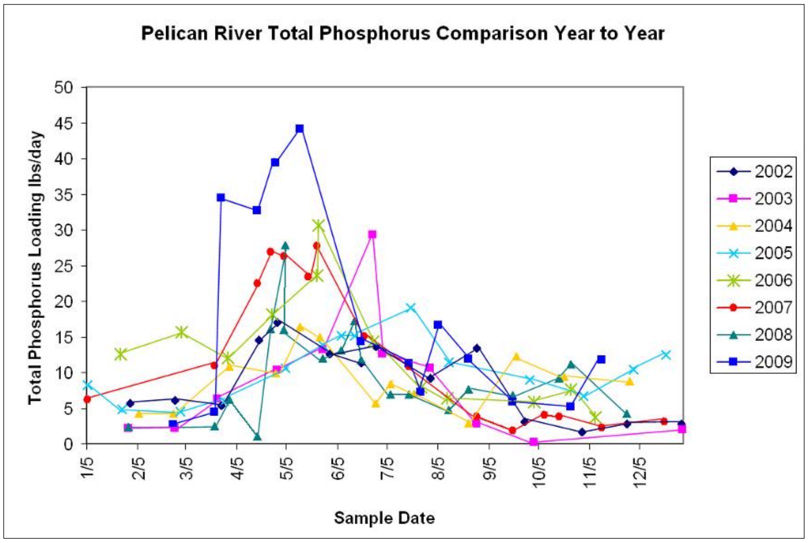



Figure 3.8 Pelican River total phosphorus loading pattern year to year.

Because data has been collected at the Pelican River inlet to Little Pelican Lake since 2002, we can compare those phosphorus concentrations to Little Pelican Lake.

Figure 3.8 shows that the phosphorus loading in Pelican River peaks in the spring and declines throughout the summer, so it is most likely not the cause of increasing phosphorus throughout the summer in Little Pelican Lake.

In 2009, water samples were collected just above the lake bottom to measure internal loading in Pelican Lake. Internal loading typically occurs in mid-summer when the oxygen at the bottom of the lake (hypolimnion) is depleted. When there is no oxygen in the hypolimnion, a chemical reaction occurs where phosphorus is released from the lake sediment back into the water. Then in the fall when the lake turns over this phosphorus comes up to the surface.

In shallow lakes (where the majority of the lake surface area is 15 feet deep or less) this pattern is somewhat different because the lake is not deep enough to strongly stratify. The lake may weakly stratify after a stretch of hot calm weather and then a day of strong wind will mix the lake up again. This means that the phosphorus in the lake sediment is constantly being replenished at the surface, which could explain the pattern seen in Figure 3.7.

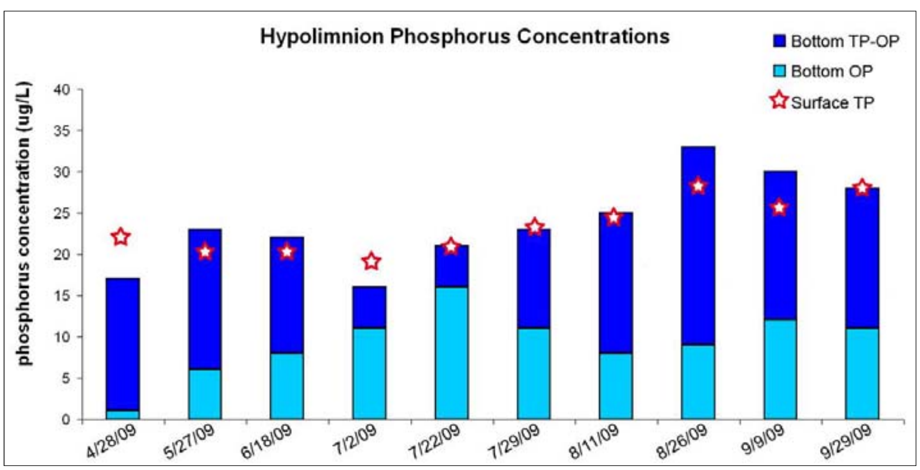



Figure 3.9. Hypolimnion phosphorus concentrations (ug/L) for Little Pelican Lake (data set from 2009).

Figure 3.9 shows that Little Pelican Lake follows a typical pattern shallow lake for internal loading. Most of the summer the hypolimnion phosphorus concentrations are similar to the surface water concentrations because the lake water column is fully mixed. On August 26th, the hypolimnion phosphorus concentration is higher than the surface, which could mean that the lake is weakly stratified and a windy day would mix phosphorus back up to the surface of the lake. The dissolved oxygen and temperature profiles on page 41 show that Little Pelican Lake was stratified on August 26, 2009.

# Chlorophyll *a*

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.

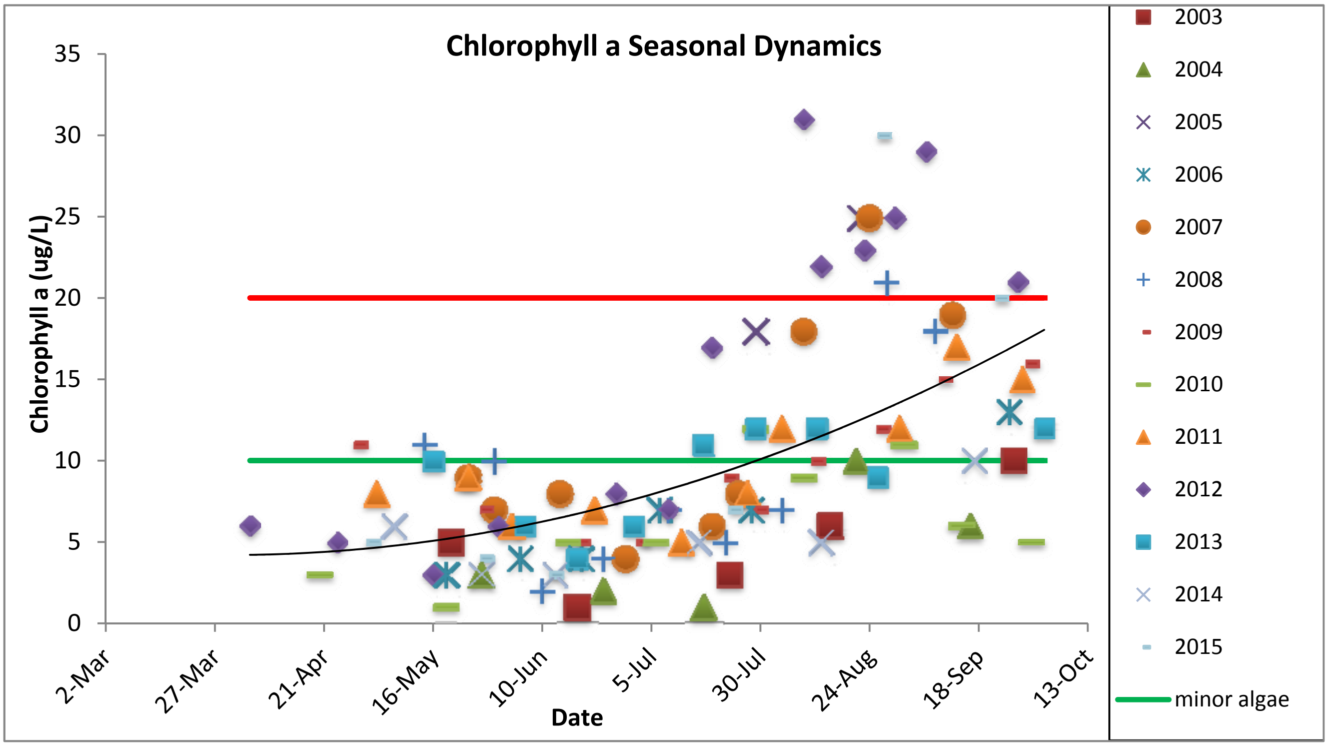


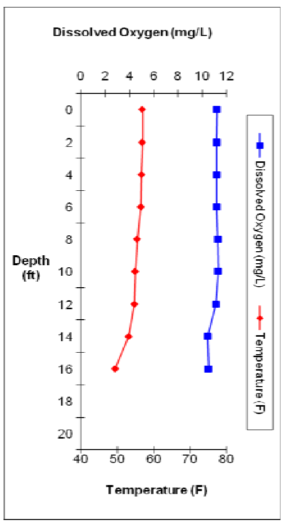

Figure 3.10 Chlorophyll a concentrations (ug/L) for Little Pelican Lake (data set from 2003-2015).

Chlorophyll *a* was evaluated in Little Pelican Lake in 2003-2015 (Figure 3.10). Chlorophyll *a* concentrations start out low in June and then increase to a peak in mid to late August. This pattern follows the phosphorus concentration because phosphorus is food for the algae (Figure 3.7). Chlorophyll *a* concentrations in Little Pelican Lake reached 10 ug/L every year indicating minor algae blooms toward the end of the summer. In 2005, 2007, 2008, 2012, and 2015 chlorophyll *a* concentrations reached 20 ug/L indicating nuisance algae blooms in late August. These chlorophyll *a* levels are typical for a shallow lake in northern Minnesota.

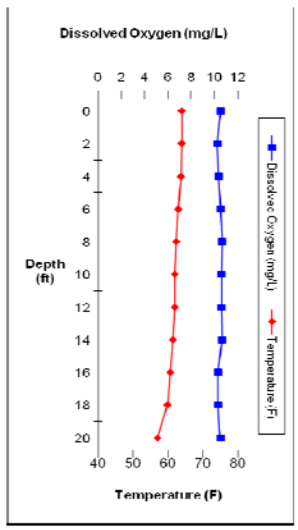
# Dissolved Oxygen

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 oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fish.

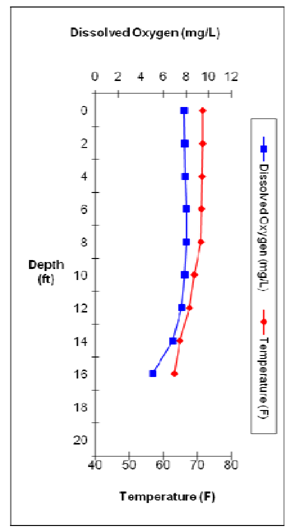
Little Pelican Lake is a shallow lake, with the majority of its depth less than 20 ft. Shallow lakes aren't deep enough to stratify throughout the whole summer. The dissolved oxygen/temperature profiles below show the dynamics in Little Pelican Lake in the summer of 2015. The graph shows that the temperature remains consistent from the surface of the lake to the bottom, which indicates no thermal stratification. On some dates in July and August the oxygen was depleted at the bottom of the lake. This usually occurs after a few warm calm days, and then a wind will mix the water column again.



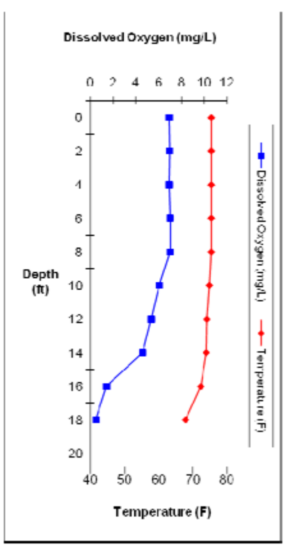

5/1/2015



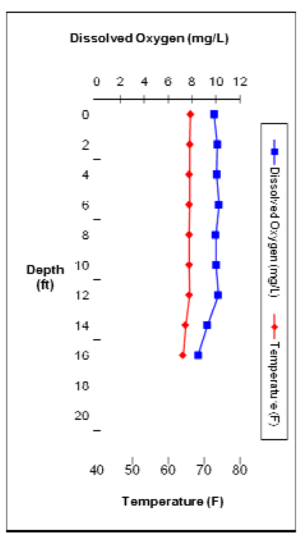

5/27/2015



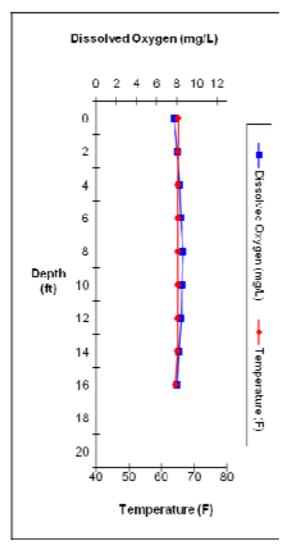

6/12/2015




7/23/2015




8/26/2015




9/22/2015

# Trophic State Index

| Trophic State Index | Site 202 |
|---|---|
| TSI Total Phosphorus | 50 |
| TSI Chlorophyll-a | 53 |
| TSI Secchi | 46 |
| TSI Mean | 50 |
| Trophic State: | Mesotrophic/Eutrophic |

*Numbers represent the mean TSI for each parameter.*

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases.

The results from these three measurements cover different units and ranges and thus cannot be directly compared to each other or averaged. In order to standardize these three measurements to make them directly comparable, we convert them to a trophic state index (TSI).

The mean TSI for Little Pelican Lake falls in the mesotrophic/eutrophic border (Figure 3.11). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related.

Higher mesotrophic lakes (TSI=47-49) are characteristic of a dense aquatic plant population and algae blooms in mid to late summer. Fishing consists of panfish and bass.

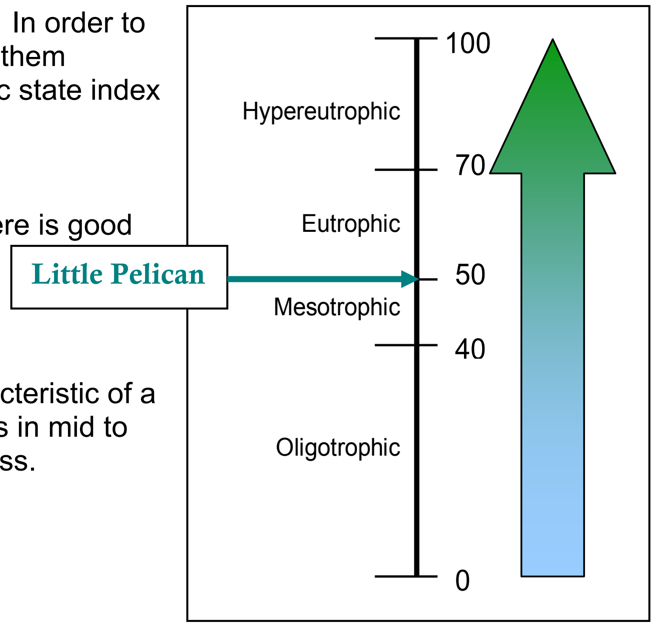



Figure 3.11 Trophic state index chart with corresponding trophic status.

| TSI | Attributes | Fisheries & Recreation |
|---|---|---|
| <30 | **Oligotrophy:** Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water. | Trout fisheries dominate. |
| 30-40 | Bottom of shallower lakes may become anoxic (no oxygen). | Trout fisheries in deep lakes only. Walleye, Tullibee 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.

Little Pelican Lake has enough data to analyze long-term trends. The data was analyzed using the Mann Kendall Trend Analysis.

| Lake Site | Parameter | Date Range | Trend |
|---|---|---|---|
| 202 | Total Phosphorus | 2003-2015 | No Trend |
| 202 | Chlorophyll *a* | 2003-2015 | No Trend |
| 202 | Transparency | 2003-2015 | No Trend |
| 201 | Long Term Transparency | 1997-2011 | No Trend |

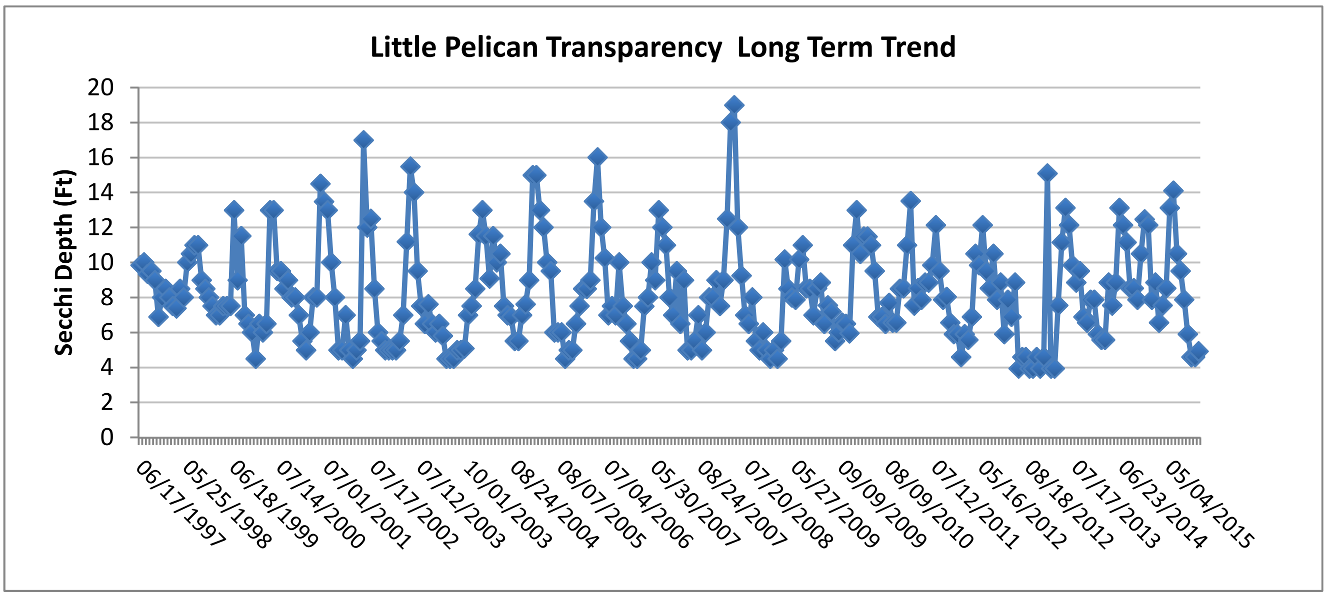
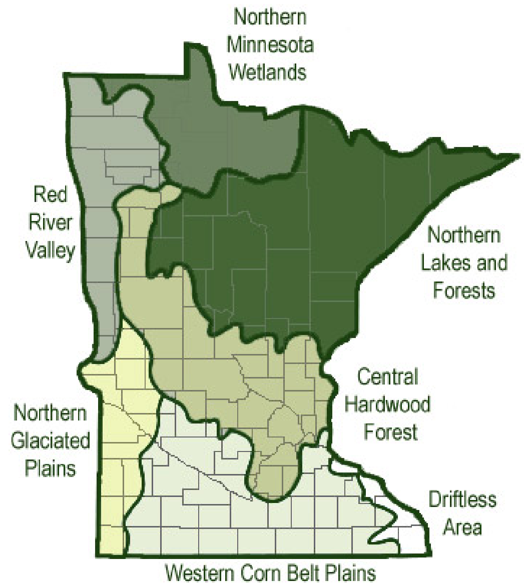



Figure 3.13 Little Pelican Lake long term transparency trend from 1997-2015.

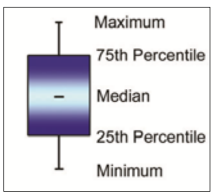
Little Pelican Lake shows no current trends in water quality. The majority of phosphorus loading into Little Pelican Lake comes from the Pelican River (89%), while 8% comes from runoff, 2% from precipitation and 1% from septic systems (see page 94 for lake loading models).

Little Pelican Lake has a very dense native plant population along with emergent plants such as bulrush and cattails. This vegetation has been increasingly removed over the past decade, which could contribute to higher phosphorus levels. The aquatic plants take up a lot of the phosphorus in the water and stabilize the lake sediments. When aquatic plants are removed, the phosphorus is available for more algae growth. In order to maintain the water quality in Little Pelican Lake, aquatic plants should be protected and not removed by homeowners.

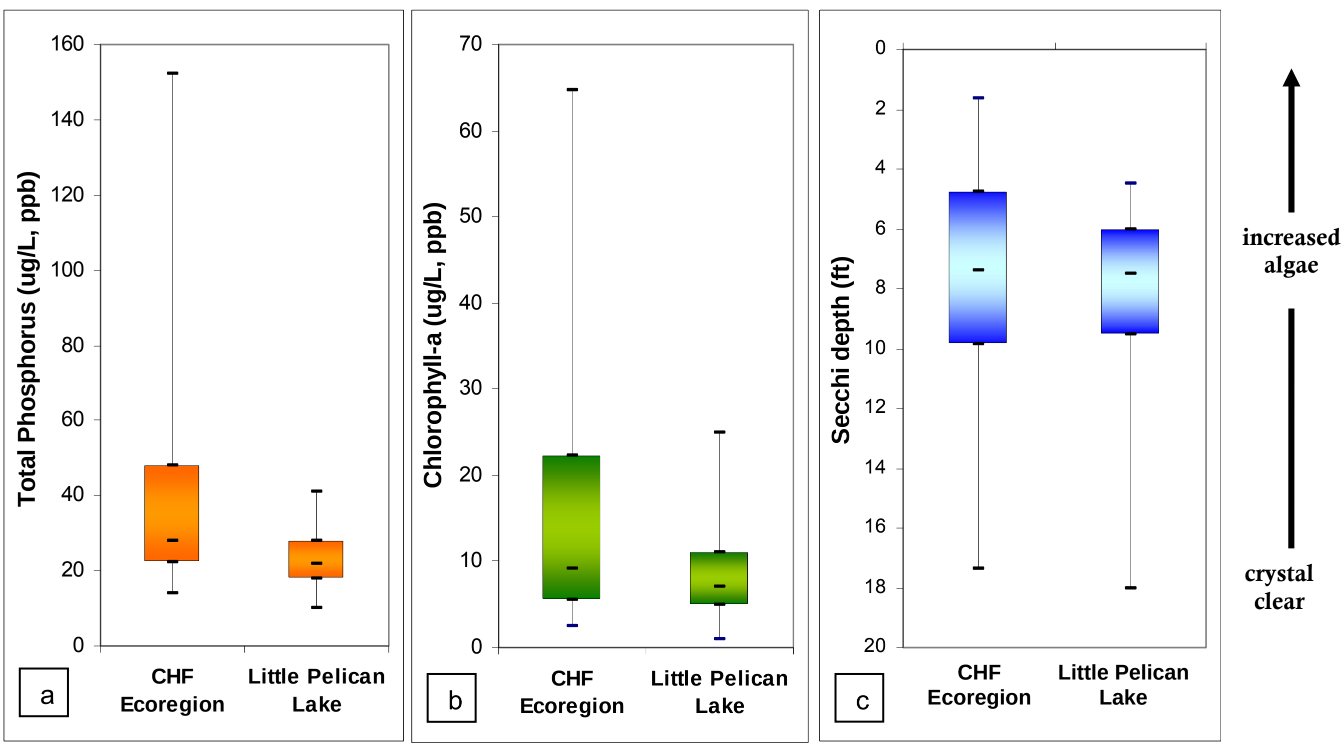
# Ecoregion Comparisons




Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.




Little Pelican Lake is in the Central Hardwood Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Little Pelican Lake are all within the expected ecoregion ranges (Figures 3.14a-c).




Figures 3.14a-c. Little Pelican Lake ranges compared to North Central Hardwood Forest Ecoregion ranges (data from 2003-2009).

## State Assessments (Minnesota Pollution Control Agency)

**Impaired Waters Assessment 303(d) List**
There are two main types of Impaired Waters Assessment for lakes: eutrophication (excess phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption. Little Pelican Lake is not listed as impaired for mercury in fish tissue; however, Pelican Lake is listed and is connected to Little Pelican Lake. Therefore, the fish in Little Pelican Lake should be considered impaired for mercury as well. See page 111 for fish consumption guidelines. Little Pelican Lake is not listed as impaired for eutrophication.

**Aquatic Recreational Use Assessment 305(b)**
In the 2008 MPCA Aquatic Use Assessment (305(b)), Little Pelican Lake was classified as being fully supporting for Aquatic Recreational Use.

## Shallow Lakes and plants vs. algae (*article by Moriya Rufer*)

Have you ever wondered why shallow lakes have such dense aquatic plant growth? Having aquatic plants established in a shallow lake is a good thing, because the alternative is not so desirable. This article explains the natural state and importance of shallow lakes and what happens if this natural state is not protected.

Before we go any further, let's define "shallow". Shallow lakes are lakes where the sunlight can reach the bottom. Generally, this corresponds to 15 feet deep or less. Since the sunlight can reach the bottom, plants are able to grow there. Examples of shallow lakes in the Detroit Lakes area include Little Pelican, Rock, Rice, Rossman, Marshall, and Shell Lakes.

Shallow lakes provide some of the most important wildlife habitat. Aquatic plants in and around the lake are home to nearly all aquatic animals such as waterfowl, muskrats, otters, fish, insects, frogs and turtles. These lakes are also important resting areas for migrating waterfowl. There are over 5,000 shallow lakes in Minnesota that are over 50 acres in size.

Shallow lakes behave differently and have different dynamics than deep lakes. Deep lakes only mix in spring and fall, and the bottom of deep lakes stays cold and dark because light cannot reach the bottom. Shallow lakes, in contrast, mix all summer because light reaches the bottom of the lake and warms the whole water column.

A healthy shallow lake has clear water and dense aquatic plant growth. Many shallow lakes have large stands of bulrush and/or wild rice. The plants in these shallow lakes lock up a lot of the nutrients in their tissues so that there is not as much algae growth, and they produce oxygen throughout the water as a byproduct of photosynthesis. These plants also keep the sediments stable at the bottom of the lake and not mixed up into the water column. Tiny invertebrates called zooplankton eat algae and use plants as a hiding place from their predators (perch, sunfish and crappies).

Unfortunately, if a shallow lake isn't taken care of, it can turn into pea soup. If large areas of plants are removed by pulling them out, cutting them with a weed roller or with a boat motor, the sediments can get churned up and nutrients are released. If there are fewer plants to use the nutrients, the algae will use them and multiply. In addition, bulrushes and wild rice are protected by the DNR, and a DNR permit is necessary to remove them.

Once the water is "green" with dense algae, these lakes have mostly muck on the bottom instead of plants because the sunlight can't get through the dense algae to the bottom of the lake. Algae-dominated shallow lakes are also not as high of quality habitat for fish and wildlife. If the plants are gone there is no place for aquatic animals to hide. In addition, the oxygen at the bottom of these shallow lakes is usually depleted because of all the decomposition of dead algae that sinks to the bottom.

If there are fewer plants, the zooplankton have nowhere to hide and are eaten up by small fish. With the zooplankton gone, there is nothing to eat the algae and keep it in check. The lake just continues to support more algae.

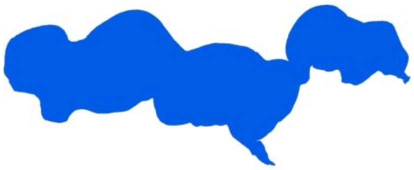
All these factors are like a positive feed back loop that just keeps pushing the lake towards more and more algae, cloudier (turbid) water, and less plants and wildlife.

If you live on a shallow lake, keep in mind that the natural state of the lake is to have abundant aquatic vegetation. Enjoy the excellent bird and wildlife viewing available on these lakes.

To learn more about shallow lakes, visit:
http://www.dnr.state.mn.us/wildlife/shallowlakes/index.html.

# Pelican Lake 56-0786-00 OTTER TAIL COUNTY

## Summary



Pelican Lake is the largest lake in the Pelican Group of Lakes. The Pelican River enters Pelican Lake on the east end, and Spring Creek and Bob Creek enter Pelican Lake on the west end. The Pelican River exits Pelican Lake to the south, flowing through Fish Lake until finally exiting the Pelican Group of Lakes.

Due to its size, good fishing and good recreational opportunities, Pelican Lake is one of the most popular tourism lakes in northwest Minnesota. Approximately half of the Pelican Lake visitors come from North Dakota.

In 2009, Zebra mussels were found in Pelican Lake. Due to the size of the mussels and their distribution, it was concluded that they have probably been established in the lake for over a year. Unfortunately, at this time there is no treatment or fix for zebra mussels.

Currently, the main threats to Pelican Lake include land use changes upstream from the inlets, removal of aquatic plants, unnatural shorelines (manicured lawns by the lake), any new development that clears vegetation, and boats with large motors speeding around in the lake in areas less than 10 feet deep. The west end of Pelican Lake is most susceptible to boat motor stirring because it is shallow.

Water quality data have been collected in Pelican Lake since 1997. These data show that the lake is mesotrophic, which is characteristic of moderately clear water all summer.

## Vitals

| | |
|---|---|
| MN Lake ID: | 56-0786-00 |
| County: | Otter Tail |
| Ecoregion: | North Central Hardwood Forest |
| Major Drainage Basin: | Red River |
| Latitude/Longitude: | 46.70138889 / -96.02805556 |
| Water Body Type: | Public |
| Monitored Sites: | 206 (primary), 201, 205 |
| Invasive species present: | Zebra Mussels (confirmed September 2009), Curly-leaf pondweed |

## Physical Characteristics

| | | |
|---|---|---|
| Surface area (acres): | 3,986 | |
| Littoral area (acres): | 1,625 | |
| % Littoral area: | 40% | |
| Max depth (ft): | 55 | (m): 16.8 |
| Mean depth (ft): | 22 | (m): 6.7 |
| Lakeshed size (acres): | 15,783 | |
| Lakeshed : lake area ratio | 4 : 1 | |
| Inlets | Pelican River, Bob Creek, Spring Creek | |
| Outlets | Pelican River to Fish Lake | |
| Public Accesses | 2 | |

## Data Availability

| | | |
|---|---|---|
| Transparency data |  | Data exist from the MPCA CLMP program from 1996-2002, and RMB Labs from 2003-2015. |
| Chemical data |  | Data exist from RMB Labs from 2003-2015. |
| Inlet/Outlet data |  | The inlets and outlets been monitored by RMB Lab from 2002-2015. |

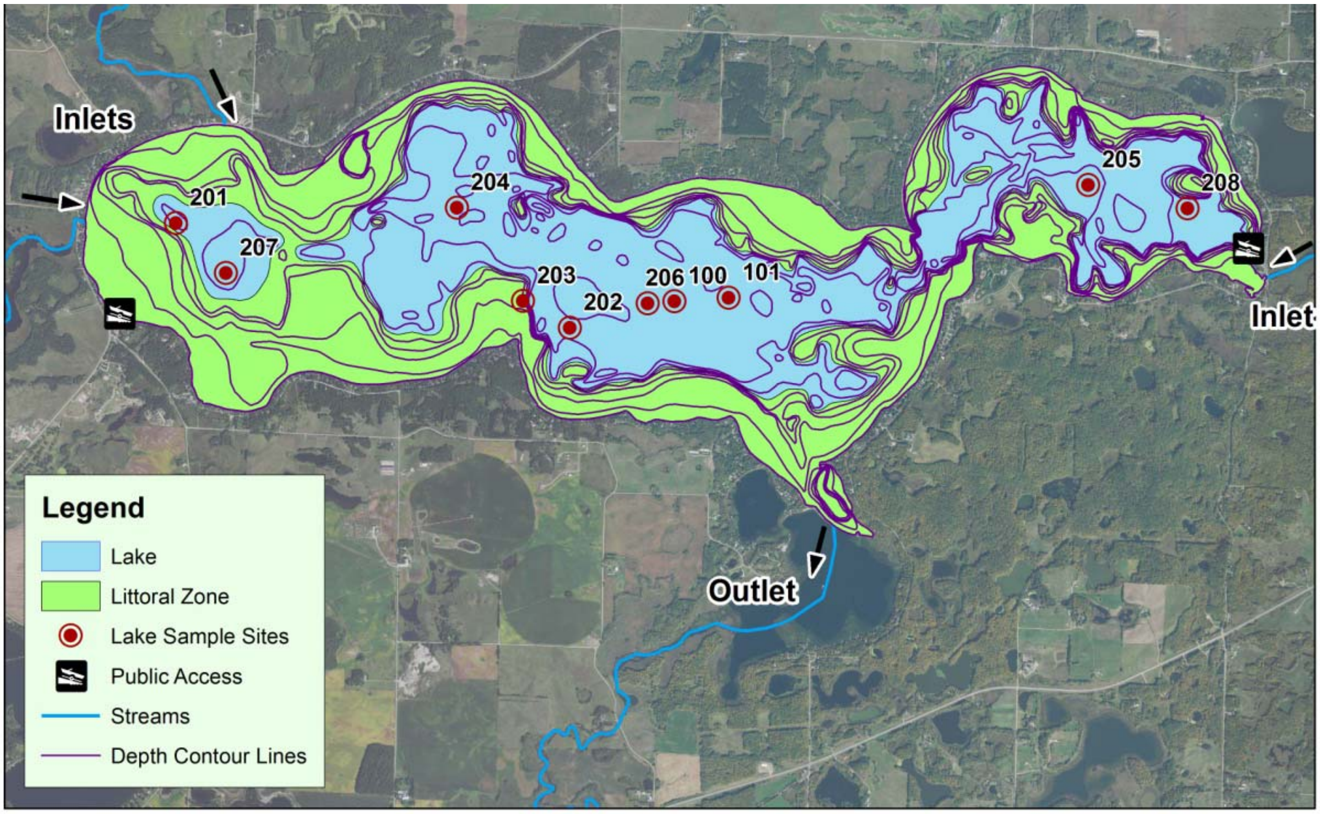



Figure 3.15. Map of Pelican Lake illustrating bathymetry, lake sample site locations, stream inlets and outlets and aerial land use.  The pink shaded areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom allowing aquatic plants to grow.

| Lake Site | Depth (ft) | Monitoring Programs |
|---|---|---|
| 201 | 30 | CLMP: 1982, 1995-1996;<br>PGOLID: 2007-2015 |
| 202 | 40 | CLMP: 1982-1985, 1995 |
| 203 | 20 | CLMP: 1988 |
| 204 (103) | 50 | CLMP: 1995-2008 |
| 205 | 52 | CLMP: 1995-2012;<br>PGOLID: 2007-2015 |
| 206 (19406, 101)<br>*Primary Site | 50 | MPCA: 1980, 1986, 1997, 2005<br>CLMP: 1996-2009<br>PGOLID: 2003-2015 |
| 207 | 30 | CLMP: 1997-2007 |
| 208 (102) | 40 | CLMP: 2006-2012 |

KEY:
CLMP (MPCA Citizens Lake Monitoring Program)
PGOLID (Pelican Group of Lakes Improvement District), monitoring done by Lake Resource Coordinator (RMB Lab)
MPCA (Minnesota Pollution Control Agency)

The information below describes available chemical data for Pelican Lake through 2009. Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion

| Parameter | Mean | Ecoregion Range[1] | Interpretation |
|---|---|---|---|
| Total phosphorus (ug/L) | 15.2 | 23 - 50 | Results are better than the expected range for the ecoregion. For more details, see page 60. |
| Chlorophyll *a* (ug/L) [2] | 4.8 | 5 – 22 | |
| Chlorophyll *a* max (ug/L) | 17 | 7 – 37 | |
| Secchi depth (ft) | 12.7 | 4.9 – 10.5 | |
| Dissolved oxygen | Dimictic *See page 58* | | Dissolved oxygen depth profiles show that the deep areas of the lake are anoxic in late summer. |
| Chloride (mg/L) | 17.8 | 4 - 10 | Slightly higher than the Ecoregion range, which could be due to winter road salt. |
| Total Kieldahl Nitrogen (mg/L) | 0.3 | 0.62 – 1.2 | Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms. |
| Ortho phosphorus (surface, ug/L) | 5.3 | NA | Indicates that all available ortho-phosphorus is taken up by plants and algae living in the lake. |
| Alkalinity (mg/L) | 179.3 | 75 – 150 | Indicates a low sensitivity to acid rain and a good buffering capacity. |
| Color (Pt-Co Units) | 6.5 | 10-20 | Indicates very clear water with little to no tannins (brown stain). |
| Total Suspended Solids (mg/L) | 1.6 | 2 – 6 | Below the ecoregion average range indicating clear water. |
| Specific Conductance | 404.7 | 300-400 | Within the ecoregion average range. |
| Total Nitrogen : Total Phosphorus | 20:1 | 25:1 – 35:1 | The lake is phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake. |
| Calcium (mg/L) | 33.6 | | Indicates a hard water lake with sufficient calcium for Zebra mussel survival. |
| Magnesium (mg/L) | 27.8 | | Indicates a hard water lake. |

*Data Source: 1997 MPCA LAP, 2003-2015 PGOLID Monitoring Program*

[1]The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes

[2]Chlorophyll *a* measurements have been corrected for pheophytin

Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

## Water Quality Characteristics - Historical Means

Years monitored: 1997-2015

| Parameters | Site 206* | Site 201 | Site 205 | Site 204 | Site 207 |
|---|---|---|---|---|---|
| **Total Phosphorus Mean (ug/L):** | **14.6** | **12.8** | **15.6** | **13.4** | |
| Total Phosphorus Min: | 5 | 6 | 5 | 10 | |
| Total Phosphorus Max: | 45 | 24 | 39 | 17 | |
| Number of Observations: | 122 | 73 | 75 | 5 | |
| **Chlorophyll *a* Mean (ug/L):** | **4.7** | **4.3** | **5.6** | **5.1** | |
| Chlorophyll *a* Min: | 1 | 1 | 1 | 2.8 | |
| Chlorophyll *a* Max: | 12 | 12 | 17 | 8.2 | |
| Number of Observations: | 122 | 73 | 75 | 5 | |
| **Secchi Depth Mean (ft):** | **13.0** | **13.1** | **12.1** | **15.9** | **11.7** |
| Secchi Depth Min: | 6.5 | 3.9 | 5.5 | 8.5 | 2.0 |
| Secchi Depth Max: | 35.0 | 32.1 | 27.9 | 29.0 | 19.3 |
| Number of Observations: | 198 | 126 | 251 | 99 | 84 |

*primary site

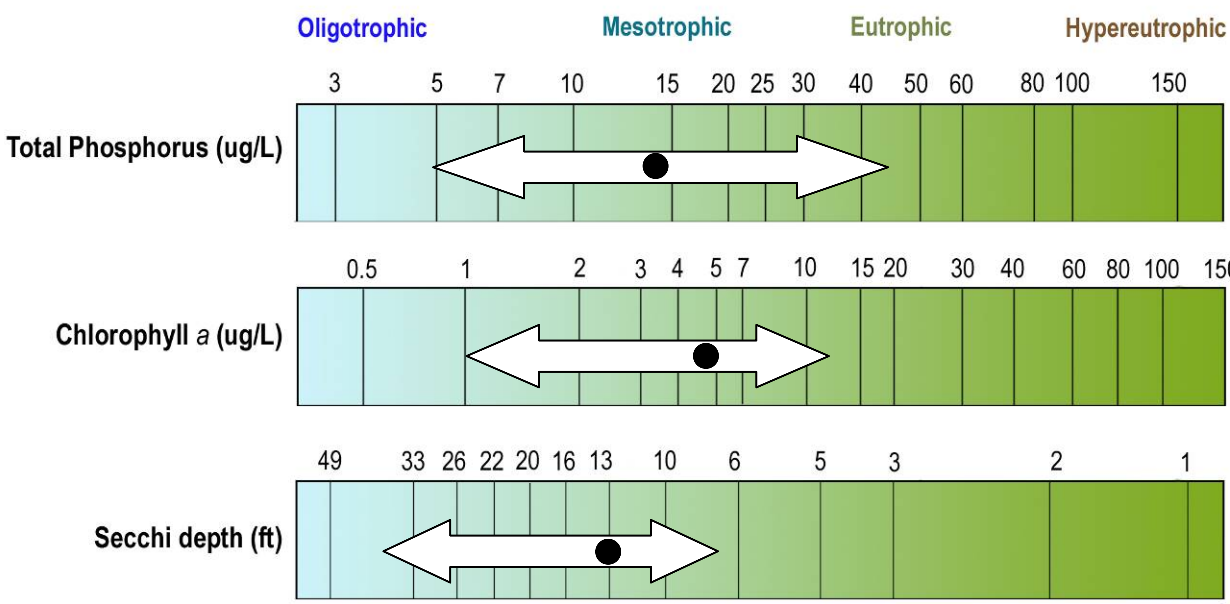



Figure 3.16. Pelican Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 206). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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 amount 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. Sites 205 and 206 in Pelican Lake have been monitored from 1996-2015, and Site 201 has been monitored from 2007-2015. The annual means for Pelican Lake range from 9.1-22.3 ft. Figure 3.17 shows that Site 206 in the middle of the lake consistently has the best transparency in the lake. Site 205 on the east end of the lake consistency has the lowest transparency, which makes sense because the Pelican River is the largest contributor of phosphorus to Pelican Lake. The Pelican River enters Pelican Lake on the east end. Transparency has been higher since 2011, which is likely due to Zebra mussels filtering the water.

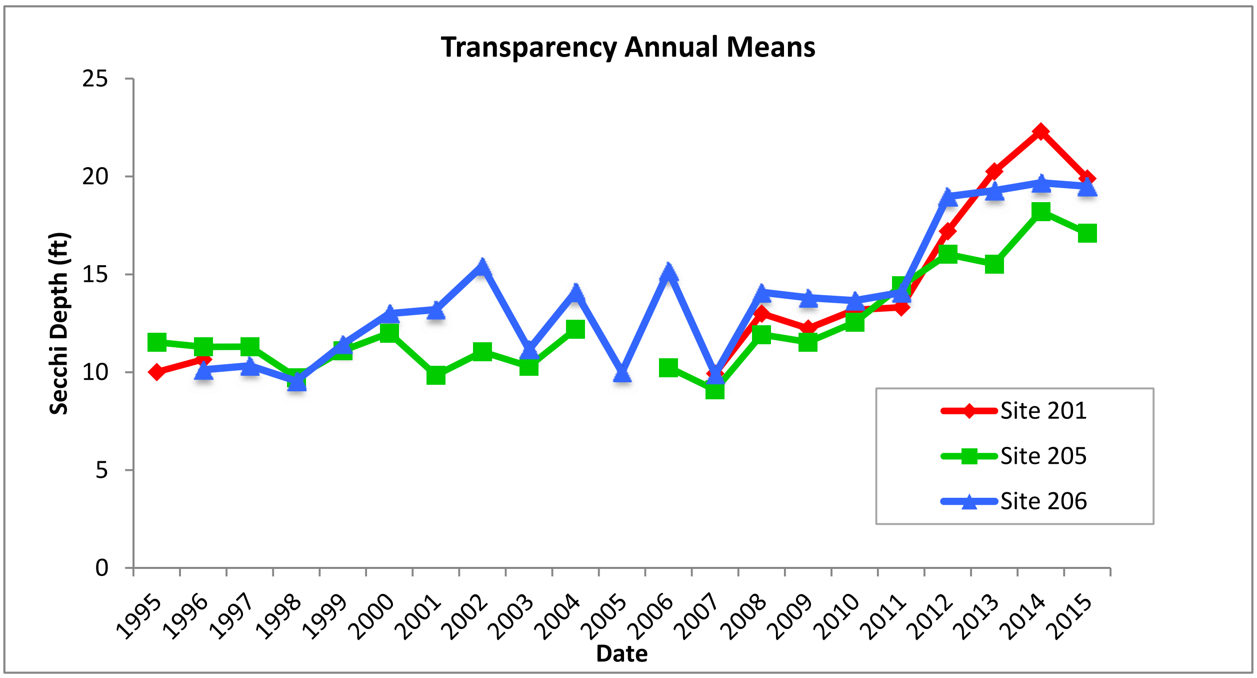



Figure 3.17 Pelican Lake annual mean transparency for sites 201, 205 and 206.

Pelican Lake transparency ranges from 6.5 to 30 feet throughout the summer. Figure 3.18 shows the seasonal transparency dynamics. Pelican Lake transparency is highest in May and early June and then declines throughout the summer. After the lake turns over in September the transparency improves in late September - October. This pattern is typical for a lake of this depth in Minnesota. The transparency dynamics have to do with algae population dynamics and lake turnover.

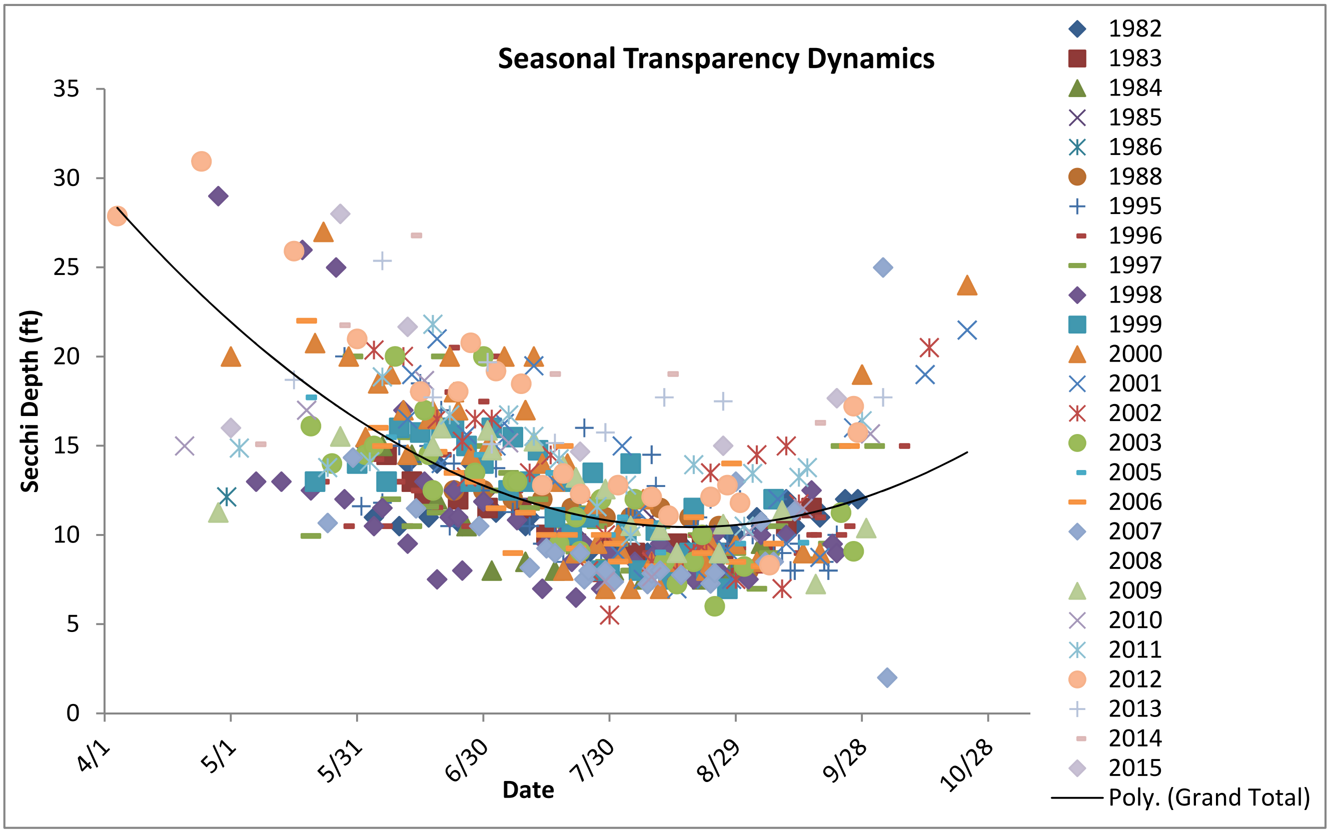



Figure 3.18 Seasonal transparency dynamics and year-to-year comparison.

## User Perceptions

When Secchi depth readings are collected, the perceptions of the water based on the physical appearance and the recreational suitability is recorded. 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 rating decreases. Pelican Lake was rated as being "not quite crystal clear" 48% of the time between 1997-2015 (Figure 3.19).

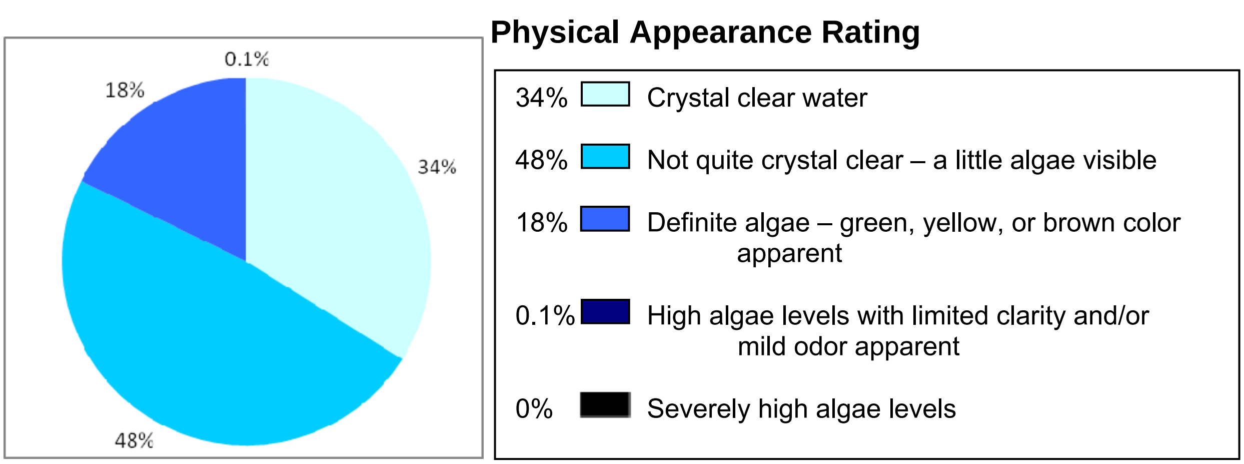



Figure 3.19. Physical appearance rating, as rated by the lake monitor (1997-2015).

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Pelican Lake was rated as being "beautiful" 57% of the time from 1997-2015 (Figure 3.20). For 99% of the time, Pelican Lake was rated as being swimmable.

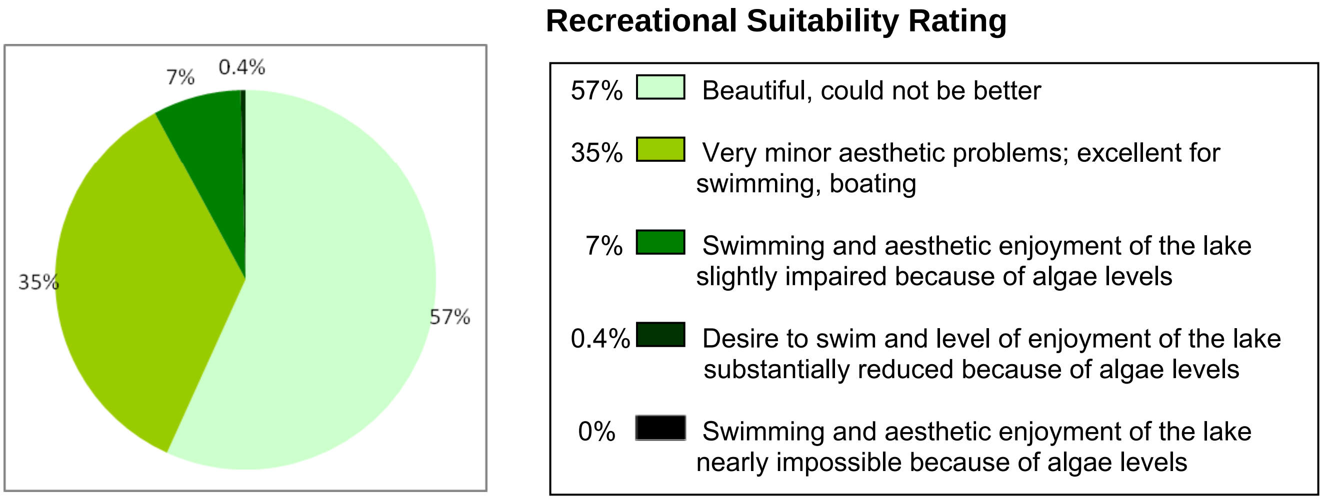



Figure 3.20 Recreational suitability rating, as rated by the lake monitor (1997-2015).

# Total Phosphorus

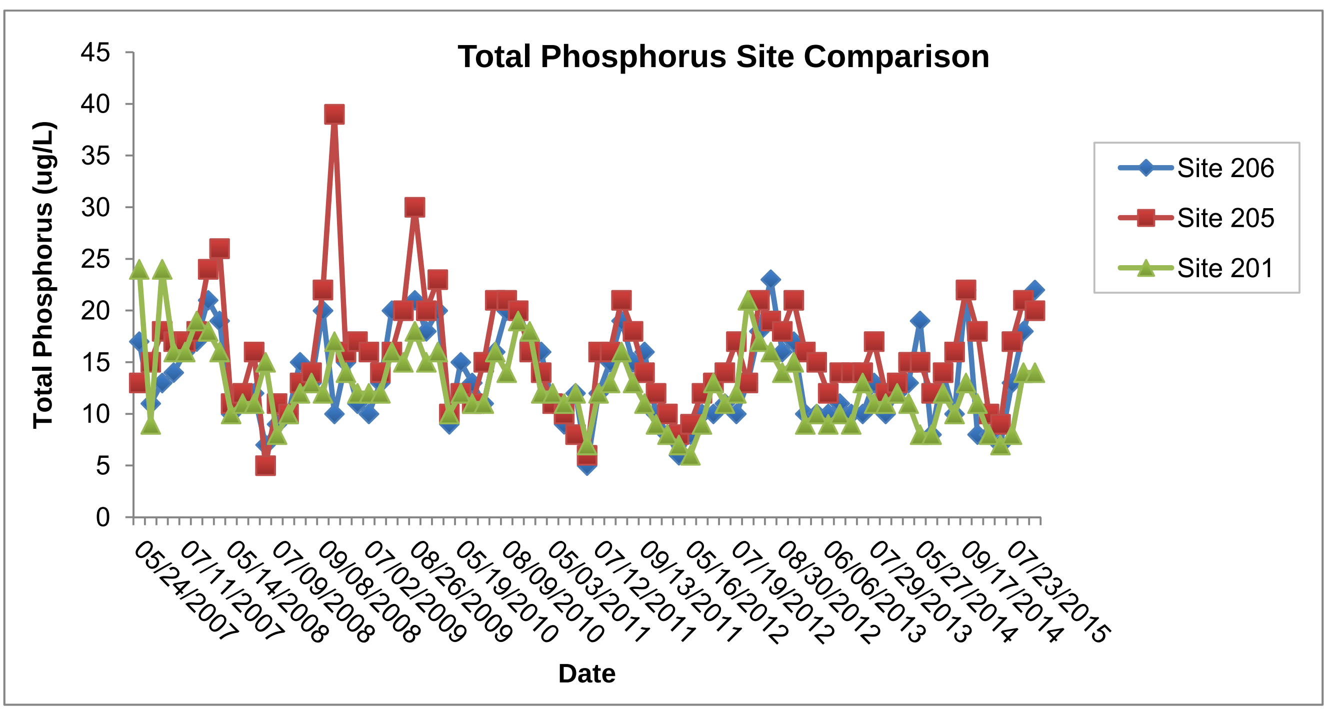



Figure 3.21 2007-2015 total phosphorus concentrations (ug/L) for Pelican Lake comparing sites 206, 205 and 201.

Pelican Lake is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus. Generally, the less phosphorus in the lake, the better the water quality for recreation.

From 2007-2015, all three Pelican Lake sites were monitored for total phosphorus. The lowest phosphorus concentration was consistently at Site 206 in the middle of the lake (Figure 3.21). This makes sense because this site is the furthest from any inlets to the lake, and lake inlets are usually the highest source of phosphorus. Site 205 had the highest phosphorus concentration, which makes sense because the Pelican River is the largest contributor of phosphorus to Pelican Lake. The Pelican River enters Pelican Lake on the east end. Site 201 was higher than the middle of the lake due to the Spring Creek and Bob Creek inlets which carry phosphorus into the lake from the west side.

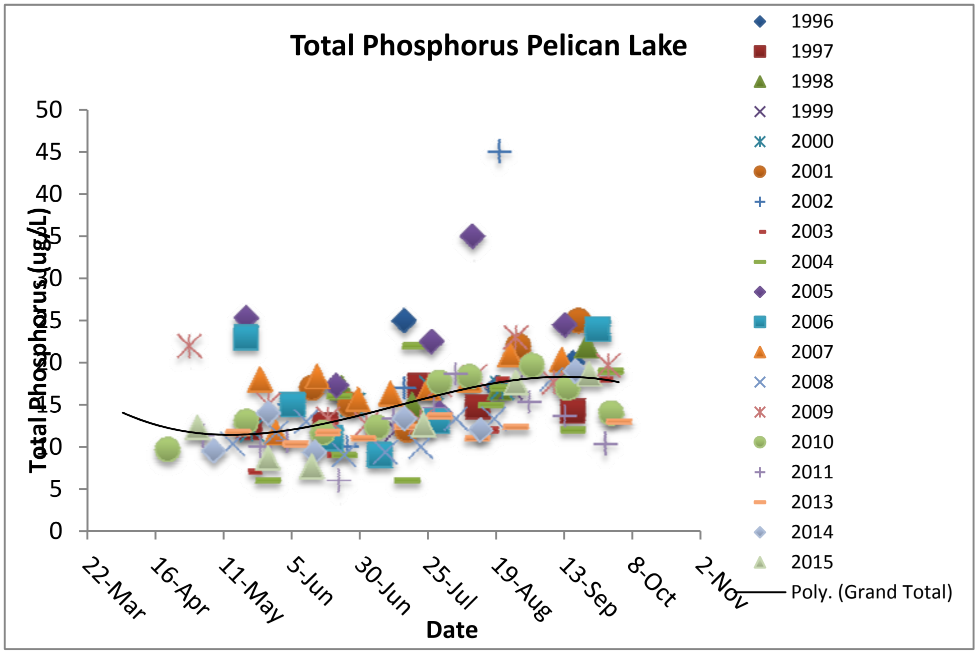



Figure 3.22. 1996-2015 total phosphorus concentrations (ug/L) for Pelican Lake. The Black line is the best fit trend line.

In Pelican Lake, the total phosphorus concentration starts out low in the spring and gradually increases throughout the summer (Figure 3.22). There are two possible explanations to this pattern. One is that it follows the pattern in the Pelican River since that is a very large inlet to Pelican Lake. The other possible explanation is internal loading.

Because data has been collected at the Pelican River inlet to Pelican Lake (Strom's Bridge) since 2002, we can compare those phosphorus concentrations to Pelican Lake.

Figure 3.23 shows that the phosphorus loading in Pelican River peaks in the spring and declines throughout the summer, so it is most likely not the cause of increasing phosphorus throughout the summer in Pelican Lake.

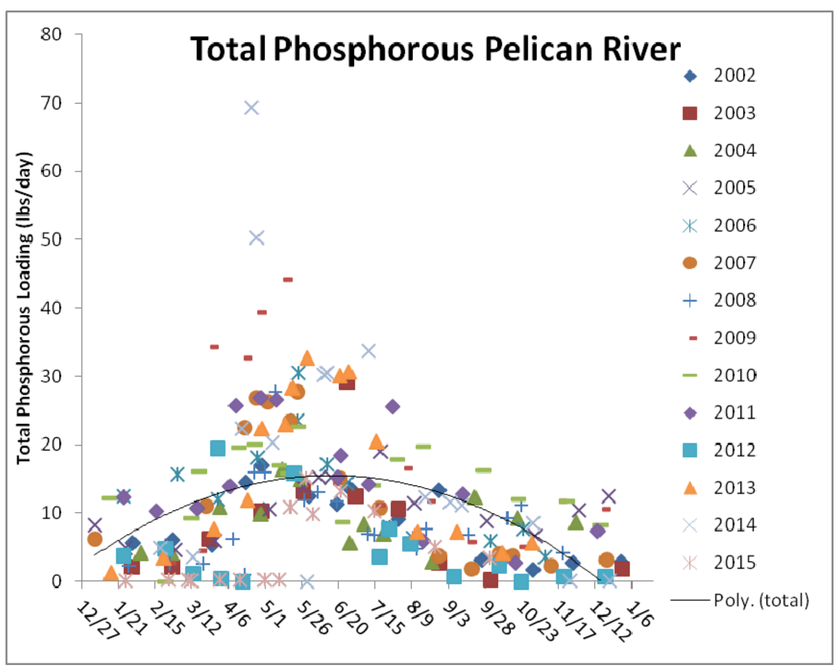



Figure 3.23. 2001-2015 total phosphorus loading (lbs/day) for Pelican River. The black line represents the pattern.

In 2009, water samples were collected just above the lake bottom to measure internal loading in Pelican Lake. Internal loading typically occurs in mid-summer when the oxygen at the bottom of the lake (hypolimnion) is depleted. When there is no oxygen in the hypolimnion, a chemical reaction occurs where phosphorus is released from the lake sediment back into the water. Then in the fall when the lake turns over this phosphorus comes up to the surface.

Pelican Lake follows a typical pattern for internal loading in a lake of its depth and geographical placement in Minnesota (Figures 3.24-3.27). The different lake sites vary in the degree of stratification and internal loading that occurs. Both sites 206 (middle of lake) and 205 (east end of lake) stratify in the summer (pages 58-59); however, site 205 shows high internal loading and site 206 does not (Figure 3.26). A possible explanation for this result is that the Pelican River carries a large load of phosphorus into the lake on the east side and this phosphorus settles at the bottom of the east end of the lake. Site 206 is far from any inlets to the lake, which is why there could be less phosphorus at the bottom to re-circulate into the water column.

Most of the summer the hypolimnion phosphorus concentrations at site 201 are similar or less than the surface water concentrations because the lake water column is fully mixed.

Site 201 (west end of the lake) behaves like a shallow lake site since it is only 30 feet deep. In shallow lakes the pattern is somewhat different because the lake is not deep enough to strongly stratify. The west end of Pelican Lake may weakly stratify after a stretch of hot

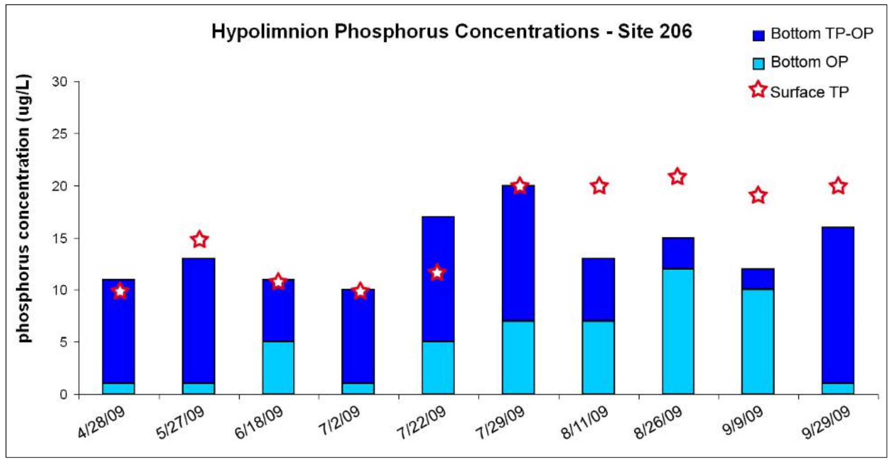



Figure 3.24 Site 206 internal loading data from 2009. These data show that hypolimnion phosphorus is only higher than surface phosphorus on 7/22/09.

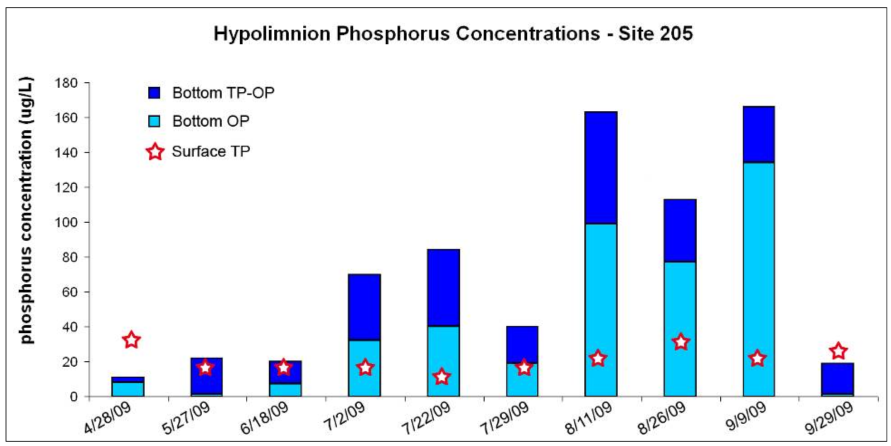



Figure 3.25 Site 206 internal loading data from 2009. These data show that hypolimnion phosphorus is only higher than surface phosphorus on 7/22/09.

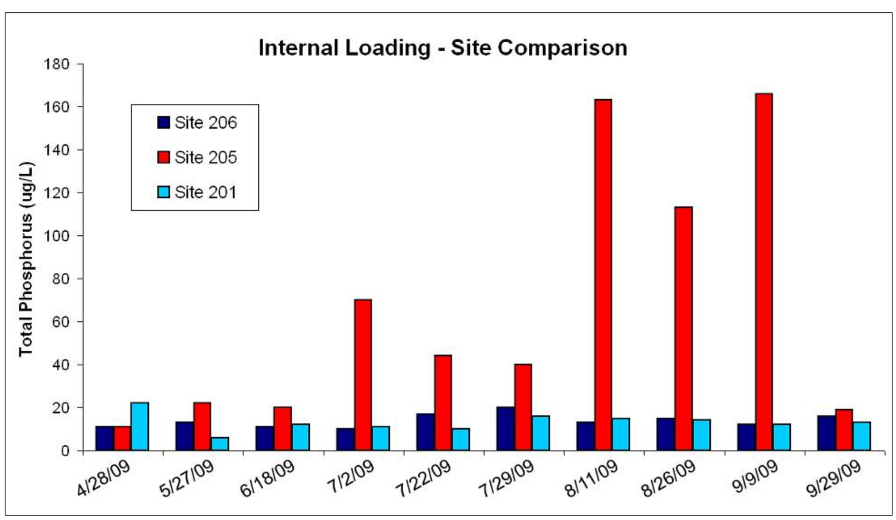



Figure 3.26 Internal loading comparison between sites in Pelican Lake. Site 205 shows much higher hypolimnion phosphorus levels than sites 201 and 206.

calm weather and then a day of strong wind will mix the lake up again.

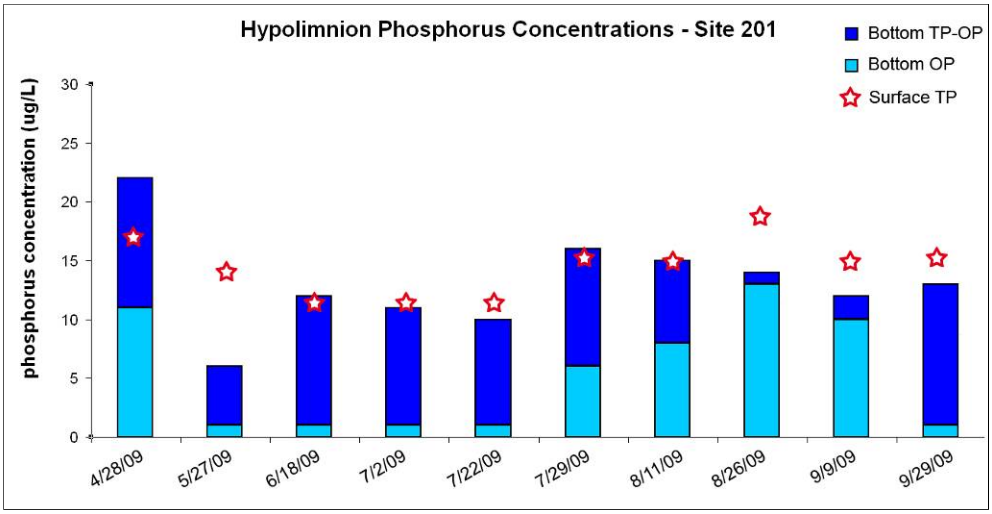



Figure 3.27 Site 201 internal loading data from 2009. These data show that hypolimnion phosphorus is only higher than surface phosphorus on 4/28/09 and 7/29/09.

# Chlorophyll *a*

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 algae bloom.

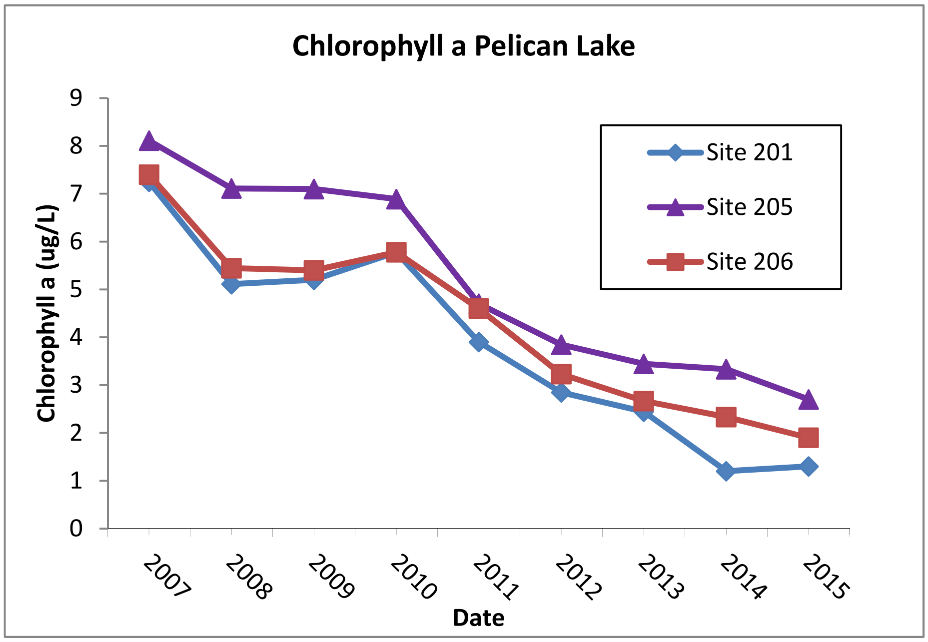



Figure 3.28. 2007-2015 chlorophyll a annual mean concentrations (ug/L) for Pelican Lake comparing sites 201, 205 and 206. .

Chlorophyll *a* concentrations are highest at site 205 and lowest at site 206, which matches the total phosphorus results (Figures 3.21 and 3.28). Since phosphorus is food for algae, this result makes sense. Chlorophyll a concentrations at site 205 exceed 10 ug/L, indicating minor algae blooms in late summer (Figure 3.29). Sites 201 and 206 barely ever make it to 10 ug/L, indicating clear water most of the summer.

Chlorophyll a concentrations in Pelican Lake have decreased dramatically since Zebra mussels were established in 2009 (Figure 3.28).

Chlorophyll *a* was evaluated at site 206 in Pelican Lake from 2002-2013 (Figure 3.29). Chlorophyll *a* concentrations start out low in June and then increase to a peak in mid to late August. This pattern follows the phosphorus concentration because phosphorus is food for the algae (Figures 3.22 and 3.29).

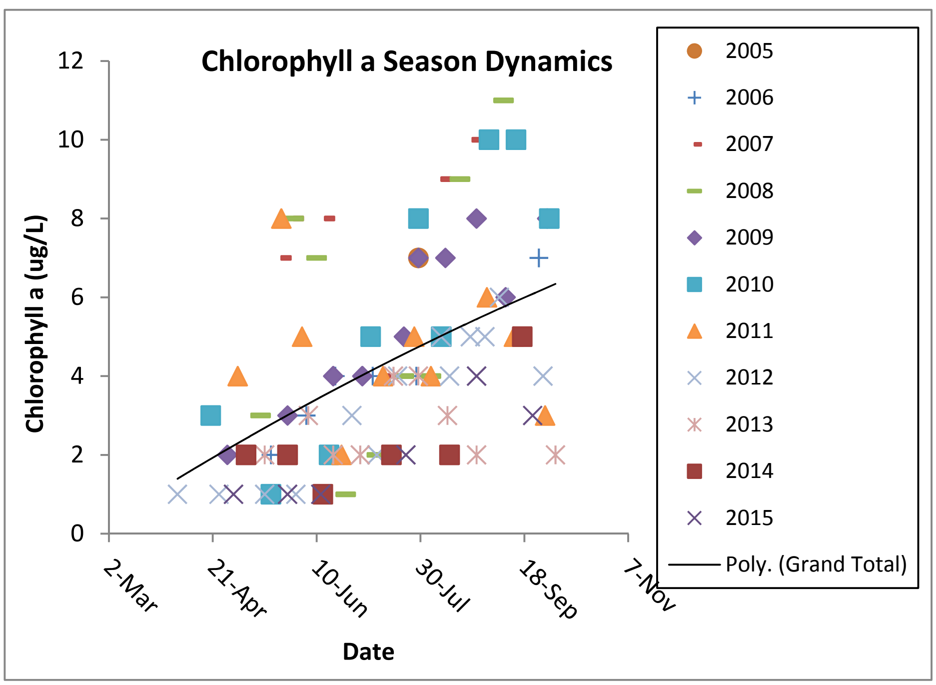



Figure 3.29. Chlorophyll a seasonal dynamics at site 206 for Pelican Lake 2002-2015.

## Dissolved 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 oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fish. Dissolved oxygen profiles Lake have been collected in Pelican Lake by the Lake Resource Coordinator from 2007-2009.

Site 205 (east end of the lake) has a maximum depth of 52 ft. The profiles indicate that site 205 in Pelican Lake stratifies in mid summer (Figure 3.30). In 2015, the lake began stratifying in June and turned over in September. In the summer the thermocline was at approximately 24 feet, which means that game fish were most likely absent below 24 feet.

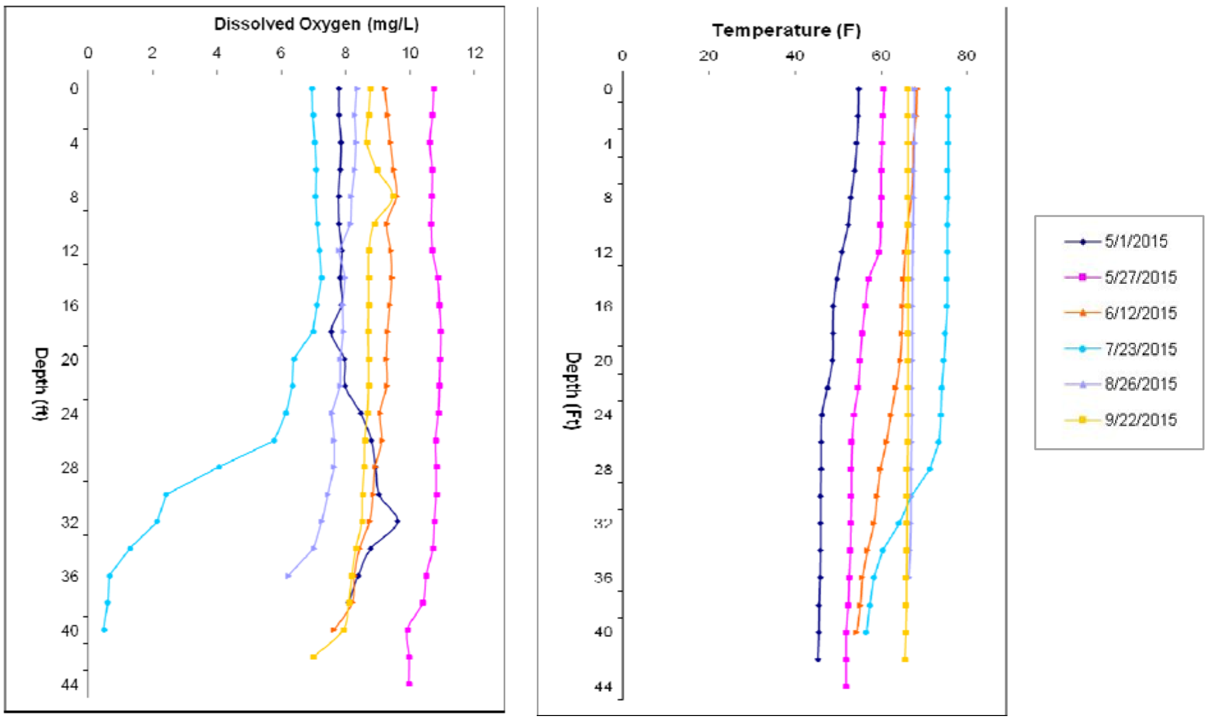



Figure 3.30. Site 205 dissolved oxygen and temperature profiles, 2015.

Site 206 (middle of the lake) has a maximum depth of 50 ft. The profiles indicate that site 206 in Pelican Lake stratifies in mid summer, but not as strongly as site 205 (Figure 3.31). Because Pelican Lake has such a long fetch (area for wind to whip up the water) site 206 is subject to more wind mixing. In 2015, the lake began stratifying in early June and turned over in early September. In the summer the thermocline was at approximately 28 feet, which means that game fish were most likely absent below 28 feet.

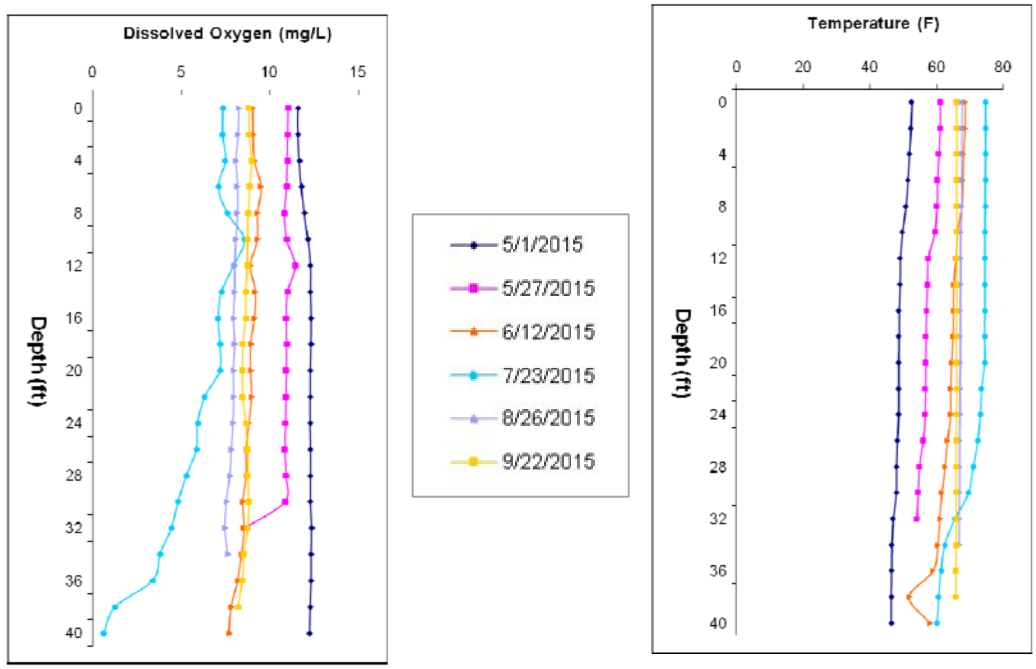



Figure 3.31 Site 206 dissolved oxygen and temperature profiles, 2015.

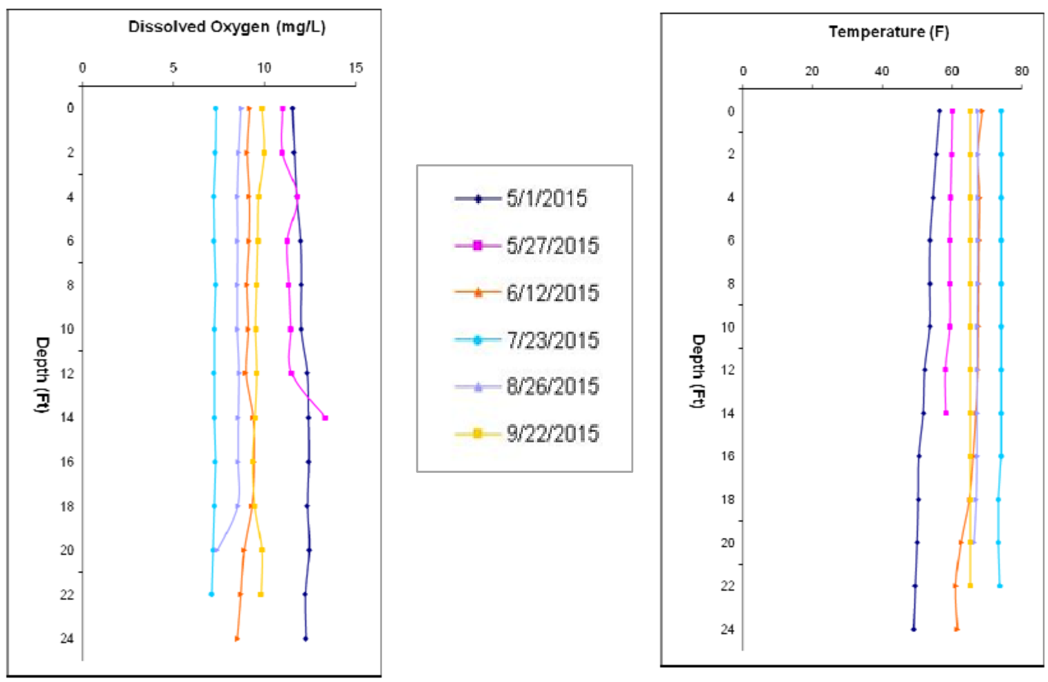



Figure 3.32 Site 201 dissolved oxygen and temperature profiles, 2015.

The west end of Pelican Lake is relatively shallow, with the majority of its depth less than 30 ft. This area of Pelican Lake isn't deep enough to stratify throughout the whole summer. The dissolved oxygen/temperature profiles (Figure 3.32) show the dynamics at site 201 in Pelican Lake in the summer of 2015. The graph shows that the temperature remains consistent from the surface of the lake to the bottom, which indicates no thermal stratification. On some dates in July and August the oxygen was depleted at the bottom of the lake. This usually occurs after a few warm calm days, and then a wind will mix the water column again.

## Trophic State Index

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases.

| Trophic State Index | Site 206 | Site 205 | Site 201 |
|---|---|---|---|
| TSI Total Phosphorus | 43 | 44 | 42 |
| TSI Chlorophyll-a | 46 | 50 | 46 |
| TSI Secchi | 36 | 42 | 36 |
| TSI Mean | 42 | 45 | 41 |
| Trophic State: | Mesotrophic | Mesotrophic | Mesotrophic |

*Numbers represent the mean TSI for each parameter.*

The results from these three measurements cover different units and ranges and thus cannot be directly compared to each other or averaged. In order to standardize these three measurements to make them directly comparable, we convert them to a trophic state index (TSI).

The mean TSI for Pelican Lake falls in the mesotrophic range (Figure 3.33). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are related. In comparing sites, these results match the phosphorus, chlorophyll *a* and secchi results. Site 205 has the highest TSI, while site 206 has the lowest.

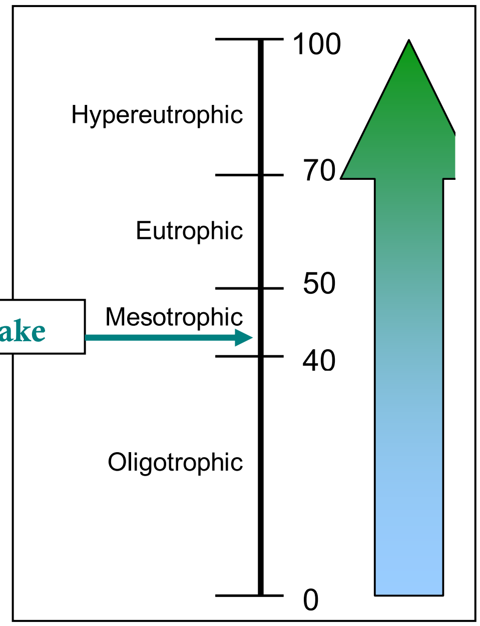



Figure 3.33 Trophic state index chart with corresponding trophic status.

Mesotrophic lakes (TSI 40-50) are characterized by moderately clear water most of the summer. "Meso" means middle or mid; therefore, mesotrophic means a medium amount of productivity. Mesotrophic lakes are commonly found in central Minnesota and have clear water with some algal blooms in late summer. Mesotrophic lakes can also be good walleye lakes.

| TSI | Attributes | Fisheries & Recreation |
|---|---|---|
| <30 | **Oligotrophy:** Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water. | Trout fisheries dominate. |
| 30-40 | Bottom of shallower lakes may become anoxic (no oxygen). | Trout fisheries in deep lakes only. Walleye, Tullibee 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.

Pelican Lake has data for site 206 from 1996 to 2015. The data was analyzed using the Mann Kendall Trend Analysis.

| Lake Site | Parameter | Date Range | Trend | Probability |
|---|---|---|---|---|
| Site 206 | Transparency | 1997-2015 | Improving | 99.9% |
| Site 206 | Chlorophyll a | 1997-2015 | Improving | 99.9% |
| Site 206 | Total Phosphorus | 1997-2015 | Improving | 99.9% |

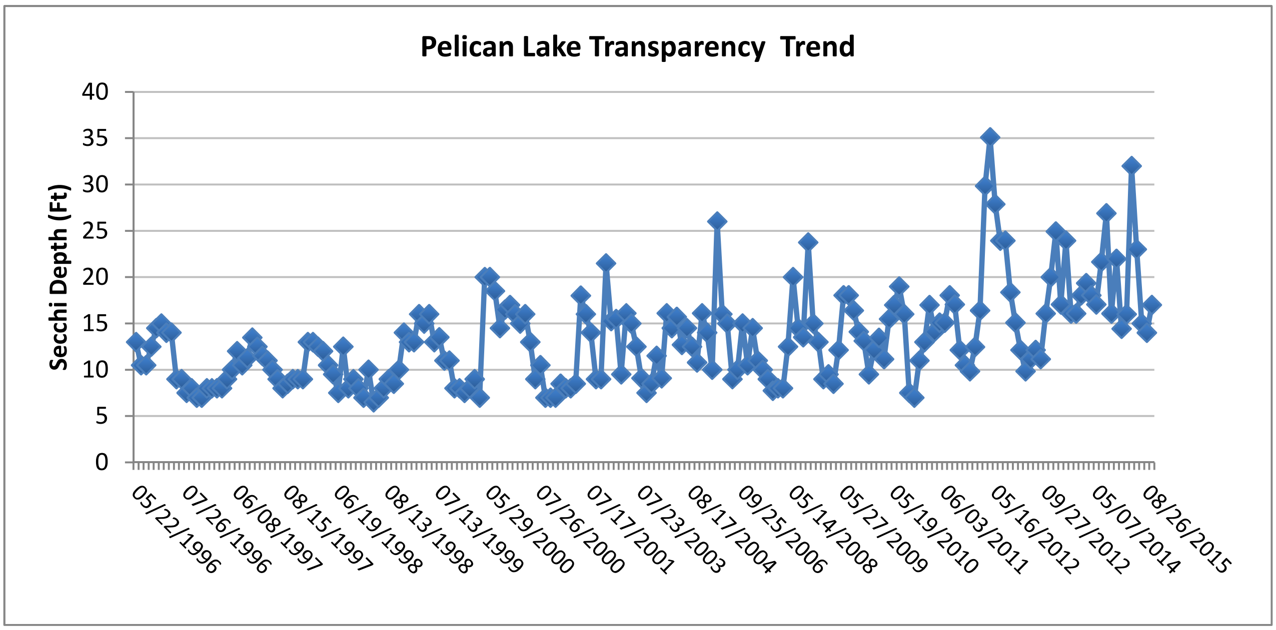
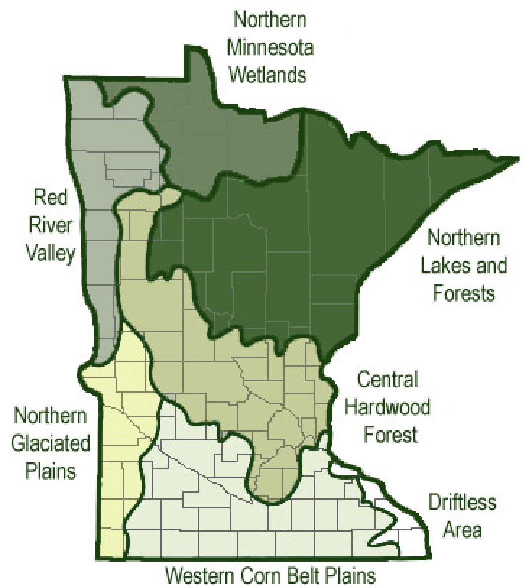


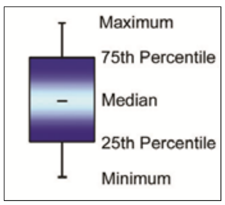

Figure 3.34 Pelican Lake transparency trends from 1997-2015 at primary site 206.

Pelican Lake shows an improving trend in transparency at site 206 from 1996-2015 (Figure 3.34). There is also an improving trend in phosphorus and chlorophyll a, which means that those concentrations are decreasing. The improving trends are likely due to Zebra mussels. They were found in 2009, and in 2011 were noticed throughout the whole lake. In 2011 was when the clarity started drastically improving.

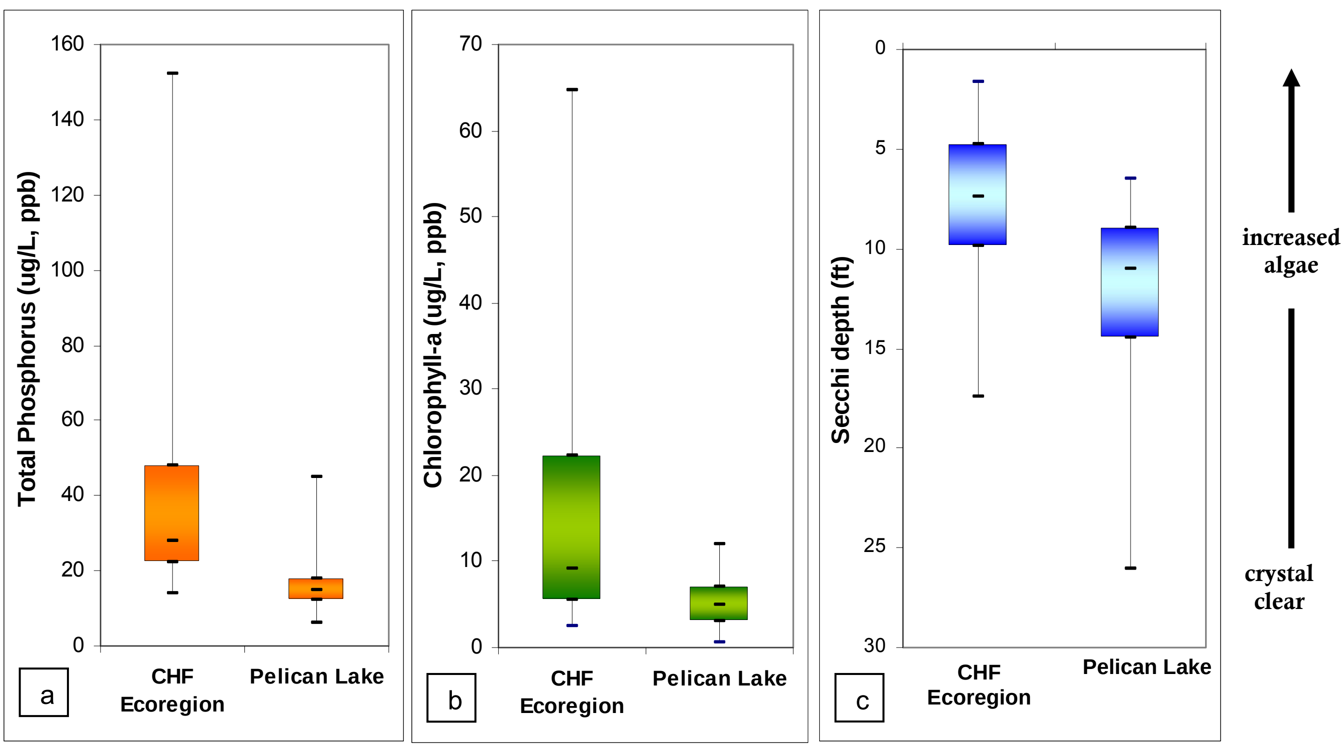
# Ecoregion Comparisons

Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the $25^{th}$ - $75^{th}$ percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.




Pelican Lake is in the Central Hardwood Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Pelican Lake are all better than the expected ecoregion ranges (Figures 3.35a-c).




Figures 3.35a-c. Pelican Lake ranges compared to Central Hardwood Forest Ecoregion ranges (data from 2003-2009).

## State Assessments (Minnesota Pollution Control Agency)

**Impaired Waters Assessment 303(d) List**

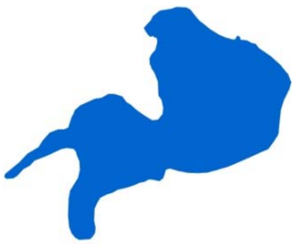
There are two main types of Impaired Waters Assessment for lakes: eutrophication (excess phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption. Pelican Lake is listed as impaired for mercury in fish tissue. See page 111 for fish consumption guidelines. Pelican Lake is not listed as impaired for eutrophication.

**Aquatic Recreational Use Assessment 305(b)**

In the 2008 MPCA Aquatic Use Assessment (305(b)), Pelican Lake was classified as being fully supporting for Aquatic Recreational Use.

# Fish Lake 56-0768-00 OTTER TAIL COUNTY

## Summary



Fish Lake is attached to Pelican Lake at its north end. Water flows from Pelican Lake through Fish Lake and the Pelican River exits at the southwest end of the lake. Fish Lake has the best water quality of the Pelican Group of Lakes. This is most likely due to the fact that it doesn't have any stream inlets, it is fairly deep, and has a good population of emergent vegetation around its shoreline (cattails and bulrushes).

Currently, the main threat to Fish Lake is the removal of bulrush around the shoreline. Historically, the lake was most likely ringed entirely with bulrush. Since human development on the lake, bulrush has been removed to create swimming areas. Aquatic plants such as bulrush filter pollutants and take up a lot of the phosphorus in the water and stabilize the lake sediments. In order to maintain the excellent water quality in Fish Lake, aquatic plants should be protected and not removed by homeowners.

Water quality data have been collected in Fish Lake since 1995. These data show that the lake is on the oligotrophic/mesotrophic border (TSI 39-41), which is characteristic of clear water throughout the summer and excellent recreational opportunities.

## Vitals

| | |
|---|---|
| MN Lake ID: | 56-0768-00 |
| County: | Otter Tail |
| Ecoregion: | North Central Hardwood Forest |
| Major Drainage Basin: | Red River |
| Latitude/Longitude: | 46.67805556 / -96.00061111 |
| Water Body Type: | Public |
| Monitored Sites: | 201, 202, 203 |
| Invasive species present: | Zebra Mussels *(confirmed in 2009)*, Curly-leaf pondweed |

## Physical Characteristics

| | | |
|---|---|---|
| Surface area (acres): | 261 | |
| Littoral area (acres): | 127 | |
| % Littoral area: | 48% | |
| Max depth (ft): | 69 | (m): 21 |
| Mean depth (ft): | 27 | (m): 8.2 |
| Lakeshed size (acres): | 15,783 | |
| Lakeshed : lake area ratio | 60 : 1 | |
| Inlets | Connection to Pelican Lake | |
| Outlets | Connection to Pelican Lake | |
| Public Accesses | 0 | |

## Data Availability

| | |
|---|---|
| Transparency data | Data exist from the MPCA CLMP program from 1995-2002, and RMB Labs from 2003-2015. |
| Chemical data | Data exist from RMB Labs from 2003-2015. |
| Inlet/Outlet data | The Fish Lake outlet has been monitored by RMB Lab from 2003-2015. |

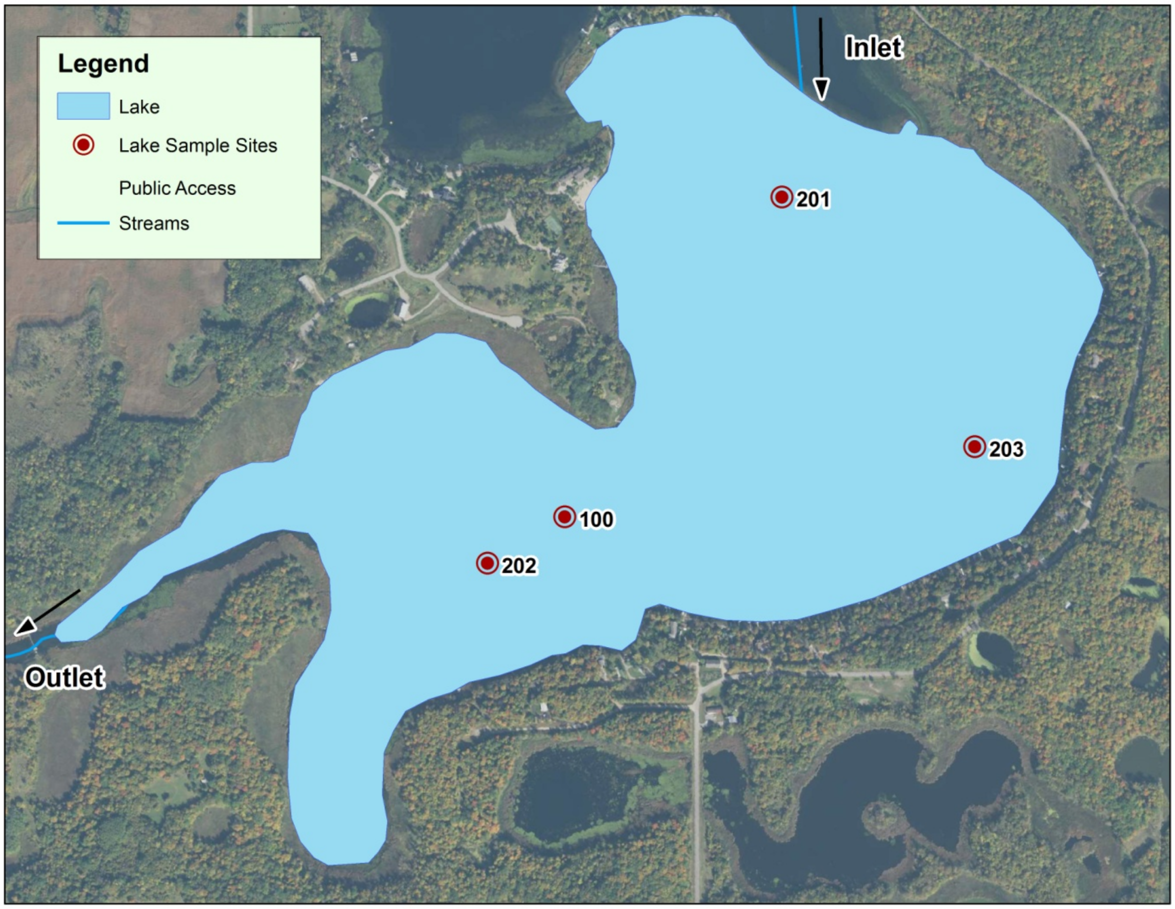



Figure 3.36 Map of Fish Lake illustrating lake sample site locations, stream inlets and outlets and aerial land use.

| Lake Site | Depth (ft) | Monitoring Programs |
|---|---|---|
| 201 | 45 | PGOLID: 2003-2015; CLMP: 1995-2012; MPCA: 1997 |
| 202 | 40 | PGOLID: 2007-2008, 2015 |
| 203 | 40 | CLMP: 2008 |

KEY:
MPCA (Minnesota Pollution Control Agency);
CLMP (MPCA Citizens Lake Monitoring Program)
PGOLID (Pelican Group of Lakes Improvement District)

The information below describes available chemical data for Fish Lake through 2015. Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion.

Below are typical measurements one might find for lakes in this ecoregion.

| Parameter | Mean | Ecoregion Range[1] | Interpretation |
|---|---|---|---|
| Total phosphorus (ug/L) | 11.8 | 23 - 50 | Results are below the expected range for the ecoregion. For more information, see page 75. |
| Chlorophyll *a* (ug/L) [2] | 3.9 | 5 – 22 | |
| Chlorophyll *a* max (ug/L) | 9 | 7 – 37 | |
| Secchi depth (ft) | 13.6 | 4.9 – 10.5 | |
| Dissolved oxygen | Dimictic *See page 73* | | Dissolved oxygen depth profiles show that the deep areas of the lake are anoxic in late summer. |
| Total Kieldahl Nitrogen (mg/L) | 0.43 | 0.62 – 1.2 | Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms. |
| Ortho phosphorus (surface, ug/L) | 4.4 | | Indicates that all available ortho-phosphorus is taken up by plants and algae living in the lake. |
| Alkalinity (mg/L) | 176.1 | 75 – 150 | Indicates a low sensitivity to acid rain and a good buffering capacity. |
| Color (Pt-Co Units) | 7.1 | 10-20 | Indicates very clear water with little to no tannins (brown stain). |
| Total Suspended Solids (mg/L) | 1.7 | 2 – 6 | Below the ecoregion average range indicating clear water. |
| Total Nitrogen :Total Phosphorus | 36:1 | 25:1 – 35:1 | The lake is most likely phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake. |
| Calcium (mg/L) | 32.3 | | Indicates a hard water lake sufficient for Zebra mussel survival. |
| Magnesium (mg/L) | 27.7 | | Indicates a hard water lake. |

*Data Source: 2003-2015 PGOLID Monitoring Program*

[1] The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes
[2] Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

## Water Quality Characteristics - Historical Means

Years monitored: 1997-2015

| Parameters | Site *201 | Site 202 | Site 203 |
|---|---|---|---|
| **Total Phosphorus Mean (ug/L):** | **11.7** | **12.6** | |
| Total Phosphorus Min: | 6 | 5 | |
| Total Phosphorus Max: | 21 | 34 | |
| Number of Observations: | 94 | 17 | |
| **Chlorophyll *a* Mean (ug/L):** | **3.7** | **5.1** | |
| Chlorophyll *a* Min: | 1 | 3 | |
| Chlorophyll *a* Max: | 9 | 8 | |
| Number of Observations: | 94 | 17 | |
| **Secchi Depth Mean (ft):** | **12.4** | **11.5** | **16.7** |
| Secchi Depth Min: | 6.0 | 9.0 | 7.9 |
| Secchi Depth Max: | 26.6 | 16.0 | 25.9 |
| Number of Observations: | 275 | 17 | 117 |

*primary site

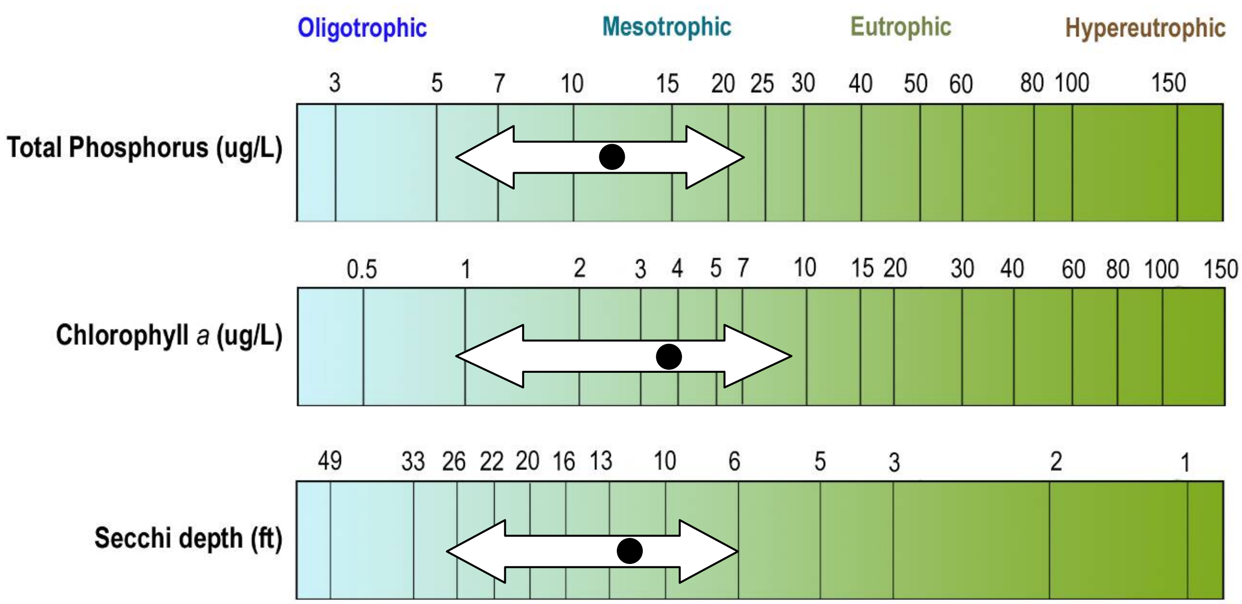



Figure 3.37. Fish Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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 amount 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. Site 201 in Fish Lake has been monitored from 1995-2015. The annual means for Fish Lake range from 9.5-20 ft (Figure 3.38). The annual mean transparency has been above the historical average since 2011. Zebra mussels were found in Pelican Lake in 2009 and residents noticed them everywhere in 2011. It is likely that the Zebra mussels have caused the increase in water clarity since 2011.

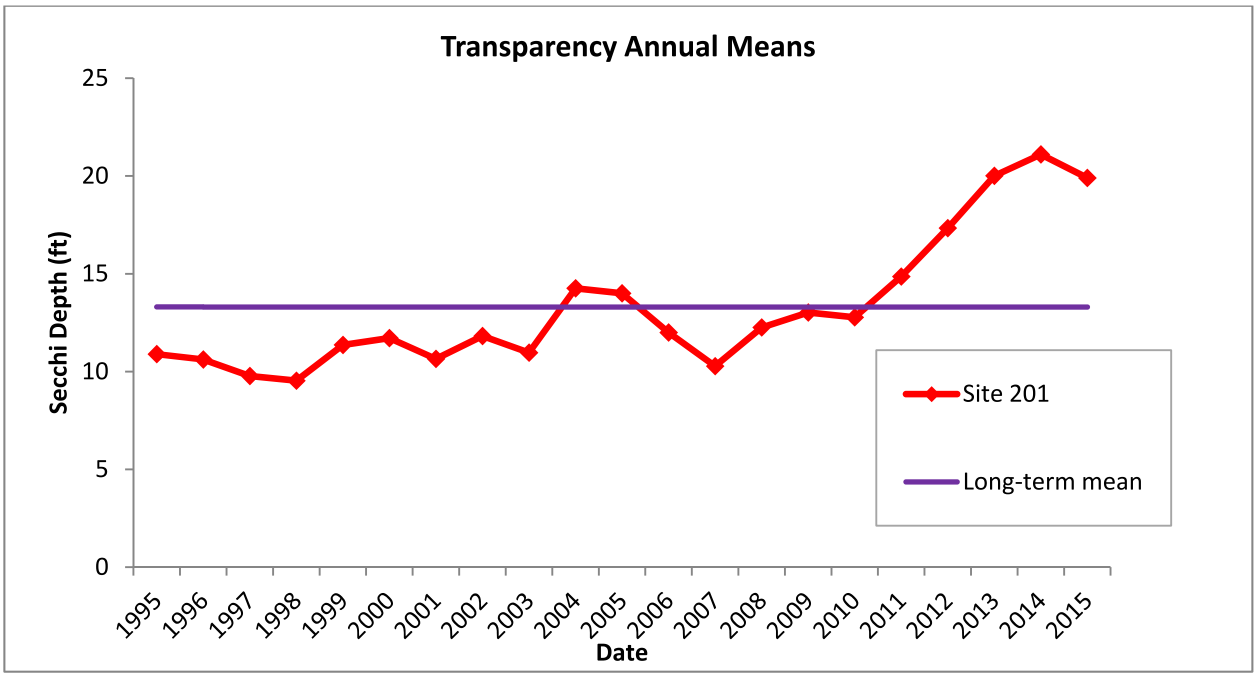



Figure 3.38. Fish Lake annual mean transparency for sites 201.

Fish Lake transparency ranges from 6 to 20 feet throughout the summer. Figure 3.39 shows the seasonal transparency dynamics. Fish Lake transparency varies greatly year to year, but shows an overall slight decline throughout the summer. After fall turnover the transparency most likely recovers to near spring levels, but there are not much data past mid-September for Fish Lake, so this pattern is not shown. This pattern is typical for a lake of this depth in Minnesota. The transparency dynamics have to do with algae population dynamics and lake turnover.

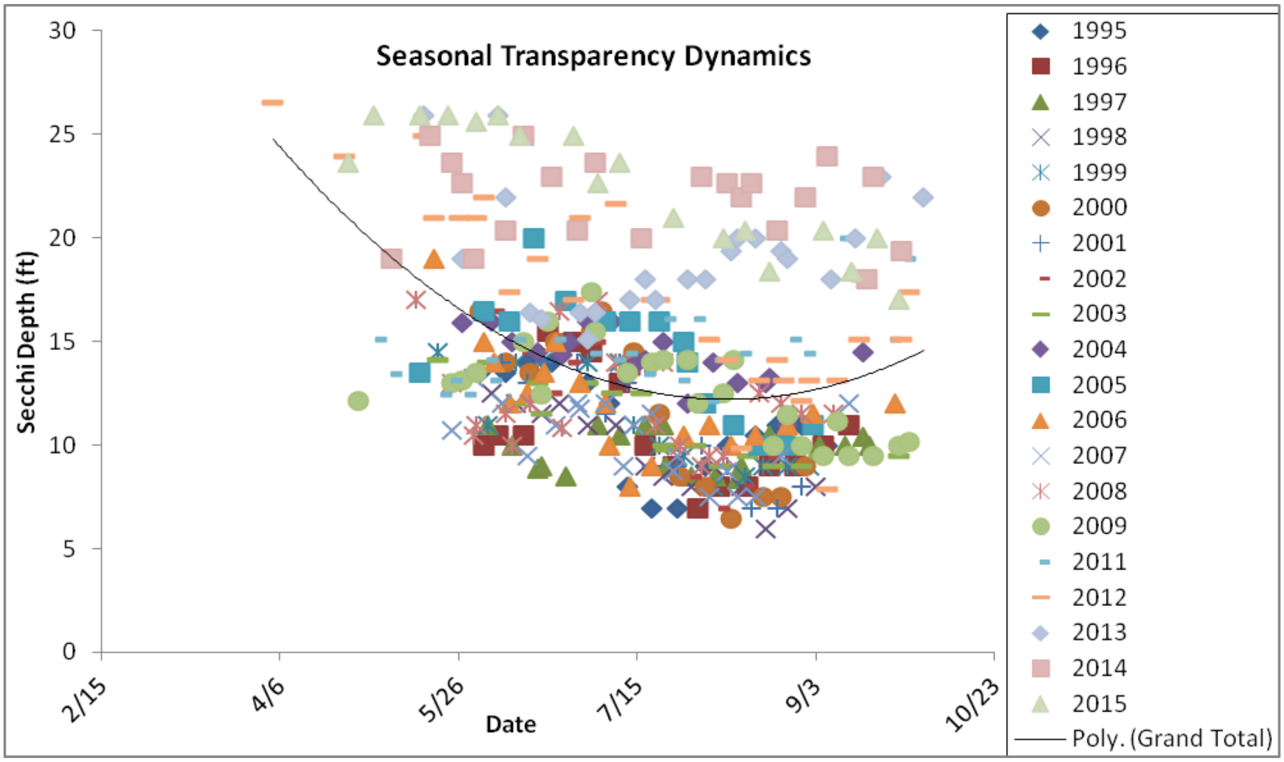



Figure 3.39. Seasonal transparency dynamics and year-to-year comparison. The light yellow line represents the best fit line to show the pattern in the data.

# User Perceptions

When Secchi depth readings are collected, the perceptions of the water based on the physical appearance and the recreational suitability is recorded. 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 rating decreases. Fish Lake was rated as being "not quite crystal clear" 61% of the time between 1995-2015 (Figure 3.40).

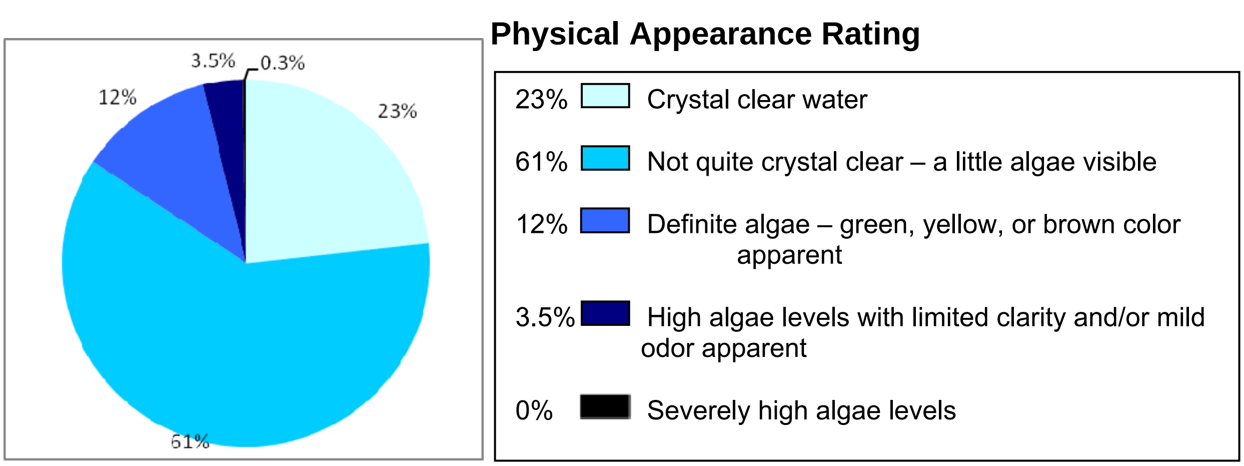
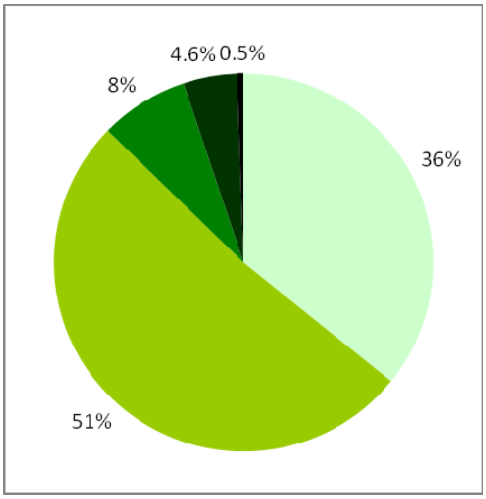



Figure 3.40. Physical appearance rating, as rated by the lake monitor (1995-2015).

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Fish Lake was rated as having "very minor aesthetic problems" 51% of the time from 1995-2015 (Figure 3.41). For 95% of the time, Fish Lake was rated as being swimmable.




**Recreational Suitability Rating**

| | |
|---|---|
| 36% | Beautiful, could not be better |
| 51% | Very minor aesthetic problems; excellent for swimming, boating |
| 8% | Swimming and aesthetic enjoyment of the lake slightly impaired because of algae levels |
| 4.6% | Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels |
| 0.5% | Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels |

Figure 3.41. Recreational suitability rating, as rated by the lake monitor (1995-2015).

## Total Phosphorus

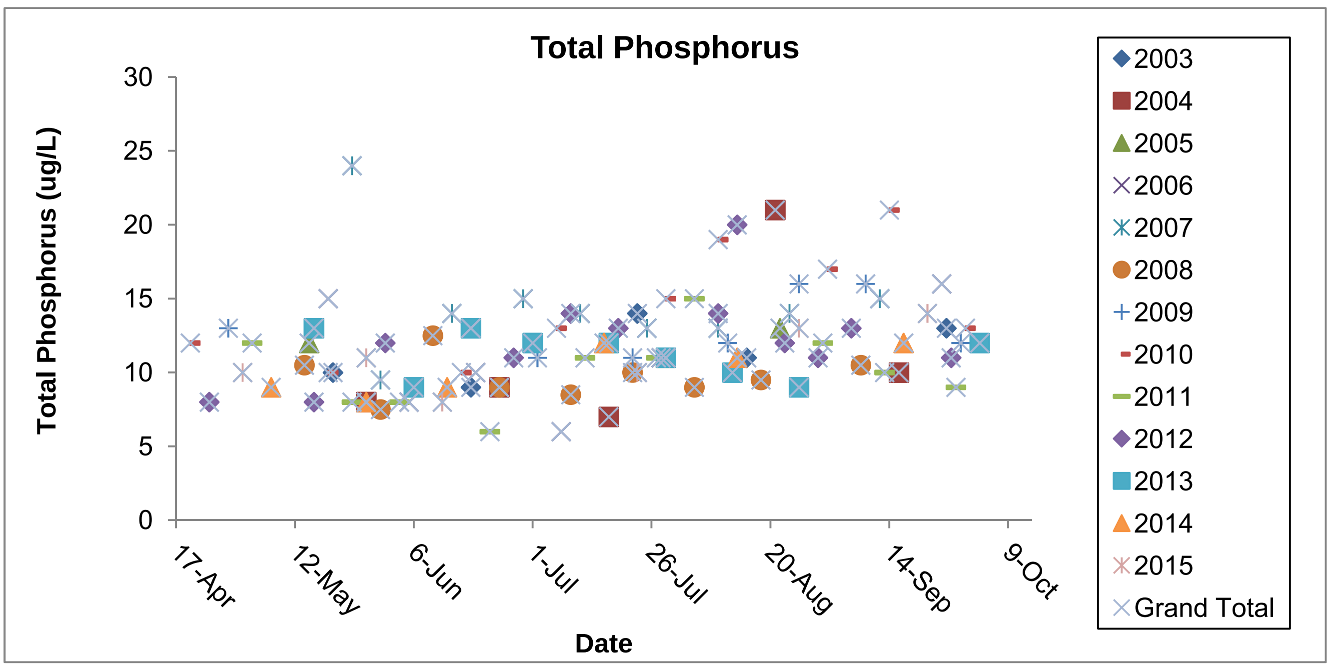


Figure 3.42. Historical total phosphorus concentrations (ug/L) for Fish Lake site 201 from 2003-2015.

Fish Lake is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus. The total phosphorus concentrations remain fairly consistent all season long. This could be due to the lack of any stream inlets into Fish Lake.

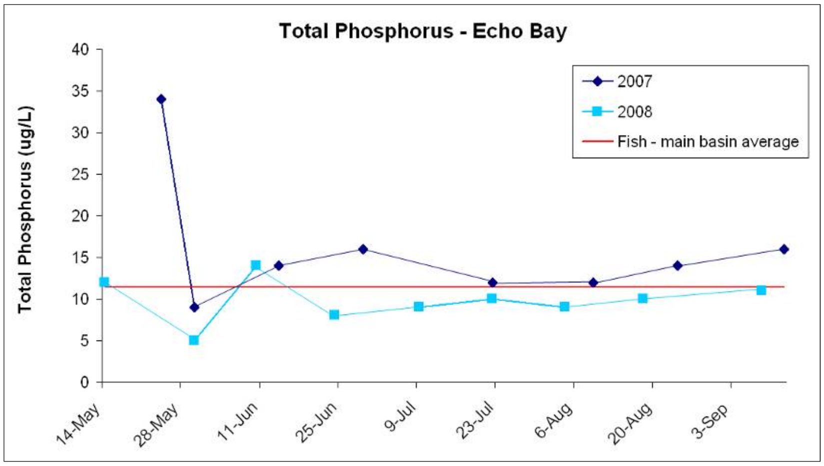



Figure 3.43. Historical total phosphorus concentrations (ug/L) for Echo Bay site 202 (data set from 2007-2008).

The south bay of Fish Lake (Echo Bay) is some of the only shoreline in the Pelican group of lakes that is still undeveloped. It is not sandy, but is lined with reeds and cattails, which make excellent habitat for aquatic animals and fish. Due to a proposed development project in this area in 2006, site 202 was monitored in 2007-2008 to get a good picture of baseline water quality. Since then, this development has fallen through, but now we have baseline conditions to compare in case this area ever gets developed in the future. The results from 2007-2008 show that Echo Bay has some of the best water quality in the Pelican Group of Lakes (Figure 3.43).

In 2009, water samples were collected just above the lake bottom to measure internal loading in Fish Lake. Internal loading typically occurs in mid-summer when the oxygen at the bottom of the lake (hypolimnion) is depleted. When there is no oxygen in the hypolimnion, a chemical reaction occurs where phosphorus is released from the lake sediment back into the water. Then in the fall when the lake turns over this phosphorus comes up to the surface.

Figure 3.44 shows that Fish Lake follows a typical pattern for internal loading. Internal loading is usually highest in July through mid-August when the surface water is warm. In spring, the hypolimnion phosphorus concentrations are similar to the surface water concentrations because the lake water column is fully mixed. In late fall, the lake turns over again. In 2009, September was very warm, so the lake may have turned over later than normal, which is why there is still internal loading occurring on 9/29/09.

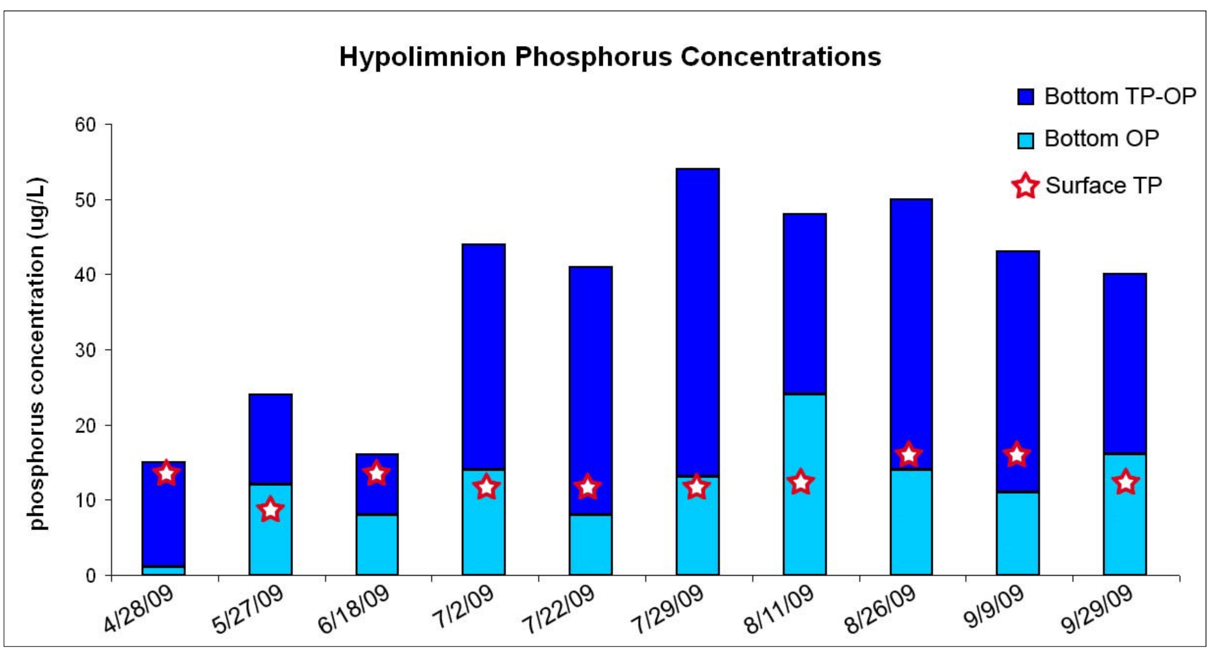



Figure 3.44. Hypolimnion phosphorus concentrations (ug/L) for Fish Lake (data set from 2009).

# Chlorophyll *a*

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.

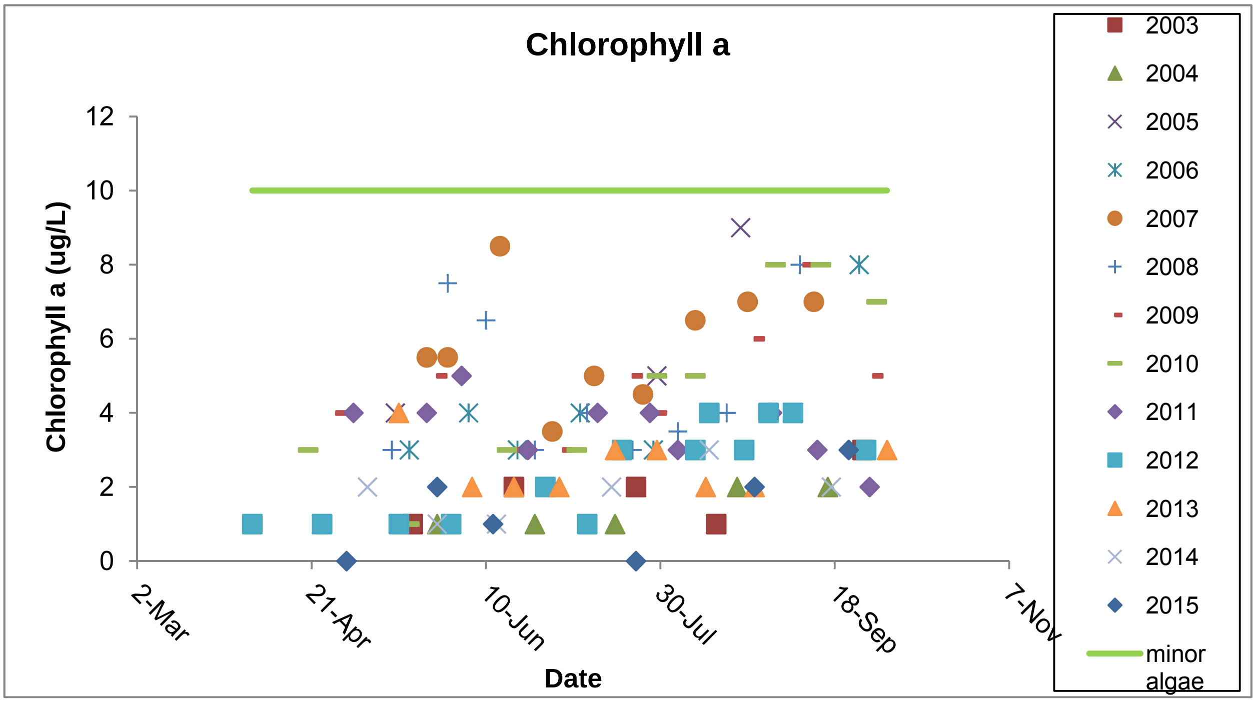


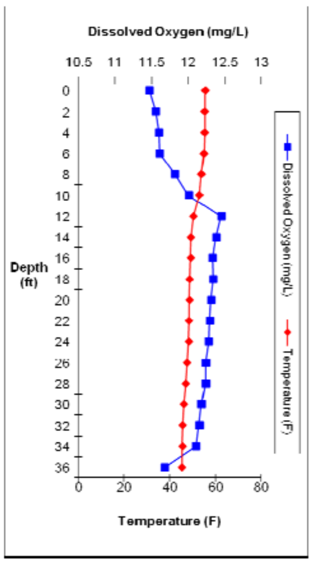

Figure 3.45. Chlorophyll *a* concentrations (ug/L) for Fish Lake (data set from 2003-2015).

Chlorophyll *a* was evaluated in Fish Lake in 2003-2011 (Figure 3.45). Chlorophyll *a* concentrations don't follow much of a pattern in Fish Lake. Chlorophyll *a* concentrations in Fish Lake remained below 10 ug/L during all years from 2003-2011, indicating clear water all summer.

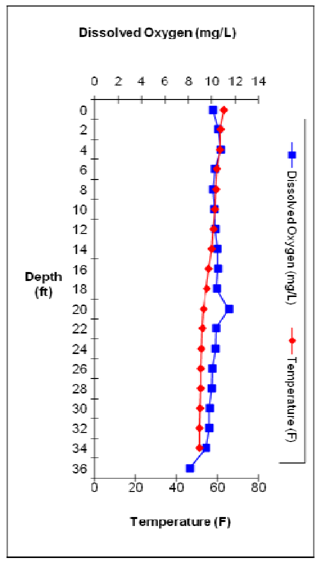
# Dissolved Oxygen

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 oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fish.

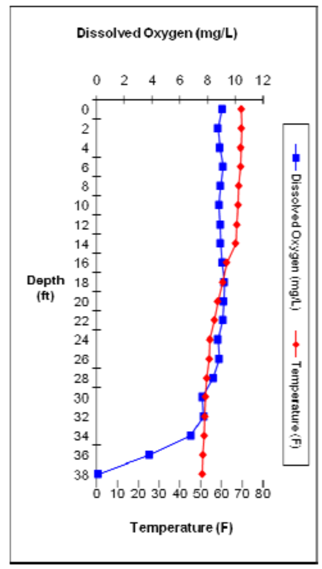
Fish Lake is its own distinct basin with a maximum depth of 69 ft. Dissolved oxygen profiles for Fish Lake have been collected by the Lake Resource Coordinator from 2007-present. The profiles indicate that Fish Lake stratifies in mid summer. In 2015, the lake began stratifying in early June and turned over in late September. In the summer the thermocline was at approximately 28 feet, which means that game fish were most likely absent below 28 feet.



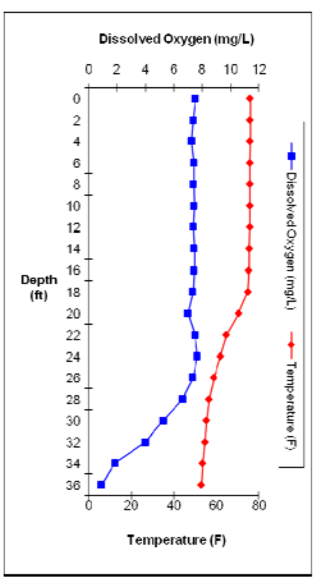

5/1/2015



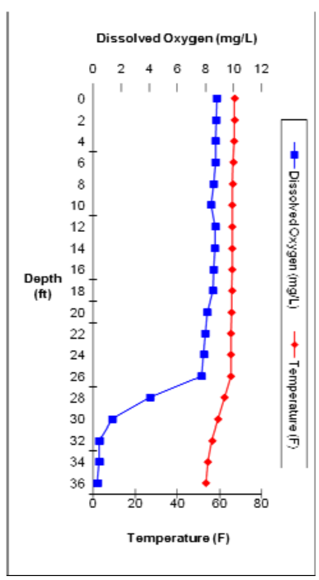

5/27/2015



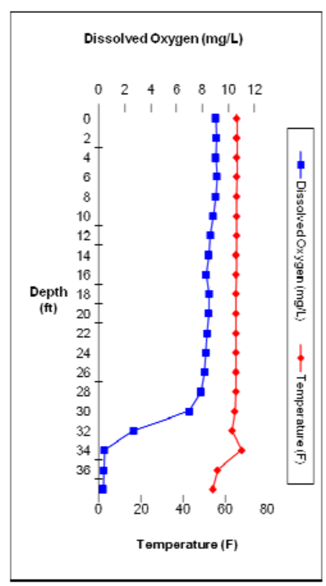

6/12/2015




7/23/2015




8/26/2015




9/22/2015

# Trophic State Index

| Trophic State Index | Site 201 |
|---|---|
| TSI Total Phosphorus | 40 |
| TSI Chlorophyll-a | 43 |
| TSI Secchi | 36 |
| TSI Mean | 40 |
| Trophic State: | Oligotrophic/ Mesotrophic |

*Numbers represent the mean TSI for each*

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases.

The results from these three measurements cover different units and ranges and thus cannot be directly compared to each other or averaged. In order to standardize these three measurements to make them directly comparable, we convert them to a trophic state index (TSI).

The mean TSI for Fish Lake falls in the lower mesotrophic range, close to the oligotrophic/mesotrophic border (Figure 3.46). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related.

Lakes on the oligotrophic/mesotrophic border (TSI 39-41) are characteristic of clear water throughout the summer and are excellent for recreation.

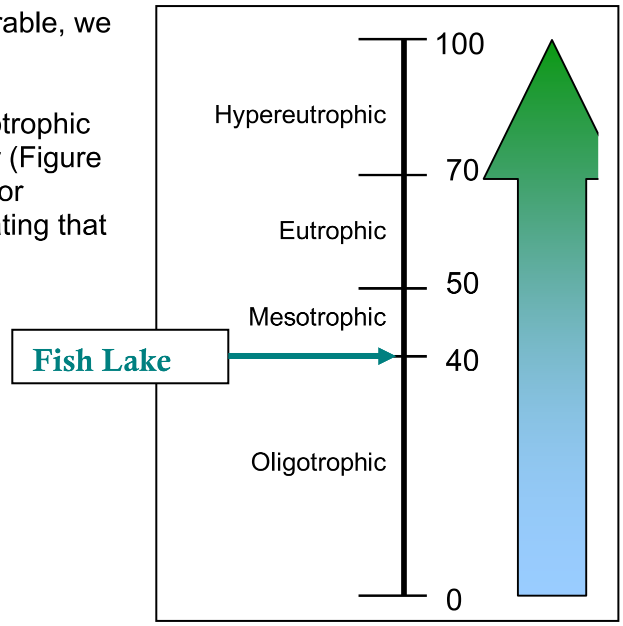



Figure 3.46. Trophic state index chart with corresponding trophic status.

| TSI | Attributes | Fisheries & Recreation |
|---|---|---|
| <30 | **Oligotrophy:** Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water. | Trout fisheries dominate. |
| 30-40 | Bottom of shallower lakes may become anoxic (no oxygen). | Trout fisheries in deep lakes only. Walleye, Tullibee 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.

Bass Lake has data from 2003-2009, which covers seven consecutive years. Because there is not ten years of data, the trends below would be considered short-term trends. The data was analyzed using the Mann Kendall Trend Analysis.

| Lake Site | Parameter | Date Range | Trend | Probability |
|---|---|---|---|---|
| 201 | Transparency | 1995-2015 | Improving | 99.9% |
| 201 | Phosphorus | 2003-2015 | No trend | -- |
| 201 | Chlorophyll *a* | 2003-2015 | Improving | 99.9% |

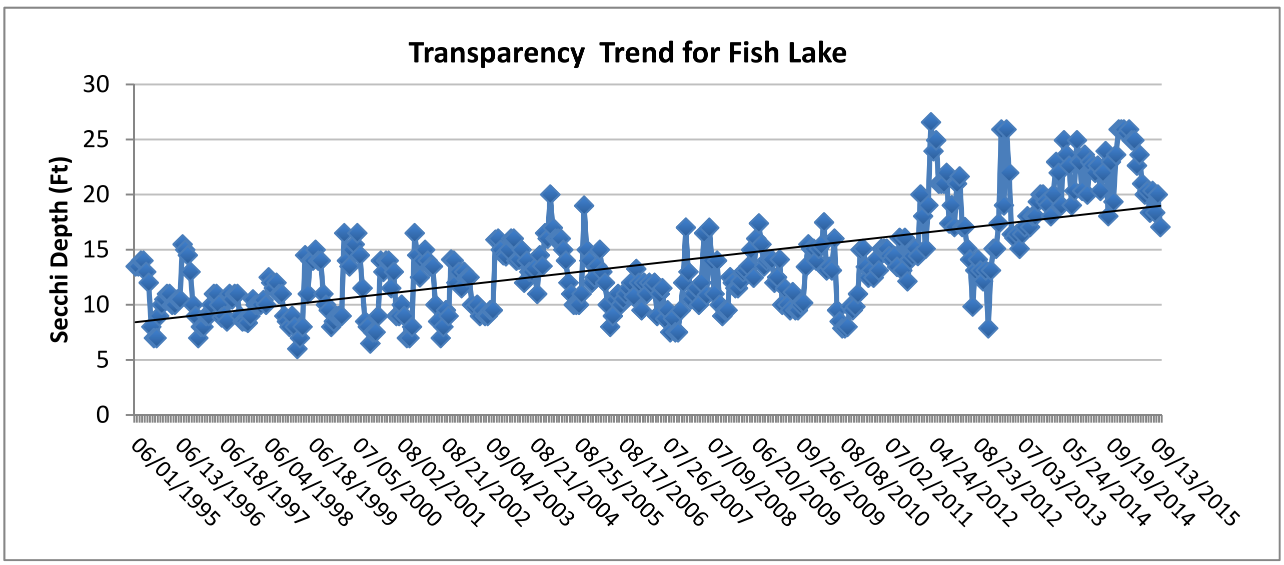
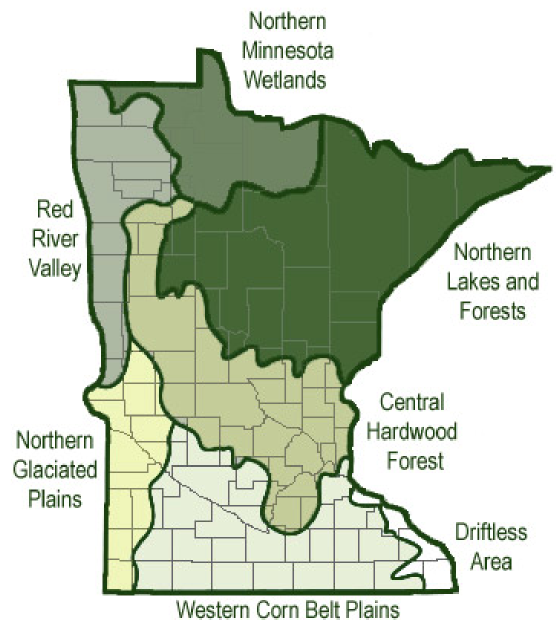



Figure 3.47 Fish Lake chlorophyll *a* trend from 2003-2015.

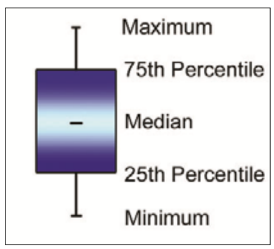
Fish Lake shows a significant improving long-term trend in transparency from 1995-2015. Over this time period, the transparency has improved an average of five feet. This trend is likely due to zebra mussels establishing in the lake in 2009. The phosphorus and concentration shows no trend from 2003 to 2015, which means it is not getting significantly better or worse, it is maintaining at the same level (Figure 3.47).

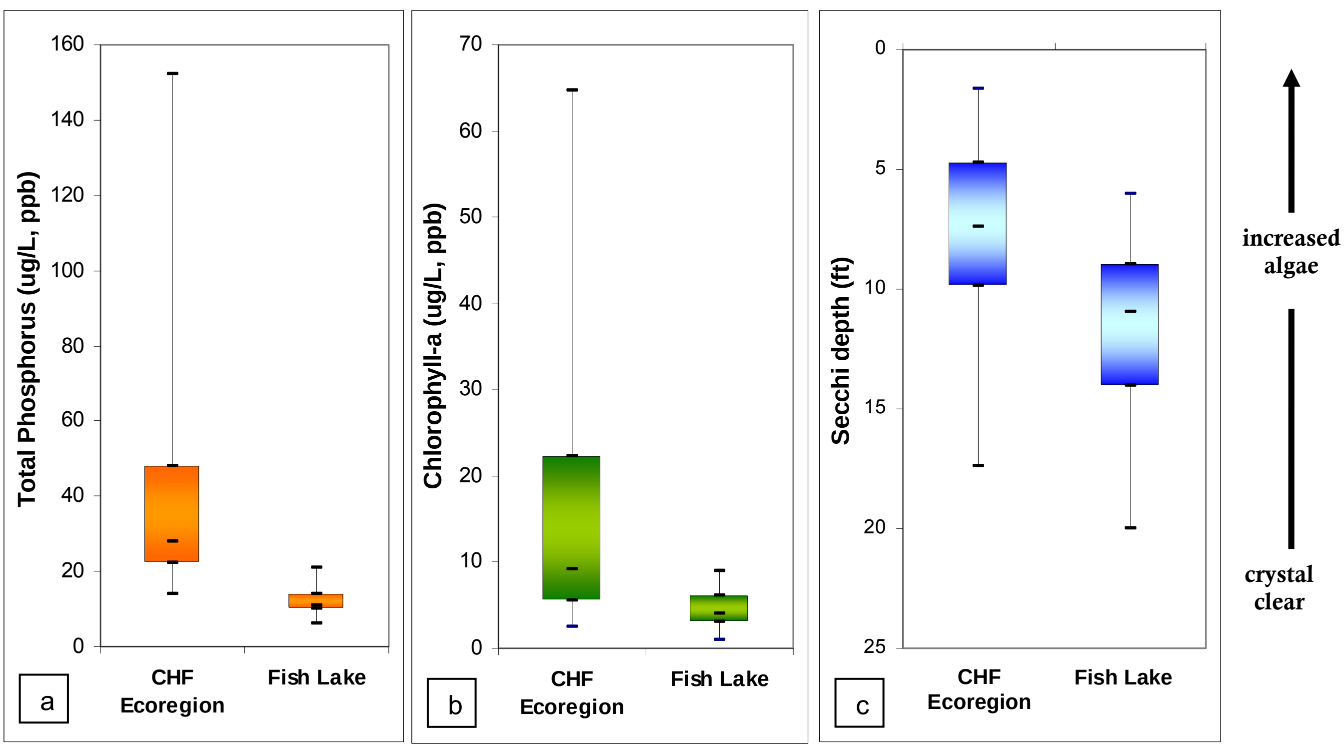
# Ecoregion Comparisons

Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.




Fish Lake is in the Central Hardwood Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Fish Lake are all better than the expected ecoregion ranges (Figures 3.48a-c).




Figures 3.48a-c. Fish Lake ranges compared to Central Hardwood Forest Ecoregion ranges (data from 2003-2009).

## State Assessments (Minnesota Pollution Control Agency)

**Impaired Waters Assessment 303(d) List**
There are two main types of Impaired Waters Assessment for lakes: eutrophication (excess phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption. Fish Lake is not listed as impaired for mercury in fish tissue; however, Pelican Lake is listed and is connected to Fish Lake. Therefore, the fish in Fish Lake should be considered impaired for mercury as well. See page 111 for fish consumption guidelines. Fish Lake is not listed as impaired for eutrophication.

**Aquatic Recreational Use Assessment 305(b)**
In the 2008 MPCA Aquatic Use Assessment (305(b)), Fish Lake was classified as being fully supporting for Aquatic Recreational Use.

# Bass Lake 56-0770-00 OTTER TAIL COUNTY

## Summary

Bass Lake is a very small basin (48 acres) attached to Fish and Pelican Lakes. Bass Lake has no direct inlets and outlets, just a connection with Fish Lake that doesn't show much flow of water either direction. Because of its isolation and small surface area, Bass Lake is more susceptible to impacts occurring on the shoreline of the lake such as adding impervious surface, adding artificial sand beaches, and removing aquatic plants.

Currently, the main threat to Bass Lake is the removal of aquatic plants. Trend analyses of water quality data show that there is a significant increasing trend in algae over the past seven years. Bass Lake has a very dense native plant population along with emergent plants such as bulrush and cattails. This vegetation has been increasingly removed over the past decade, which could contribute to higher algae levels. The aquatic plants take up a lot of the phosphorus in the water and stabilize the lake sediments. When aquatic plants are removed, the phosphorus is available for more algae growth. In order to maintain the water quality in Bass Lake, aquatic plants should be protected and not removed by homeowners.

Water quality data have been collected on Bass Lake since 1997. These data show that the lake is mesotrophic (TSI 40-50). Mesotrophic lakes are commonly found in north-central Minnesota and have clear water with occasional algal blooms in late summer.

## Vitals

| | |
|---|---|
| MN Lake ID: | 56-0770-00 |
| County: | Otter Tail |
| Ecoregion: | North Central Hardwood Forest |
| Major Drainage Basin: | Red River |
| Latitude/Longitude: | 46.68441667 / -96.01061111 |
| Water Body Type: | Public |
| Monitored Sites: | 201 |
| Invasive species present: | Zebra Mussels (confirmed in 2009), Curly-leaf pondweed |

## Physical Characteristics

| | | |
|---|---|---|
| Surface area (acres): | 48 | |
| Littoral area (acres): | 24 | |
| % Littoral area: | 50% | |
| Max depth (ft): | 33 | (m): 10.1 |
| Mean depth (ft): | 18 | (m): 5.5 |
| Inlets | Connection to Fish Lake | |
| Outlets | Connection to Fish Lake | |
| Public Accesses | 0 | |

## Data Availability

| | |
|---|---|
| Transparency data | Data exist from the MPCA CLMP program from 1997-2002, and RMB Labs from 2003-2012. |
| Chemical data | Data exist from RMB Labs from 2003-2012. |
| Inlet/Outlet data | Bass Lake has no inlet or outlet |

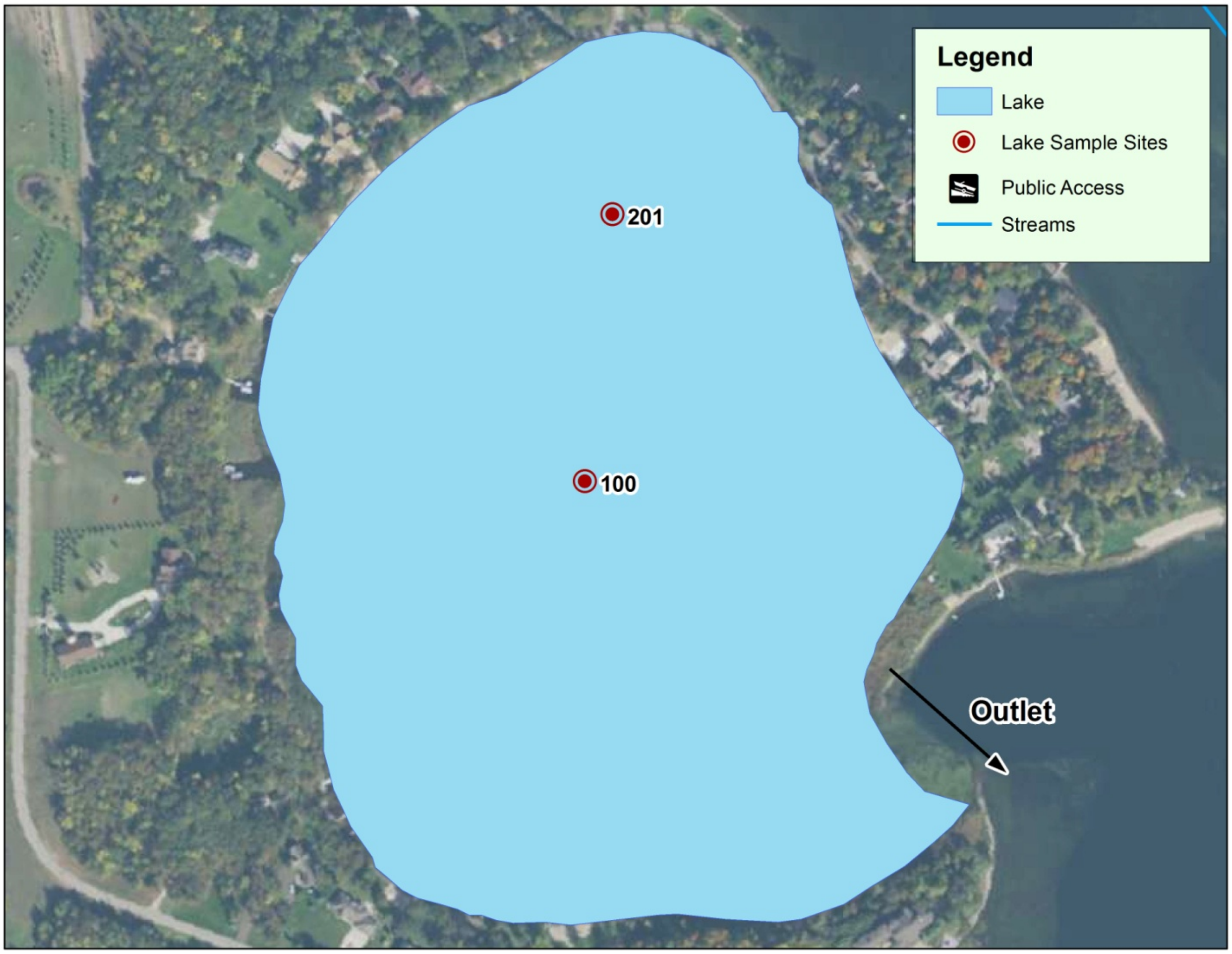



Figure 3.49 Map of Bass Lake lake sample site locations, stream inlets and outlets and aerial land use. The pink shaded areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic plants to grow.

| Lake Site | Depth (ft) | Monitoring Programs |
|---|---|---|
| 201 | 33 | PGOLID 2003-2012; CLMP: 1997-2003; MPCA: 1997 |

KEY:
MPCA (Minnesota Pollution Control Agency);
CLMP (MPCA Citizens Lake Monitoring Program)
PGOLID (Pelican Group of Lakes Improvement District)

The information below describes available chemical data for Bass Lake through 2009. Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion.

This ecoregion is an area of transition between the forested areas to the north and east and the agricultural areas to the south and west. The terrain varies from rolling hills to smaller plains. Upland areas are forested by hardwoods and conifers. Plains include livestock pastures, hay fields and row crops such as potatoes, beans, peas and corn.

The ecoregion contains many lakes, and water clarity and nutrient levels are moderate. Land surrounding many of these lakes has been developed for housing and recreation, and the densely populated metropolitan area dominates the eastern portion of this region. Water quality problems that face many of the water bodies in this area are associated with contaminated runoff from paved surfaces and lawns.

Below are typical measurements one might find for lakes in this ecoregion.

| Parameter | Mean | Ecoregion Range[1] | Interpretation |
|---|---|---|---|
| Total phosphorus (ug/L) | 11.8 | 23-50 | Results are better than the expected range for the ecoregion. For more details, see page 89. |
| Chlorophyll *a* (ug/L) [2] | 3.9 | 5 – 22 | |
| Chlorophyll *a* max (ug/L) | 9 | 7 – 37 | |
| Secchi depth (ft) | 13.6 | 4.9 – 10.5 | |
| Dissolved oxygen | *See page 87* | | Dissolved oxygen depth profiles show that the deep areas of the lake are anoxic in late summer. |
| Total Kieldahl Nitrogen (mg/L) | 0.7 | 0.62 – 1.2 | Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms. |
| Ortho phosphorus (surface, ug/L) | 5.2 | | Indicates that most available ortho-phosphorus is taken up by plants and algae living in the lake. |
| Alkalinity (mg/L) | 181.4 | 75 – 150 | Indicates a low sensitivity to acid rain and a good buffering capacity. |
| Color (Pt-Co Units) | 8.2 | 10-20 | Indicates very clear water with little to no tannins (brown stain). |
| Total Suspended Solids (mg/L) | 1.3 | 2 – 6 | Better than the ecoregion average range, which indicates clear water. |
| Total Nitrogen :Total Phosphorus | 59:1 | 25:1 – 35:1 | The lake is phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake. |
| Calcium (mg/L) | 33.5 | NA | Indicates a hard water lake with sufficient calcium for Zebra mussel survival. |
| Magnesium (mg/L) | 28.2 | NA | Indicates a hard water lake. |

*Data Source: 2003-2012 PGOLID Monitoring Program*

[1]The ecoregion range is the 25$^{th}$-75$^{th}$ percentile of summer means from ecoregion reference lakes
[2]Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

## Water Quality Characteristics - Historical Means

Years monitored: 1997-2015

| Parameters | Site *201 |
|---|---|
| **Total Phosphorus Mean (ug/L):** | **16.7** |
| Total Phosphorus Min: | 5 |
| Total Phosphorus Max: | 47 |
| Number of Observations: | 93 |
| **Chlorophyll *a* Mean (ug/L):** | **5.2** |
| Chlorophyll *a* Min: | 1 |
| Chlorophyll *a* Max: | 17 |
| Number of Observations: | 93 |
| **Secchi Depth Mean (ft):** | **12.0** |
| Secchi Depth Min: | 7.5 |
| Secchi Depth Max: | 21.6 |
| Number of Observations: | 189 |

*primary site

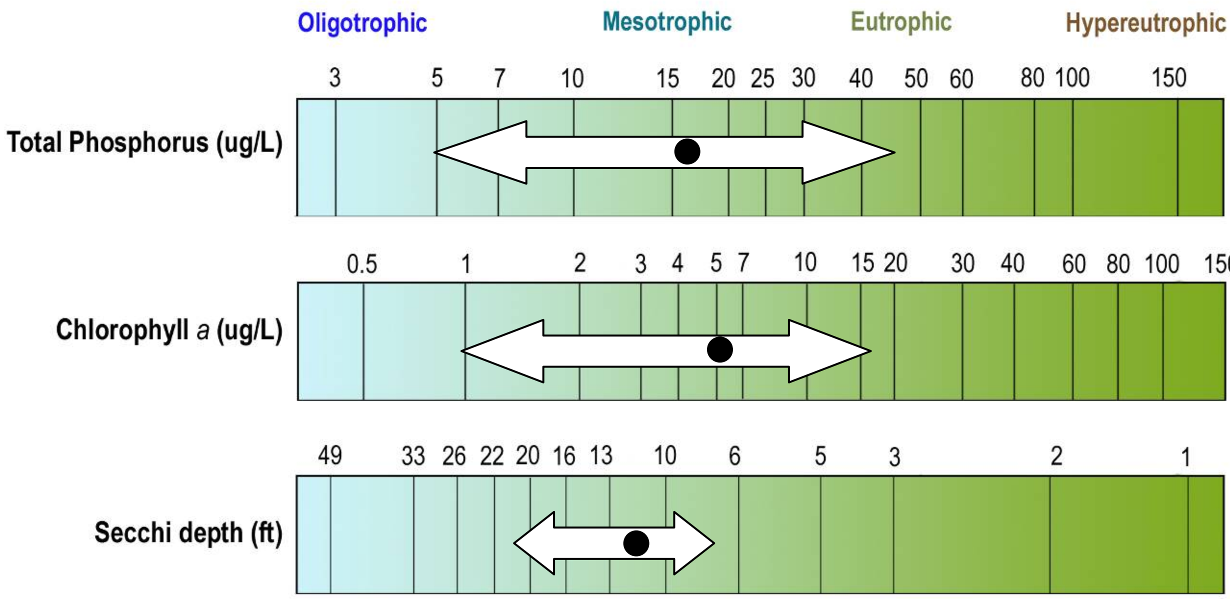



Figure 3.50. Bass Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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 amount 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. Site 201 in Bass Lake has been monitored from 1997-2015. The annual means for Bass Lake range from 9.8-21 ft (Figure 3.51). The annual mean transparency stays right around the historical mean for most years until 2011 when Zebra mussels were found all over the lake. Since then, transparency has been higher.

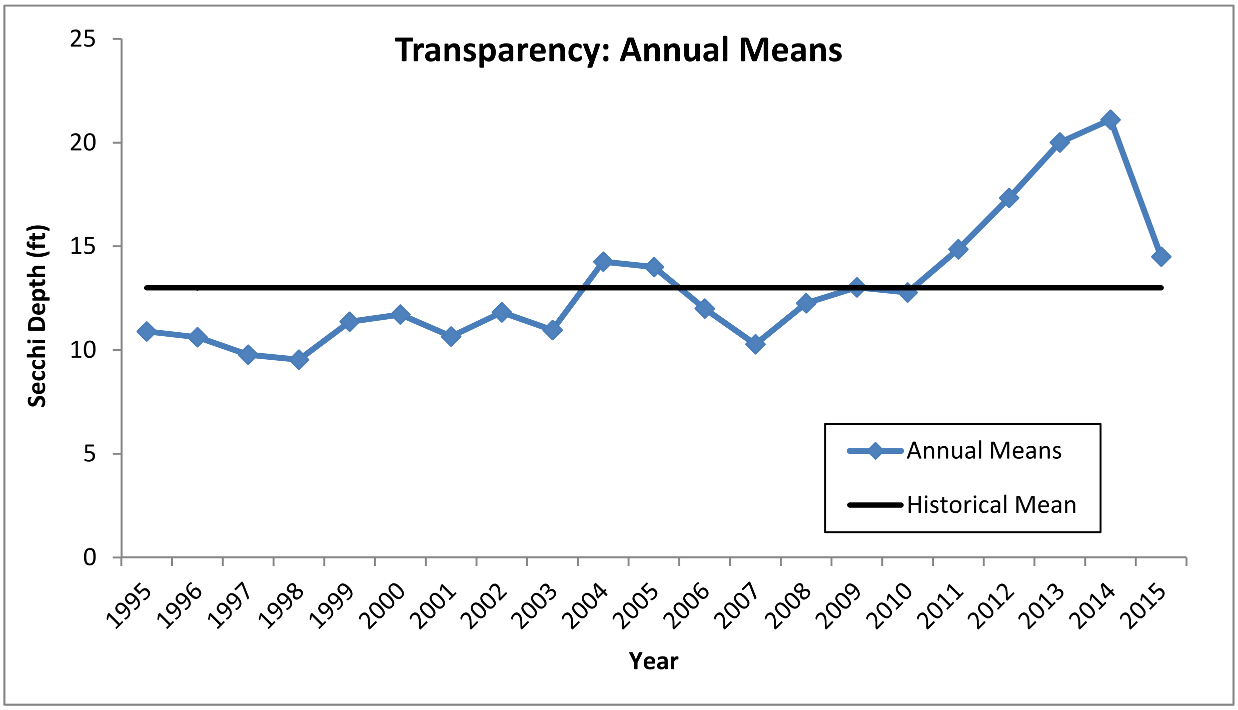



Figure 3.51 Annual mean transparency for site 201.

Bass Lake transparency ranges from 7.5 to 20 feet throughout the summer. Figure 3.52 shows the seasonal transparency dynamics. Bass Lake transparency varies greatly in May and early June and then declines slightly throughout the summer. This pattern is typical for a lake of this depth in Minnesota. The transparency dynamics have to do with algae population dynamics and lake turnover.

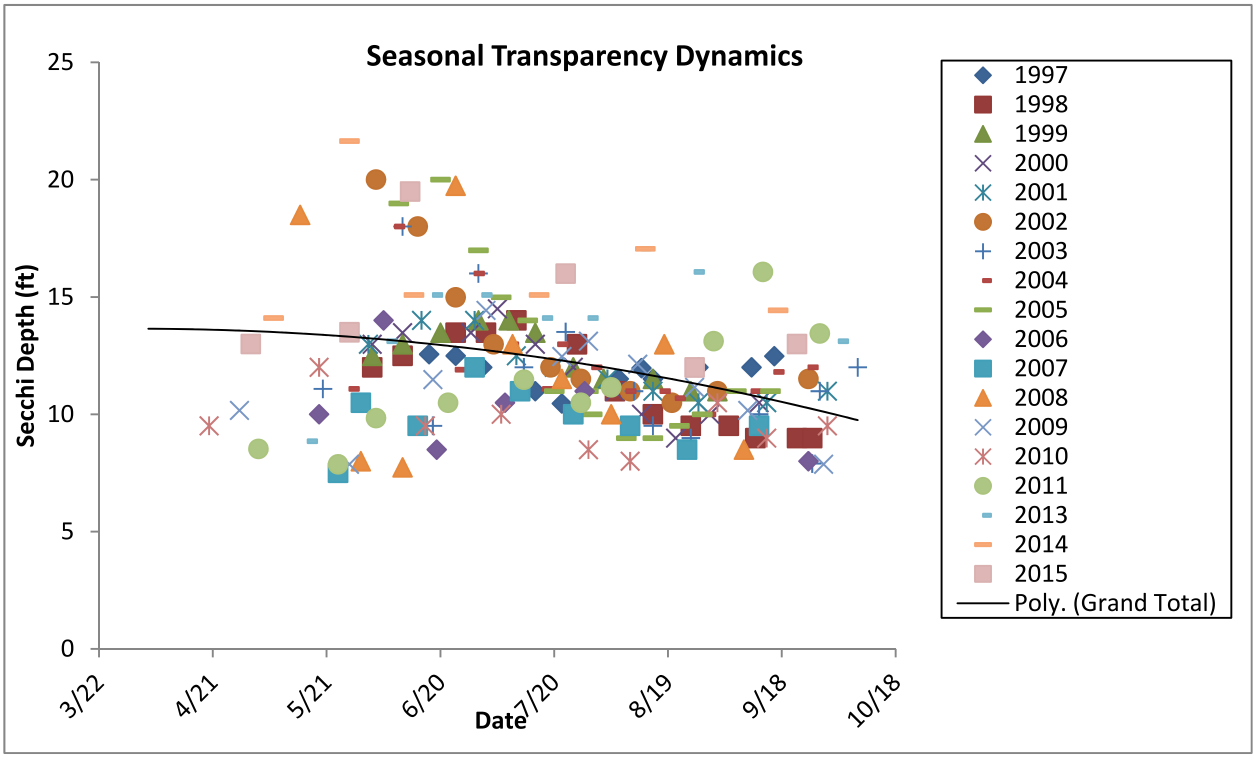



Figure 3.52 Seasonal transparency dynamics and year-to-year comparison.

## User Perceptions

When Secchi depth readings are collected, the perceptions of the water based on the physical appearance and the recreational suitability is recorded. 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 rating decreases. Bass Lake was rated as being "not quite crystal clear" 81% of the time between 1997-2015 (Figure 3.53).

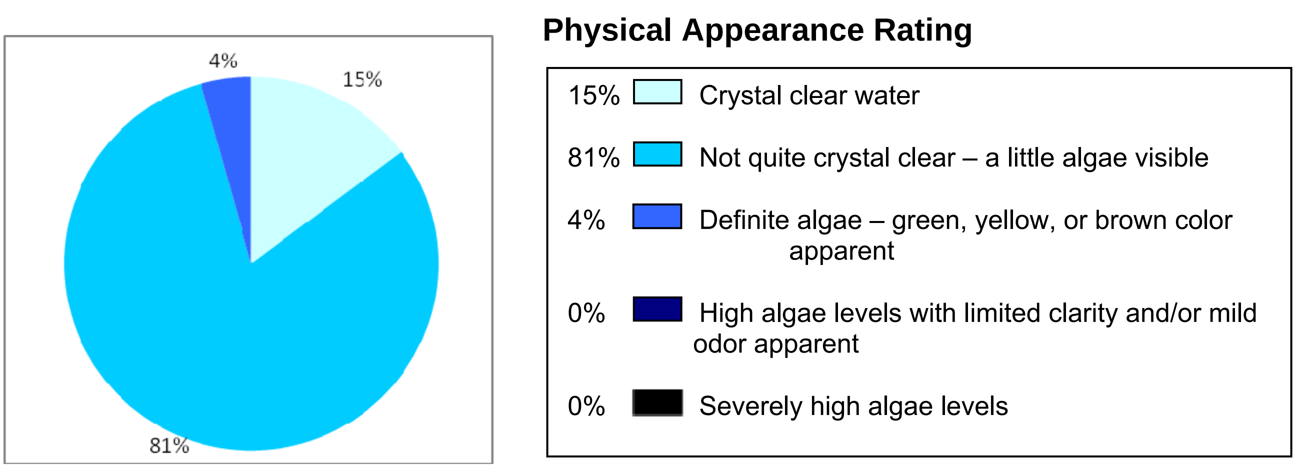
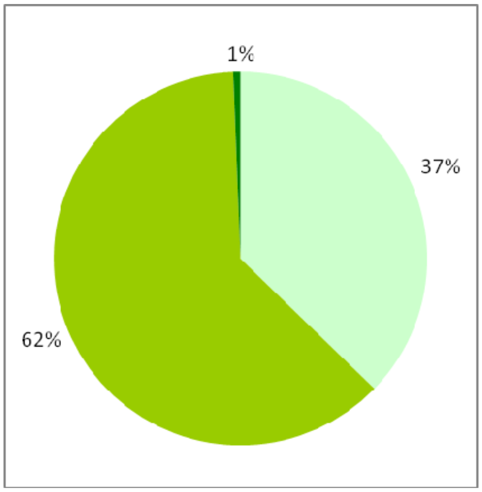



Figure 3.53 Physical appearance rating, as rated by the lake monitor (1997-2015).

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Bass Lake was rated as having "very minor aesthetic problems" 62% of the time from 1997-2015 (Figure 3.54). For 99% of the time, Bass Lake was rated as being swimmable.




**Recreational Suitability Rating**

- 37% Beautiful, could not be better
- 62% Very minor aesthetic problems; excellent for swimming, boating
- 1% Swimming and aesthetic enjoyment of the lake slightly impaired because of algae levels
- 0% Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels
- 0% Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels

Figure 3.54 Recreational suitability rating, as rated by the lake monitor (1997-2015).

# Total Phosphorus

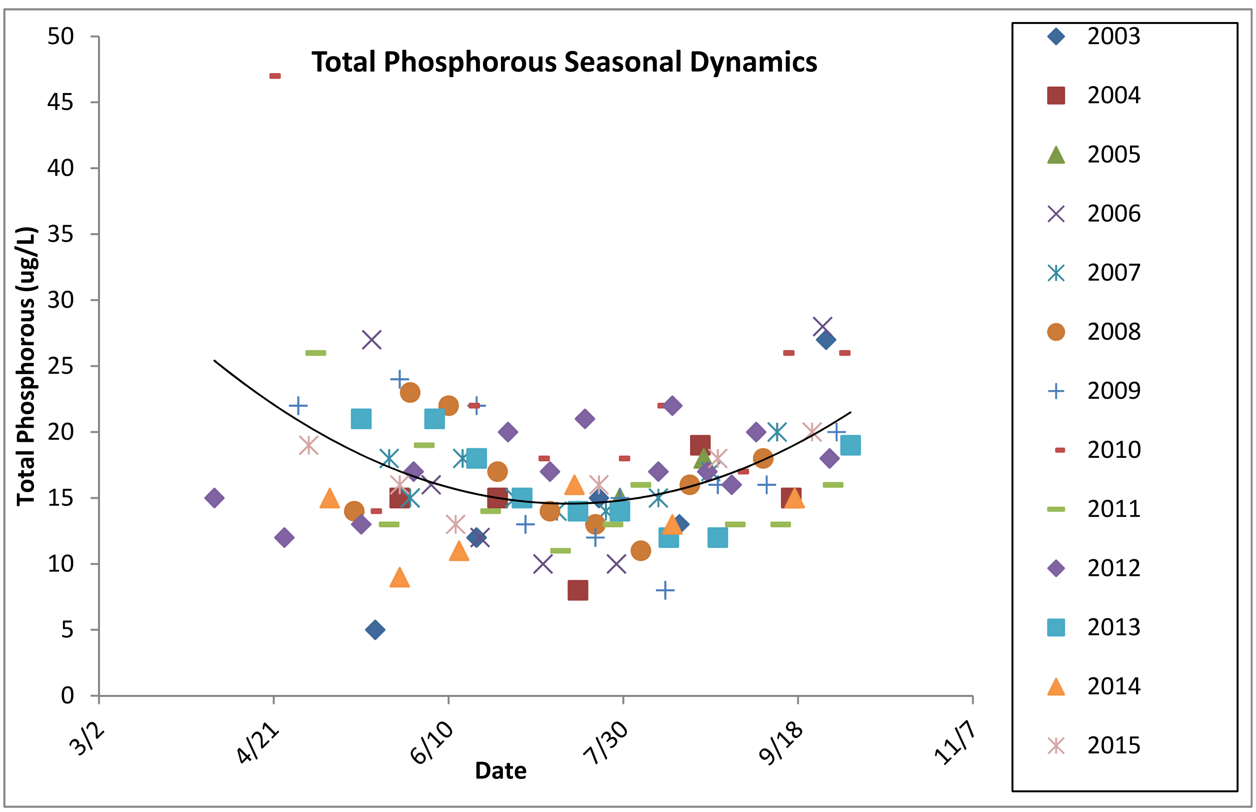



Figure 3.55 Historical total phosphorus concentrations (ug/L) for Bass Lake ( 2003-2015).

Bass Lake is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus. The total phosphorus concentrations follow a pattern in Bass Lake. Concentrations are high in May, when the lake is turning over, low in June through mid-August when the lake is stratified, and high again in September when the lake turns over again (Figure 3.55). This pattern is typical for dimictic lakes that have a distinct bowl-shaped basin and no stream inlets like Bass Lake does.

In 2009, water samples were collected just above the lake bottom to measure internal loading. Internal loading typically occurs in mid-summer when the oxygen at the bottom of the lake (hypolimnion) is depleted. When there is no oxygen in the hypolimnion, a chemical reaction occurs where phosphorus is released from the lake sediment back into the water. Then in the fall when the lake turns over this phosphorus comes up to the surface.

Figure 3.56 shows that Bass Lake follows a typical pattern for internal loading. Internal loading is usually highest in July through mid-August. In spring and fall, the hypolimnion phosphorus concentrations are similar to the surface water concentrations because the lake water column is fully mixed.

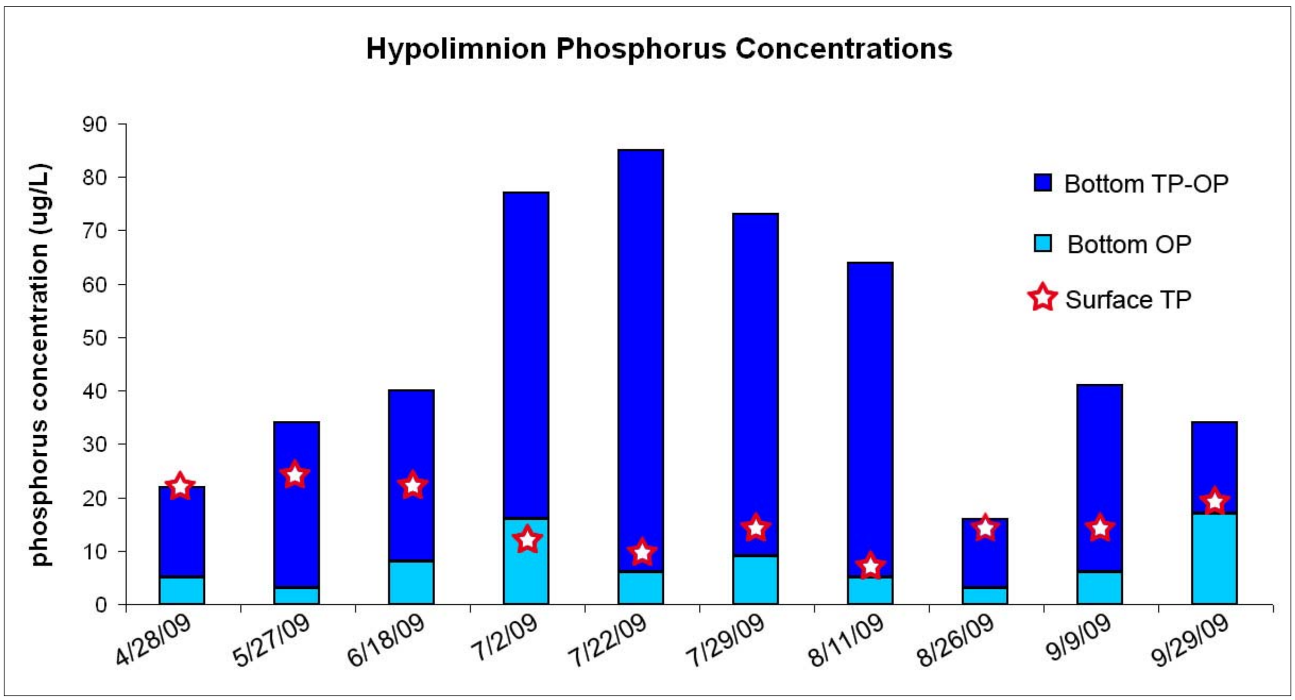



Figure 3.56 Hypolimnion phosphorus concentrations (ug/L) for Bass Lake (data set from 2009).

## Chlorophyll *a*

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.

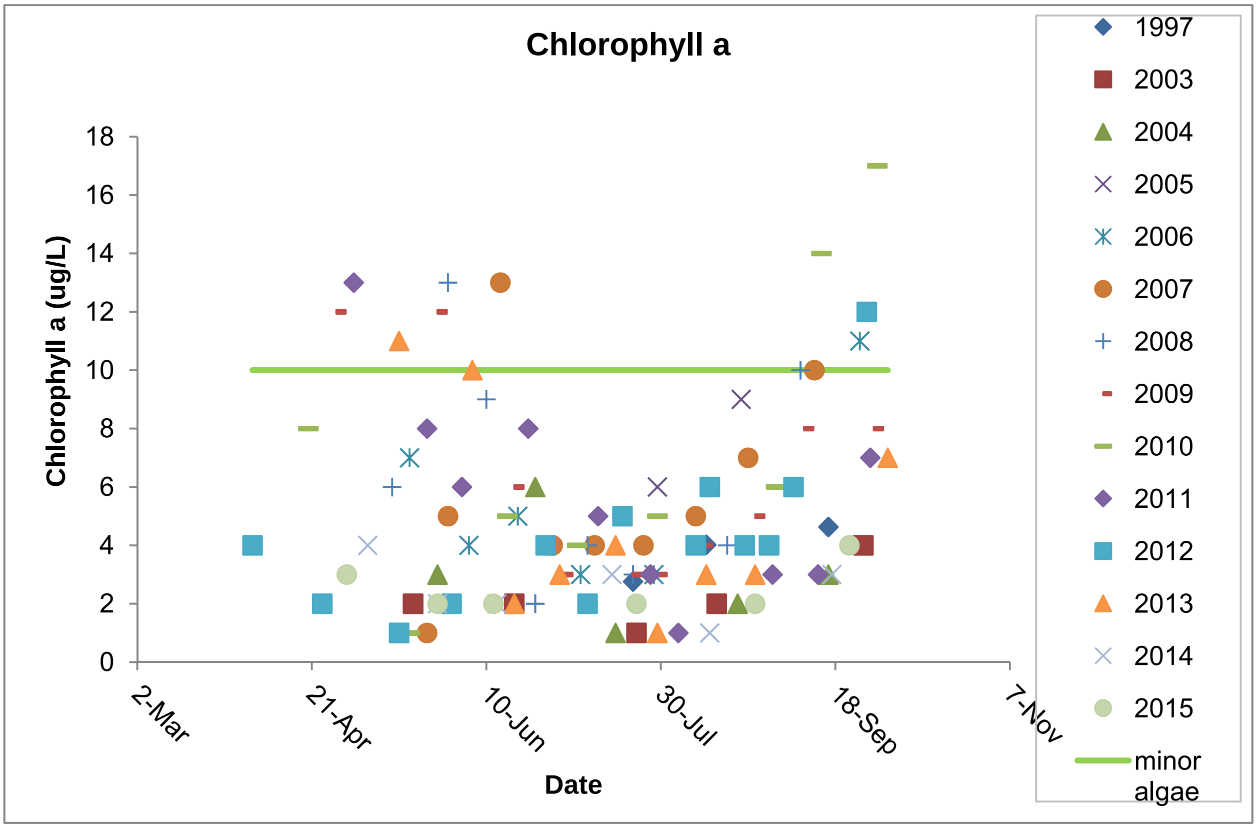


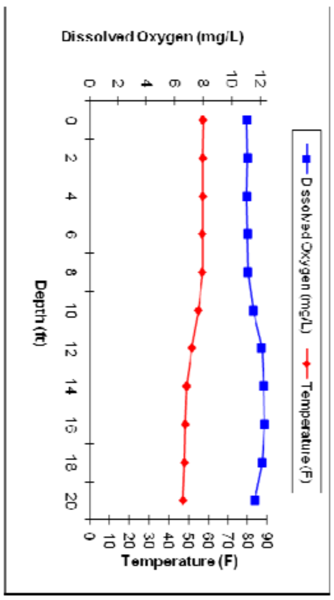

Figure 3.57 Chlorophyll *a* concentrations (ug/L) for Bass Lake (data set from 2003-2015).

Chlorophyll *a* was evaluated in Bass Lake in 2003-2015 (Figure 3.57). Chlorophyll *a* concentrations follow the phosphorus concentrations because phosphorus is food for the algae (Figures 3.55 and 3.57). Chlorophyll *a* concentrations are highest in spring and fall and lowest in the summer. Chlorophyll *a* concentrations in Bass Lake remained below 10 ug/L except for some dates in spring and fall, indicating clear water most of the summer. Chlorophyll *a* concentrations did not reach levels that are considered a nuisance algae bloom on any of the sample dates from 2003-2015.

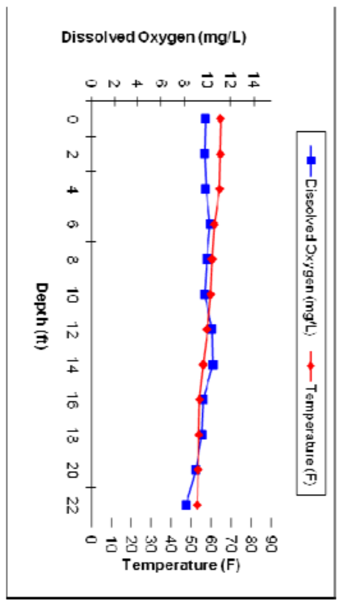
## Dissolved Oxygen

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 oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fish.

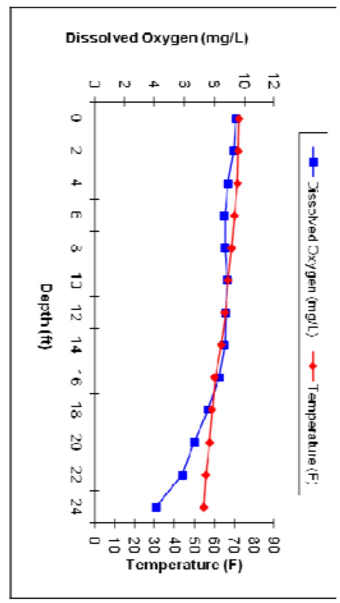
Bass Lake is its own distinct basin with a maximum depth of 33 ft. Dissolved oxygen profiles for Bass Lake have been collected by the PGOLID Water Resource Coordinator from 2007-2015. The profiles indicate that Bass Lake stratifies in mid summer. In 2015, the lake began stratifying in mid June and turned over in late August. In the summer the thermocline was at approximately 17 feet, which means that game fish were most likely absent below 17 feet.



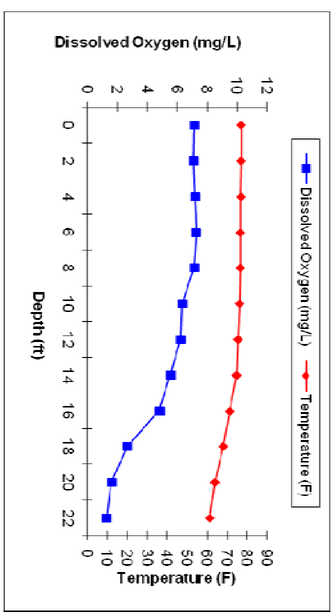
5/1/2015



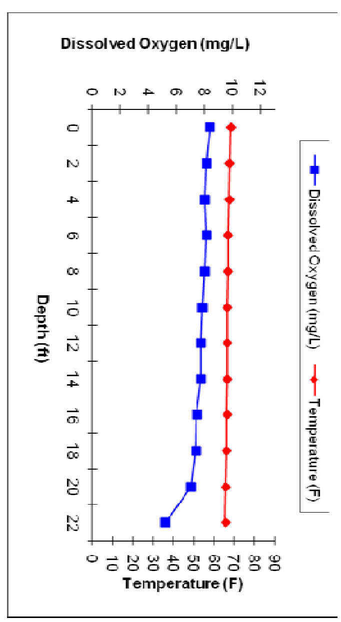
5/27/2015



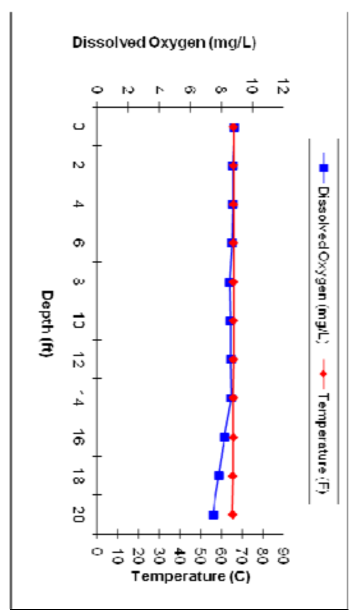
6/12/2015



7/23/2015



8/26/2015



9/22/2015

# Trophic State Index

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases.

| Trophic State Index | Site 201 |
|---|---|
| TSI Total Phosphorus | 45 |
| TSI Chlorophyll-a | 47 |
| TSI Secchi | 41 |
| TSI Mean | 44 |
| Trophic State: | Mesotrophic |

*Numbers represent the mean TSI for each parameter.*

The results from these three measurements cover different units and ranges and thus cannot be directly compared to each other or averaged. In order to standardize these three measurements to make them directly comparable, we convert them to a trophic state index (TSI).

The mean TSI for Bass Lake falls in the mesotrophic range (Figure 3.58). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related.

Mesotrophic lakes (TSI 40-50) are characterized by moderately clear water most of the summer. "Meso" means middle or mid; therefore, mesotrophic means a medium amount of productivity. Mesotrophic lakes are commonly found in central Minnesota and have clear water with some algal blooms in late summer. Mesotrophic lakes can also be good walleye lakes.

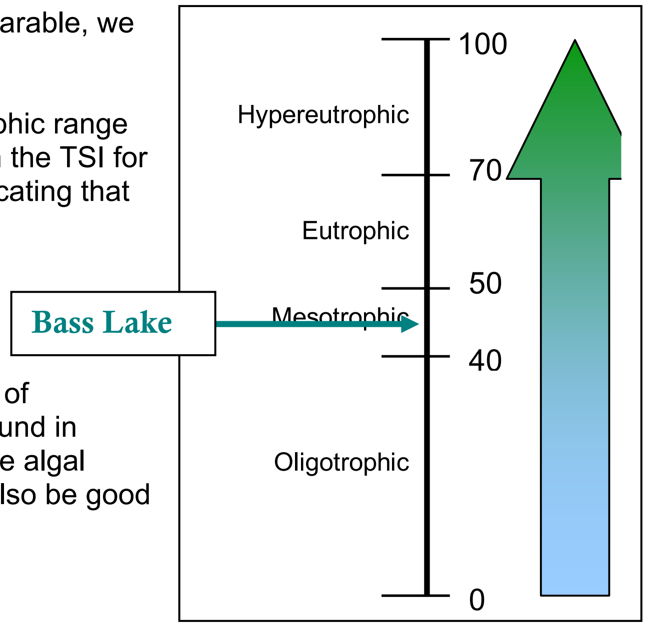



Figure 3.58 Trophic state index chart with corresponding trophic status.

| TSI | Attributes | Fisheries & Recreation |
|---|---|---|
| <30 | **Oligotrophy:** Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water. | Trout fisheries dominate. |
| 30-40 | Bottom of shallower lakes may become anoxic (no oxygen). | Trout fisheries in deep lakes only. Walleye, Tullibee 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.

Bass Lake has data from 2003-2015. The data was analyzed using the Mann Kendall Trend Analysis.

| Lake Site | Parameter | Date Range | Trend | Probability |
|---|---|---|---|---|
| 201 | Total Phosphorus | 2003-2015 | No Trend | -- |
| 201 | Chlorophyll *a* | 2003-2015 | No Trend | -- |
| 201 | Transparency | 1997-2015 | No Trend | -- |

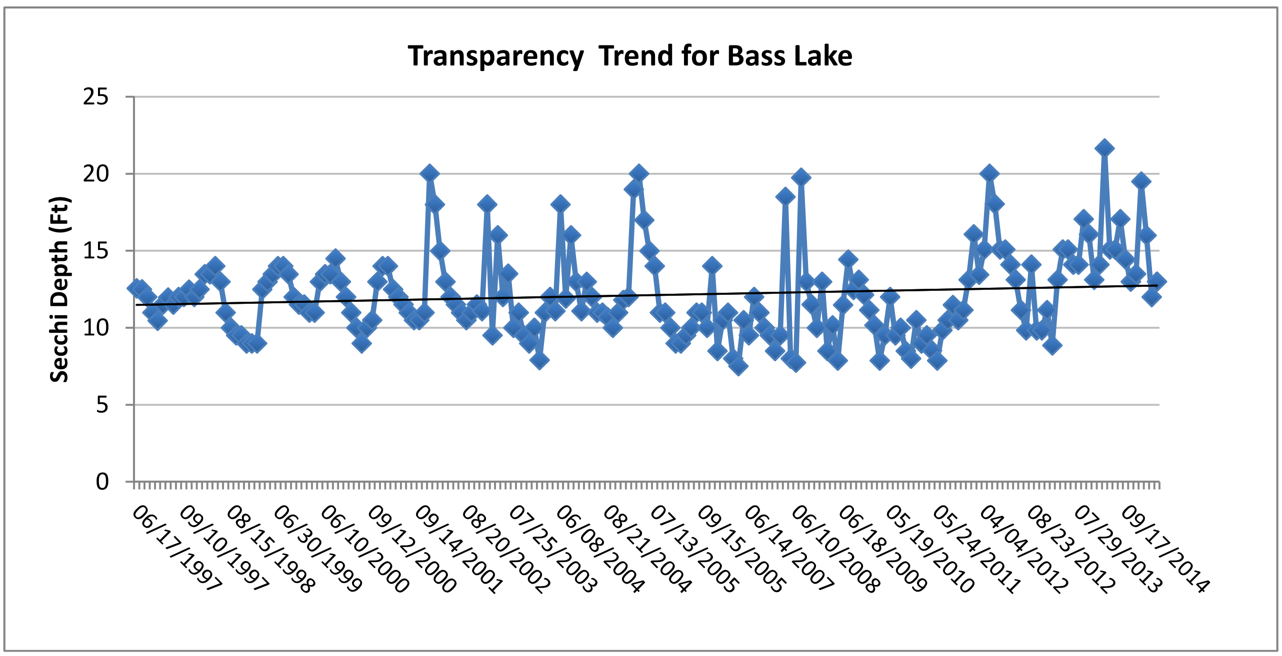


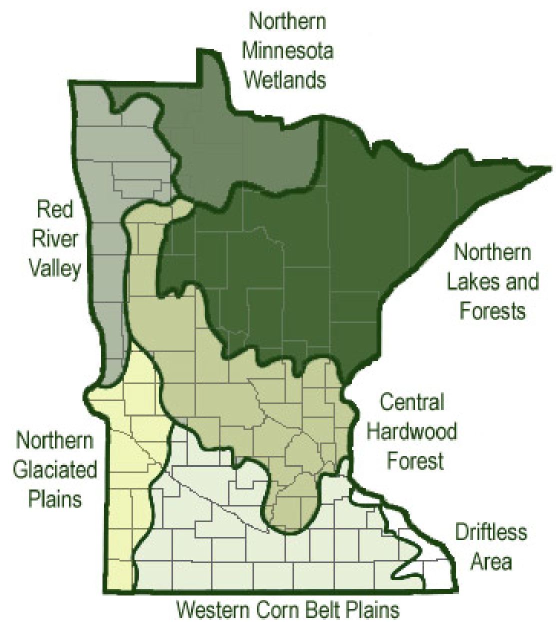

Figure 3.59 Bass Lake transparency trend from 2003-2015.

Bass Lake shows no water quality trends, which means that the water quality is stable (Figure 3.59).

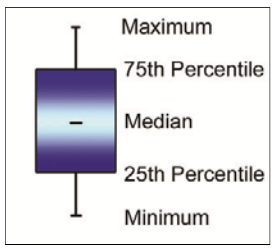
Bass Lake has a very dense native plant population along with emergent plants such as bulrush and cattails. This vegetation has been increasingly removed over the past decade, which could contribute to higher algae levels. The aquatic plants take up a lot of the phosphorus in the water and stabilize the lake sediments. When aquatic plants are removed, the phosphorus is available for more algae growth. In order to maintain the water quality in Bass Lake, aquatic plants should be protected and not removed by homeowners.

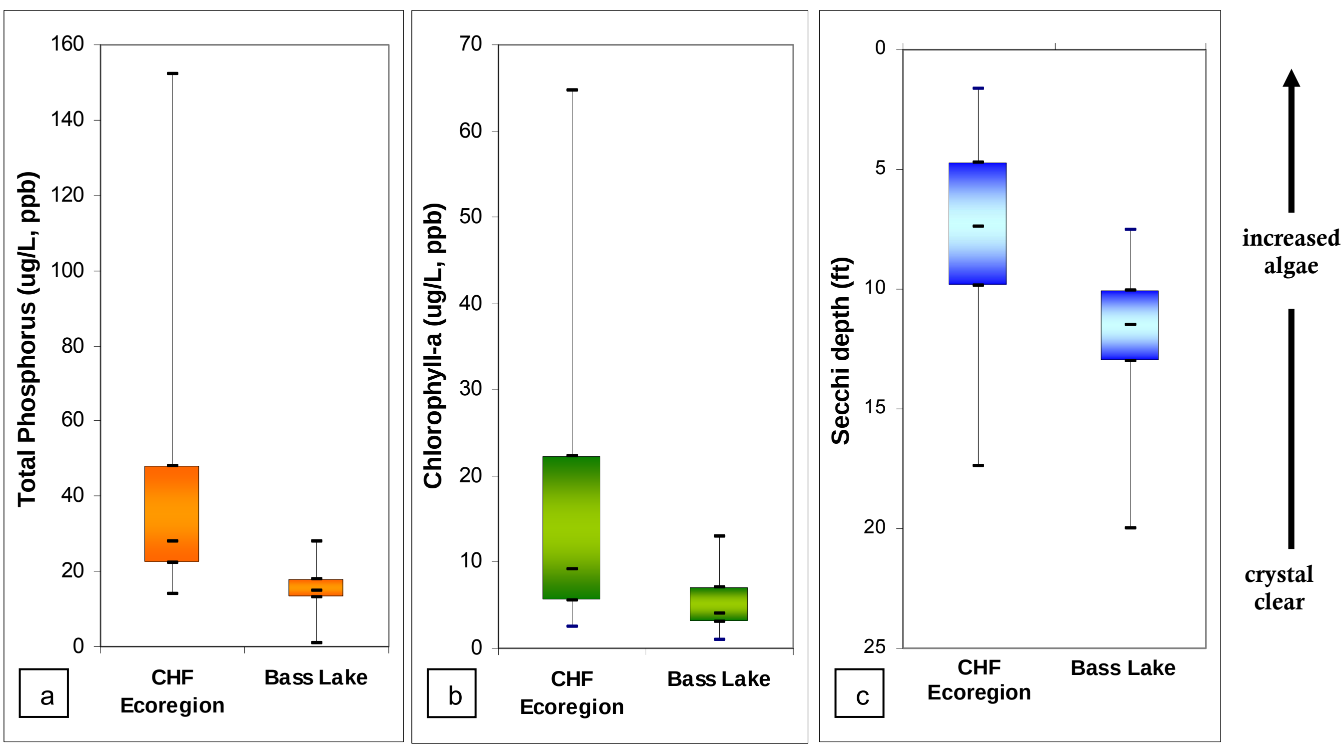
# Ecoregion Comparisons

Minnesota is divided into seven ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.




Bass Lake is in the Central Hardwood Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Bass Lake are all better than the expected ecoregion ranges (Figures 3.60a-c).




Figures 3.60a-c. Bass Lake ranges compared to Central Hardwood Forest Ecoregion ranges (data from 2003-2009).

# State Assessments (Minnesota Pollution Control Agency)

**Impaired Waters Assessment 303(d) List**
There are two main types of Impaired Waters Assessment for lakes: eutrophication (excess phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption.  Bass Lake is not listed as impaired for mercury in fish tissue; however, Pelican Lake is listed and is connected to Bass Lake.  Therefore, the fish in Bass Lake should be considered impaired for mercury as well.  See page 111 for fish consumption guidelines.  Bass Lake is not listed as impaired for eutrophication.

**Aquatic Recreational Use Assessment 305(b)**
In the 2008 MPCA Aquatic Use Assessment (305(b)), Bass Lake was classified as being fully supporting for Aquatic Recreational Use.

# Phosphorus Loading Models

## Introduction

**Introduction**
PGOLID has an extensive data set from its monitoring programs. The lake monitoring program was started in 1996, and has resulted in consistent data from 1996 to 2014. The stream monitoring program was started in 2001 and has resulted in consistent data from 2001 to 2014. This data was inputted to a BATHTUB computer model (US Army Corps of Engineers) to determine the proportion of phosphorus loading from different sources to the lake. These results can be used to implement programs to improve or maintain the water quality by addressing the phosphorus sources. Potential phosphorus sources include septic systems, shoreline runoff, precipitation, internal loading and inlet loading.

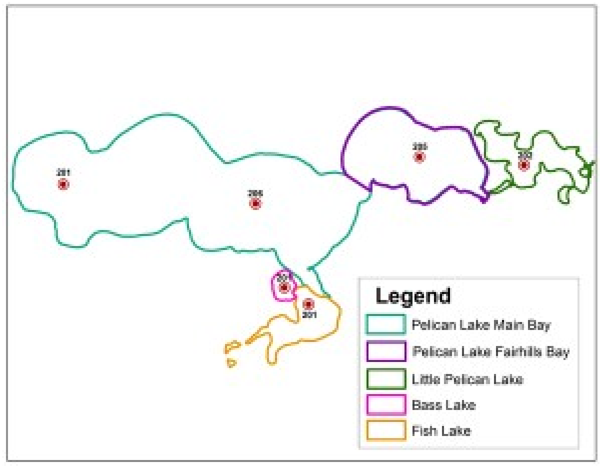


Figure 3.61. Watersheds contributing water and phosphorus to PGOLID.

**Results**
The model output for each lake shows the percentage of phosphorus loading from each of the different sources (Figure 3.62). Little Pelican, Pelican, and Fish Lakes look somewhat similar because they have major inflows from the Pelican River. Overall, the largest source of phosphorus loading to the lakes is the inlets, especially the Pelican River. Septic systems and shoreline runoff are minimal in comparison to the inlets.

Bass Lake looks different from the other lakes because it is fairly isolated, with no major inlets. The connection between Bass and Fish Lakes does not appear to move much water back and forth, but there is undoubtedly some exchange (~11%). Therefore, the septic systems and shoreline runoff have a larger proportional impact in Bass Lake than the other PGOLID lakes (Figure 3.62).

| | Little Pelican Lake | Pelican Fairhills Bay | Pelican Main Bay | Fish Lake | Bass Lake |
|---|---|---|---|---|---|
| Inlet Loading | 94.1% | 76.8% | 77.0% | 96.2% | 10.5% |
| Internal Loading | 2.4% | 16.6% | 7.0% | 1.0% | 11.1% |
| Precipitation | 1.9% | 4.5% | 11.5% | 1.6% | 30.4% |
| Shoreline Runoff | 1.1% | 0.9% | 2.2% | 0.7% | 31.0% |
| Septic Systems | 0.6% | 1.1% | 2.3% | 0.5% | 17.0% |

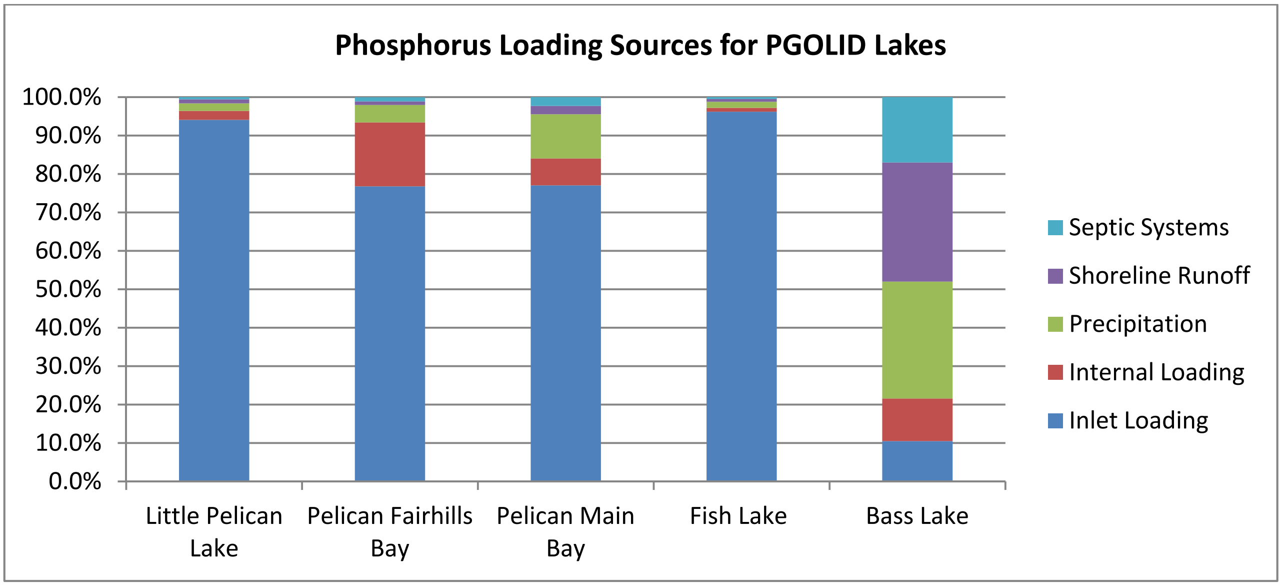



Figure 3.62. Phosphorus loading sources for PGOLID Lakes.

**Implications**

Because the Pelican Group of Lakes has so much water flowing through them, they are continually flushed out. This is good, because much of the nutrients coming into the lake go back out of the lake. The nutrients that stay in the lake are taken up by plants and algae and settle down into the sediments.

### *Septic Systems*

Septic systems are a phosphorus source to the lake that can be controlled. Because of the Pelican River flow through the lakes, septic systems do not have much impact on the lake. Bass Lake, however, is different. Because there is not the water exchange occurring in Bass Lake, the septic system nutrients stay in the lake. It is still important to make sure the septic systems in the lake remain in good working order.

### *Shoreline Runoff*

Shoreline runoff is a phosphorus source to the lake that can be controlled. Because of the Pelican River flow through the lakes, shoreline runoff is not a major source of phosphorus to the lake, but it does still affect it, especially in localized areas. When looking at the shoreline area from the water's edge to 250 feet back from the lake, 58-85% of the phosphorus loading from that land area comes from developed lots (impervious surface and turf grass). Shoreline runoff can fuel plant growth in swimming areas near shore. PGOLID has been implementing a Shoreline Restoration Program with a DNR Shoreline Habitat Restoration Grant since 2009. Restoring turf lawns to native grasses, wildflowers, trees and shrubs, and limiting the impervious surface in new development will limit future shoreline runoff. Having a natural shoreline is especially important in Bass Lake because it does not have a major inlet flushing it out.

### *Precipitation*

Precipitation is a phosphorus source to the lake that cannot be controlled. The amount of phosphorus loading from precipitation is determined by the surface area of the lake. The more surface area the lake has, the more rain it receives directly from rainfall. Bass Lake had the highest loading from precipitation, but this is because it has very little inlet loading. Of the other segments, the Main Bay of Pelican Lake had the most phosphorus loading from precipitation because it has the largest surface area. There is nothing that can be done to limit phosphorus loading from precipitation.

### *Internal Loading*
Internal loading is a phosphorus source to the lake that can be somewhat controlled. It is based on the morphometry (size and depth), and biology of the lake, but it is also based on the amount of phosphorus in the lake. Limiting external phosphorus inputs to the lake can help reduce the amount of internal loading in a lake. Internal loading is most prevalent in Fairhills Bay of Pelican Lake. This is because this bay is deep enough to stratify (separate into a warm top layer and cold bottom layer) and it receives nutrients and sediment from the Pelican River. Little Pelican Lake has the highest in-lake phosphorus of all the PGOLID lakes, but because it is shallow it does not fully stratify in the summer. The water column remains fairly mixed, and so the bottom of the lake has oxygen present, which keeps the phosphorus in the sediments from releasing in to the water.

### *Inlet Loading*
Inlet loading is a phosphorus source to the lake that can be somewhat controlled. The best way to manage inlet loading is to maintain good relationships with upstream neighbors, and to monitor for any problems that could arise. If problems are detected they can hopefully be fixed before the impact to the lake is large. PGOLID has been implementing a stream monitoring program since 2001.

The largest source of phosphorus to the PGOLID Lakes is the Pelican River (Figure 3.62). This means much of the phosphorus comes from upstream in the watershed such as Detroit Lakes.

It is difficult to control phosphorous inputs upstream in the watershed. PGOLID maintains good working relationships with upstream entities such as the Pelican River Watershed District and the City of Detroit Lakes.

## MINLEAP model *(run by MPCA, 1997)*

**Summary**
In 1997, the Minnesota Pollution Control Agency (MPCA) conducted their Lake Assessment Program on Pelican Lake. The summary report showed that Pelican Lake phosphorus levels are better than one would predict taking into account the watershed. In short, this means that the lake water quality is better than expected for the area. For Pelican Lake, it would be desirable to maintain the currently low in-lake phosphorus (P) concentration. An in-lake P goal on the order of 15 – 22 µg/L may be appropriate based on historical data. Should in-lake P concentrations increase, it is likely that the frequency of nuisance algal blooms would increase and transparency would decrease. One indication of a declining trend in water quality would be if summer-mean transparency remained consistently below the current long-term mean of 11.3 feet (3.4 m) or if summer-mean TP increased above 25 µg/L.

**Details**
Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow of amount of water that enters the lake.

To analyze the in-lake water quality of Pelican Lake, the model, MINLEAP (Wilson and Walker, 1989), was used. The "Minnesota Lake Eutrophication Analysis Procedures" (MINLEAP), was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). The model, Vighi and Chiaudani (1985), was also used estimated a background phosphorus (P) concentration for Pelican Lake. This model is built into the MINLEAP model and is run concurrently with MINLEAP.

MINLEAP uses the total watershed area of the lake (minus lake surface area) combined with ecoregion-based typical runoff and stream total phosphorus (TP) as a basis for predicting TP loading to the lake.

In our first model run for Pelican MINLEAP predicted an in-lake TP of 27 (± 11) µg/L. This value is higher than the historical observed mean of 15.7 µg/L (1996-2009). Since the initial MINLEAP model run predicted a TP value that was higher than anticipated, we decided a closer review was in order. Upon closer examination of the watershed map and model inputs for Pelican Lake, it was thought that the southwestern portion of the watershed (area containing Tamarac Lake) may, in fact, not even drain to Pelican Lake – as it appears to be a closed basin. In addition, the model does not consider the "processing" of the watershed TP loading that takes place in Little Pelican Lake; which leads to a much lower P-loading to Pelican from that portion of the watershed. Both of these factors would contribute to a higher predicted P-loading, to the lake than what actually occurs. Thus, in an attempt to generate a more "realistic" loading, we calibrated the model by reducing the inflow stream TP concentration. This resulted in a predicted in-lake TP of 22 µg/L. This value, while higher, is not significantly different than the historical observed TP (Table 3.1) nor the long-term mean (Table 3.2). In turn, predicted chlorophyll *a* and Secchi values were quite similar to observed.

A second mathematical model developed by Vighi and Chiaudani (1985) estimated a background phosphorus (P) concentration for Pelican Lake at 22.3 µg/L. This prediction is based on the morphoedaphic index routinely used in fishery science and predicts background (~ natural) P based on the lake's alkalinity and mean depth. Because of its large size and volume the lake retains a very high percentage of the P which enters the lake (about 83 percent). The model estimates water residence time (time it would take to fill the lake if it was completely empty) at about 8-9 years.

Table 3.1. MINLEAP Model Results for Pelican Lake.

| **Parameter** | **Observed** Historical (1996-2009) | **MINLEAP** Predicted | **MINLEAP** Calibrated |
|---|---|---|---|
| TP (µg/L) | 15.7 ± 5.7 | 27 ± 11 | 22 ± 9 |
| chl-*a* (µg/L) | 5.3 ± 2.8 | 8.1 ± 5.5 | 6.2 ± 4.2 |
| % chl-*a* >20 µg/L | 0 | 2 | 11 |
| % chl-*a* >30 µg/L | 0 | 0 | 0 |
| Secchi (ft) | 11.8 ± 3.8 | 7.5 ± 3.3 | 8.9 ± 3.9 |
| P loading rate (kg/yr) | | 2,368 | 1,754 |
| P retention (%) | | 85 | 83 |
| P inflow conc. (µg/L) | | 177 | 131 |
| water load (m/yr) | | 0.84 | 0.84 |
| outflow volume (hm3/yr) | | 13.41 | 13.41 |
| "background P" (µg/L) | | 22.3 | 22.3 |
| residence time (yrs) | | 8.6 | 8.6 |

Table 3.2. Pelican Lake Summer-Mean TP Concentrations & Model Estimates.

| **2009 Mean** | **Long-Term Mean** | **MINLEAP** | **Vighi – P** |
|---|---|---|---|
| 15.8 ± 4.5 µg/L | 15.7 ± 5.7 | 22 – 27 µg/L | 22.3 µg/L |

**Goal Setting**

The phosphorus criteria value for lakes in the North Central Hardwoods Forest ecoregion, for support of swimmable use, is less than 40 µg/L (Heiskary and Wilson, 1990). At or below 40 µg P/L, "nuisance algal blooms" (chlorophyll *a* > 20 µg/L ) should occur less than 20% of the summer and transparency should remain above 1m over 90% of the summer. Pelican Lake, with a summer-mean P of 15.7 µg/L and a summer-mean chlorophyll *a* of 5.3 µg/L, does not experience nuisance blooms during the summer (MINLEAP model, Table 3.1). For Pelican Lake, it would be desirable to maintain the currently low in-lake P concentration. An in-lake P goal on the order of 15 – 22 µg/L may be appropriate based on data from 1997, and model results (Table 3.2). The summer-mean P concentration in 1997 was below the background concentrations as estimated by Vighi and Chiaudani regression – 22.3 µg/L. Should in-lake P concentrations increase, it is likely that the frequency of nuisance algal blooms would increase and transparency would decrease.

Based on historical user perception information, perceptions of “impaired swimming” and “algal green” never occurred. Maintaining a summer-mean P concentration of about 15 - 22 µg/L or lower over the long term, may ultimately require that P-loading to the lake be reduced. Important considerations include implementation of BMP’s in the shoreland area and ultimately through the watershed with a particular emphasis on the direct drainage area. A more comprehensive review of land use practices in the watershed may reveal opportunities for implementing BMPs in the watershed and reducing P-loading to the lake. Proper maintenance of buffers areas between lawns and the lakeshore, minimizing use of fertilizers, and minimizing the introduction of new significant sources of P loading, e.g., stormwater from nearshore development activities in the watershed, will serve to minimize loading to the lake. These and other considerations will be important if the good water quality of Pelican Lake is to be maintained over the long term.

Reference: Klang, Jennifer. 2004. Lake Assessment Program, 1997. Minnesota Pollution Control Agency Report, St. Paul, MN. http://www.pca.state.mn.us/publications/reports/lar-56-0786.pdf