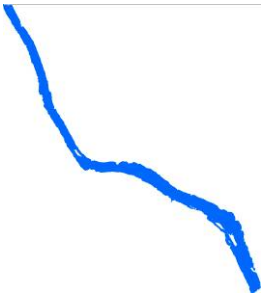
# Big Stone Lake 06-0152-00 BIG STONE COUNTY

## Summary



Big Stone Lake covers 12,610 acres of surface area, stretching 26 miles from end to end and averaging around 1 mile wide. It straddles the Minnesota – North Dakota border. Big Stone Lake is the source of the Minnesota River, which flows 332 miles to the Mississippi River. Flow from the lake to the Minnesota River is regulated by the Big Stone Lake Dam, located at the southern end of the lake. The lake is fed by the Little Minnesota River at its north end and numerous tributaries along its length.

Big Stone Lake is not a typical lake. It is a reservoir in the Minnesota River, and acts more like a large river system than a contained lake.

Big Stone Lake is located in the Northern Glaciated Plains Ecoregion (page 9). The rolling terrain of this ecoregion is heavily cultivated. The vast majority of natural vegetation in this area has been replaced by row crops including corn, wheat, soybeans and sunflowers. Because of the extensive agricultural land use, many lakes and streams face increasing sedimentation and elevated nutrient levels.

The data assessment for Big Stone Lake shows that phosphorus concentrations are much higher than what one would expect when looking at the chlorophyll a and transparency data. This means that not all the phosphorus is being utilized by algae. One possible explanation could be that the phosphorus loading from the numerous tributaries is so high that it overloads the system and flows right through the lake to the Minnesota River. In addition, the phosphorus concentrations are highest at the north end of the lake and steadily decline as one moves south throughout the lake. This could indicate that a high proportion of the phosphorus is entering the lake from the north end.

**Recommendations**

Phosphorus concentrations at the north end of the lake seem to be the biggest problem for the lake. Look into possibilities for phosphorus reduction in this area.

Further investigation into the Little Minnesota River inlet could help in determining the source of phosphorus on the north end of the lake. Continue the stream monitoring program that was started in 2010 (see page 11 for stream results).

Continue yearly in-lake monitoring for 8-10 years so a long-term trend analysis can be performed. Trend information will tell you if the lake is getting better, worse, or staying stable over time.

## Vitals

| | |
|---|---|
| MN Lake ID: | 06-0152-00 |
| County: | Big Stone |
| Ecoregion: | Northern Glaciated Plains |
| Major Drainage Basin: | Minnesota River |
| Latitude/Longitude: | 45.30 /-96.45 |
| Monitored Sites: | 108, 205, 208, 209, 210, 217 |

## Physical Characteristics

| | | |
|---|---|---|
| Surface area (acres): | 12,610 | |
| Littoral area (acres): | 12,484 | |
| % Littoral area: | 99% | |
| Max depth | (ft): 16 | (m): 4.9 |
| Mean depth | (ft): 11 | (m): 3.4 |
| Inlets | Little Minnesota River and numerous tributaries | |
| Outlets | Minnesota River at Ortonville | |

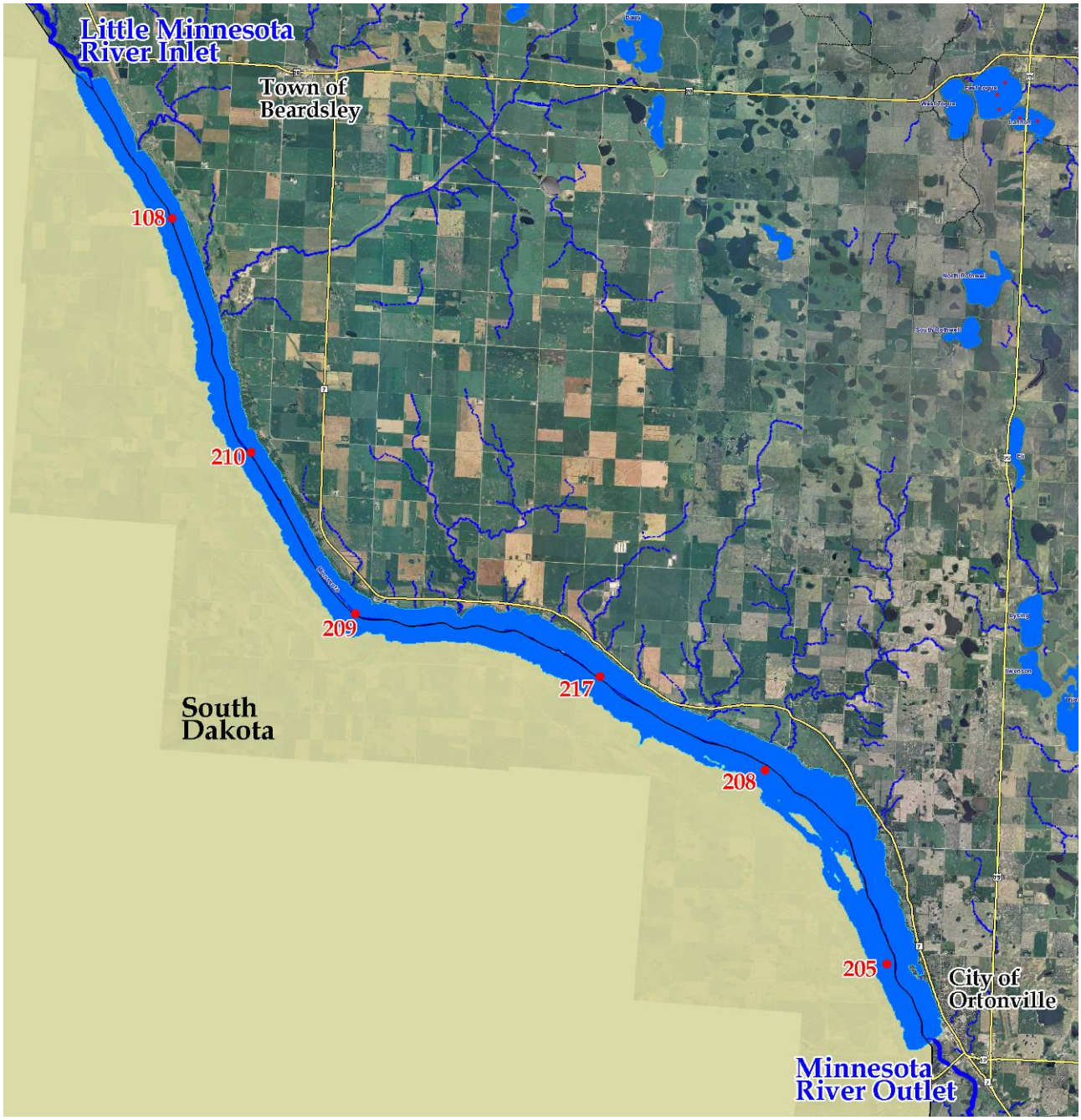



Figure 1. Map of Big Stone Lake illustrating lake sample site locations, stream inlets and outlets and aerial land use.

| Lake Site | Site Name | Depth (ft) | Monitoring Programs |
|---|---|---|---|
| 108 | Horstein's | 5 | RMB Lab: 2007-2010 |
| 210 | Bonanza | 15 | CLMP: 1991-1992; RMB Lab: 2007-2010 |
| 209 | Hartford Beach | 15 | CLMP: 1991-1993; RMB Lab: 2007-2010 |
| 217 | Buck's Point | 15 | CLMP: 2005-2010; RMB Lab: 2007-2010 |
| 208 | Twin Silos | 15 | CLMP: 1991; RMB Lab: 2007-2010 |
| 205 | Peninsula | 10 | CLMP: 1991-1992; RMB Lab: 2007-2010 |

**KEY**: CLMP – MPCA Citizens Lake Monitoring Program

## Water Quality Characteristics - Historical Means

Years monitored: 2007-2010

| | North End of Lake → | | | | South End of Lake | |
|---|---|---|---|---|---|---|
| **Parameters** | **Site 108** | **Site 210** | **Site 209** | **Site 217** | **Site 208** | **Site 205** |
| **Total Phosphorus Mean (ug/L):** | **207** | **191** | **170** | **157** | **145** | **149** |
| Total Phosphorus Min: | 87 | 99 | 106 | 95 | 68 | 92 |
| Total Phosphorus Max: | 391 | 352 | 270 | 243 | 246 | 225 |
| Number of Observations: | 23 | 23 | 23 | 22 | 22 | 22 |
| **Chlorophyll *a* Mean (ug/L):** | **25** | **37** | **45** | **32** | **32** | **50** |
| Chlorophyll-a Min: | 1 | 1 | 1 | 1 | 2 | 1 |
| Chlorophyll-a Max: | 90 | 179 | 169 | 138 | 157 | 284 |
| Number of Observations: | 22 | 23 | 23 | 22 | 22 | 21 |
| **Secchi Depth Mean (ft):** | **3.1** | **4.9** | **5.3** | **6.2** | **6.2** | **5.1** |
| Secchi Depth Min: | 1 | 0.5 | 1.5 | 3 | 3 | 1.5 |
| Secchi Depth Max: | 6.5 | 11 | 13.5 | 14 | 12.5 | 12 |
| Number of Observations: | 21 | 21 | 21 | 19 | 20 | 20 |

**Primary site*

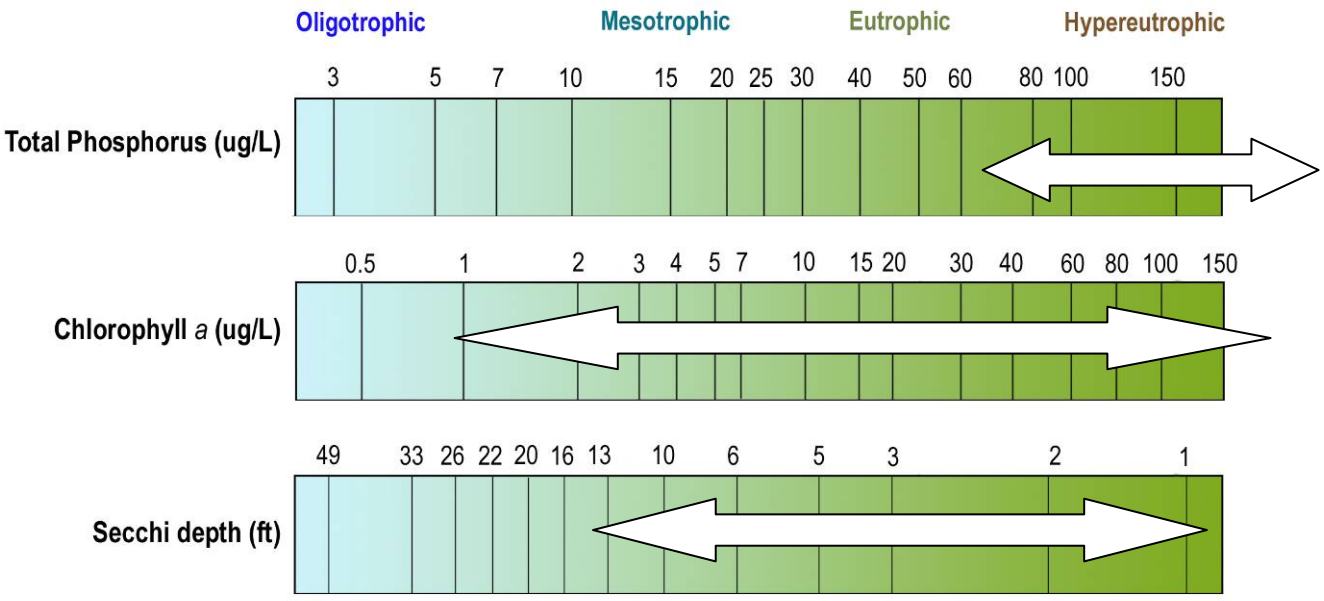



Figure 2. Big Stone Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow represents the range for the lake including all sample sites. Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. EPA 440/5-88-002)

# 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.

The transparency data from 2007-2010 is shown below (Figure 3). Site 108 at the north end of the lake has consistently the lowest transparency. This result could be due to the fact that this site is only five feet deep and that it is closest to the Little Minnesota River inlet. The best transparency from 2007-2010 was consistently at sites 217, 209, and 208 (see map on page 2 for site locations).

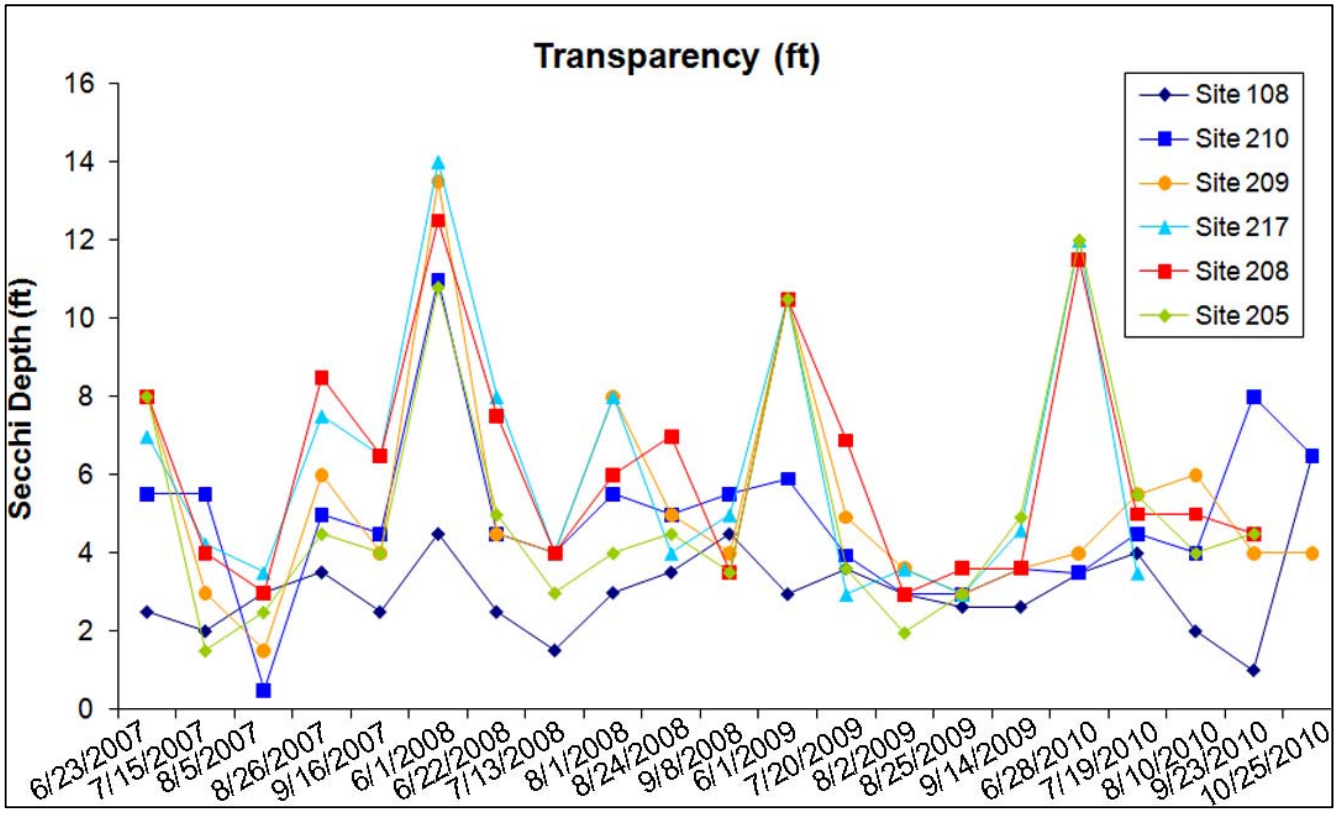



Figure 3. Transparency comparisons between monitoring sites.

Big Stone Lake transparency ranges from 2.5 to 15.5 feet throughout the summer. Figure 4 shows the seasonal transparency dynamics. Big Stone Lake transparency is highest in early June, declines steadily throughout the summer, and then rebounds somewhat in late September. This pattern is typical for a Minnesota Lake. The transparency dynamics have to do with algae population dynamics and lake turnover.

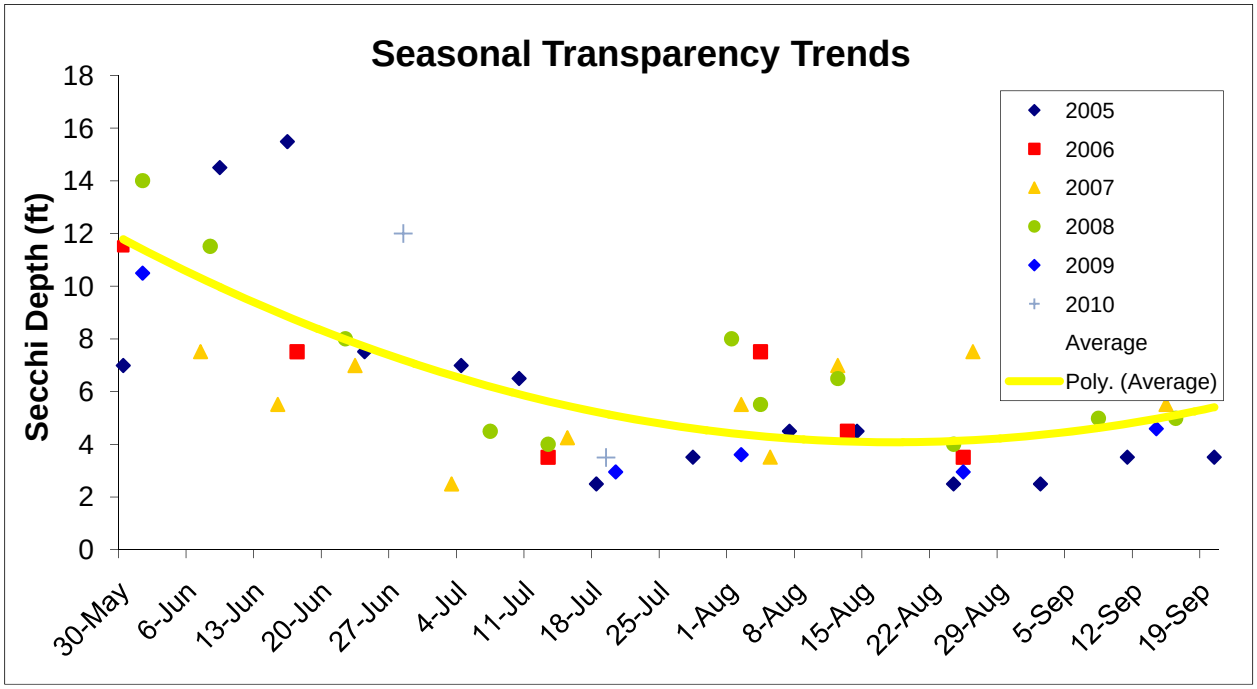



Figure 4. Seasonal transparency dynamics and year-to-year comparison (site 217). The yellow line represents the average best fit line.

## Total Phosphorus

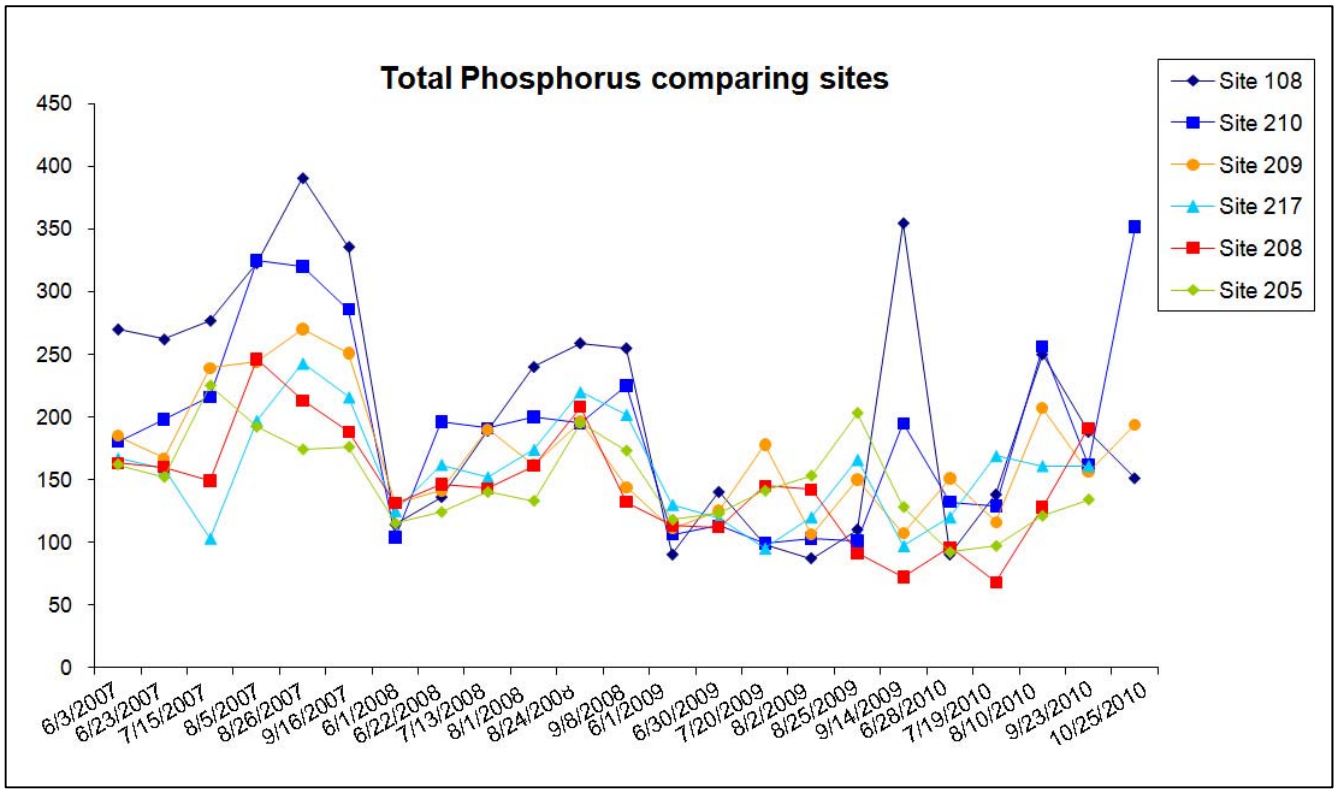



Figure 5. Historical total phosphorus concentrations (ug/L) in Big Stone Lake.

Total phosphorus was evaluated in Big Stone Lake from 2007-2010, and concentrations ranged from 68-391 ug/L (Figure 5). The phosphorus concentrations appear to decrease as one moves south throughout the length of the lake from north to south.

Site 108 at the north end of the lake consistently has the highest phosphorus concentrations. There are three major tributaries located at this site; Hoss Creek, which has a drainage area of 25,600 acres, Fish Creek, which has a drainage area of 40,600 acres, and the Little Minnesota River, which has a drainage area of 290,400 acres, this amounts to a total of 356,600 acres of direct drainage to this site. The lowest mean phosphorus concentrations are at sites 217, 208 and 205 at the south end of the lake.

As far as a seasonal pattern, phosphorus concentrations peaked in August of each year from 2007-2010 and were lowest in early June.

In comparing result year to year, 2007 had the highest phosphorus concentrations for all sites and 2009 had the lowest phosphorus concentrations for all sites except 205 (Figure 6). This year to year variation could be just due to weather variation. In 2007, the northern part of the Big Stone Lake watershed had above normal rainfalls and flooding. These climatic factors could have contributed to higher phosphorus concentrations in 2007.

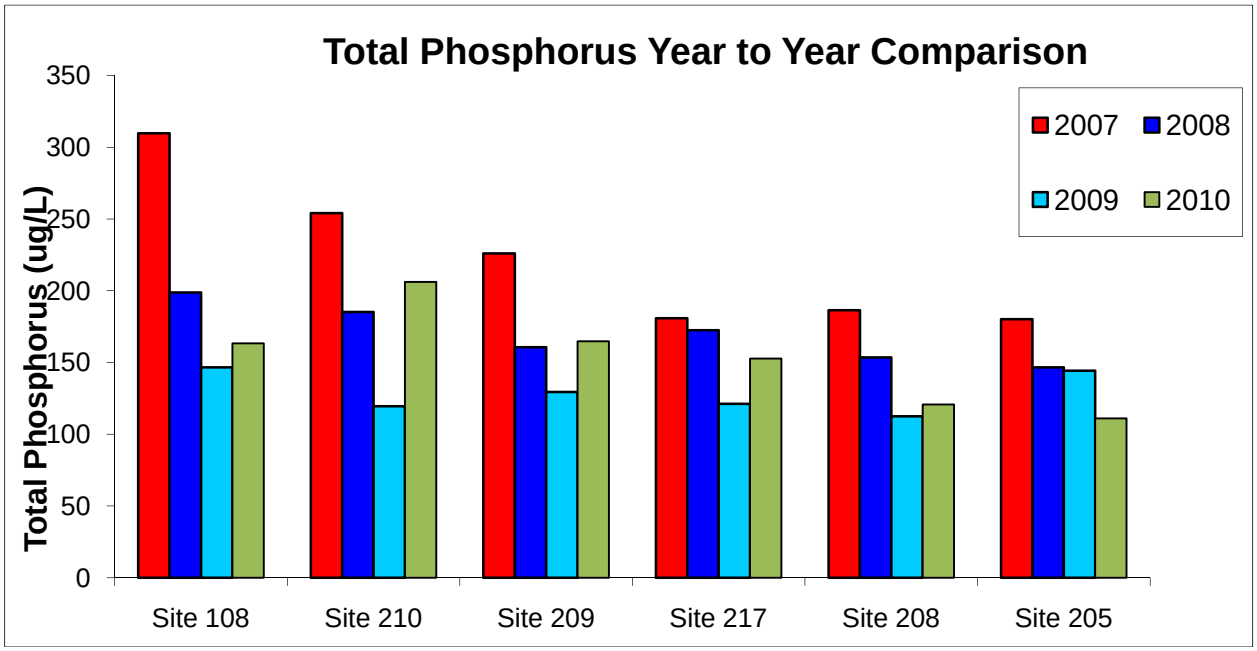


Figure 6. Year to year comparisons of total phosphorus concentrations (ug/L) in Big Stone Lake for each of the six monitoring sites.

For detecting trends, a minimum of 8-10 years of data with 4 or more readings per season are recommended. Big Stone Lake only has four years of data at these lake sites. 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.

The Impaired Waters Standard for the Northern Glaciated Plains Ecoregion is 90 ug/L. At each site, Big Stone Lake exceeded this standard. Big Stone Lake is currently not considered impaired for eutrophication because the chlorophyll a and transparency data do not exceed the impaired waters standards. Phosphorus should continue to be monitored to track any future changes in water quality.

## 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.

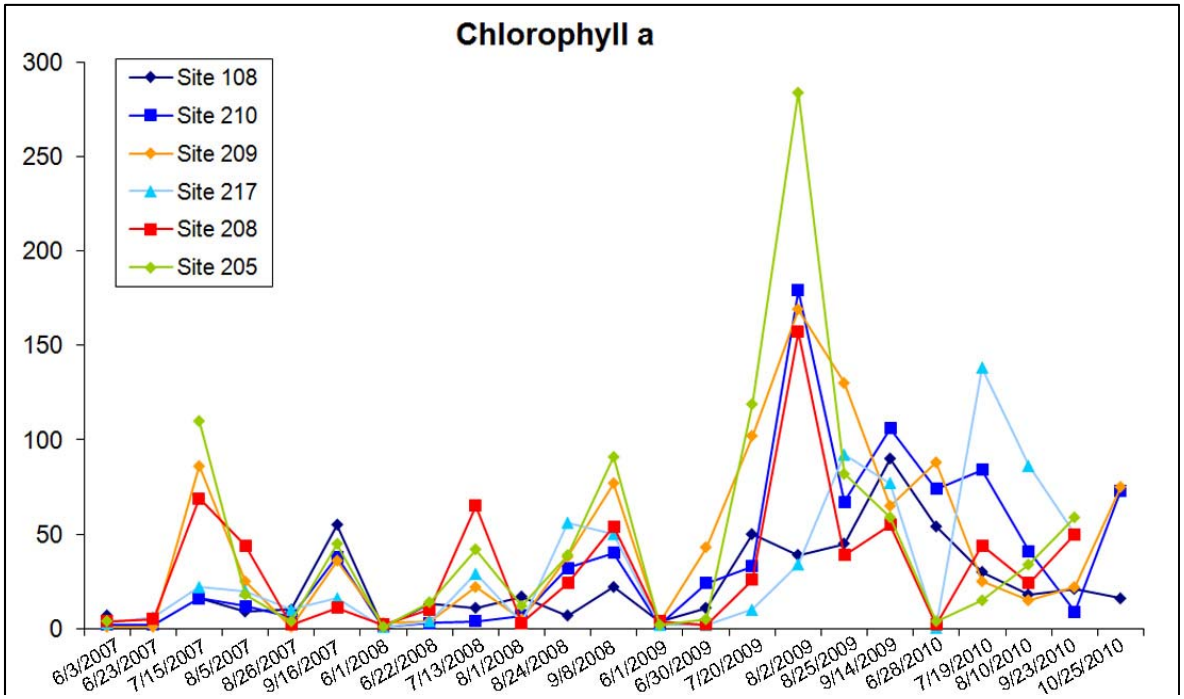
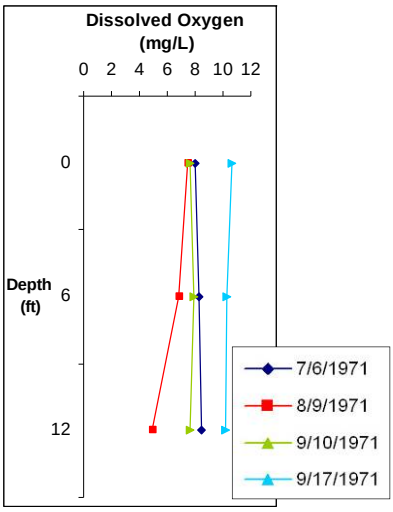


Figure 7. Historical chlorophyll *a* concentrations (ug/L) for Big Stone Lake (data set from 2007-2009).

Chlorophyll *a* concentrations greater than 10 ug/L are perceived as a mild algae bloom, while concentrations greater than 20 ug/L are perceived as a nuisance. Chlorophyll *a* was evaluated in Big Stone Lake in 2007-2010 (Figure 7). Chlorophyll *a* concentrations exceeded 20 ug/L every year, which indicates nuisance algae blooms. In August of 2009, there was an abnormal spike in chlorophyll a concentration at all sites except for 217 and 108. Phosphorus concentrations do not show a spike; therefore, the cause of this spike in chlorophyll a is unknown. Usually if phosphorus is high, the chlorophyll a is high because phosphorus is a main nutrient source for algae.

## 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.

Big Stone Lake is a relatively shallow lake, with a maximum depth of 16 feet. Dissolved oxygen profiles from 1971 (DNR) indicate that Big Stone Lake mixes throughout the summer (Figure 8). The sunlight can reach the bottom of 99% of the lake, allowing aquatic plants to grow. These plants produce oxygen as a by-product of photosynthesis, which keeps the water column fully oxygenated. The fact that the bottom of Big Stone Lake remains oxygenated throughout the summer means that fish may be found at all water depths throughout the summer.

Figure 8. Dissolved oxygen profile for Big Stone Lake in 1971 (data from Minnesota DNR Fisheries).

# Trophic State Index

TSI is a standard measure or means for calculating the trophic status or productivity of a lake. 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 | Big Stone Lake TSI | Trophic State |
|---|---|---|
| TSI Total Phosphorus | 76-80 | Hypereutrophic |
| TSI Chlorophyll-a | 55-61 | Eutrophic |
| TSI Transparency | 52-62 | Eutrophic |

*Numbers represent the mean TSI range for 2007-2010 across all 6 monitoring sites.*

The mean TSI for Big Stone Lake chlorophyll a and transparency fall within in the eutrophic range (Figure 9). There is good agreement between the TSI for chlorophyll *a* and transparency, indicating that these variables are strongly related.

The TSI for phosphorus is much higher and falls in the hypereutrophic range. This means that not all the phosphorus is being utilized by algae. One possible explanation could be that the phosphorus loading from the numerous tributaries is so high that it overloads the system. Since the lake acts like a large river, this phosphorus is carried through the lake and into the Minnesota River.

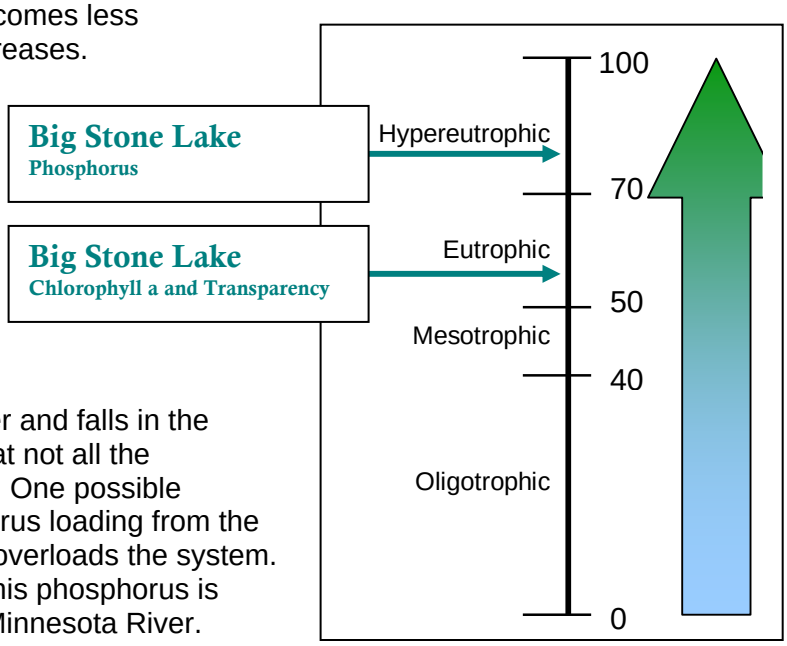



Figure 9. Trophic state index chart with corresponding trophic status.

| 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.

# 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.


Big Stone Lake is in the Northern Glaciated Plains Ecoregion. The total phosphorus for sites 108 and 210 at the northern end of the lake are higher than the expected ecoregion ranges (Figure 10). The chlorophyll a and Secchi depth for Big Stone Lake are within expected ecoregion ranges (Figures 11-12).

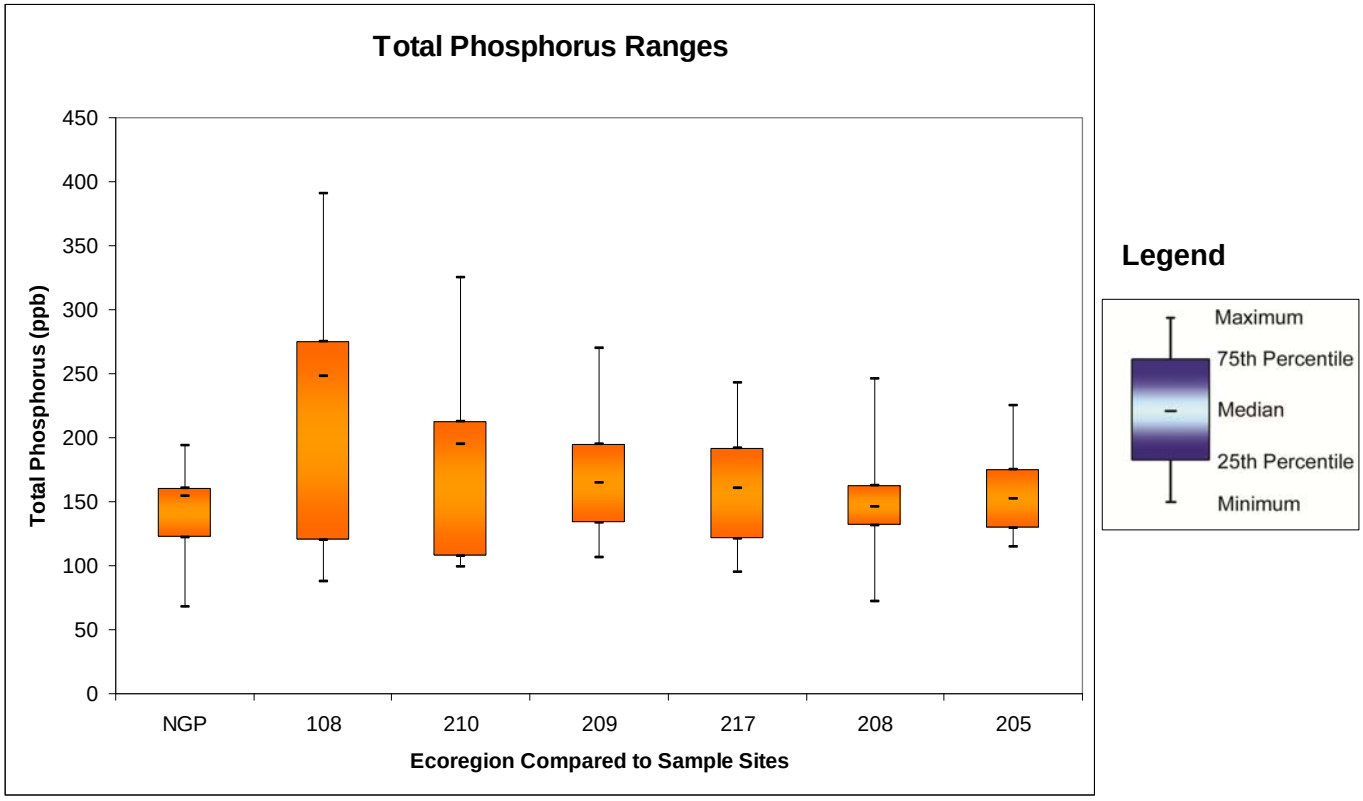



Figure 10. Big Stone Lake site phosphorus ranges compared to the Northern Glaciated Plains Ecoregion ranges.

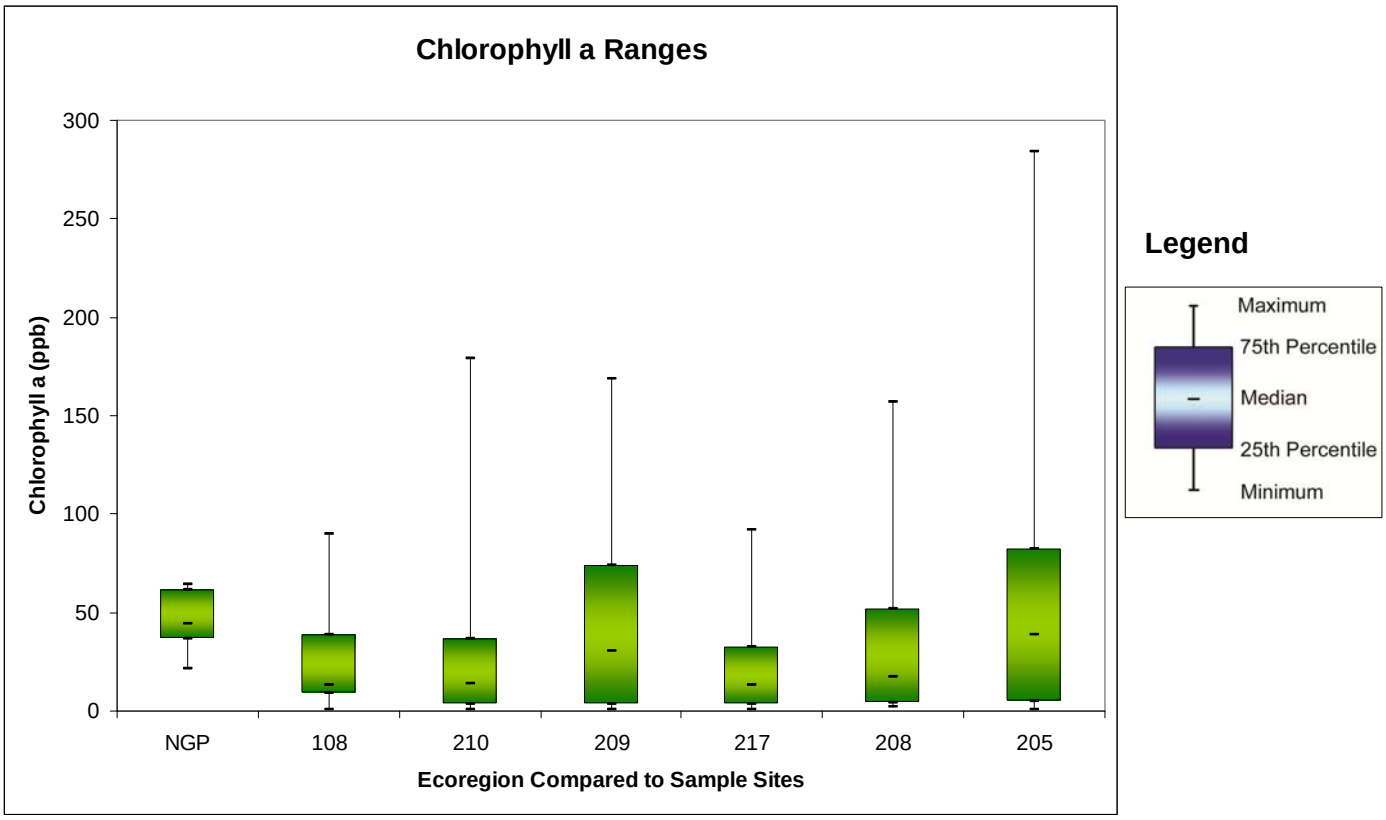



Figure 11. Big Stone Lake site chlorophyll a ranges compared to the Northern Glaciated Plains Ecoregion ranges.

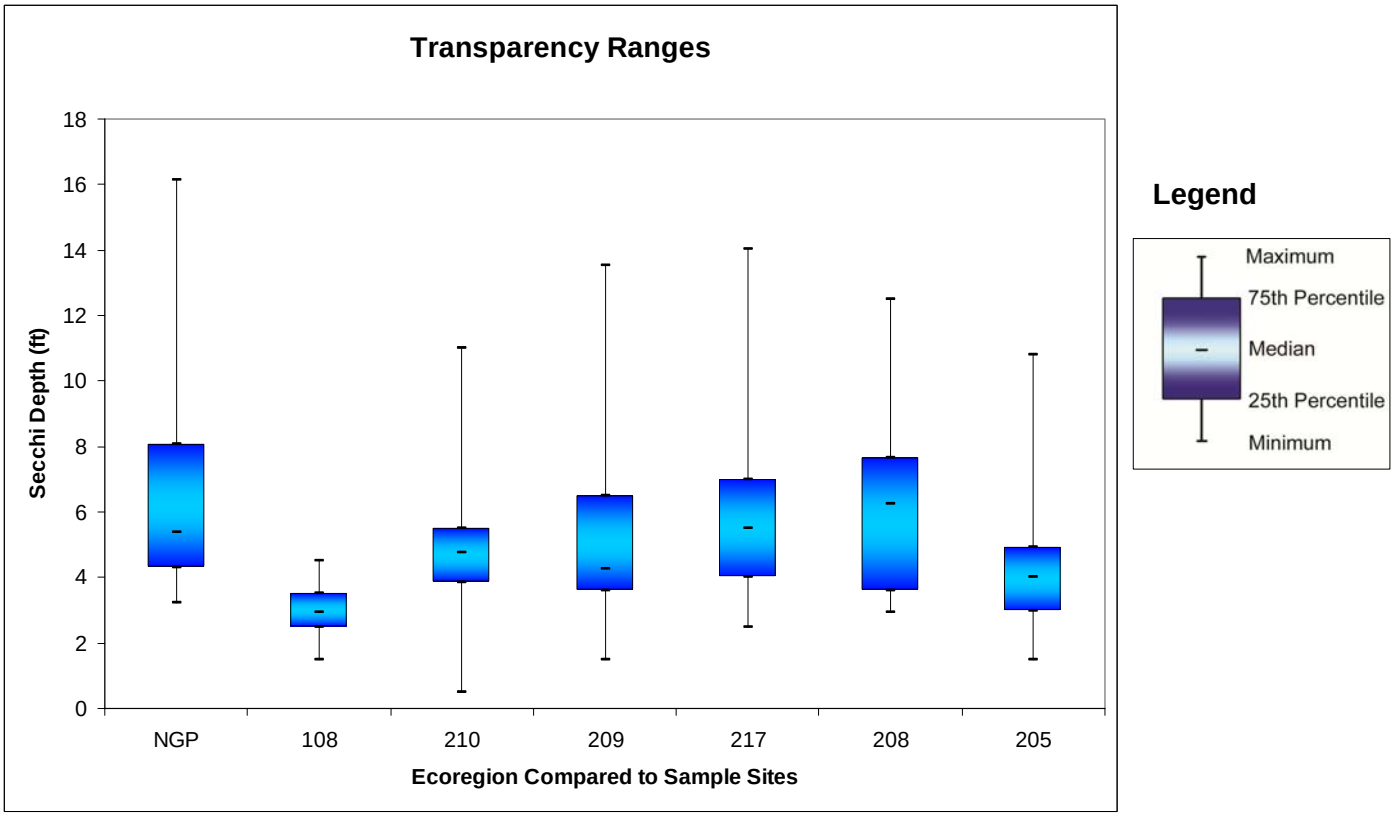



Figure 12. Big Stone Lake site transparency ranges compared to the Northern Glaciated Plains Ecoregion ranges.

# Inlet Data Analysis

**Introduction**
In order to best compare the inlets, two field measurements needed to be recorded: 1) the water velocity flowing at each site and 2) the concentration of phosphorus in that water. These two measurements are used to determine the phosphorus loading, or in other words, the lbs of phosphorus entering the lake from that source. Comparing loading, taking into account the water volume of each inlet, is more accurate than just comparing concentrations. A water source with high flow and low phosphorus could be putting as many pounds of phosphorus into the lake as a source with low flow and high phosphorus.

The rolling terrain of the Northern Glaciated Plains ecoregion is heavily cultivated. The vast majority of natural vegetation in this area has been replaced by row crops including corn, wheat, soybeans and sunflowers. Because of the extensive agricultural land use, many lakes and streams face increasing sedimentation and elevated nutrient levels. Below are typical measurements one might find for streams in this ecoregion compared to the 2010 monitoring data for each of three sites.

Table 1. 2010 monitoring results (means) for Big Stone Lake stream sites compared to the Ecoregion range.

| Site Description | BOD (mg/L) | *E. coli* (MPN/100ml) | N+N (mg/L) | $NH_3$ (mg/L) | TKN (mg/L) | TP (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|
| LCW1 | 1.99 | 199.6 | 0.44 | 0.083 | 0.684 | 0.045 | 3 |
| LCE1 | 3.43 | 628.6 | 1.99 | 0.206 | 1.276 | 0.283 | 17.8 |
| LM2E1N | 5.49 | 847.5 | 1.53 | 0.202 | 1.91 | 0.491 | 34 |
| Ecoregion Range | 2.3 – 4.5 | NA | 0.01 – 0.51 | NA | NA | 0.090-0.250 | 11 – 63 |

**Summary**
Actual stream measurements such as water flow are not available. Loading calculations cannot be completed, but general conclusions can be drawn by looking at the data. In order to get a better comparison of loading from the inlets and tributaries, water flow data should be collected in the future.

In comparing results above, it appears that LCW1 is at the low end of the ecoregion ranges, while LCEI1 and LM2E1N exceed the ecoregion ranges in both total phosphorus and nitrate + nitrite. In addition, LM2E1N exceeds the ecoregion range in biological oxygen demand. Site LM2E1N especially could be further investigated for phosphorus sources so one can better pinpoint the source of the phosphorus at the north end of the lake. Phosphorus appears to be the main problem in Big Stone Lake as shown by the lake's trophic status index analysis.

***E. coli***
At all three sites, the average *E. coli* levels were above the state standard of 126 MPN/100 ml. With that said, the standard applies to streams where the geometric mean of a minimum of five samples per month is above 126 MPN/100 ml. The following is the *E. coli* standard as it is stated in Minnesota Administrative Rule 7050.0222:

> "Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31."

## MPCA Assessment Status, *Minnesota Pollution Control Agency, 2010*

**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. Big Stone Lake was listed as impaired for mercury in fish tissue in the 2006 Impaired Waters List; however, it is part of the statewide mercury TMDL, so it was removed from the 2008 Impaired Waters List.

Big Stone Lake is currently not listed as impaired for eutrophication. The Impaired Waters Standard for the Northern Glaciated Plains Ecoregion is 90 ug/L. At each site, Big Stone Lake exceeded this standard. Big Stone Lake is currently not considered impaired for eutrophication because the chlorophyll a and transparency data do not exceed the impaired waters standards. Phosphorus should continue to be monitored to track any future changes in water quality.

**Aquatic Recreational Use Assessment 305(b)**
In the 2008 MPCA Aquatic Use Assessment (305(b)), Big Stone Lake was classified as having insufficient data for this assessment.

## Fisheries Status, *Minnesota Department of Natural Resources, 6/29/2010*

Big Stone Lake is located in western Minnesota adjacent to Ortonville. It is a highly productive lake that measures 12,610 acres with a maximum depth of 16 feet. Big Stone is a Minnesota-South Dakota border water subject to border water fishing regulations.

Big Stone Lake provides a high quality walleye fishery. Walleye from a wide range of sizes were present in 2010. The walleye population is maintained by natural reproduction and supplemental fry stocking. Walleye fry are normally stocked during even years, but the schedule is adjusted as needed based on walleye abundance, fish condition, and available forage. Walleye year classes have been present annually since 1998.

Good fishing for white bass and yellow perch also occurs. High numbers of white bass were present in 2010 with fish measuring up to 16 inches. White bass commonly experience excellent natural reproduction. Yellow perch were abundant in the 5-12 inch size range. A moderate bluegill population has developed during recent years and anglers occasionally report good catches of large bluegills from localized areas.

**Special Fishing Regulations (2011)**

**Walleye:** Possession limit four. One 20" or larger allowed in possession.

**Crappie:** Possession limit 10.

**Sunfish:** Possession limit 10.