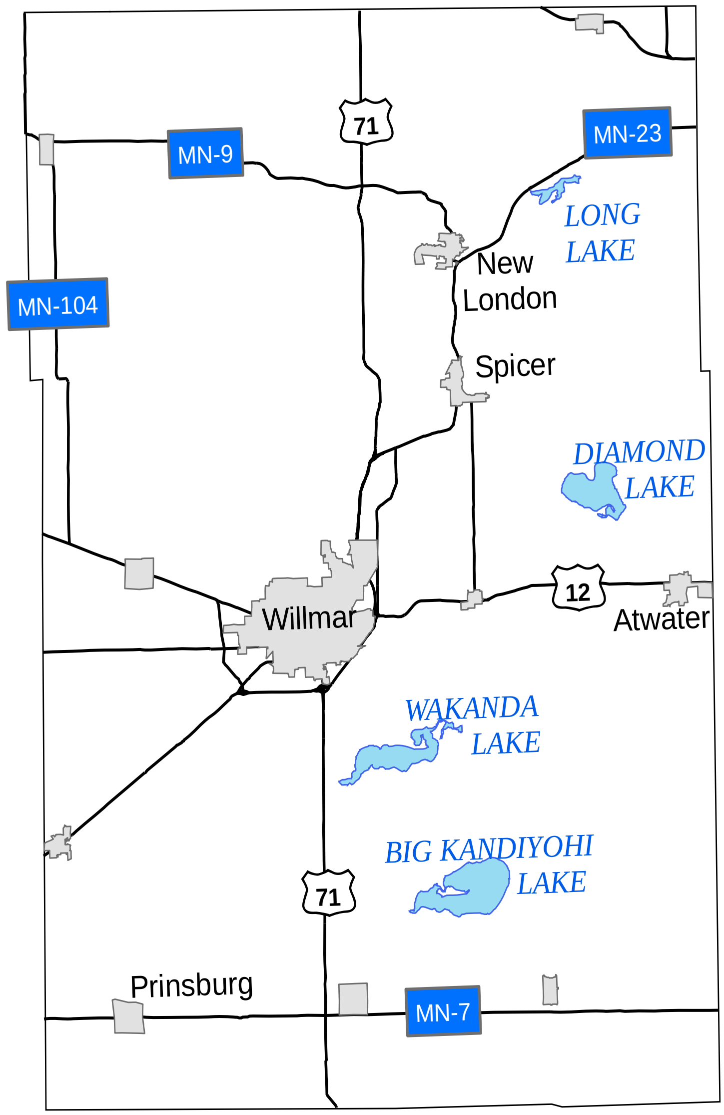
Citizen Lake-Monitoring Program (CLMP+):
Advanced Volunteer Lake Monitoring in Kandiyohi County



Minnesota Pollution Control Agency

December 2005

Citizen Lake-Monitoring Program (CLMP+): Advanced Volunteer Lake Monitoring in Kandiyohi County

Big Kandiyohi Lake	**(34-0086)**
Wakanda Lake	**(34-0169-03)**
Diamond Lake	**(34-0044)**
Long Lake	**(34-0066)**

Minnesota Pollution Control Agency

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Part 1: Program History and Background Information on Minnesota Lakes

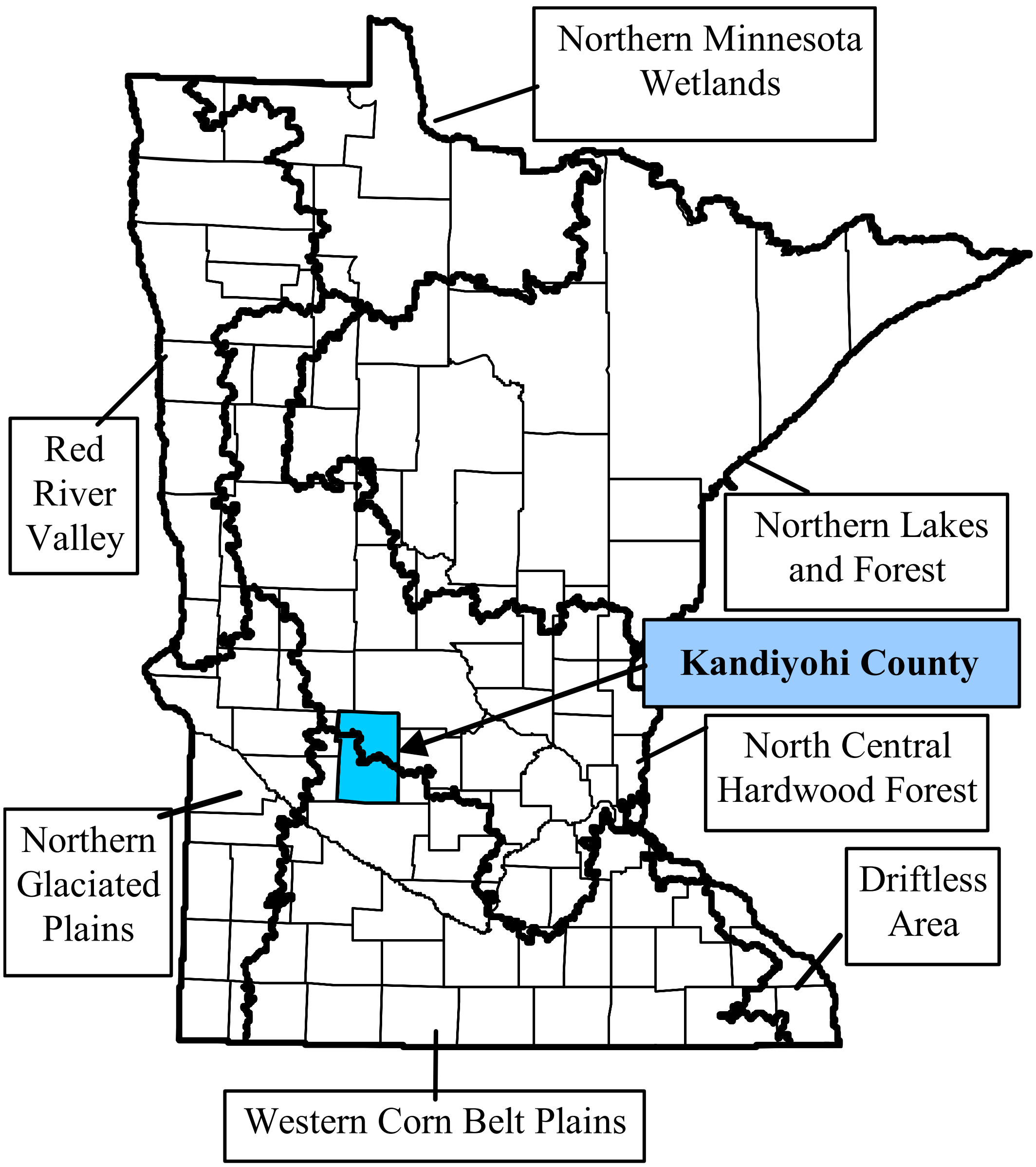
Minnesota's Citizen Lake-Monitoring Program (CLMP) is the largest and oldest volunteer lake-monitoring program in the country. Volunteers in the CLMP currently use a Secchi disk to measure the clarity on hundreds of Minnesota's lakes. The expanded program, including the collection of water chemistry samples for analysis along with Secchi transparency collection, was conducted in several counties. A total of sixteen lakes were selected for monitoring in 2005 by volunteer lake monitors. These lakes were: Latoka, Lobster and Mary Lakes (Douglas County); Big Kandiyohi, Diamond, Long, and Wakanda Lakes (Kandiyohi County); Blueberry, Duck, Jim-Cook, Lower Twin, Morgan, Upper Twin Lakes (Hubbard/Wadena Counties); Bass, Howard, and Pleasant Lakes (Wright County). Spirit and Stocking Lakes (Wadena County) were also sampled by volunteer lake monitors through the County. The data from these two additional lakes was incorporated in the 2005 Wadena County CLMP+ report. All equipment and analytical costs for the samples were provided for and paid by the Minnesota Pollution Control Agency (MPCA). *Note: Only data from Kandiyohi County Lakes will be discussed in this update report.*

Volunteers on these lakes collected water chemistry samples and temperature profiles twice per month along with their weekly Secchi transparency readings. After sampling, the volunteers dropped off their samples at a predetermined location within their county. Forrest Peterson and Sheri Reuss (MPCA-Willmar Office), helped plan and coordinate the sample drop-off/pick up schedule for the samples in Kandiyohi County. Special thanks to the volunteers who helped make this project a success: Timothy Furr (Big Kandiyohi Lake), Jon Gilmer (Diamond Lake), Larry Zink (Long Lake) and Marilee Druskin, Allan & Linda Bjornberg and Bruce Vruwink (Lake Wakanda). MPCA staff and volunteer monitors collected quality assurance and quality control (QA/QC) samples for this project.

The MPCA core lake-monitoring programs include the CLMP, the Lake Assessment Program (LAP), and the Clean Water Partnership (CWP) Program. In addition to these programs, the MPCA annually monitors numerous lakes to provide baseline water quality data, provide data for potential LAP and CWP lakes, and characterize lake conditions in different regions of the state. MPCA also examines year-to-year variability in ecoregion reference lakes and provides additional trophic status data for lakes exhibiting trends in Secchi transparency. All four of the Kandiyohi lakes have been previously assessed: Big Kandiyohi Lake was one of a few lakes to participate in the MPCA's LAP program in 1985 (the first year of this program's existence),Wakanda was included in the US EPA's National Eutrophication Surevey (NES) in the 1974, Diamond Lake was included as a CWP in 1997, and Long Lake was included in a sediment-diatom reconstruction project (Heiskary and Swain, 2002).

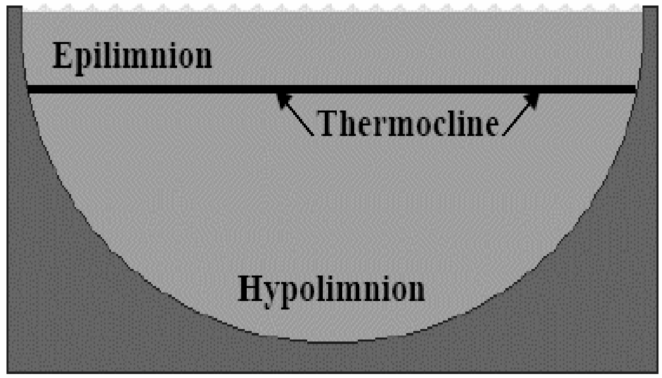
The state of Minnesota is divided into seven ecoregions (Figure 1), based on soils, landform, potential natural vegetation, and land use. Kandiyohi County is located within both the North Central Hardwood Forest (NCHF) and Western Corn Belt Plains (WCBP) ecoregions. Comparing a lake's water quality to that of reference lakes in the same ecoregion provided one basis for characterizing the condition of the lake. Big Kandiyohi Lake and Lake Wakanda are located in the WCBP ecoregion; while Diamond and Long Lakes are located in the NCHF ecoregion; however, they are near the transition zone of the WCBP-NCHF ecoregions.

Figure 1. Minnesota's Ecoregions and Counties

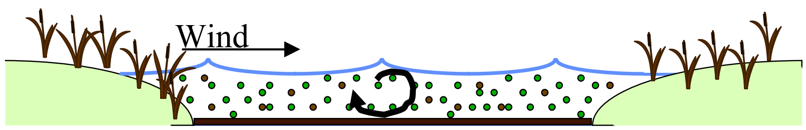


Lake depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers), in which deep lakes (maximum depths of 30 - 40 feet or more) often stratify (form layers) during the summer months and are referred to as *dimictic*. These lakes full-mix or turn-over twice per year; typically in spring and fall. Shallow lakes (maximum depths of 20 feet or less) in contrast, typically do not stratify and are often referred to as *polymictic*. Some lakes, intermediate between these two, may stratify intermittently during calm periods. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well-mixed or stratified. It can also identify the depth of the thermocline (zone of maximum change in temperature over the depth interval). In general, the upper, well-mixed layer (epilimnion) is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. Most of the fish in the lake will be found in the epilimnion or near the thermocline. The combined effect of depth and stratification can influence overall water quality.

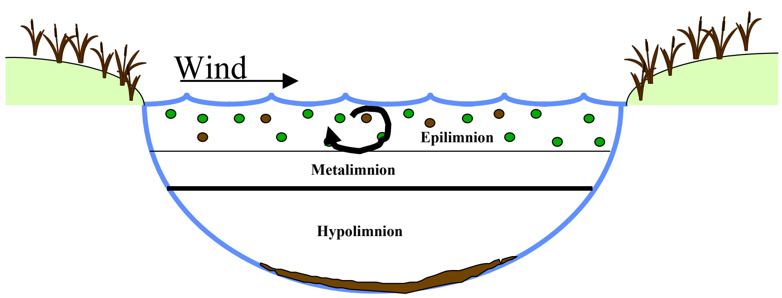
Diagrams of Lake Layers for Shallow and Deep Lakes



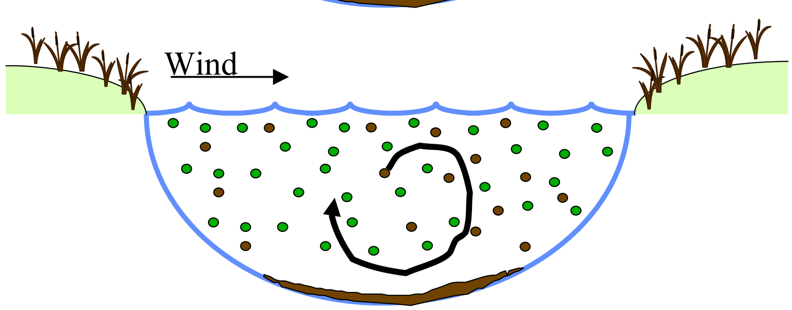
Polymictic Lake
Shallow, No Layers,
Mixes Continuously
Spring, Summer & Fall



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Summer



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Spring/Fall



Part 2: 2005 Lake Surveys

Methods

This report includes data from 2005 as well as previously collected data available in STORET, U.S. Environmental Protection Agency's (EPA) national water quality data bank (Appendix). The following discussion assumes familiarity with basic limnology terms as used in a "Citizens Guide to Lake Protection" and as commonly used in LAP reports. A glossary of terms is included in the appendix and can also be accessed at http://www.pca.state.mn.us/water/lakeacro.html.

One site was monitored twice per month in each lake, from June through September. Lake surface samples were collected with an integrated sampler, constructed from a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). Lake-bottom samples were collected 1 meter off the bottom of the lake by MPCA staff using a Kemmerer sampler. Seasonal averages were calculated using June – September data. Sampling procedures were employed as described in the MPCA Quality Control Manual and Citizen Lake-Monitoring Program "Plus" Manual. Laboratory analyses were performed at the Minnesota Department of Health using EPA-approved methods. Surface samples from volunteers were analyzed for: total phosphorus (TP), chlorophyll-*a*, and pheophytin. Secchi disk transparency and user perception information was recorded at all sites. Volunteers also collected temperature profiles for each site using a FishHawk Model 520 digital depth and temperature meter. Algae samples were collected from the chlorophyll-*a* sample bottles and preserved with Lugol's solution.

MPCA staff collected surface samples and bottom samples for each site on three occasions. These data serve to augment the volunteer collection and provide an opportunity for comparison of results. MPCA collected surface samples were analyzed for the following parameters: TP, chlorophyll-*a*, pheophytin, total Kjeldahl nitrogen (TKN), total suspended solids (TSS), suspended volatile solids (SVS), total chloride, alkalinity and color. Conductivity, pH, and dissolved oxygen and temperature profiles were collected using a Hydrolab multi-probe unit. Lake-bottom samples were analyzed for TP. Secchi disk transparency and user perception information was recorded for each site. Qualitative analysis of zooplankton collected using a zooplankton net was also recorded for each site.

Additional information, such as bathymetric (contour) and location maps, was obtained from the DNR's lakefinder Web site (http://www.dnr.state.mn.us/lakefind/index.html) and the MPCA Web site (http://www.pca.state.mn.us) and from U.S. Geological Survey (USGS) quad maps. Watershed area information for the lake was provided from LAP or CWP reports or the USGS.

Data Analysis

A series of graphs are presented for each lake including: TP, chlorophyll-*a*, Secchi disk transparency, and temperature profiles. Sample dates with a single asterisk indicate data collected by the MPCA. Dates with no asterisk were collected by CLMP volunteer lake monitors. All raw data for each lake and site are available in the appendix.

The Quality Assurance/Quality Control (QA/QC) samples were taken routinely throughout the sampling season. Thirteen field duplicate TP samples were taken. A field duplicate is a second sample taken right after an initial sample in the exact same location. Field duplicates assess the sampler's precision, laboratory precision, and possible temporal variability. The duplicate sample should be collected in the exact same manner as the first sample, including the normal sampling equipment cleaning procedures. Of these 13 samples, the percent difference ranged from 0 – 33 percent of the original sample, with the majority (77 %) falling within the 0 – 15 percent range. Of the 12 paired chlorophyll-*a* samples, the percent difference range was 2 – 16 percent, with the majority (83 %) falling within the 0 – 15 percent range. These results are very good considering the difference in quality of the participating lakes and varying concentration levels of these parameters. Four TP sample results from the following lakes were omitted due to sample contamination from adding Lugol's solution instead of sulfuric acid preservative: Duck Lake (Hubbard County), Upper Twin Lake (Hubbard County), Lower Twin Lake (Wadena County), and Pleasant Lake (Wright County). One chlorophyll-*a* sample from Duck Lake (Hubbard County) was also omitted due to sample contamination from Lugol's.

Several TP samples from early June, for the CLMP+ lakes, were held for one week longer than the recommended holding time due to the 2005 government shutdown. However, given that the samples were properly preserved with acid, kept cool and in a dark place, we do not feel these samples were compromised. Several color results were also held over the recommended holding time by one day. As with the TP samples, the integrity of these samples should also still be acceptable.

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration, chlorophyll-*a* concentration, and Secchi disk transparency of the lakes based on lake area, lake depth, and the area of the lakes' watershed. Additional information about this model can be found in the modeling section of this report or a complete explanation of this model may be found in Wilson and Walker (1989).

Table 1. Lake Morphometry & Watershed Areas for Kandiyohi County CLMP+ Lakes

Characteristic	Big Kandiyohi	Wakanda	Diamond	Long
DNR Lake ID #	34-0086	34-0169-03	34-0044	34-0066
Maximum depth	15 ft 4.6 m	15 ft 4.6 m	27 ft 8.2 m	46 ft 14 m
[1]*Mean depth*	9.3 ft 2.8 m	7 ft 2.1 m	15.9 ft 4.8 m	17.8 ft 5.4 m
Lake area *(ha = hectares)* *(mi^2 = square miles)*	2,526 acres 1,023 ha 3.9 mi^2	1,560 acres 632 ha 2.4 mi^2	1,565 acres 634 ha 2.4 mi^2	286 acres 116 ha 0.4 mi^2
[2]*Watershed area DIRECT* *(Excludes lake area)*	12,642 acres 5,118 ha 19.8 mi^2	14,646 acres 5,934 ha 22.9 mi^2	14,080 acres 5,700 ha 22 mi^2	897 acres 363 ha 1.4 mi^2
[2]*Watershed area TOTAL* *(Excludes lake area)*	28,962 acres 11,726 ha 45.3 mi^2	14,646 acres 5,934 ha 22.9 mi^2	23,040 acres 9,328 ha 36 mi^2	897 acres 363 ha 1.4 mi^2
[3]*Watershed:lake area ratio*	11:1	9:1	15:1	3.5:1
Volume (acre-ft) *(hm^3)*	26,985 acre-ft 33.3 hm^3	10,922 acre-ft 13.5 hm^3	25,091 acre-ft 31 hm^3	5,079 acre-ft 6.3 hm^3
Littoral Area	1,263 acres ~ 100 %	1,560 acres 100 %	635 acres 41 %	127 acres 44 %
Ecoregion	WCBP	WCBP	NCHF	NCHF
Inlets[4]	3	~ 10	4	0
Outlets[4]	1	2	1	1
Accesses	2	2	2	2

[1]Mean depth and volume provided by MN DNR or historic MPCA reports.
[2]Watershed area provided by MN DNR, MPCA or USGS web site: http://gisdmnspl.cr.usgs.gov/watershed/index.htm
[3]Watershed: lake area ratio based on TOTAL watershed.
[4]Provided by Lake Association, County, historic MPCA reports.

Table 2. Summer-Mean Water Quality Parameters for Kandiyohi County CLMP+ Lakes.
(Based on 2005 summer epilimnetic data.)

Parameters	Big Kandiyohi	Wakanda	Typical Range for WCBP Ecoregion[3]	Diamond	Long	Typical Range for NCHF Ecoregion[3]
Total Phosphorus (µg/L)	175	157	**65 – 150**	87	21	**23 – 50**
Chlorophyll-*a* (µg/L)[4] **Mean**	24	153	**30 – 80**	47	6	**5 – 22**
Chlorophyll-*a*(µg/L)[4] **Max.**	50	183	**60 – 140**	97	11	**7 – 37**
Secchi disk (m)	0.8	0.2	**0.5 – 1.0**	1.5	2.9	**1.5 – 3.2**
Secchi disk (feet)	2.6	0.8	**1.6 – 3.3**	5.1	9.5	**4.9 – 10.5**
Total Kjeldahl Nitrogen (mg/L)	1.7	3.2	**1.3 – 2.7**	1.7	0.6	**0.62 – 1.2**
Alkalinity (mg/L)	200	157	**125 – 165**	173	175	**75 – 150**
Color (Pt-Co Units)	17	27	**15 – 25**	13	7.5	**10 – 20**
pH (SU)	8.6	8.7	**8.2 – 9.0**	8.6	7.9	**8.6 – 8.8**
Chloride (mg/L)	32	34	**13 – 22**	18	12	**4 – 10**
Total Suspended Solids (mg/L)	12	27	**7 – 18**	11	3	**2 – 6**
Total Suspended Inorganic Solids (mg/L)	4	19	**3 – 9**	9	2	**1 – 2**
Conductivity (µmhos/cm)	568	486	**300 – 650**	310	307	**300 – 400**
TN:TP Ratio	10:1	20:1	**17:1 – 27:1**	20:1	29:1	**25:1 – 35:1**

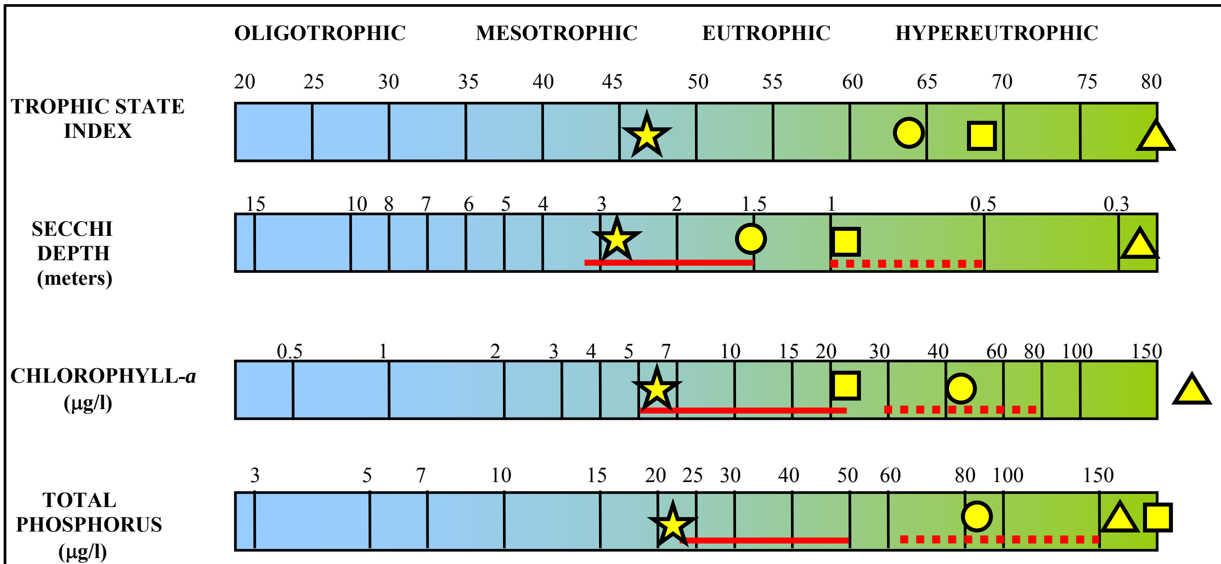
[1]Ecoregion" range is the 25th – 75th percentile of summer means from ecoregion reference lakes.
[2]Chlorophyll-*a* measurements have been corrected for pheophytin.
[3]TSS = Total Suspended Solids.
[4]TSIS = Total Suspended Inorganic Solids = Total Suspended Volatile Solids

Table 3. 2005 Trophic State Index Values for Kandiyohi County CLMP+ Lakes.

2005 Trophic State Index	**Big Kandiyohi**	**Wakanda**	**Diamond**	**Long**
TISP	**79**	**77**	**69**	**48**
TSIC	**62**	**80**	**68**	**48**
TSIS	**63**	**83**	**54**	**45**
Overall TSI	**68**	**80**	**64**	**47**

Figure 2. Carlson's Trophic State Index, based on a scale of 0 – 100. (Carlson 1977)

TSI < 30	Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.
TSI 30 - 40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI 50 - 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of bluegreen algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, L. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

WCBP Ecoregion Range, 25th – 75th percentile: *NCHF Ecoregion Range, 25th – 75th percentile:*

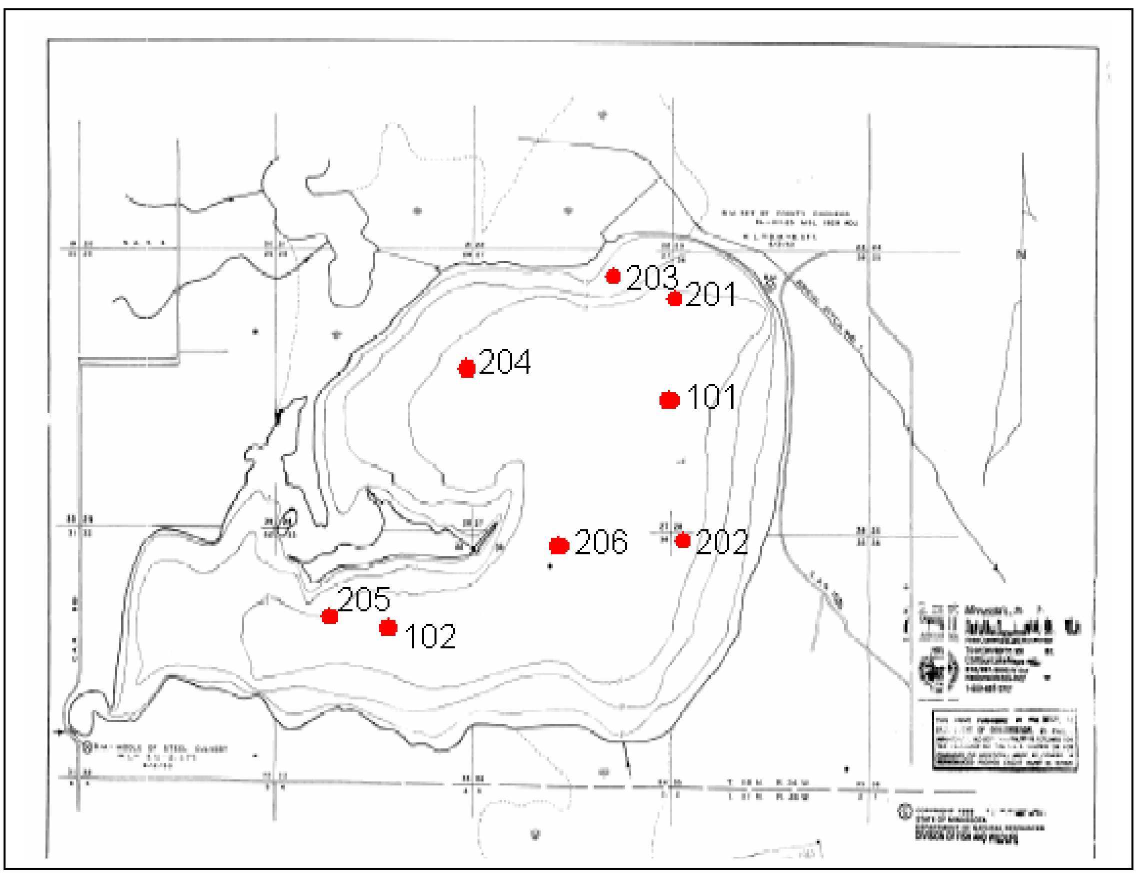
Big Kandiyohi: **Wakanda:** **Diamond:** **Long:**

BIG KANDIYOHI (34-0086)

Big Kandiyohi Lake is a very large, shallow lake. It covers 2,526 acres with a maximum depth of 15 feet and mean depth of 9.3 feet (Table 1). It is in the upper one percent of lakes in terms of its size. The lake is located four miles northwest of the town of Lake Lillian, Minnesota. Nearly 100 percent of the lake is littoral (percent of the lake that is 15 feet or less) and there are two public accesses for the lake. It has a very large total (all contributing) watershed area of approximately 45 mi^2. The watershed to lake ratio is 11:1 (Table 1, Appendix 2). Its water residence time is on the order of 2 years. Big Kandiyohi Lake has a long history of water quality problems and citizen complaints about the water quality. This lake is well known for high phosphorus concentrations and chronic bluegeen algae blooms. In fact, a MPCA report from 1970 cites: “On June 13, 1960, four dogs were reported to have died after drinking contaminated water from Big Kandiyohi Lake. A later report set the total at six dogs, a cow and a calf.”(MPCA, 1971). In August of 1985, more than thirty letters were received by the MPCA regarding citizen/property owner concerns over the poor water quality conditions on Big Kandiyohi Lake (MPCA lake files).

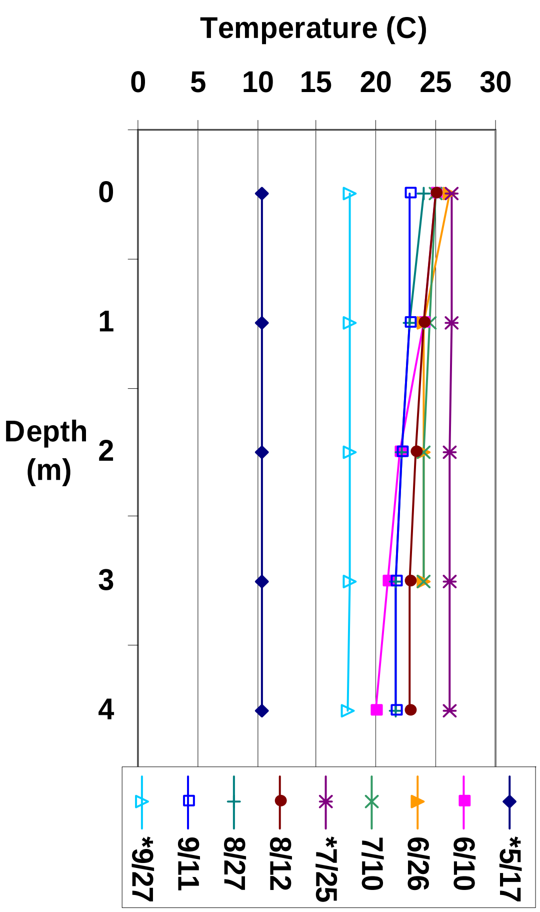
Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitor: Timothy Furr. One site was used on Big Kandiyohi Lake: Site 101 – located in the northern end of the lake (Figure 3).

Figure 3. Big Kandiyohi Lake Bathymetric Map and Monitoring Locations



Temperature data indicated that the lake was well-mixed on all sampling events with surface temperatures ranging from 10° C in May to 26° C in July. This is to be expected given that the lake is shallow and has a large surface area and long fetch (distance wind can blow unimpeded by land).

Figure 4. Big Kandiyohi Lake Temperature Profile Data for 2005



Total phosphorus (TP) concentrations averaged 175 µg/L (micrograms per liter or parts per billion) in Big Kandiyohi Lake during the summer of 2005. This value is well above the range of concentrations for reference lakes in this ecoregion (Table 2). In fact, these results were the highest of the four lakes included in this study. TP concentrations ranged from 88 – 225 µg/L (Figure 5) and increased over the summer through late August; and then declined slightly in September. This pattern of increasing TP over the summer is consistent with what we see in other shallow Minnesota lakes (Heiskary and Lindon, 2005). Surface and bottom TP concentrations collected by MPCA staff did not differ significantly (Appendix). These data, along with corresponding temperature profiles, indicate that Big Kandiyohi Lake is well mixed throughout the summer.

Chlorophyll-*a* concentrations for Big Kandiyohi Lake averaged 24 µg/L; which is below the ecoregion reference range (Table 2). These lower levels were unexpected given the TP levels and appearance of the lake during sampling trips. It is possible that the continual wind mixing of the lake, as noted by temperature profiles in

Figure 5. Big Kandiyohi Lake Total Phosphorus & Chlorophyll-*a* Results for 2005

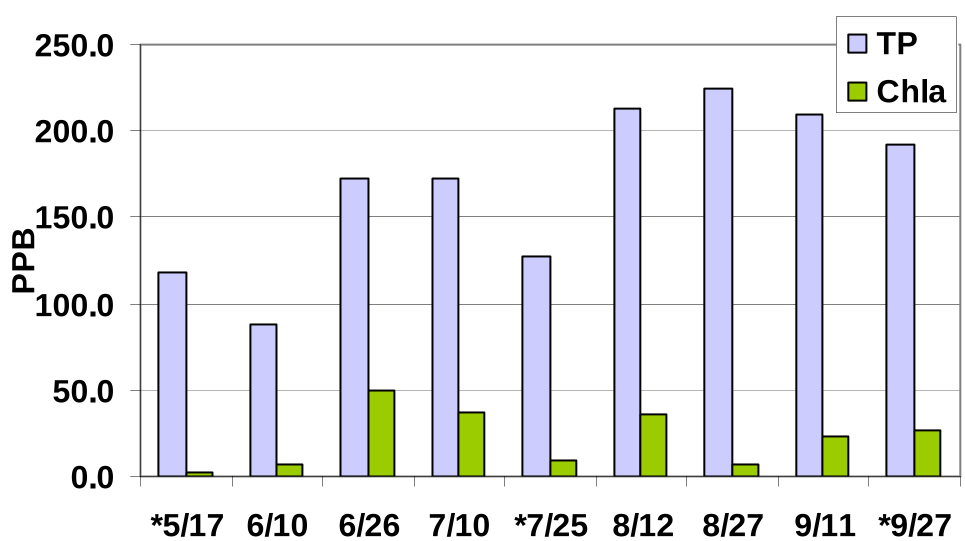
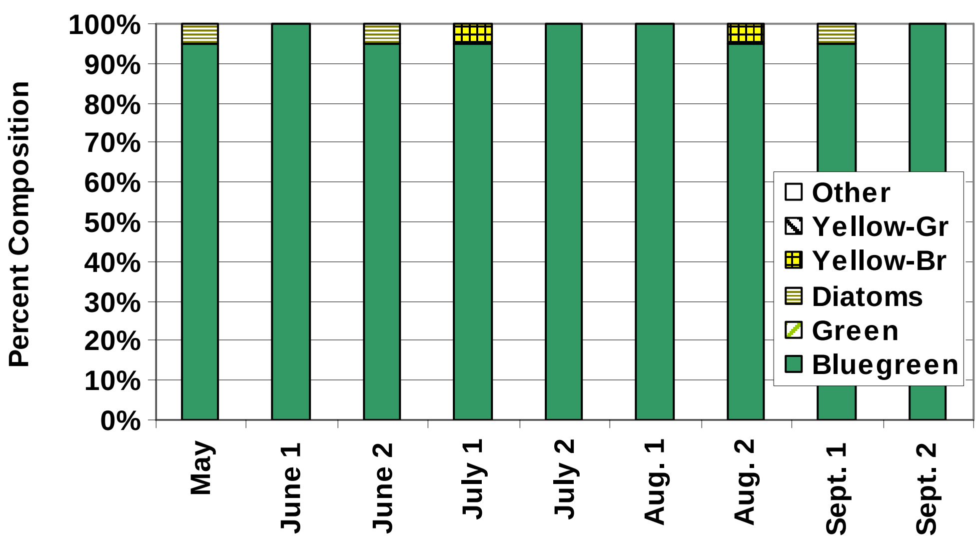


Photo of algae from Big Kandiyohi Lake (July). Photo: MPCA

Figure 4, distributed the algae throughout the entire water column of the lake, thereby reducing (i.e. diluting) concentrations in the upper surface waters. Wind-mixing in the deeper portions of the lake may cause algae to be circulated below the "light zone," so to some degree the algae may be "light limited." Concentrations on Big Kandiyohi Lake ranged from 2.4 – 50.1 µg/L with no distinct pattern over the summer (Figure 5). Chlorophyll-*a* concentrations above 20 µg/L would be considered nuisance blooms and concentrations over 30 µg/L would be considered severe nuisance blooms. Big Kandiyohi Lake experienced nuisance or severe nuisance blooms over 60 percent of the sampling occasions.

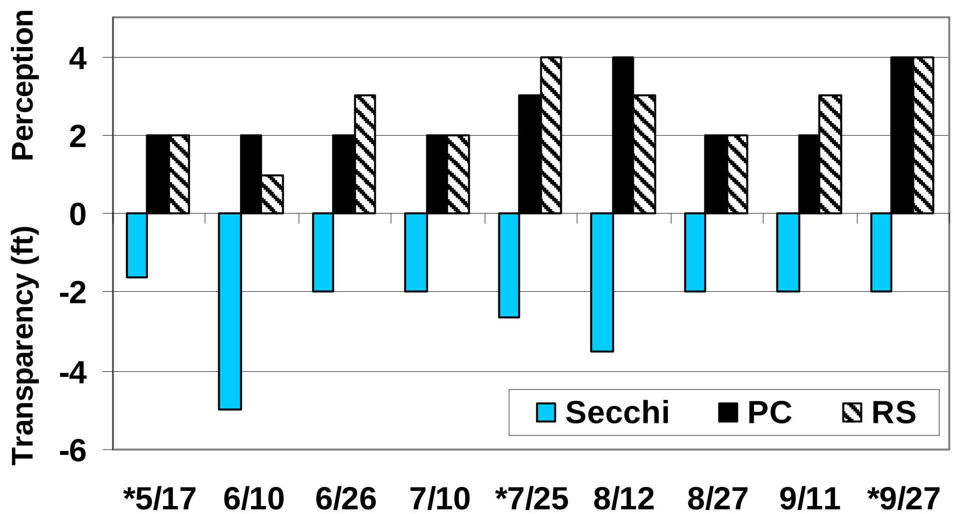
The composition of the phytoplankton (algae) population of Big Kandiyohi Lake is presented in Figure 6. Data are presented in terms of algal type. Samples were collected at Site 101. The bluegreens dominated the algae population throughout the entire summer, with the forms *Anacystis* and *Aphanizomenon* being most common. Bluegreens, as a whole, are the group most often associated with nuisance algal blooms. A seasonal transition in algal types from diatoms to greens to bluegreen is more typical for mesotrophic and eutrophic lakes in Minnesota.

Figure 6. Big Kandiyohi Algal Populations for 2005



Secchi disk transparency on Big Kandiyohi Lake ranged from 2.0 – 5.0 feet (0.6 – 1.5 meters) and averaged 2.6 feet (0.8 meters) (Figure 7). These transparency measures are well within the typical range for ecoregion reference lakes (Table 2). As with the TP and chlorophyll-*a* data, there does not appear to be any particular pattern in transparency over the summer. Along with transparency measurements, subjective measures of Big Kandiyohi Lake's "physical appearance" and "recreational suitability" were made. Lake physical condition for Big Kandiyohi Lake was typically characterized as "not quite crystal clear" (Class 2); while recreational suitability was typically characterized as "minor aesthetic problems" and "swimming slightly impaired" (Classes 2 and 3) throughout the summer (Figure 7). It should be noted that there were two recreational suitability ratings of "would not swim" (Class 4) also observed.

Figure 7. Big Kandiyohi Secchi Transparency for 2005



Other parameters, such as total suspended solids and conductivity, analyzed for Big Kandiyohi Lake were all near or well within the typical range of values for ecoregion reference lakes (Table 2). Concentrations for alkalinity and chloride; however, were slightly, but not significantly, higher than the typical range for this ecoregion.

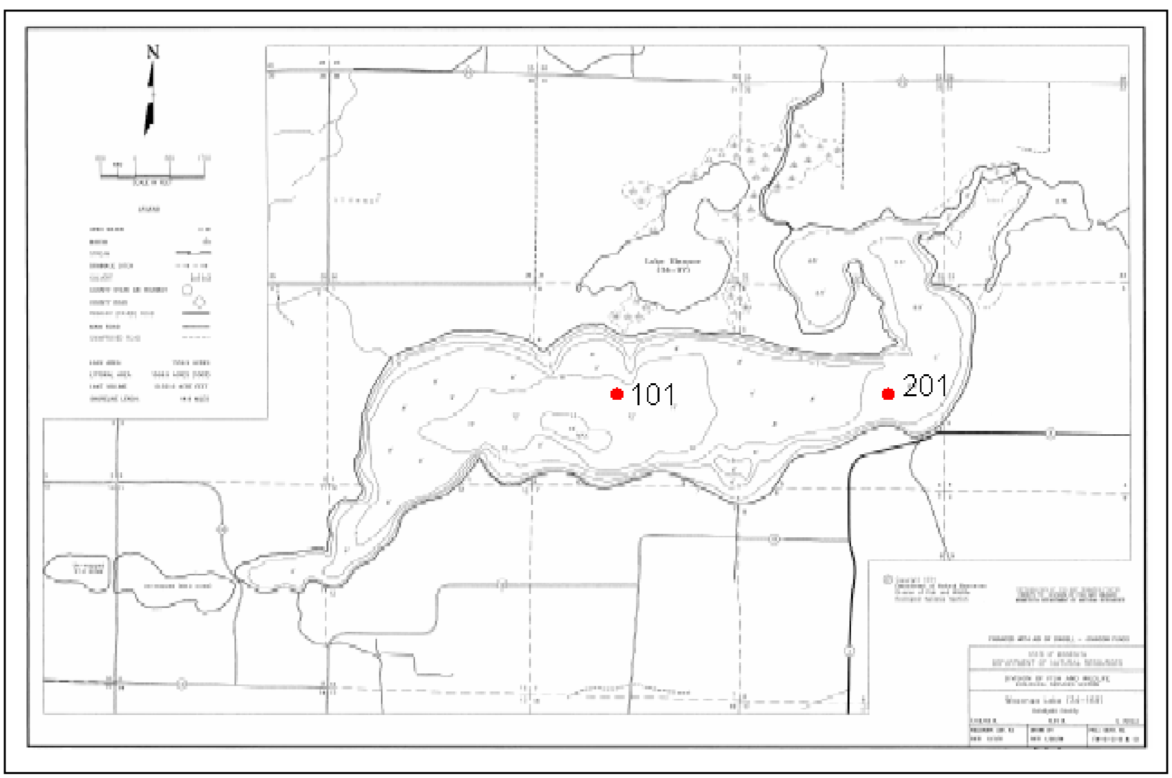
Trophic State Index (TSI) values for chlorophyll-*a* and Secchi transparency for Big Kandiyohi Lake compare very favorably to each other (Table 3); whereas, the TSI value for TP is significantly higher. As such, Secchi transparency may not be a good estimator for TP; however, it appears that it could be a good estimator for chlorophyll-*a* values. Based on TP, Kandiyohi has the potential for much higher chlorophyll-*a* values than were observed in 2005. The overall TSI value indicates *hypereutrophic* conditions for Big Kandiyohi Lake.

WAKANDA (34-0169-03)

LakeWakanda is a large lake located at two miles north of Svea, Minnesota. It was formerly known as Lake Wagonga, but had its name officially changed in the fall of 2005 to Lake Wakanda. The lake has five distinct basins; however, only the main basin was monitored for this study, and further references in this report to Lake Wakanda will be understood to refer to the main basin unless clearly indicated otherwise. Lake Wakanda has a surface area of 1,560 acres, a maximum depth of 15 feet (4.6 m) and mean depth of 7 feet (2.1 m). One hundred percent of the lake is littoral and there are two public accesses for the lake. Its direct and total watershed areas are nearly equivalent at 22.9 mi^2 area (Table 1, Appendix 2). The watershed to lake ratio is 9:1 (Table 1). According to a 1970 MPCA report, there are about 10 tributary and marsh inlets and two outlets for the lake (MPCA, 1970). It is also a lake with a very long history of water quality problems and citizen concerns. A MPCA report from 1970 cites: "An investigation was made by the Minnesota Department of Health for the Minnesota Water Pollution Control Commission of Wagonga Lake and County Ditch 23A on September 18, 1956. A sample taken at the junction of the county ditch and County Road 88…had high concentrations of coliform group organisms, suspended solids, and biochemical oxygen demand." (MPCA, 1971). A US EPA report from 1974 cites: "Survey limnologists noted the lake had a 'pea-soup' appearance at all sampling visits and reported an 'enormous' bloom decomposing in late August, 1972." (US EPA, 1974). Its water residence time is on the order of 1 – 2 years.

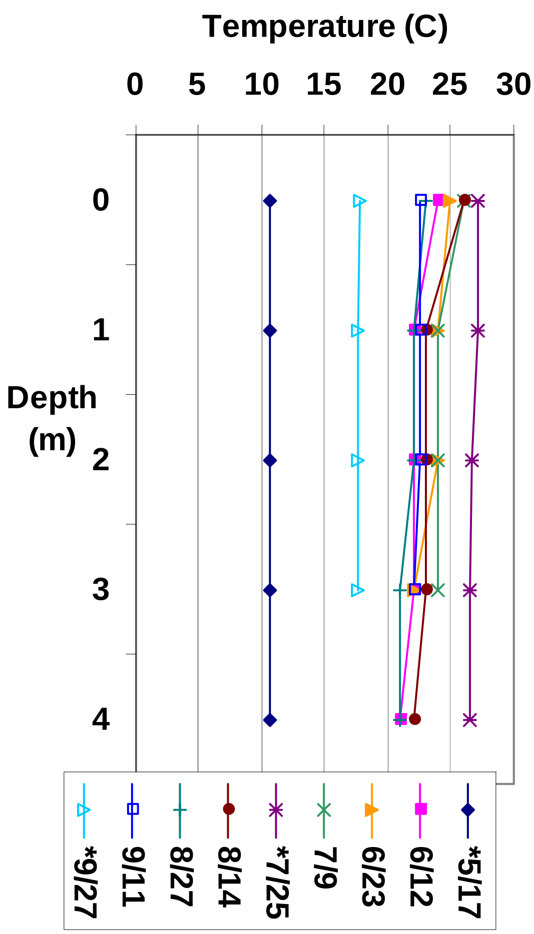
Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitors: Marilee Druskin, Allan & Linda Bjornberg and Bruce Vruwink. One site was used on Lake Wakanda: Site 101, located near the point of maximum depth in the lake (Figure 8).

Figure 8. Lake Wakanda Bathymetric Map and Monitoring Locations



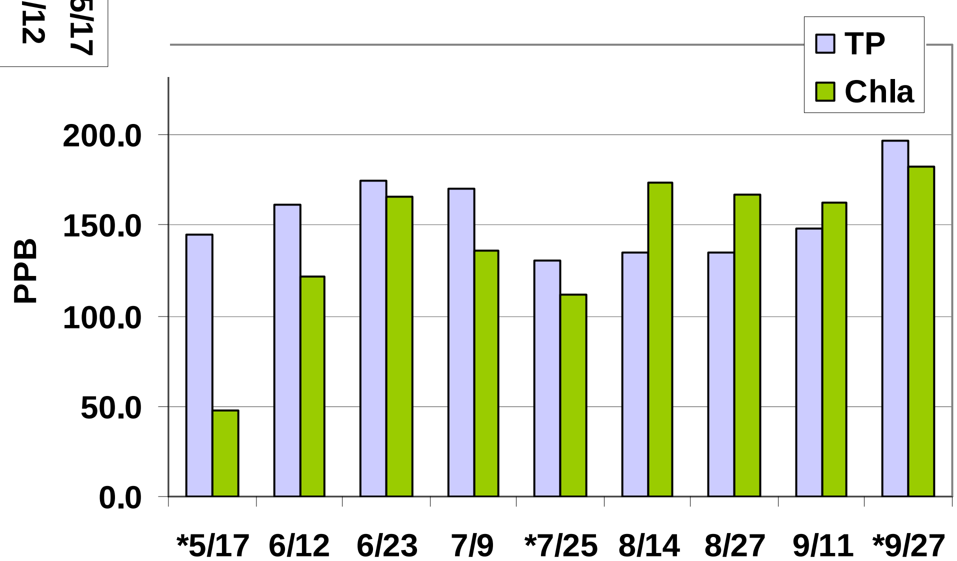
Temperature data indicated that the lake was well mixed throughout the entire summer (Figure 9). Surface temperatures ranged from 10.7°C in May to 27° C in July. Field notes from the surveys also indicated that the lake was very susceptible to wind-mixing.

Figure 9. Lake Wakanda Temperature Profile Data for 2005



Total phosphorus (TP) concentrations averaged 157 µg/L (micrograms per liter or parts per billion) in Lake Wakanda during the summer of 2005. This value is slightly above the top end of the range of concentrations for reference lakes in this ecoregion (Table 2). TP concentrations ranged from 131 – 197 µg/L (Figure 10). Concentrations increased in early summer, declined slightly through mid summer and then increased again in late summer. TP samples collected one meter off the bottom of the lake in May and late July were nearly identical to the surface samples collected at those same sampling events. This data, along with the temperature profile data and conductivity data from the sediment-water interface, indicates that Lake Wakanda is polymictic and has the potential for internal loading of phosphorus from the sediments (Appendix).

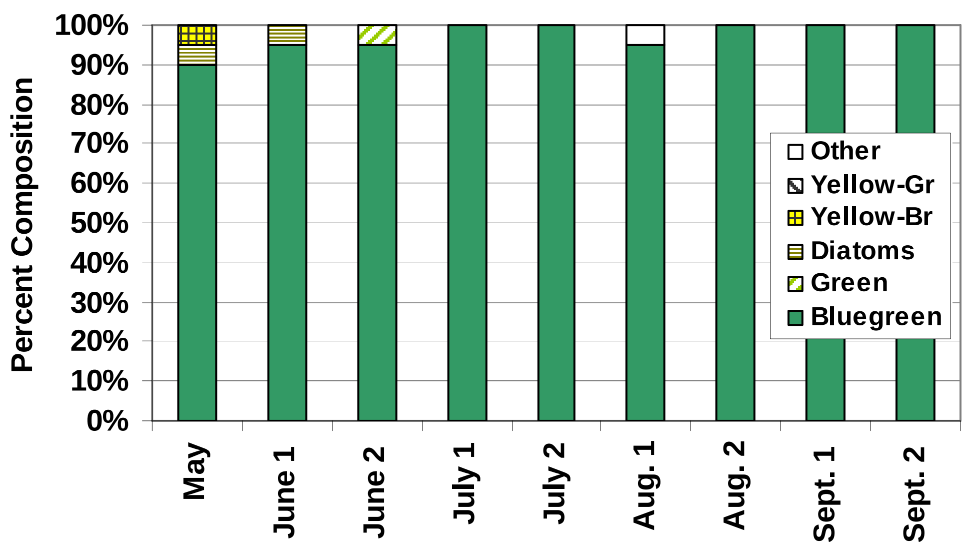
Figure 10. Lake Wakanda Total Phosphorus & Chlorophyll-*a* Results for 2005



Chlorophyll-*a* concentrations for Lake Wakanda were the highest observed of these four study lakes. Concentrations averaged 153 µg/L and were nearly twice the upper end value for the ecoregion range (Table 2). Concentrations on Lake Wakanda ranged from 112 – 183 µg/L and followed a similar pattern to TP concentrations – increasing through early summer, declining in mid summer and then increasing in late summer. Severe nuisance algae blooms (chl-*a* > 30 µg/L) were noted for the entire summer based on these concentrations. These high chlorophyll-*a* concentrations indicate that Lake Wakanda was more "efficient" at converting TP into algal biomass than Big Kandiyohi Lake.

The composition of the phytoplankton (algae) population of Lake Wakanda is presented in Figure 11. Data are presented in terms of algal type and samples were collected at Site 101. The bluegreens dominated the algae population throughout the entire summer, with the form *Aphanizomenon* being most common. Bluegreens, as a whole, are the form most often associated with nuisance bloom conditions. A seasonal transition in algal types from diatoms to greens to bluegreen is more typical for mesotrophic and eutrophic lakes in Minnesota.

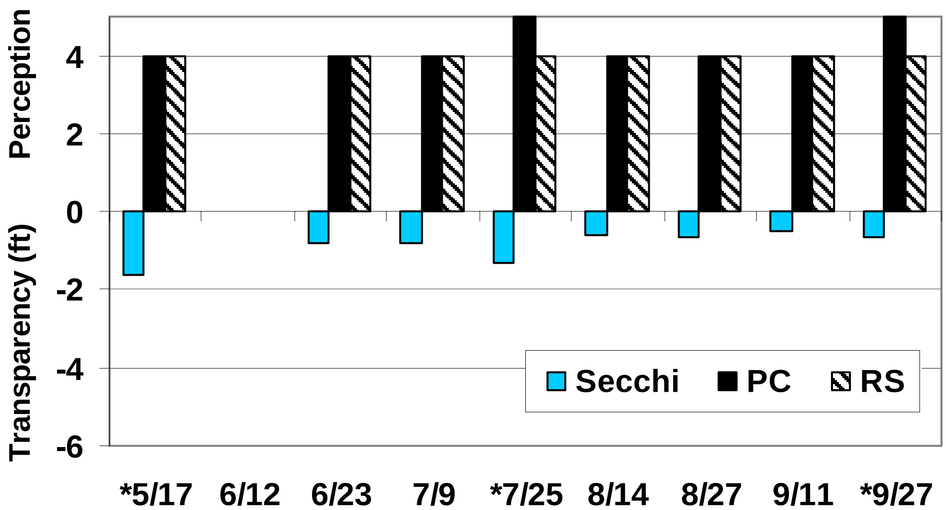
Figure 11. Lake Wakanda Algal Populations for 2005



Secchi disk transparency on Lake Wakanda ranged from 0.5 feet (0.2 meters) in late July to 1.6 feet (0.5 meters) in May (Figure 12) and averaged 0.8 feet (0.2 meters). These transparency measures are slightly below the typical range for ecoregion reference lakes (Table 2). The high algal levels as evidenced from the extremely high chlorophyll-*a* concentrations would have severely limited transparency in this lake. Lake Wakanda's physical condition was generally characterized as "high to severe algae levels" (Classes 4 and 5); while its recreational suitability was characterized as "no swimming" (Class 4) throughout the summer.

Other parameters, such as alkalinity, color, pH and conductivity, analyzed for Lake Wakanda were all near or within the typical range of values for ecoregion reference lakes (Table 2). It should be noted that total Kjeldahl nitrogen, chloride, and total suspended solids and total suspended inorganic solids were above the typical range of values for ecoregion reference lakes (Table 2) for Lake Wakanda.

Figure 12. Lake Wakanda Secchi Transparency for 2005



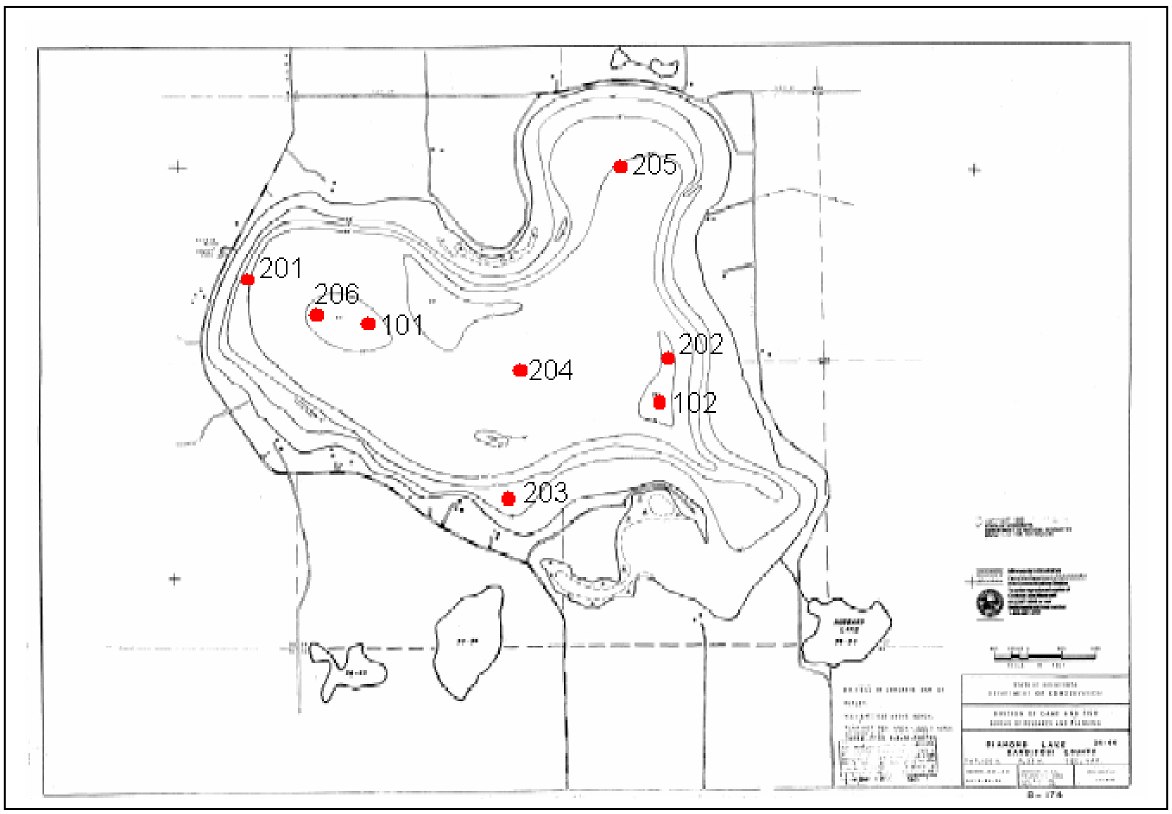
Trophic State Index (TSI) values for Lake Wakanda compare somewhat favorably to each other (Table 3); although the TSI value for TP was slightly, but not significantly, lower than the other TSI values. As such, Secchi transparency should still continue to be a good estimator for TP and chlorophyll-*a* values as well as an indicator of overall water quality for Lake Wakanda. The TSI values for Lake Wakanda indicate *hypereutrophic* conditions.

DIAMOND (34-0044)

Diamond Lake is a large lake located four miles southeast of Spicer, Minnesota. In fact, with a surface area of 1,565 acres, it is in the upper two percent of lakes in terms of its size. It has a maximum depth of 27 feet and a mean depth of 15.9 feet. Approximately 41 percent of the lake is littoral and there are two public accesses for the lake. It has fairly large direct and total watershed areas of 22 and 36 mi^2, respectively (Table 1, Appendix 2). As such, the watershed to lake ratio is also large (Table 2). Diamond Lake is only two miles from the WCBP and NCHF ecoregion boarder; and although it is located on the NCHF side, many of the lake parameters monitored more closely resemble the WCBP ecoregion reference range. Because it lies in a "transitional" ecoregion area, the data should be examined within the context of both ranges. Its water residence time is on the order of 2.5 – 4 years.

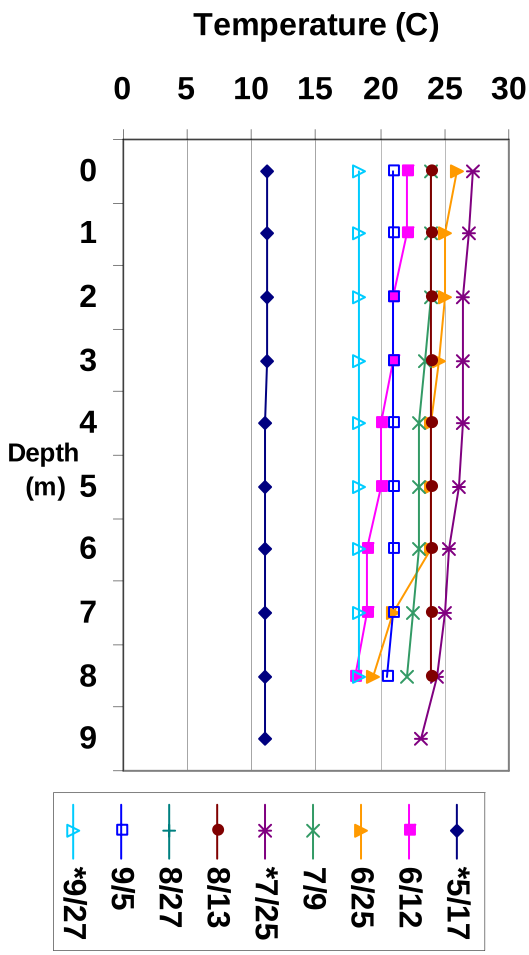
Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitor: Jon Gilmer. One site was used on Diamond Lake: Site 101– located over the point of maximum depth in the lake (Figure 13).

Figure 13. Diamond Lake Bathymetric Map and Monitoring Locations



Temperature data indicated that the lake was well mixed throughout the summer (Figure 14) with very slight thermal stratification below five to six meters in late June and early July. Surface temperatures ranged from 11° C in May to 27° C in July.

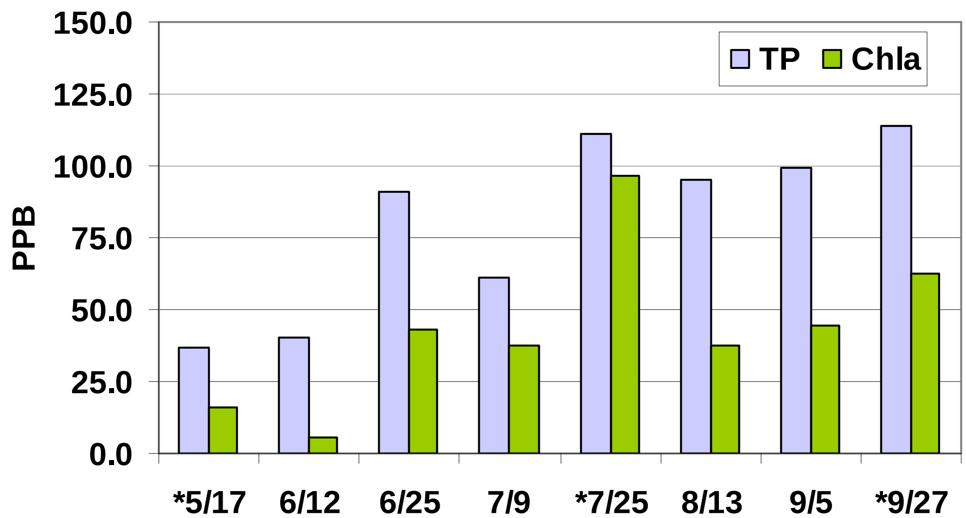
Figure 14. Diamond Lake Temperature Profile Data for 2005



Total phosphorus (TP) concentrations averaged 87 µg/L (micrograms per liter or parts per billion) in Diamond Lake during the summer of 2005. This value is above the NCHF range of concentrations for reference lakes in this ecoregion, but well within the WCBP ecoregion range (Table 2). TP concentrations ranged from 40 – 114 µg/L (Figure 15) and increased over the summer; again, consistent with other well-mixed lakes. TP samples collected one meter off the bottom of the lake in May, July and September were nearly identical to the surface samples collected at those same sampling events (Appendix), indicating that the lake was not stratified at those sampling events.

Chlorophyll-*a* concentrations for Diamond Lake averaged 47 µg/L and were more than twice the upper values for the NCHF ecoregion range but well within the WCBP ecoregion range (Table 2). Concentrations on Diamond Lake ranged from 5.6 – 96.7 µg/L with an increase in concentrations over the summer, with a dramatic increase in late July. Mild to nuisance algae blooms (chl-*a* >10 and >20 µg/L, respectively) were noted in May and early June for 2005 (Figure 15). Severe algae blooms (chl-*a* >30 µg/L) were noted on the remaining sampling occasions.

Figure 15. Diamond Lake Total Phosphorus and Chlorophyll-*a* Results for 2005



The composition of the phytoplankton (algae) population of Diamond Lake is presented in Figure 16. Data are presented in terms of algal type. Samples were collected at Site 101. The diatoms dominated the algal population in May and were fairly well represented the rest of the summer, given the strong dominance of bluegreens from June – September. The forms of *Anacystis* and *Aphanizomenon* were the most common bluegreens throughout the summer. The bluegreens, as a whole, are the forms most commonly associated with nuisance algal conditions. A seasonal transition in algal types from diatoms to greens to bluegreen is more typical for mesotrophic and eutrophic lakes in Minnesota.

Figure 16. Diamond Lake Algal Populations for 2005

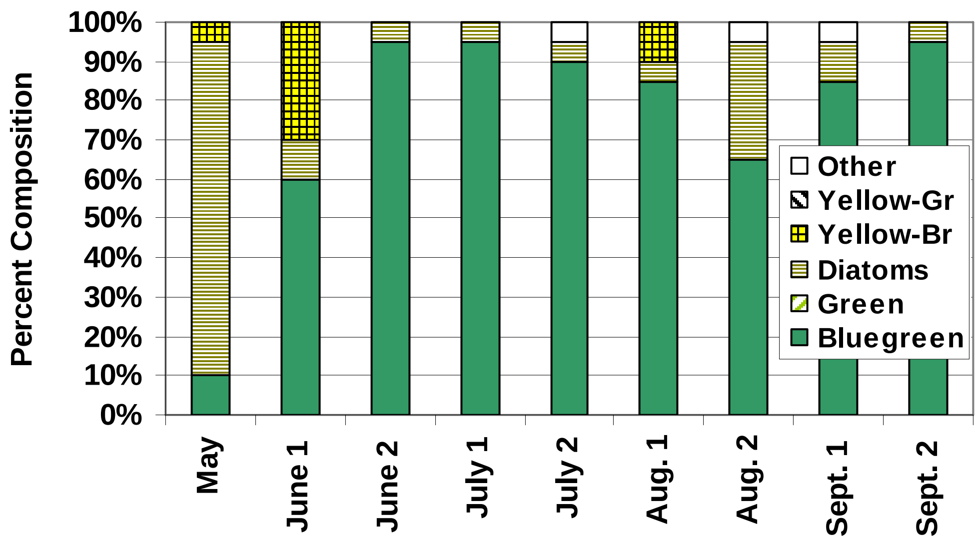
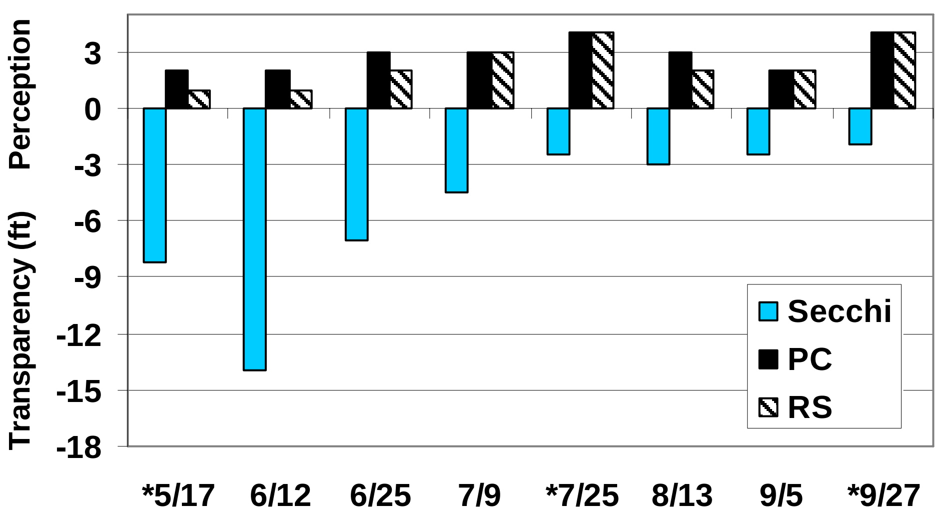


Figure 17. Diamond Lake Secchi Transparency for 2005



Secchi disk transparency on Diamond Lake ranged from 2 feet (0.6 meters) in late September to 14 feet (4.3 meters) in early June (Figure 17) and averaged 5.1 feet (1.5 meters). These transparency measures are within the typical range for NCHF ecoregion reference lakes and better than the typical range for WCBP reference lakes (Table 2). Lake condition (i.e. user perception) ratings by MPCA staff were routinely lower, indicating poorer water quality, than those provided by the volunteer lake monitor for a given Secchi reading. Physical condition ratings ranged from “not quite crystal clear” to “high algae levels” (Classes 2 – 4); while recreational suitability ratings ranged from “beautiful” to “no swimming” (Classes 1 – 4).

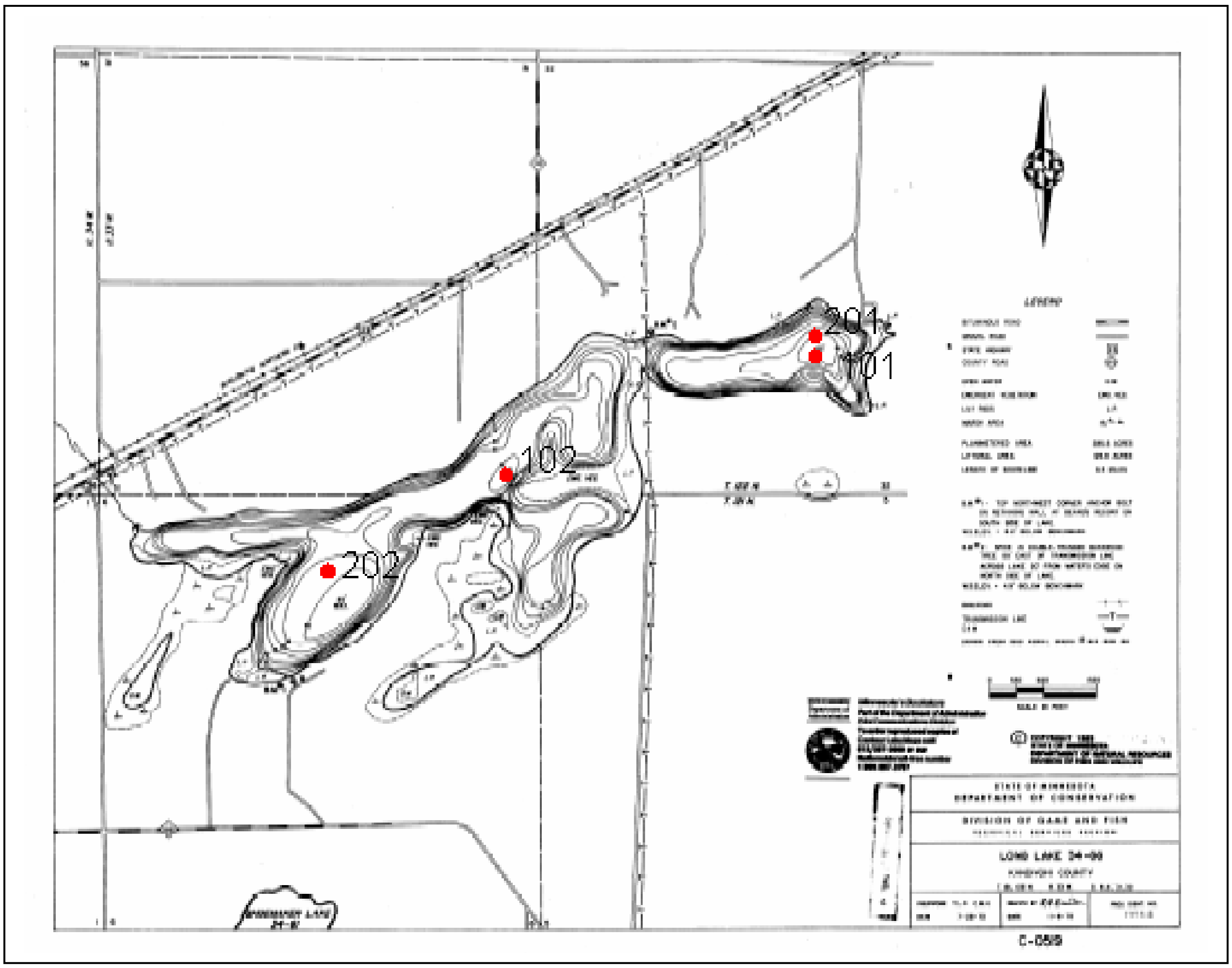
Other parameters, such as total suspended solids, total suspended inorganic solids, total Kjeldahl nitrogen, and chloride, analyzed for Diamond Lake were all above the typical range of values for NCHF ecoregion reference lakes but within the range of values for WCBP reference lakes (Table 2). Color, pH, and conductivity were within or near the range of values for both ecoregions (Table 2).

Trophic State Index (TSI) values for TP and chlorophyll-*a* compare very favorably to each other for Diamond Lake (Table 3); however, the TSI value for Secchi transparency was significantly lower than the other TSI values. Based on the 2005 data, Secchi transparency is not a good estimator for TP and chlorophyll-*a* values or indicator of overall water quality for Diamond Lake; however, it should still continue to be a good tool for examining transparency trends within the lake. The overall TSI value for Diamond Lake indicates *hypereutrophic* conditions.

LONG (34-0066)
Long Lake is located two miles southwest of Hawick, Minnesota. With a surface are of 286 acres, it is in the upper ten percent of lakes in terms of size; however, it is small compared to the other lakes monitored in 2005 from this county (>1,500 acres). It has a maximum depth of 46 feet and mean depth of 17.8 feet, making it the deepest lake monitored in 2005 from this county. Approximately 44 percent of the lake is littoral and there are two public accesses for the lake. Its direct and total watershed areas are small, covering only 1.4 mi^2 (Table 1, Appendix 2). Its water residence time is on the order of 12 years.

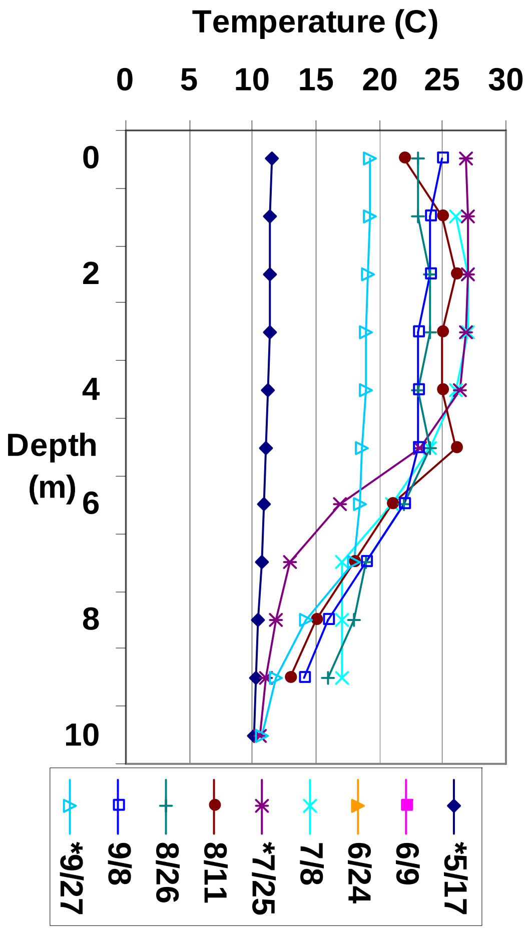
Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitor: Larry Zink. One site was used for collecting chemistry data and temperature profiles on Long Lake: Site 102 – located over the point of maximum depth in the lake (Figure 18). Sites 201(101) and 202 were monitored for Secchi transparency comparison only.

Figure 18. Long Lake Bathymetric Map and Monitoring Locations



Temperature data indicated that the lake was well mixed on the first and last sampling event; however, the remaining events indicated some thermal stratification below 4 – 6 meters (13.1 – 19.7 ft). Surface water temperatures ranged from 11.5°C in May to 27°C in July (Figure 19).

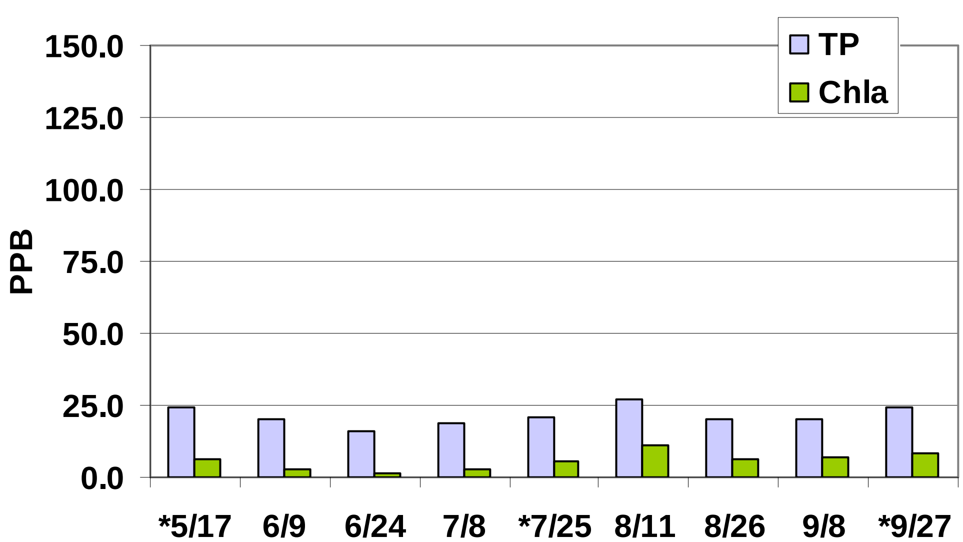
Figure 19. Long Lake Temperature Profile Data for 2005



Total phosphorus (TP) concentrations averaged 21 µg/L (micrograms per liter or parts per billion) in Long Lake during the summer of 2005. This value is better than the range of concentrations for reference lakes in the NCHF ecoregion (Table 2). TP concentrations ranged from 16 – 27 µg/L (Figure 20) with a slight peak in concentrations during the month of August. The August 11 peak TP may be due to runoff from rain events earlier in the week prior to sampling.

Chlorophyll-*a* concentrations for Long Lake averaged 6 µg/L and were within the NCHF ecoregion range (Table 2). Concentrations on Long Lake ranged from 1.7 – 11.1 µg/L with a peak in concentrations in August, corresponding to the peak in TP concentrations from that same sampling event (Figure 20).

Figure 20. Long Lake Total Phosphorus and Chlorophyll-*a* Results for 2005



The composition of the phytoplankton (algae) population of Long Lake is presented in Figure 21. Data are presented in terms of algal type. Samples were collected at site 102. The yellow-browns and bluegreens were well represented throughout the entire summer. The forms *Dinobryon* (yellow-brown), *Anacystis* and *Aphanizomenon* (bluegreens) were the most dominate algal kind for their respective algal groups. A seasonal transition in algal types from diatoms to greens to bluegreen is more typical for mesotrophic and eutrophic lakes in Minnesota.

Figure 21. Long Lake Algal Populations for 2005

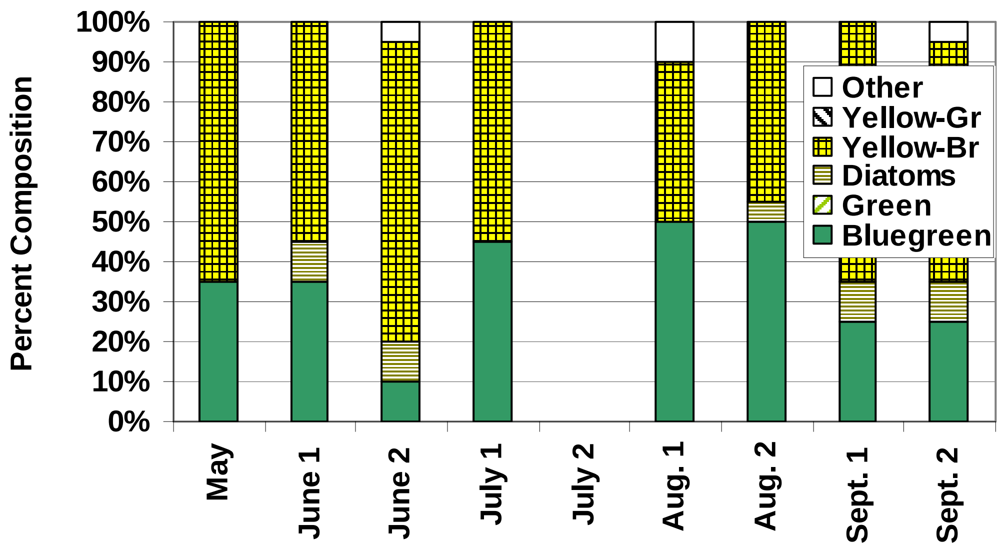
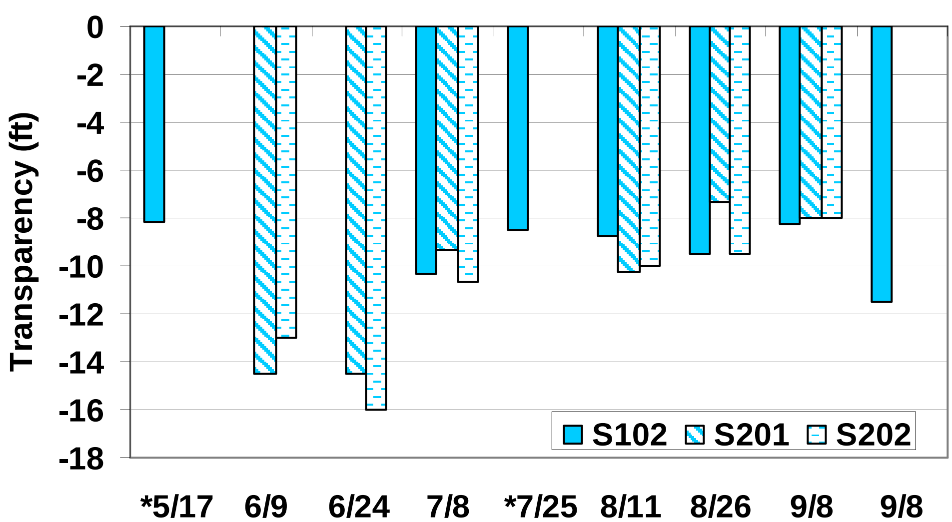


Figure 22. Long Lake Secchi Transparency for 2005



Secchi disk transparency at site 102 on Long Lake ranged from 8.2 feet in May to 11.5 feet in late-September (Figure 22) and averaged 9.5 feet (2.9 meters). These transparency measures are well within the typical range for NCHF ecoregion reference lakes (Table 2). Transparency data was also collected at sites 201 and 202. Those data ranged from 7.3 feet in August to 16 feet in late-June (Figure 22). There was no significant difference between the three sites on days with paired data. Overall, transparency tended to decline at all three sites after late-June. The physical condition of Long Lake was generally characterized as “crystal clear” and "not quite crystal clear" (Classes 1 and

2) throughout the summer at all three sites. The recreational suitability for Long Lake was generally characterized as "beautiful" and "minor aesthetic problems" (Classes 1 and 2) throughout the summer at all three sites as well (Appendix).

Other parameters, such as total suspended solids, total suspended inorganic solids, total Kjeldahl nitrogen, chloride and conductivity, analyzed for Long Lake were all near or well within the typical range of values for ecoregion reference lakes (Table 2). Color and pH values were slightly below of the range for NCHF ecoregion reference lakes; while alkalinity values were slightly above the range for NCHF ecoregion reference lakes (Table2).

Trophic State Index (TSI) values for Long Lake compare very favorably to each other (Table 3); therefore, Secchi transparency should continue to be a good estimator for TP and chlorophyll-*a* values, as well as an indicator of overall water quality for Long Lake. The overall TSI values for Long Lake indicate *mesotrophic* conditions.

Part 3. Water Quality Trends

All available Secchi transparency data from STORET (U.S. EPA's national water quality database) were used for these assessments. The majority of the data collected is from volunteer lake monitors in the MPCA's Citizen Lake-Monitoring Program. For our trend analysis, we ran Kendall statistical test using WQ Stat Plus™ software on the CLMP+ lakes with four or more transparency readings per summer (June – September) and eight or more years of data. We used a probability (p) level of $p \leq 0.1$ as the basis for identifying significant trends. At this p-level, there is a 10 percent chance of identifying a trend when it does not exist. Simply stated, the smaller the p-value, the stronger the trend (i.e. more likely a trend occurred). Summer-mean transparency in a lake varies from year to year due to climatic changes (precipitation, runoff, and temperature), nutrient and sediment loading, and biological factors. Understanding and quantifying the relative magnitude of this variability is essential to assessing trends. Based on a previous study (Heiskary and Lindbloom, 1993), typical year-to-year Secchi transparency variability was found to be on the order of 1 – 2 feet. In general, annual transparency in Minnesota lakes fluctuates within about 20 percent of the long-term mean. Lakes with larger fluctuations or non-random fluctuations, relative to the long-term mean, often exhibit a trend. Three of the Kandiyohi County CLMP+ lakes (Big Kandiyohi, Diamond and Long) were included for Secchi transparency trend analysis; while only one lake had sufficient nutrient data for trend analysis (Diamond). The figures of this section (Figures 23 – 34) contain a factor called standard error. Standard error is defined as the standard deviation of a dataset divided by the square root of the number of samples from that dataset. Standard error is a measure of variability within a dataset and provides a simple basis for comparing means. The closer the values are to each other, the smaller this line will be in following figures. Small standard error means minimal variability in the data during a given summer, whereas a large standard error implies a high degree of variability.

Big Kandiyohi Lake (34-0086)

Based on 18 years of data there has been some fluctuation, but an overall improvement in transparency is noted ($p<0.05$); however, the most recent two years' data do not follow this pattern with summer-means for 2004 and 2005 well below the long-term mean. Secchi transparency has ranged from a low of 1.5 feet in 1977 to a maximum of 6.1 feet in 2001 with a long-term average of 3.7 feet (Figure 23). It is important to note that there is a significant break in the record between the years: 1979 – 1985. Data for this period would help us improve our assessment of trends in Big Kandiyohi Lake.

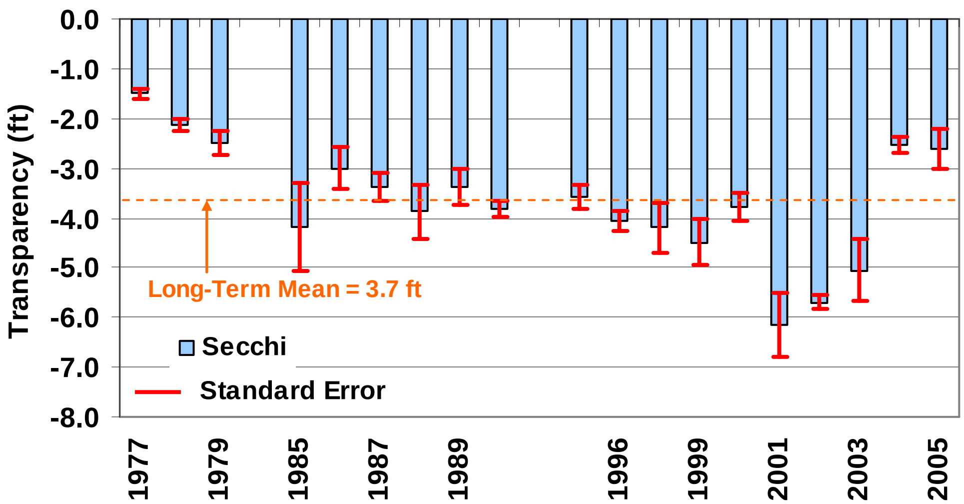
The history of Big Kandiyohi and Wakanda Lakes are intrinsically tied together because of both natural watershed connections (part of south Fork of the Crow River) as well as man-made changes in drainage patterns, discharge of wastewater effluent from Willmar and Kandiyohi and other factors. As a part of a 1985 MPCA Lake Assessment Program (LAP) study on Big Kandiyohi, a history was developed from several resources and has been updated to include new activities since that time (Table 4). We can now see when earlier monitoring studies were conducted as well as significant changes in the watershed of each of the lakes. In addition to these observations, MN DNR Shallow Lakes staff conducted assessments of the lakes as well. A summary of their findings is included in the appendix as well (Appendix 5).

Table 4. Big Kandiyohi & Wakanda Lakes Watershed Historical Summary

1895	State Capital Lands Ditch #1 constructed to improve natural drainage provided a defined waterway from Wagonga to Fanny to Big Kandiyohi to Lillian to Dog Lake.
1908	J.D. #1 established – completely changed natural drainage route – outlet of Wagonga to Fanny was blocked. Wagonga was connected to Little Kandiyohi ditch then passed to NE of Big Kandiyohi to Lake Lillian. Effectively diverted flow of South Fork of Crow from Fanny, Big Kandiyohi and Lillian. [Reduced watershed of Big Kandiyohi from 15:1 (watershed to surface area) to a ratio of less than 3:1.]
1920's	Levels of Big Kandiyohi Lake began to recede. Attempts were made to construct an auxiliary ditch from J.D. #1 to Big Kandiyohi. Temporary improvement in lake levels.
1931	A secondary sewage treatment plant was constructed at Willmar. Effluent discharged to C.D. 23A thence to Wagonga Lake.
1938	Drought – maximum depth – 4 feet.
1941	Minnesota Department of Natural Resources (MDNR) survey shows water level of Big Kandiyohi was about 10 feet below normal.
1945-55	Wet years filled in Big Kandiyohi and also flooded some surrounding land.
1950's	J.D. #1 was deepened to alleviate flooding. Made it difficult to divert water from J.D. #1 to Big Kandiyohi.
1953	Lake level was up, some problems with flooding of adjacent land.
1957	Ditch between J.D. #1 and Big Kandiyohi was constructed but become inoperative.
1967	Legislature allocates money for construction of an overland ditch from Wagonga to Big Kandiyohi.
1968	Toxic algae blooms noted on Big Kandiyohi. Diversion from overland ditch was halted.
1972	Lake Wagonga included in USEPA National Eutrophication Survey.
1978	Study of alternatives for augmenting water levels temporary pumping (by MDNR) from J.D. #1 to Big Kandiyohi to augment water levels.
1981	City of Willmar diverted discharge from Wagonga Lake to Hawk Creek.
1985	LAP study on Big Kandiyohi.
1989	Clean Lakes Phase I Study conducted on Big Kandiyohi
1990	Water control structure and fish barriers installed on outlet of Wagonga
1993	Winter aeration initiated in SW basin of Wagonga. Increased fish stocking.
1995-05	Grass Lake Wetland Restoration Project in various stages of planning
2005	Lake Wagonga name changed to Wakanda. CLMP+ study of both lakes.

A comparison of historical summer-mean TP and chlorophyll-*a* data is presented in Figures 24 and 25, respectively. Based on this data, there has been a marked increase in TP concentrations (Figure 24). Summer-mean TP concentrations range from a high of 175 µg/L in 1989 and 2005 to a low of 101 µg/L in 1978. Chlorophyll-*a* concentrations have also fluctuated over time, with peak summer-mean concentrations of 47 µg/L in 1978 and a low of 24 µg/L in 2005. It should be noted that variability of the chlorophyll-*a* samples was greater (i.e. standard error was greater) in 1978 and 1985 versus 1989 and 2005. Unfortunately, with only four years of data each, there is not enough data at this time to run a trend analysis on these two parameters.

Figure 23. Historic Big Kandiyohi Lake Secchi Transparency



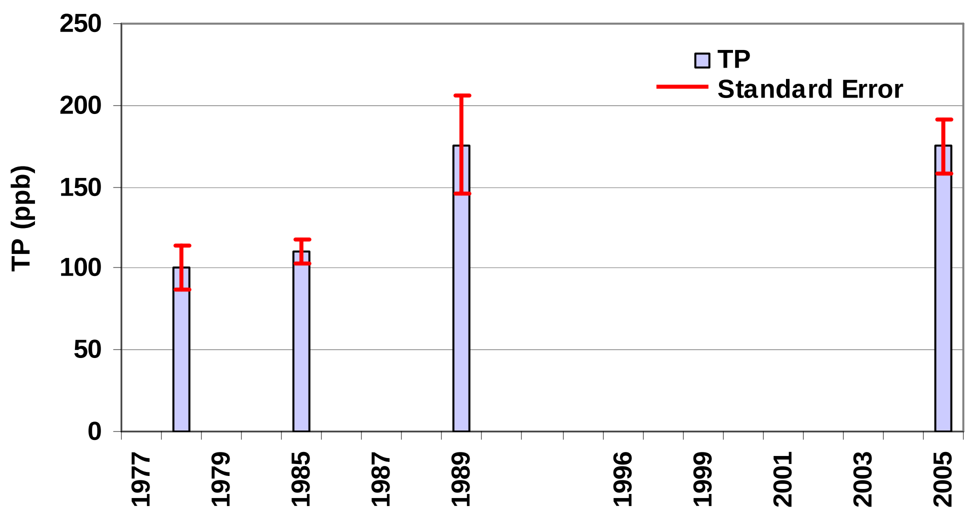


Figure 24. Historic Big Kandiyohi Lake Total Phosphorus

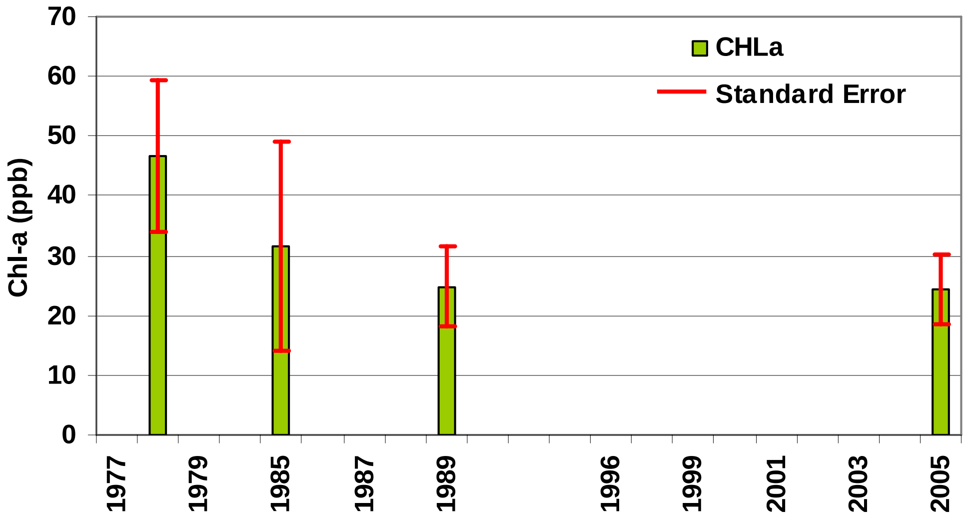


Figure 25. Historic Big Kandiyohi Lake Chlorophyll-*a*

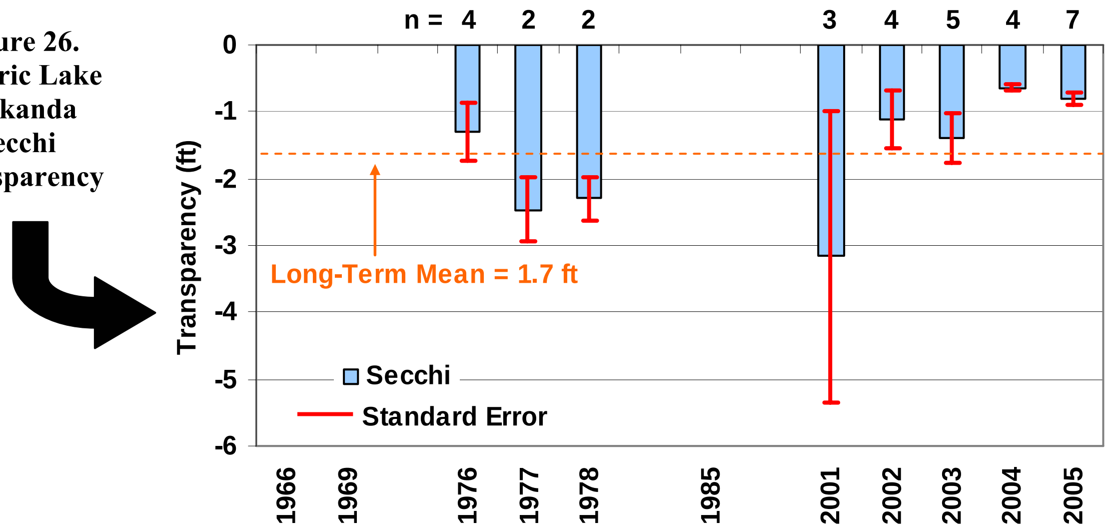
Lake Wakanda (34-0169-03)

The Secchi dataset for Lake Wakanda is poor. It includes large breaks in the record and many of the years have only two or three readings; therefore, the dataset does not have enough data for statistical analysis. Based on eight years of available data for the lake, there has been some fluctuation among years, as well as within any given year – particularly in 2001 (Figure 26). Secchi transparency has ranged from a low of 0.64 feet in 2004 to a maximum of 3.2 feet in 2001 with a long-term average of 1.7 feet (Figure 26). Consistent and continual monitoring will improve future assessments of trends in Lake Wakanda.

Lake Wakanda TP records date as far back as 1966; although there is a very significant record break between the late 1970's and 2000. A comparison of historical summer-mean TP and chlorophyll-*a* data is presented in Figures 27 and 28, respectively. These records also include large breaks and many of the years have only two readings; therefore, these datasets do not have enough data for statistical analysis either. Based on the available data, there has been a decrease in TP concentrations since the late 1970's (Figure 27). Summer-mean TP concentrations range from a high of 2,580 µg/L in 1977 to a low of 157 µg/L in 2005. The 1972 NES study of Wakanda reported TP values on the order of 1,000 µg/L for Wakanda (US EPA, 1974). These high values were a direct reflection of the wastewater from the Willmar Wastewater Treatment Facility (WWTF) discharged to Co. Ditch 23a, which US EPA estimated to contribute about 92% of the P-loading to the lake. The subsequent decline in Wakanda TP can be attributed to the diversion of the Willmar WWTF effluent away from the lake in 1981 (Table 4). TP in Co. Ditch 23a, though much reduced from levels measured in the 1960's and 1970's, remains somewhat high as a result of both nonpoint sources (urban and agricultural) and the City of Kandiyohi's WWTF discharge (Table 4). Along with this external loading, the lake must contend with internal recycling of phosphorus (P) from the sediments as a results of both physical processes like wind-mixing; which is quite intense on a shallow basin such as this, and chemical reactions that may allow P that is normally attached to soil particles to be released into the water column. Factors that promote this include low DO, high pH and/or high temperatures at the sediment-water interface.

Chlorophyll-*a* concentrations have fluctuated greatly over time, with peak summer-mean concentrations of 294 µg/L in 1976 and a low of 45 µg/L the following year in 1977. As noted in earlier discussion, Lake Wakanda was extremely efficient at converting TP to algal biomass in 2005 with a chlorophyll-*a* : TP ratio of 1:1 as compared to Big Kandiyohi, Diamond and Long Lakes with ratios of 0.14:1.0, 0.54:1.0 and 0.29: 1.0, respectively. Typical ratios for NCHF and WCBP lakes are on the order of 0.4:1.0 and 0.6:1.0, respectively (Heiskary and Wilson, 2005). It is likely that the smaller overall size and shallower mean depth (refer to Table 1) of Lake Wakanda does not allow the algae to be suspended below the euphotic (light penetrating) zone under wind-mixing conditions. As a result, the algae may not be "light-limited" as may be the case in Big Kandiyohi Lake or perhaps, even Diamond Lake.

Figure 26. Historic Lake Wakanda Secchi Transparency



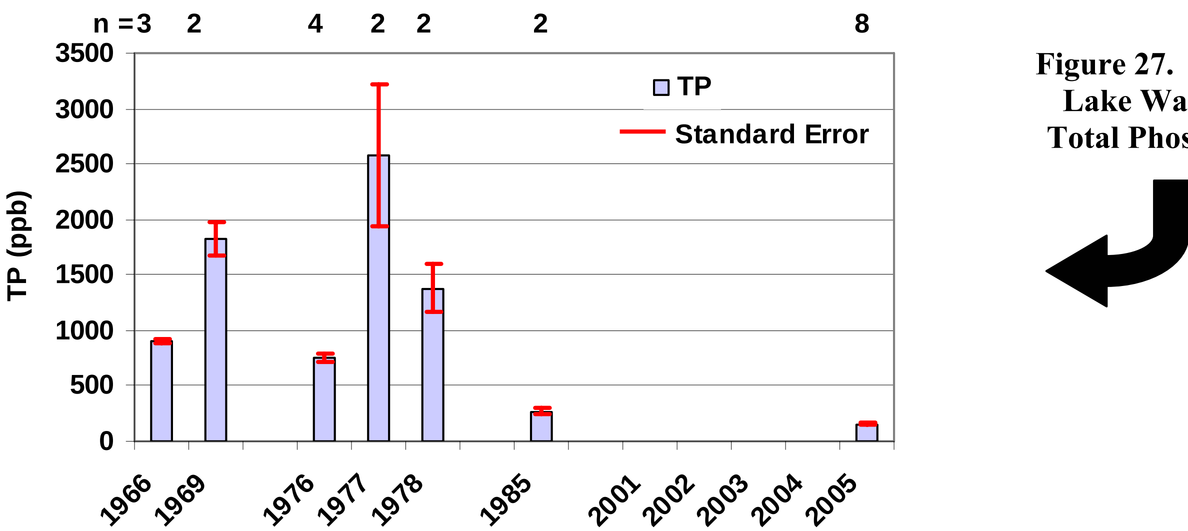


Figure 27. Historic Lake Wakanda Total Phosphorus

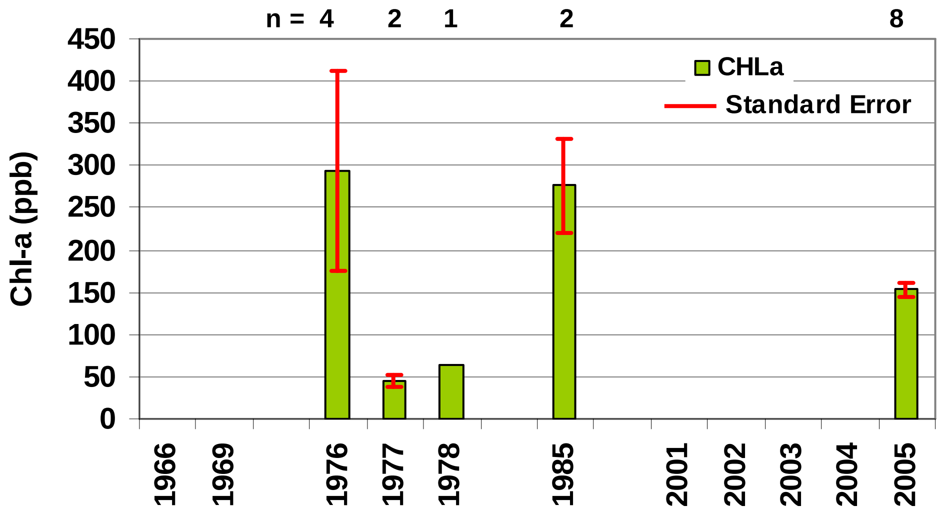
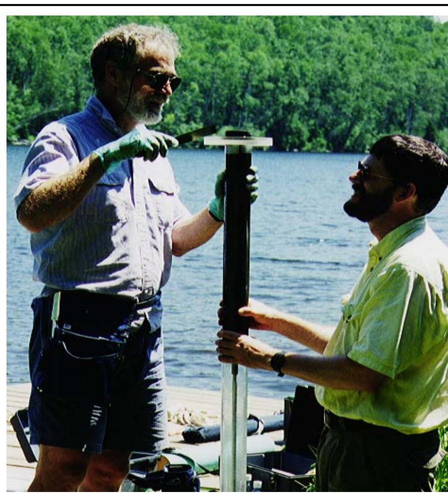


Figure 28. Historic Lake Wakanda Chlorophyll-*a*

Diamond Lake (34-0044)

Diamond Lake has an extensive Secchi transparency record dating back to the mid-1970's. Based on 24 years of data, there has been some fluctuation, but no overall trend in transparency is noted ($p>0.2$). Secchi transparency has ranged from a low of 3.3 feet in 2001 to a maximum of 9.6 feet in 1993 with a long-term average of 5.7 feet (Figure 29).

The total watershed area for Diamond Lake is very large, covering 36 mi^2 and is primarily comprised of agricultural land uses (Table 1, Appendix 2). Diamond Lake also has a long history of water quality problems and citizen concerns. The lake was included in the Clean Water Partnership Program (CWP) following a public meeting about declining water quality in 1990. The lake was also monitored as part of a diatom reconstruction project in 2002 using lake sediments to estimate background or pre-European conditions. Lake sediments can serve as historical archives of information on lakes and their watersheds. Dated core samples allow researchers to describe time trends in water quality. Because phosphorus is not stable in sediments, they do not give an accurate record of eutrophication. Rather, diatom fossils are used to estimate phosphorus (trophic status) for any given year in the past. Diatoms have long been used for this purpose because they are well-preserved in sediment cores and their environmental requirements are well known and documented. For more detailed information on this study, refer to Heiskary and Swain, 2002.



Lake sediment core – similar to the sample from Diamond Lake Photo: Ed Swain-MPCA

The 1993 diatom-derived phosphorus value corresponds quite well with monitoring data from 1990 - 2005 (Figure 30). Diatom-derived phosphorus from ~1750, 1800 and

1970; along with subsequent monitored values, reveal a distinct increase in TP concentration in Diamond Lake over time. Based on a combination of the diatom-inferred TP and modern-day observed-TP we see the following, almost step-wise increases in TP over time as follows:

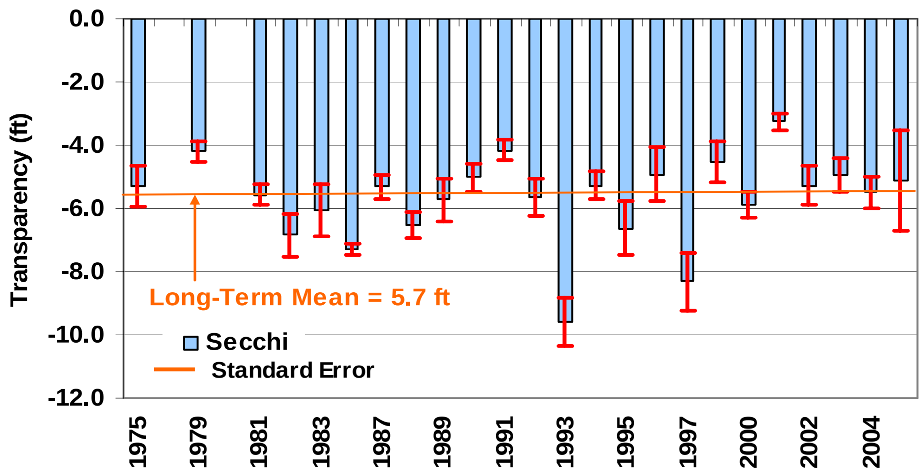
- Pre-European: ~ 25 – 29 µg/L;
- 1970's- early 1980's: ~ 35 – 50 µg/L
- 1990's – 2005: ~ 60 – 100 µg/L

These data clearly indicate that Diamond Lake is currently much more eutrophic than it was in pre-European times; and even more troubling is the continued increase in TP over the past decade or two (since about 1980). Absent any point sources in the watershed these increases are most likely a function of past or changing landuses or landuse practices in the watershed.

Chlorophyll-*a* concentrations for Diamond Lake date back to 1990 and have fluctuated greatly over time (Figure 31). There is a significant break in the record after 1990; as no chlorophyll-*a* data was collected again until 1997. Concentrations have generally increased over time, with peak summer-mean concentrations of 47 µg/L in 2005 and a low of 21 µg/L in 1998. Standard error for chlorophyll-*a* was quite high in 1997 (25.3 µg/L) indicating high within year variability; however, there were only two chlorophyll-*a* samples collected that year, one in July and one in September. Based on the high average concentrations it is estimated that nuisance blooms (chlorophyll-*a* > 30 µg/L) likely occur from 30 – 60 % of the summer in most years.

While Diamond has a good dataset for trend assessment it will be important to continue monitoring to allow for future trend assessments and provide a basis for evaluating changes that may occur as a result of Total Maximum Daily Load (TMDL) development and implementation.

Figure 29. Historic Diamond Lake Secchi Transparency



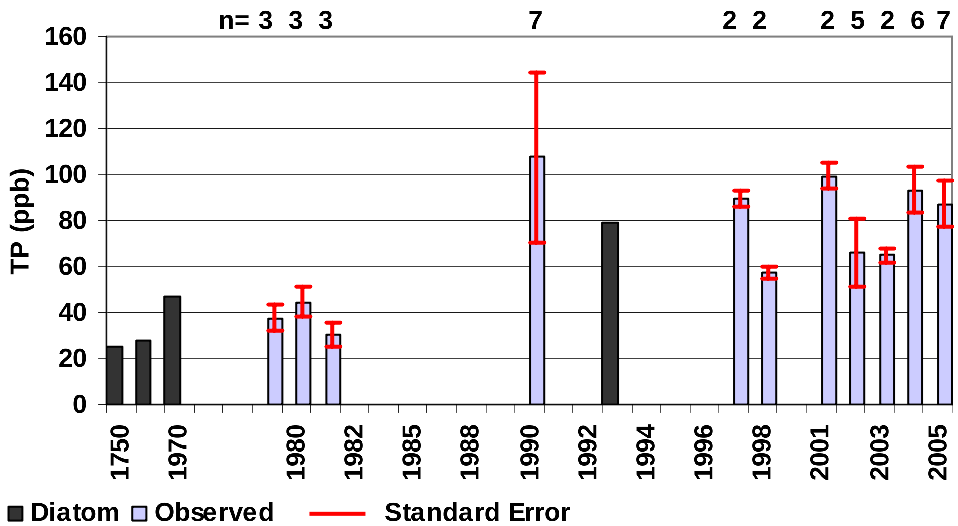
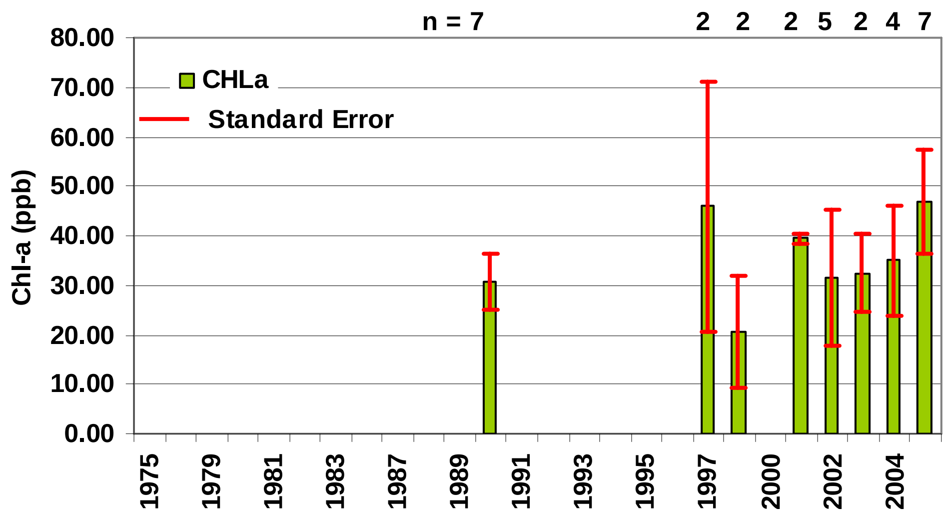


Figure 30. Historic Diamond Lake Total Phosphorus

Figure 31. Historic Diamond Lake Chlorophyll-*a*



<u>Long Lake (34-0066)</u>

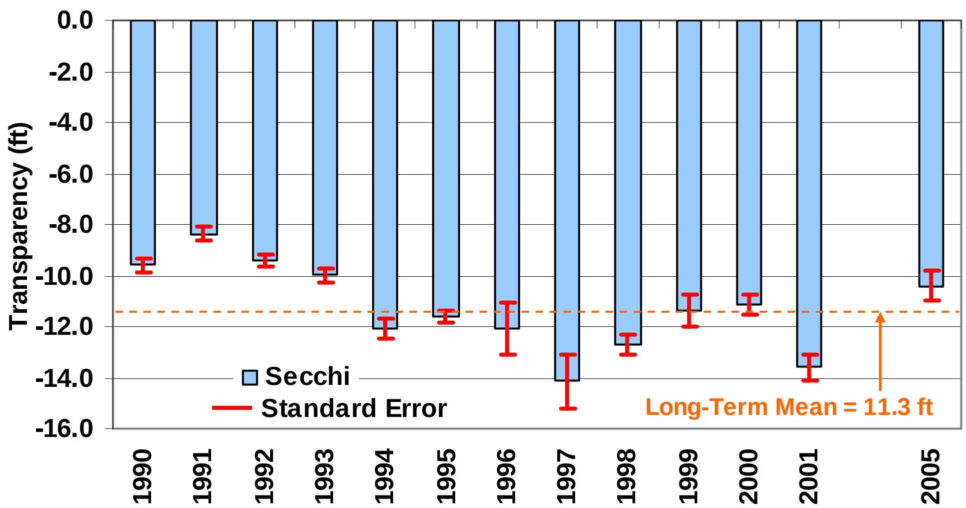
Based on 13 years of Secchi transparency data, there has been some fluctuation in transparency, with an overall improvement in transparency noted ($p>0.1$). Secchi transparency has ranged from a low of 8.4 feet in 1991 to a maximum of 14.2 feet in 1997, with a long-term average of 11.3 feet (Figure 32). Typically, lakes fluctuate between 1 – 2 feet of the long-term mean. Although transparency in 2005 was less than previous years, at 10.4 feet, it is still within 1 – 2 feet of the long-term mean.

Long Lake was also included as part of a diatom reconstruction project in 2002 using lake sediments to estimate background or pre-European conditions. A comparison of diatom-inferred and historical summer-mean TP data is presented in Figure 33. Based on this data, there has been a slight, although not statistically significant decline in TP concentrations since 1990 (Figure 33); however, there is no difference between the average of the diatom-inferred TP (22.3 µg/L) and actual observed TP (18.5 µg/L) once standard error is taken into account. Summer-mean TP concentrations range from a high of 20.9 µg/L in 2005 to a low of 15.5 µg/L in 1998. Standard error for these data ranged from ~ 1 – 4 µg/L, indicating minimal variability between samples.

Likewise, chlorophyll-*a* concentrations have also fluctuated over time, with peak summer-mean concentrations of 6.5 µg/L in 1997 and a low of 3.0 µg/L in 1998. Standard error for these data was consistent at ~ 1 µg/L for each year monitored, indicating minimal variability between samples.

There are not enough years of data to run a trend analysis on either TP or chlorophyll-*a* at this time; however, when combined with the Secchi data, it is apparent that Long Lake has experienced a slight increase in TP and chlorophyll-*a* in 2005, which would contribute to the subsequently noted decline in transparency in 2005. There is a break in the Secchi record from 2002 – 2004. Data from this time period would have given a more complete picture of the change in transparency for Long Lake.

Figure 32. Historic Long Lake Secchi Transparency



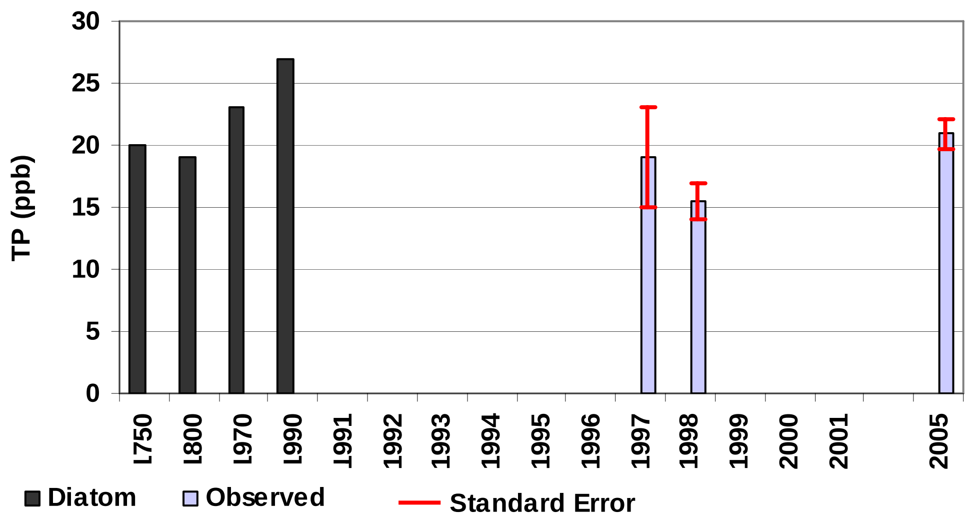
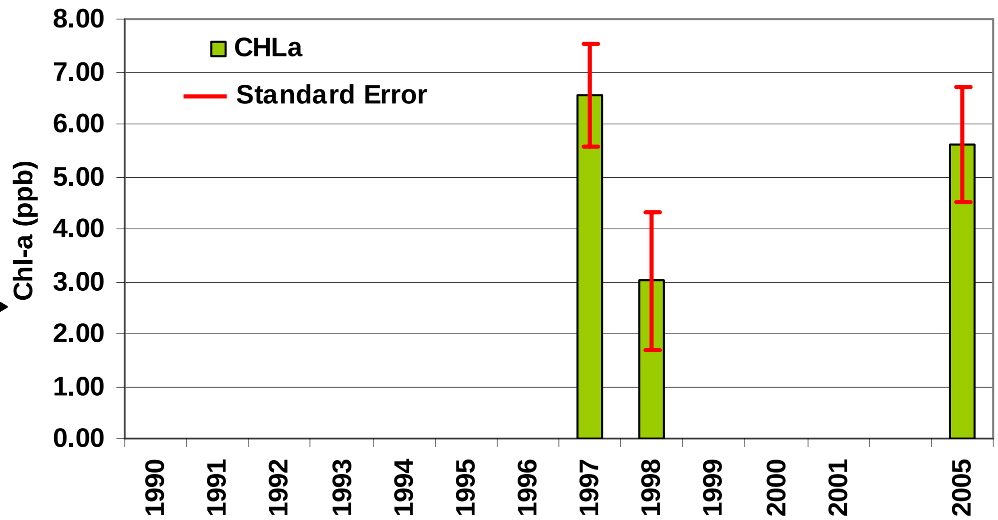


Figure 33. Historic Long Lake Total Phosphorus

Figure 34. Historic Long Lake Chlorophyll-*a*



Part 4. Water Quality Modeling

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration of each lake. These predictions are based on: lake area, mean depth, watershed area, and ecoregion in which the lake is located. Known information such as lake and watershed areas, and mean depth are inputs to the model; which in turn, computes a "predicted" TP value. The predicted TP value is used to predict a chlorophyll value, which in turn, is used to predict a Secchi value. The predicted values can then compared to the observed values (summer means) for each lake to determine if the lake's condition is what would be expected – based on its size, depth and watershed area. The model has some limitations in that it cannot take into account groundwater influence and cannot account for TP-trapping or settling in large lakes that may be upstream of the lake being modeled.

A subroutine in the MINLEAP model provides an estimate of background TP concentration for each lake based on its mean depth and alkalinity. This estimate was derived from an equation developed by Vighi and Chiaudani (1985) and is based on the morphoedaphic index commonly used in fisheries science. This equation assumes that most of the phosphorus entering the lake arises from soil erosion in the watershed, and that phosphorus and other minerals, which contribute to alkalinity, are delivered in relatively constant proportions. In turn, the mean depth of the lake will moderate the in-lake phosphorus concentration (e.g. deep lakes settle material readily, which contributes to low phosphorus concentrations). This estimated "background" concentration helps place modern-day results and goal setting in perspective. Mean depth and volumes were found for each lake in existing literature or from the MNDNR. Watershed area information was derived for all lakes based on the MNDNR and USGS web sites. In addition, watershed maps for these area lakes are included in the appendix.

Lake Wakanda

Lake Wakanda is a large lake covering about 1,560 acres. The total watershed area for Lake Wakanda is about 22.9 miles square based on US EPA (1974) NES report. Using this watershed area and lake morphometric data (Table 1) MINLEAP predicts an in-lake TP of 117 ± 44 µg/L. The Vighi-Chiaudani model predicted a significantly lower TP concentration for lake as compared to the 2005 observed value (Table 4). TP-loading for Lake Wakanda is estimated to be on the order of 4,587 kg P/yr, based on the total watershed area and the predicted in-lake TP value. *(Note: there are 2.2 pounds of phosphorus per kilogram.)* The actual loading is likely much higher given that the observed in-lake TP was 157 µg/L. The TP-retention coefficient is estimated to be 0.79. This means that roughly 79 percent of the TP that enters Lake Wakanda stays in the lake. The observed 2005 chlorophyll-*a* concentration for the lake (153 µg/L) is higher than the MINLEAP predicted value (69 ± 45 µg/L). The predicted Secchi transparency (0.6 ± 0.3 m) is slightly better than the 2005 observed (0.2 m) for Lake Wakanda.

The Lake Wakanda Watershed Group conducted some monitoring of Co. Ditch 23a and a ditch that flows from the City of Kandiyohi during 2005. This monitoring was conducted to determine relative concentrations of TP, bacteria and other constituents in the tributaries and gain some sense as to the significance of these sources on the water quality of Lake Wakanda. A detailed analysis of that data was prepared in a memorandum to the Watershed Group (Heiskary, 2005) and is available upon request. A summary of mean TP concentrations for 2005 from that study are as follows:

- Ditch 23a @ Willmar freeway bypass (above Kandiyohi ditch): TP = 233 ± 13 µg/L
- Kandiyohi ditch at Co. Rd 8 TP = 593 ± 104 µg/L
- Ditch 23a at Co. Rd. 19 at inflow to Wakanda: TP = 338 ± 43 µg/L

When the model was calibrated and rerun using a TP-stream concentration of 338 µg/L as provided by the Watershed Group (above), MINLEAP predicted even lower concentrations than were observed in 2005 (Table 5). Overall, the model predictions suggest that in-lake quality could be better than observed based on the size of the lake, its depth and watershed size. Current loads are likely higher than we have estimated using MINLEAP and it is quite likely that internal recycling from the lake sediments plays an important role as well.

Big Kandiyohi Lake

Big Kandiyohi Lake is a large lake covering 2,526 acres. The total watershed area for the lake is on the order of 31,488 acres including the lake based on the 1985 LAP report (Heiskary, 1986). However, the exact area is a bit hard to discern given the ditch and watershed alterations over time (Table 4). For the purposes of this discussion and modeling we will use the area as reported in Heiskary (1986). MINLEAP predicted a significantly lower TP concentration (112 ± 43 µg/L) than the 2005 observed value (175 µg/) for Big Kandiyohi Lake, based on the total watershed area. The Vighi-Chiaudani model predicted a background TP of about 31 µg/L (Table 5), which is in the range of the pre-European diatom-inferred values for Diamond Lake (Figure 30). TP-loading for Big Kandiyohi Lake is estimated to be on the order of 9,000 kg P/yr, based on the total watershed area. The TP-retention coefficient is estimated to be 0.80 based on the predicted TP value. Predicted chlorophyll-*a* is actually higher than 2005 observed and suggests that chlorophyll-*a*: unit TP was lower than expected in Big Kandiyohi in 2005. The predicted Secchi transparency (0.7 ± 0.3 m) is similar to the 2005 observed (0.8 m) for Big Kandiyohi Lake. The difference between the observed and predicted TP may be a function of underestimating the external loading to the lake and/or not taking internal recycling into consideration; which on a large, shallow lake like Big Kandiyohi could be considerable.

Table 5. MINLEAP Model Outputs & Predictions for Kandiyohi CLMP+ Lakes

LAKE	TP (µg/L) Observed[1]	TP (µg/L) Predicted	TP (µg/L) Vighi-Chiaudani	Chl-a (µg/L) Observed[1]	Chl-a (µg/L) Predicted	Secchi (m) Observed[1]	Secchi (m) Predicted
Wakanda[3]	**157 ± 8**	117 ± 44	32	**153 ± 9**	69 ± 45	**0.2 ± 0.03**	0.6 ± 0.3
Wakanda[3,4]	**157 ± 8**	83 ± 30	32	**153 ± 9**	42 ± 27	**0.2 ± 0.03**	0.9 ± 0.4
Big Kandiyohi[2]	**175 ± 17**	78 ± 32	31	**24 ± 6**	39 ± 27	**0.8 ± 0.1**	0.9± 0.4
Big Kandiyohi[3]	**175 ± 17**	112 ± 43	31	**24 ± 6**	65± 43	**0.8 ± 0.1**	0.7 ± 0.3
Diamond[2]	**87 ± 10**	37 ± 14	25	**47 ± 11**	13 ± 8	**1.5 ± 0.5**	1.7 ± 0.7
Diamond[3]	**87 ± 10**	43 ± 15	25	**47 ± 11**	16 ± 10	**1.5 ± 0.5**	1.5 ± 0.6
Diamond[2,5]	***87 ± 10***	*79 ± 32*	*24.7*	***47 ± 11***	*39 ± 27*	***1.5 ± 0.5***	*0.9 ± 0.4*
Diamond[3,5]	***87 ± 10***	*98 ± 39*	*24.7*	***47 ± 11***	*54 ± 36*	***1.5 ± 0.5***	*0.7 ± 0.3*
Long[2,3]	**21 ± 1**	25 ± 10	24	**6 ± 1**	7.2 ± 5.1	**2.9 ± 0.2**	2.4 ± 1.1

[1]Observed values reported as summer-mean ± standard error.
[2]Predicted values based on the direct watershed.
[3]Predicted values based on the total watershed.
[4]Lake Wakanda model run calibrated for TP-inflow from Lake Association provided data.
[5]Diamond Lake values calibrated for the WCBP ecoregion.

Diamond Lake

Diamond Lake is a large lake covering 1,565 acres. It has a large direct and total watershed area of 22 and 36 mi^2, respectively (Table 2). MINLEAP was run for both watershed areas using NCHF and WCBP ecoregion input values. MINLEAP, when based on the NCHF and direct watershed area, predicted a slightly lower, but not significantly different TP concentration (79 ± 32 µg/L) than the 2005 observed value (87 µg/L) for Diamond Lake (Table 5). When MINLEAP was run a second time and based on the total watershed area; the model predicted a higher, but not significantly different, TP value (98 ± 39 µg/L) than the 2005 observed value for the lake (Table 5). The Vighi-Chiaudani predicted background TP is similar to the pre-European diatom-inferred TP values (Figure 30). Results from the WCBP-calibrated runs corresponded more closely to 2005 observed values (Table 4). Using the WCBP inputs; which yielded a predicted TP in the range of the observed TP, loading for Diamond Lake is estimated to be on the order of 4,400 – 7,100 kg P/yr. The TP-retention coefficient is estimated to range between 0.73 – 0.86 depending on which model scenario is used. In contrast to the WCBP scenarios, the NCHF model runs suggest an in-lake TP on the order of 37 – 43 µg/L. This concentration range is consistent with 1980's observed data and diatom-inferred for circa 1970 (Figure 30). These in-lake TP values correspond to loading rates on the order of 1,300 – 2,000 kg P/yr.

Long Lake

Long Lake is a moderate-sized lake covering 286 acres. The direct and total watershed areas are equivalent at 1.4 mi^2 (Table 1). MINLEAP predicted a slightly higher, but not significantly different TP concentration (25 ± 10 µg/L) than the 2005 observed value (Table 5). The Vighi-Chiaudani model was in the same range as well and was only slightly higher than the diatom-inferred TP values (Figure 33). TP-loading for the lake is estimated to be on the order of 105 kg P/yr, and the TP-retention coefficient is estimated to be 0.88. The predicted chlorophyll-*a* concentration was slightly, but not significantly higher than the 2005 observed value; and subsequently, the predicted Secchi transparency value was slightly lower than the 2005 observed value. Overall, the model does a good job of estimating concentrations and values for Long Lake and suggests the lake is at or near "background" condition.

Part 5. Goal Setting

For several of the lakes involved in this study: Big Kandiyohi, Wakanda, and Diamond Lakes; it would be desirable to reduce overall in-lake TP concentrations. These lakes were more nutrient rich than predicted "background" conditions expected and an overall reduction in in-lake TP and nutrients from the contributing watersheds would be needed to achieve "background" conditions. For Long Lake it would be desirable to maintain the currently low in-lake TP-concentrations. The summer-mean TP-concentrations for this lake was near or better than both the predicted TP-value and Vighi and Chiaudani "background" estimate.

Based on 2005 data (Table 5) Diamond, Big Kandiyohi and Wakanda Lakes exceed the listing thresholds for the 303(d) "Impaired Waters Listing" (Table 6). Twelve pairs of TP, chlorophyll-*a*, and Secchi data are needed to "officially" determine whether a lake is listed on the impaired waters list. Diamond Lake had sufficient data prior to the 2005 sampling and was found to exceed both the TP and chlorophyll-*a* threshold. It was placed on the draft 2006 303(d) list that will be provided to US EPA later in 2006. Given that Big Kandiyohi and Wakanda Lakes are in excess of these thresholds and draft criteria (Table 7), which will replace the values in Table 6 once the criteria are adopted into Minnesota's water quality standards, it would be wise to gather the four additional samples needed in order to have the lakes assessed for 303(d) listing. Once a lake is listed, a detailed and formal study of the lake and watershed are conducted to determine actual nutrient sources and loadings to the resource. Subsequently, a plan is developed for the resource for overall nutrient reduction. This can be a long, detailed, and sometimes complicated process but Federal 319 funds and CWP grant funds are available to help develop the TMDLs.

In the meantime, some important considerations for improving and protecting the water quality of all the lakes in this study include implementation of BMP's in the shoreland areas and ultimately through the watersheds with a particular emphasis on the direct drainage areas. A more comprehensive review of land use practices in the watersheds may reveal opportunities for implementing BMPs in the watersheds and reducing TP-loading to the lakes. Proper maintenance of buffer areas between lawns and the lakeshore, minimizing use of fertilizers, and minimizing the introduction of new significant sources of TP-loading (e.g., stormwater from near-shore development activities in the watershed), will serve to minimize loading to the lakes. These and other considerations will be important if the water quality of these Kandiyohi County lakes is to be maintained or improved over the long term.

Table 6. Nutrient and Trophic Status Thresholds for Determination of Use Support for Lakes.

Ecoregion (TSI)	TP (ppb)	Chl (ppb)	Secchi (m)	TP Range (ppb)	TP (ppb)	Chl (ppb)	Secchi (m)
305(b):	**Full Support**			*Partial Support*	*Non-Support*		
303(d):	**Not Listed**			**Review**	**Listed**		
NCHF	**< 40**	**< 15**	**≥ 1.2**	**40 - 45**	**> 45**	**> 18**	**< 1.1**
(TSI)	(< 57)	(< 57)	(< 57)	(57 – 59)	(> 59)	(> 59)	(> 59)
WCBP	**< 70**	**< 24**	**> 1.0**	**70 - 90**	**> 90**	**> 32**	**< 0.7**
(TSI)	(< 66)	(< 61)	(< 61)	(66 – 69)	(> 69)	(> 65)	(> 65)

Derived from MPCA Guidance Manual for Assessing Minnesota Surface Waters for Determination of Impairment (MPCA 2003). *TSI* = Carlson's Trophic State Index; *Chl-a* = Chlorophyll-*a*, includes both pheophytin-corrected and non-pheophytin-corrected values; *ppb* = parts per billion or µg/L; *m* = meters

Table 7. Draft Eutrophication Criteria by Ecoregion & Lake Type with 2005 Observed Summer-Means (Heiskary and Wilson, 2005)

Ecoregion	TP (ppb)	Chl-*a* (ppb)	Secchi (meters)
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

Kandiyohi Lakes: 2005 Observed (Ecoregion)	TP (ppb)	Chl-*a* (ppb)	Secchi (meters)
Long (NCHF)	21	6	2.9
Diamond (NCHF)	87	47	1.5
Wakanda (WCBP)	157	153	0.2
Big Kandiyohi (WCBP)	175	24	0.8

Part 6. Summary & Recommendations

During the summer of 2005, four lakes in Kandiyohi County were sampled by CLMP volunteers as a part of a monitoring program, CLMP "Plus". These lakes (Big Kandiyohi, Wakanda, Diamond and Long) were selected because they were a priority, exhibited a trend or lacked data beyond CLMP Secchi data. The combination of water chemistry and Secchi data provides a good baseline for these lakes. Following are a few general observations and recommendations based on our monitoring and data analysis:

A. Secchi transparency monitoring: All the selected lakes have participated in CLMP in the past. Monitoring Secchi transparency provides a good basis for estimating trophic status and detecting trends; therefore, routine participation is essential to allow for trend analysis. Of the four lakes, only Wakanda Lake lacked enough years of data needed for trend analysis. Continued CLMP monitoring on all the lakes will contribute to the database which already exists and allow for further and future trend assessments.

B. Water quality and trophic status: Based on data collected in 2005, all of the lakes except Long Lake exhibited TP concentrations above the typical range for minimally-impacted lakes in their ecoregion. These lakes were much higher than the typical range; most likely as a result of the lakes being: large, shallow and well-mixed; having very large watersheds and and being hypereutrophic. Conversely, Long Lake's TP concentration was actually better than the expected range and is considered mesotrophic. Lake Wakanda exhibited chlorophyll-*a* concentrations above the typical range for reference lakes, while Big Kandiyohi and Long Lake values were better than the typical range for the ecoregions in which they are located. Diamond Lake values were within the range for the WCBP ecoregion, but above the NCHF ecoregion. Secchi transparency values for the lakes were all within ecoregion reference ranges, with the exception of Lake Wakanda; which was poorer than expected. Big Kandiyohi, Wakanda, and Diamond Lakes are all candidates for 303(d) listing (with Diamond appearing on the 2006 draft list). In the case of Big Kandiyohi and Wakanda Lakes the associations are encouraged to gather additional samples in 2006 so that the lakes may be assessed as part of the 2008 303(d) listing.

C. Water quality trends: Of the four lakes monitored, only Lake Wakanda lacked a sufficient number of previous years of Secchi data for trend analysis. Statistical improvements in transparency were found for Big Kandiyohi and Long Lakes; while Diamond Lake showed no statistical trend over time. Diamond Lake, however did exhibit a significant increase in TP over time based on diatom-inferred data for the periods: 1750, 1800, 1970 and 1990 and observed water quality data for the period from 1980 through 2005. The combination of these data suggest modest increases in TP for the period between the 1800s and circa 1970; however a dramatic increase in TP occurred over the past 10 – 15 years. These increases are likely a function of increased agricultural activity in the watershed, more intensive shoreland development and related factors. Continued monitoring of all of these lakes will enhance our ability to assess trends.

D. Model predictions: MINLEAP underestimated in-lake TP for Wakanda, Big Kandiyohi, and Diamond Lakes, which implies that these lakes are much more nutrient-rich than we would anticipate based on their size, depth and the ecoregion in which they are located. The

MINLEAP estimate for Diamond corresponded quite nicely with monitored and diatom-inferred values from the 1970 – 1980 period. In general the model estimates can provide some perspective on the load reductions that might be required to achieve reduced concentrations as well as the potential changes in chlorophyll-*a* and Secchi as a result of those changes. In the case of Long Lake observed and model predicted values corresponded rather well.

E. Watersheds: With the exception of Long Lake, these lakes are of very poor water quality. Every effort to protect Long Lake from degradation and steps to reduce TP-loading to the other three lakes should be taken. Further development or land use change in the watersheds should occur in a manner that minimizes water quality impacts on the lakes. In the shoreland areas, setback provisions should be strictly followed. MDNR and County shoreland regulations will be important in this regard. Other considerations for these lakes follow:

- Stormwater regulations should be strictly adhered to during and following any major construction/development activities in the watershed. Limiting the amount of impervious surfaces can have beneficial affects as well, in terms of reduced runoff and P-loading as both high volume and high concentration can impact downstream wetlands, rivers and lakes. Properly designed sedimentation ponds should be included in any development to minimize P-loading to the lakes. A "no-net-increase" in TP is recommended in the case of Long Lake and would be beneficial to the other lakes as well.
- Agricultural activities in the watershed including row crop cultivation and land application of bio-solids from animal confinement areas should be conducted in such a way as to minimize runoff of nutrient and sediment rich water to watercourses (ditches, rivers, wetlands and lakes) in the watershed. Likewise pasturing operations should be managed so as to minimize erosion adjacent to watercourses and when possible animals should be kept out of watercourses. Maintaining vegetated buffers (1 rod minimum) will help to stabilize ditch and stream banks and should help minimize transport of nutrients and sediments from upland areas in the watershed.
- The City of Kandiyohi discharges treated wastewater upstream of Co. Ditch 23a which flows toward Lake Wakanda. While TP concentrations for this small facility are in the typical range for that type of facility there may be a need for a phosphorus effluent limit for this facility in a future permit to minimize the loading from this source. At this point we have not documented the exact contribution of this source; however its impact on stream concentration was quite evident in the 2005 monitoring conducted by the Wakanda Lake Watershed Group.
- Activities in the watersheds that change drainage patterns, such as wetland removal or major alterations in lake use, should be discouraged unless they are carefully planned and adequately controlled. Restoring or improving wetlands in the watersheds (e.g., Grass Lake in Wakanda watershed) may also be beneficial for reducing the amount of nutrients or sediments that reach the lakes. The U.S. Fish and Wildlife Service at Fort Snelling may be able to provide technical and financial assistance for these activities.
- The lake associations should continue to seek representation on boards or commissions that address land management activities so that their impact can be minimized. The booklet, Protecting Minnesota's Waters: The Land-Use Connection, may be a useful educational tool in this area.

- Macrophyte population and distribution maps for each lake may be beneficial to the associations. Exotic species such as *Eurasian water milfoil* and *curly-leaf pondweed* can dramatically impact resources such as these CLMP+ lakes in Kandiyohi County. Tracking the population and distribution of rooted aquatic plants can be helpful in determining if changes within the system are occurring and be a possible warning signs for those changes.

F. Septics: On-site septic systems are a *potential* source of nutrients to lakes that are not sewered. While their influence may not be express in terms of dramatic increases in algae in the lake, they may be expressed by increased near-shore weed growth or excessive attached algae on docks and plants. A house-to-house septic system survey may help the individual lake associations and Kandiyohi County determine if homeowners are somewhat familiar with the age and maintenance (pumping) of their systems and if further education is needed on proper maintenance of their systems. This may also help them encourage all homeowners with non-code systems to bring their systems up to code. The lake associations may want to facilitate a lake-wide schedule for pumping systems.

G. Loadings: An examination of land use practices in the watershed and identification of possible nutrient sources such as lawn fertilizer, the effects of ditching and draining of wetlands, and development practices etc., may aid the lake associations in determining areas where best management practices may be needed. In April 2004, a new law came into effect restricting the use of phosphorus fertilizers in Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington Counties and set a three percent (by weight) limit outside the metro area. In 2005 this law was extended statewide. The lake associations, together with Kandiyohi County, should encourage the use of P-free fertilizers on lawns in the watershed. There may be other opportunities to implement/promote Best Management Practices (BMP's) that may reduce nutrient loading from other sources in the watershed as well.

H. Overall: Results from the Kandiyohi County CLMP+ show that properly trained volunteers can collect consistent and reliable data for use in lake water quality assessments, and are a resource that can and should be used to gather additional information.

Appendix

1. **Kandiyohi County CLMP+ Lakes Data for 2005 and Historic Data**

2. **Watershed Maps for Kandiyohi County CLMP+ Lakes**

3. **Lake Level Data for CLMP+ Lakes**

4. **Status of the Kandiyohi County CLMP+ Lakes' Fishery**

5. **Lake Wakanda MN DNR Shallow Lakes Survey and Summary (DRAFT)**

Appendix 1. Kandiyohi County CLMP+ Lakes Data

2005 CLMP+ Data for Big Kandiyohi Lake (34-0086), Kandiyohi County

Sampler	Site	Date	Time	Depth (m)	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	101	5/17	11:15	0	118.0	2.35	2.26	14.0	2.7	20	200.0	29.0	1.91	1.64	8.43	548	2	2
MPCA	101	5/17	11:15	3	129.0													
Volunteer	101	6/10	12:05	0	88.0 Q	6.65	0.74							5.00			2	1
Volunteer	101	6/26	11:05	0	172.0	50.10	8.81							2.00			2	3
Volunteer	101	7/10	11:30	0	173.0	36.50	4.20							2.00			2	2
MPCA	101	7/25	11:30	0	127.0	9.76	1.31	8.2	2.8	20 Q	200.0	34.0	1.47	2.62	8.63	532	3	4
MPCA	101	7/25	11:30	3	130.0													
MPCA-FD	101	7/25	11:30	0	128.0	9.56	1.21K	7.2	2.8	10 Q	200.0	34.0	1.49					
Volunteer	101	8/12	13:30	0	213.0	35.60	0.93							3.50			4	3
Volunteer	101	8/27	11:45	0	225.0	6.46	2.24							2.00			2	2
Volunteer	101	9/11	14:45	0	209.0	23.40	1.73							2.00			2	3
MPCA	101	9/27	12:15	0	192.0	26.70	2.36	15.0	7.6	10 Q	200.0	33.0	1.58	1.97	8.62	623	4	4
MPCA	101	9/27	12:15	3	188.0													

2005 CLMP+ Data for Lake Wakanda (34-0169-03), Kandiyohi County

Sampler	Site	Date	Time	Depth (m)	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	101	5/17	12:15	0	145.0	48.10	8.10	26.0	10.0	30	170.0	32.0	2.27	1.64	8.73	481	4	4
MPCA	101	5/17	12:15	3	143.0													
Volunteer	101	6/12	13:40	0	161.0 Q	122.00	9.68											
Volunteer	101	6/23	19:15	0	175.0	166.00	5.92							0.83			4	4
Volunteer	101	7/9	13:20	0	170.0	136.00	12.00							0.83			4	4
MPCA	101	7/25	12:30	0	131.0	112.00	15.00	22.0	20.0	20 Q	160.0	37.0	3.14	1.31	8.85	458	5	4
MPCA	101	7/25	12:30	3	131.0													
Volunteer	101	8/14	16:30	0	135.0	174.00	7.04							0.58			4	4
Volunteer	101	8/27	10:00	0	135.0	167.00	6.60							0.67			4	4
Volunteer	101	9/11	10:10	0	148.0	163.00	4.77							0.50			4	4
MPCA	101	9/27	13:00	0	197.0	183.00	4.98	33.0	28.0	30 Q	140.0	34.0	4.09	0.66	8.45	519	5	4

TP = Total Phosphorus (ppb or µg/L)
Chla = Chlorophyll-*a* (ppb or µg/L)
Pheo = Pheophytin (ppb or µg/L)
TSS = Total Suspended Solids (mg/L)
TSV = Total Suspended Volatile Solids (mg/L)
COL = Color (Pt-Co Units)
Alk = Alkalinity (mg/L)
CL = Chloride (mg/L)
TKN = Total Kjeldahl Nitrogen (mg/L)
SDF = Secchi Transparency (ft)
pH = pH of Sample (SU)
Cond = Conductivity of sample (umhos/cm)
PC = Physical Condition
RS = Recreational Suitability
FD, Q, K = Remark codes for parameters *(FD = field duplicate sample; Q=held past holding time; K=less than the detection limit)*

2005 CLMP+ Data for Diamond Lake (34-0044), Kandiyohi County

Sampler	Site	Date	Time	Depth (m)	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	101	5/17	13:45	0	37.0	15.80	1.41	6.4	2.8	20	190.0	17.0	1.17	8.20	8.87	320	2	1
MPCA	101	5/17	13:45	8	37.0													
Volunteer	101	6/12	14:00	0	40.0 Q	5.59	0.50							14.00			2	1
Volunteer	101	6/25	14:45	0	91.0	43.40	0.88							7.00			3	2
Volunteer	101	7/9	11:15	0	61.0	37.70	2.22							4.50			3	3
Volunteer-FD	101	7/9	11:15	0	81.0	36.60	3.19											
MPCA	101	7/25	13:45	0	111.0	96.70	3.37	13.0	11.0	10 Q	170.0	19.0	2.20	2.46	8.79	279	4	4
MPCA	101	7/25	13:45	8	128.0													
Volunteer	101	8/13	13:00	0	95.0	37.70	5.46							3.00			3	2
Volunteer	101	9/5	11:30	0	99.0	44.10	3.84							2.50			2	2
MPCA	101	9/27	14:30	0	114.0	62.40	9.09	13.0	13.0	10 Q	160.0	19.0	1.80	1.97	8.26	332	4	4
MPCA	101	9/27	14:30	7	110.0													
MPCA-FD	101	9/27	14:30	0	119.0	53.70	20.00											
MPCA-FD	101	9/27	14:30	7	119.0													

TP = Total Phosphorus (ppb or µg/L)
Chla = Chlorophyll-*a* (ppb or µg/L)
Pheo = Pheophytin (ppb or µg/L)
TSS = Total Suspended Solids (mg/L)
TSV = Total Suspended Volatile Solids (mg/L)
COL = Color (Pt-Co Units)
Alk = Alkalinity (mg/L)
CL = Chloride (mg/L)
TKN = Total Kjeldahl Nitrogen (mg/L)
SDF = Secchi Transparency (ft)
pH = pH of Sample (SU)
Cond = Conductivity of sample (umhos/cm)
PC = Physical Condition
RS = Recreational Suitability
FD, Q, K = Remark codes for parameters *(FD = field duplicate sample; Q=held past holding time; K=less than the detection limit)*

2005 CLMP+ Data for Long Lake (34-0066), Kandiyohi County

Sampler	Site	Date	Time	Depth	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	Secchi	pH	Cond	PC	RS
MPCA	102	5/17	14:45	0	24.0	6.06	0.71	2.0						8.20	7.39	310	2	2
Volunteer	102	6/9	11:15	0	20.0 Q	2.65 Q	0.85 Q											
Volunteer	*201*	*6/9*	*11:25*	*0*										*14.50*			*1*	*1*
Volunteer	*202*	*6/9*	*11:00*	*0*										*13.00*			*1*	*1*
Volunteer	102	6/24	10:05	0	16.0	1.71	0.58											
Volunteer	*201*	*6/24*	*9:25*	*0*										*14.50*			*2*	*1*
Volunteer	*202*	*6/24*	*10:25*	*0*										*16.00*			*2*	*1*
Volunteer	102	7/8	13:05	0	19.0	2.63	0.53							10.33			2	2
Volunteer	*201*	*7/8*	*12:35*	*0*										*9.33*			*2*	*2*
Volunteer	*202*	*7/8*	*13:25*	*0*										*10.67*			*2*	*2*
MPCA	102	7/25	14:30	0	21.0	5.21	0.69 K	2.0	1.6	5 Q	170.0	12.0	0.65	8.53	8.37	273	1	1
MPCA	102	7/25	14:30	10	66.0													
Volunteer	102	8/11	10:35	0	27.0	11.10	1.25							8.75			2	2
Volunteer	*201*	*8/11*	*10:15*	*0*										*10.25*			*2*	*2*
Volunteer	*202*	*8/11*	*11:00*	*0*										*10.00*			*2*	*2*
Volunteer	102	8/26	9:05	0	20.0	6.08	0.74							9.50			1	1
Volunteer	*201*	*8/26*	*8:50*	*0*										*7.33*			*2*	*1*
Volunteer	*202*	*8/26*	*9:25*	*0*										*9.50*			*2*	*1*
Volunteer	102	9/8	15:10	0	20.0	6.94	0.53							8.25			2	2
Volunteer	*201*	*9/8*	*14:40*	*0*										*8.00*			*2*	*2*
Volunteer	*202*	*9/8*	*15:30*	*0*										*8.00*			*2*	*2*
MPCA	102	9/27	15:30	0	24.0	8.25	0.72	3.6	2.8	10 Q	180.0	12.0	0.60	11.50	8.05	339	1	1
MPCA	102	9/27	15:30	11	101.0													

TP = Total Phosphorus (ppb or µg/L)
Chla = Chlorophyll-*a* (ppb or µg/L)
Pheo = Pheophytin (ppb or µg/L)
TSS = Total Suspended Solids (mg/L)
TSV = Total Suspended Volatile Solids (mg/L)
COL = Color (Pt-Co Units)
Alk = Alkalinity (mg/L)
CL = Chloride (mg/L)
TKN = Total Kjeldahl Nitrogen (mg/L)
SDF = Secchi Transparency (ft)
pH = pH of Sample (SU)
Cond = Conductivity of sample (umhos/cm)
PC = Physical Condition
RS = Recreational Suitability
FD, Q, K = Remark codes for parameters *(FD = field duplicate sample; Q=held past holding time; K=less than the detection limit)*

2005 Temperature Data for Kandiyohi CLMP+ Lakes

Big Kandiyohi (34-0086) Temperature (°C)

Depth (m)	5/17	6/10	6/26	7/10	7/25	8/12	8/27	9/11	9/27
0	10.35	25	26.1	25	26.25	25	23.9	22.8	17.82
1	10.33	24	23.9	24.4	26.25	23.9	22.8	22.8	17.8
2	10.33	22	23.9	23.9	26.21	23.3	22.2	22.2	17.79
3	10.33	21	23.9	23.9	26.18	22.8	21.7	21.7	17.8
4	10.33	20			26.13	22.8	21.7	21.7	17.61

Wakanda (34-0169-03) Temperature (°C)

Depth (m)	5/17	6/12	6/23	7/9	7/25	8/14	8/27	9/11	9/27
0	10.65	24	25	26	27.18	26	23	22.5	17.72
1	10.66	22	24	24	27.09	23	22	22.5	17.68
2	10.64	22	24	24	26.7	23	22	22.5	17.66
3	10.64	22	22	24	26.57	23	21	22	17.66
4	10.64	21			26.49	22	21		

Diamond (34-0044) Temperature (°C)

Depth (m)	5/17	6/12	6/25	7/9	7/25	8/13	8/27	9/5	9/27
0	11.13	22	26	24	27.14	24		21	18.41
1	11.13	22	25	24	26.92	24		21	18.39
2	11.14	21	25	24	26.48	24		21	18.37
3	11.12	21	24.5	23.5	26.44	24		21	18.33
4	11.1	20	24	23	26.36	24		21	18.31
5	11.1	20	24	23	26.15	24		21	18.33
6	11.1	19	24	23	25.29	24		21	18.3
7	11.09	19	21	22.5	24.98	24		21	18.29
8	11.08	18	19.5	22	24.34	24		20.5	18.3
9	11.05				23.23				

Long (34-0066) Temperature (°C)

Depth (m)	5/17	6/9	6/24	7/8	7/25	8/11	8/26	9/8	9/27
0	11.47				26.89	22	23	25	19.33
1	11.43			26	26.93	25	23	24	19.23
2	11.4			27	26.93	26	24	24	19.06
3	11.34			27	26.91	25	24	23	18.98
4	11.28			26	26.35	25	23	23	18.89
5	11.05			24	23.27	26	24	23	18.68
6	10.93			21	16.91	21	22	22	18.54
7	10.72			17	12.93	18	19	19	18.04
8	10.37			17	11.84	15	18	16	14.2
9	10.25			17	11.06	13	16	14	11.77
10	10.14				10.59				10.8

2005 Dissolved Oxygen Concentrations for Kandiyohi CLMP+ Lakes

Dissolved Oxygen (mg/L)

Big Kandiyohi @ 101	Depth (m)	5/17	7/25	9/27
34-0086	0	9.79	7.2	12.49
34-0086	1	9.85	6.97	9.82
34-0086	2	9.78	6.84	9.44
34-0086	3	9.8	7.05	9.34
34-0086	4	9.68	6.2	9.1

Dissolved Oxygen (mg/L)

Wakanda @ 101	Depth (m)	5/17	7/25	9/27
34-0169-03	0	12.28	8.64	9.61
34-0169-03	1	10.35	8	8.71
34-0169-03	2	10.22	6.75	8.52
34-0169-03	3	10.1	6.38	8.42
34-0169-03	4	9.43	5.6	

Dissolved Oxygen (mg/L)

Diamond @ 101	Depth (m)	5/17	7/25	9/27
34-0044	0	**11.58**	**11.01**	**10.29**
34-0044	1	10.88	10.75	8.58
34-0044	2	10.69	9.34	8.36
34-0044	3	10.47	8.8	8.21
34-0044	4	10.37	8.01	8.04
34-0044	5	10.36	7.17	7.99
34-0044	6	10.32	2.94	7.83
34-0044	7	10.2	0.79	7.74
34-0044	8	10.24	0.42	7.28
34-0044	9	9.32	0.35	

Dissolved Oxygen (mg/L)

Long @ 102	Depth (m)	5/17	7/25	9/27
34-0066	0	12.71	8.33	8.91
34-0066	1	11.16	7.93	8.3
34-0066	2	10.47	7.73	8.16
34-0066	3	10.34	7.62	7.91
34-0066	4	10.18	6.84	7.77
34-0066	5	10.1	6.31	7.47
34-0066	6	9.72	2.21	6.98
34-0066	7	9.54	0.54	6.12
34-0066	8	9.08	0.39	3.27
34-0066	9	8.68	0.31	1.28
34-0066	10	8.54	0.3	0.6

Historic Data for Kandiyohi County CLMP+ Lakes

Big Kandiyohi Lake (34-0086) Historic Data

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1977	1.50	0.09	8						
1978	2.13	0.11	17	101	13.6	6	46.6	12.7	6
1979	2.50	0.25	8						
1985	4.18	0.90	4	110	7.5	4	31.5	17.6	4
1986	3.00	0.42	7						
1987	3.37	0.30	8						
1988	3.87	0.55	4						
1989	3.37	0.37	4	175.4	30	12	24.8	6.7	13
1990	3.83	0.17	3						
1995	3.57	0.23	28						
1996	4.06	0.19	9						
1997	4.20	0.49	10						
1999	4.50	0.46	8						
2000	3.78	0.28	14						
2001	6.14	0.64	14						
2002	5.70	0.14	10						
2003	5.05	0.62	10						
2004	2.53	0.16	16						
2005	2.6	0.4	8	175	16.5	8	24.4	5.7	8

Lake Wakanda (34-0169-03) Historic Data

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1966				910	21	3			
1969				1827	157	2			
1976	1.30	0.44	4	756.00	41.00	4	294.25	118.59	4
1977	2.46	0.49	2	2580.00	640.00	2	44.75	7.25	2
1978	2.30	0.33	2	1380.00	220.00	2	64.00		1
1985				271.00	21.00	2	276.00	55.00	2
2001	3.16	2.18	3						
2002	1.12	0.43	4						
2003	1.39	0.37	5						
2004	0.64	0.05	4						
2005	0.8	0.1	7	157	8.3	8	153	9.2	8

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
TP = Total Phosphorus (ppb or µg/L)
SEP = Standard Error for TP
NP = # TP samples/yr
CHLa = Chlorophyll-*a* (ppb or µg/L)
SEC = Standard Error for CHLa
NC = # CHLa samples/yr

Diamond Lake (34-0044) Historic Data

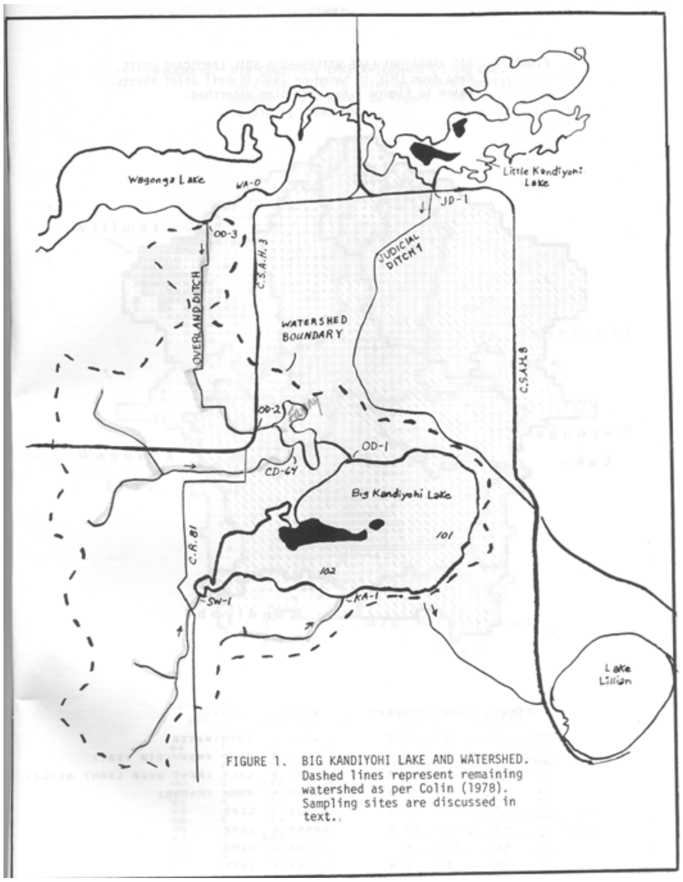
Year	SDF	SES	NS	D-TP	TP	SEP	NP	CHLa	SEC	NC
1750				25						
1800				28						
1970				47						
1975	5.29	0.62	12							
1979	4.21	0.34	17		37. 7	5.5	3			
1980					44.7	6.8	3			
1981	5.56	0.33	17		30.3	5.2	3			
1982	6.85	0.69	17							
1983	6.07	0.84	14							
1985	7.31	0.17	13							
1987	5.31	0.37	16							
1988	6.54	0.41	12							
1989	5.73	0.65	13							
1990	5.03	0.44	22		107.4	36.9	7	30.7	5.8	7
1991	4.16	0.33	16							
1992	5.67	0.58	12							
1993	9.56	0.76	8	79						
1994	5.27	0.45	11							
1995	6.63	0.84	15							
1996	4.92	0.87	12							
1997	8.32	0.89	13		89.5	3.5	2	46.1	25.3	2
1998	4.54	0.65	14		57.5	2.5	2	20.8	11.4	2
2000	5.89	0.41	23							
2001	3.26	0.26	31		99.5	5.5	2	39.5	1.1	2
2002	5.27	0.64	30		66.2	14.7	5	31.4	13.7	5
2003	4.93	0.53	25		65.0	3.0	2	32.4	7.9	2
2004	5.50	0.48	26		93.3	10.2	6	35.0	11.1	4
2005	5.10	1.60	7		87.3	10.3	7	46.8	10.5	7

Long Lake (34-0066) Historic Data

Year	SDF	SES	NS	D-TP	TP	SEP	NP	CHLa	SEC	NC
1750				20						
1800				19						
1970				23						
1990	9.58	0.27	6	27						
1991	8.36	0.28	18							
1992	9.41	0.20	22							
1993	10.00	0.25	16							
1994	12.08	0.37	18							
1995	11.61	0.27	14							
1996	12.06	1.04	16							
1997	14.15	1.08	19		19.0	4.04	3	6.5	0.99	3
1998	12.70	0.41	17		15.5	1.50	2	3.0	1.32	2
1999	11.38	0.62	16							
2000	11.13	0.39	16							
2001	13.58	0.52	12							
2005	10.4	0.6	6		20.9	1.2	8	5.6	1.1	8

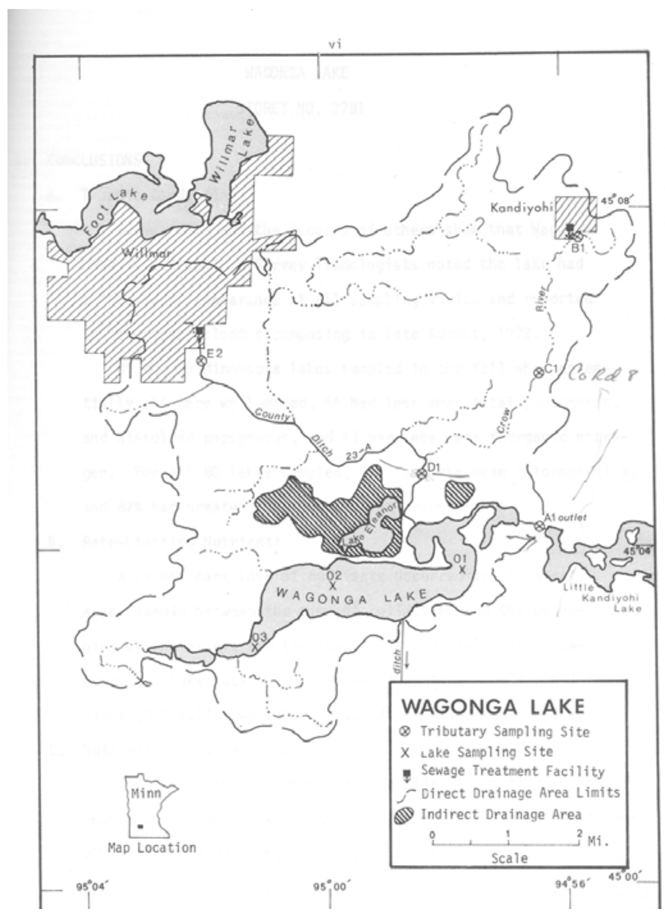
Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
D-TP = Diatom-inferred TP (ppb or µg/L)
TP = Total Phosphorus (ppb or µg/L)
SEP = Standard Error for TP
NP = # TP samples/yr
CHLa = Chlorophyll-*a* (ppb or µg/L)
SEC = Standard Error for CHLa
NC = # CHLa samples/yr

Appendix 2. Watershed Maps for Selected Kandiyohi County CLMP+ Lakes
(Source: Existing old reports & http://gisdmnspl.cr.usgs.gov/watershed/index.htm)

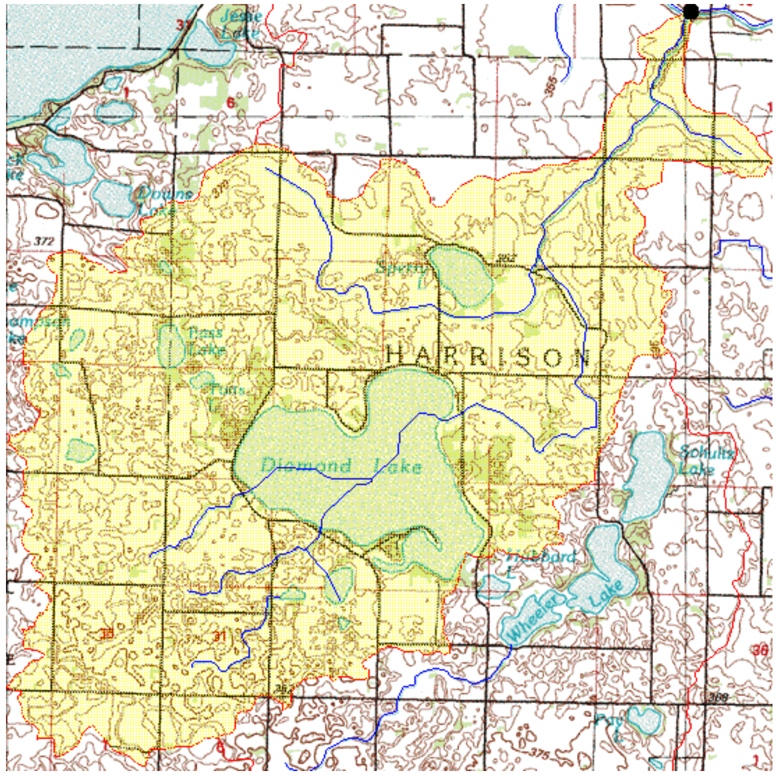


Big Kandiyohi Lake Watershed
(Total Watershed Area Shown)

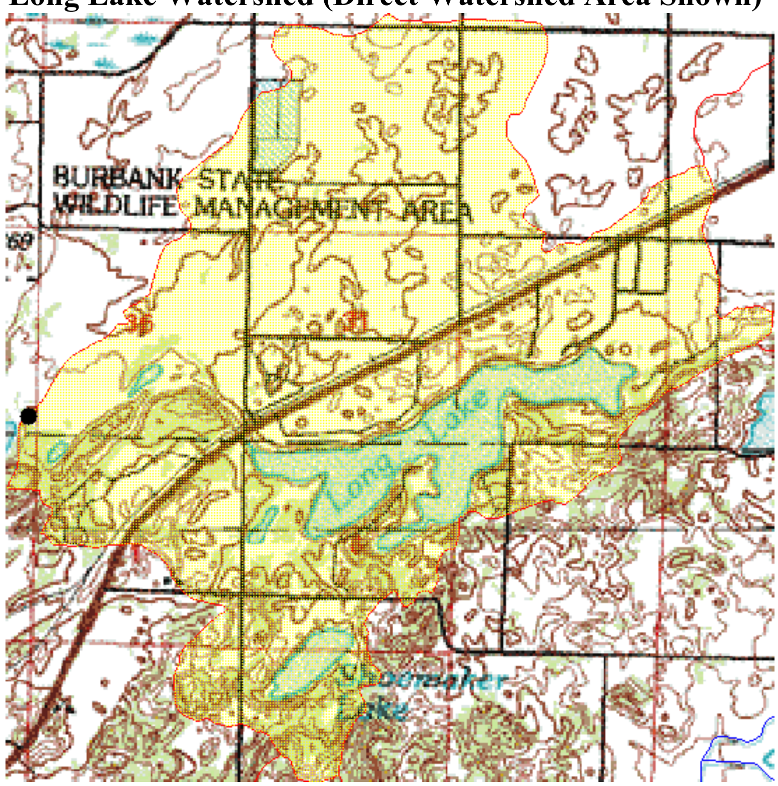
Lake Wakanda Watershed
(Total Watershed Area Shown)



Diamond Lake Watershed (Direct Watershed Area Shown)



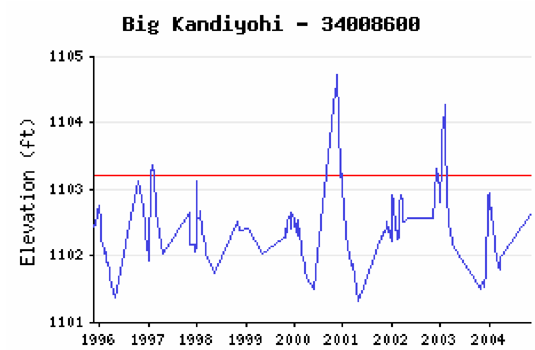
Long Lake Watershed (Direct Watershed Area Shown)



Appendix 3. Lake Level Information for CLMP+ Lakes
(From MN DNR Web site: www.dnr.state.mn.us)

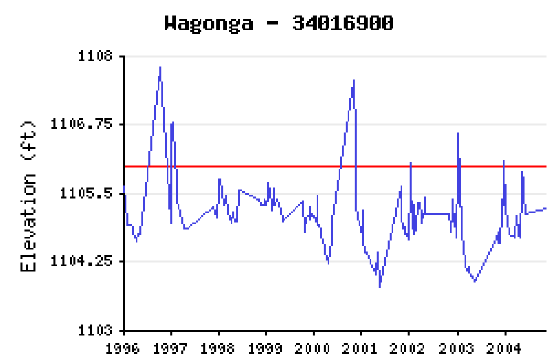
Big Kandiyohi (34-0086)

Period of record: 07/10/1945 to 04/21/2005
# of readings: 581
Highest recorded: 1104.73 ft (05/02/2001)
Highest known: 1105 ft (07/01/57)
Lowest recorded: 1098.92 ft (09/22/1977)
Recorded range: 5.81 ft
Average water level: 1102.66 ft
Last reading: 1102.61 ft (04/21/2005)
OHW elevation: 1103.2 ft
Datum: 1929 (ft)



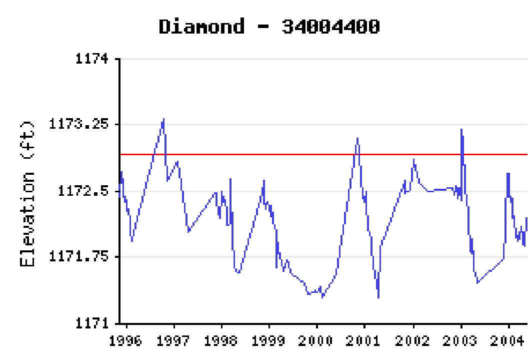
Lake Wakanda (34-0169-03)

Period of record: 03/20/1950 to 04/21/2005
# of readings: 280
Highest recorded: 1107.8 ft (04/07/1997)
Lowest recorded: 1102.88 ft (11/03/1988)
Recorded range: 4.92 ft
Average water level: 1105.22 ft
Last reading: 1105.23 ft (04/21/2005)
OHW elevation: 1106 ft
Datum: 1929 (ft)



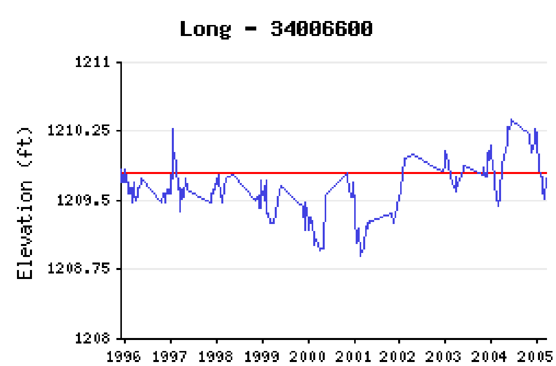
Diamond Lake (34-0044)

Period of record: 09/01/1949 to 10/29/2004
# of readings: 446
Highest recorded: 1173.46 ft (06/18/1984)
Highest known: 1173.46 ft (06/18/84)
Lowest recorded: 1169.51 ft (11/07/1989)
Recorded range: 3.95 ft
Average water level: 1172.19 ft
Last reading: 1172.19 ft (10/29/2004)
OHW elevation: 1172.9 ft
Datum: 1929 (ft)



Long Lake (34-0066)

Period of record: 05/18/1977 to 08/29/2005
# of readings: 424
Highest recorded: 1210.37 ft (12/07/2004)
Highest known: 1210.37 ft (12/07/04)
Lowest recorded: 1208.68 ft (08/30/1988)
Recorded range: 1.69 ft
Average water level: 1209.61 ft
Last reading: 1209.73 ft (08/29/2005)
OHW elevation: 1209.8 ft
Datum: 1929 (ft)



Appendix 4. Status of the Kandiyohi County CLMP+ Lakes' Fishery

Excerpts from DNR Lakefinder http://www.dnr.state.mn.us/lakefind/index.html
For a complete report, please visit the MDNR web site

Big Kandiyohi Lake (34-0086) Status of the Fishery (as of 07/26/2004): A population assessment of Big Kandiyohi Lake was conducted during late July of 2004. Winterkills are rare in Big Kandiyohi. A significant partial summerkill of carp, crappies, and bullheads occurred due to a suspected bacterial outbreak of columnaris during May of 2002. An outlet structure is located on the southeast side of the lake which connects to Lake Lillian via a ditch. Big Kandiyohi is a reference lake for a DNR statewide regulations study. Yellow perch were large, but their numbers were moderate in 2004 compared to the normal range for similar lakes. Yellow perch growth rates in Big Kandiyohi were above the Spicer Area normal ranges for ages 1-4. Northern pike were small and their numbers were low in 2004 compared to the normal range for similar lakes. The largest northern pike captured in the 2004 assessment was 33.19 inches. Bluegills were moderate to large in size; however their numbers were low in 2004 compared to area largemouth bass/bluegill dominated lakes (clear, small, deep), but within the normal range for similar lakes (turbid, large, shallow). Black crappies were large but their numbers were low in 2004 compared to the normal range for similar lakes. Channel catfish numbers were low in 2004 compared to the normal range for Big Kandiyohi. Channel catfish were last stocked into Big Kandiyohi during 1987. Channel catfish fingerlings are proposed to be stocked in 2005. Walleyes were moderately sized, but their numbers were low in 2004 compared to the historical average catch rate for Big Kandiyohi, but within the normal range for similar lakes. Walleye growth rates in Big Kandiyohi were below the Spicer Area normal ranges for ages 1-3, but above the normal ranges for ages 4-8. Big Kandiyohi was stocked with approximately 2.1 million walleye fry in the spring of 2003. Smallmouth bass abundance in 2004 was the lowest recorded value for Big Kandiyohi, and below the normal range for similar lakes. Black bullhead numbers were abundant in 2004 compared to the historical average catch rate for Big Kandiyohi, but within the normal range for similar lakes. Carp numbers were abundant in 2004 and above the normal range for similar lakes.

Current fish management activities on Big Kandiyohi include protecting aquatic vegetation through the permit process, improving yellow perch spawning habitat, stocking various species as needed, and stocking walleye fry every other year. The Big Kandiyohi Lake fishery will be surveyed in the 2006 summer for all fish species. Fall electrofishing surveys will be conducted during walleye fry stocked years to assess the success or failure of the stockings.

Lake Wakanda (34-0169-03 Status of the Fishery (as of 06/10/2002): A fish population assessment of Lake Wakanda was conducted in early June of 2002. A twelve subsurface helixor aeration system is operated during the winter months to prevent winterkill of gamefish. In the past, operational problems with the aeration system in conjunction with adverse winter conditions resulted in partial winterkills (1995-96, 1996-97, 1999-2000) of both gamefish (walleye, northern pike, yellow perch, black crappie) and non-gamefish (carp, black bullhead). However, the winterkills were not complete, thus adequate brood stock numbers of most fish species were present to reproduce in the lake. Also, gamefish were restocked into the lake after each partial winterkill. Black crappie numbers were moderate in 2002 compared to similar lakes, but the highest historical recorded value for Wakanda. Northern pike were small but their numbers were abundant in 2002 compared to the Wakanda historical average catch rate and similar lakes. Yellow perch were large and their numbers were moderate in 2002, and above the previous 2000 Wakanda summer survey. Walleyes were small in size, but their numbers were abundant in 2002 assessment and the highest recorded value for Wakanda. Walleye natural reproduction in Wakanda is generally absent or rare based on previous fall and summer surveys. Local anglers reported excellent success catching walleye (1-2 lbs.) during the early ice-fishing season in December of 2002. Both black bullhead and carp were small in size, but their numbers were abundant in 2002 compared to the historical averages.

Current fish management activities on Wakanda include assisting Kandiyohi County in the operation of the aeration system, monitoring winter dissolved oxygen levels, protecting aquatic vegetation through the permit process, and stocking walleye fry every other year. The Lake Wakanda fishery will be surveyed in the 2006 summer for all fish species. Fall electrofishing surveys will be conducted during walleye fry stocked years to assess the success or failure of the stockings.

Diamond Lake (34-0044) Status of the Fishery (as of 07/10/2003): A fish population assessment of Diamond Lake was conducted in July of 2003. Emergent vegetation (bulrush) is present along the north shore point, east shoreline area, and Dogfish bay area. Submergent vegetation densities within the lake are moderate with high densities of curly-leaf pondweed possible during some years especially in the north bay area. Local anglers had good fishing success for walleye during the last several years, especially during the early winter months. Largemouth bass were moderate in size, but their numbers were low to moderate in the 2003 spring electrofishing survey compared to the normal range for area lakes, but above the Diamond Lake historical average. Black crappie were small in size, but their numbers were high in 2003 compared to the normal range for similar lakes. Northern pike were moderate in size, but their numbers were low in 2003 compared to the normal range for similar lakes. The largest northern pike capture was 33.2 inches in the Diamond 2003 assessment nets. Yellow perch were small in size, and their numbers were low to moderate in 2003 compared to the normal range for similar lakes. Walleye were moderate in size, but their numbers were low in 2003 compared to the Diamond Lake historical average, but within the normal range for similar lakes. The largest walleye captured was 24.2 inches in the Diamond 2003 assessment. Diamond Lake was last stocked with walleye fingerlings in 1998 (37,274 fish). Bluegills were large in size but their numbers were low in 2003 compared to the Diamond Lake historical average and the normal range for similar lakes. Black bullheads were moderate in size, and their numbers were high in 2003 compared to the normal range for similar lakes and the highest historical recorded value for gillnets from Diamond Lake. Other fish species of special interest captured in the Diamond 2003 nets included high numbers of carp.

Current fish management activities on Diamond Lake include monitoring the fish population on a periodic basis, protecting aquatic vegetation through the permit process, participating in local watershed initiatives, and stocking various fish species as warranted. The Diamond Lake fishery will be surveyed in the 2004 fall for young-of-the-year walleye and resurveyed in the 2007 spring and summer for all fish species.

Long Lake (34-0066) Status of the Fishery (as of 06/25/2003): A fish resurvey of Long Lake was conducted in June of 2003. Emergent vegetation (waterlilies, bulrush, cattails, wild rice) densities are abundant in Long, especially in bay areas and south shoreline areas. Submergent vegetation densities (muskgrass, coontail, various pondweed species) were abundant in the lake. Water levels were down by late summer of 2003 due to drought conditions. An experimental regulation was implemented for bass (12 inch maximum size limit) in 1997. The experimental regulation will be evaluated and a public meeting held at the end of the 2005 fishing season to determine if the regulation will remain, changed, or discontinued. Long is a popular fishing lake for largemouth bass, bluegill, black crappie, and northern pike. Anglers also seek walleye occasionally in Long Lake.

Largemouth bass numbers were high in the 2003 spring electrofishing survey compared to the average catch rate from area lakes. Largemouth bass growth rates in Long were below the normal ranges for ages 1-5 compared to area lakes. Black crappies were small and their numbers were moderate in 2003 compared to the normal range of similar lakes. Northern pike were moderate in size but their numbers were low to moderate in 2003 compared to the normal range of similar lakes. Northern pike growth rates in Long were below the normal ranges for ages 1-3, but within the normal ranges for ages 4-5 compared to area lakes. The largest northern pike captured was 35.9 inches from the 2003 survey nets. Yellow perch were not captured in the Long 2003 survey gillnets or trapnets. Walleye were moderate in size, but their numbers were low in 2003. Bluegill were moderate in size and numbers in 2003 compared to the normal range of similar lakes. Bluegill growth rates in Long Lake were generally below the normal ranges for ages 1-6 compared to area lakes. Yellow bullhead were large in size and their numbers were moderate to high in 2003 compared to the normal range of similar lakes.

Current fish management activities on Long Lake include monitoring the fish population on a periodic basis, protecting aquatic vegetation through the permit process, evaluating the bass experimental regulation, and stocking various fish species as warranted. The Long Lake fishery will be resurveyed in the 2004 spring for largemouth bass and 2005 spring and summer for all fish species.

Lake Wakanda MN DNR Shallow Lakes Survey and Summary (DRAFT)
(Provided by LeRoy Dahlke, MN DNR Shallow Lakes Program)

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DRAFT

State of Minnesota Dept. of Natural Resources
Shallow Lakes Program

Lake Wakanda (Wagonga) Review

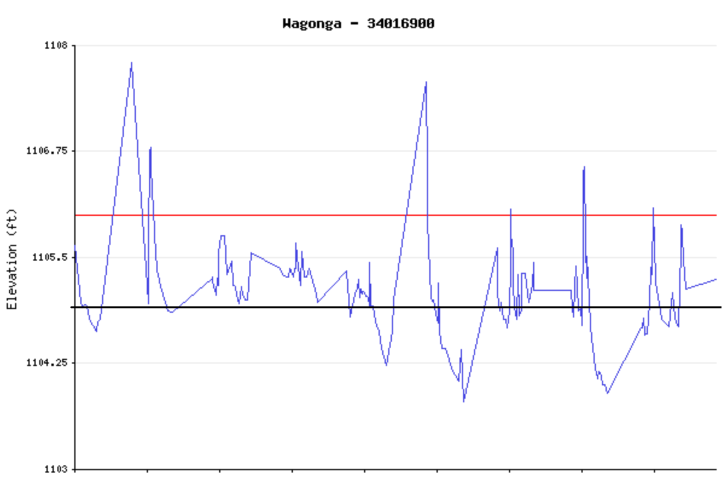
Lake Identification: 34-169 **Legal Description**: T.118-119; R. 34-35; S. 1,10-12,4-6,31-33
Watershed Tributary Number and Name: 17-Crow River Watershed **County**: Kandiyohi

Previous Surveys:

1) Game Lake Survey: a) June 15 and August 16, 2005 by K. LaFortune and J. Kavanagh
b) July 12, 1988 by L. Dahlke and J. Miller
c) August 4, 1965 by R. Nelson and P. Egeland
d) September 3, 1947 by V. Reid and D. Wiley
2) Lake Mapping Unit: a) June 3, 1991
3) Minnesota Pollution Control Agency: a) September and October, 1969 and October, 1970, 1972
4) Fisheries Division: a) Initial Survey 1988
b) Resurvey 1992, 1996
c) Population Assessment 2000, 2002
d) Special Assessment 1995, 1998, 2000, 2004
e) Dissolved Oxygen Reports 1986-1992
f) Water Quality Reports from Fisheries Research Lab 1947, 1964, 1966
5) Dept of Health, Division of Sanitation: a) Water Quality 1929
6) EPA a) National Eutrophication Survey 1974
7) Citizen Lake Monitoring: a) Secchi Disk Readings 2001-2004

Summary:

The Wakanda Lake basin is long (maximum length 6.17 miles) and shallow with an irregular shoreline (14.9 miles) and a littoral acreage of 1560 acres. The lake has a maximum depth of 14 feet and an average depth of 7 feet with shallow bays (less than 3 feet deep) on the east and west end. There have been fluctuations in these readings through the years. Historic surveys have found maximum depths of 19 feet (1947) and a littoral acreage of 1664, most likely due to fluctuations in water levels. According to the most recent surveys, agricultural row crops predominate the surrounding land use at approximately 70%. Shorelines are generally undeveloped and wooded with willow, elm, cottonwood and ash. In 2005, water levels were below the ordinary high water mark set at 1106.0 but above the



runout elevation of 1104.8. Water levels fluctuate through the seasons and through the years due to changes in weather patterns. Highest recorded level was 1107.8 in spring of 1997 and the lowest was 1102.88 feet on 11/3/88.

There are 12 inlets to Wakanda Lake, most of which are intermittent and drain agricultural land. The largest, County Ditch #23A, constructed in the early 1900's, is a major contributor of water to Wakanda Lake. CD #23A receives a significant amount of storm sewer runoff from the City of Willmar and Kandiyohi and drainage from surrounding agricultural land as it runs through the Grass Lake bed south to Wakanda Lake.

There are two outlets from Wakanda Lake, State Ditch #1, the overland ditch constructed in 1967 that diverted water to Big Kandiyohi Lake, and the connection to Little Kandiyohi. Both are regulated by structures modified from concrete stoplogs to sheet piling dams in 1990. The structures control water levels at 1104.8 feet. Additional swinging finger fish barriers were installed on March, 1996 for the purpose of reducing the immigration of rough fish.

The percent of vegetation in the basin has fluctuated since the earliest surveys.

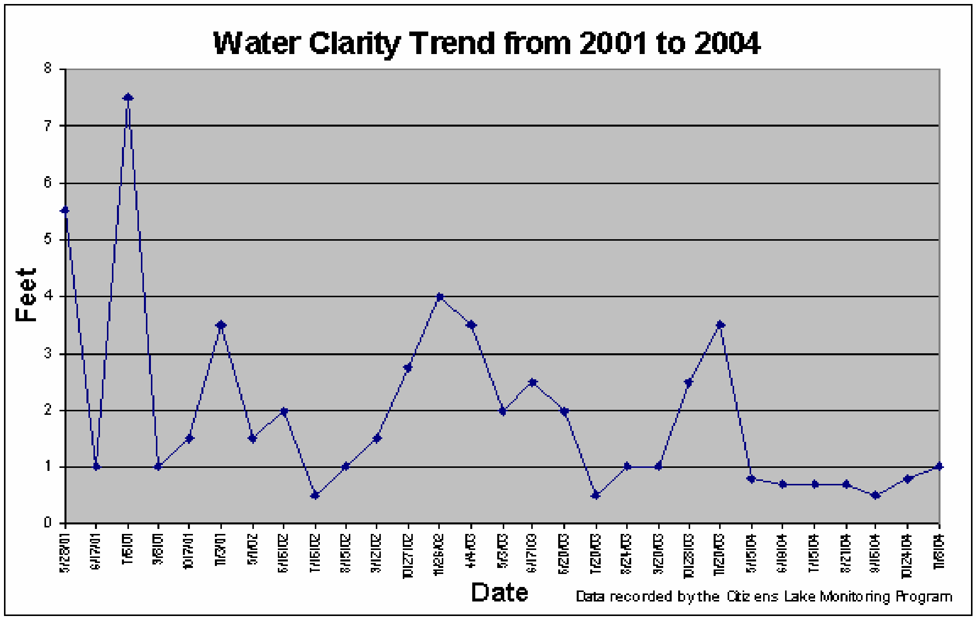
- Game lake survey of 1947: 12 species of emergent vegetation at an occurrence of 7.5% of the 80 sampling stations and the submergent sago pondweed was found at 10% of the sampling stations. Emergents were noted in occasional abundance along the shorelines, marshy edges and SW/NE bays.
- Game lake survey of 1965: 5 species of emergents covered less than 1% of the present lake area mostly in the outlet channel on the northeast bay and one small stand off the wooded point on the north shore. 5 species of submerged vegetation occurred at 41% of the sampling stations. Sago pondweed was scattered throughout the lake in water less than 8 feet deep, while 4 other species were found in the shallower areas of the bays and shorelines.
- Game lake survey of 1988: Common cattail was the only emergent described in small pockets along the shoreline at the NE end of the lake. Submergent vegetation consisted of 4 species the majority being sago pondweed occurring at 20% of the sampling stations and scattered along the shoreline in depths of 5 feet or less.
- From that time until 1998, it was noted in Fisheries surveys that submerged vegetation was moderately abundant along the shorelines especially in the SW and NE bays, the majority of which was sago pondweed, and the emergent common cattail being present but rare on the main part of the lake.
- The 2005 survey conducted on Wakanda Lake, which focused on the SW and NE bay areas only, found submergent vegetation almost entirely lacking, with only one sampling point with sago pondweed present. Cattails were observed along the north shore and the northeast bay area.

According to the data on file, fish populations have existed in the basin since at least the early 1900's but there is no information on the native abundance or diversity. Past management activities have primarily been carp and bullhead removal, game fish winter rescue operations, and game fish stocking. Between 1926 and 1932, 239,203 pounds of the rough fish carp were removed from Wakanda Lake. Since that time, over 1 million pounds of carp and black bullheads have been removed from the basin; carp making up the majority of the catch. Northern pike, black crappies, largemouth bass, and sunfish have been stocked in different numbers throughout the years as early as 1912.

Wakanda Lake is susceptible to winterkill. Dissolved oxygen levels have historically been monitored and the lake has been opened to unlimited fishing 11 times since 1944. Winterkills may have reduced the fish populations for a few years but a sufficient number of breeding adults survived or moved in to repopulate the basin. The over abundance of rough fish and decline of quality habitat led to walleye being stocked in 1994, and subsequent years, to biologically control bullhead populations. In an effort to minimize the possibility of winterkill and support a predator fish population, an aeration system was installed in the late fall of 1995 as part of the Wakanda Lake Cooperative Management Plan.

Water Quality:
Secchi Disks readings
(point in time):

Date	Feet
8/4/19659.5	
8/31/1977	1.97
7/11/1978	2.6
7/12/1988	1
7/6/19924	
6/26/1996	9.8
6/19/2000	7.1
6/20/2001	2
6/16/2002	2
6/20/2003	2
6/18/2004	0.7



Abundant carp and bullheads add to the water quality problem by uprooting aquatic vegetation, creating turbidity problems, and redistributing nutrients from the lakebed. Consequently, shoal water areas are prone to erosion from wave action, spawning areas are disturbed or destroyed, vegetation used for food and cover by various fish and wildlife species is lost, and algal bloom frequency and intensity are increased.

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GLOSSARY

Alkalinity: Capacity of a lake to neutralize acid.

Chloride: Common anionic form of chlorine which carries one net negative charge. A common anion in many waters.

Chlorophyll a: The main pigment in algae. It is used to measure aquatic productivity.

Ecoregion: Areas of relative homogeneity based on land use, soils, topography and potential natural vegetation.

Epilimnion: Most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and lighter water.

Eutrophic: Describes a lake of high photosynthetic productivity. Nutrient rich.

Hypolimnion: The bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

Littoral Area: The shallow areas around a lake's shoreline, dominated by aquatic plants.

Mesotrophic: Describes a lake of moderate photosynthetic productivity.

Metalimnion: The middle layer of lake water during the summer months.

Nitrite/Nitrate Nitrogen: The weight of concentration of the nitrogen in the nitrate ion.

Oligotrophic: Describes a lake of low photosynthetic productivity.

Phosphate: An essential nutrient containing phosphorus and oxygen. Phosphate is often a critical nutrient in lake eutrophication management.

Phosphorus: Phosphorus is an element that can be found in commercial products such as foods, detergents, and fertilizers as well as in larger amounts naturally in organic materials, soils, and rocks. Phosphorus is one of many essential plant nutrients. Phosphorus forms are continually recycling throughout the aquatic environment. All forms are measured under the term "Total Phosphorus" in parts per billion (ppb).

Photosynthesis: The process by which green plants produce oxygen from sunlight, water and carbon dioxide.

Secchi Disk: A metal plate used for measuring the depth of light penetration in water.

Suspended Solids: Small particles that hang in the water column and create turbid, or cloudy conditions.

Total Maximum Daily Load (TMDL): This process determines why waters are impaired, the amount by which pollution must be reduced to meet water-quality standards and determines allocations (limits) for all contributing sources plus future growth.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth. Zone of maximum change in temperature over the depth interval.

Trophic Status: The level of growth or productivity of a lake as measured by phosphorus content, algae abundance, and depth of light penetration.

Turnover (Overturn): Warming or cooling surface waters, activated by wind action, mix with lower, deeper layers of water.

Watershed: Geographical area that supplies water to a stream, lake, or river.

Zooplankton: Microscopic animals.