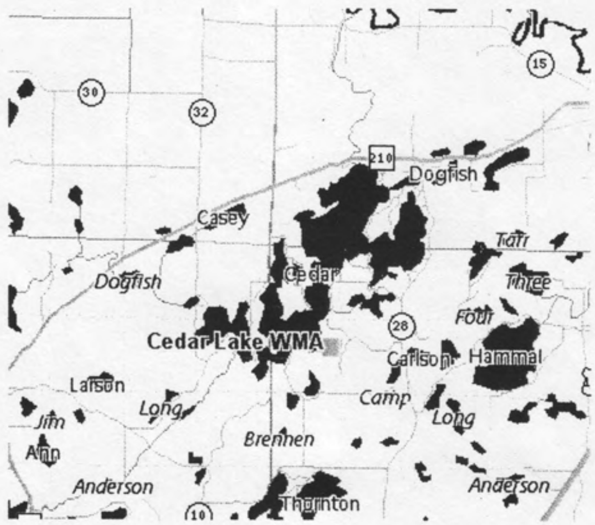
LAKE ASSESSMENT PROGRAM
2002

Cedar Lake
(DNR DOW # 01-0209)

Aitkin County, Minnesota



Minnesota Pollution Control Agency
Environmental Outcomes Division
in cooperation with the

Cedar Lake Conservancy

Minnesota Pollution Control Agency

April 2003

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SUMMARY AND RECOMMENDATIONS

Cedar Lake is located in Aitkin County, near Aitkin, Minnesota. With a surface area of approximately 1,729 acres, it ranks near the 90th percentile in terms of surface area as compared to over 11,000 lakes in Minnesota (less than 10% of MN lakes are larger than Cedar Lake). Cedar Lake has a maximum depth of about 100 feet and a mean depth of about 28 feet. The lake is characterized by numerous bays and in this study distinctions are made between sites in the main basin of the lake as compared to the small southwest basin. The total watershed, at approximately 37 square miles, is moderate-sized compared to the size of the lake (17:1 ratio). Land use in the watershed is composed of about 59 % forest and wetland and 22 % grass and pasture land. The pasture and grass land uses are slightly high as compared to other lake watersheds in this region of the state -- Northern Lakes and Forests (NLF) ecoregion.

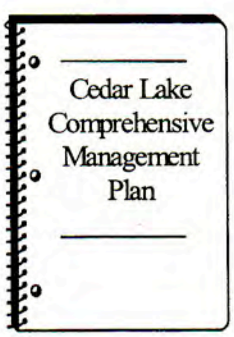
Cedar Lake was sampled during the summer of 2002 by the Minnesota Pollution Control Agency (MPCA) staff and citizens from the Cedar Lake Conservancy (Association). Water quality data collected during the study at four sites reveal lake-wide summer-mean total phosphorus (TP) concentration of 20 µg/L, chlorophyll a of 9.6 µg/L and Secchi transparency of 7.9 feet. All three measures are within or near the range of values exhibited by reference lakes in the NLF ecoregion. Total phosphorus, chlorophyll a and Secchi transparency help to characterize the trophic status of a lake. These measures indicate *mesotrophic* to mildly *eutrophic* conditions for Cedar Lake. Other water quality parameters measured are comparable to minimally impacted lakes in the NLF ecoregion. TP and chlorophyll-a concentrations in the southwest basin were slightly higher than concentrations in the main basin. The Association also monitored TP and flow in several tributaries to the lake in 2002. This monitoring showed some differences between some of the watersheds. The aggregate mean TP from all tributary measurements was 55 µg/L, which is fairly close to the typical range for streams in the NLF ecoregion.

Cedar Lake had minimal long-term data available in STORET for assessing trends. However it did have a very good record of Secchi transparency data for the period 1995 – 2002. These data show distinct differences between transparency in the main basin as compared to the southwest basin. For both basins there was evidence of declining transparency over time, based on a review of summer-means, maxima and minima. The decline was more acute in the southwest basin as compared to the main basin.

Three lake water quality prediction models were used to assess the water quality of Cedar Lake based on morphometry and watershed characteristics. These models provide a means to compare the measured water quality (2002) of the lake relative to the predicted water quality. The first model, MINLEAP, predicted a summer-mean phosphorus (P) concentration of 20 ± 3 µg/L, which is equal to the observed summer-mean of 20 µg/L for Cedar Lake. This model estimated a phosphorus loading of ~ 1,190 kg P/year and a water residence time of about 2-3 years. A regression model, Vighi and Chiaudani (1985), predicted a background P concentration of 17 µg/L for Cedar Lake, which is slightly lower than the 2002 observed concentration. The third model, Reckhow and Simpson, estimated in-lake water quality based on precipitation, land use composition, runoff and phosphorus export coefficients. Predicted P was estimated at 19-21 μg/L, which is essentially equal to the observed P for 2002. The P loading rate from the model was estimated at 1,113 – 1,284 kg P/yr. The "estimated" relative contributions to the P-loading rate are as follows: precipitation on the lake: 8-9 %, runoff from the watershed: 78 - 86 % and septic systems: 5 - 14 %. The contribution from septic systems was _estimated_ based on: the number of residences around the lake, standard per-capita P-loading rates, and an estimated soil retention of 70 (low) to 90 (high) percent. The actual relative contribution (loading rates) could be higher or lower, depending on the efficiency and maintenance of on-site systems and soils in the shoreland area. For example, well-maintained and up-to-code systems on good soils will retain a high percentage of P loaded to the system while poorly maintained systems on waterlogged soils will retain a low percentage of P.

The following recommendations are based on the Lake Assessment Program (LAP) study of Cedar Lake:

The water quality of the main basin of Cedar Lake in 2002 was similar to a reference set of minimally impacted lakes in the NLF ecoregion. TP and chlorophyll-a were slightly higher and Secchi was lower in the southwest basin. The differences between the basins are reasonable since the southwest basin is much smaller and shallower and receives a large portion of the runoff from the watershed. The lake exhibited increased algae and reduced transparency with increases in in-lake total phosphorus in 2002. Cedar Lake is sensitive to changes in trophic status due to the nutrient loading from watershed or in-lake sources. These sources increase phosphorus causing degradation of the lake. It is essential, therefore, that all local governments work with lake protection groups and land use/zoning authorities for Aitkin County. Since the western portion of the watershed is in Crow Wing County there will be a need to coordinate efforts with Crow Wing County as well. Land use protections such as buffers, green spaces and fewer paved areas in the watershed can minimize the amount of phosphorus getting into the lake. The Association should be commended for their efforts to date, which include interacting with Aitkin County, MDNR, and participating in the Citizen Lake-Monitoring Program (CLMP).



The Association should develop a Lake Management Plan for protecting the water quality of the lake. This plan should convey a series of prioritized activities for the long-term protection and improvement of the lake water quality. The plan should be developed cooperatively by a committee of representatives from state agencies (e.g., the Minnesota Department of Natural Resources [MDNR], Minnesota Board Water and Soil Resources, MPCA), local units of government, and association members. MDNR fisheries and vegetation plans should be included as well. Below are some activities that could be included in the plan.

_a)_ **The Association should continue to participate in the CLMP and related monitoring programs**. Data from CLMP provides an excellent basis for assessing long-term and year-to-year variations in algal productivity (i.e., trophic status) of the lake. The sites noted in this report should continue to be monitored. This will allow for a continued assessment of trends to determine if the observed changes are short-term (e.g. weather related) or are of a longer term nature (e.g., long-term increase in TP loading). Whenever possible transparency measurements should be made a minimum of two times per month and weekly is preferable.

_b)_ Further development or land use change in the lake's watershed should occur in a manner that minimizes water quality impacts on the lake.

In the shoreland areas, setback provisions should be strictly followed. MDNR and County shoreland regulations are important in for protecting lakes. Storm water regulations should be adhered to during and following any major construction/development activities in the watershed. Limiting the amount of impervious surfaces can reduce runoff and P loading. Properly designed sedimentation ponds should be included in any development to minimize P-loading to the lake.

Activities in the total watershed that change drainage patterns, such as wetland removal or major alterations in lake use, should be discouraged unless they are carefully planned and controlled. Restoring or improving wetlands in the watershed may also be beneficial for reducing the amount of nutrients or sediments that reach Cedar Lake. The U.S. Fish and Wildlife Service at Fort Snelling may be able to provide technical and financial assistance for these activities.

The Association should continue to seek representation on boards or commissions that address land management activities so that their impact can be minimized. Various publications on shoreland and watershed management available at:
http://www.shorelandmanagement.org/depth/index.html may be useful for educational efforts.

_c)_ On-site septic systems are a _potential_ source of nutrients to Cedar Lake.
Poorly functioning on-site systems could potentially be an important source of nutrient loading to Cedar Lake. The influence of septic systems may not necessarily be expressed in the form of dramatic increases in algae in the lake. Septic system impacts may appear as increased near-shore weed growth or excessive attached algae on docks and plants. A house-to-house septic system survey may be a useful tool to assess the general status of systems around the lake and homeowners knowledge of their systems. The Association and Aitkin County should continue to educate homeowners on proper maintenance of their systems. Any non-code systems should be brought into compliance with current standards. The Association may want to facilitate a lake-wide schedule for pumping systems to help encourage proper maintenance of systems.

d) **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 agricultural practices etc., may aid the Association in determining areas where best management practices may be needed**. For example, recent studies indicated that a majority of lawns in the Twin Cities metro area do not need additional phosphorus – this may be true for lawns in Aitkin County as well. The Association, together with Aitkin County, should encourage the use of P-free fertilizers on lawns in the watershed. The Association could work with the county to consider the feasibility of developing ordinances consistent with the 2002 State rule on phosphorus bearing fertilizers (Minn. Rule Ch. 345). Likewise, there may be opportunities to implement/promote Best Management Practices (BMP's) that may reduce nutrient loading from other sources in the watershed. Focused sampling of tributaries (flow and concentration) may be helpful as well. In this case the previous monitoring can be used to target efforts to the tributaries (subwatershed areas) that appear to have the greatest influence on Cedar Lake. The county GIS maps may be of use as well.

g) **The MPCA's Clean Water Partnership Program (CWP) is also an option for further assessing and dealing with nonpoint sources of nutrients in the watershed**. Since there is

extensive competition for CWP funding, it may be in the best interest of the Association and Cedar Lake to continue to work with Aitkin County, the local water planner and the local townships to protect the condition of the lake by means of local ordinances and education of shoreland residents. If these steps prove to be inadequate or lake conditions worsen (as evidenced by significant declines in Secchi transparency measurements), application to CWP may then be appropriate. *One indication of a declining trend in water quality would be if summer-mean transparency continue to decline from levels noted in this report or if summer-mean TP increased above about 25 μg/L.*

LAKE ASSESSMENT PROGRAM: Cedar Lake 2002

INTRODUCTION

The Minnesota Pollution Control Agency (MPCA) and Cedar Lake Conservancy sampled Cedar Lake during the summer of 2002 as a part of the Lake Assessment Program (LAP). This program is designed to assist lake associations or municipalities in the collection and analysis of baseline water quality data in order to assess the trophic status of their lakes. The general work plan for LAP includes Association participation in the Citizen Lake-Monitoring Program (CLMP), cooperative examination of land use and drainage patterns in the watershed of the lake, and an assessment of the data collected by MPCA staff.

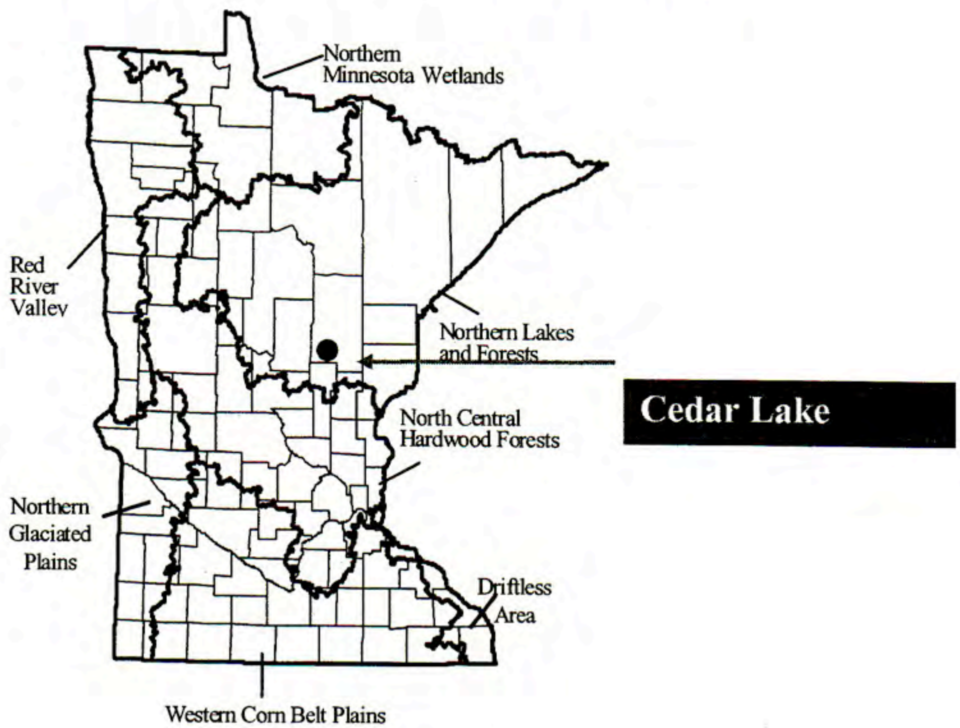
This study was conducted at the request of the Cedar Lake Conservancy (Association) and Aitkin County. Cedar Lake was sampled on three occasions during the spring and summer of 2002. Participants in this effort included Jennifer Klang and Steve Heiskary from the MPCA and Walt Sauerbrei and Les Martin from the Association. Dan Haasken, Aitkin County GIS Department, assembled land-use and watershed information for Cedar Lake. Tom Eberhardt and Walt Sauerbrei coordinated the Association's efforts on this study. Les Martin assisted with sample collection and data management for the Association. Cedar Lake also had several CLMP volunteers who collected data in 2002 and previous years. Dr. Howard Markus, MPCA, provided identification of the phytoplankton samples. Steven Heiskary, Environmental Outcomes Division MPCA, prepared this report.

BACKGROUND: Watershed, Soils, and Land Use

Cedar Lake is located in Aitkin County, near the city of Aitkin, Minnesota (Fig. 1). Cedar Lake is in the upper ten percent of lakes in the state in terms of size (1,729 acres) and has a maximum depth of over 100 feet and mean depth of about 28 feet. The lake is characterized by numerous bays. The lake has several inlets and one outlet in the northern-most basin that drains toward the Mississippi River. Cedar Brook, which drains from Portage Lake in the southwest corner of the watershed is one of the largest tributaries to the lake and flows to the small southwest bay of Cedar Lake (Fig. 2b). The lake has a fetch, longest distance can travel unimpeded by land, of about 2.0 miles with a northeast to southwest orientation.

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation and current land use. Data gathered from representative, minimally impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. Cedar Lake is located in the Northern Lakes and Forests (NLF) ecoregion (Fig. 1). Cedar Lake's watershed is about 37 mi^2 and much of that lies to the south and west of the lake based on a map provided by Aitkin County GIS (Fig. 2a). Based on conversation with Tom Eberhardt and inspection of maps it appears that portions of the land that lies to the north and east of the lake (Fig. 2b) is likely outside the watershed, since the outlet drains to the north and the highway and railroad grade serve to limit flow toward the lake from the north and east. The majority (60%) of the watershed

Figure 1. Cedar Lake Location (Ecoregion) and Lake Map



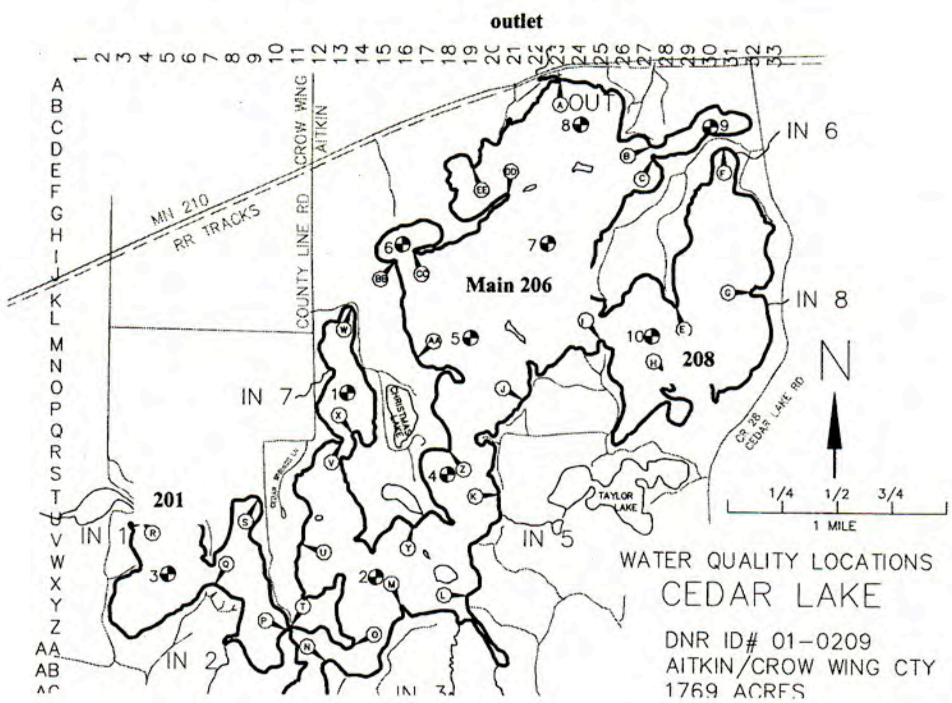


TABLE 1. Morphometric, Watershed, Fishery Characteristics
Cedar Lake (01-0209)
STORET ID #s:
01-0209-01 – main basin, 01-0209-03 – southwest basin, 01-209-02 – northeast basin

Area[1]: **1,729** acres (700 ha)

Mean Depth: **28.2** feet (8.5 meters)

Maximum Depth: **105** feet (31.8 m)

Fetch: ~ **2** miles

Littoral: **1,209** acres (70 %)

Volume[1]: ~ **48,788** acre-feet (60.2 hm^3)

Watershed Area[2]: ~**23,488** acres (36.7 mi^2) (9,069ha) (excludes lake)
~**25,257** acres (39.4 mi^2) (9,752ha) (includes lake)

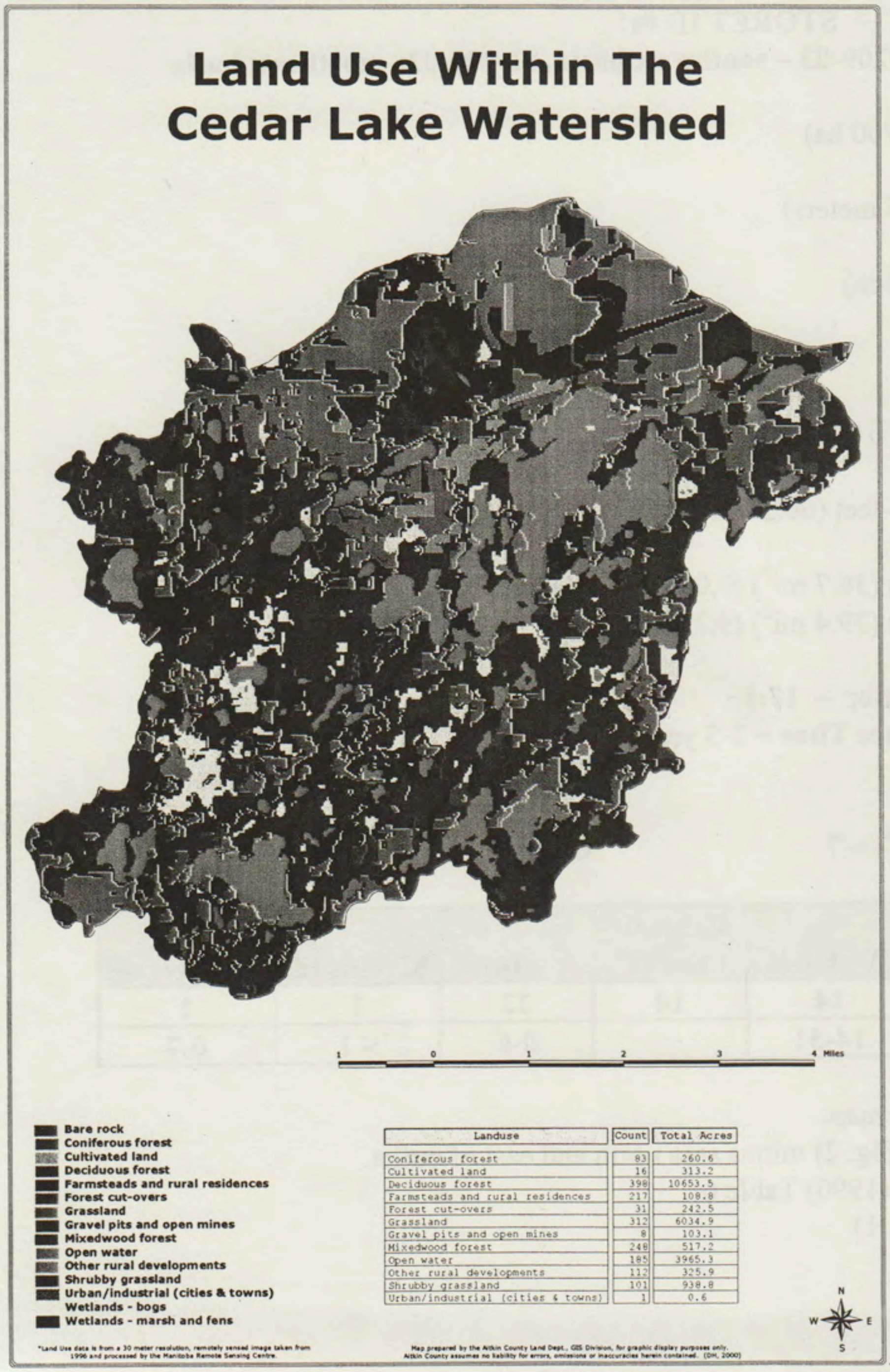
Watershed Area Lake Surface Ratio: ~ 17:1
Estimated Average Water Residence Time ~ 2-3 years

Public Access: 1 **Inlets[4]: ~ 7** **Outlets[4]:** 1

LAND USE	Forest	Wetlands	Lakes or ponds	Grass or pasture	Cropland	Residential
Cedar Watershed %	45	14	14	22	1	1
NLF Ecoregion %	54-81	14-31		0-6	< 1	0-7

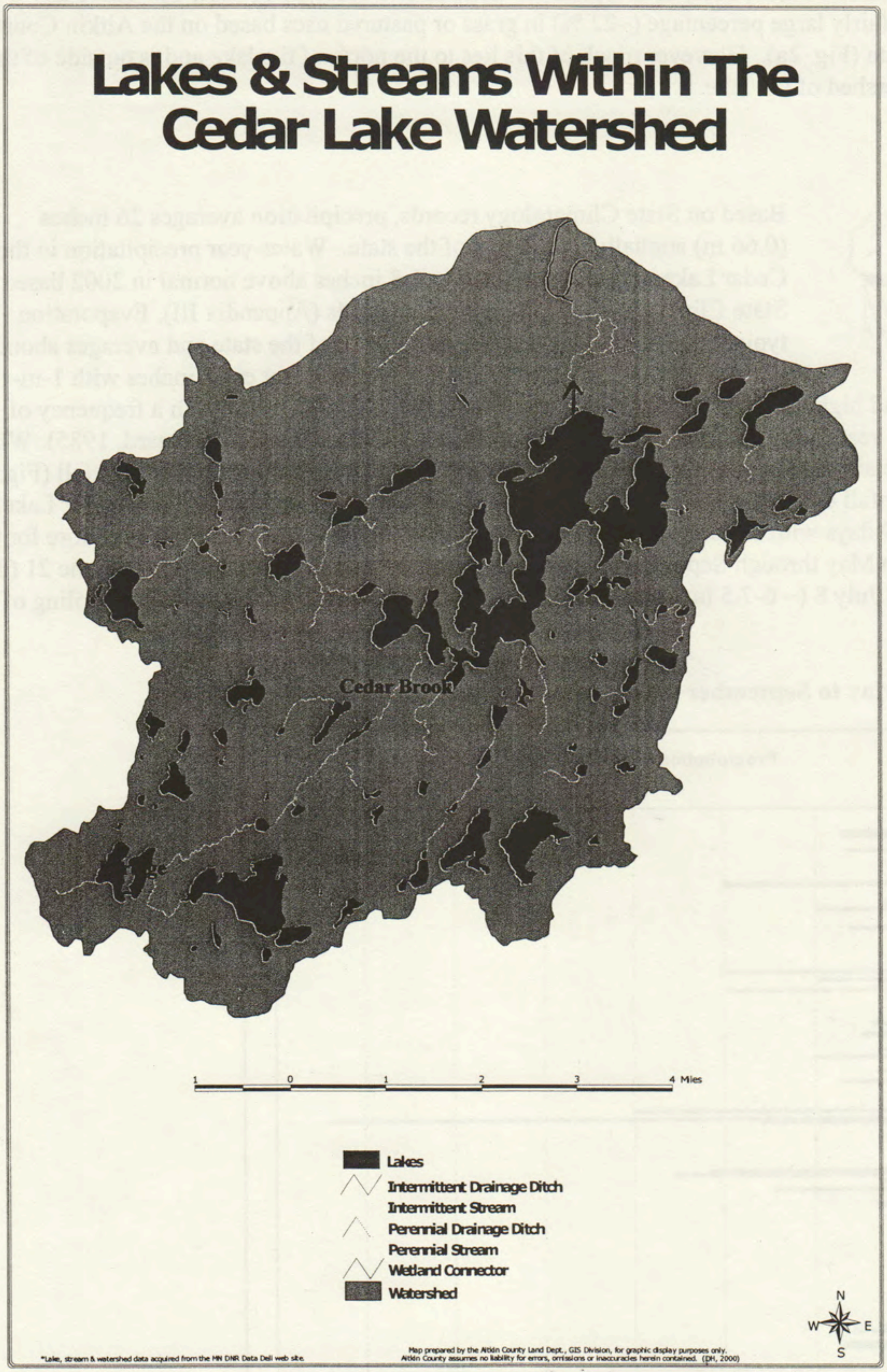
[1]Area and volume from MDNR lake map.
[2]Based on Aitkin County GIS map (Fig. 2) minus area north and east of outlet.
[3]Derived from Heiskary and Wilson (1990) Table 6.
[4] Cedar Lake Conservancy map (Fig. 1)

Figure 2a. Cedar Lake Watershed and Land use Map.
Provided by Aitkin County Land Department



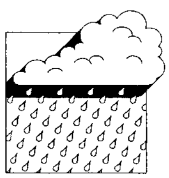
Land Use	Acres	% total
Ag- Cultivated	313	1.14%
Ag- grassland	6,035	21.98%
Develop-rural	326	1.19%
Develop-rural residence	109	0.40%
Develop-urban	1	0.00%
Forest cut-overs	243	0.88%
Forest -mixed	517	1.88%
Forest-coniferous	261	0.95%
Forest-deciduous	10,654	38.80%
Forest-Shrubby grassland	939	3.42%
Gravel pits and open mines	103	0.38%
Water	3,965	14.44%
Wetlands - bogs	968	3.52%
Wetlands - marsh and fens	3,025	11.02%
Sum	27,457	

Figure 2b.


Lakes & Streams Within The
Cedar Lake Watershed
Cedar Brook
1
0
1
2
3
4 Miles
Lakes
Intermittent Drainage Ditch
Intermittent Stream
Perennial Drainage Ditch
Perennial Stream
Wetland Connector
Watershed
N
W
E
S
*Lake, stream & watershed data acquired from the MN DNR Data Deli web site.
Map prepared by the Aitkin County Land Dept., GIS Division, for graphic display purposes only.
Aitkin County assumes no liability for errors, omissions or inaccuracies herein contained. (DH, 2000)

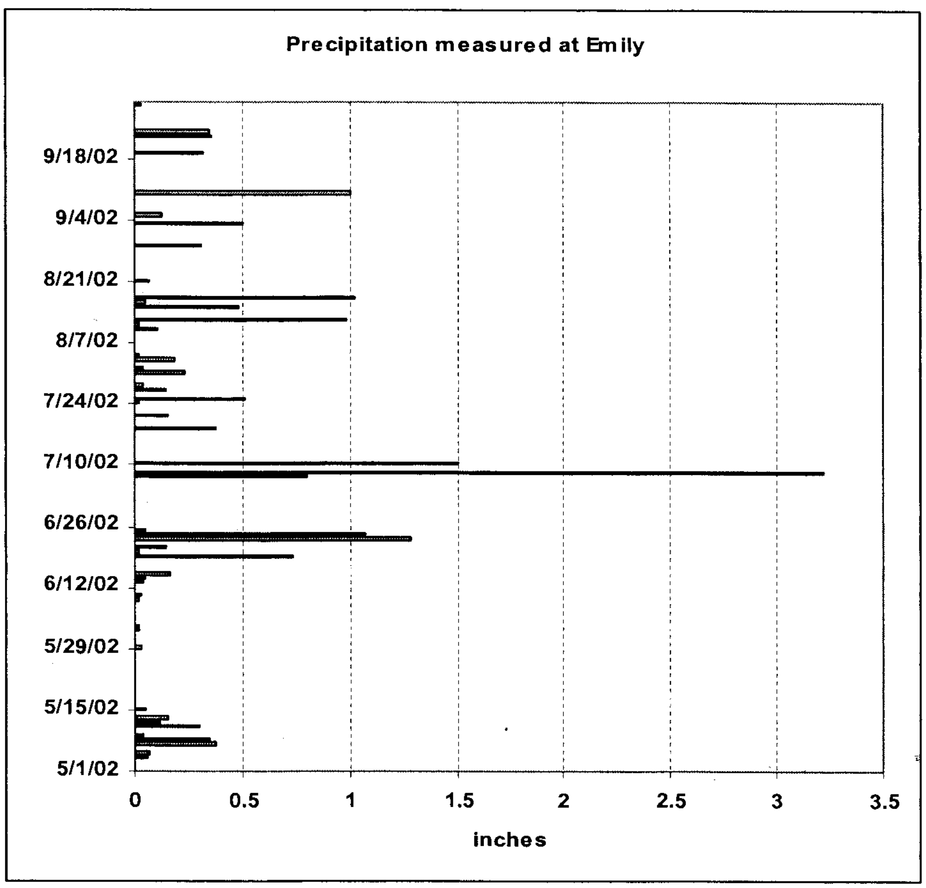
is in forested or wetland uses, as is typical for lakes in this ecoregion (Table 1). There is however a fairly large percentage (~22 %) in grass or pastured uses based on the Aitkin County land use data (Fig. 2a). However much of this lies to the north of the lake and is outside of the actual watershed of the lake.

Climate



Based on State Climatology records, precipitation averages 26 inches (0.66 m) annually in this part of the state. Water-year precipitation in the Cedar Lake watershed was about 6-8 inches above normal in 2002 based on State Climatology Office and local records (Appendix III). Evaporation typically exceeds precipitation in this part of the state and averages about 32 inches (0.81 m) per year. Runoff averages about eight inches with 1-in-10-year low and high values (low and high runoff values which might occur with a frequency of once in ten years) of 3.0 inches and 10.0 inches, respectively for this area (Gunard, 1985). While May was relatively dry (Fig. 3) June, July and August were marked by extensive rainfall (Fig. 3, MDNR rainfall data from Emily, MN). Eleanor Eberhardt, monitoring rainfall at Cedar Lake, recorded 19 days with 0.5 or more inches of rainfall and ten days with 1.0 inches or more for the period from May through September. Two particularly large storms were noted on June 21 (2.3 inches) and July 8 (~ 6-7.5 inches). The June storm was just prior to the June 27 sampling of the lake.

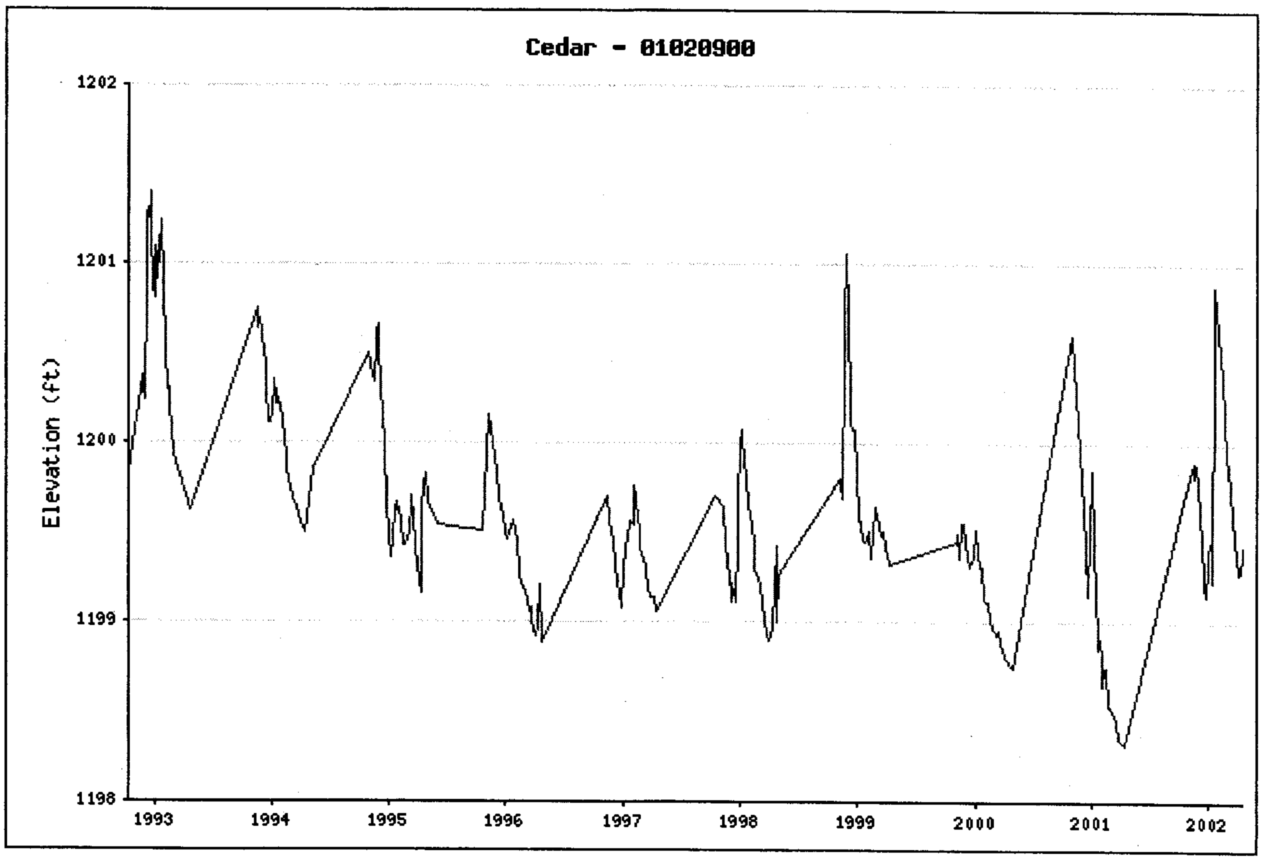
Figure 3. May to September 2002 precipitation as measured at Emily MN.

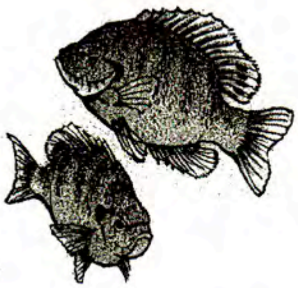


Lake Level

A summary of lake level information was drawn from the MDNR Web site and is summarized as follows. Lake level data have been collected on Cedar Lake since April 7, 1937 to October 10, 2002. The highest recorded level was 1202.33 ft (July 9, 1975) and lowest recorded was 1198.31 ft (September 29, 2001). The average for the period of record is 1199.64 ft. and the overall range is 4.02 ft. A summary of records for the most recent 10 years shows fluctuating but overall declining water levels from the high levels of 1993 to low levels in early 2000 and 2001. 2002 was marked by a sharp increase in lake level – peaking near 1201 ft. The dramatic rise in lake level in 2002 was in response to the intense summer storms (Fig. 4).

Figure 4. Cedar Lake Water Level Data (1993-2002)





Status of the Fishery: The following summary is based on an August 11, 1997 MDNR fisheries survey and was taken directly from the MDNR Web site. A survey was scheduled for summer 2002 and that survey should be referred to for up-to-date information.

Cedar Lake's physical structure and fish communities are complex and provide varied conditions for anglers and other recreational users. Though 48% of the shoreline is residentially developed most shoreline areas consist of steep slopes covered with natural woody vegetation. The shoal water substrates consist mostly of sand, gravel or muck. Marl also occurs on almost a third of the lakeshore. Cedar Lake has many bays and a high proportion of shoreline to lake volume, yet shallow productive areas are limited and steep drop-offs lead to comparatively deep and unproductive water.

Spawning habitat appears to be adequate to maintain harvestable populations of most sport fishes, including northern pike, black crappies, bluegills, largemouth bass, tullibees and walleyes. Walleye reproduction is limited despite abundant spawning habitat, therefore the walleye population is regularly supplemented with stocking. Muskellunge reproduction as of 1997 has not been documented. The population is relatively young with limited mature fish. Northern pike were caught at normal rates for this type of lake, yet the pike were small, averaging only 18.1 inches long and 1.44 pounds. Growth is slow for northern pike in the lake, particularly for four to six year old fish. Recruitment, or production of new fish to catchable size, is consistent among years. No fish older than seven years were caught in this survey, indicating that harvest may be relatively high on larger northern pike in the lake. The largest northern pike was only 29.1 inches long. Muskellunge, or muskies, are a recent addition to Cedar Lake and have been stocked annually since 1994. Only one musky was caught in this survey, however anglers have reported good catches in 1997. Some of the muskies were reported to be near the statewide 40 inch minimum harvestable size.

Walleyes were caught at an average rate for this lake type. Walleyes averaged 19.2 inches long and 2.6 pounds each, largely due to a strong 1992 year class of fish. Walleyes ranged from 10.1 to 26.4 inches long. The 1994 and 1993 year classes were not as strong as the 1992 year class and angling success for smaller walleyes may decrease for a couple of years. Large walleye catch rates are expected to remain consistent. Catches of black crappies for this lake type were normal for trap nets and above normal for gill nets in this survey. Many of the crappies sampled were from a strong 1994 year class, which averaged 7 inches. The 1994 year class of crappies will be more readily accepted by anglers in the next two years when the fish will be 8 to 10 inches long. Bluegills were caught at average rates for this lake type. Most of the bluegills in the survey nets were small, averaging only 5.2 inches long and the largest just 7.6 inches long. Recruitment is relatively stable and growth is slow. The bluegill fishing will remain as it is, producing an average catch of fish, which are generally smaller than most anglers prefer.

Largemouth bass on Cedar Lake also appear to be stable. Most of the bass in the survey nets were less than 12 inches long, however other sampling conducted indicate that the largemouth bass population is healthy with a quality size distribution. Tullibees were caught in the main basin of the lake and nearly all of the tullibees were less than 11 inches long. No tullibees were caught in any of the other nets. The tullibee population has a size structure that provides excellent forage potential for the muskies. Yellow perch catches were very low and most of the perch were small. No white suckers were caught in this survey. Low forage abundance for northern pike restricts pike growth and limits recruitment of smaller northern pike to trophy sizes. Muskies prey heavily on tullibees and are becoming the trophy species in Cedar Lake.

Septic System Survey

The Association did not conduct a house to house septic system survey. However an inspection of county records by Eleanor Eberhardt indicated that there are about 405 residences around the lake and of these, about 154 are year-round residences. No information was available on the status of (compliance) on-site systems around the lake. Aitkin County does have an ordinance that requires compliant systems prior to obtaining a building permit or selling a property.

Economic significance of Cedar Lake to local economy

In addition to being valuable natural resources, lakes are also valuable for their contribution to local and state economy. For example, it is estimated that lakes in the Big Sandy Area Lake Watershed (BSALW), north of McGregor, with a total surface area of 14,996 acres, generated an estimated $10,302,252 in consumer purchases, plus an estimated 247 jobs (BSALW Management Plan, 1993). Riparian lots and buildings on Big Sandy Lake, for instance, have an assessed market value of over $46 million. Further details on this approach for estimating the economic contributions of lakes may be found in the Minnesota Lake and Watershed Data Collection Manual (Heiskary et al. 1994)

Similar estimates were made for Cedar Lake based on a surface area of 1,729 acres and formulas presented by Hank Todd (1990), Director of Minnesota Department of Tourism (adjusted for inflation to 1992):

a) Consumer purchases $687/acre-year x 486 acres = $1,187,823 / year
b) Value added $501/acre-year x 1.744 = $1,510,703 / year
c) Impact on employment 16.5 jobs/thousand acres = 28 jobs

Based on these estimates it is evident that Cedar Lake makes an important contribution to the local and state economy.

RESULTS AND DISCUSSION

Water quality data was collected in May, June, and September, 2002. MPCA coordinated sampling for May and September and the Association coordinated efforts for June, July and August. Collections were not made in July. An August sample was collected but was lost in shipment to the laboratory. Four sites were monitored on Cedar Lake: site 208 (east basin, main lake), 206 (west basin, main lake), 202 (southwest basin, main lake) and 201 (southwest bay) (Fig. 1). These sites are used for CLMP measurement and were previously used by the Association in earlier monitoring efforts and correspond to sites 10, 7, 2, and 3 respectively (Fig. 1). 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). Phytoplankton (algae) samples were taken at two sites in May and September with an integrated sampler. Secchi disk monitoring through the CLMP has historically been conducted at several sites on the lake.

Sampling procedures were employed as described in the MPCA Quality Control Manual. Laboratory analyses were performed by the laboratory of the Minnesota Department of Health using U.S. Environmental Protection Agency (EPA)-approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, turbidity, conductivity, chloride and chlorophyll (Table 2). Temperature and dissolved oxygen profiles and Secchi disk transparency measurements were also taken.

Minimal historical data was available for comparison. All data was stored in STORET, the EPA's national water quality data bank. The following discussion assumes that the reader is familiar with basic water quality terminology as used in the Citizens' Guide to Lake Protection.

In-lake Conditions: 2002

Dissolved oxygen and temperature profiles were taken at one-meter intervals at each site on each date in May, June, August, and September. Data from the June and August samplings are presented in Fig. 4 and MPCA profile data from May and September are presented in Appendix I. Surface temperatures ranged from13-14 degrees C in May to a peak of 22-23 degrees C in September (Fig. 5, Appendix I)). Thermal stratification was evident from June through September. The thermocline (zone of rapid change in temperature over a short range in depth) formed between 5 to 7 meters (16.5-23 feet) in June. The main basin remained stratified through September as evidenced by the temperature and DO gradient and the low hypolimnetic DO concentrations (Appendix I).

Dissolved oxygen (DO) concentrations fell below 2 mg/L in the hypolimnion during stratification (Fig. 5). This would be too low for game fish, which typically require a dissolved oxygen concentration of 5 mg/L or greater for long-term survival. Also, as oxygen concentrations fall below 2 mg/L at the sediment-water interface, internal recycling of phosphorus from the sediments to the water may occur. Chemical and biological reactions in the lower layer (during stratified conditions) lead to lower pH and increased conductivity (Appendix I).

Total phosphorus (TP) concentrations (an important nutrient for plant growth) averaged approximately 20 ±3 µg/L (micrograms per liter or parts per billion) in the surface waters of Cedar Lake during the summer of 2002 as a lake-wide mean. This value is within the range of concentrations typically found in reference lakes in the NLF ecoregion (Table 2). TP concentrations were slightly higher in the southwest bay ("Little Cedar Lake") as compared to the sites in the main basin (Table 2). TP concentrations and patterns at all four sites were quite similar across the three sample dates (Fig. 6). All sites exhibited a slight decline from May to June followed by an increase in September. The September increase likely reflects the frequent storms and runoff that occurred between the June and September sample dates (Fig. 3). The slightly higher TP in the southwest basin seems reasonable since this basin is much smaller and shallower than the main lake and receives runoff from one of the larger subwatersheds of Cedar (Cedar Brook, Fig. 2b).

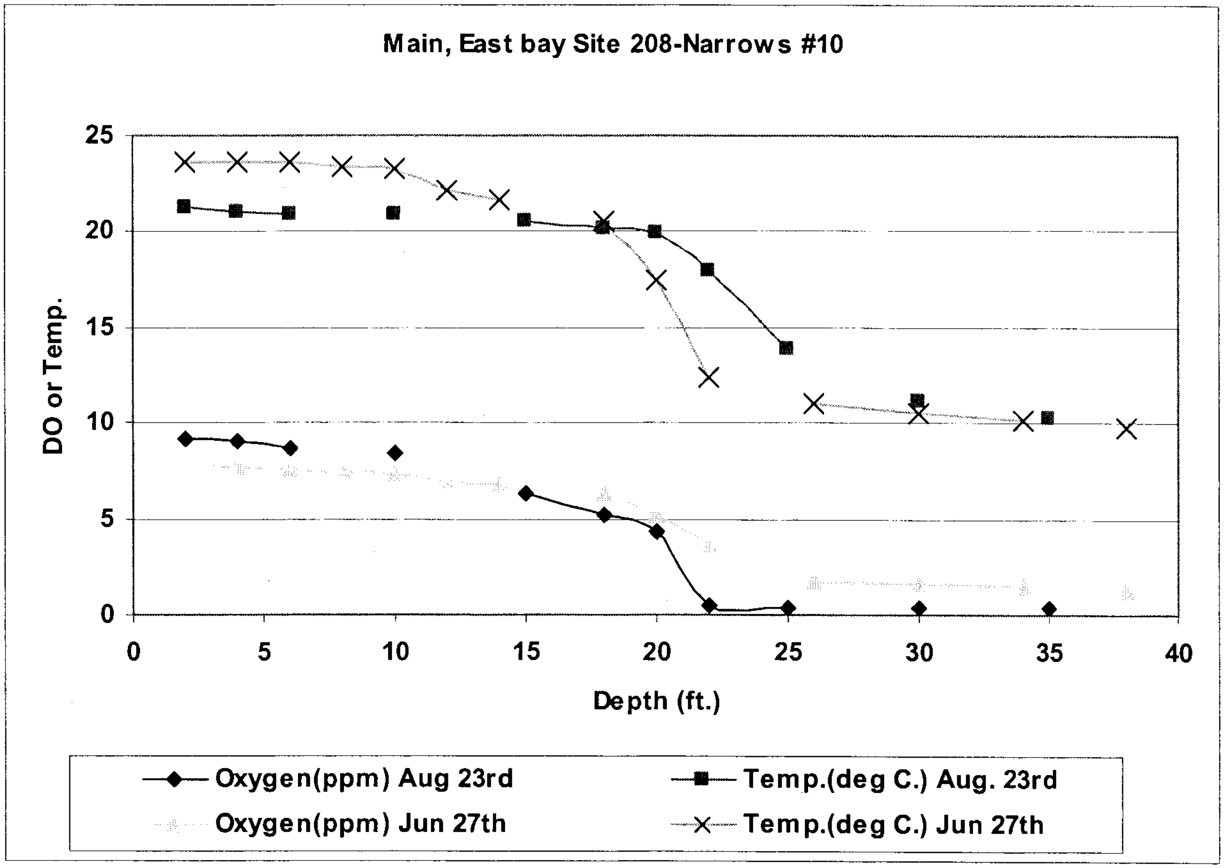
Hypolimnetic TP samples were collected in May and September. Samples are typically collected one meter above the bottom of the lake. These concentrations were quite similar to the surface concentrations in May, when the lake was relatively well-mixed, but were elevated in September, when the lake was stratified (Appendix I). A summary of surface and bottom samples for September are as follows:

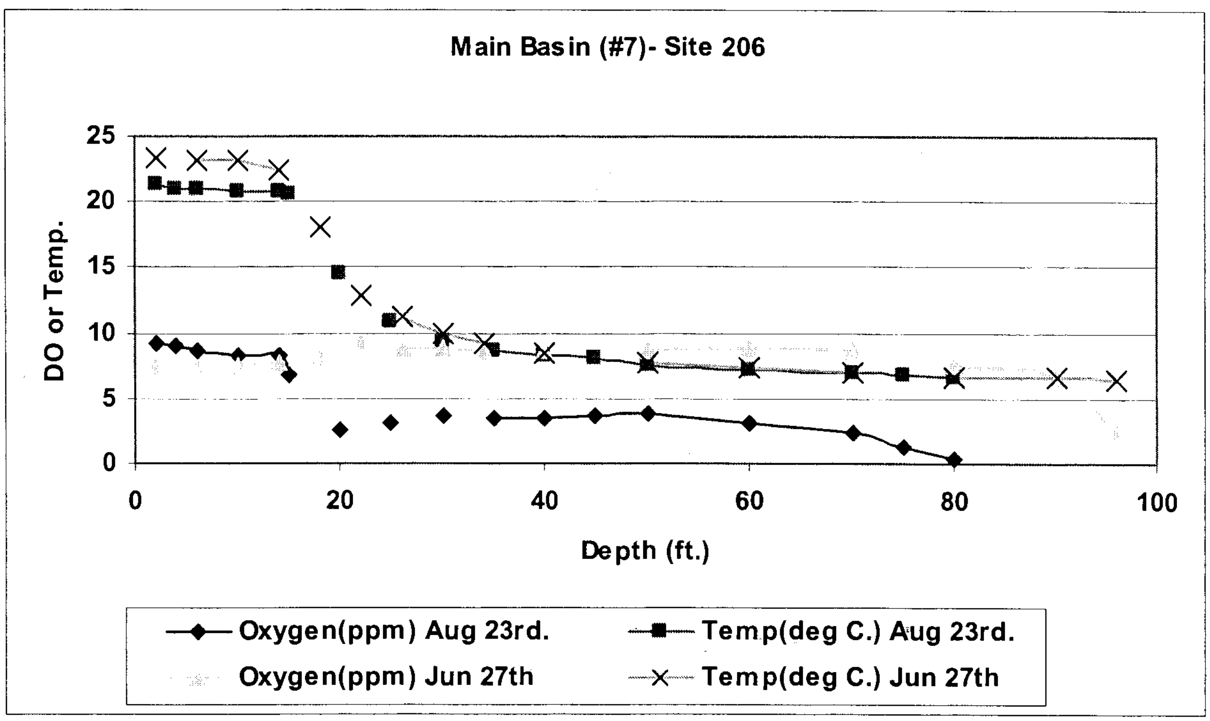
Site	surface	bottom
202	22 ppb	120 ppb
206	20 ppb	10 ppb
208	21 ppb	234 ppb
201 (SW bay)	27 ppb	149 ppb

This increase in TP in the bottom waters reflects some internal release of TP from the sediments (which is typical for a stratified lake) that occurs under oxygen poor conditions. In each case, with the exception of site 206, DO at the depth of collection was less than one mg/L (Appendix I). The sample at 206 was collected about two meters off the bottom and DO was slightly above one mg/L. Though TP was elevated in the hypolimnion it had minimal influence on surface concentrations during the summer (and was not available for algae growth) until fall mixing of the lake.

Total Kjeldahl nitrogen (TKN) averaged 0.626 mg/L on Cedar Lake in summer 2002, and as with TP concentrations were slightly higher in the southwest basin (Table 2). These concentrations are well within the typical range for TKN concentrations found in reference lakes in the NLF ecoregion.

Figure 5. Dissolved oxygen and temperature profiles for Cedar Lake. Profiles taken and graphs prepared by Les Martin.





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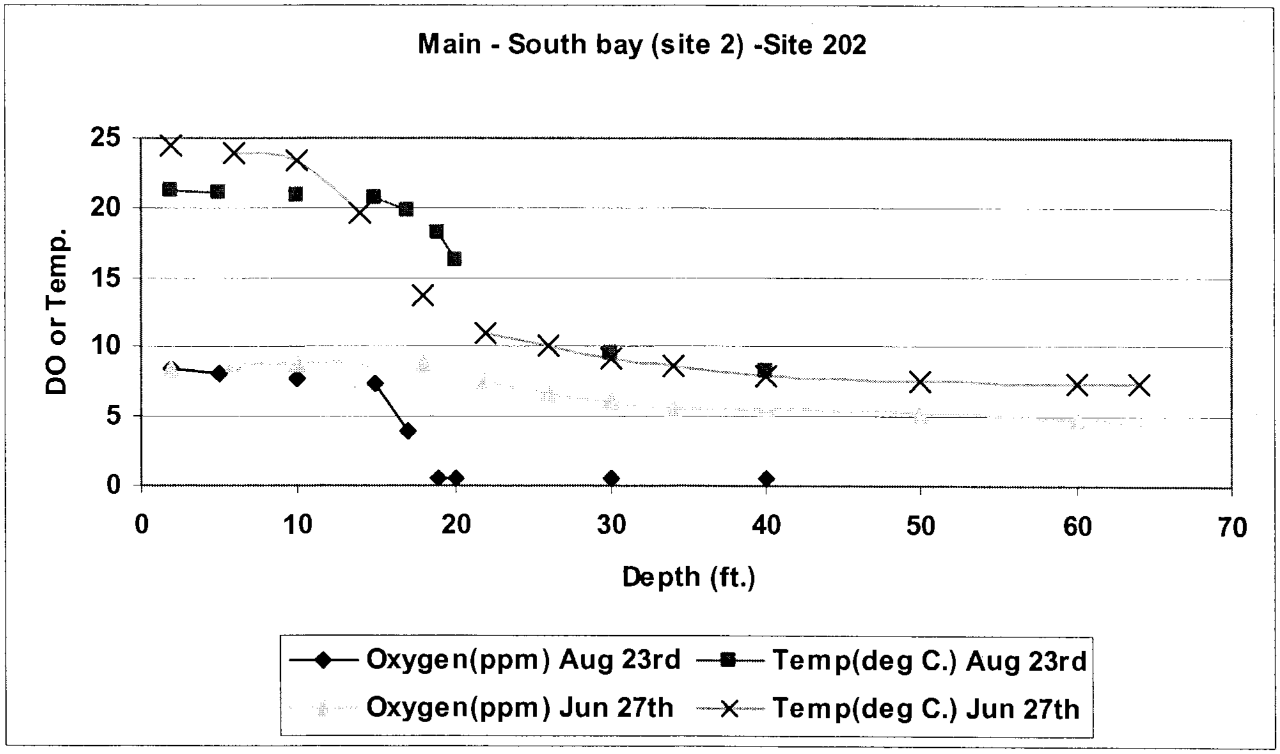
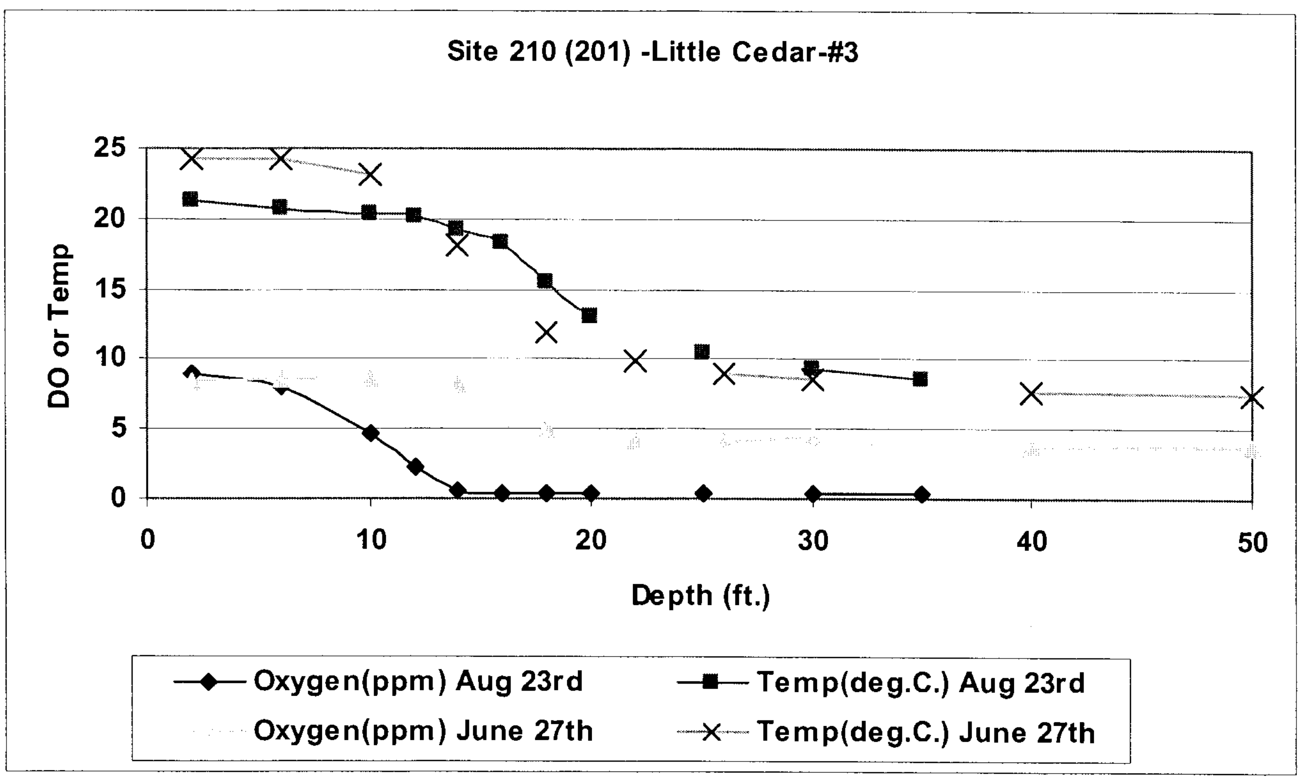

Main - South bay (site 2) -Site 202
25
20
15
10
5
0
DO or Temp.
0
10
20
30
40
50
60
70
Depth (ft.)
Oxygen(ppm) Aug 23rd
Temp(deg C.) Aug 23rd
Oxygen(ppm) Jun 27th
Temp(deg C.) Jun 27th


Site 210 (201) -Little Cedar-#3
25
20
15
10
5
0
DO or Temp
0
10
20
30
40
50
Depth (ft.)
Oxygen(ppm) Aug 23rd
Temp(deg.C.) Aug 23rd
Oxygen(ppm) June 27th
Temp(deg.C.) June 27th

The ratio of total nitrogen: total phosphorus (TN: TP) can provide an indication as to which nutrient is limiting the production of algae in the lake. For Cedar Lake, the TN:TP ratio is about 31:1 as a lakewide average. This indicates that phosphorus is the limiting (controlling) nutrient in Cedar Lake. Generally, phosphorus is the least abundant nutrient and, therefore, is the limiting nutrient for biological productivity in a lake. Lakes are often considered "nitrogen-limited" when the TN: TP ratio falls below about 10:1. The TN: TP ratio for Cedar Lake is quite comparable to that found in the NLF reference lakes (Table 2).

Chlorophyll a concentrations can estimate of the amount of algal production in a lake. The average and maximum chlorophyll a concentrations for Cedar Lake were well within the typical range for NLF reference lakes (Table 2). During the summer of 2002, chlorophyll a concentrations on Cedar Lake ranged from about 5 µg/l to 36 µg/L with an average of 9.6 µg/L as a lakewide mean (Figure 5). Concentrations were quite comparable among the three sites in the main basin but were slightly higher in the southwest basin (Fig. 5). Concentrations ranging from 10 – 20 µg/L are frequently perceived as a *mild algal bloom*, while concentrations greater than 20 µg/L may be perceived as a nuisance bloom (Heiskary and Walker, 1988). The peak chlorophyll-a (36 µg/L) in September in the southwest basin would be an example of a nuisance bloom.

Phytoplankton (algae) composition of Cedar Lake was assessed for the main basin at site 208 and the southwest basin at site 201. Data are presented in terms of algal type. In May the diatoms Fragilaria, Tabellaria, Asterionella, and Melosira, along with some golden-brown and red algae were common at both sites. In September blue-green forms were common at both sites with Anabena, Aphanizomenon, and Microcystis being the most common at both September. These blue-green algae tend to float at the surface so it is likely that the high chlorophyll-a concentration noted in the southwest basin in September would have been dominated by these forms and would have appeared as surface blooms. A seasonal transition in algal types from diatoms to greens to blue-green is rather typical for mesotrophic and eutrophic lakes in Minnesota. So what we see here, based on these two sample dates would not be considered unusual.

TABLE 2: Average Summer Water Quality and Trophic Status Indicators: Cedar Lake, based on 2002 Epilimnetic Data.
Based on three sites in main basin and site 101 southwest basin.

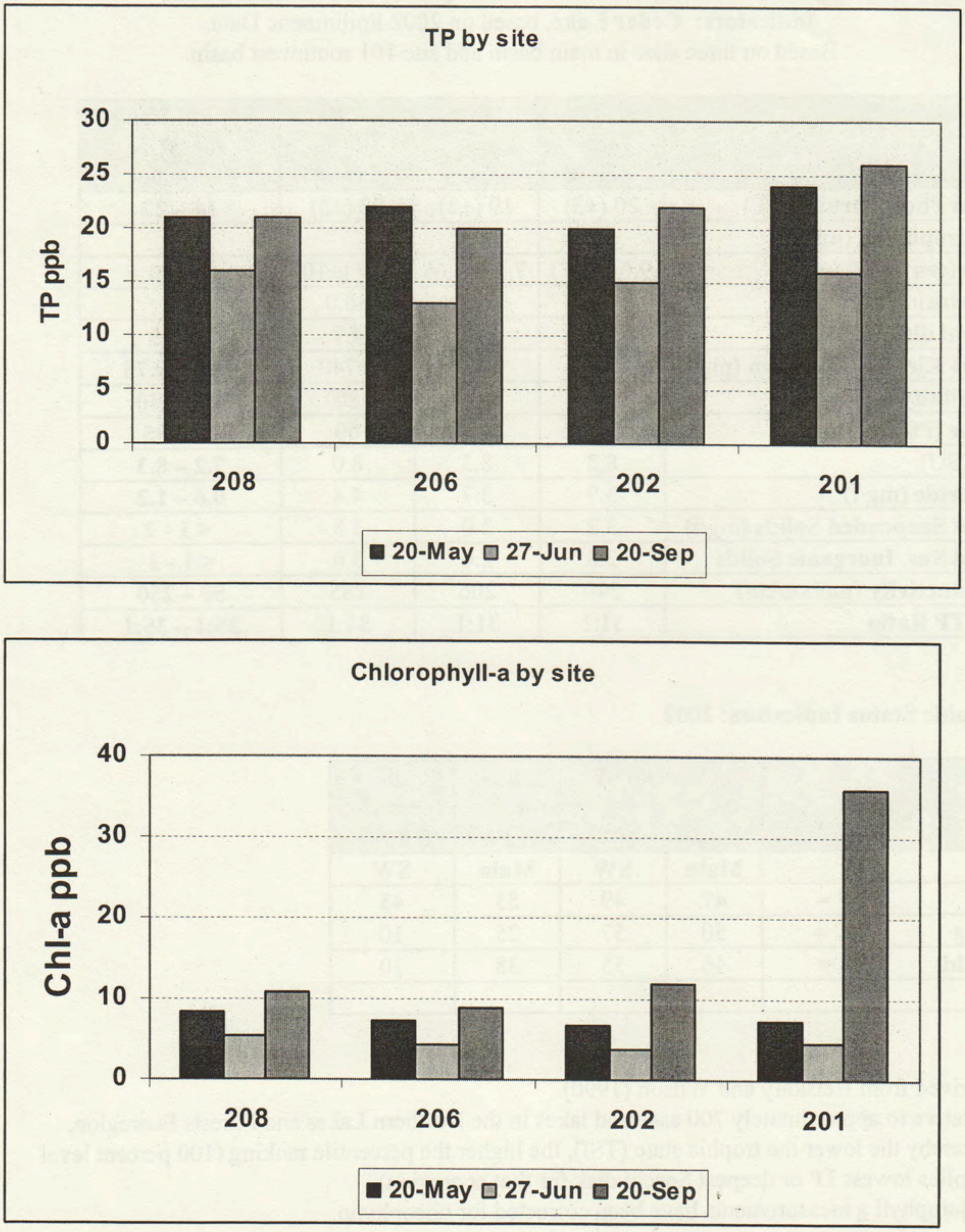
Parameters	Lake Mean	Main	SW Basin (Little Cedar)	**Typical Range for NLF Ecoregion**[1]
Total Phosphorus (µg/L)	20 (±3)	19 (±3)	22 (±3)	**14 – 27**
Chlorophyll a (µg/L)[3]				
Mean	9.6 (±3.7)	7.5 (±1.6)	15.9 (±10)	**4 – 10**
Maximum		11.8	36.0	
Secchi disk (feet)	7.9	8.9	4.7	**8 – 15**
Total Kjeldahl Nitrogen (mg/l)	0.626	0.588	0.740	**0.40 – 0.75**
Alkalinity (mg/l)	98	103	80	**40 – 140**
Color (Pt-Co Units)	31	22	60	**10 – 35**
pH (SU)	8.2	8.3	8.0	**7.2 – 8.3**
Chloride (mg/l)	3.9	3.7	4.4	**0.6 – 1.2**
Total Suspended Solids (mg/l)	3.2	3.0	3.8	**< 1 - 2**
Total Sus. Inorganic Solids	2.3	2.0	3.0	**< 1 - 2**
Conductivity (µmhos/cm)	240	206	285	**50 – 250**
TN:TP Ratio	31:1	31:1	34:1	**25:1 – 35:1**

Trophic Status Indicators: 2002

		Carlson's TSI		**%tile for NLF**	**% tile for NLF**
site		**Main**	**SW**	**Main**	SW
TP	TSIP =	47	49	53	45
Chl a	TSIC =	50	57	25	10
Secchi	TSIS =	46	55	38	10

[1] Derived from Heiskary and Wilson (1990).
[2] Relative to approximately 700 assessed lakes in the Northern Lakes and Forests Ecoregion, whereby the lower the trophic state (TSI), the higher the percentile ranking (100 percent level implies lowest TP or deepest Secchi disk for that ecoregion).
[3] Chlorophyll a measurements have been corrected for pheophytin.

Figure 6. Cedar Lake 2002 Total Phosphorus and Chlorophyll-a Concentrations – Surface Samples by site and date.



Secchi disk transparency is generally a function of the amount of algae in the water. Suspended sediments or color due to dissolved organic material may also reduce water transparency. Color for the main basin of Cedar Lake averaged about 22 Pt-Co units, indicating slight coloration due to incompletely dissolved organic matter (tannin from upstream wetlands), while color values for the southwest basin were slightly higher at 60 Pt Co units, which indicates moderate to dark coloration. Total suspended solids (TSS) averaged 3 – 4 mg/L and total suspended inorganic solids averaged about 1mg/L for Cedar Lake over the summer. Suspended volatile sediment (organic sediment, i.e., algae) is the primary contributor to the TSS. The total suspended and inorganic solids values are slightly higher than typical of values found in reference lakes in this region (Table 2). These levels of color and total suspended solids should not appreciably limit water transparency in Cedar Lake.

Secchi disk transparency data for Cedar Lake was collected by volunteers in MPCA's Citizen Lake-Monitoring Program (CLMP). Along with CLMP transparency measurements, subjective measures of Cedar Lake's "physical appearance" and "recreational suitability" were made. These data are particularly valuable as they help fill the gap in the chemical data between the June and September sample dates and are the primary basis for assessing trends over time in Cedar. Secchi transparency varied over the course of the summer and among sites in 2002 (Fig. 7). In the north portion of the main basin (site 207) Secchi varied from about 9.5 feet in June to about 8.5-9.0 feet in the latter part of the summer, with the biggest change falling between July 6 and July 24. In the east bay of the main basin a gradual decline in transparency from 9 feet in June to 7 feet in August and September was noted with significant changes noted between July 5th and July 18th and between August 4th and August 10th. The northeast bay (site 201), which is relatively isolated from the main body of the lake, had Secchi measurements ranging from 12 feet in June to 8 feet by September (Fig. 7). The southwest bay, also referred to as Little Cedar, had the lowest transparency ranging from 7 feet in June to 3-4 feet in July through September, with the largest change occurring between July 6th and July 13th. The marked change in Secchi at all sites in mid July was likely a result of the major rainfall and runoff that occurred during that period of time (Fig. 3). These storms and the runoff that accompanied them would have increased the phosphorus loading to the lake, which would have stimulated the growth of algae (Fig. 6). The increased algae, combined with the humic (coffee) coloration from the wetlands, would serve to reduce transparency in the lake. The reduction is most evident in Little Cedar, which receives much of the runoff from the southern watershed that has extensive wetland areas.

The average transparency based on the four sites in Fig. 7 was 7.9 feet (2.4 m), which is near the lower end of the typical range for reference lakes in the NLF ecoregion (Table 2). The average for the main basin was 8.9 feet as compared to 4.7 feet for the southwest basin. The northeast basin had the highest transparency at 9.9 feet. Perceptions of "physical condition" and "recreational suitability" varied somewhat among sample sites and observers. In the northeast basin the decline in transparency from 11 to 9 feet was accompanied by perceptions of "definite green" and "slightly impaired for swimming." As transparency fell below about 8 feet at sites

207 and 208 similar perceptions were recorded. In Little Cedar perceptions of "swimming impaired" and "nuisance blooms" were recorded as transparency fell below 4 feet.

The change in the transparency of Cedar Lake over the course of the summer is fairly typical for lakes in Minnesota. Typically, transparency is high in the spring when the water is cool and algae populations are low. Frequently, zooplankton (small crustaceans which feed on algae) populations are high at this time of year also, but will decline later in the summer because of predation by young fish. As the summer goes on, the waters warm and the algae make use of available nutrients. As the algae become more abundant, the transparency declines. Based on the 2002 data there are some distinct differences in transparency among the various basins that comprise Cedar Lake.

One way to evaluate the **trophic status** of a lake and to interpret the relationship between total phosphorus, chlorophyll a and Secchi disk readings is Carlson's Trophic State Index (TSI) (Carlson 1977). This index was developed from the interrelationships of summer Secchi disk transparency and the concentrations of surface water chlorophyll a and total phosphorus. TSI values are calculated as follows:

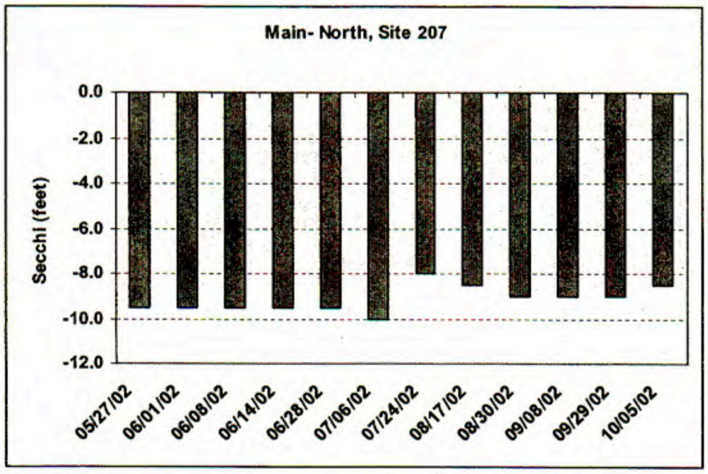
Total phosphorus TSI (TSIP) = $14.42 \ln(TP) + 4.15$
Chlorophyll a TSI (TSIC) = $9.81 \ln(\text{Chl-a}) + 30.6$
Secchi disk TSI (TSIS) = $60 - 14.41 \ln(SD)$

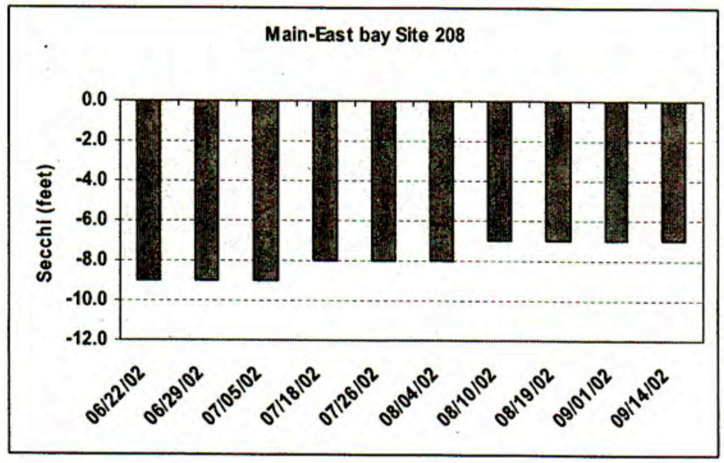
TP and chlorophyll a are in µg/L and Secchi disk transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal biomass.

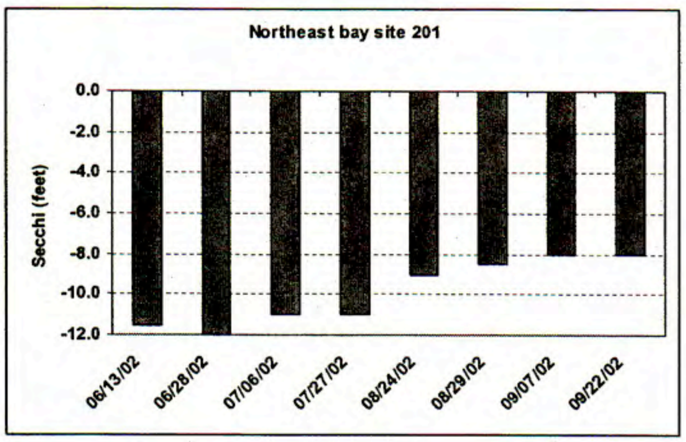
Average values for the trophic variables in Cedar Lake and respective TSIs are presented in Figure 8. Based on these values, Cedar Lake's condition would be characterized as *mesotrophic* to *eutrophic*. The TP TSI of 47 (main basin) and 49 (southwest basin) ranks Cedar Lake at the 53rd to 45th percentiles, respectively, relative to other lakes in the NLF ecoregion. This implies that relative to other assessed lakes in the NLF, 47 and 55 percent had a lower TSI value (i.e., lower TP). The individual TSI values for TP, chlorophyll-a and Secchi transparency agree fairly well with one another (Table 2 and Figure 7) for the main basin and implies that Secchi transparency should provide a good estimate of trophic status for Cedar Lake. In the southwest basin the chlorophyll-a and Secchi TSI values are slightly higher than the TP TSI value. The darker coloration of the water in the southwest basin contributes in part to the higher Secchi TSI value.

The other measured water quality parameters were within or slightly above the typical range of values for the NLF reference lakes. Alkalinity and conductivity are within or near the typical range of expected values for the reference lakes, indicated moderately hard-water (moderate dissolved minerals). Chloride values are slightly higher than the typical range and likely reflect the use of road-salt on roads in the watershed.

Figure 7. Cedar Lake CLMP Secchi Transparency for 2002.







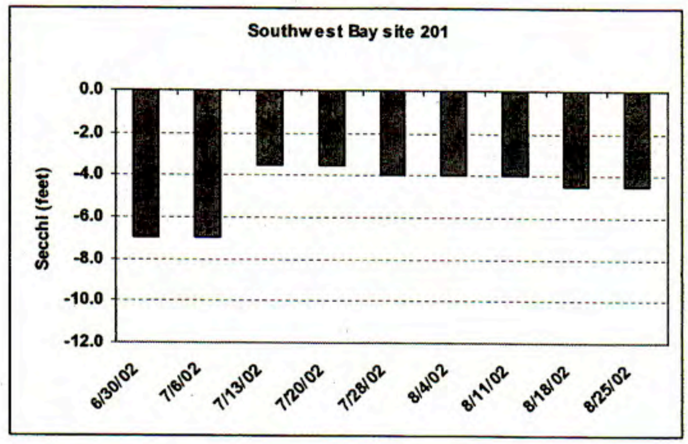


Figure 8. Carlson's Trophic State Index for Cedar Lake, Aitkin County
R.E. Carlson

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.

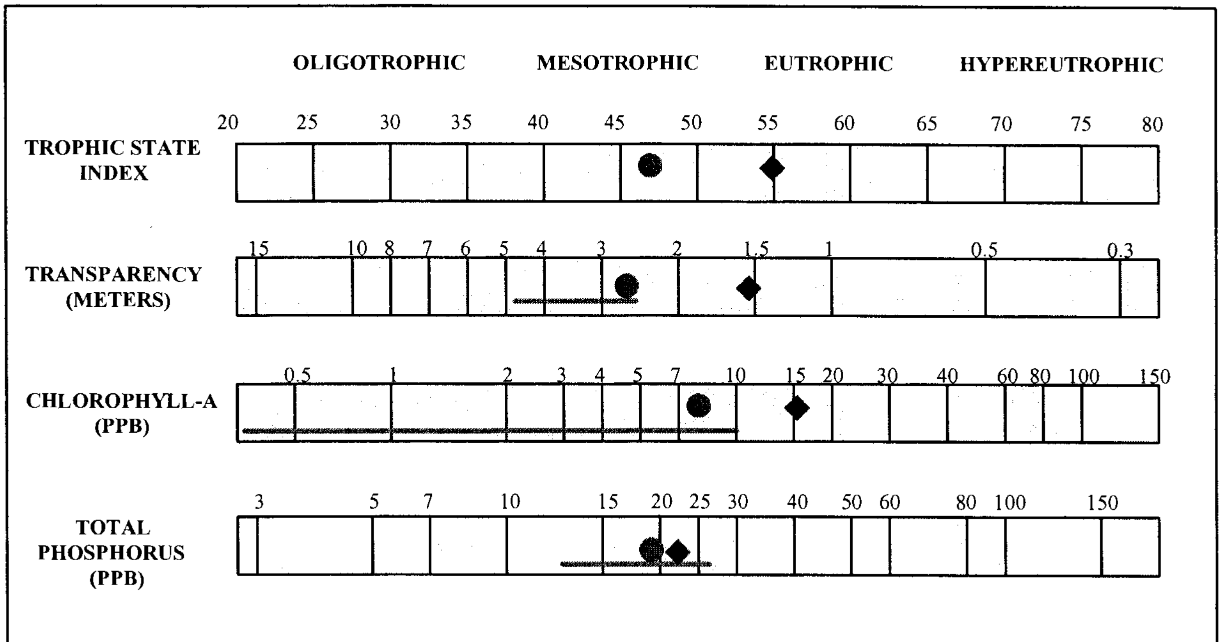
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

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 blue-green 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.

NLF Ecoregion Range: ———— ● ◆ Cedar Lake – main and southwest

Tributary sampling

Several tributaries to Cedar Lake were sampled by the Association in 2002 to help determine water and pollutant loading to the lake. These tributaries reflect runoff from different portions of the watershed. Raw data as supplied by Les Martin are included in Appendix II. In most instances the tributaries were sampled on three to seven occasions between June and November. On most occasions flow was estimated and field or laboratory measurements of pH, conductivity and TP were made. Data collected at each site were summarized for the summer period in Table 3. Since not all sites were measured on each date or at the same frequency it is a bit difficult to draw conclusions as to which sites exhibit the highest loading to Cedar. However the data can be used to make some relative comparison to one another and to the typical concentrations (TP) for streams in the NLF ecoregion. This may help to prioritize sampling efforts in the future.

Typical summer TP concentrations from minimally-impacted streams in the NLF ecoregion are between 30-50 ppb (McCollor and Heiskary, 1993). In the more nutrient-rich NCHF ecoregion typical concentrations range between 70-170 ppb. Using the NLF values as one basis of comparison it would appear that TP concentrations from Black Bass, Casey, Dogfish, and Back Brook are fairly typical for the NLF ecoregion. In contrast, Cedar entry, Sandstrom, Blue and Taylor Lake are a bit high. Of these four, only Cedar entry had an appreciable flow during the summer of 2002. This flow value was strongly influenced by the July 8 sampling (320 cfs) that followed high rainfall in late June and early July. Also the mean TP for Cedar entry is strongly influenced by a August 20th measurement of 170 µg/L. This high measurement may be the result of sediments and nutrients scoured from an upstream beaver pond (dam) that had been breeched by the July storms (Les Martin, personal communication).

The aggregate mean TP from all tributaries was 55 µg/L, which is close to the typical range for minimally impacted NLF streams. Cedar outlet TP concentrations were rather similar to the in-lake TP concentrations (Table 2), which they should be, and this suggests that the TP concentrations measured by the Association are reasonably accurate. Based on the 2002 sampling effort it appears that the most emphasis should be placed on the watershed drained by Cedar entry as it tended to have the highest flow and a high TP concentration. The Sandstrom tributary may merit additional consideration as well since TP was high on all three sample dates (Appendix II).

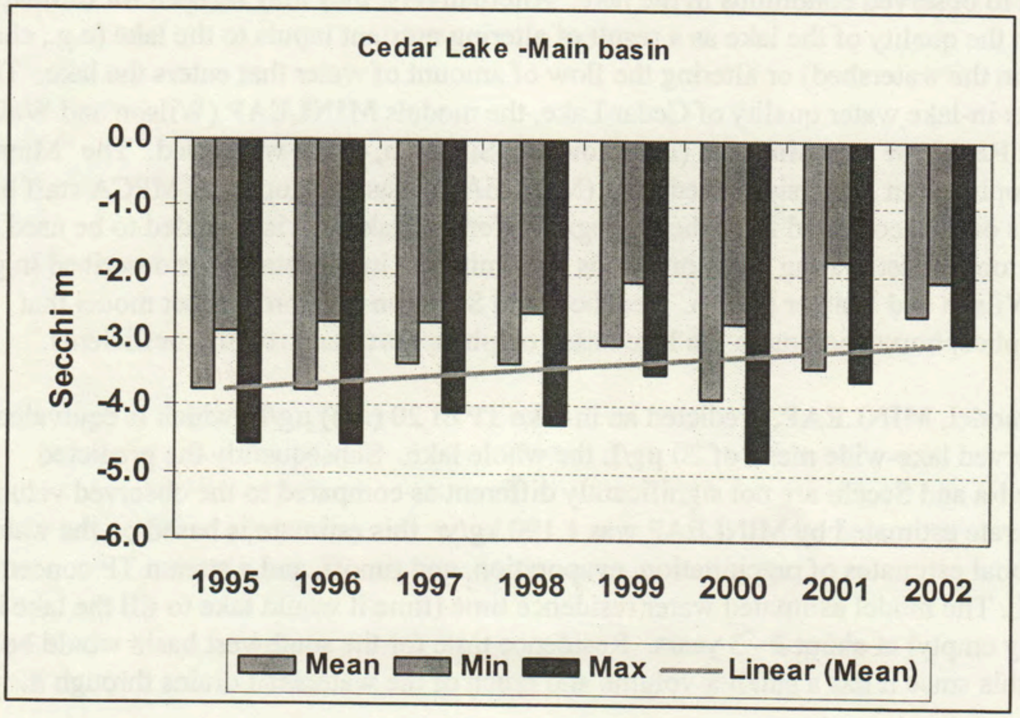
Table 3. Cedar Lake tributary June to September mean measurements

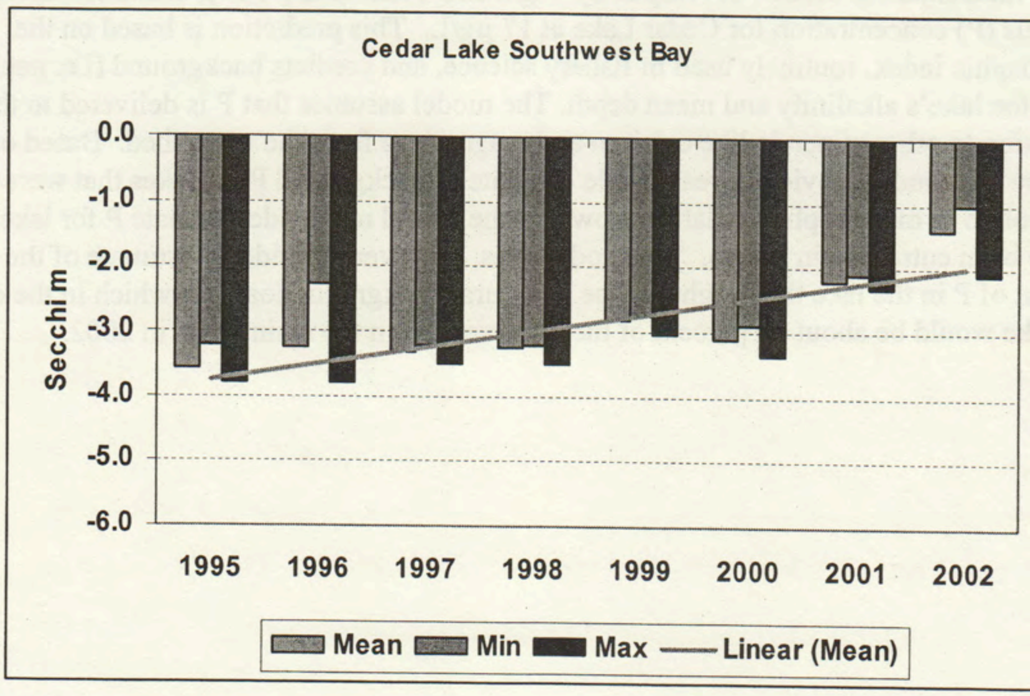
Stream	Number of visits	Flow (cfs)	pH	conductivity (umhos)	TP (ppb)
Black Bass	3	22	7.2	88	40
Cedar entry	5	58	7.7	191	85
Casey	7	35	7.3	133	46
Sandstrom	3	4	6.3	88	107
Dogfish	3	5	7.3	91	15
Blue	3	6	7.2	326	78
Taylor Lake	4	8	8.0	296	64
Back Brook	3	13	7.5	219	39
Cedar Outlet	5	79	8.4	229	25

Water Quality Trends

Cedar Lake has limited data, in STORET, from previous samplings for comparison to the 2002 results. Single observations of TP and chlorophyll-a from 1981 revealed concentrations of 13 µg/L and 8.6 µg/L respectively. Secchi based on five measurements in 1981 averaged 2.1 meters. The best basis for evaluating trends in Cedar Lake is the CLMP Secchi data that has been collected since 1995 (Fig. 9). Main basin data were collected by numerous observers. Pooling the data from all observers in each year reveals mean transparency values in the 3.0 to 3.5 meter (10-11 feet) range in most summers. Maximum Secchi is typically between 4.0 – 4.5 meters 13-15 feet) and minimum Secchi is typically between 2.0 – 3.0 meters (6.6-10 feet). Based on these eight years of data there is a slight trend toward declining transparency. The southwest bay exhibits somewhat lower transparency as compared to the main lake, which is reasonable considering that much of the watershed drains to this bay and it is much shallower (less volume) than the main lake. Its trend toward declining transparency was somewhat more pronounced than the trend for the main lake. The declining transparency trend in both basins was most pronounced in 2002 and may be attributed to the high rainfall and runoff that was experienced in this area.

Figure 9. Summer-mean, maximum and minimum transparency for Cedar Lake





Modeling and Phosphorus Loading

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow of amount of water that enters the lake. To analyze the in-lake water quality of Cedar Lake, the models **MINLEAP** (Wilson and Walker, 1989) and **Reckhow and Simpson** (Reckhow and Simpson, 1980) were used. The "Minnesota Lake Eutrophication Analysis Procedures" (MINLEAP), was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). Reckhow and Simpson is a spreadsheet model that estimates phosphorus loading to the lake based on phosphorus and runoff coefficients.

The first model, **MINLEAP,** predicted an in-lake TP of 20 (± 6) µg/L, which is equivalent to the 2002 observed lake-wide mean of 20 µg/L the whole lake. Subsequently the predicted chlorophyll-a and Secchi are not significantly different as compared to the observed values. The P-loading rate estimated by MINLEAP was 1,190 kg/yr. this estimate is based on the watershed area, regional estimates of precipitation, evaporation, and runoff, and a stream TP concentration of 50 µg/L. The model estimated water residence time (time it would take to fill the lake if it was completely empty) at about 2 - 3 years. Residence time for the southwest basin would be much less than this since it has a smaller volume and much of the watershed drains through it.

A second mathematical model, developed by Vighi and Chiaudani (1985), estimated background phosphorus (P) concentration for Cedar Lake at 17 µg/L. This prediction is based on the morphoedaphic index, routinely used in fishery science, and predicts background (i.e. natural) P based on the lake's alkalinity and mean depth. The model assumes that P is delivered to the lake in proportion to other minerals like calcium and magnesium from the watershed. Based on past experience this model provides a reasonable estimate of background P for lakes that were naturally oligo to mesotrophic in nature, however the model may underestimate P for lakes that may have been eutrophic in nature. The model does, however, provide an estimate of the proportion of P in the lake that might be due to natural background loading, which in the case of Cedar Lake would be about 80 percent of the observed TP in the main basin in 2002.

TABLE 4. MINLEAP Model Results for Cedar Lake.

Parameter	Observed 2002	Standard MINLEAP
TP (μg/L)	20	20±6
chl-a (μg/L)	9.6	5.2±3.1
% chl-a >20 μg/L	4%	0-3%
% chl-a >30 μg/L		
Secchi (meters)	2.4	2.9±1.2
P loading rate	--	1,190 kg/yr
P retention (%)	--	.64
P inflow conc.	--	55 μg/L
water load	--	10.2 ft/yr
outflow volume	--	24.4 cfs
"background P"	--	17
residence time	--	2-3 yrs.

Another way to place lake condition in perspective is to compare modern-day TP concentrations to historic, specifically pre-European conditions, which for most of Minnesota, corresponds to the 1750-1800 time period. One technique for estimating pre-European conditions or changes over time involves the collection of a sediment core (~2 m long) from the bottom of the lake. This core is sectioned and the various sections are "dated" by means of various techniques. Diatom (algae) fossils in the cores can be used to estimate the trophic status since their environmental requirements are well known. A recent study (Heiskary and Swain, 2002) documented pre-European trophic status and trends for 55 Minnesota lakes. While Cedar Lake was not a part of this study, 20 other NLF ecoregion lakes were. Based on these lakes, they found that typical pre-European TP concentrations in NLF lakes were in the 11-16 μg/L range. This information combined with observed data and modeling estimates for Cedar Lake suggests the lake is likely quite near background.

The **Reckhow-Simpson model** was used to estimate the water quality of Cedar Lake. For Reckhow-Simpson modeling, estimates of precipitation, runoff and evaporation for Cedar Lakes' watershed were used. The Reckhow and Simpson model provides a basis for estimating water and nutrient budgets for Cedar Lake using a combination of runoff and P export coefficients based on land use in the watershed. Estimates for P and water loading were made as follows:

1. *P export coefficients* - standard coefficients based on the literature and past experience were used.
2. *Precipitation* - was estimated based on 2002 water year data and runoff was estimated from statewide isopleth maps.
3. *Atmospheric coefficients* – estimated at 15 to 20 kg/km^2/yr.
4. *Septic Systems* – based on the number of seasonal (~154) and annual (~251) residences, standard per capita loading rate, and a soil retention coefficient of 70 (low retention) – 90 (high retention) percent.

The "low" range of P export coefficients provided the best estimate of in-lake P for Cedar Lake (19-21 μg/L predicted vs. 20 μg/L observed). This yielded an estimated P- loading rate of 1,163 – 1,284 kg P/yr. The model estimates that precipitation on the lake could potentially contribute about 8-9 percent; watershed sources could contribute about 78-86 percent; and septic systems could potentially contribute about 5 – 14 percent (Table 5). The predicted loading rate seems reasonable since it is similar to the MINLEAP estimate (Table 4) and yields an in-lake P similar to the observed. The high percent contribution from the watershed seems reasonable as well because of the large watershed that drains to the lake.

Table 5. Potential P-Loading Percent Contribution by Source for Cedar Lake

Potential Source	Estimated Relative Contribution (%)
Precipitation	**8 – 9%**
Watershed	**78 – 86%**
Septics	**5 – 14%**

Goal Setting

The current phosphorus criteria value for lakes in the North Central Hardwoods Forest ecoregion, for support of swimmable use, is less than 30 μg/L (Heiskary and Wilson, 1990). At or below 30 μg P/L, "nuisance algal blooms" (chlorophyll a > 20 μg/L) should occur less than 10 percent of the summer. Cedar Lake, with a summer-mean P of 20 μg/L and a summer-mean chlorophyll a of 9.6 μg/L, experienced nuisance blooms about 5 percent of the summer. A significant bloom was noted in the southwest bay on the September sample date (Fig. 6). And based on the Secchi and user perception data (Fig. 7) there may have been other occurrences as well in 2002.

For Cedar Lake, it is desirable to maintain, and if possible reduce, in-lake P concentration from the current 20 μg/L for the whole lake. Based on the observed data and model predictions (Table 6) Cedar Lake appears to be near background conditions and exhibits in-lake TP near that expected for a lake of its size and watershed area in the NLF ecoregion (MINLEAP results, Table 4). The trend in Secchi suggests there has been some decline in transparency in recent years – whether this is evidence of a long-term trend in the quality of the lake or is a short-term trend reflecting recent years of high rainfall and runoff is unclear at this point. User perception information from the CLMP participants suggest that it is desirable to maintain transparency above about 8 feet (2.4 m) to minimize the perception of "definite algal green" and "swimming impaired conditions." The southwest bay, for example, exhibited transparency below 7 feet for most of the summer and perceptions routinely indicated "algal green" or "high algal color" for most of the summer.

Based on the tributary data from 2002 (Table 3) it appeared that TP concentrations may be slightly high in a couple of the tributaries and these subwatersheds would likely be a good focus for future monitoring and may afford opportunities for reducing TP loading to the lake. Actual delineation of the subwatershed areas from the GIS maps will further place TP concentrations and loads in perspective. This would allow for calculation of loads on a per unit area basis and provide an improved basis for characterizing and comparing loads from different tributaries.

Maintaining a summer-mean P concentration of about 20 µg/L or lower over the long term, would require that P loading to the lake be reduced wherever possible. For the southwest basin this would include a focus on the major tributaries to this basin. Any reductions here would benefit the main basin as well. In the main basin attention could be placed on the shoreland area and those areas that drain directly to the lake, i.e., surrounding homes (septics) and its immediate watershed. Current information used to develop this report is sufficient to begin to identify specific tributaries (subwatersheds) to focus on. However, more detailed sampling of P concentration and flow (to estimate P loads) would aid this process. Using this information in conjunction with the GIS landuse data may be a god next step. A more comprehensive review of land use practices in the watershed, in particular tributaries with high TP concentrations may reveal opportunities for implementing BMPs in the watershed and reducing P loading to the lake. Proper maintenance of buffers areas between lawns and the lakeshore, minimizing use of fertilizers, and minimizing the introduction of new significant sources of P loading, e.g., stormwater from nearshore development activities in the watershed, will serve to minimize loading to the lake. These and other considerations will be important if the currently (2002) good water quality of Cedar Lake is to be maintained over the long term.

Table 6. Cedar Lake Summer-Mean Phosphorus Concentrations & Model Estimates.

Basin	2002 Mean	Standard MINLEAP	Vighi – P	Reckhow- Simpson
Main	19 ±2			
West	22 ±3			
Whole	20 ±2	20 ±3	17	19-21

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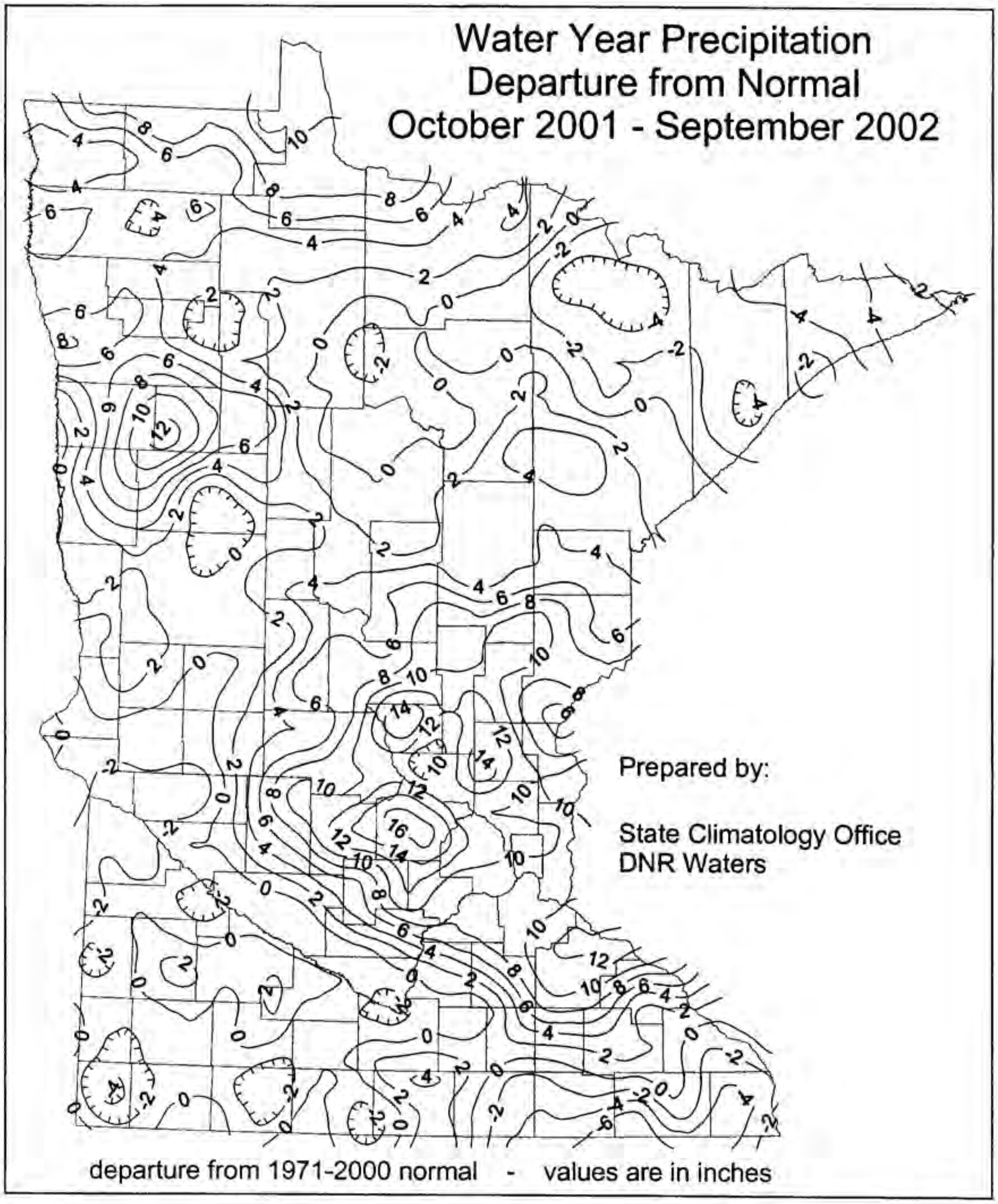
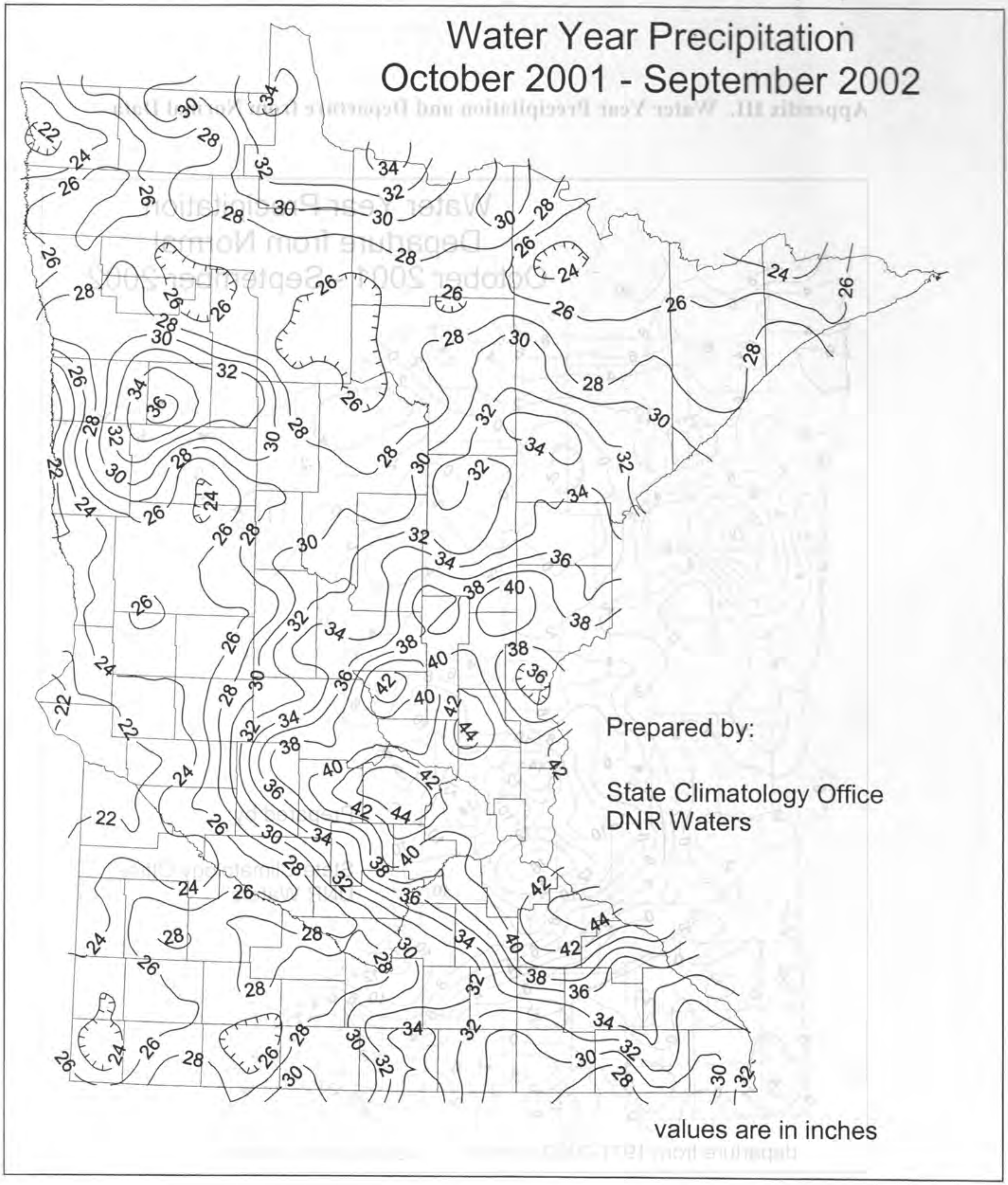
Appendix III. Water Year Precipitation and Departure from Normal Data




Water Year Precipitation
October 2001 - September 2002
Prepared by:
State Climatology Office
DNR Waters
values are in inches

Appendix I. 2002 Water Quality Data

MPCA water chemistry and Hydrolab profile data.
Mean, number of observations and standard error calculated for each site based on surface samples.

Station	Date	Site #	Top ft	Bot ft	TP mgL	Chl-a ug/L	Pheo Ug/L	TKN mg/L	TSS mg/L	TSV mg/L	Color	Alk Tot	Cl mg/L
Main													
01-0209-01	20020520	202	0	2	0.020	6.73	2.67	0.59	2.8	2.4	20	100	3.9
01-0209-01	20020520	202	20	20	0.018								
01-0209-01	20020627	202	0	2	0.015	3.68	0.32						
01-0209-01	20020920	202	0	2	0.022	11.80	2.74	0.62	2.8	2.0	30	92	3.1
01-0209-01	20020920	202	13	13	0.120								
mean					0.019	7.40	1.91	0.605	2.8	2.2	25	96	3.5
N					3.000	3.00	3.00	2.000	2.0	2.0	2	2	2.0
SE					0.004	1.79	1.18	0.107	0.6	0.7	1	25	1.2
01-0209-01	20020520	206	0	2	0.022	7.37	0.79	0.54	2.0	1.2	20	110	4.0
01-0209-01	20020520	206	25	25	0.014								
01-0209-01	20020627	206	0	2	0.013	4.23	0.59						
01-0209-01	20020920	206	0	2	0.020	8.94	2.25	0.59	3.2	2.0	20	98	3.3
01-0209-01	20020920	206	21	21	0.010								
mean					0.018	6.85	1.21	0.565	2.6	1.6	20	104	3.7
N					3.000	3.00	3.00	2.000	2.0	2.0	2	2	2.0
SE					0.003	1.38	0.52	0.025	0.6	0.4	0	6	0.4
01-0209-01	20020520	208	0	2	0.021	8.38	1.27	0.58	3.6	2.0	20	120	4.3
01-0209-01	20020520	208	10	10	0.022								
01-0209-01	20020627	208	0	2	0.016	5.38	0.36						
01-0209-01	20020920	208	0	2	0.021	10.90	2.38	0.61	3.6	2.4	20	100	3.6
01-0209-01	20020920	208	10	10	0.234								
mean					0.019	8.22	1.34	0.595	3.6	2.2	20	110	4.0
N					3.000	3.00	3.00	2.000	2.0	2.0	2	2	2.0
SE					0.002	1.60	0.58	0.015	0.0	0.2	0	10	0.3
SW Bay													
01-0209-03	20020520	201	0	2	0.024	7.24	2.36	0.62	2.6	2.0	50	89	4.9
01-0209-03	20020520	201	15	15	0.027								
01-0209-03	20020627	201	0	2	0.016	4.52	0.55						
01-0209-03	20020920	201	0	2	0.026	36.00	2.93	0.86	5.0	4.0	70	71	3.8
01-0209-03	20020920	201	12	12	0.149								
mean					0.022	15.92	1.95	0.740	3.8	3.0	60	80	4.4
N					3.000	3.00	3.00	2.000	2.0	2.0	2	2	2.0
SE					0.003	10.07	0.72	0.120	1.2	1.0	10	9	0.6

main

Date	Time	Depth m	Temp ø C	DO mg/l	DO% Saturation	Cond umhos	pH Units	Redox ORP mV
site 208								
5/20/02	132128	0.4	12.5	12.1	115	206	8.4	314
5/20/02	132207	1.0	12.1	12.1	115	205	8.6	314
5/20/02	132242	2.2	11.3	12.2	113	205	8.4	314
5/20/02	132314	3.0	11.2	12.2	113	205	8.4	315
5/20/02	132346	4.2	10.5	12.1	110	205	8.4	317
5/20/02	132416	5.2	10.0	11.7	105	204	8.2	320
5/20/02	132530	6.2	9.7	11.1	98	205	8.1	324
5/20/02	132553	6.9	9.3	1.2	10	205	8.0	324
5/20/02	132620	8.0	9.2	10.7	94	205	7.9	325
5/20/02	132642	9.5	8.9	10.3	90	206	7.8	328
5/20/02	132701	11.1	8.8	9.7	84	206	7.7	331
site 206								
5/20/02	134057	0.4	11.8	13.1	123	200	8.3	244
5/20/02	134120	1.1	11.4	12.4	115	199	8.3	248
5/20/02	134208	2.1	10.3	12.4	112	199	8.3	249
5/20/02	134219	3.1	10.2	12.3	111	200	8.3	250
5/20/02	134233	4.4	10.0	2.5	24	200	8.3	251
5/20/02	134257	5.1	9.8	13.2	116	199	8.3	253
5/20/02	134314	6.1	9.6	12.4	110	200	8.3	255
5/20/02	134329	6.9	9.4	12.1	107	200	8.2	257
5/20/02	134351	8.1	9.0	12.0	105	200	8.2	259
5/20/02	134422	9.5	8.1	11.4	98	199	8.0	262
5/20/02	134438	9.9	8.1	11.4	97	199	8.0	264
5/20/02	134459	11.0	7.9	11.3	96	199	7.9	266
5/20/02	134520	11.3	7.7	11.2	95	199	7.9	265
5/20/02	134539	12.3	7.5	11.1	94	198	7.9	265
5/20/02	134551	12.9	7.5	11.0	93	198	7.9	266
5/20/02	134607	13.7	7.3	10.9	92	198	7.8	267
5/20/02	134626	14.9	7.1	10.9	91	198	7.8	268
5/20/02	134703	15.2	7.1	10.8	91	198	7.8	268
5/20/02	134717	16.1	6.9	10.8	90	198	7.8	269
5/20/02	134807	16.9	6.9	10.8	90	198	7.8	270
5/20/02	134833	17.8	6.7	10.8	90	198	7.7	272
5/20/02	134852	18.8	6.6	10.7	88	199	7.7	272
5/20/02	134928	19.8	6.5	10.6	88	198	7.7	272
5/20/02	135015	20.9	6.4	10.5	87	198	7.7	272
5/20/02	135052	21.8	6.3	10.5	86	198	7.7	273
5/20/02	135111	23.2	6.2	10.6	86	198	7.7	273
5/20/02	135129	23.8	6.1	10.5	86	198	7.7	274
site 202								
5/20/02	140957	0.5	13.1	11.8	114	191	8.4	276
5/20/02	141042	1.3	12.0	12.0	113	189	8.3	281
5/20/02	141059	2.9	11.4	12.0	111	189	8.3	281
5/20/02	141114	4.1	11.0	12.1	111	190	8.3	282
5/20/02	141158	4.9	10.4	11.9	108	189	8.2	284
5/20/02	141212	5.9	9.9	11.8	104	189	8.1	286
5/20/02	141235	7.2	9.1	11.1	98	189	7.9	289

5/20/02	141301	8.1	8.4	10.5	91	188	7.8	291
5/20/02	141327	9.3	8.1	10.2	88	190	7.7	291
5/20/02	141344	11.1	7.8	10.1	86	189	7.7	292
5/20/02	141400	12.0	7.5	10.0	85	190	7.7	293
5/20/02	141415	12.9	7.4	9.9	84	190	7.6	293
5/20/02	141510	14.1	7.3	9.8	82	190	7.6	293
5/20/02	141525	14.9	7.1	9.6	81	190	7.6	294
5/20/02	141605	16.1	7.0	9.4	79	190	7.5	295
5/20/02	141619	17.2	7.0	9.4	78	189	7.5	295
5/20/02	141632	18.4	6.9	9.3	78	190	7.5	296
5/20/02	141646	19.3	6.9	9.3	77	190	7.5	295
5/20/02	141700	20.0	6.8	9.3	77	190	7.5	296
5/20/02	141710	21.1	6.8	9.1	76	190	7.5	296
5/20/02	141723	22.0	6.8	9.2	76	190	7.5	296
5/20/02	141737	23.3	6.7	9.2	76	191	7.5	298
5/20/02	141752	23.9	6.7	9.0	74	191	7.5	299
SW Bay								
site 201								
5/20/02	142748	0.5	13.8	11.3	111	168	8.1	285
5/20/02	142843	1.0	13.2	11.3	109	169	8.1	290
5/20/02	142905	1.9	12.2	11.4	108	169	8.1	292
5/20/02	142944	2.8	11.8	11.1	104	169	8.0	293
5/20/02	143002	2.8	11.8	11.1	104	169	8.0	293
5/20/02	143053	3.8	11.5	13.2	123	170	8.0	295
5/20/02	143127	5.0	9.6	10.5	93	171	7.8	299
5/20/02	143159	5.8	8.7	9.1	80	172	7.6	301
5/20/02	143314	6.7	8.2	8.2	71	172	7.5	302
5/20/02	143337	7.1	8.1	8.2	70	172	7.5	303
5/20/02	143403	7.8	8.0	8.0	68	172	7.4	303
5/20/02	143433	8.9	7.8	8.2	70	171	7.4	303
5/20/02	143525	9.9	7.5	8.4	71	171	7.4	303
5/20/02	143552	11.0	7.4	8.2	69	172	7.4	304
5/20/02	143630	11.9	7.3	7.9	67	172	7.4	306
5/20/02	143646	13.0	7.2	7.9	67	173	7.4	307
5/20/02	143704	13.8	7.2	7.9	66	173	7.4	307
5/20/02	143723	15.1	7.2	7.7	65	173	7.3	310
5/20/02	143742	17.0	7.1	7.5	63	181	7.3	249

Main

Date	Time	Depth meters	Temp øC	DO mg/l	DO% Sat	Cond æS/cm	pH Units	ORP mV
Site 208								
9/20/02	111134	0	20.0	6.9	80	194	8.2	353
9/20/02	111204	1	19.9	6.8	79	193	8.1	357
9/20/02	111249	2	19.8	6.7	78	193	8.0	360
9/20/02	111308	3	19.8	6.6	77	193	8.0	361
9/20/02	111333	4	19.8	6.7	77	193	8.0	361
9/20/02	111431	5	19.7	6.4	74	194	8.0	363
9/20/02	111458	6	19.7	6.2	71	194	7.9	364
9/20/02	111607	7	16.2	0.3	4	225	7.2	252
9/20/02	111652	8	12.5	0.2	2	251	7.2	133
9/20/02	111722	9	11.0	0.3	2	254	7.2	94
9/20/02	111749	10	10.4	0.2	2	260	7.2	83
9/20/02	111822	11	9.9	0.1	1	287	7.1	68

Site 206								
9/20/02	113125	0	20.2	7.3	85	181	8.4	241
9/20/02	113203	2	20.1	7.3	85	181	8.3	249
9/20/02	113238	2	20.1	7.1	83	181	8.3	252
9/20/02	113320	3	20.0	7.1	82	181	8.3	258
9/20/02	113340	4	20.0	7.1	82	181	8.3	256
9/20/02	113411	4	20.0	7.0	81	181	8.2	260
9/20/02	113451	6	20.0	7.0	81	182	8.2	263
9/20/02	113540	6	19.9	6.8	78	182	8.2	265
9/20/02	113621	7	19.4	6.3	72	185	8.0	269
9/20/02	113657	8	13.6	1.6	15	203	7.2	283
9/20/02	113735	10	9.3	1.6	15	203	7.1	288
9/20/02	113830	11	9.2	1.6	15	202	7.1	292
9/20/02	113917	12	8.2	1.9	17	202	7.1	295
9/20/02	114032	13	8.0	1.9	17	202	7.1	299
9/20/02	114108	14	7.9	1.7	15	202	7.1	300
9/20/02	114153	15	7.7	1.9	17	202	7.1	302
9/20/02	114230	16	7.5	2.1	18	202	7.1	311
9/20/02	114321	18	7.2	1.9	17	202	7.1	318
9/20/02	114356	19	7.1	1.4	13	202	7.1	320
9/20/02	114432	20	7.0	1.3	11	202	7.1	321
9/20/02	114510	21	6.9	1.2	10	203	7.1	321
9/20/02	114534	21	6.8	0.9	8	203	7.0	322
9/20/02	114615	23	6.7	0.4	3	204	7.0	322
9/20/02	114647	23	6.6	0.1	1	205	7.0	270
site 202								
9/20/02	115922	0	19.9	7.1	83	170	7.9	280
9/20/02	120002	2	19.7	6.9	79	170	7.8	285
9/20/02	120039	3	19.7	6.6	76	170	7.8	288
9/20/02	120104	4	19.7	6.4	73	170	7.7	291
9/20/02	120126	5	19.6	6.3	73	170	7.7	292
9/20/02	120152	6	18.0	5.9	62	185	7.3	291
9/20/02	120239	7	14.1	0.5	5	205	7.1	216
9/20/02	120302	8	10.4	0.2	2	205	7.1	159
9/20/02	120325	9	9.4	0.4	4	203	7.1	143
9/20/02	120349	10	8.6	0.1	1	205	7.0	131
9/20/02	120416	11	8.2	0.1	1	204	7.0	123
9/20/02	120446	12	7.9	0.2	1	205	7.0	120
9/20/02	120512	13	7.6	0.1	1	207	7.0	115
9/20/02	120548	14	7.5	0.2	2	208	7.1	108
SW Bay								
site 201								
9/20/02	122047	0	19.9	7.4	85	137	7.8	288
9/20/02	122047	1	19.9	7.4	85	137	7.8	288
9/20/02	122123	2	19.8	6.9	79	137	7.6	289
9/20/02	122156	3	19.7	6.4	74	138	7.5	289
9/20/02	122236	4	19.7	6.2	71	138	7.5	288
9/20/02	122306	5	18.1	6.0	22	171	7.1	248
9/20/02	122418	6	13.9	0.4	4	185	7.0	168
9/20/02	122447	7	11.7	0.2	2	197	7.1	110
9/20/02	122514	8	10.1	0.1	1	196	7.1	96
9/20/02	122537	8	9.7	0.0	0	191	7.1	92
9/20/02	122620	10	8.3	0.1	1	194	7.1	89
9/20/02	122649	11	7.9	0.1	0	197	7.1	85
9/20/02	122716	12	7.6	0.1	0	200	7.1	80
9/20/02	122759	13	7.5	0.1	1	202	7.1	74
9/20/02	122956	14	7.4	0.0	0	273	7.2	33

Appendix II. Tributary data collected by Cedar Lake Conservancy in 2002. Mean for June – September samples noted.

2002 Date	Stream Name	Map Index	Flow rate (CFS)	pH	Conduc tivity (umhos)	TP (ppb) CCC	TP (ppb) AWR lab
22-Jun	BlackBass	A	1.2				
8-Jul	Black Bass	A	64.0	7.2	88	40	
19-Aug	Black Bass	A	0.0				
	mean		21.7	7.2	88	40	
10-Jun	Cedar entry	B	2.9	7.9	261		
17-Jun	Cedar entry	B	3.3				
19-Jun	Cedar entry	B	2.9			50	41
8-Jul	Cedar entry	B	320.0	7.4	134	35	
20-Aug	Cedar Entry	B	20.0	7.7	178	170	180
22-Oct	Cedar In	B	1.3				43
	mean		58.4	7.7	191	85	88
2-Jun	Casey	C	0.5	7.6	171		
20-Jun	Casey	C	4.0				
20-Jun	Casey	C	4.2			50	
22-Jun	Casey	C	6.1			24	27
8-Jul	Casey total	C	118.0	7.2	113	50	
11-Jul	Casey total	C	131.0	7.3	114	60	61
19-Aug	Casey total	C	9.0	7.2	132	45	
22-Oct	Casey In	C	5.0				93
	mean		34.7	7.3	133	46	60
23-Jun	Sandstrom	D	0.7	6.5	140	80	
8-Jul	Sandstrom	D	10.5	6.5	60	115	
21-Aug	Sandstrom	D	0.4	5.8	65	125	
	mean		3.8	6.3	88	107	
2-Jun	Cedar exit	E	19.8	8.6	250		22
20-Jun	Cedar exit	E	24.0				20
8-Jul	Cedar exit	E	96.0	8.5	263	20	20
11-Jul	Cedar exit	E	299.2			20	17
21-Aug	Cedar Exit	E	60.5	8.0	165	20	16
22-Oct	Cedar Exit	E	34.0				19
19-Nov	Cedar out	E	17.6	8.3	239	40	
	mean		78.7	8.4	229	25	19
23-Jun	Dog Fish	F	0.0				
8-Jul	Dog Fish	F	13.3	7.1	92	15	
19-Aug	Dog Fish	F	1.6	7.5	90	15	
	mean		5.0	7.3	91	15	
23-Jun	Blue	G	0.2	7.2	469	95	

8-Jul	Blue	G	17.5	7.3	216	35	
19-Aug	Blue	G	0.2	7.1	294	105	
	mean		6.0	7.2	326	78	
17-Jun	Taylor	H	0.1	7.5	413		
19-Jun	Taylor	H	0.6			105	110
8-Jul	Taylor	H	30.0		215	57	
19-Aug	Taylor Lake	H	1.0	8.4	259	30	
	mean		7.9	8.0	296	64	110
22-Jun	Public A	I	0.0				
22-Jun	Public B	I	0.0				
23-Jun	Back Brook	J	0.5	7.7	310	28	
8-Jul	Back Brook	J	36.0	7.4	149	45	
19-Aug	Back Brook	J	3.0	7.4	198	45	
	mean		13.2	7.5	219	39	