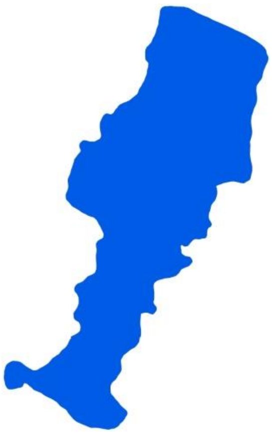
Bluewater Lake 31-0395-00 ITASCA COUNTY

Lake Water Quality

Summary



Bluewater Lake is located 16 miles southeast of Suomi, MN in Itasca County. It is a long lake covering 359 acres (Table 1).

Bluewater Lake has no inlets and one outlet, which classify it as a groundwater drainage lake. Water exits Bluewater Lake from Wabana Creek on the south side of the Lake and carries water south to the Mississippi River.

Water quality data have been collected on Bluewater Lake from 1988-2015 (Tables 2 & 3). These data show that the lake is oligotrophic (TSI = 36) with very clear water conditions most of the summer and excellent recreational opportunities.

Bluewater Lake is part of the Wabana Chain of Lakes Association (WCOLA). WCOLA is involved in many projects including water quality monitoring and education.

Table 1. Bluewater Lake location and key physical characteristics.

Location Data	
MN Lake ID:	31-0395-00
County:	Itasca
Ecoregion:	Northern Lakes and Forests
Major Drainage Basin:	Mississippi R. -Grand Rapids
Latitude/Longitude:	47.421375/ -93.5526
Invasive Species:	None

Physical Characteristics	
Surface area (acres):	359
Littoral area (acres):	75
% Littoral area:	21
Max depth (ft), (m):	120, 37
Inlets:	0
Outlets:	1
Public Accesses:	0

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

Data Availability		
Transparency data		Good data set from 1988-2015.
Chemical data		Good data set from 1991, 1999, 2003, 2010-2011, and 2014-2015.
Inlet/Outlet data	--	Not necessary
Recommendations		**For recommendations refer to page 19.**

Lake Map

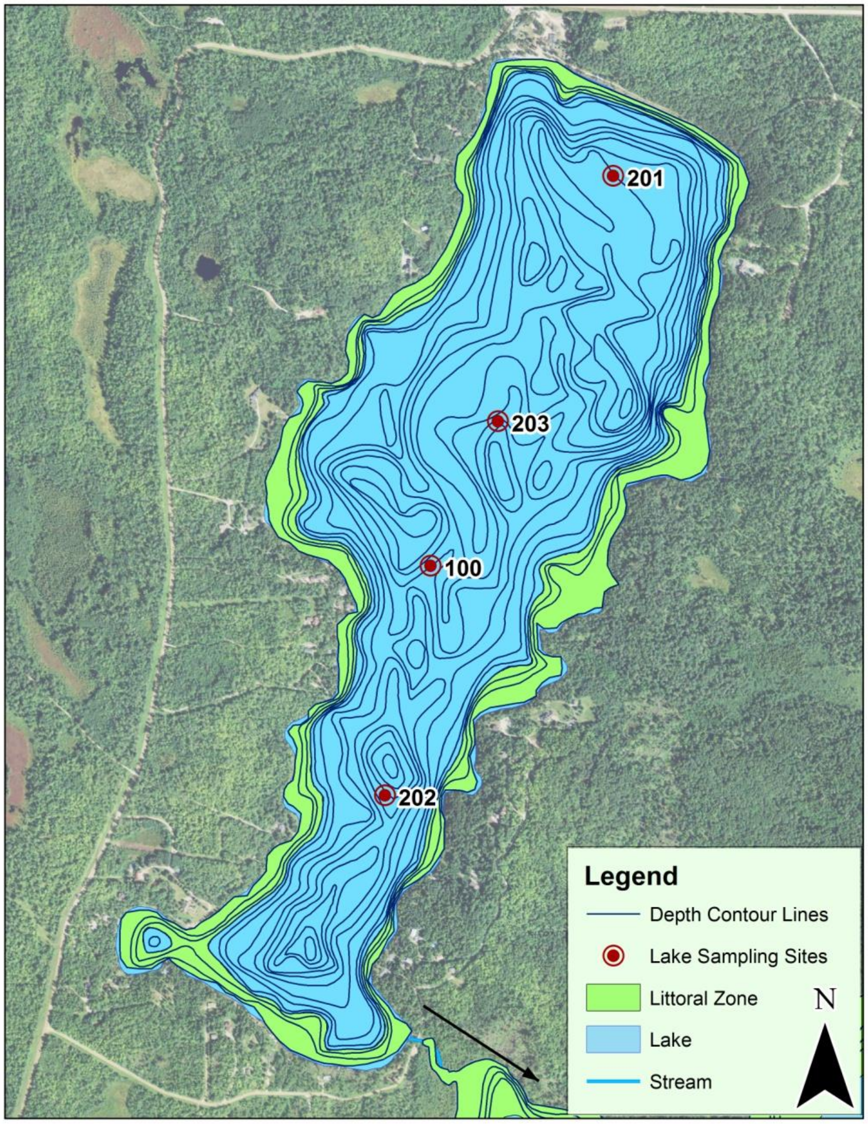


Figure 1. Map of Bluewater Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic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

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), Itasca County Lake Assessment (ICLA), Lake Monitoring Program (LMP), MPCA Lake Monitoring Program Project (LMPP), Clean Water Legacy Surface Water Monitoring (CWLSWM); Wabana Chain of Lakes (WCOLA).

Lake Site	Depth (ft)	Monitoring Programs
100	90	ICLA: 2001-2002; LMP: 2000; LMPP: 1988,1991
201	90	CLMP: 1988-1993; CWLSWM: 2015
202* primary site	80	CLMP: 1992-2015; WCOLA: 2003, 2010-2011, 2014
203	80	CLMP: 1999-2015

Average Water Quality Statistics

The information below describes available chemical data for Bluewater Lake through 2015 (Table 4).

Minnesota is divided into 7 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. For more information on ecoregions and expected water quality ranges, see page 11. Bluewater Lake is in the Northern Lakes and Forests Ecoregion.

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

Parameter	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	9.4	14 – 27	> 30	Results are better than the expected range for the Northern Lakes and Forests Ecoregion.
[3]Chlorophyll *a* (ug/L)	1.3	4 – 10	> 9	
Chlorophyll *a* max (ug/L)	2.0	< 15		
Secchi depth (ft)	18.9	8 – 15	< 6.5	
Dissolved oxygen	*See page 8*			Dissolved oxygen depth profiles show that the lake is dimictic. It also supports lake trout and tullibee (cisco).
Total Kjeldahl Nitrogen (mg/L)	0.3	<0.4 – 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	130	40 – 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	1.7	10 – 35		Indicates clear water with little to no tannins (brown stain).
pH	8.1	7.2 – 8.3		Within the expected range for the ecoregion. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water.
Chloride (mg/L)	1.1	0.6 – 1.2		Within the expected range for the ecoregion.
Total Suspended Solids (mg/L)	1.5	<1 – 2		Indicates low suspended solids and clear water.
Specific Conductance (umhos/cm)	261.2	50 – 250		Slightly above the ecoregion range. Could indicate some watershed loading.
TN:TP Ratio	33:1	25:1 - 35:1		Shows the lake is phosphorus limited.

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

Water Quality Characteristics - Historical Means and Ranges

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

Parameters	Primary Site 202	Site 201	Site 203
Total Phosphorus Mean (ug/L):	**9.4**	**4.2**	**9.7**
Total Phosphorus Min:	4	3.0	4
Total Phosphorus Max:	18	5.0	36
Number of Observations:	26	12	26
Chlorophyll *a* Mean (ug/L):	**1.4**	**1.3**	**1.4**
Chlorophyll-a Min:	1	0.7	1
Chlorophyll-a Max:	2	2.3	2
Number of Observations:	4	13	4
Secchi Depth Mean (ft):	**18.9**	**18.3**	**18.4**
Secchi Depth Min:	11.3	12.0	10.5
Secchi Depth Max:	27.0	25.6	27.5
Number of Observations:	657	176	600

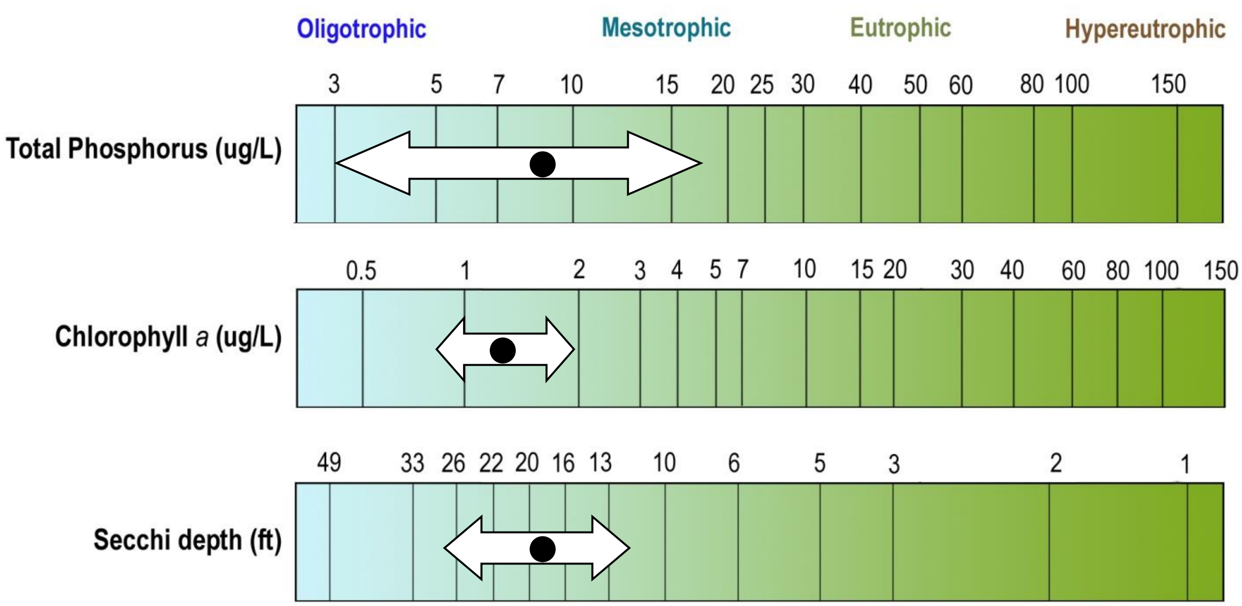


Figure 2. Bluewater Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 202). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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.

The annual mean transparency in Bluewater Lake ranges from 15.0 to 22.8 feet (Figure 3). The annual means hover fairly close to the long-term mean. For trend analysis, see page 10. Transparency monitoring should be continued annually at site 202 in order to track water quality changes.

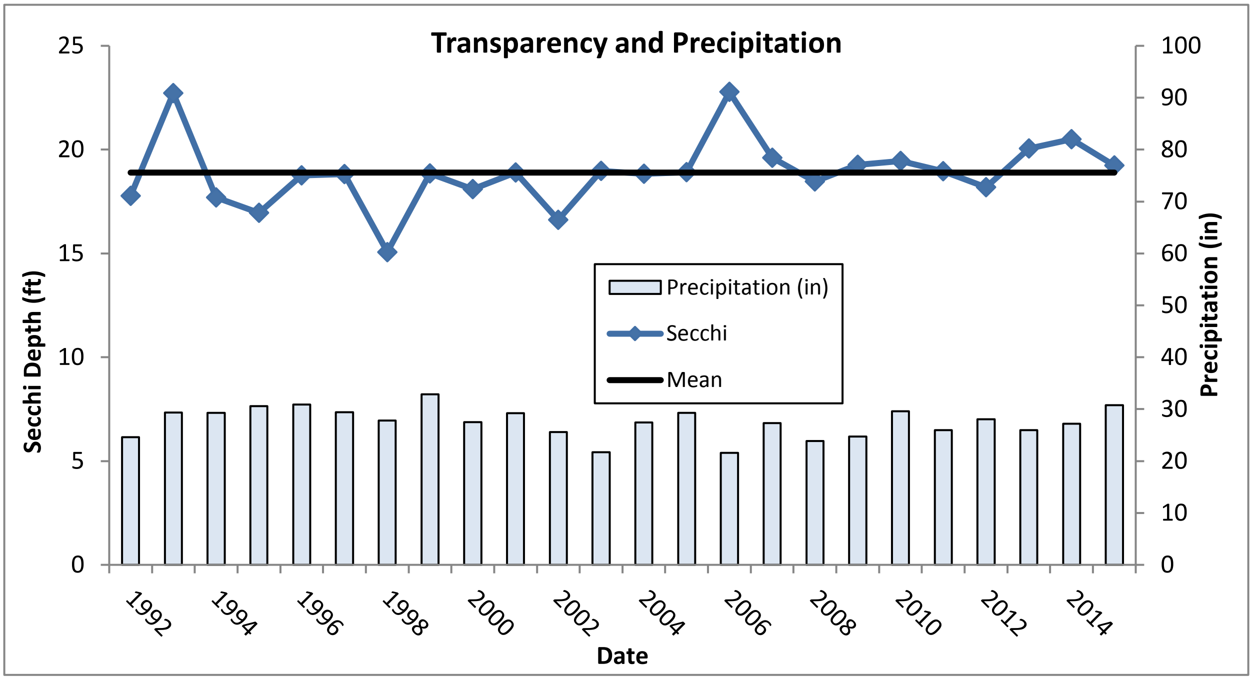


Figure 3. Annual mean transparency compared to long-term mean transparency.

Bluewater Lake transparency ranges from 11.3 to 27.0 feet at the primary site (202). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Bluewater Lake transparency is high in June-July, and then declines through August. The transparency then rebounds in October after fall turnover. This transparency dynamic is typical of a Minnesota lake. The dynamics have to do with algae and zooplankton population dynamics, and lake turnover.

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

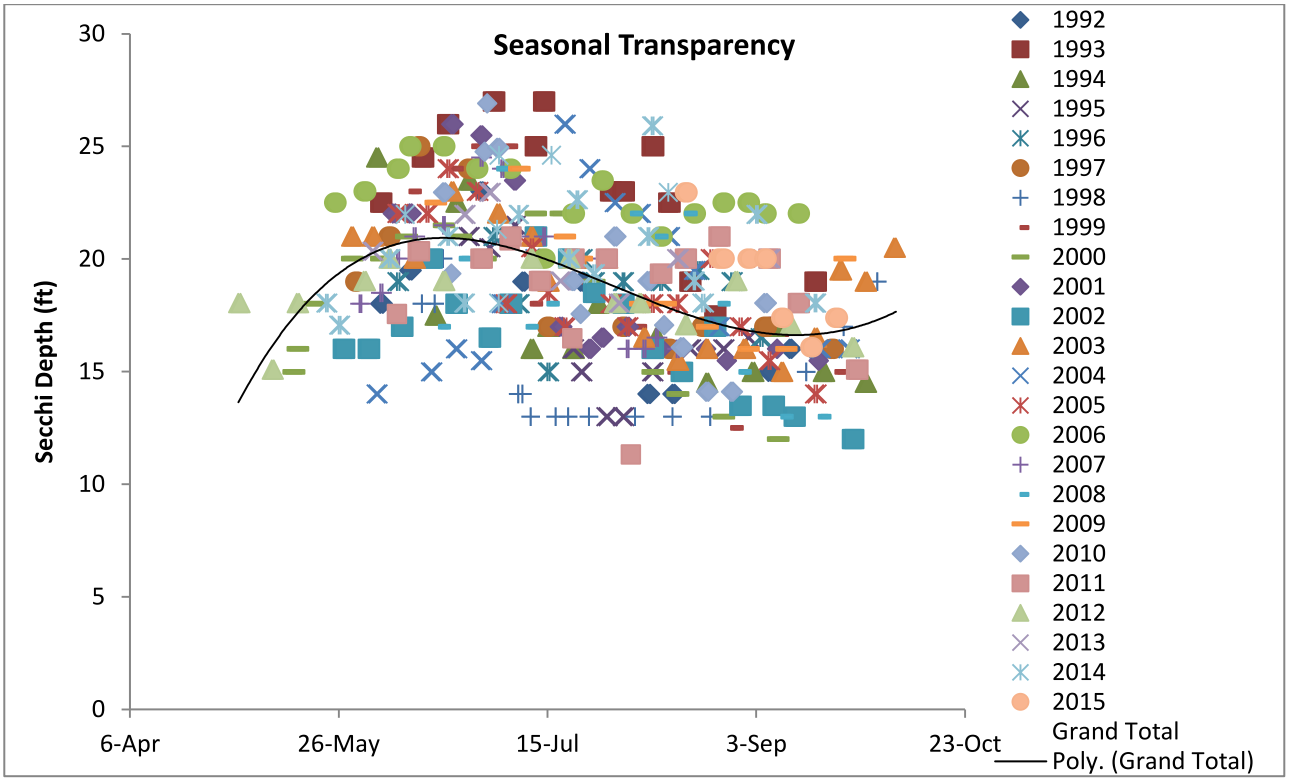


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 202). The black line represents the pattern in the data.

User Perceptions

When volunteers collect Secchi depth readings, they record their perceptions of the water based on the physical appearance and the recreational suitability. These perceptions can be compared to water quality parameters to see how the lake "user" would experience the lake at that time. Looking at transparency data, as the Secchi depth decreases the perception of the lake's physical appearance rating decreases. Bluewater Lake was rated as being "crystal clear" 90% of the time by samplers between 1988-2015 (Figure 5).

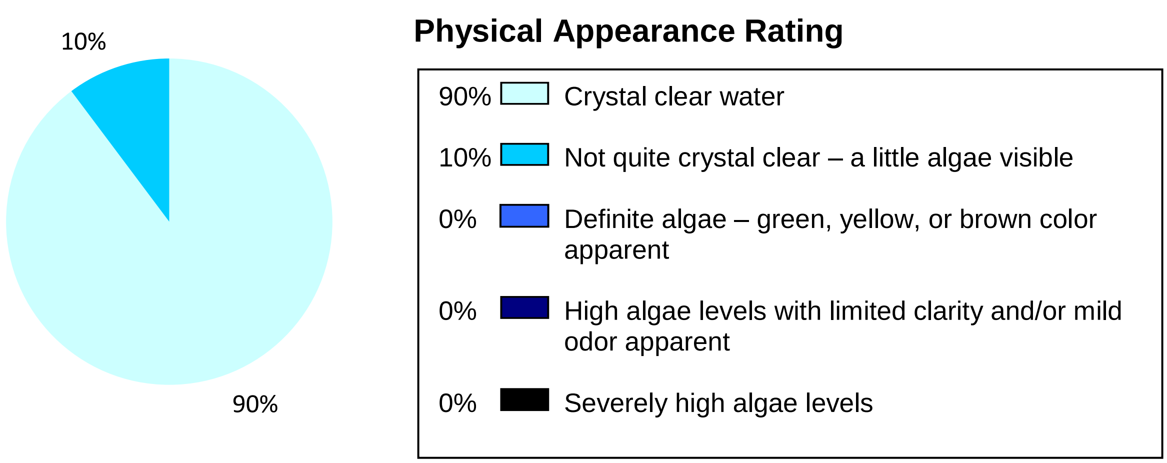


Figure 5. Bluewater Lake physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Bluewater Lake was rated as being "beautiful" 83% of the time from 1988-2015 (Figure 6).

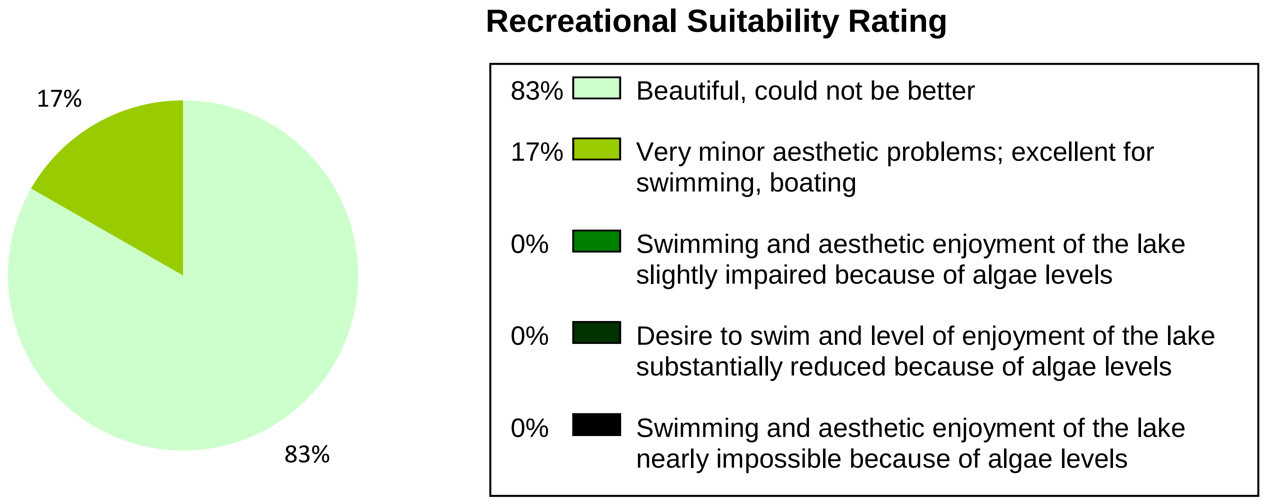


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

Total Phosphorus

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

Total phosphorus was evaluated in Bluewater Lake in 1991, 1999, 2003, 2010-2011, and 2014-2015. The data do not indicate much seasonal variability. The majority of the data points fall into the oligotrophic range (Figure 7).

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

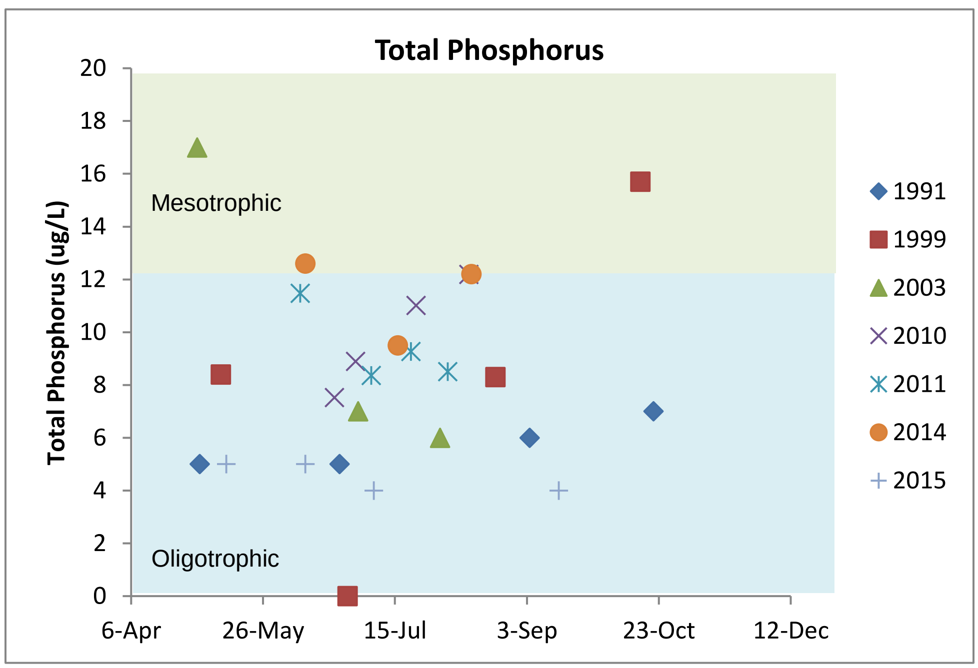


Figure 7. Historical total phosphorus concentrations (ug/L) for Bluewater Lake site 203.

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.

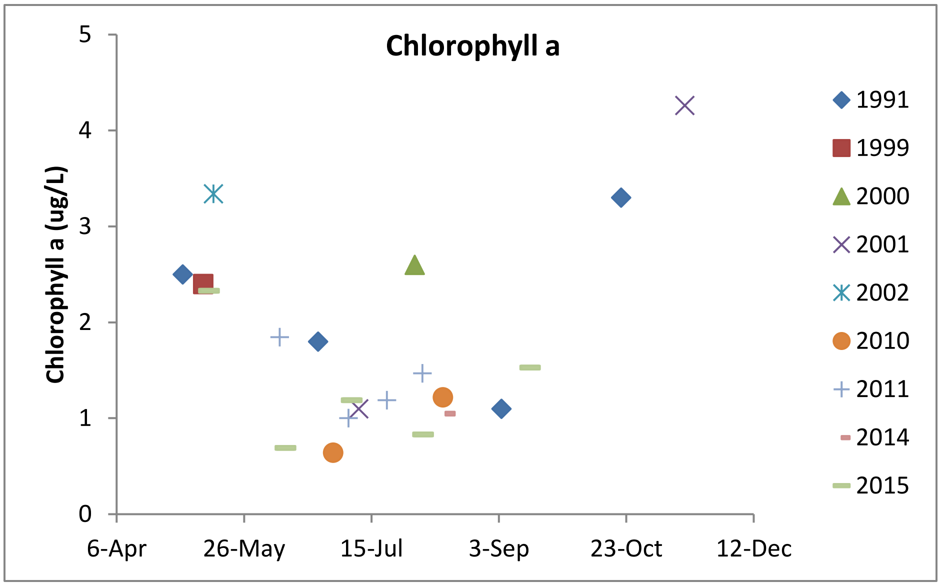


Figure 8. Chlorophyll *a* concentrations (ug/L) for Bluewater Lake.

Chlorophyll *a* was evaluated in Bluewater Lake at site 201, 202, and 203 in 1991, 1999-2002, 2010-2011, and 2014-2015 (Figure 8). Chlorophyll *a* concentrations stayed below 10 ug/L in all four years, indicating no minor algae blooms. There was not much variation over the years monitored and chlorophyll *a* concentrations remained relatively steady over the summer.

Dissolved Oxygen

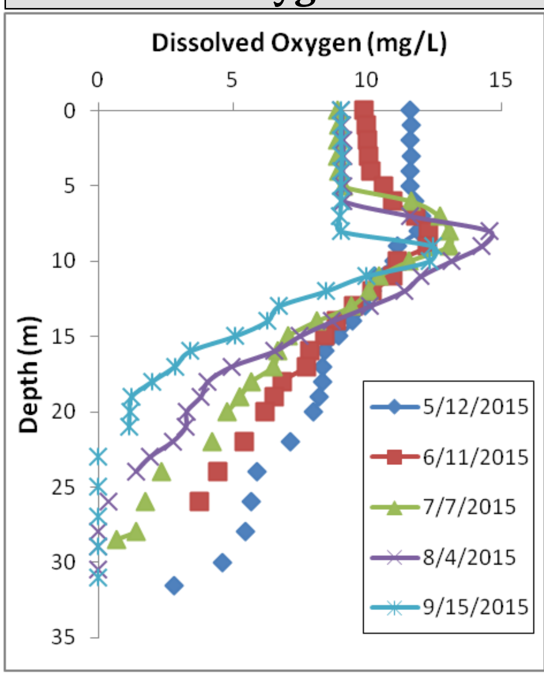


Figure 9. Dissolved oxygen profile for Bluewater Lake.

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

Bluewater Lake is a deep lake, with a maximum depth of 120 feet. Dissolved oxygen profiles from data collected in 2015 at site 201 show periodic stratification developing early-summer (Figure 9). The thermocline occurs at approximately 8 meters (26 feet). In fact, the oxygen shows an interesting pattern in that it is highest from 7-10 meters (23 - 32 feet). This pattern is called a Metalimnetic Oxygen Maxima. It is caused by algae producing oxygen in that area of 7-10 meters deep. This pattern is usually only observed in lakes with good transparency and a very small closed deep basin, which applies Bluewater Lake (Figure 1). This small deep hole stratifies very strongly as there is not much surface area for wind mixing. Bluewater lake does support lake trout and tullibees (page 18).

Trophic State Index (TSI)

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

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. If all three TSI numbers are within a few points of each other, they are strongly related. If they are different, there are other dynamics influencing the lake's productivity, and TSI mean should not be reported for the lake.

The mean TSI for Bluewater Lake falls into the oligotrophic range (Figure 10). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related (Table 6).

Oligotrophic lakes (TSI 0-39) are characteristic of extremely clear water throughout the summer and sandy or rocky shores. They are excellent for recreation. Some very deep oligotrophic lakes are able to support a trout fishery (Table 7).

Table 6. Trophic State Index for Bluewater Lake.

Trophic State Index	Site 202
TSI Total Phosphorus	36
TSI Chlorophyll-a	37
TSI Secchi	36
TSI Mean	36
Trophic State:	Oligotrophic

Numbers represent the mean TSI for each parameter.

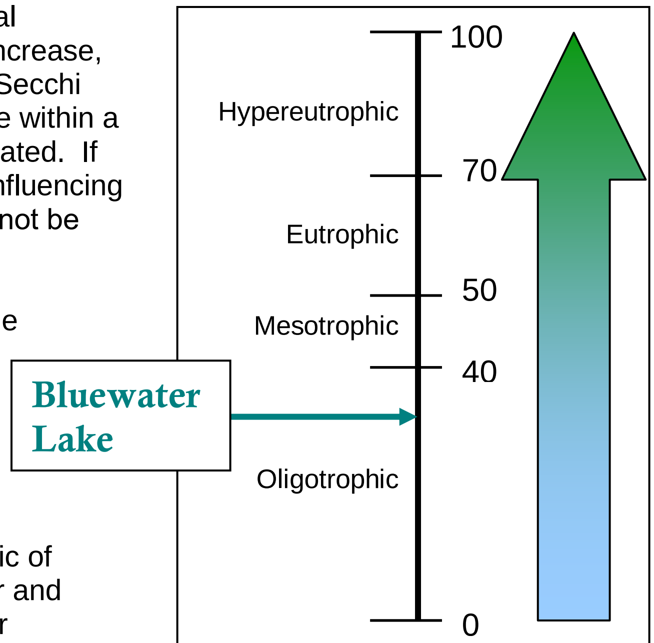


Figure 10. Trophic state index chart with corresponding trophic status.

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

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

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

Trend Analysis

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

Bluewater Lake had enough data to perform a trend analysis on all three parameters (Table 8). The data were analyzed using the Mann Kendall Trend Analysis.

Table 8. Trend analysis for Bluewater Lake.

Lake Site	Parameter	Date Range	Trend
202	Total Phosphorus	1999, 2003, 2010-2011, and 2014-2015	No Trend
202	Chlorophyll *a*	1999-2002, 2010-2011, and 2014-2015	No Trend
202	Transparency	1992-2015	No Trend

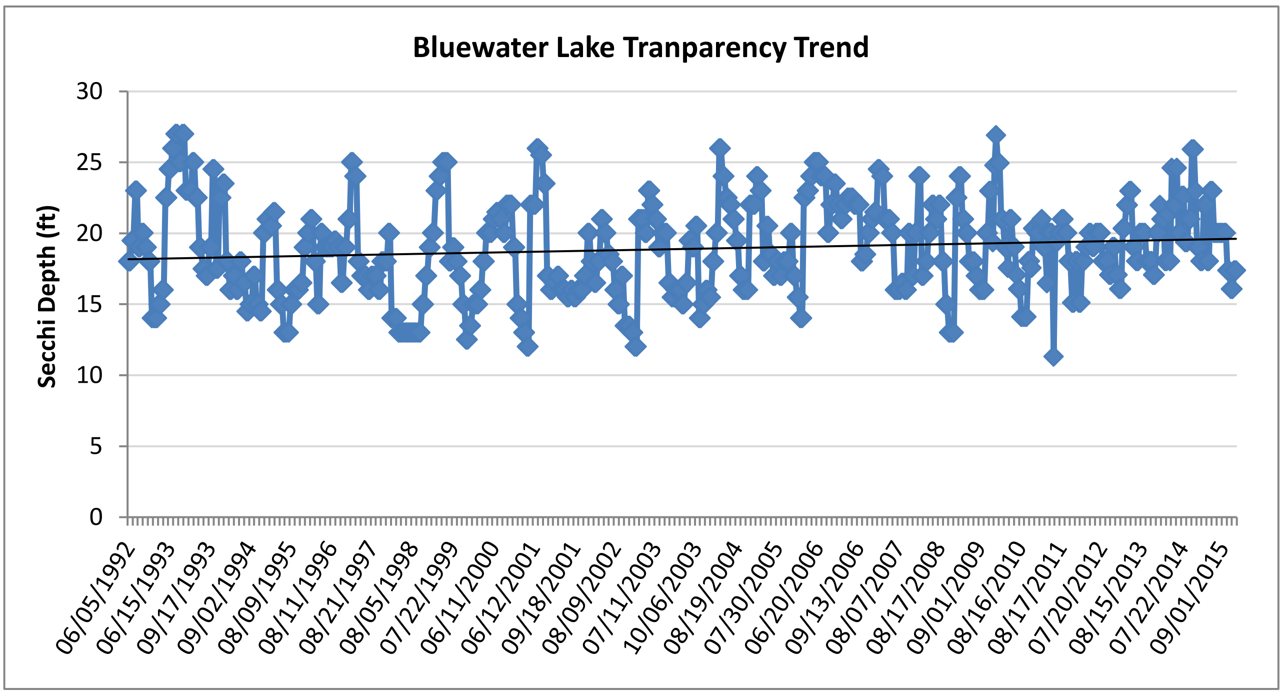


Figure 11. Transparency (feet) trend for site 202 from 1992-2015.

Bluewater Lake shows no evidence of trends in transparency, phosphorus, or algae concentration (chlorophyll a) (Table 8, Figure 11). This means the lake has been stable since 1992. Monitoring should continue so this trend can be tracked in the future.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology (Figure 12). 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.

Bluewater Lake is in the Northern Lakes and Forests Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Bluewater Lake are better than the ecoregion ranges (Figure 13).

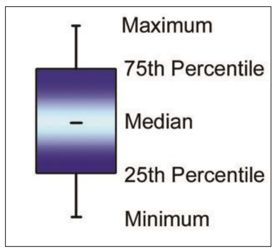
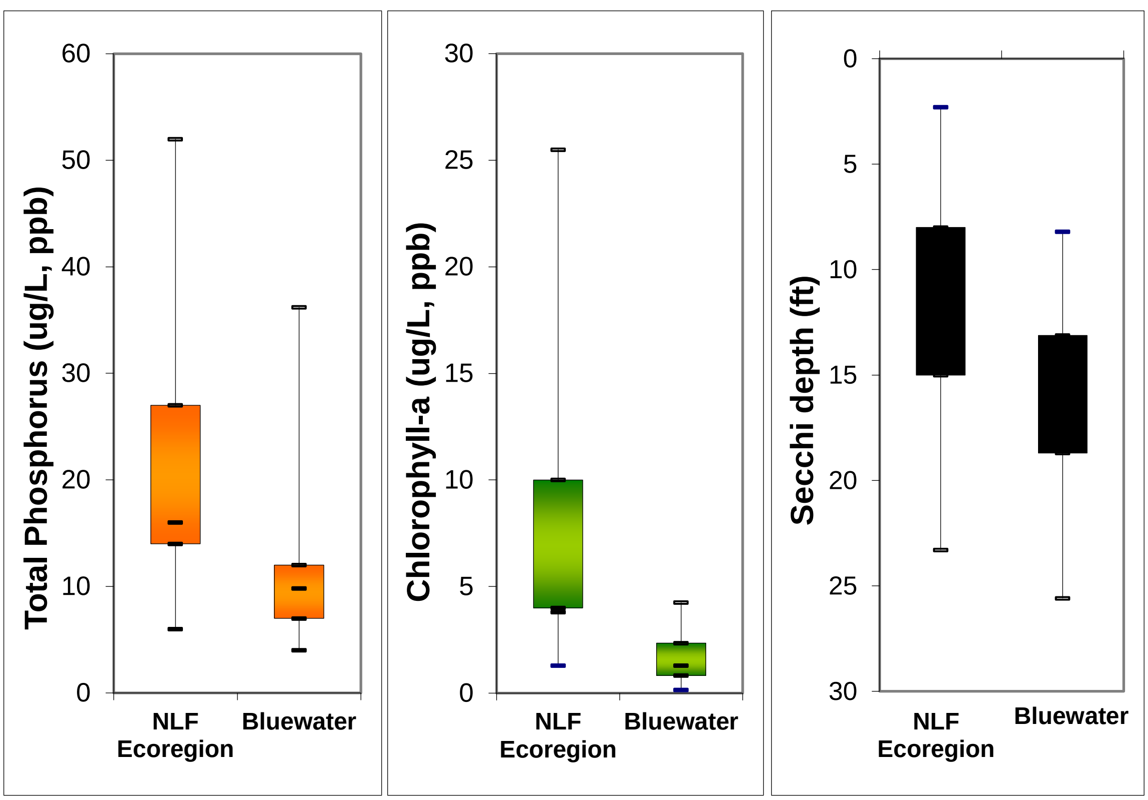


Figure 12. Minnesota Ecoregions.



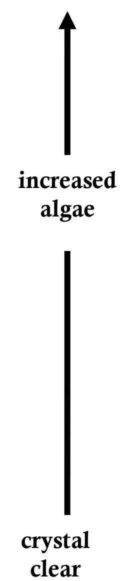


Figure 13. Bluewater Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Bluewater Lake total phosphorus and chlorophyll *a* ranges are from 92 data points collected in May-September of 1988,1991,1999-2003,2008,2010-2011, and 2014-2015. The Bluewater Lake Secchi depth range is from 657 data points collected in May-September of 1992-2015.

Lakeshed Data and Interpretations

Lakeshed

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

The Mississippi River Grand Rapids Watershed is one of the watersheds that make up the Mississippi River Basin, which drains south to the Golf of Mexico (Figure 14). This major watershed is made up of 133 minor watersheds. Bluewater Lake is located in minor watershed 09047 (Figure 15).

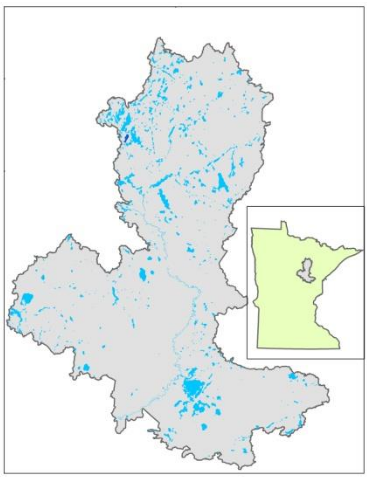


Figure 14. Major Watershed.

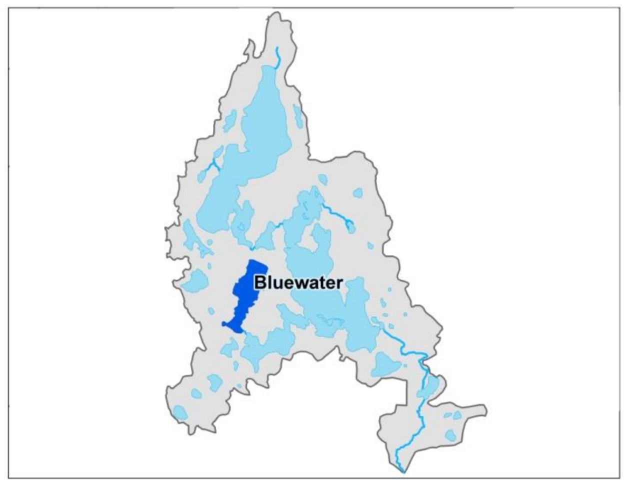


Figure 15. Minor Watershed.

The MN DNR also has evaluated catchments for each individual lake with greater than 100 acres surface area. These lakesheds (catchments) are the “building blocks” for the larger scale watersheds. Bluewater Lake falls within lakeshed 0904702 (Figure 16). Though very useful for displaying the land and water that contribute directly to a lake, lakesheds are not always true watersheds because they may not show the water flowing into a lake from upstream streams or rivers. While some lakes may have only one or two upstream lakesheds draining into them, others may be connected to a large number of lakesheds, reflecting a larger drainage area via stream or river networks. For further discussion of Bluewater Lake ’s watershed, containing all the lakesheds upstream of the Bluewater Lake lakeshed, see page 17. The data interpretation of the Bluewater Lake

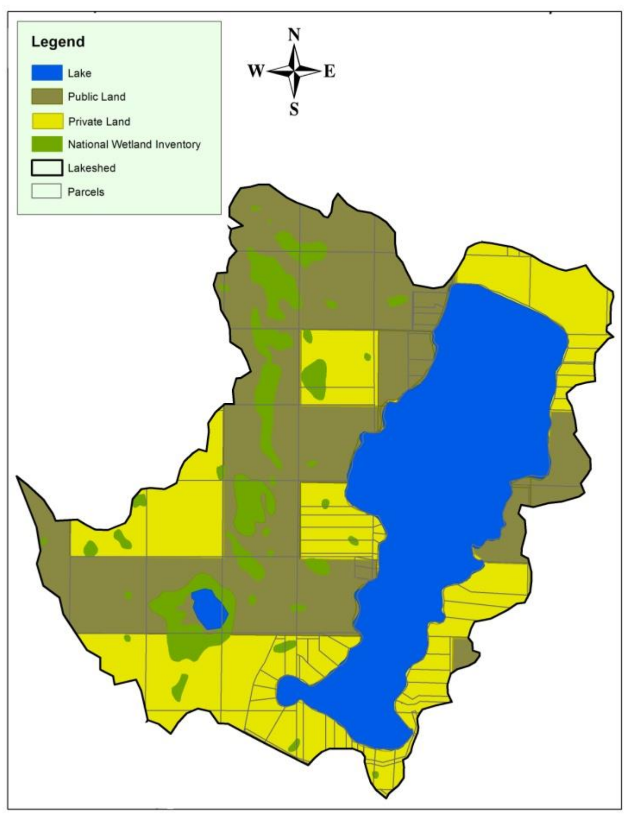


Figure 16. Bluewater Lake lakeshed (0904702) with land ownership, lakes, wetlands, and rivers illustrated.

lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Bluewater Lake.

The lakeshed vitals table identifies where to focus organizational and management efforts for each lake (Table 9). Criteria were developed using limnological concepts to determine the effect to lake water quality.

KEY

- Possibly detrimental to the lake
- Warrants attention
- Beneficial to the lake

Table 9. Bluewater Lake lakeshed vitals table.

Lakeshed Vitals		**Rating**
Lake Area (acres)	359	descriptive
Littoral Zone Area (acres)	75	descriptive
Lake Max Depth (feet)	120	descriptive
Lake Mean Depth (feet)	48.3	Beneficial to the lake
Water Residence Time	NA	NA
Miles of Stream	0	descriptive
Inlets	0	Beneficial to the lake
Outlets	1	Beneficial to the lake
Major Watershed	Mississippi R. –Grand Rapids	descriptive
Minor Watershed	09047	descriptive
Lakeshed	0904702	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	4	Beneficial to the lake
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	4	Beneficial to the lake
Wetland Coverage, NWI (acres)	94.2	Beneficial to the lake
Aquatic Invasive Species	None	Beneficial to the lake
Public Drainage Ditches	0	Beneficial to the lake
Public Lake Accesses	0	Beneficial to the lake
Miles of Shoreline	4.6	descriptive
Shoreline Development Index	1.74	Beneficial to the lake
Public Land to Private Land Ratio	1.2:1	Beneficial to the lake
Development Classification	Recreational Development	Warrants attention
Miles of Road	7.1	descriptive
Municipalities in lakeshed	None	Beneficial to the lake
Forestry Practices	None	Beneficial to the lake
Feedlots	0	Beneficial to the lake
Sewage Management	Individual Waste Treatment Systems (septic systems and holding tanks)	Warrants attention
Lake Management Plan	WCOLA, 2016	Beneficial to the lake
Lake Vegetation Survey/Plan	DNR, 2000	Beneficial to the lake

Land Cover / Land Use

The activities that occur on the land within the lakeshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed. The basic purpose of land use planning is to ensure that each area of land will be used in a manner that provides maximum social benefits without degradation of the land resource.

Changes in land use, and ultimately land cover, impact the hydrology of a lakeshed. Land cover is also directly related to the land's ability to absorb and store water rather than cause it to flow overland (gathering nutrients and sediment as it moves) towards the lowest point, typically the lake. Impervious intensity describes the land's inability to absorb water, the higher the % impervious intensity the more area that water cannot penetrate in to the soils. Monitoring the changes in land use can assist in future planning procedures to address the needs of future generations.

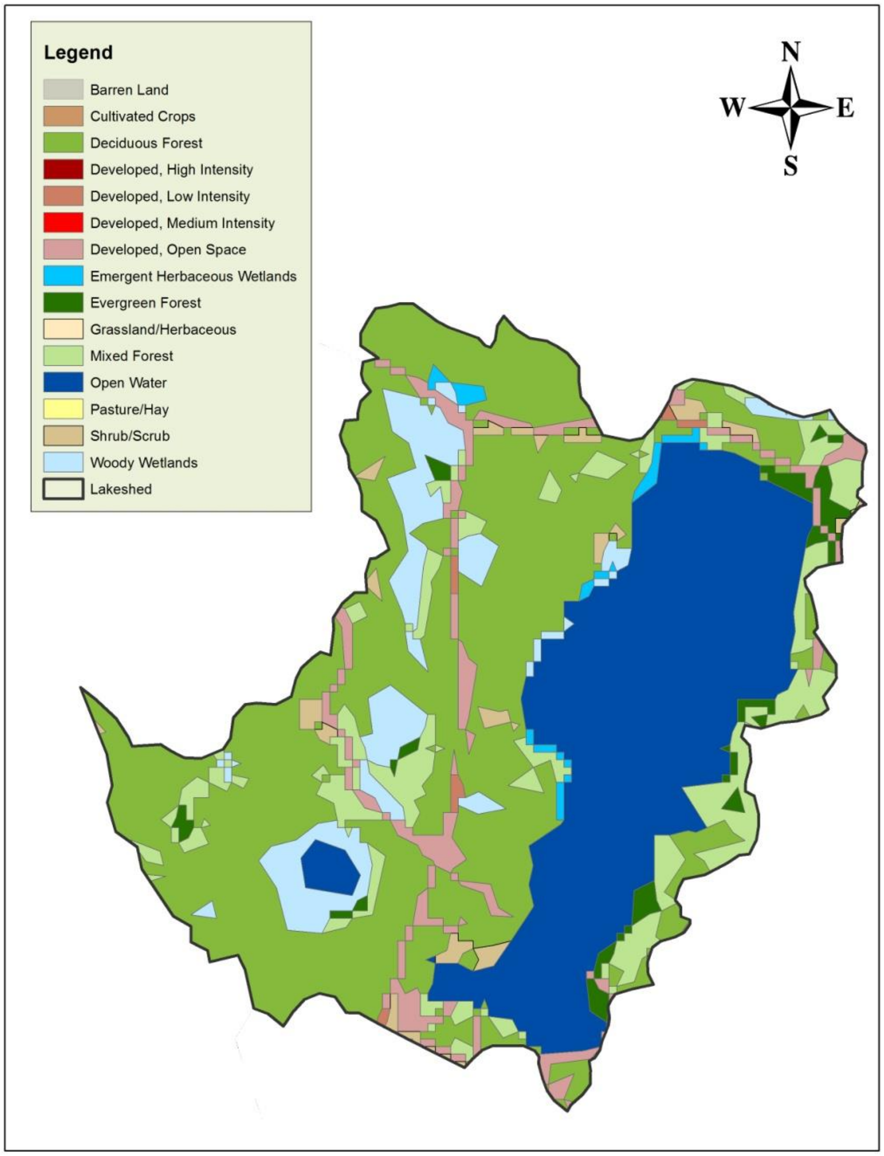


Figure 17. Bluewater Lake lakeshed (0904702) land cover (NLCD 2011).

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 17 depicts the land cover in Bluewater Lake's lakeshed.

The National Land Cover Dataset (NLCD) has records from 2001 and 2011. Table 10 describes Bluewater Lake's lakeshed land cover statistics and percent change from 2001 to 2011. Overall, there was not much change over this decade or from 1990-2000 (Table 11)

Table 10. Bluewater Lake's lakeshed land cover statistics and % change from 2001 to 2011 (Data Source: NLCD).

Land Cover	2001 Acres	Percent	2011 Acres	Percent	% Change 2001 to 2011
Deciduous Forest	593.85	44.72	594.12	44.75	0.03
Developed, Low Intensity	4.72	0.36	4.70	0.35	-0.01
Developed, Open Space	66.86	5.04	66.98	5.04	0
Emergent Herbaceous Wetlands	11.33	0.85	11.22	0.85	0
Evergreen Forest	27.98	2.11	27.85	2.10	-0.01
Mixed Forest	124.91	9.41	124.18	9.35	-0.06
Shrub/Scrub	24.10	1.82	24.56	1.85	0.03
Woody Wetlands	91.45	6.89	92.33	6.95	0.06
Open Water	382.59	28.81	381.85	28.76	-0.05
Total Area	1327.79		1327.79		

Table 11. Bluewater Lake development area and % change from 1990-2000 (Data Source: UMN Landsat).

Category	1990 Acres	Percent	2000 Acres	Percent	% Change 1990 to 2000
Total Impervious Area	5	0.53	7	0.72	0.19
Urban Acreage	60	4.52	60	4.52	0

Demographics

Bluewater Lake is classified as a Recreational Development lake. Recreational Development lakes usually have between 60 and 225 acres of water per mile of shoreline, between 3 and 25 dwellings per mile of shoreline, and are more than 15 feet deep.

The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. Compared to Itasca County as a whole, Wabana Township has a higher growth projection (Figure 18). (source: http://www.demography.state.mn.us)

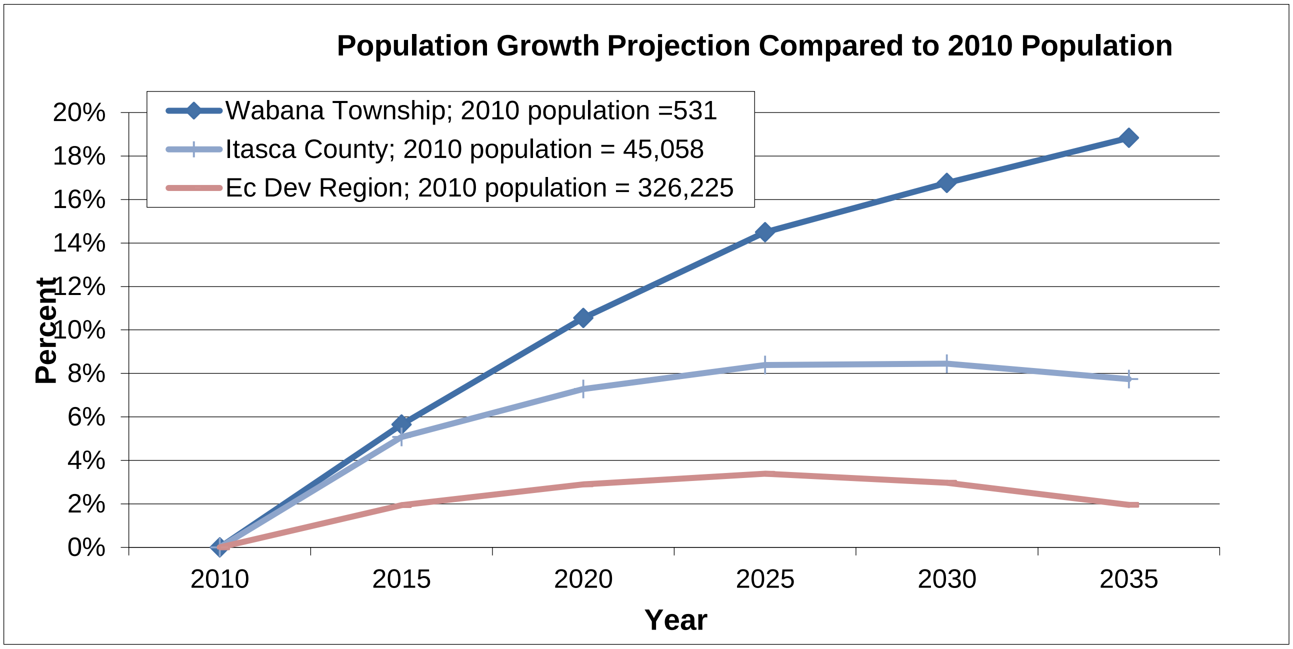


Figure 18. Population growth projection for adjacent townships and Itasca County.

Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection.

The majority of the privately owned land within Bluewater Lake's lakeshed is forested (Table 12). This land can be the focus of protection efforts in the lakeshed such as forest stewardship planning.

Table 12. Land ownership, land use/land cover, estimated phosphorus loading, and ideas for protection and restoration in the lakeshed (Sources: County parcel data and the 2011 National Land Cover Dataset).

	Private (29.87)						Public (39.8)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	3.17	0	24.61	1.09	1.00	30.33	0	1.49	38.31
Runoff Coefficient Lbs of phosphorus/acre/year	0.45 – 1.5	0.26 – 0.9	0.09		0.09		0.09	0.09	0.09
Estimated Phosphorus Loading Acreage x runoff coefficient	19-62	0	28.8		1.18		0	1.74	44.86
Description	Focused on Shoreland	Cropland	Focus of development and protection efforts	Open, pasture, grassland, shrubland	Protected				
Protection and Restoration Ideas	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

DNR Fisheries approach for lake protection and restoration

Credit: Peter Jacobson and Michael Duval, Minnesota DNR Fisheries

In an effort to prioritize protection and restoration efforts of fishery lakes, the MN DNR has developed a ranking system by separating lakes into two categories, those needing protection and those needing restoration. Modeling by the DNR Fisheries Research Unit suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes that have watershed with disturbance greater than 25%. Therefore, lakes with watersheds that have less than 25% disturbance need protection and lakes with more than 25% disturbance need restoration (Table 13). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 13. Suggested approaches for watershed protection and restoration of DNR-managed fish lakes in Minnesota.

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

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

Bluewater Lake's lakeshed is classified with having 67% of the watershed protected and 5% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a protection focus. Goals for the lake should be to limit any increase in disturbed land use. Bluewater Lake is a headwaters lakeshed, which means that no other lakesheds flow into it (Figure 20).

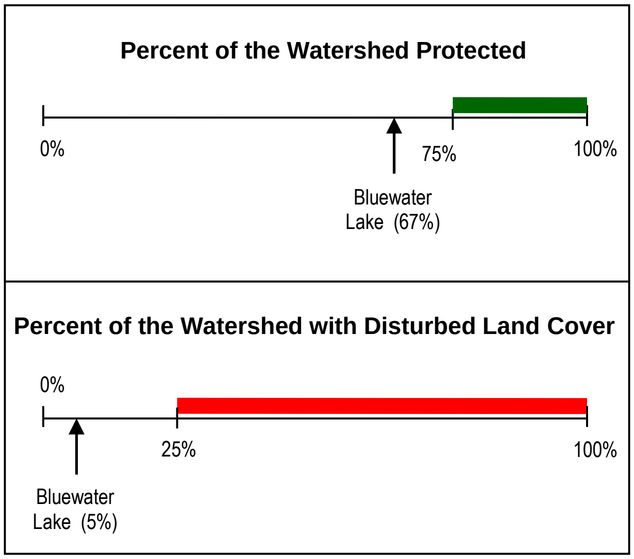


Figure 19. Bluewater Lake's lakeshed percentage of watershed protected and disturbed.

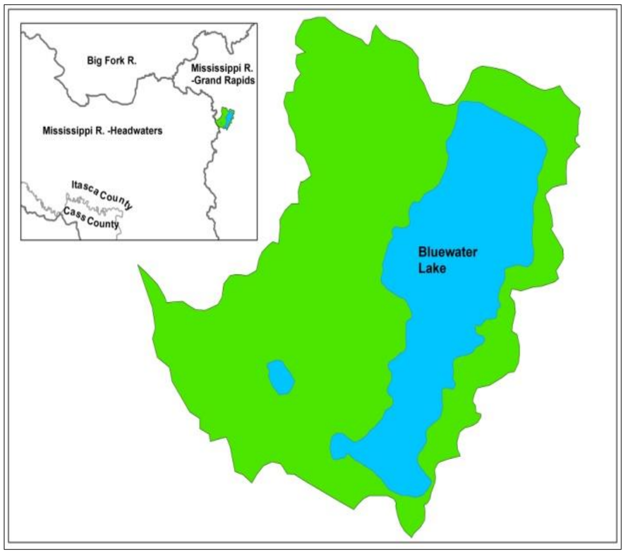


Figure 20. Lakesheds that contribute water to the Bluewater Lake lakeshed. Color-coded based on management focus (Table 13).

Status of the Fishery (DNR, as of 07/16/2007)

Bluewater Lake has been primarily managed for lake trout since 1967, and recently, yearlings have been stocked on an every-other-year schedule. Because of the difficulty of ageing lake trout, all stocked yearlings, since 1993, were given a specific fin clip to differentiate between stocked age classes and natural reproduction. Beginning in 2005, as part of a strain evaluation project, both Gillis Lake and Mountain Lake strain lake trout were stocked at 5 fish/acre (910). Each strain was assigned a fin clip to distinguish between the strains and assign ages to individual fish. The goal of the project was to evaluate survival and growth of the paired stockings at age-4 across the state.

Deepwater gill nets sampled 25 lake trout at a rate consistent with the previous assessment, and consistent with the lake average since deepwater gill net sets were used. Captured lake trout ranged in length from 7.4-30.7 inches, with an average length of 18.8 inches. Field inspection indicated that six of the lake trout sampled had an identifying fin clip. Five fish were identified as age-1 through fin clip markings, of which three were Gillis strain and two were Mountain strain. All age-1 fish sampled were from the 2007 spring stocking. Another fin clipped fish was identified as an age-3 Gillis strain (2005 stocking). The remaining 76% of sampled lake trout lacked a fin clip and are assumed to be from natural reproduction. The length frequency of known age fish indicates unclipped fish around 16 inches are age-3. Scale analysis of non-clipped fish suggests that ages 3-9 were present in the sample. Caution should be exercised when reviewing back-calculated length-at-age data due to the difficulty of accurately reading lake trout scales. The mean length at the time of capture of the yearling lake trout was 8.4 inches, while the mean back calculation at age-1 of fish assumed to be from natural recruitment was 5.7 inches. This is consistent with hatchery-reared fish being longer at age-1 due to diet and growing conditions than fish of natural origins. Scale analysis along with the length frequency suggests that ages 3-7 average about two inches per year. Statewide averages are inadequate for growth comparisons due to the naturally slow growth and the variability of trout water productivity.

Evaluating between the strains in Bluewater is difficult due to a limited sample size of the target age in the sample (age-3). Only one age-3 fish was sampled, a 414mm Gillis strain lake trout. Five marked yearlings were sampled, three Gillis strain and two Mountain strain. Other lakes in the Grand Rapids area included in the project were Trout Lake (31-0410) and Caribou Lake. There was no age-3 fish captured in Trout Lake, however 91% of the yearling sampled were Gillis strain. There was five age-3 fish sampled in Caribou, of which four were identified as Gillis strain and one Mountain strain. There was no yearling stocked lake trout sampled in Caribou. At this time, more Gillis strain lake trout have been sampled in the Grand Rapids area, but more time and a larger sample size is needed to make a definitive answer.

Catch rates for tullibee can be highly variable due to their open water, schooling nature. Tullibee were sampled at the lowest rate since deepwater gill nets have been used. The one tullibee sampled was 7.4 inches. Larger size tullibee are not typically sampled in Bluewater Lake.

Catch rates for other species sampled in gill nets set deep to sample lake trout are not very useful as an indicator of species abundance. Other species sampled in deepwater gill nets in relatively low abundance were largemouth and smallmouth bass, northern pike, walleye, and white sucker.

Bluegill were sampled at a rate near the lower end of the expected range, and below the previous two assessments. Lengths ranged from 3.5-8.1 inches with an average length of 5.9 inches. Largemouth bass were sampled at a rate above the expected range, and above the previous assessment. Lengths ranged from 5.2-14.7 inches with an average length of 8.7 inches. Yellow perch were sampled at a rate within the expected range. Other species sampled in trap nets include green sunfish, pumpkinseed, rock bass, smallmouth bass, and yellow bullhead.

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. http://www.dnr.state.mn.us/lakefind/showreport.html?downum=31039500

Key Findings / Recommendations

Monitoring Recommendations
Transparency monitoring at site 202 should be continued annually. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year-to-year comparisons and trend analyses. Total Phosphorus and chlorophyll *a* monitoring should continue, as the budget allows, to track trends in water quality.

Overall Summary
Bluewater Lake is an oligotrophic lake (TSI = 36) with no evidence of a long-term trend in transparency, phosphorus or algae concentration (chlorophyll a). The total phosphorus, chlorophyll *a* and transparency ranges are better than the ecoregion ranges.

Only 5% percent of the Bluewater Lake lakeshed is disturbed by development and agriculture (Figure 19). The threshold of disturbance where water quality tends to decline is 25%. Bluewater Lake is well under this threshold. Sixty-seven percent (67%) of the lakeshed is protected, which is generally good for water quality (Figure 19).

Bluewater Lake has the advantage of a very small watershed. The lake does not have any major inlets, which means that it is probably groundwater fed. This means that the main potential impacts to the lake are from land practices directly around the shoreline.

Ciscos (*Coregonus artedi),* also called Tullibee, can be an early indicator of eutrophication in a lake because they require cold hypolimnetic temperatures and high dissolved oxygen levels. Bluewater Lake is classified by the DNR as a Cisco Refuge Lake because it has deep, cold water, and a well-protected lakeshed. The 2007 DNR Fisheries survey did show Ciscoes present in the lake (page 18), which is an indicator that the lake has good water quality. Lake Trout also require high dissolved oxygen, and Bluewater Lake is managed for a Lake Trout fishery.

Priority Impacts to the Lake
About half of the Bluewater Lake lakeshore is federally owned, which protects it from development (Figure 16). The priority impact to Bluewater Lake would be the expansion of residential housing development around the northern and southern lakeshore. The conversion of small lake cabins to year-round family homes increases the impervious surface and runoff from the lake lots.

Best Management Practices Recommendations
The management focus for Bluewater Lake should be to protect the current water quality and lakeshed. Efforts should be focused on managing and/or decreasing the impact caused by additional development, and impervious surface area on existing lots (conversion of seasonal cabins to year-round homes).

The current lakeshore homeowners can lessen their negative impact on water quality by installing or maintaining the existing trees on their properties. Forested uplands contribute significantly less phosphorus (lbs/acre/year) than developed land cover (Table 12).

A quarter of the lakeshed is privately owned forested uplands (Table 12). Forested uplands can be managed with Forest Stewardship Planning, 3rd party certification, SFIA, and local woodland cooperatives. Contact the Itasca Soil and Watershed Conservation District for options for managing private forests.

The lakeshed still has large undeveloped shoreline parcels (Figure 16). Because a lot of undeveloped private land still exists, there is a great potential for protecting this land with conservation easements and aquatic management areas (AMAs). Conservation easements can be set up easily and with little cost with help from organizations such as the Board of Soil and Water Resources and the Minnesota Land Trust. AMAs can be set up through the local DNR fisheries office.

Project Implementation
The best management practices above can be implemented by a variety of entities. Some possibilities are listed below.

Individual property owners
- Shoreline restoration
- Rain gardens
- Aquatic plant bed protection (only remove a small area for swimming)
- Conservation easements

Lake Associations
- Lake condition monitoring
- Ground truthing – visual inspection upstream on stream inlets
- Watershed runoff mapping by a consultant
- Shoreline inventory study by a consultant
- Conservation easements

Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS)
- Shoreline restoration
- Stream buffers
- Wetland restoration
- Forest stewardship planning

Organizational contacts and reference sites

Wabana Chain of Lakes Association	http://www.wcola.org/
Itasca County Environmental Services Department	124 NE 4th St., Grand Rapids, MN 55744 (218) 327-2857 https://www.co.itasca.mn.us
Itasca Soil and Water Conservation District	1889 East Highway 2, Grand Rapids, MN 55744 (218) 326-0017 http://www.itascaswcd.org
DNR Fisheries Office	1201 East Highway 2, Grand Rapids, MN 55744 (218) 327-4430 http://www.dnr.state.mn.us/areas/fisheries/grandrapids/index.html
Regional Minnesota Pollution Control Agency Office	525 Lake Avenue South, Duluth, MN 55802 (218) 723-4660 http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2383 http://www.bwsr.state.mn.us