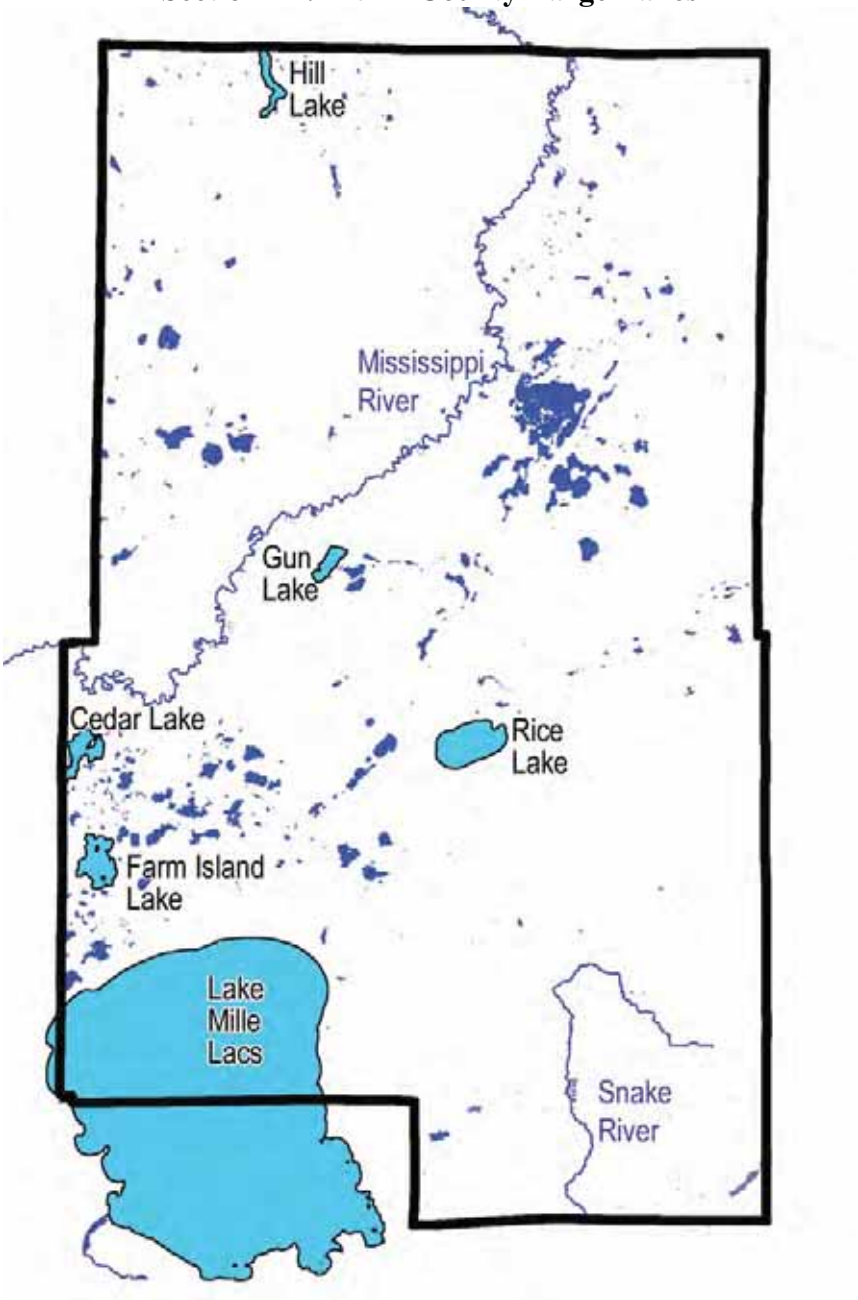
Section III. Aitkin County Large Lakes



2008

Aitkin County Soil and Water Conservation District
Minnesota Board of Soil and Water Resources

List of Abbreviations

BWSR: Board of Soil and Water Resources

CHLA: Chlorophyll *a*

CLMP: Citizens Lake Monitoring Program – transparency data collection

CLMP+: Citizens Lake Monitoring Program – transparency and chemical data collection

CSMP: Citizens Stream Monitoring Program

DNR: Minnesota Department of Natural Resources

LAP: Lake Assessment Program

MPCA: Minnesota Pollution Control Agency

STORET: (short for STOrage and RETrieval) is the U.S. Environmental Protection Agency's (EPA's) repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others.

SWCD: Soil and Water Conservation District

TMDL: Total Maximum Daily Load

TP: Total phosphorus

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Cedar Lake Conservancy
Farm Island Lake Improvement Association

Agencies contributing data and information:
Minnesota Department of Natural Resources (DNR)
Minnesota Pollution Control Agency

Rice Lake National Wildlife Refuge, US Fish and Wildlife Service

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Introduction

Aitkin County is located in the lakes country of northern Minnesota. More than 350 lakes and 900 miles of streams and rivers are found in Aitkin County. These resources are valued for their excellent recreation opportunities and water quality.

For the purpose of future water planning, the Aitkin SWCD decided to evaluate the water quality of the largest lakes in Aitkin County including: Hill, Gun, Rice, Cedar, Farm Island and Lake Mille Lacs. Lake Minnewawa and Big Sandy Lake are large, but since they are being evaluated through the TMDL process, they were not included in this report. Lakes evaluated in this report are indicated in light blue in Figure 1.

Aitkin County large lakes have been monitored off and on between 1971 and 2008. This monitoring has been completed by numerous organizations including Lake Associations, Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, Aitkin Soil and Water Conservation District, and the Mille Lacs Band.

The purpose of this report was to compile all available data for these lakes from all the different sources, evaluate the data quality, identify data gaps, assess the data, and look for water quality trends. This report contains a summary of the current state of large Aitkin County lakes and recommendations for future monitoring.

Individual lake reports follow with more in-depth assessments and recommendations.

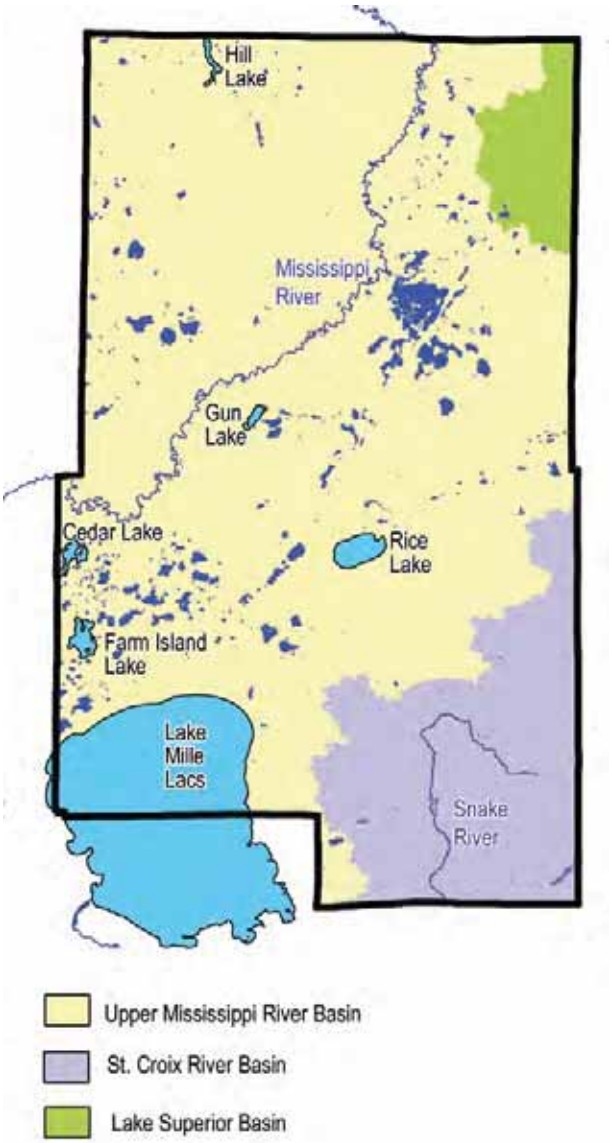


Figure 1. Lakes of Aitkin County. Lakes evaluated in this report are in light blue, while each major basin is highlighted in a different color.

Data Availability		
Transparency data		Secchi disk data were collected through the MPCA Citizens Lake Monitoring Program off and on between 1987 and 2008. On Cedar, Hill and Rice Lakes, there is no transparency data from the past few years.
Chemical data		Chemical data (total phosphorus and chlorophyll *a*) were collected only one or two years for each lake.
Inlet/Outlet data		Inlet/outlet data were collected only as part of an MPCA LAP study for Cedar and Mille Lacs Lakes.

Lake Name	Lake ID	Lake Size (acres)	Data Sources
Cedar Lake	01-0209-00	1,745	**STORET, CLMP 1995-2006, MPCA LAP 2002, DNR, Cedar Lake Conservancy**
Farm Island Lake	01-0159-00	2,002	STORET, CLMP 1985-2008, MPCA LAP 2004, DNR, Farm Island Lake Improvement Association
Gun Lake	01-0099-00	730	STORET, CLMP 1987-2008 MPCA LAP 1987, DNR
Hill Lake	01-0142-00	817	STORET, CLMP 1994-2002 MPCA LAP 1994, DNR, Hill Lake Association
Lake Mille Lacs	48-0002-00	128,223	STORET, CLMP:1993-2007 MPCA LAP 1992, DNR, Mille Lacs Band
Rice Lake	01-0067-00	3,698	DNR, Rice Lake National Wildlife Refuge

General Recommendations

- Monitor transparency weekly or bi-monthly through the MPCA Citizen Lakes Monitoring Program (CLMP) every year. Continual annual transparency data is a great way to monitor lake water quality and track trends. Avoid missing years of monitoring, which leads to gaps in data. For example, if a lake is showing a significant decline in water quality but there are gaps in their data, it is hard to determine when the impact occurred and whether it was acute or chronic.

- Monitor phosphorus and chlorophyll *a* concentrations more frequently. If annual monitoring is not feasible, consider monitoring on a 3-5 year rotation. Collecting one more year of data on

each of these lakes in the next two years will enable them to be included in the next MPCA Impaired Waters Assessment and recreational use Assessment.

- Continue to follow BMPs (Best Management Practices) in the watershed:
  - Plant natural vegetation along the shoreline
  - Properly maintain septic systems and their drainfields
  - Limit the use phosphorus fertilizer on lawns
  - Surface water onsite management (rain gardens, drainage, etc)

- Complete a ground truthing study of the watersheds of the lakes showing significant declines in water quality over the past 10 years:
  - Visually inspect the shoreline of each parcel and look for erosion, lack of a vegetation buffer and other harmful management practices.
  - Visually inspect ditch and stream networks leading into the lake to look for sources of phosphorus and erosion.

- Begin stream inlet monitoring and storm event monitoring for the lakes showing significant declines in water quality over the past 10 years to determine where the phosphorus is coming from.

Trophic State Index (TSI)

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).

Trophic states are defined divisions of a continuum in water quality. The continuum is total phosphorus concentration, chlorophyll a concentration and Secchi depth. Scientists define certain ranges in the above lake measures as different trophic states so they can be easily referred to.

The large Aitkin County lakes fall into the mesotrophic to eutrophic category. Due to the lack of total phosphorus and chlorophyll *a* data for these lakes, it was

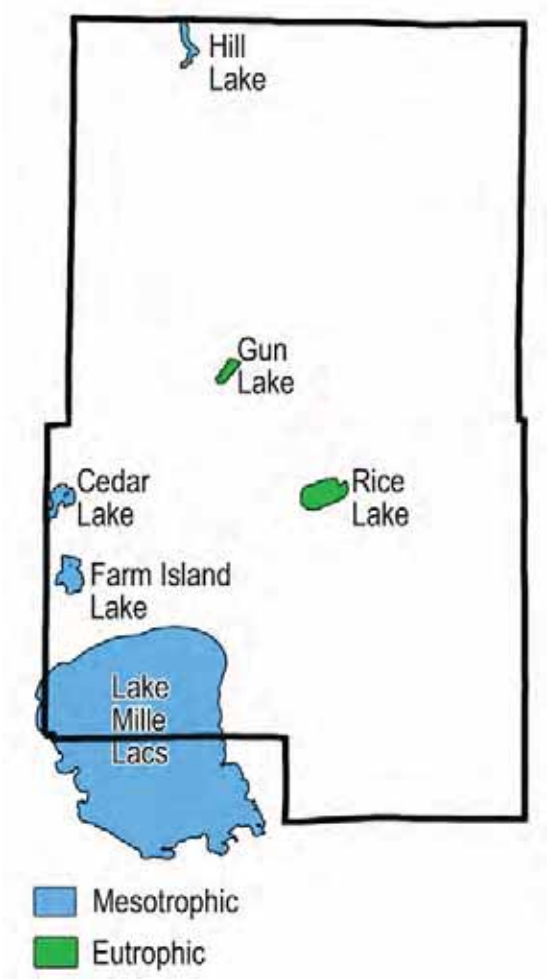


Figure 2. Aitkin County large lakes illustrating trophic states.

difficult to determine a mean trophic state index for each lake. Technically, if the TSI for any of the 3 parameters are more than 5 points apart, they should not be averaged. Only in Farm Island and Gun Lakes did the TSI for all parameters show strong agreement. This means that the dynamics between the phosphorus, chlorophyll *a* and secchi depth are strongly related.

In the remaining lakes, the lack of agreement in the 3 parameters could be due to the limited phosphorus and chlorophyll a data. Most lakes only had one or two years of chemical data and 5-10 years of transparency data. Additional chemical data would be beneficial for further determining the dynamics of productivity in each lake.

Lake	Mean TSI	Trophic State	Mean TSI Secchi	Mean TSI phosphorus	Mean TSI chlorophyll *a*
Farm Island	44	Mesotrophic	42	46	45
Mille Lacs	46*	Mesotrophic	43	52	43
Cedar	47	Mesotrophic	45	46	50
Hill	47*	Mesotrophic	41	50	49
Gun	53	Eutrophic	53	53	53
Rice	**	Eutrophic	75	54	43

**Mean TSIs for Secchi, phosphorus and chlorophyll a are more than 5 points apart, see above for explanation*

***Due to the shallow nature of the lake (mean depth of 4 ft), it does not behave as a typical lake and mean TSI is not applicable*

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.

Water Quality Trends

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.

There is not enough historical data to perform trend analysis for total phosphorus or chlorophyll *a* on any of the evaluated Aitkin County lakes. All lakes, except for Rice, had enough data for trend analysis of transparency. The data was analyzed using the Mann Kendall Trend Analysis.

Gun Lake and the south basin of Hill Lake showed improving trends in transparency, although the data stops at 2001. The north basin of Hill Lake and the north end of Lake Mille Lacs show no trend in data up to 2002. The south end of Mille Lacs, as well as Cedar and Farm Island lakes show declining trends in transparency.

Lake	Parameter	Date Range	Trend	Probability
Gun	Transparency	1987-2000	Improving	90-99%*
Hill – south basin	Transparency	1994-2001	Improving	99%
Hill – north basin	Transparency	1994-2002	No Trend	--
Mille Lacs – north end	Transparency	1997-2002	No Trend	--
Mille Lacs – south end	Transparency	1993-2002	Declining	90-99.9*%
Cedar	Transparency	1995, 1997-1998, 2000-2007	Declining	99.9%
Farm Island	Transparency	1996-2007	Declining	95-99.9%*
Rice	--	insufficient data	--	--

* Different lake sites showed differing probabilities for trends. To see results for each lake refer to the individual lake reports

Ecoregion Comparisons

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. 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.

All of Aitkin County is in the Northern Lakes and Forests (NLF) Ecoregion. This heavily forested ecoregion is made up

of steep, rolling hills interspersed with pockets of wetlands, bogs, lakes and ponds. Lakes are typically deep and clear, with good gamefish populations. These lakes are very sensitive to damage from atmospheric deposition of pollutants (mercury), storm water runoff from logging operations, urban and shoreland development, mining, inadequate wastewater treatment, and failing septic systems. Agriculture is somewhat limited by the hilly terrain and lack of nutrients in the soil, though there are some beef and dairy cattle farms.

Most of the lakes evaluated in this report fall within the expected ecoregion ranges. Gun Lake does not fall within the expected ecoregion ranges; however, land use in the watershed of Gun Lake is predominated by marsh and agricultural/marsh land uses. This is atypical for lakes in the NLF Ecoregion, where forested and marsh land uses are typically dominant. This difference in land use/cover could explain why Gun Lake does not fit into the NLF Ecoregion ranges. Rice Lake is an extremely shallow lake (2-8 ft deep) and behaves more like a marsh, which may be why it doesn't fit into the ecoregion ranges.

	Total Phosphorus (ug/L)	**Chlorophyll-a** (ug/L)	**Secchi Depth** (ft)	**Evaluation**
Northern Lakes and Forests Ecoregion range*	14 – 27	<10	7.5 – 15	-
Cedar Lake	18.3	7.3	11.2	Within expected range
Farm Island Lake	18.8	4.8	11.7	Within expected range
Lake Mille Lacs	25.7	4.4	10.7	Within expected range
Hill Lake	26.6	8.5	13.3	Within expected range
Gun Lake	34	10	6.5	Poorer than expected range
Rice Lake	30.8	3.5	0.9	Poorer than expected range

* The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For more information visit: http://www.pca.state.mn.us//data/eda/wqguide.html

Statewide Assessments

Lake monitoring should be designed and accomplished for achieving specific goals. There are two main purposes for lake monitoring in Minnesota. The first is the MPCA statewide 303(d) and 305(b) assessments that occur every two years. Statewide MPCA Assessments are performed with a minimum data set of 10 data points each of total phosphorus, chlorophyll *a*, and secchi depth over a two-year period in the past 10 years. This assessment can be considered the first step to understanding a lake.

The second purpose for lake monitoring is ongoing education, awareness and lake condition. After the lake's current condition is determined, associations can monitor water quality each year to learn about seasonal variability, year to year variability, and if the water quality is improving, declining or staying the same (trend analysis). Condition monitoring involves collecting at least 5 samples during the growing season (the typical program involves monitoring once a month May-September) each year.

Impaired Waters Assessment 303(d) List

There are two main types of Impaired Waters Assessment for lakes: eutrophication (phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption.

Mille Lacs, Round, Farm Island, Cedar, Pickerel, Clear, Dam, Hill, Big Sandy, and Minnewawa were listed as impaired for aquatic consumption on the 2006 Impaired Waters List; however it is part of the statewide mercury TMDL and therefore was not on the 2008 Impaired Waters List.

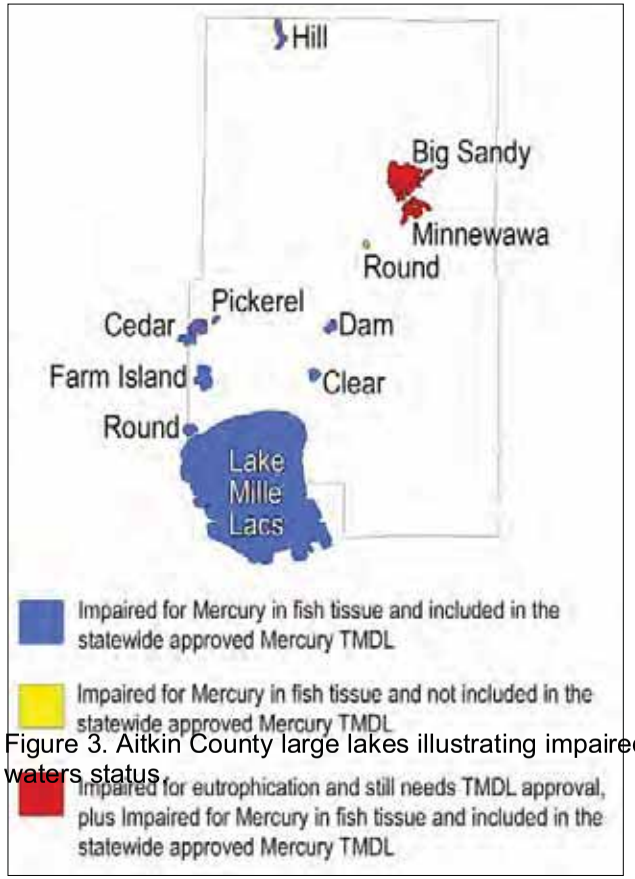


Figure 3. Aitkin County large lakes illustrating impaired waters status.

As of the date of this report, all lakes evaluated in this report had insufficient data sets for Impaired Waters Assessment for eutrophication. Most of the large lakes in Aitkin County only need one more year of monitoring data to be included in the Impaired Waters Assessments. See the table below for specific data requirements.

Lake	Last year of chemical data in STORET	Data points need for Impaired Waters Assessment for eutrophication

Gun	2008	One more year before 2017
Hill	2008	One more year before 2017
Mille Lacs	1992	Two years of data needed
Cedar	2002	One more year before 2011
Farm Island	2004	One more year before 2013
Rice	No data in STORET	Two years of data needed

Aquatic Recreational Use Assessment 305(b)

In the 2008 MPCA Aquatic Use Assessment (305(b)), only Farm Island Lake had enough data to be fully evaluated. Farm Island Lake was listed as fully supporting for recreational usage. Data requirements for 305(b) Assessment follow those of the Impaired Waters Assessment above.

Aitkin County Lakeshed Assessments

The lakeshed vitals table identifies where to focus organizational and management efforts for each lake. Criteria were developed using limnological concepts to determine the effect to lake water quality. For explanations of the lakeshed vitals and rating criteria, see the reference document.

Table 1. Lakeshed vitals with rating for large lakes in Aitkin County.

Lakeshed Vitals	Cedar	Farm Island	Gun	Hill	Mille Lacs	Rice
Lake Mean Depth	+	-	-	+	+	-
Water Residence Time	+	-	+	+	NA	NA
Municipalities	+	+	+	-	-	+
Sewage Management	x	x	x	x	x	+
Public Drainage Ditches	x	+	x	x	x	+
Lake Management Plan	x	x	x	x	x	+
Lake Vegetation Survey/Plan	x	x	x	x	x	+
Forestry Practices	+	+	+	+	+	+
Development Classification	x	x	x	-	-	+
Shoreline Development Index	-	-	-	-	+	+

Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	x	x	x	x	+	x
Public Lake Accesses	x	x	x	x	x	+
Inlets	x	x	x	x	x	x
Outlets	x	x	x	x	x	x
Feedlots	-	+	-	+	-	-
Agriculture Zoning	x	x	x	x	x	x
Public Land : Private Land	-	-	-	-	-	+
Wetland Coverage	+	+	+	+	+	+
Lake Transparency Trend	-	-	+	+	-	NA
Exotic Species	+	+	+	+	-	+

Rating Key: + *beneficial to the lake;* - *possibly detrimental to the lake,* x *warrants attention*

Table 1 allows for comparisons across lakes and highlights issues that are impacting numerous lakes in Aitkin County. Forestry Practices and Wetland Coverage were beneficial lakeshed vitals that applied to all lakes assessed. Areas that warrant attention in most lakes assessed are Sewage Management, a Lake Management Plan, a Lake Vegetation Survey and Plan, Public Lake Access educational signage, Inlet and Outlet investigation, and Agricultural Zoning within the lakeshed. In all lakes assessed except Rice Lake, the extremely low acreage of Public Land could possibly be detrimental to the lake. Additional areas within the lakeshed could be identified for public ownership to ensure protection.

Land Cover / Land Use

The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Table 2 describes the lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture, water, and grass/shrub/wetland acreages to forest and urban acreages in most of the lakesheds. In addition, the impervious area increased in all lakes except for Rice Lake, which is located within a National Wildlife Refuge.

Table 2. Aitkin County lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

Lakeshed Vitals	Cedar	Farm Island	Gun	Hill	Mille Lacs	Rice
Land Cover						
Agriculture	42.1 % Decrease	35.7 % Decrease	19.1 % Decrease	3.5 % Decrease	23.9 % Decrease	18.1 % Decrease
Forest	29.7 % Increase	23.4 % Increase	41.4 % Increase	6.3 % Decrease	17.9 % Increase	21.9 % Increase
Grass/Shrub/Wetland	32.6% Decrease	16.9 % Decrease	8.5 % Decrease	26.4 % Increase	11.2 % Decrease	41.8 % Decrease
Water	17.4 % Decrease	9.0 % Decrease	10.9 % Decrease	12.9 % Decrease	0.5 % Decrease	12.8 % Decrease
Urban	16.7 % Increase	20.7 % Increase	20.8 % Increase	21.8 % Increase	23.1 % Increase	16.8 % Increase
Impervious Intensity %						
0	0.9 % Decrease	1.5 % Decrease	0.9 % Decrease	1.1 % Decrease	0.5 % Decrease	0.1 % Decrease
1-10	20.8 % Increase	22.0 % Increase	11.1 % Decrease	12.1 % Decrease	23.3 % Increase	71.7 % Increase
11-25	13.6 % Increase	37.9 % Increase	128.6 % Increase	20.0 % Increase	26.7 % Increase	2.5 % Decrease
26-40	122.2 % Increase	81.3 % Increase	23.1 % Increase	53.6 % Increase	72.5 % Increase	No Change
41-60	64.3 % Increase	18.5 % Increase	33.3 % Decrease	90.9 % Increase	53.6 % Increase	50.0 % Decrease
61-80	11.1 % Decrease	75% Increase	66.7 % Decrease	162.5 % Increase	27.6 % Increase	100.0 % Decrease
81-100	20.0 % Decrease	300% Increase	400 % Increase	540 % Increase	14.8 % Increase	100.0 % Increase
Total Area	8,564	7,706	2,850	9,142	164,552	18,983
Total Impervious Area (Percent Impervious Area Excludes Water Area)	32 % Increase	57.6 % Increase	40 % Increase	96.7 % Increase	37.8 % Increase	8.7 % Decrease

Cedar Lake 01-0209-00 AITKIN COUNTY

Summary

Cedar Lake is located in Aitkin County near Aitkin, MN. With a surface area of 1,729 acres, it is in the upper 10% of lakes in Minnesota in terms of its size.

Cedar Lake has 7 inlets and one outlet, which classifies it as a drainage lake. There are only two streams that flow most of the year that enter Cedar Lake - Cedar Brook and Casey Brook. The others flow intermittently. Water flows north out of Cedar Lake into Cedar Creek, which drains into the Mississippi River.

Water quality data has been collected for Cedar Lake off and on since 1981. The Cedar Lake Conservancy has participated in lake monitoring and stream inlet/outlet monitoring since 1995. These data show that Cedar Lake is mesotrophic (page 8). Mesotrophic lakes are commonly found in central Minnesota and have clear water with occasional algal blooms in late summer.

Vitals	
MN Lake ID:	01-0209-00
County:	Aitkin
Ecoregion:	Northern Lakes and Forest
Major Drainage Basin:	Upper Mississippi River
Latitude/Longitude:	46.64583333 / -93.52111111
Water Body Type:	Public Waters
Monitored Sites (Primary):	206
Monitored Sites (Secondary):	201, 202, 203, 204, 205, 207, 208

Physical Characteristics		
Surface area (acres):	1,745	
Littoral area (acres):	405	
% Littoral area:	23%	
Max depth (ft):	105	(m): 31.8
Mean depth (ft):	28	(m): 8.5
Watershed size (acres):	23,488	
Watershed:lake area ratio	17:1	
Inlets	7	
Outlets	1	
Accesses	1 public	

Invasive species present: none documented

Data Availability

Transparency data		Transparency data were collected through the MPCA CLMP program from 1995-2007.
Chemical data		Chemical data were only collected in 1981 and 2002 by the MPCA.
Inlet/Outlet data		Inlet/outlet data were collected as part of an MPCA LAP study in 2002.
Recommendations		For recommendations refer to page 12.

Figure 1. Map of Cedar 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.

Basin	Lake Site	Depth (ft)	Monitoring Programs
Main	201 (105)	65	CLMP: 1995-1996, 1998-2001, 2004-2005
Main	202 (104)	84	CLMP: 1995-2002, 2006
Main	203	65	CLMP: 1995-2001, 2005-2006
Main	204	80	CLMP: 1995-1996, 2000-2001, 2005-2006
Main	205	71	CLMP: 1995-2001, 2005-2006
Main	206 (103) *Primary Site	80	CLMP: 1995-2000, 2002, 2005
Main	207 (102)	70	CLMP: 1995, 1997, 2000-2007
Main	208	30	CLMP: 1995, 1997-1998, 2000-2007
Southwest	201	50	CLMP: 1995-2002, 2005
Northeast	201	24	CLMP: 1995, 2001-2002, 2006-2007

The information below describes available chemical data for Cedar Lake through 2008 for the primary site 206(103). The data set is limited, and all parameters with the exception of total phosphorus, chlorophyll *a* and secchi depth, are means for just 2002 data.

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 10.

Parameter	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	18.3	14 - 27	> 35	Results are within the expected range for the ecoregion, and show that Cedar Lake is mesotrophic. For more information about Impaired Waters Assessment, see page 12.
[3]Chlorophyll *a* (ug/L)	7.3	4 - 10	> 12	
Chlorophyll *a* max (ug/L)	8.9	<15		
Secchi depth (ft)	11.2	7.5 - 15	< 4.5	
Dissolved oxygen				Dissolved oxygen depth profiles show that the deeper areas of the lake are anoxic in late summer
Total Kieldahl Nitrogen (mg/L)	0.59	0.4 - 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms
Alkalinity (mg/L)	103	40 - 140		Indicates a low sensitivity to acid rain and a good buffering capacity
Color (Pt-Co Units)	22	10 - 35		Indicates clear water with little to no tannins (brown stain)
pH	8.3	7.2 - 8.3		A pH of 8 is common in a hardwater lake. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water
Chloride (mg/L)	3.7	0.6 - 1.2		Chloride levels are slightly higher than the ecoregion range, but still considered low level.
Total Suspended Solids (mg/L)	3	<1 - 2		Indicates moderately clear water
Total Suspended Volatile Solids (mg/L)	2	<1 - 2		Indicates moderately clear water
Conductivity (umhos/cm)	206	50 - 250		Within the expected range for the ecoregion
Total Nitrogen :Total Phosphorus	31:1	25:1 – 35:1		Indicates the lake is phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake.

Data Source: Minnesota Pollution Control Agency 2002

[1]The ecoregion range is the 25th-75th 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

Years monitored: 1981, 1995-2007

Parameters	Primary Site 206	Site 201	Site 202	Site 203	Site 204	Site 205	Site 207	Site 208	South West Basin 201	North East Basin 201
Phosphorus Mean:	**18.3**	**12**	**17**				**9**	**18**	**22**	
Total Phosphorus Min:	13		11					14	16	
Total Phosphorus Max:	22		22					21	26	
Number of Observations:	4	1	4				1	4	3	
Chlorophyll *a* Mean:	**7.3**	**7.7**	**8**					**8.3**	**15.9**	
Chlorophyll-a Min:	4.2		3.7					5.4	4.5	
Chlorophyll-a Max:	8.9		11.8					10.9	36	
Number of Observations:	4	1	4					4	3	
Secchi Depth Mean:	**11.2**	**11.5**	**9.7**	**10.8**	**12.1**	**12.5**	**10.8**	**9.4**	**9.2**	**11.2**
Secchi Depth Min:	8.9	6.5	6	7	7.5	8.5	8	6	3.5	8
Secchi Depth Max:	15	16	15	14	16	18	13	13.5	12.5	14.5
Number of Observations:	55	92	75	87	68	110	93	104	132	33

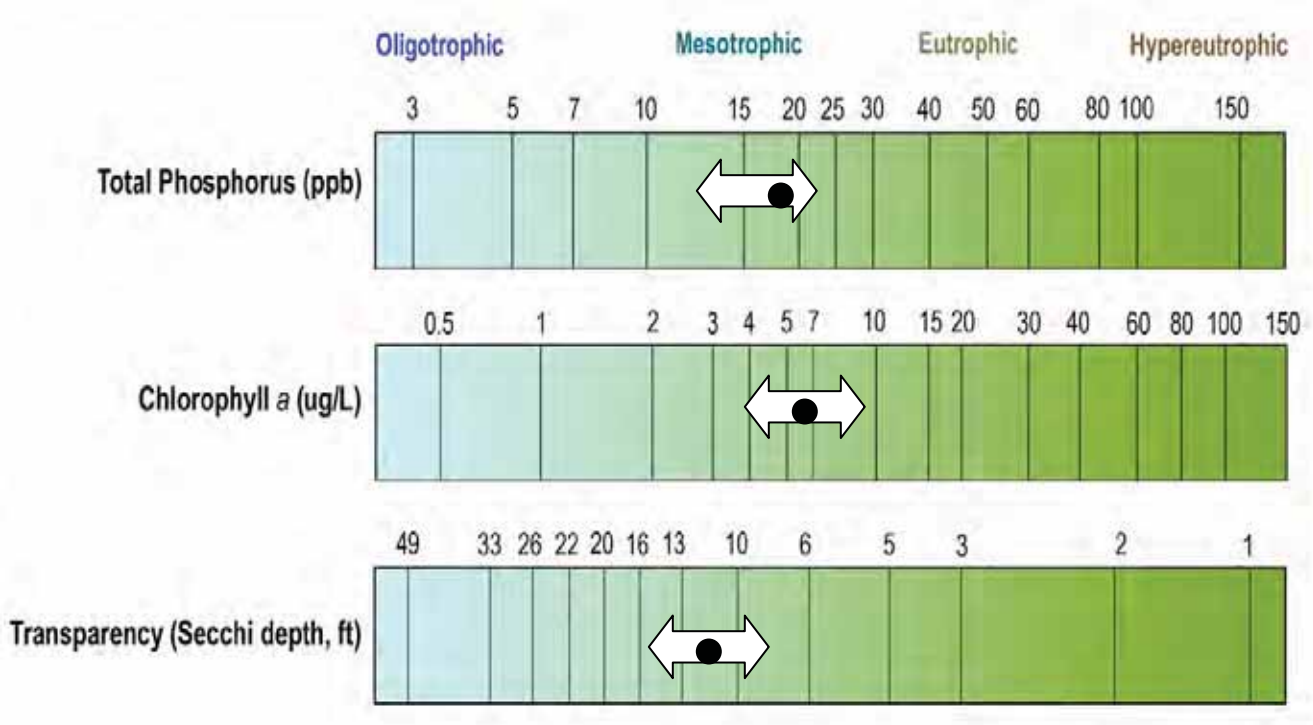


Figure 2. Cedar Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow

Transparency (Secchi Depth)

Transparency is how easily light can pass through a substance. In lakes it refers to 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.

For all the sites, the mean transparency ranges from 9.2 to 12.5 feet. The transparency throughout the lake appears to be better toward the north end of the lake and less at the south end of the lake. The south end of the main basin had an average of 9.7 feet and the southwest bay had an average of 9.2 feet transparency.

The transparency was best in 2000, 2006 and 2007 (Figure 3). There is no transparency data at the primary site since 2005. It is recommended that the lake association begin collecting transparency data at all sites again to compare to the previous data.

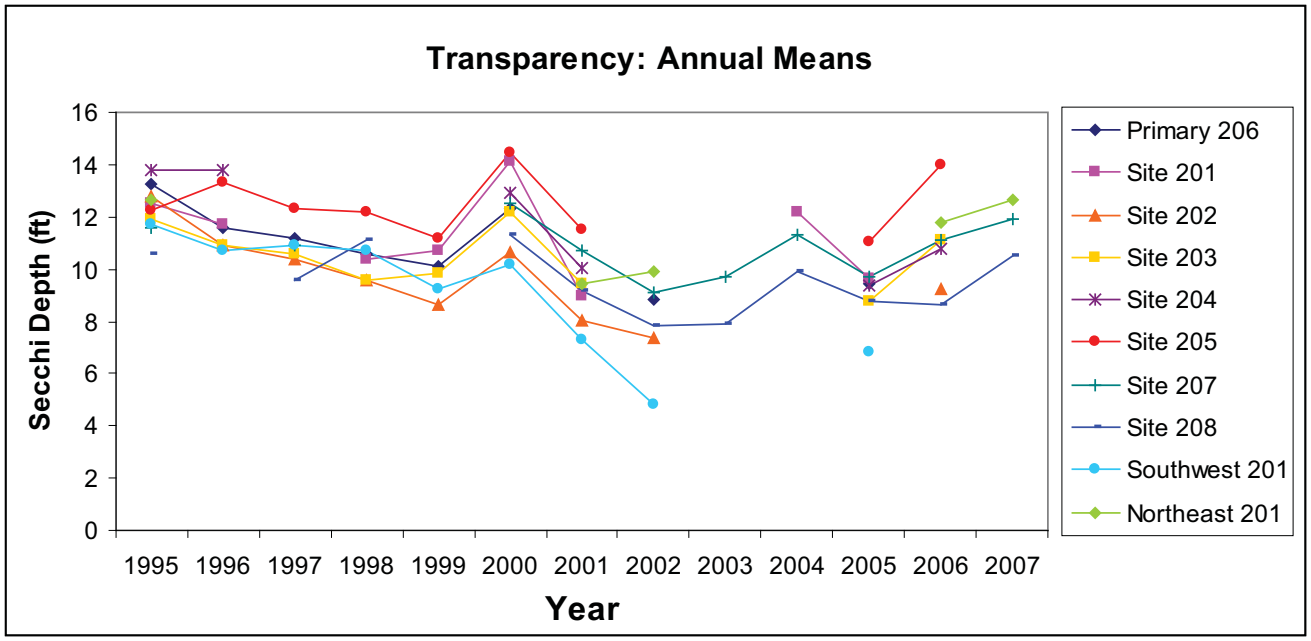


Figure 3. Annual mean transparency for each sample site.

Cedar Lake transparency ranges from 8.9 to 15 ft at the primary site (206). Figure 4 shows the seasonal transparency dynamics. The transparency in the main basin of Cedar Lake remains fairly constant throughout the year without following a pattern. Some lakes have fairly constant transparency while others follow seasonal highs and lows.

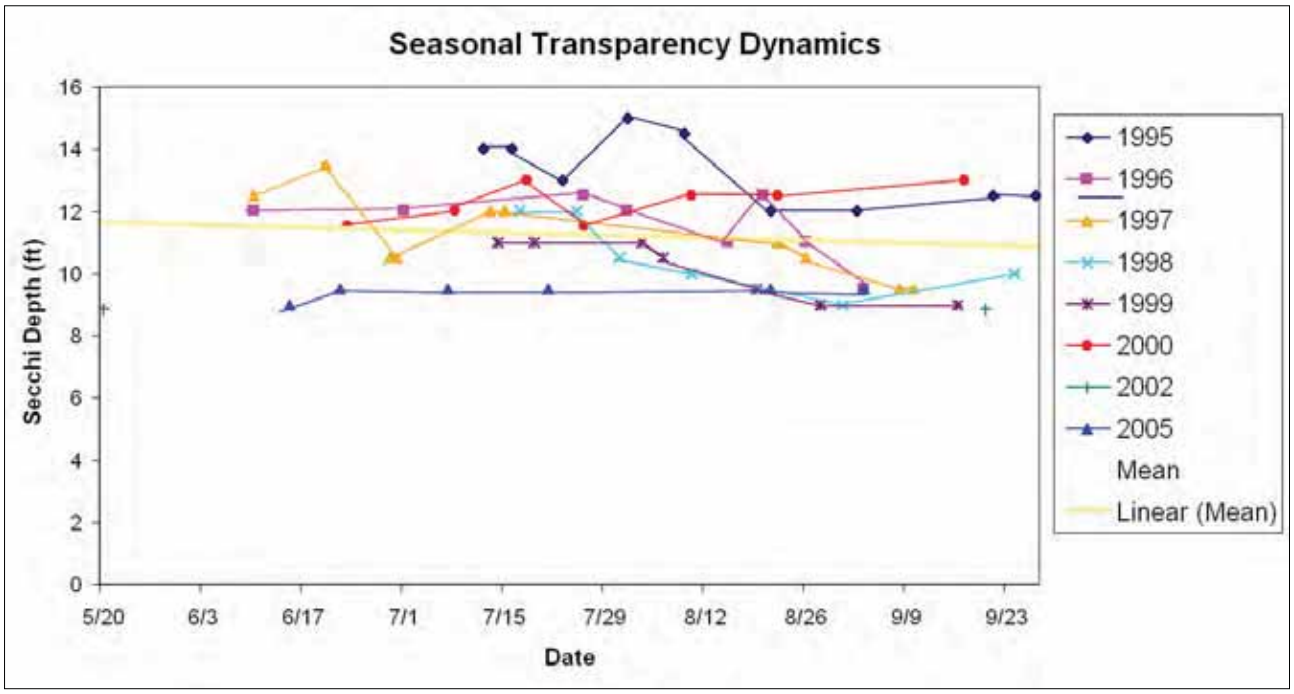


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 206).

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. Cedar Lake was rated as being "not quite crystal clear" 66% of the time between 1995-2007.

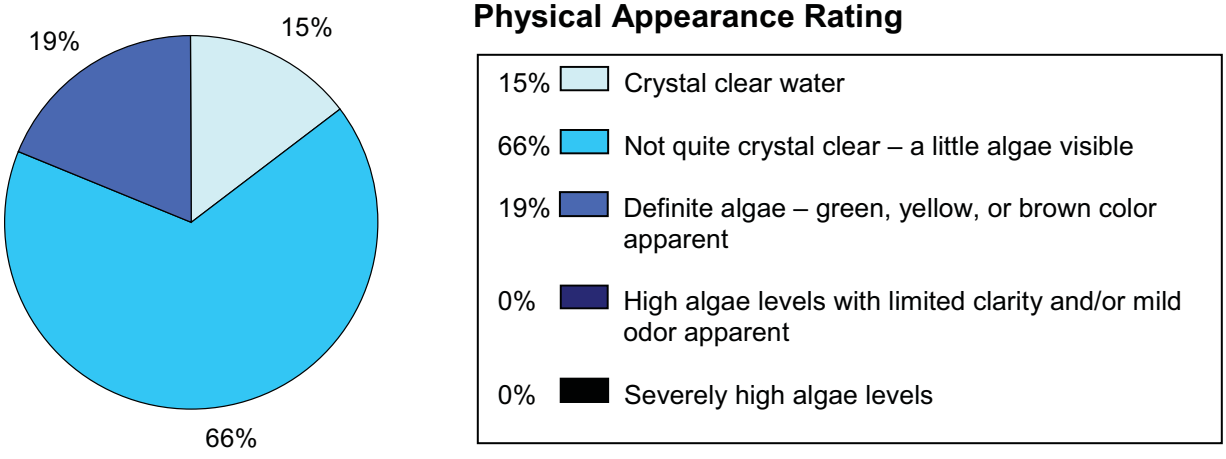


Figure 5. Physical appearance rating, as rated by the volunteer monitor (all sites, 1995-2007).

As the secchi depth decreases, the perception of recreational suitability of the lake decreases. Cedar Lake was rated as having "very minor aesthetic problems" 59% of the time from 1995-2007.

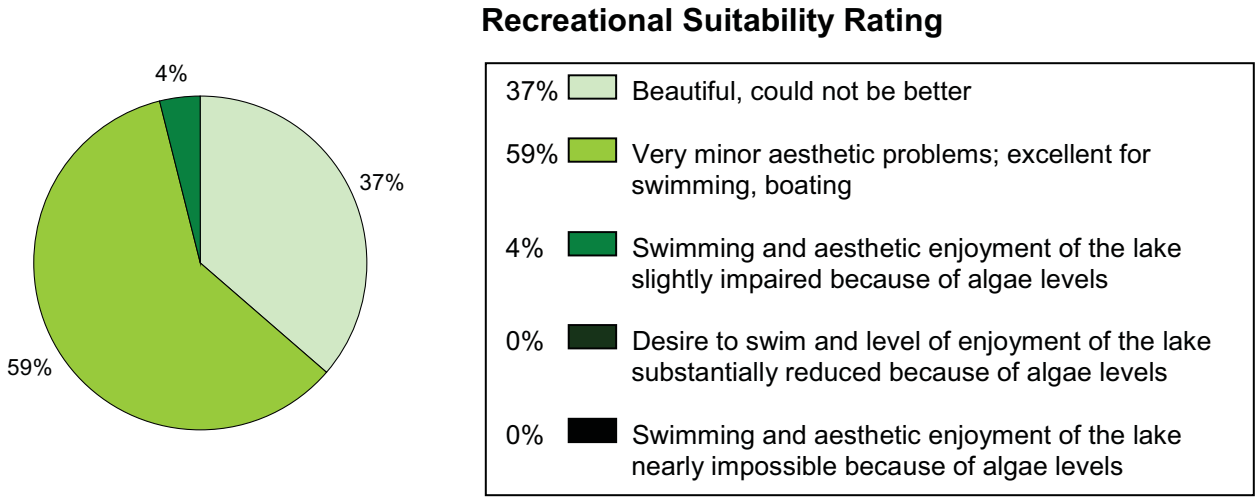


Figure 6. Recreational suitability rating, as rated by the volunteer monitor (all sites, 1995-2007).

Total Phosphorus

Cedar Lake is phosphorus limited. This means that algae and aquatic plant growth is dependent upon available phosphorus, and reducing phosphorus sources to the lake will decrease algae concentrations.

Total phosphorus was evaluated in Cedar Lake in 1981 and 2002. In 1981, only one phosphorus sample was collected in August, so those data were not included in Figure 7.

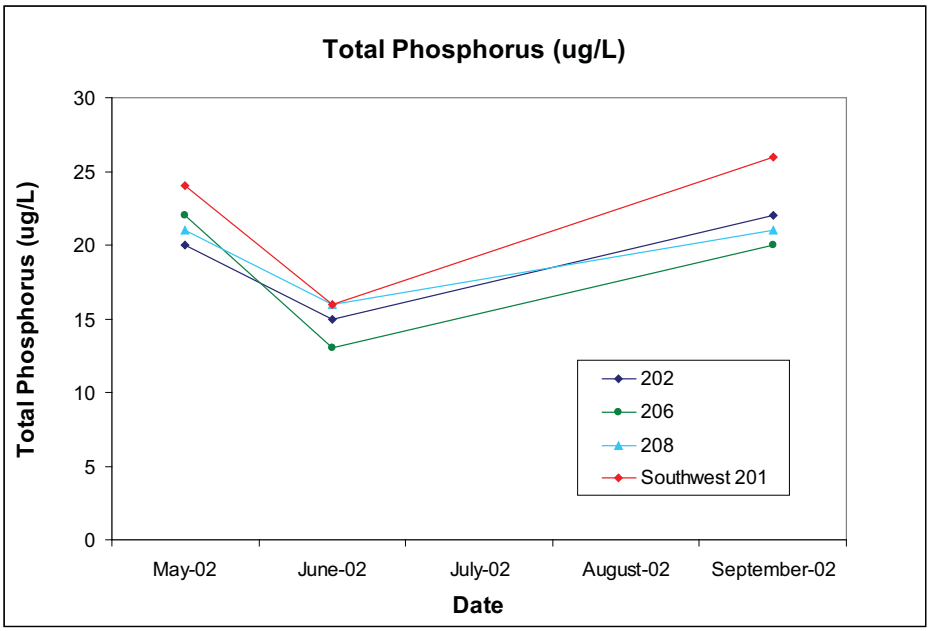


Figure 7. 2002 total phosphorus concentrations (ug/L) for Cedar Lake.

Phosphorus concentrations at all sites followed the same pattern in 2002 of being lowest in June and highest in September. The primary site, 206 had the lowest phosphorus concentrations overall, while the southwest bay had the highest concentrations. Phosphorus should be tested more often to get a better understanding of Cedar Lake.

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.

Chlorophyll *a* was evaluated in Cedar Lake in 1981 and 2002. In 1981, only one chlorophyll *a* sample was collected in August, so those data were not included in Figure 8.

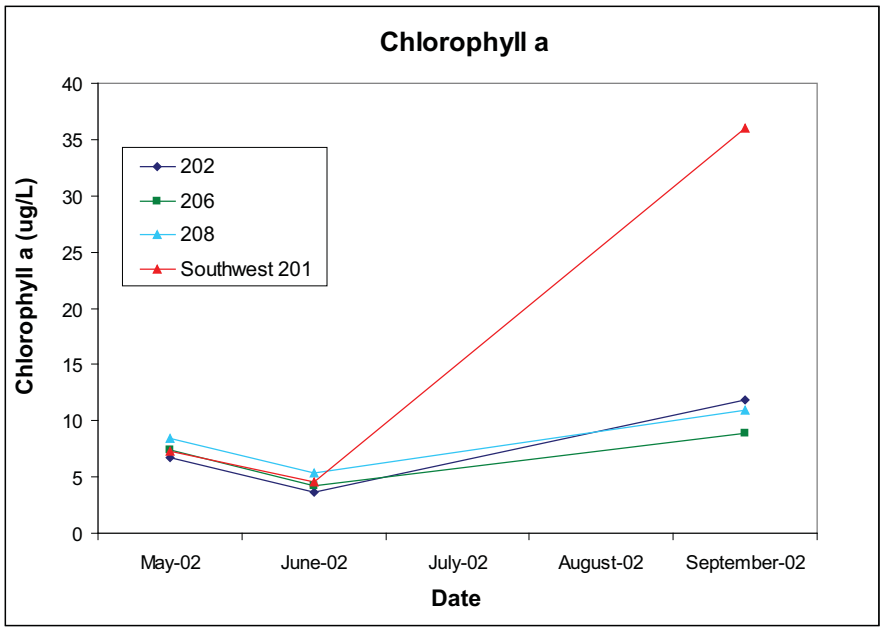
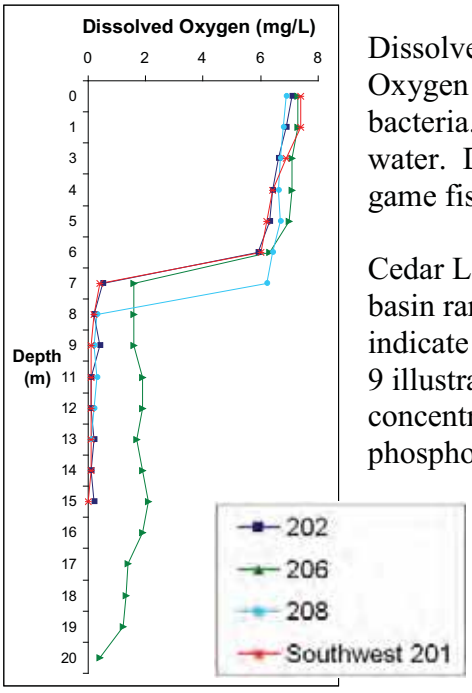


Figure 8. 2002 chlorophyll *a* concentrations (ug/L) for Cedar Lake.

Chlorophyll *a* concentrations in the main basin were relatively similar and did not fluctuate much throughout the year. In addition, main basin chlorophyll a concentrations stayed below 10 ug/L, which is perceived as a mild algae bloom. Chlorophyll a concentrations in the southwest bay were very high in September, indicating a nuisance algae bloom. User perceptions during this period were rated as a severe algae bloom. Chlorophyll *a* should be tested more often to get a better understanding of Cedar Lake, and to see if the southwest bay has a severe algae bloom each year or only in 2002.

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

Cedar Lake is a relatively deep lake. Most of the middle of the main basin ranges from 60-80 feet deep. Dissolved oxygen profiles from 2002 indicate that both the main basin and the southwest basin stratify. Figure 9 illustrates stratification in September of 2002. Benthic phosphorus concentrations indicate internal loading when this site is stratified (total phosphorus ranged from 120 ug/L – 234 ug/L for all sites in Fig. 9).

Figure 9. Dissolved oxygen profile for Cedar Lake, September, 2002.

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 202	Site 206	Site 208	Southwest 201
TSI Total Phosphorus	44	46	46	48
TSI Chlorophyll-a	50	50	51	54
TSI Secchi	45	42	45	46
TSI Mean	*Not appropriate	*Not appropriate	*Not appropriate	*Not appropriate
Trophic State:	Mesotrophic	Mesotrophic	Mesotrophic	Mildly Eutrophic

Numbers represent the mean TSI for each parameter.
**Because the TSI for phosphorus and chlorophyll a are not within 5 points of each other, it is not appropriate to average them to determine an overall TSI mean*

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).

In all sites, the TSI for Secchi is relatively similar to the TSI for phosphorus. The TSI for chlorophyll *a* is higher than expected for all sites. This result could be due to the fact that the chlorophyll *a* data cover only one year. Because the TSI for phosphorus and chlorophyll *a* are not within 5 points of each other, it is not appropriate to average them to determine an overall TSI mean.

The main bay is classified as mesotrophic, while the southwest bay is mildly eutrophic. Collecting more data would better explain the pattern and the relationship between phosphorus, chlorophyll *a* and transparency in Cedar Lake.

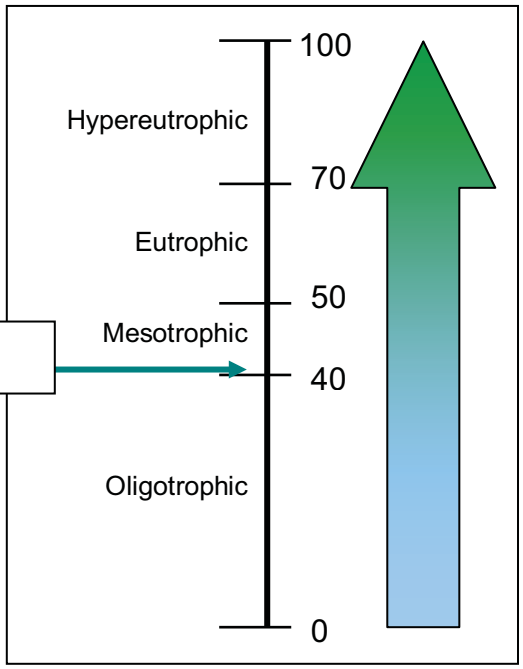


Figure 10. Trophic state index chart with corresponding trophic status.

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.

There is not enough historical data to perform trend analysis for total phosphorus or chlorophyll *a* on Cedar Lake. Sites 202, 206, 208 and southwest basin 201 had enough transparency data from to perform a long-term trend analysis. Bear in mind these data are disjointed, and there are gaps in the data in different years for different lake sites. The data was analyzed using the Mann Kendall Trend Analysis.

Basin	Lake Site	Parameter	Date Range	Trend	Probability
Main	202	Transparency	1995-2002, 2006	Declining	99.9%
Main	206	Transparency	1995-2000, 2005	Declining	99.9%
Main	208	Transparency	1995, 1997-1998, 2000-2007	Declining	99.9%
Southwest	201	Transparency	1995-2002, 2005	Declining	99.9%

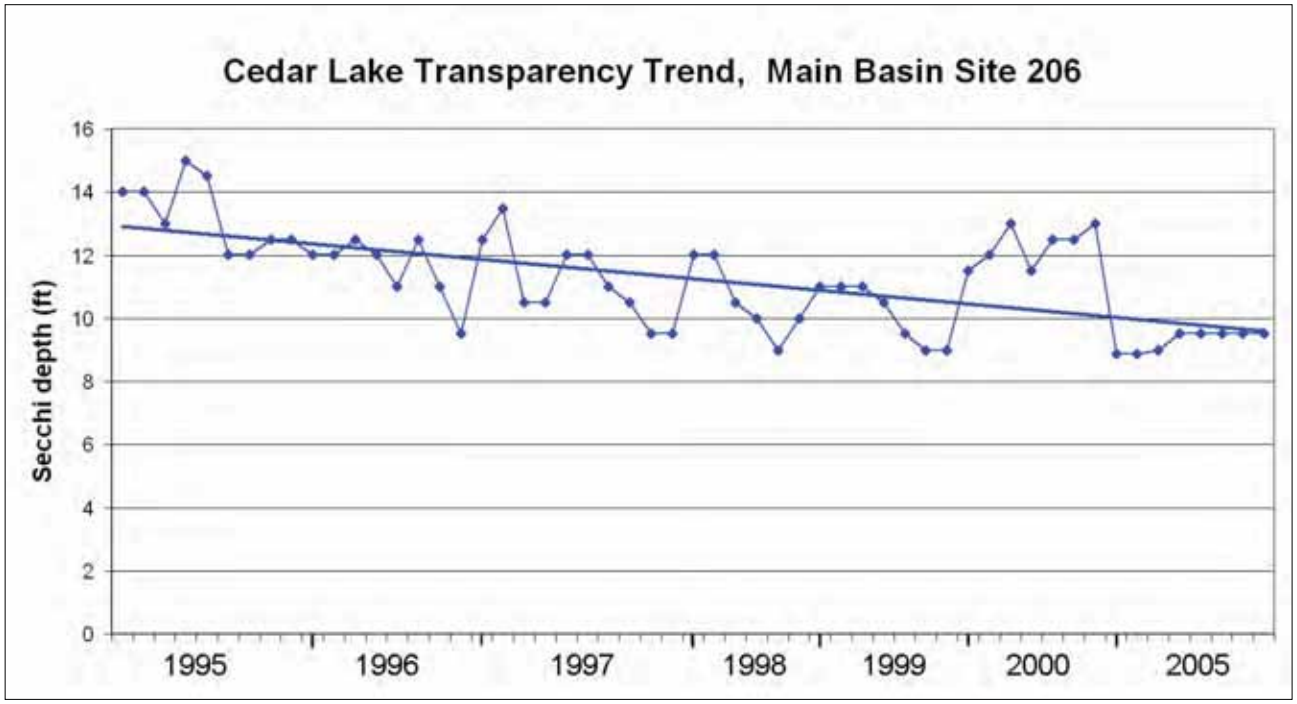


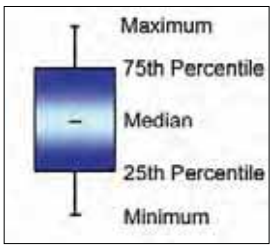
Figure 11. Transparency trends for site 206 from 1995-2000, 2005.

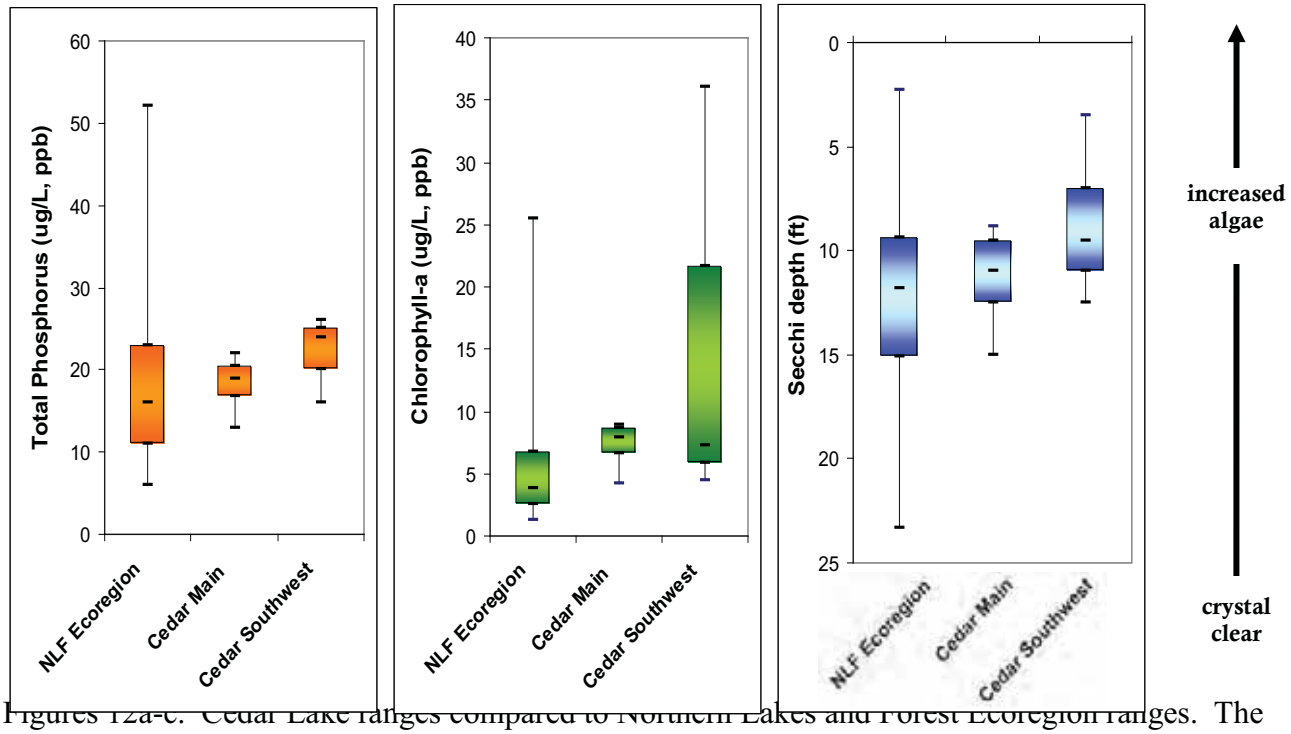
All four sites show a declining transparency trend from 1995-2007. The southwest bay has shown the greatest decline in average transparency from 12 ft in 1995 to 6 ft in 2005. In the main basin, site 206 declined from about 13 ft to about 10 ft, site 202 declined from about 11 ft to about 8 ft and site 208 from about 10 ft to about 8 ft. Transparency data should be collected again to determine if this trend continues or not.

Ecoregion Comparisons

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. 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.

Cedar Lake is in the Northern Lakes and Forests (NLF) Ecoregion. The mean total phosphorus, chlorophyll a and transparency (secchi depth) for the main basin of Cedar Lake are within the expected ecoregion ranges. The southwest basin is slightly higher than the ecoregion ranges. This result could be due to the difference in the watershed of that area. In addition, the southwest basin is much smaller than the main basin.





Figures 12a-c. Cedar Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Cedar Lake total phosphorus and chlorophyll *a* ranges are from 4 data points collected in 1981 and 2002. The Cedar Lake secchi depth range is from 132 data points collected in May-September from 1995-2005.

Inlet/Outlet Data Assessment

The MPCA conducted a Lake Assessment Program (LAP) project for Cedar Lake in 2002. As part of this project, the Lake Association monitored total phosphorus (TP) and flow in several tributaries to the lake. The following text is excerpted from the LAP report.

The aggregate TP from all tributary measurements was 55 ug/L, which is fairly close to the typical range for streams in the NLF ecoregion. Cedar outlet TP concentrations were rather similar to the in-lake TP concentrations, which they should be. Based on the 2002 sampling effort, it appears that the most emphasis should be placed on the watershed drained by Cedar inlet as it tended to have the highest flow and a high TP concentration. The Sandstrom tributary may merit additional consideration as well since TP was high on all three 2002 sample dates. There are only two streams that flow most of the year that enter Cedar Lake - Cedar Brook and Casey Brook. The others flow intermittently. For stream names and locations, see Figure 1 on page 2 of this report.

Assessment/Findings Recommendations

Transparency

Transparency data is extremely disjointed for Cedar Lake. Monitoring at sites 202, 206 and 208 in the main basin and site 201 in the southwest basin should be continued each year. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year to year comparisons and trend analyses.

Impaired Waters Assessment 303(d) List

There are two main types of Impaired Waters Assessment for lakes: eutrophication (phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption. Cedar Lake was listed as impaired for aquatic consumption on the 2006 Impaired Waters List; however it is part of the statewide mercury TMDL and therefore was not on the 2008 Impaired Waters List.

As of the date of this report, the Cedar Lake data set is insufficient for Impaired Waters Assessment for eutrophication. A data set of 10 data points each of total phosphorus, chlorophyll *a*, and secchi depth over a two-year period in the past 10 years is required for eutrophication assessment. In 2002, chemical monitoring was conducted on Cedar Lake. Scheduling one more year of chemical data collection before 2011 would complete this assessment data set (see standards on page 3).

Aquatic Recreational Use Assessment 305(b)

In the 2008 MPCA Aquatic Use Assessment (305(b)), Cedar Lake did not have enough data to be included this assessment.

Inlet/Outlet Assessment

Inlet/Outlet monitoring was completed in 2002, with limited monitoring in 2003 and 2006. This monitoring could be continued yearly to determine changes in watershed contributions to Cedar Lake.

Organizational contacts and reference sites

Cedar Lake Association	http://www.cedarlake.info/
Aitkin Soil and Water Conservation District	130 Southgate Drive, Aitkin, MN 56431 (218) 927-6565, http://www.aitkincountyswcd.org/
DNR Fisheries Office	1200 Minnesota Avenue South, Aitkin, MN 56431

	(218) 927-3751, http://www.dnr.state.mn.us/lakefind/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105, Baxter, MN 56425 (218) 828-2492, 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

Cedar Lake Lakeshed Assessment

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

Lakeshed Vitals		Rating
Major Basin	Upper Mississippi River	descriptive
Major Watershed	Mississippi River - Brainerd	descriptive
Minor Watershed	10033	descriptive
Lakeshed	Cedar Creek (1003301)	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Lake Area	1,745 acres	descriptive
Miles of Shoreline	26.8	descriptive
Miles of Stream	6.2	descriptive
Miles of Road	29.8	descriptive
Lake Max Depth	105 ft (31.8 m)	descriptive
Lake Mean Depth	28 ft (8.5 m)	+
Water Residence Time	2 - 3 years	+
Municipalities	None	+
Sewage Management	Individual waste treatment systems (septic systems and holding tanks – inspections only for new permit requests)	x
Public Drainage Ditches	CD-1; Open ditch-county	x
Lake Management Plan	None	x
Lake Vegetation Survey/Plan	None	x
Forestry Practices	None	+
Development Classification	Recreational Development	x
Shoreline Development Index	4.6	-
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	4.9:1	x
Public Lake Accesses	1	x
Inlets	7 – Cedar Brook, Casey Brook, 5 Unnamed	x
Outlets	1 – Cedar Creek	x

Lakeshed Vitals		Rating
Feedlots	2	-
Agriculture Zoning	1,514 acres > 200 ft. from lake	x
Public Land : Private Land	.03:1	-
Wetland Coverage	17%	+
Lake Transparency Trend	Declining trend (99.9% probability)	-
Exotic Species	None	+

Rating Key:
\+ *beneficial to the lake*
\- *possibly detrimental to the lake*
x *warrants attention*

Lakeshed

Understanding a lakeshed requires the understanding of basic hydrology. A watershed is the area of land that drains into a surface water body such as a stream, river, or lake and contributes to the recharge of groundwater. There are three categories of watersheds: 1) basins, 2) major watersheds, and 3) minor watersheds.

Cedar Lake is found within the Upper Mississippi River Basin, which includes the Mississippi River - Brain**erd Major Watershed** as one of its sixteen major watersheds (Figure 1). The basin covers 20,000 square miles, while the Mississippi River - Brainerd Watershed covers 1,687 square miles (approximately 1,079,950 acres). Cedar Lake falls within **minor watershed 10033**, one of the 126 minor watersheds that comprise the Mississippi River - Brainerd Major Watershed (Figure 2).

Within this watershed hierarchy, lakesheds also exist. A lakeshed is defined simply as the land area that drains to a lake. While some lakes may have only one or two minor watersheds draining into them, others may be connected to a large number of minor watersheds, reflecting a larger drainage area via stream or river networks. Cedar Lake falls within the **Cedar Creek (1003301) lakeshed**, covering 8,564 acres (includes lake area) (Figure 3). Even though Cedar Lake receives water from minor watersheds 10034 and 1035, for the purpose of this assessment it is decided that only the immediate lakeshed be inventoried and assessed.

Cedar Lake 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 Cedar Lake's lakeshed is made up of private forested uplands. This land can be the focus of development and protection efforts in the lakeshed.

	Private (75%)					23%	Public (2%)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	5.5%	6%	38%	10.5 %	15%	23%	0%	1.7%	0.3%
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
Description	Focused on Shoreland	Cropland	Focus of development and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Potential Phase 3 Discussion Items	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

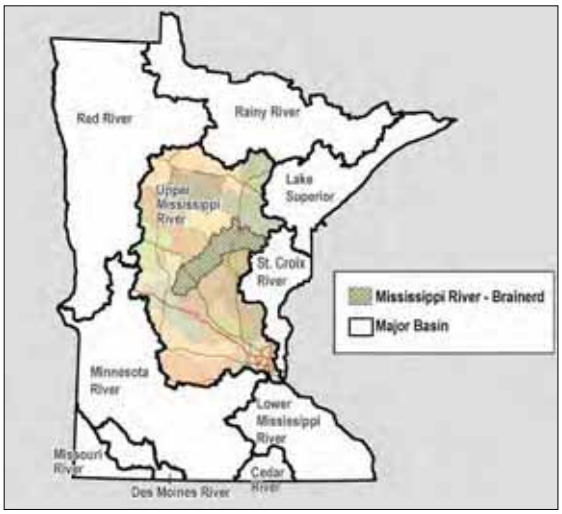


Figure 1. Upper Mississippi Basin and the Mississippi River - Brainerd Watershed.

Figure 2. Minor Watersheds 10033, 10034, & 10035 contribute water to Cedar Lake.

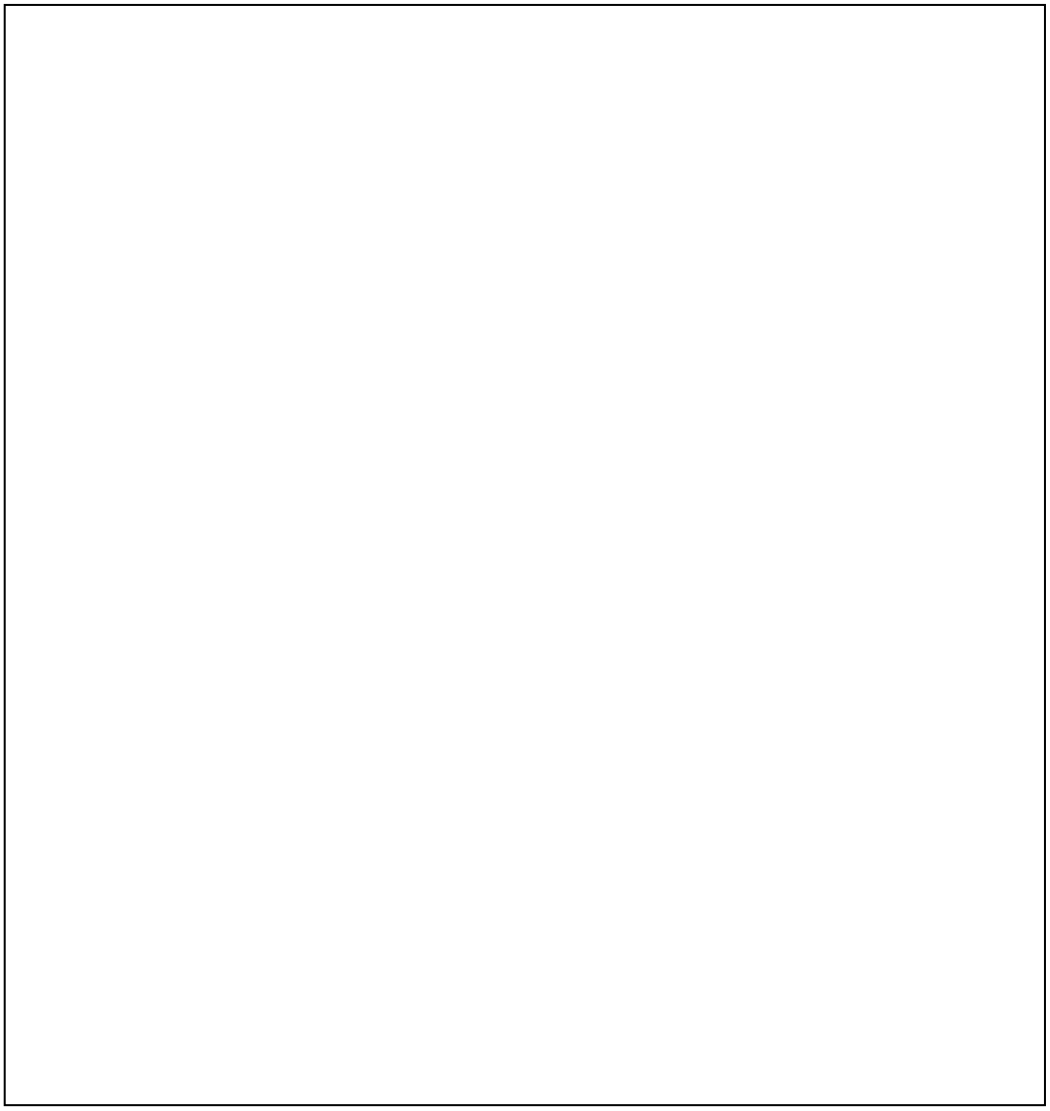


Figure 3. The Cedar Creek (1003301) Lakeshed (Aerial Imagery 2008 1M).**Land Cover / Land Use**

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.

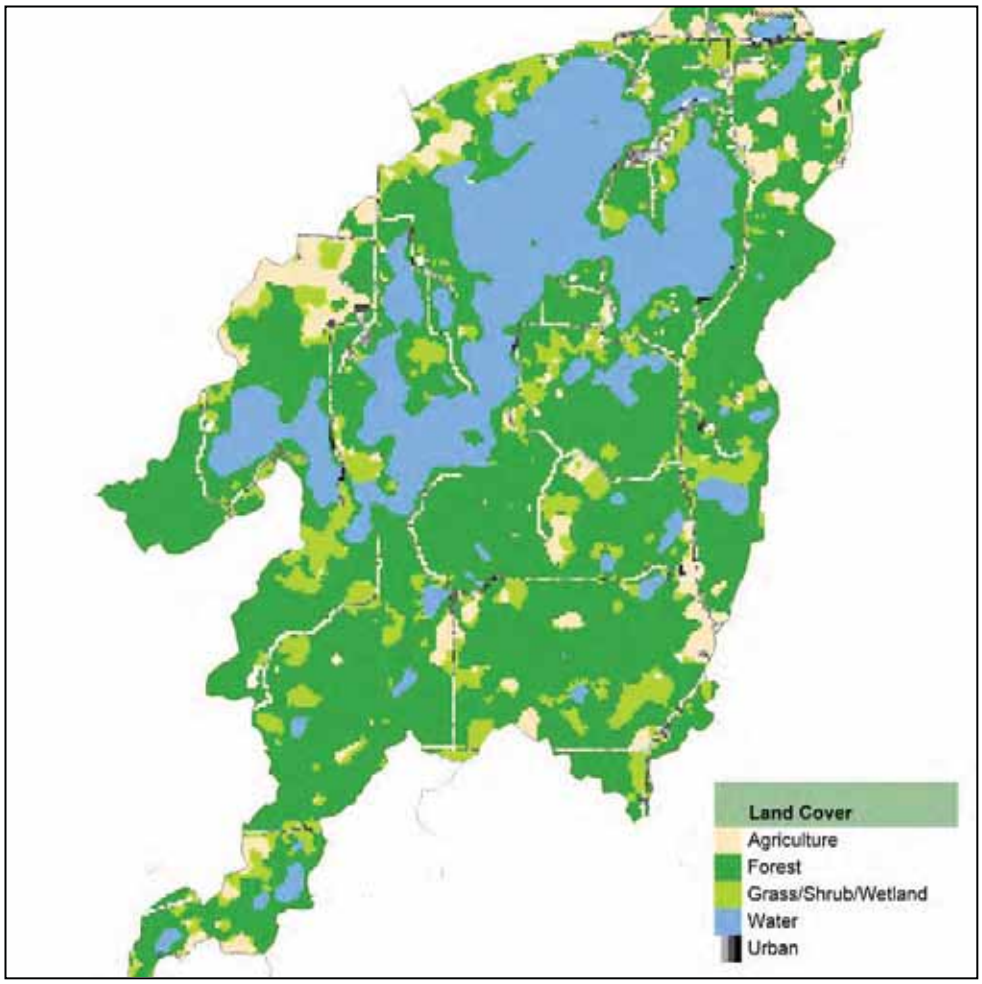


Figure 5. The Cedar Creek (1003301) lakeshed land cover (http://land.umn.edu).

Changes in land use, and ultimately land cover, impact the hydrology of a lakeshed. Land cover is also directly related to the lands 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 decribes the lands 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.

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 5 depicts Cedar Lake's lakeshed land cover.

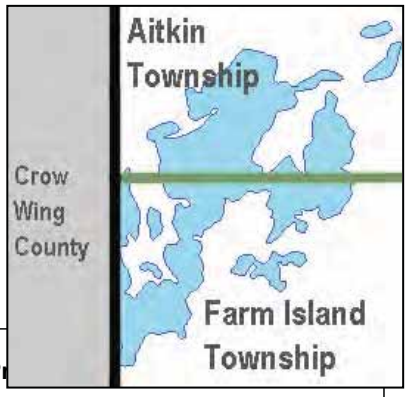
The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Table 1 describes Cedar Lake's lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture and grass/shrub/wetland acreages to forest and urban acreages. The largest change in percentage is the decrease in agriculture (42.1%); however, in acreage, forest cover has increased the most (1,117 acres). In addition, the impervious intensity has increased, which has implications for storm water runoff into the lake. The increase in impervious intensity is consistent with the increase in urban acreage.

Table 1. Cedar Lake's lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

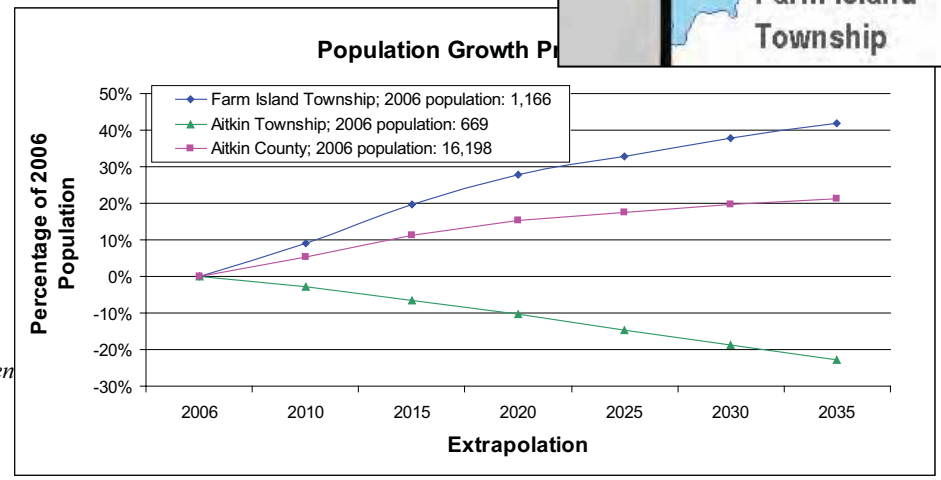
	1990		2000		% Change
Land Cover	**Acres**	**Percent**	**Acres**	**Percent**	**1990 to 2000**
Agriculture	901	10.52	522	6.1	42.1 % Decrease
Forest	3,759	43.89	4,876	56.94	29.7 % Increase
Grass/Shrub/Wetland	1,297	15.14	874	10.21	32.6% Decrease
Water	2,199	25.68	1,817	21.22	17.4 % Decrease
Urban	408	4.76	476	5.56	16.7 % Increase
Impervious Intensity %					
0	8,304	96.96	8,227	96.06	0.9 % Decrease
1-10	96	1.12	116	1.35	20.8 % Increase
11-25	110	1.28	125	1.46	13.6 % Increase
26-40	27	0.32	60	0.7	122.2 % Increase
41-60	14	0.16	23	0.27	64.3 % Increase
61-80	9	0.11	8	0.09	11.1 % Decrease
81-100	5	0.06	4	0.05	20.0 % Decrease
Total Area	8,564		8,564		
Total Impervious Area (Percent Impervious Area Excludes Water Area)	50	0.79	66	0.98	32 % Increase

Demographics

Cedar 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.



Aitkin County records indicate that the population in Farm Island Township increased 50-100% from 1990-2000, while the population of Aitkin Township decreased 0-50% from 1990-2000. The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. These projections are shown in Figure 6



below. Compared to Aitkin County as a whole, Farm Island Township has a higher extrapolated growth over the next 30 years, whereas Aitkin Township has a negative extrapolated growth.

Figure 6. Population growth projection for the townships around Cedar Lake and Aitkin County (source: http://www.demography.state.mn.us/resource.html?Id=19332)

Status of the Fishery (DNR, as of 08/13/2007)

Cedar Lake is a large, complex lake located in western Aitkin County approximately 3 miles west of Aitkin. There is a state owned Public access with a concrete ramp that is located on the South side of the lake off of County Road 28. Cedar Lake is comprised of seven basins that vary in size from several hundred acres to less than forty acres. Water clarity varies from dark bog stained with a low secchi disk reading to light green with a 14 foot secchi disk reading. Much of the 26 miles of shoreline has a sharp drop-off with the maximum depth of the basins varying from 28 feet to 106 feet. With the exception of the main basin, none of the basins have oxygen below the thermocline.

Walleye fishing is very popular on Cedar Lake with both the local residents and seasonal cabin owners. Cedar Lake's walleye population has a healthy size distribution, including some real trophies, as documented by a 30.5-inch walleye caught in this survey. The sharp drop-offs and the many shallow reefs and gravel bars provide the walleye angler a host of areas to fish for Minnesota's state fish. Catch per unit effort for walleye was 3.4 fish per net, which was the highest we've observed and the mean size was 19.1 inches. The 2001 and 2004 year classes are the most abundant in the system right now. Walleye fingerlings are stocked in Cedar Lake on an annual basis.

Muskellunge have created a popular fishery since being introduced in 1994. They have been stocked annually except for 2005. A spring survey of the muskellunge population was conducted in 2007 with trap nets and with electrofishing. A total of 24 muskellunge were sampled in this assessment with fish ranging from 22 inches to nearly 51 inches. The mean length was 40 inches. For comparison, in 2004, we caught 18 fish in trap nets ranging in size from 22.8 to 48 inches with a mean length of 39.7 inches. In addition, seven muskellunge were sampled in one night of electrofishing, suggesting that this technique may be more effective at sampling spawning muskellunge in Cedar Lake.

Traditionally, northern pike angling has been good on Cedar Lake and numbers have increased since 2002 to 5.8 pike per gill net lift with a mean size of about 20 inches. The size structure of the pike population seems to be improving or at least maintaining itself with 2-pounds being average. For many years, Cedar Lake, like many lakes throughout central Minnesota, had an over abundant northern pike population that was dominated by small "hammer handle" northern pike. The size structure has improved in this survey, with the CUE for pike over 24 inches at 1.3 fish per net. This is the highest we have seen since the 1987 survey when there were 1.65 fish per net over 24 inches.

Black crappie numbers reached an all time high in this survey with a gill net catch of 7.3 per net, which is the highest ever recorded by DNR surveys going back to 1959. Although trap net catches for crappie were below average in this survey, they do not appear to adequately sample crappie in Cedar Lake. Strong year classes in 2001 and 2002 are producing fish in the 8-10 inch range. The 2005 year class is also strong with numerous fish 5-6 inches long. Individuals up to 11.6 inches were sampled and the mean length was 7.4 inches. Bluegill sunfish growth is slow for the first 5 years, but appears to recover to normal levels after that. The stronger year classes of 2001 and 2002 should provide a good fishery for 7 inch fish in the next few years.

The largemouth bass population in Cedar Lake appears to be increasing. The gill net catch rates are the highest we have seen. This is good news for anglers, as largemouth bass was the most sought after fish in Cedar Lake as documented by a creel survey in 1994.

Yellow perch are still below the average catch rates for this lake type, but we are seeing an upward trend in the population. In the last two surveys (2002 and 2007) catch rates have been the highest we have seen since the 1959 survey. Hopefully we continue to see this trend in the 2012 survey. Tullibee are also present in Cedar Lake and have provided good forage for existing game fish. However, just as in many lakes statewide, tullibee numbers in Cedar Lake appear to be declining. 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=01020900.

Farm Island Lake 01-0159-00 AITKIN COUNTY

Summary

Farm Island is located 7 miles south of Aitkin, MN. With a surface area of 2,054 acres, it is in the upper 2% of lakes in Minnesota in terms of its size.

Farm Island Lake has two inlets and one outlet, which classifies it as a drainage lake. It sits at the top of its minor watershed, and flows into Little Pine, Hickory and Spirit Lakes through the Ripple River.

Water quality data has been collected on Farm Island Lake in 1980, 1985-1990, 1996-2006. These data show that Farm Island Lake is mesotrophic (page 8). Mesotrophic lakes are commonly found in central Minnesota and have clear water with occasional algal blooms in late summer.

The Farm Island Lake Improvement Association (FILIA) has a mission to promote the safety and common good of its members and the surrounding Farm Island Lake community, and to improve and preserve the quality of the land and water in the Farm Island Lake area for its members, the community and future generations. FILIA has been active in many projects in water quality monitoring, with the most recent project being Curly-leaf pondweed management. After researching the problem of Curly-leaf pondweed for several years, FILIA decided to actively pursue a plan to chemically treat the largest concentrations of the Curly-leaf pondweed in April 2008. Approximately 13 acres were treated on 5/19/08.

Vitals	
MN Lake ID:	01-0159-00
County:	Aitkin
Ecoregion:	Northern Lakes and Forests
Major Drainage Basin:	Upper Mississippi River
Latitude/Longitude:	46.41666667 / -93.77111111
Water Body Type:	Public Waters
Monitored Sites (Primary):	205

Physical Characteristics		
Surface area (acres):	2,054	
Littoral area (acres):	883	
% Littoral area:	43%	
Max depth (ft):	56	(m): 17.1
Mean depth (ft):	18	(m): 4
Watershed size (acres):	24,717	
Watershed:lake area ratio	12:1	
Inlets	2	
Outlets	1	

Monitored Sites (Secondary):	201, 202, 203, 204, 206, 207	Accesses	1 public, 1 private
Invasive species present:	Curly-leaf pondweed; approximately 13 acres were chemically treated in 2008.		

Data Availability

Transparency data		Numerous yearly secchi readings from sites 204 and 205 in 1980, 1985-1990, 1996-2006 through the MPCA CLMP program.
Chemical data		Total Phosphorus and Chlorophyll *a* data exist from 1998, 1999, 2004 and 2005
Inlet/Outlet data		No inlet or outlet data exist for Farm Island Lake.
Recommendations		For recommendations refer to page 12.

Figure 1. Map of Farm Island 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: 1986, 1988-1990
202	15	CLMP: 1980, 1986
203	30	CLMP: 1985-1990
204	20	CLMP: 1980, 1985-1990, 1996-2007
205 (102) *Primary Site	30	CLMP+: 2004; CLMP: 1980, 1985-1990, 1996-2007
206 (101)	50	Aitkin SWCD: 1998-1999, 2005; CLMP+: 2004

The information below describes available chemical data for Farm Island Lake through 2007. The data set is limited, and all parameters with the exception of total phosphorus, chlorophyll *a* and secchi depth, are means for just 2004 data.

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 10.

Parameter	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	20.5	14 - 27	> 35	Results are within the expected range for the ecoregion. For more information about Impaired Waters Assessment, see page 12.
[3]Chlorophyll *a* (ug/L)	4.0	4 - 10	> 12	
Chlorophyll *a* max (ug/L)	11	<15		
Secchi depth (ft)	11.7	7.5 - 15	< 4.5	
Dissolved oxygen	see page 8			Dissolved oxygen depth profiles show that some of the deeper areas of the lake are anoxic in late summer
Total Kieldahl Nitrogen (mg/L)	0.4	0.4 - 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms
Alkalinity (mg/L)	83	40 - 140		Indicates a low sensitivity to acid rain and a good buffering capacity
Color (Pt-Co Units)	8	10 - 35		Indicates clear water with little to no tannins (brown stain)
pH	8	7.2 - 8.3		A pH of 8 is common in a hardwater lake. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water
Chloride (mg/L)	3.4	0.6 - 1.2		Chloride levels are slightly higher than the ecoregion range, but still considered low level.
Total Suspended Solids (mg/L)	1.5	<1 - 2		Indicates low suspended solids and clear water
Total Suspended Volatile Solids (mg/L)	1.3	<1 - 2		Indicates low suspended inorganic solids and clear water
Conductivity (umhos/cm)	221	50 - 250		Within the expected range for the ecoregion

Total Nitrogen :Total Phosphorus	22:1	25:1 – 35:1	Indicates the lake is phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake.

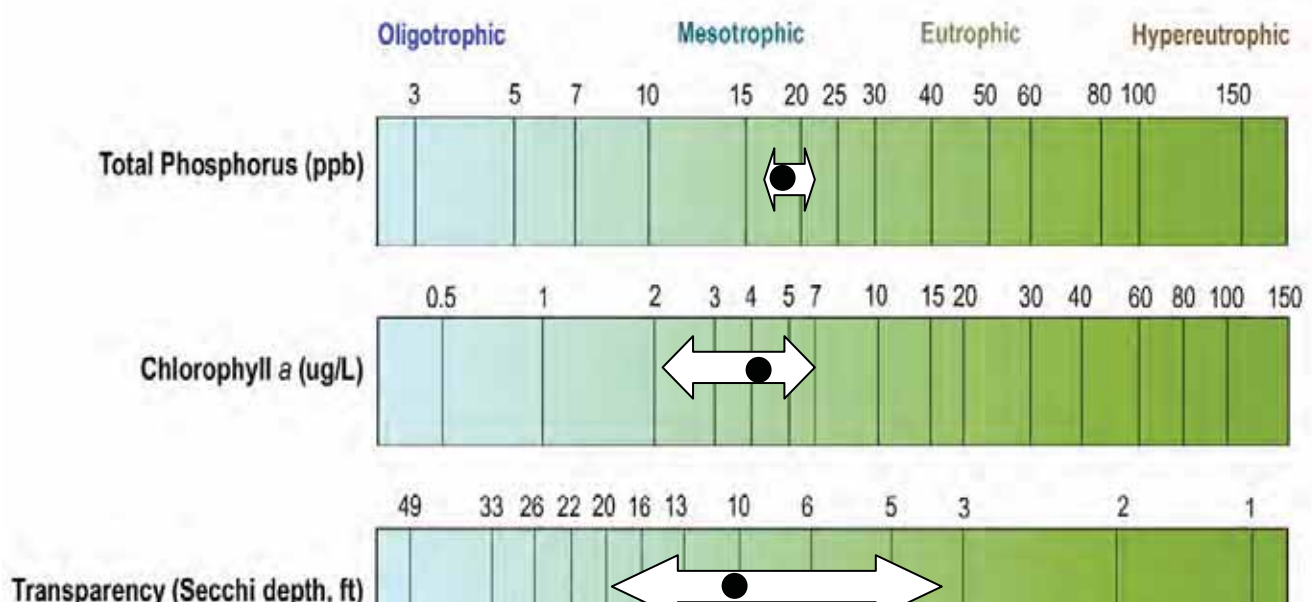
Data Source: 2004 Minnesota Pollution Control Agency CLMP+ Assessment

[1]The ecoregion range is the 25th-75th 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

Years monitored: 1980, 1985-1990, 1996-2006

Parameters	Site 205	Site 201	Site 202	Site 203	Site 204	Site 206	Site 207
Total Phosphorus Mean (ug/L)**:**	**18.8**		**20.5**			**20.5**	
Total Phosphorus Min:	16		18			<5	
Total Phosphorus Max:	22		22			57	
Number of Observations:	9		4			24	
Chlorophyll *a* Mean (ug/L)**:**	**4.8**					**4.0**	
Chlorophyll-a Min:	2.6					1.0	
Chlorophyll-a Max:	7					11.0	
Number of Observations:	9					24	
Secchi Depth Mean (ft)**:**	**11.7**	**10.4**	**8.9**	**11.2**	**12.3**	**11.6**	**10.7**
Secchi Depth Min:	4	7	6.5	6	3.5	9	7.5
Secchi Depth Max:	20	15	11	21.5	25	14	14
Number of Observations:	103	18	4	67	154	10	21



Transparency (Secchi Depth)

Transparency is how easily light can pass through a substance. In lakes, it refers to 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.

For all the sites that had more than 10 transparency data points, the mean transparency ranges from 10.4 to 12.3 feet. The transparency throughout the lake appears to be relatively uniform.

In 2007, the transparency was much less than average for the season (Figure 3). A records check showed that the same volunteer collected transparency data in both 2006 and 2007, so the decline in 2007 wasn't due to different samplers. Transparency in future years should be compared to 2007 to determine if it was an atypical year.

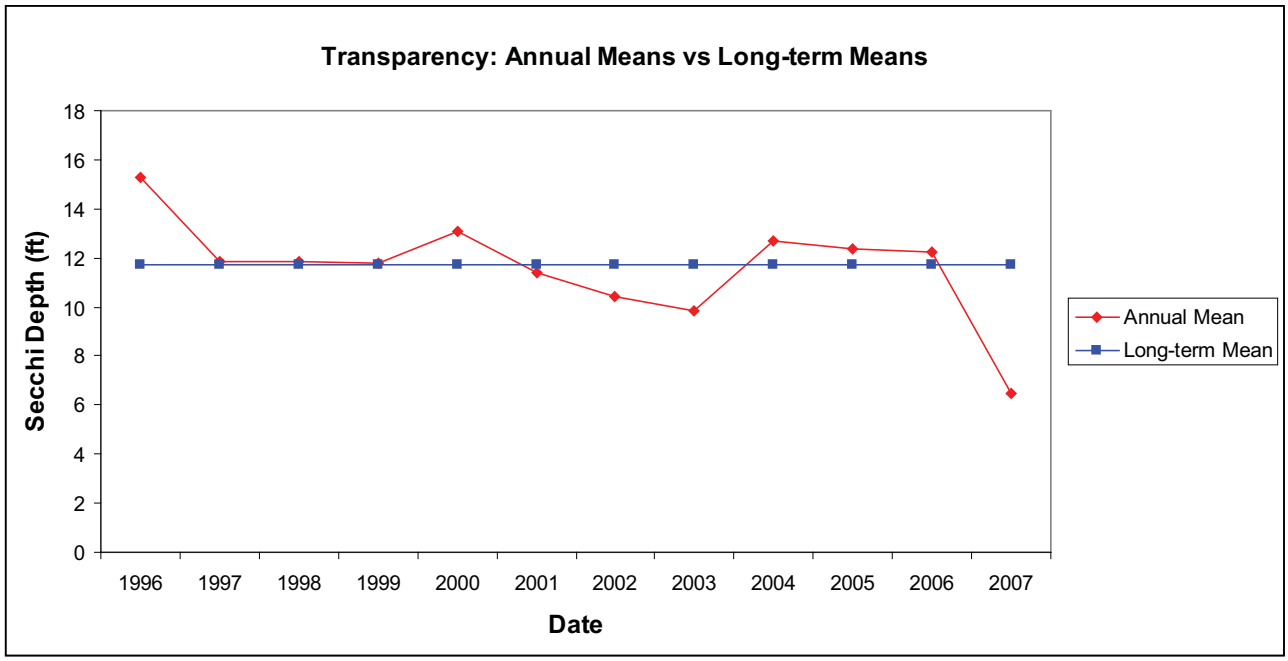


Figure 3. Annual mean transparency compared to long-term mean transparency (Primary Site 205).

Farm Island Lake transparency ranges from 4 to 20 ft at the primary site (205). Figure 4 shows the seasonal transparency dynamics. Generally, Farm Island Lake transparency is highest in May and June and then declines through August and September. This is the pattern that describes Farm Island Lake, which is different than a typical lake in northern Minnesota. This difference is most likely due to the shallow nature of the lake and the fact that it is too shallow to recover to spring transparency levels in the fall.

Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 205). Lines connect the data points for the past 5 years (2003-2007). The shaded yellow line represents the average from 1996-2007.

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. Farm Island Lake was rated as being "not quite crystal clear" 73% of the time between 1996-2007.

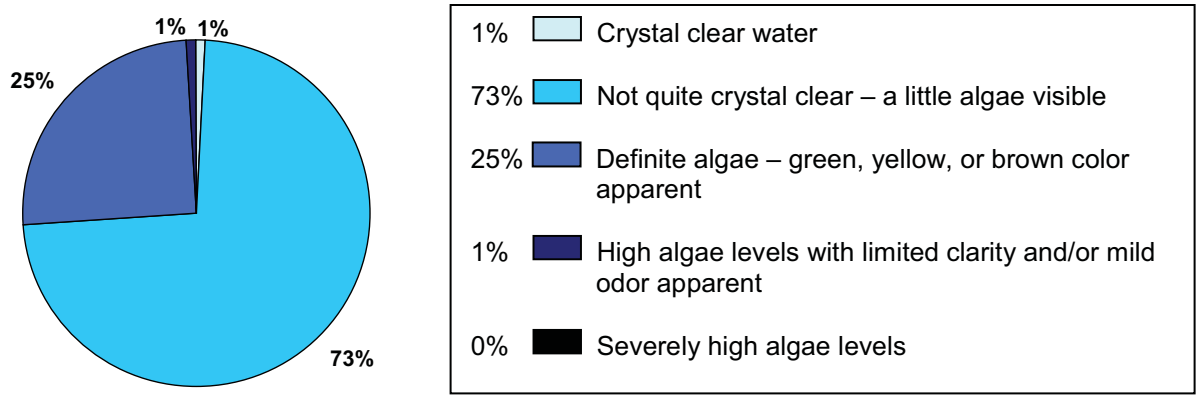


Figure 5. Physical appearance rating, as rated by the volunteer monitor (1996-2007).

As the secchi depth decreases, the perception of recreational suitability of the lake decreases. Farm Island Lake was rated as having "very minor aesthetic problems" 73% of the time from 1996-2007.

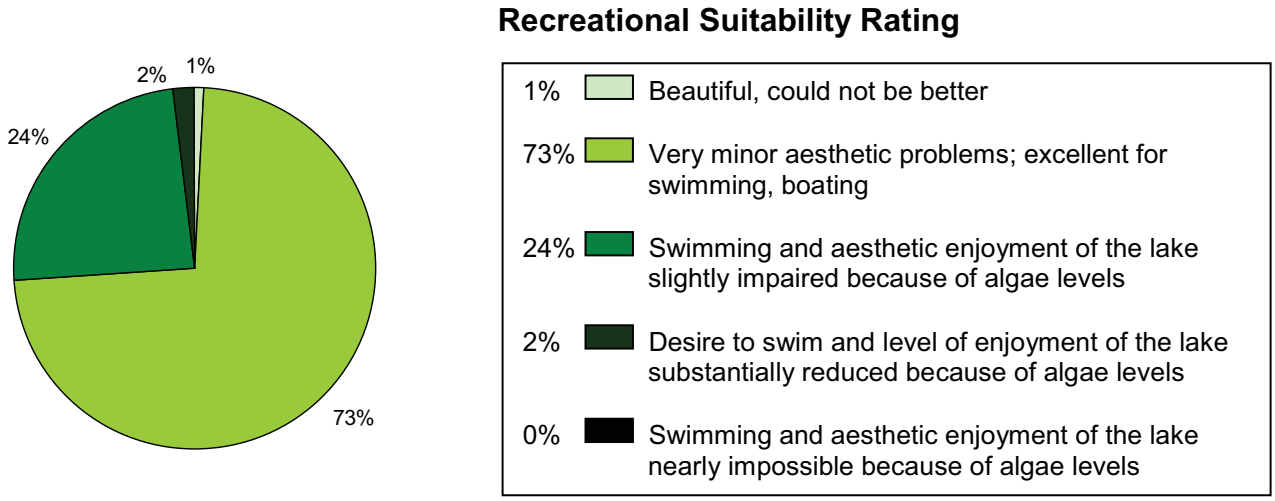


Figure 6. Recreational suitability rating, as rated by the volunteer monitor (1996-2007).

Total Phosphorus

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

Total phosphorus was evaluated in Farm Island Lake in 1980, 1998, 1999, 2004 and 2005. In all years except for 1999 there is not much seasonal variability. Values ranged from 15-28 ug/L. All three lake sites have similar phosphorus levels.

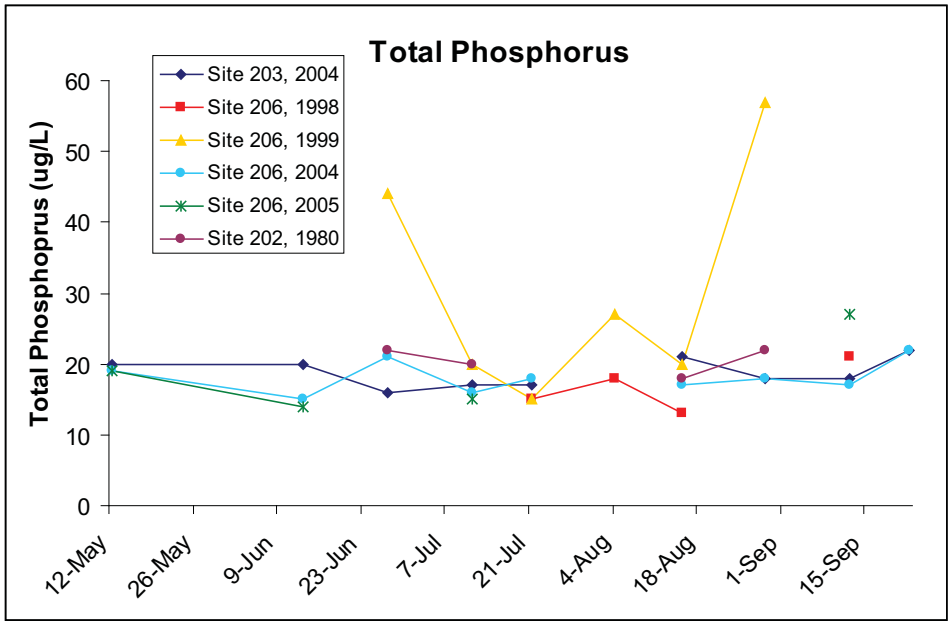


Figure 7. Historical total phosphorus concentrations (ug/L) for Farm Island Lake (1980, 2004 data sets).

There were two spikes in phosphorus concentration in 1999. Historical climate data show that there were no above average rainfalls in the weeks prior to sampling. Phosphorus should be tested more often to get a better understanding of Farm Island Lake.

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.

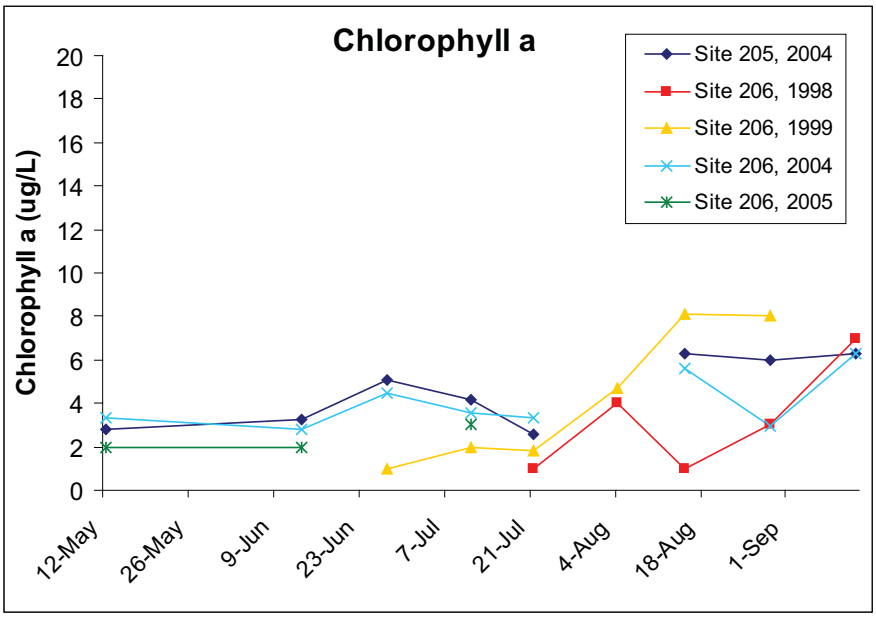
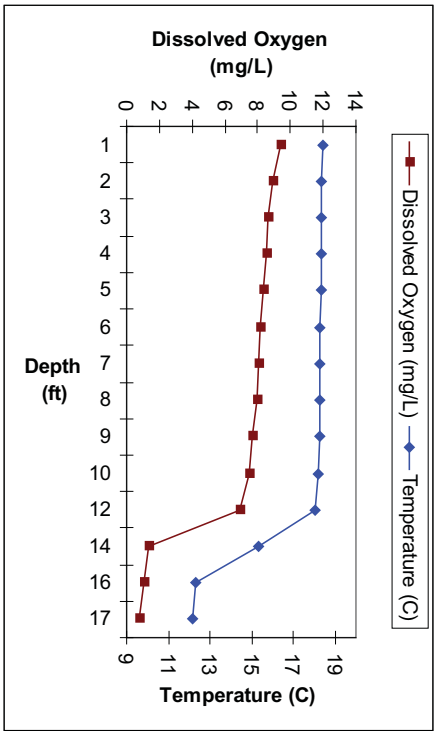


Figure 8. Historical chlorophyll *a* concentrations (ug/L) for Farm Island Lake.

Chlorophyll *a* was evaluated in Farm Island Lake in 1998, 1999, 2004 and 2005. This pattern seen in Figure 8 follows typical algae cycles. In May, the water is cold and algae abundance is low. In June the water warms up and nutrients are available so the algae multiply. In late June zooplankton (tiny crustaceans that feed on algae) populations are high, temporarily decreasing the chlorophyll *a*. In late summer the zooplankton populations are reduced by small fish predation, the weather is warm and the sun is strong, causing algae populations to increase again. Chlorophyll *a* should be tested more often to get a better understanding of Farm Island Lake.

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

Farm Island Lake is a relatively shallow lake, with a mean depth of 18 feet. Due to its large size and shallow nature, the majority of the lake is most likely polymictic (mixes often throughout the summer).

Site 206 on the south end of the lake is a 50 ft deep hole. Dissolved oxygen profiles from 2004 indicate that this area does stratify in late summer. Benthic phosphorus samples indicate internal loading when this site is stratified. Figure 9 illustrates stratification on September 22, 2004. Benthic phosphorus concentration on that same day at that same site was 386 ug/L.

Figure 9. Dissolved oxygen and temperature profile for Farm Island Lake on September 22, 2004.

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 204	Site 205	Site 206
TSI Total Phosphorus	NA	46	45
TSI Chlorophyll-a	NA	45	44
TSI Secchi	41	42	42
TSI Mean	NA	44	44
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 at both main sites of Farm Island Lake are essentially the same (44). The TSI for total phosphorus and chlorophyll a are slightly higher than for transparency. This result could be due to the fact that there is only one year (2004) of total phosphorus and chlorophyll a data available for Farm Island Lake.

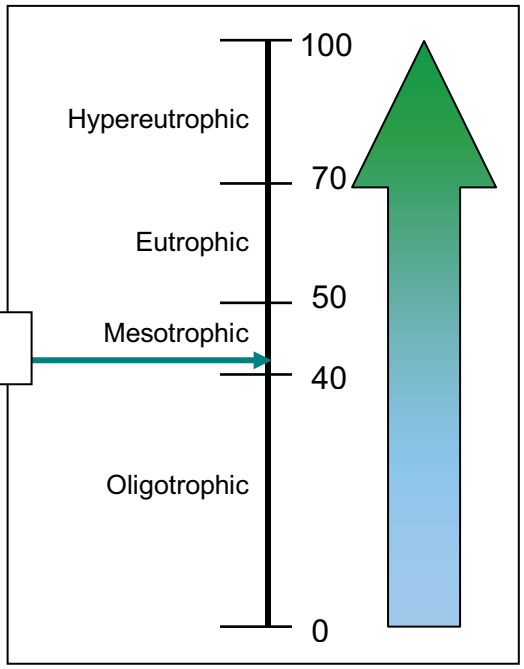


Figure 10. Trophic state index chart with corresponding trophic status.

Mesotrophic lakes (TSI 40-50) are characteristic of 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.

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. The minimum confidence accepted by the MPCA is 90%. This means that there is a 90% chance that the data set is 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.

There is not enough historical data to perform trend analysis for total phosphorus or chlorophyll *a* on Farm Island Lake. Sites 204 and 205 had transparency data from 1996-2007, which was enough data to perform both a long-term trend analysis and a short-term trend analysis. The data was analyzed using the Mann Kendall Trend Analysis.

Lake Site	Parameter	Date Range	Trend	Probability
205	Transparency	1996-2007	Declining	99.9%
205	Transparency	2000-2007	Declining	99%
204	Transparency	1996-2007	Declining	95%
204	Transparency	2000-2007	Declining	95%

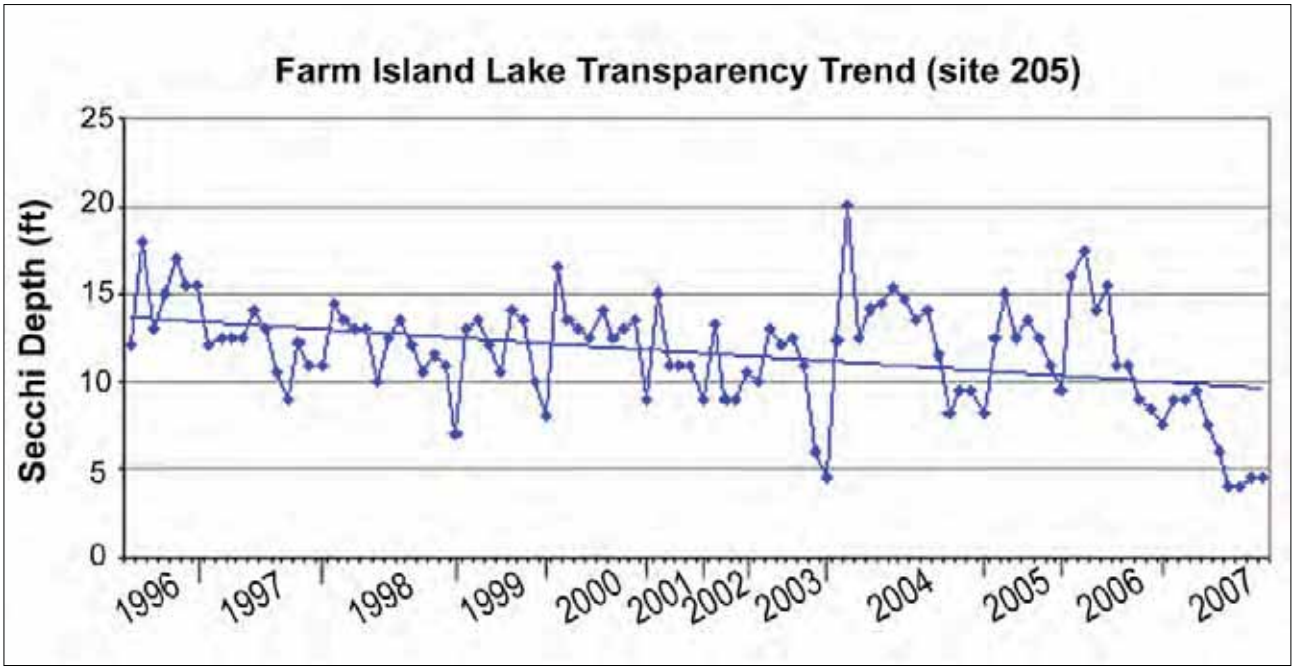


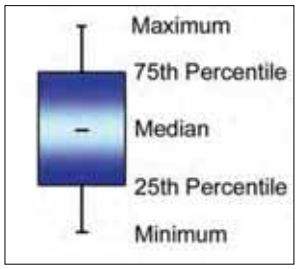
Figure 11. Transparency trend for site 205 from 1996-2007.

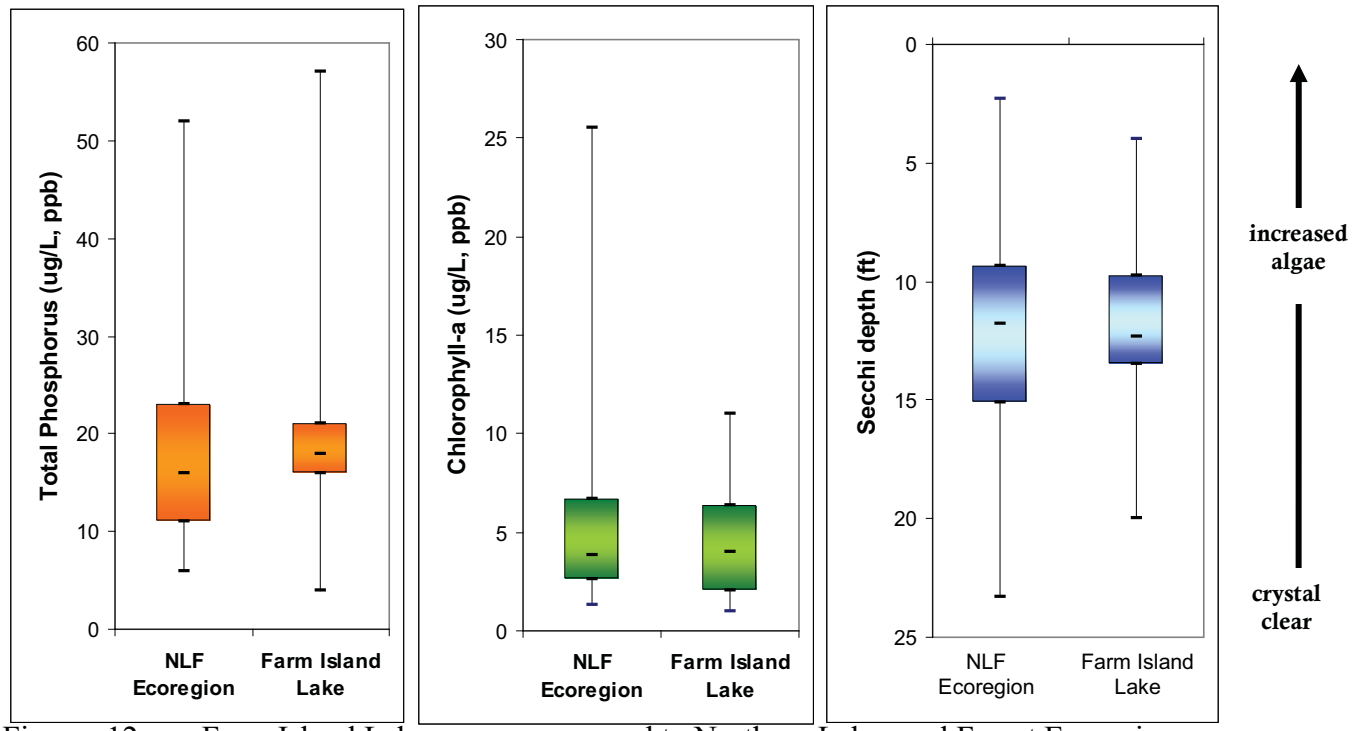
Both sites 204 and 205 show a significant declining trend in transparency from 1996-2007 and from 2000-2007. From 1996-2007 the transparency has declined an average of 4 feet at site 205 and one foot at site 204.

Ecoregion Comparisons

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. 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.

Farm Island Lake is in the Northern Lakes and Forests Ecoregion. The mean total phosphorus, chlorophyll a and transparency (secchi depth) for Farm Island Lake are all within the expected ecoregion ranges.





Figures 12a-c. Farm Island Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Farm Island Lake total phosphorus and chlorophyll *a* ranges are from 26 data points collected in

Inlet/Outlet Data Assessment

May-September of 2005. The Farm Island Lake secchi depth range is from 102 data points collected in May-September from 1996-2007.

As of 2007, no historical monitoring has been completed on either inlet or outlet of Farm Island Lake.

Assessment/Findings Recommendations

Transparency

Transparency monitoring at sites 204, 205 and 206 should be continued each year. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year to year comparisons and trend analyses.

Impaired Waters Assessment 303(d) List

There are two main types of Impaired Waters Assessment for lakes: eutrophication (phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption. Farm Island Lake is impaired for mercury in fish tissue, and is included in the statewide mercury total maximum daily load (TMDL) program.

As of the date of this report, the Farm Island Lake data set is insufficient for Impaired Waters Assessment for excess nutrients. A data set of 10 data points each of total phosphorus, chlorophyll *a*, and secchi depth over a two-year period in the past 10 years is required for eutrophication assessment. In 2004, chemical monitoring was conducted on Farm Island Lake. Scheduling one more year of chemical data collection before 2013 would complete this assessment data set. The current limited data set suggests that Farm Island Lake would not be considered impaired for eutrophication (see standards on page 3).

Aquatic Recreational Use Assessment 305(b)

In the 2008 MPCA Aquatic Use Assessment (305(b)), Farm Island Lake was classified as fully supporting for recreational usage.

Inlet/Outlet Assessment

Because of the lack of inlet/outlet data, a mass balance project should be considered. This study answers questions about nutrient loading into the lake and nutrient budget within the lake.

Organizational contacts and reference sites

Farm Island Lake Improvement Association	http://www.minnesotawaters.org/index.php?uberKey=1273
Aitkin Soil and Water Conservation District	130 Southgate Drive, Aitkin, MN 56431 (218) 927-6565 http://www.aitkincountyswcd.org/
DNR Fisheries Office	1200 Minnesota Avenue South, Aitkin, MN 56431 (218) 927-3751 http://www.dnr.state.mn.us/lakefind/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105, Baxter, MN 56425 (218) 828-2492 http://www.pca.state.mn.us

Farm Island Lake Lakeshed Assessment

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

Lakeshed Vitals		Rating
Major Basin	Upper Mississippi River	descriptive
Major Watershed	Mississippi River - Brainerd	descriptive
Minor Watershed	10036	descriptive
Lakeshed	Spirit Lake - Ripple River (1003603)	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Lake Area	2,054 acres	descriptive
Miles of Shoreline	14.72	descriptive
Miles of Stream	2.21	descriptive
Miles of Road	26.3	descriptive
Lake Max Depth	56 ft. (17.1 m)	descriptive
Lake Mean Depth	18 ft. (4 m)	-
Water Residence Time	5 years	-
Municipalities	None	+
Sewage/Storm Water Management	Individual waste treatment systems (septic systems and holding tanks – inspections only for new permit requests)	x
Public Drainage Ditches	None	+
Lake Management Plan	None	x
Lake Vegetation Survey/Plan	None	x
Forestry Practices	None	+
Development Classification	Recreational Development	x
Shoreline Development Index	2.3	-
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	3.8:1	x
Public Lake Accesses	2	x
Inlets	2 – Ripple River, Unnamed	x
Outlets	1 – Ripple River	x
Feedlots	None	+
Agriculture Zoning	2,405 acres > 200 ft. from lake	x
Public Land : Private Land	0.01:1	-

Lakeshed Vitals		Rating
Wetland Coverage	21%	+
Lake Transparency Trend	Declining trend (99.9% probability)	-
Exotic Species	None	+

Rating Key:
+ *beneficial to the lake*
- *possibly detrimental to the lake*
x *warrants attention*

Lakeshed

Understanding a lakeshed requires the understanding of basic hydrology. A watershed is the area of land that drains into a surface water body such as a stream, river, or lake and contributes to the recharge of groundwater. There are three categories of watersheds: 1) basins, 2) major watersheds, and 3) minor watersheds.

Farm Island Lake is found within the Upper Mississippi River Basin, which includes the Mississippi River - Brainerd Major Watershed as one of its sixteen major watersheds (Figure 1). The basin covers 20,000 square miles, while the Mississippi River - Brainerd Watershed covers 1,687 square miles (approximately 1,079,950 acres). Farm Island Lake falls within minor watershed 10036, one of the 126 minor watersheds that comprise the Mississippi River - Brainerd Major Watershed (Figure 2).

Within this watershed hierarchy, lakesheds also exist. A lakeshed is defined simply as the land area that drains to a lake. While some lakes may have only one or two minor watersheds draining into them, others may be connected to a large number of minor watersheds, reflecting a larger drainage area via stream or river networks. Farm Island Lake falls within the **Spirit Lake - Ripple River (1003603) lakeshed**, covering 7,706 acres (includes lake area) (Figure 3). Even though Farm Island Lake receives water from minor watershed 10035 via the Ripple River inlet, for the purpose of this assessment it is decided that only the immediate lakeshed be inventoried and assessed.

Farm Island Lake 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 Farm Island Lake's lakeshed is made up of private forested uplands. This land can be the focus of development and protection efforts in the lakeshed.

Private (69%)					30%	Public (1%)		
Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal

Land Use (%)	6%	7%	29%	8%	19%	30%	1%		
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
Description	Focused on Shoreland	Cropland	Focus of development and protection efforts	Open, pasture, grassland, shrubland	Protected				
Potential Phase 3 Discussion Items	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

Figure 1. Upper Mississippi Basin and the Mississippi River – Brainerd Watershed.

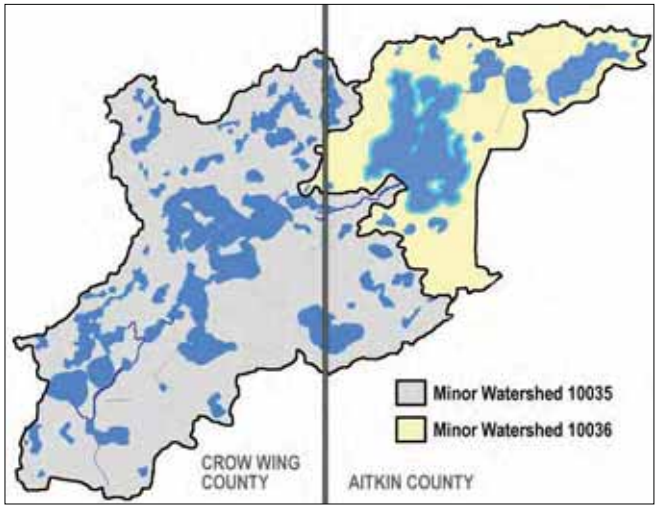


Figure 2. Minor Watersheds 10035 & 10036 contribute water to Farm Island Lake.

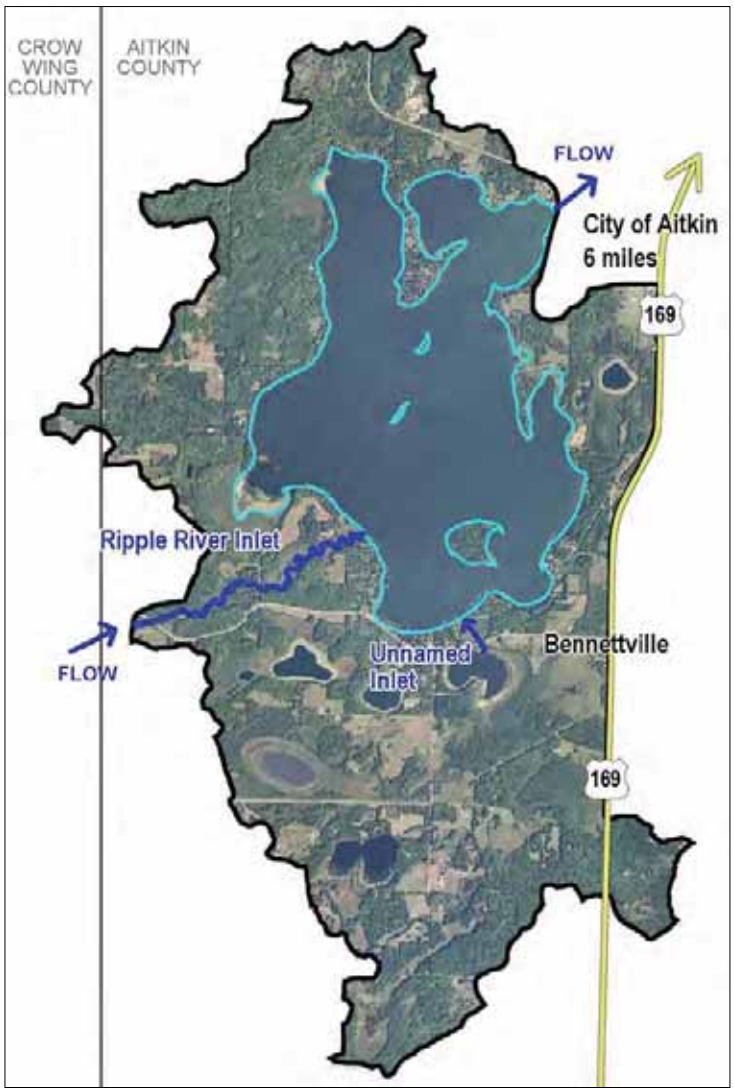


Figure 3. The Spirit Lake - Ripple River (1003603) Lakeshed (Aerial Imagery 2008 1M).

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 lands 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 decribes the lands 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.

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 5 depicts Farm Island Lake's lakeshed land cover.

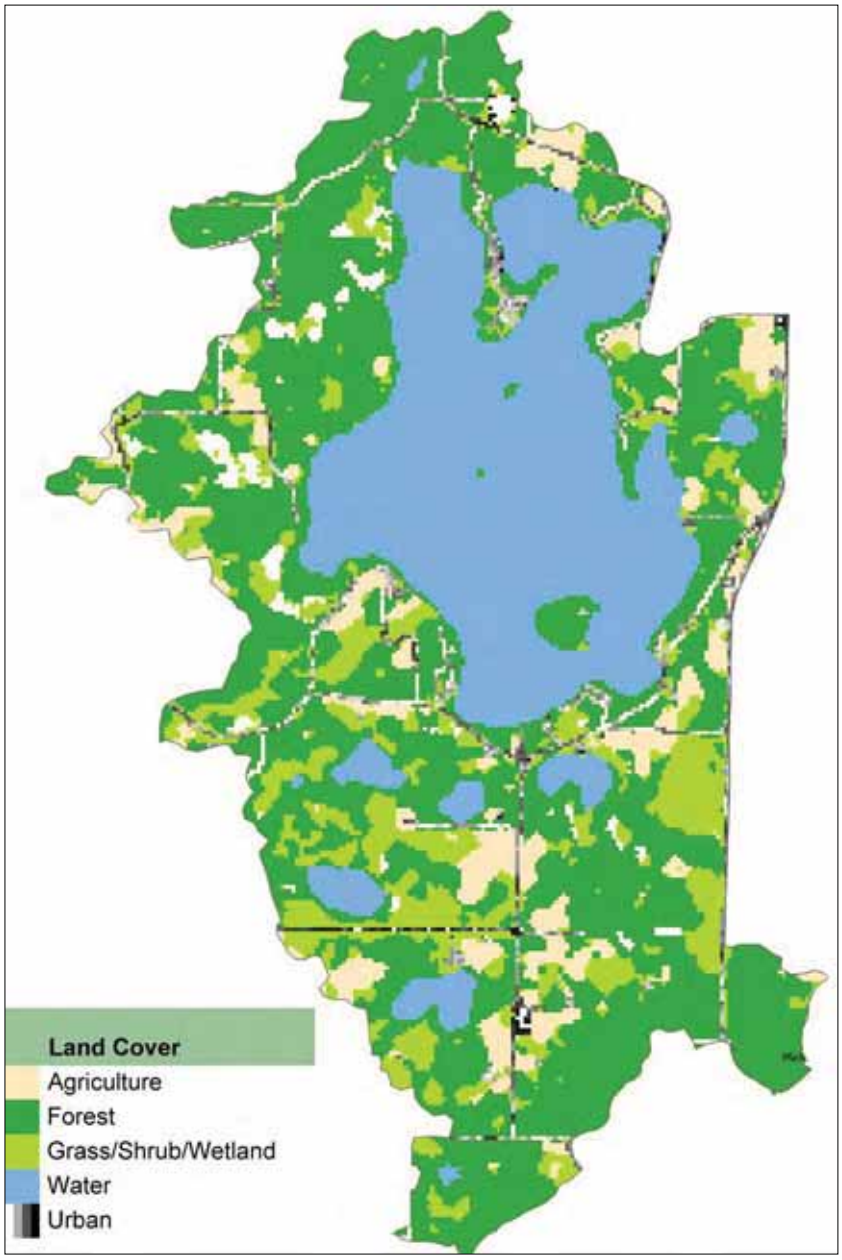


Figure 5. The Spirit Lake - Ripple River (1003603) lakeshed land cover (http://land.umn.edu).

The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Table 1 describes Farm Island Lake's lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture, grass/shrub/wetland, and water acreages to forested and urban acreages. The largest change in percentage is the decrease in agriculture (35.7%); however, in acreage, forest cover has increased the most (659 acres). In addition, the impervious intensity has increased, which has implications for storm water runoff into the lake. The increase in impervious intensity is consistent with the increase in urban acreage.

Table 1. Farm Island Lake's lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

	1990		2000		% Change
Land Cover	**Acres**	**Percent**	**Acres**	**Percent**	**1990 to 2000**
Agriculture	840	10.9	540	7.01	35.7 % Decrease
Forest	2,821	36.61	3,480	45.16	23.4 % Increase
Grass/Shrub/Wetland	1,320	17.13	1,097	14.24	16.9 % Decrease
Water	2,349	30.48	2,136	27.72	9.0 % Decrease
Urban	377	4.89	455	5.9	20.7 % Increase
Impervious Intensity %	**Acres**	**Percent**	**Acres**	**Percent**	
0	7,443	96.57	7,331	95.12	1.5 % Decrease
1-10	82	1.06	100	1.3	22.0 % Increase
11-25	95	1.23	131	1.7	37.9 % Increase
26-40	48	0.62	87	1.13	81.3 % Increase
41-60	27	0.35	32	0.42	18.5 % Increase
61-80	8	0.1	14	0.18	75% Increase
81-100	4	0.05	12	0.16	300% Increase
Total Area	7,706		7,706		
Total Impervious Area (Percent Impervious Area Excludes Water Area)	59	1.1	93	1.67	57.6 % Increase

Demographics

Farm Island 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.

Aitkin County records indicate that the population in Farm Island and Hazelton Townships increased 50-100% from 1990-2000. The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. These projections are shown in Figure 6 below. Farm Island and Hazelton Townships have higher extrapolated growth over the next 30 years compared to Aitkin County as a whole.

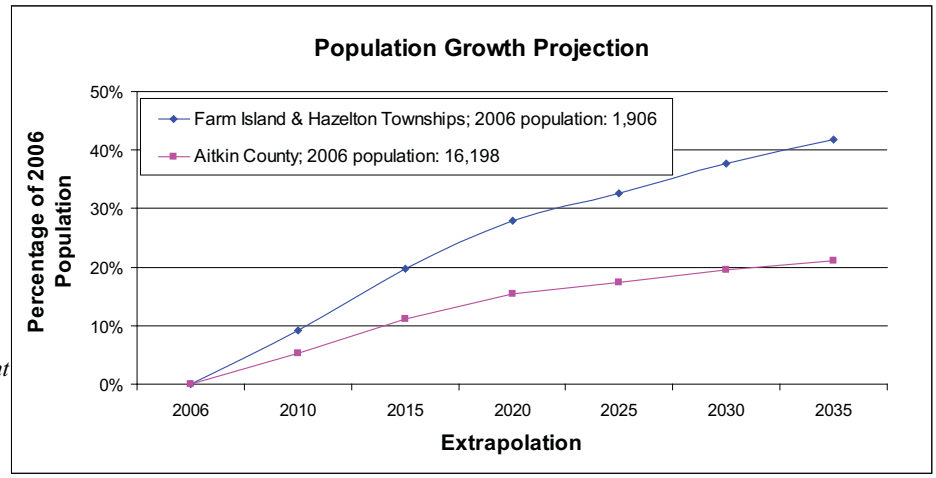


Figure 6. Population growth projection for the townships around Farm Island Lake and Aitkin County (source: http://www.demography.state.mn.us/resource.html?Id=19332)

Status of the Fishery (DNR, as of 07/30/2007)

Farm Island is a large, hardwater lake with good clarity and is located 7 miles south of Aitkin. It is 2,054 acres with a maximum depth of 56 feet. There are several islands on the lake, which also has a complex bottom structure. There are two state owned public accesses, with concrete ramps, on the lake. One is on the north side of the lake and the other on the south end. The one on the north side was recently completed in the fall of 2007.

The walleye population in Farm Island is looking good again this year. There is a strong 2002 year class that is just entering the 16 to 19 inch protected slot and two strong year classes, 2004 and 2005, coming up. The average length of the 2004 year class sampled in this survey was almost 14 inches so they should be showing up in the harvest as 14 and 15-inch walleye in 2008. Most of the fish from the strong 1999 year class will have now grown out of the protected slot. The males should be 19 to 20 inches long and the females up to 26 or 27 inches in length. Although there has been a modest increase of fish within the protected slot, it appears more fish are surviving to larger sizes. Whereas the mean gill net catch rate for walleye over 19 inches was 1.1 per net prior to the special regulation (ranging from 1.8 per net in 1970 trending down to 0.5 per net in 1991), it now averages 2.2 per net (ranging from 1.7 per net in 2000 to 2.6 per net in 2007).
Northern pike, while abundant, are still exhibiting normal growth rates. The average length is down slightly from that seen in the last few surveys, but there are still some large fish out there. While there are no special regulations in effect on northern pike in Farm Island, the lake association encourages anglers to harvest the smaller northern pike, while releasing fish greater than 24 inches in length.

For those anglers who are interested in catching panfish, Farm Island has abundant populations of black crappie and bluegill. There are two strong year classes of black crappie, the 2005 year class, which are 8 inches to 9 inches long, and the 2003 year class, which are about 11 inches long. There appears to have been very little changes to growth rates of either species in the last sixteen or more years. However, based on the trap net length frequency distribution and age distribution, it appears that most larger bluegill are being harvested before they have a chance to reach 8 inches, or age 7.

Anglers targeting largemouth bass will find a good population of fish with a wide range of sizes available. Tullibee have been decreasing in abundance since the first survey nets were set in 1957; however, this was the first year that none were sampled in the assessment gill nets. Without tullibee in the fish community, it is feasible we will observe future decreases in growth rates for walleye and northern pike.

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=01015900

Gun Lake 01-0099-00 AITKIN COUNTY

Summary

Gun Lake is located in Aitkin County near Palisade, MN. With a surface area of 730 acres, it is in the upper 25% of lakes in Minnesota in terms of its size.

Gun Lake has two inlets and one outlet, which classifies it as a drainage lake. Its inlets are drainage ditches from the surrounding area, and water flows south out of Gun Lake into French Lake.

Water quality data has been collected for Gun Lake off and on since 1975. These data show that Gun Lake is eutrophic (page 8). Eutrophic lakes are usually shallow and have "green" water throughout the summer, with some possible larger algae blooms in late summer.

The organizational purpose of the Gun Lake Association is to advocate the appreciation, conservation and restoration of Gun Lake and associated waterways and watershed. The intention of the association is to objectively represent all reasonable viewpoints on environmental issues affecting the lake and to facilitate the wise stewardship of our lake environment. The Gun Lake Association is active in many activities including water quality monitoring and curly-leaf pondweed treatment fundraising.

Vitals	
MN Lake ID:	01-0099-00
County:	Aitkin
Ecoregion:	Northern Lakes and Forest
Major Drainage Basin:	Upper Mississippi River
Latitude/Longitude:	46.64583333 / -93.52111111
Water Body Type:	Public Waters
Monitored Sites (Primary):	205
Monitored Sites (Secondary):	101, 102, 103, 204, 206, 207, 208
Invasive species present:	Curly-leaf pondweed

Physical Characteristics		
Surface area (acres):	730	
Littoral area (acres):	292	
% Littoral area:	40%	
Max depth (ft):	44	(m): 13.4
Mean depth (ft):	12	(m): 3.7
Watershed size (acres):	6,917	
Watershed:lake area ratio	9.5	
Inlets	2	
Outlets	1	
Accesses	1 public	

Data Availability

Transparency data		Yearly secchi disk readings were conducted before 2000, but data is scarce since then.
Chemical data		Chemical data were only collected in 1987, 1999-2000, 2006-2008.
Inlet/Outlet data		Inlet/outlet data were collected as part of an MPCA LAP study in 1987 and by the Aitkin SWCD in 2006.

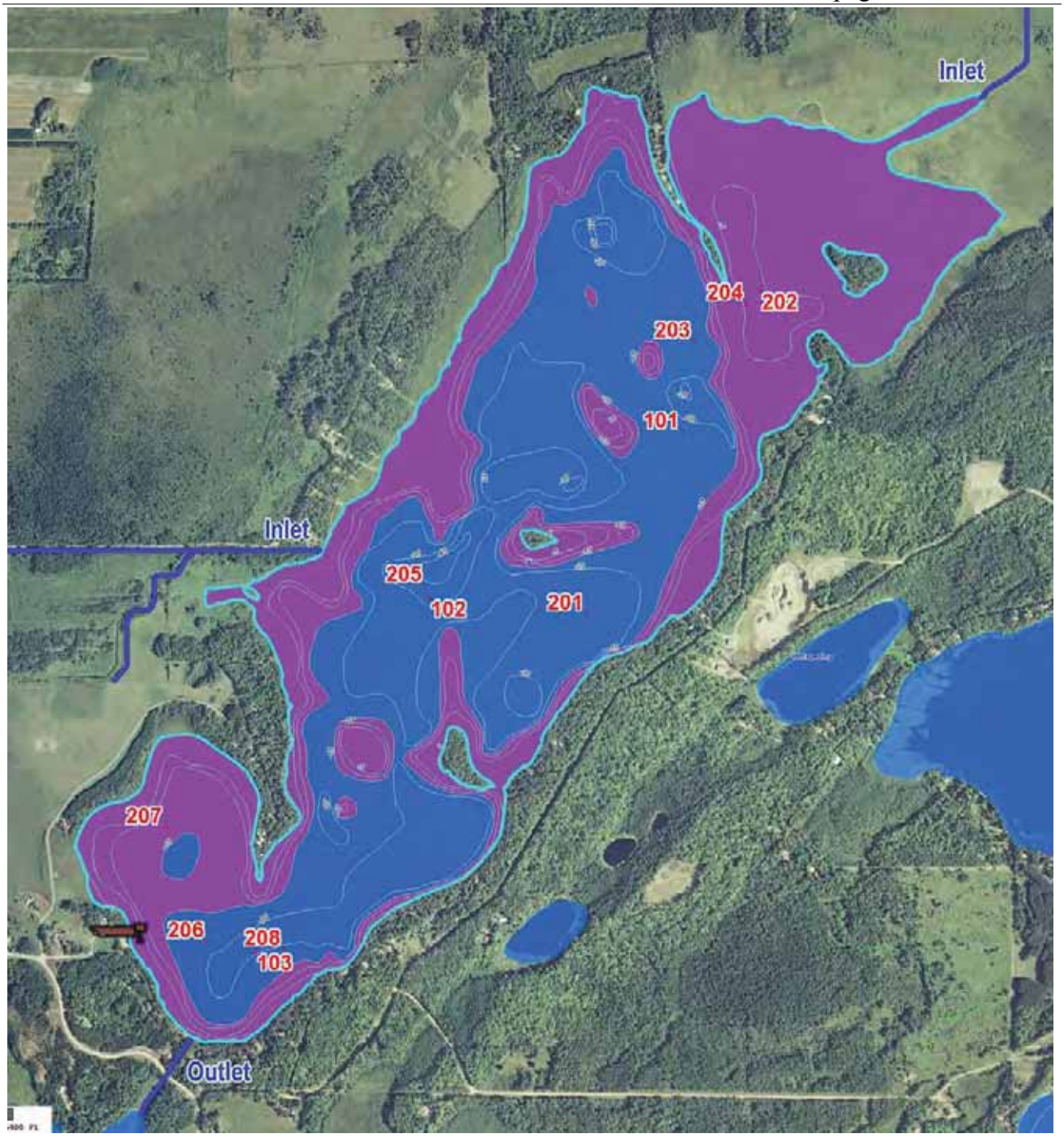


Figure 1. Map of Gun Lake illustrating bathymetry, lake sample site locations, stream inlets and outlets and aerial land use. The pink shaded areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom allowing aquatic plants to grow.

Lake Site	Depth (ft)	Monitoring Programs
101	20	MPCA: 1985, 1987; SWCD: 1999-2000, 2006-2007
201	28	CLMP: 1975-1976
203	18	CLMP: 1979
204	8	CLMP: 1987-2000
205 (102) *Primary	40	MPCA: 1987, 2008; CLMP: 1987-2000