LAKE ASSESSMENT PROGRAM
1993
Fish Lake
(I.D. #33-0036)
Kanabec County, Minnesota

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SUMMARY AND RECOMMENDATIONS

Fish Lake is located on the Ann River in Kanabec County. It is a fairly large lake (399 acres) but extremely shallow (maximum depth less than ten feet). Land use in the watershed is characterized by forest uses (50 percent) and agricultural uses (25 percent). The watershed is located in both the - North Central Hardwood Forests ecoregion (NCHF) and the Northern Lakes and Forest Ecoregion (NLF) and the land use data for Fish Lake reflects a combination of both ecoregions.

Fish Lake was sampled during the summer of 1993 by the Minnesota Pollution Control Agency (MPCA) staff and citizens from the Fish Lake Improvement Association (Association). Ann Lake, upstream of Fish Lake, was also sampled by MPCA for purpose of comparison. Water quality data for Fish Lake reveal a summer mean total phosphorus concentration of 100 µg/L, mean chlorophyll a of 77 µg/L and Secchi transparency of 2.1 feet. These values are not within the range of values exhibited by minimally-impacted (reference) lakes in the NCHF ecoregion. Total phosphorus, chlorophyll a and Secchi transparency help to characterize the trophic status of a lake. For Fish Lake these measures indicate hypereutrophic conditions. Trophic status measures for Ann Lake are as follows: total phosphorus - 70 µg/L, chlorophyll a 40 µg/L, and Secchi transparency - 3.5 feet and indicate eutrophic conditions.

Historical Citizen Lake Monitoring Program (CLMP) Secchi transparency data reveal minimal fluctuations in transparency from year to year for Fish Lake. For example, the average summer transparency fluctuated between 1.5 and 2.4 feet, based on five years of CLMP data, dating back to 1976.

Fish Lake is ecologically classified as a centrarchid-largemouth bass lake. It is a shallow, turbid, sometimes bog stained reservoir lake that experiences significant water level fluctuations. Ann River flows through Fish Lake before connecting to the Snake River. The river system has allowed for a diverse fish population in Fish Lake made up of both roughfish and warmwater gamefish.

Currently, walleye fry stocking occurs on an alternate year basis (1,000 per littoral acre; 407,000 fry). It is a supplemental stocking to the existing natural walleye population. Northern pike will be stocked if gillnet catches drop below one pike per net set. Panfish (bluegills, white and black crappies) are the most abundant gamefish species in the lake. Their numbers are in the normal range for this lake type. Lake sturgeon and channel catfish abundances have been uncertain in this lake for many years. Only now are fisheries crews beginning to understand and evaluate these two unique species in Fish Lake.

Commercial roughfish removal has removed carp and freshwater drum. It can be an ongoing project as these roughfish are well established in Fish Lake and are prevalent in the adjoining river systems.

Two lake water quality models were used to estimate the water quality of Fish and Ann Lakes based on their morphometry and watershed characteristics. These models provide a means to compare the measured water quality of the lake relative to the predicted water quality.

The first model, MINLEAP, predicts a summer-mean phosphorus (P) concentration of 105 µg/L which is very comparable to the observed summer mean of 100 µg/L for Fish Lake. For Ann Lake MINLEAP predicts an in-lake P of 78 µg/L (comparable to observed) if the lake is considered to be in the North Central Hardwood Forests ecoregion. However, the majority of Ann Lake's watershed is in the Northern Lakes and Forests ecoregion. Treating Ann Lake as a Northern Lakes and Forests lake results in a predicted in-lake P of 37 ug/L.

The second model, Reckhow and Simpson, using high P export coefficients predicts in-lake P concentration of 90 µg/L and 58 µg/L for Fish and Ann Lakes respectively. The majority of the P loading to these lakes comes from their watersheds.

Based on this study, it appears that the quality of Fish Lake will vary from year to year as a function of the flow and quality of the Ann River. It will be important to reduce the amount of nutrients which enter the lake from the watershed. If gamefish species are to remain the dominant fish species in the fish community, the water quality of the lake should not worsen.

The following recommendations are based on the 1993 Lake Assessment Program (LAP) study of Fish and Ann Lakes:

1. Fish and Ann Lakes have high phosphorus and chlorophyll concentrations compared to other lakes in the North Central Hardwood Forest Ecoregion. This is a result of their relatively large watersheds, shallowness of the lakes, and excess amounts of phosphorus reaching the lakes. Reductions in phosphorus loading to the lakes will be required to improve the quality of the lakes. It is essential, therefore, that the lake and watershed protection efforts be conveyed by all local government groups with land use/zoning authorities for Fish Lake.

   The Association should be commended for their efforts to date, which include interacting with the Kanabec County Soil and Water Conservation District (SWCD), conducting a septic system survey, and participating in the CLMP and DNR lake level programs. To complement these efforts, the Association should develop a plan for protecting the water quality of the lake. The plan should also consider Ann Lake and be done in conjunction with the Ann Lake Association. This plan, referred to as a lake management plan, should incorporate a series of activities in a prioritized fashion which will aid in the long-term protection and improvement of the lake. The plan should be developed cooperatively by a Committee consisting of representatives from State Agencies (e.g., MDNR, MPCA, BWSR), local units of government, and lake association members. The two associations could consider forming a joint association, e.g. "Ann River - Lake Association" The following activities could be included in the plan:

   a. The Fish Lake Association should continue to participate in the CLMP. Data from this program provides an excellent basis for assessing long-term and year-to-year variations in algal productivity, i.e., trophic status of the lakes. At a minimum, measurements should be taken weekly during the summer at a consistent site(s). Sites 201 and 202 are probably the most valuable for long-term characterization of the transparency of the lake. The Ann Lake Association should consider enrolling Ann Lake in CLMP.

   b. The Fish Lake Association should follow-up on the evaluation of all on-site septic systems around the lake. The Ann Lake Association should do a similar survey. The Fish Lake survey had a 70 percent response rate. Of these, about 30 percent do not pump their systems and about 26% of the systems are over 20 years old. Based on these results, the Association should focus more attention on this issue. Steps should be taken to educate all lakeshore property owners and any systems out of compliance with county/state codes should be brought into compliance. These steps may require assistance from Kanabec County. Education of homeowners around the lake, with respect to septic systems, lawn maintenance and shoreline protection may be beneficial. Staff from the MPCA and the Minnesota Department of Natural Resources (MDNR), along with the county officials, such as staff from Minnesota Extension Service, and the Kanabec County Soil and Water Conservation District and County Planning and Zoning Department could provide assistance in this area. The booklet, A Citizens' Guide to Lake Protection may also be a useful education tool for the Association.

c. Further development in the immediate watershed of the lakes should occur in a manner that minimizes water quality impacts on the lakes. Considerations such as setback provisions and septic tank regulations should be strictly followed. MDNR's and county shoreland regulations will be important in this regard. Also, activities in the total watershed that change drainage patterns, such as wetland removal or major alterations in land use, should be discouraged unless they are carefully planned and adequately controlled. The Associations should continue to seek representation on boards or commissions, e.g., watershed management organizations, 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.

d. A more detailed examination of the possible nutrient sources such as wetland runoff, agricultural runoff, septic systems, lawn fertilizer, and the effects of ditching and draining of wetlands, etc., may aid the Association in determining areas where improvement is needed. Some of the county offices mentioned above may be of help in this regard.

2. The 1993 water quality of Fish and Ann Lakes is poor relative to other lakes in the North Central Hardwoods Forest ecoregion. The lakes could, however, exhibit a decline in transparency, increases in the amount of algae, and possibly increases in the amount of rooted vegetation with an increase in in-lake total phosphorus. Changing land use practices, poor management of shorelands, or draining of wetlands in the watershed provide the greatest likelihood for changes in phosphorus loading.

   Conversely, a reduction of the amount of nutrients that enter the lakes may result in improved transparency and a reduction in algal concentrations. One means of reducing nutrient input is by implementing best management practices (BMPs) in the watershed (land management activities used to control nonpoint source pollution). Technical assistance in BMP implementation may be available through local resources management agencies. The Association should continue to work with Kanabec County SWCD to examine land use practices in the watershed and develop strategies for reducing the transport of nutrients to the lake. It may be wise to first focus efforts on the watershed near the lakes, in particular.

Restoring or improving wetlands in the watershed may also be beneficial for reducing the amount of nutrients or sediments which reach Fish and Ann Lakes. The U.S. Fish and Wildlife Service at Fort Snelling may be able to provide technical and financial assistance for these activities.

MPCA's Clean Water Partnership Program is also an option for further assessing and dealing with nonpoint sources of nutrients in the overall watershed of the Ann River. However, since there is extensive competition for CWP funding, it may be in the best interest of the two Associations to continue to work with the Kanabec SWCD, and the local townships to do as much as possible to protect the condition of the lakes by means of local ordinances and education of shoreland residents. If these steps prove to be inadequate or lake condition worsens (as evidenced by declines in Secchi transparency), application to CWP may then be appropriate.

3. Should a CWP application be deemed necessary, this LAP report serves as a foundation upon which further studies and assessments may be based. The water nutrient income-outgo summaries were estimated based on limited amounts of monitoring data and should be considered best approximations. The next step would be to define water and nutrient sources to the lake in a much more detailed fashion. These detailed studies would allow the estimation of reasonably accurate total phosphorus (and ortho-phosphorus), a total nitrogen (and inorganic nitrogen) and water income-outgo summaries. This should be accomplished prior to implementation of any extensive in-lake restoration techniques.

LAKE ASSESSMENT PROGRAM: 1993
Fish Lake
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INTRODUCTION

Fish Lake was sampled by the Minnesota Pollution Control Agency (MPCA) during the summer of 1993 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. Ann Lake, upstream from Fish Lake, was also sampled by MPCA staff in 1993. Data from Ann Lake will be used for comparison to Fish Lake.

Fish Lake was sampled on five occasions during the spring and summer of 1993. Participants in this effort include Willis Munson and Steve Heiskary from the MPCA and members of the Fish Lake Improvement Association (Association). Association participants in the sampling include Jerry Tripp and Bert Peterson. Precipitation, lake water levels and CLMP measurements were collected during the summer by Bud Rosengren. Roger Hugill, area fisheries supervisor, MDNR Hinckley Area Fisheries Office contributed to the fisheries evaluation. Water level evaluation and figures were provided by Chuck Revak from the MDNR, Division of Waters, Surface Water Unit. Precipitation information was provided by Greg Spoden from the MDNR, Division of Waters, State Climatology Office. Land-use information for the Ann River watershed was assembled by Linda Peterson from the Kanabec County Soil & Water Conservation District (SWCD).

This study was conducted at the request of the Association, whose members are interested in identifying sources of pollution to the lake, characterizing the quality of the lake, and developing a program to assist in lake management. Some data was available for Fish Lake from previous MPCA surveys and CLMP. Historical water quality data provides a basis for assessing year-to-year fluctuations in the quality of Fish Lake. The Association also conducted a septic system survey and compiled a history of events that pertain to the lake and watershed (Appendix 2).

BACKGROUND

Fish Lake is located southwest of Mora, Minnesota, in Kanabec County. With a surface area of about 399 acres and a maximum depth of 9.5 feet, it is in the upper fifteenth percent of the lakes in the state in terms of area, but is extremely shallow. Both Fish and Ann lakes are impoundments formed by dams built across the Ann River. Fish Lake basin was formed by the irregular deposition of till from the Superior Lobe (Zumberge, 1952). Soils of the watershed are varied consisting of Dalb-Brickton, Chetek-Onamia, Milaca-Mora-Bock, and Bock-Adolph-Peat series soils. These soils range from well drained to very poorly drained (Arneman, 1963).

Fish Lake is located in the west central portion of the Snake River Watershed Unit, which drains an area of approximately 960 square miles in east central

Minnesota. Fish Lake has a large watershed (84 square miles) relative to its surface areas (135:1 watershed: surface area). Ann Lake has a smaller watershed of about 39 mi^2 and a watershed to lake surface ratio of 39:1.

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. Fish Lake's immediate watershed (approximately 70%) is in the North Central Hardwood Forest ecoregion (Figure 1). The upper watershed (essentially Ann Lake's watershed) is in the Northern Lakes and Forest ecoregion.

The land uses observed in the watershed of Fish Lake are fairly comparable to the typical range for the NCHF ecoregion (Table 1). Cultivated land use is much less than expected (12 percent). Cultivated and pastured uses account for about 25 percent of the land use in this watershed. Lakes and wetlands represent about 22 percent of the watershed. Lakes and wetlands will allow pollutants in runoff to settle out and serve to slow the flows which enter Fish Lake during periods of high precipitation and runoff. Ann Lake's watershed is comprised primarily of forested and marsh uses as would be typical for lakes in the Northern Lakes and Forests ecoregion.

According to rainfall records kept by one member of the Association, 10.6 inches of precipitation was recorded near Fish Lake between June 16 and August 30. Precipitation in the Kanabec County area was about 17-18 inches for the period May - August 1993 and was about 115 percent of normal precipitation (Appendix C). Many areas of the state experienced a much wetter than normal summer during 1993.

The normal precipitation for the period of record from May through September is on the order of 18.5 inches and the period of record annual normal is on the order of 28.5 inches for this part of the state (State Climatology Office). Evaporation typically exceeds precipitation in this part of the state and averages about 34 inches per year. Runoff averages about 8 inches with 1 in 10 year low and high values of 3.2 inches and 10 inches respectively for this area (Gunard, 1985).

Water Residence Time and Lake Levels

Fish Lake's water levels and water residence time (time it would take to fill the lake if it was empty) will vary as a function of the flow from the Ann River. Based on runoff estimates for this part of the state (Wilson, 1989), water residence time will vary between about 30 days during periods of high river flow to about 50 days during periods of low river flow. Water residence time in Fish Lake in 1993 would be on the order of 30 days.

The Minnesota Department of Natural Resources, Division of Waters has monitored Fish Lake levels in cooperation with volunteer readers since 1991. The water level has fluctuated 4.8 feet since 1991, from a high of 953.60 on May 7, 1991, to a low of 948.78 on August 6, 1992 (Figure 2). Water levels fluctuated 1.5 feet to 2 feet during the summer of 1993. The lake outlets via Ann River through a concrete dam at elevation 948.71 before it enters the Snake River which is just downstream of the dam. The lake has experienced flooding largely

FIGURE 1. FISH AND ANN LAKE LOCATION AND WATERSHED MAP

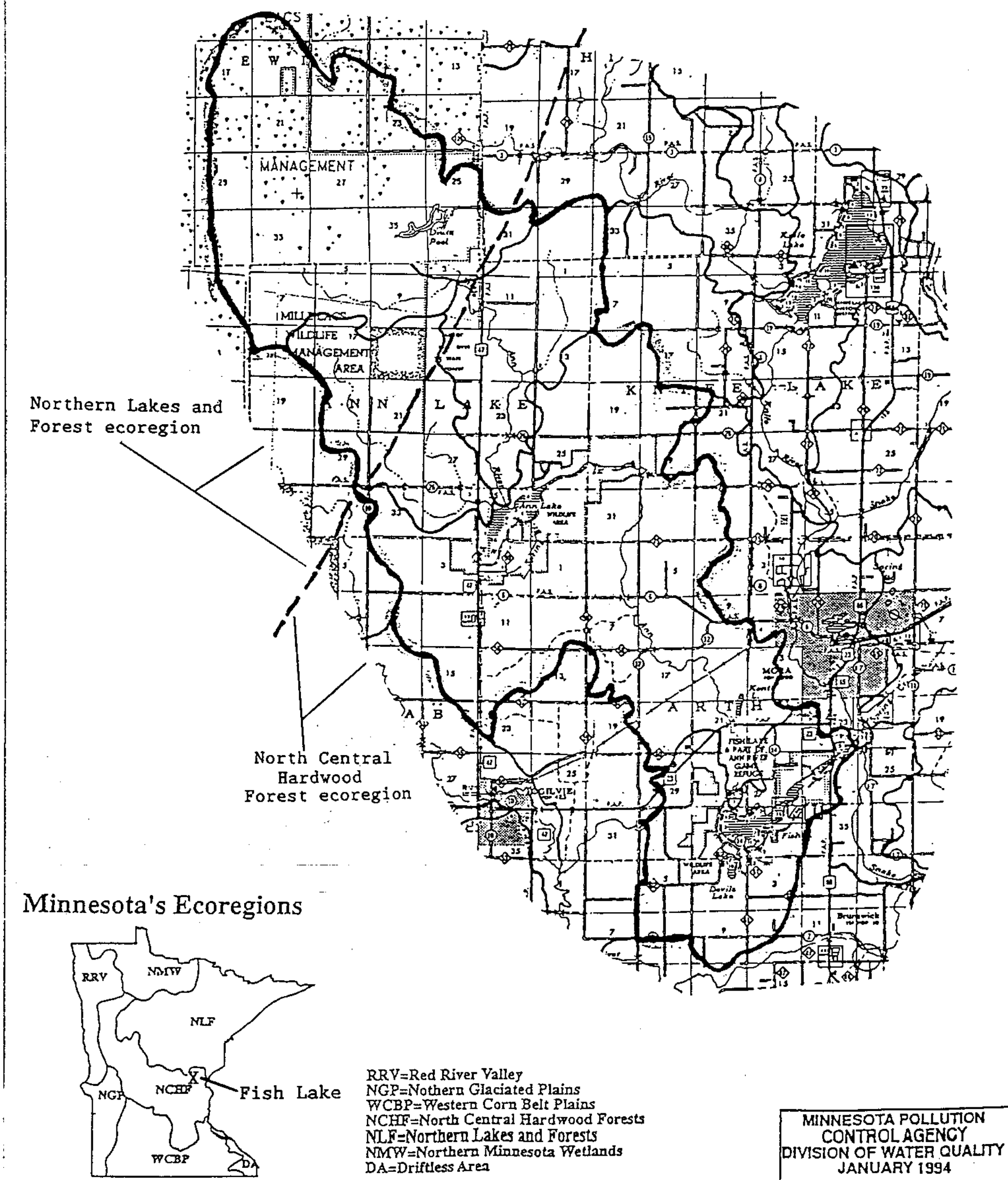
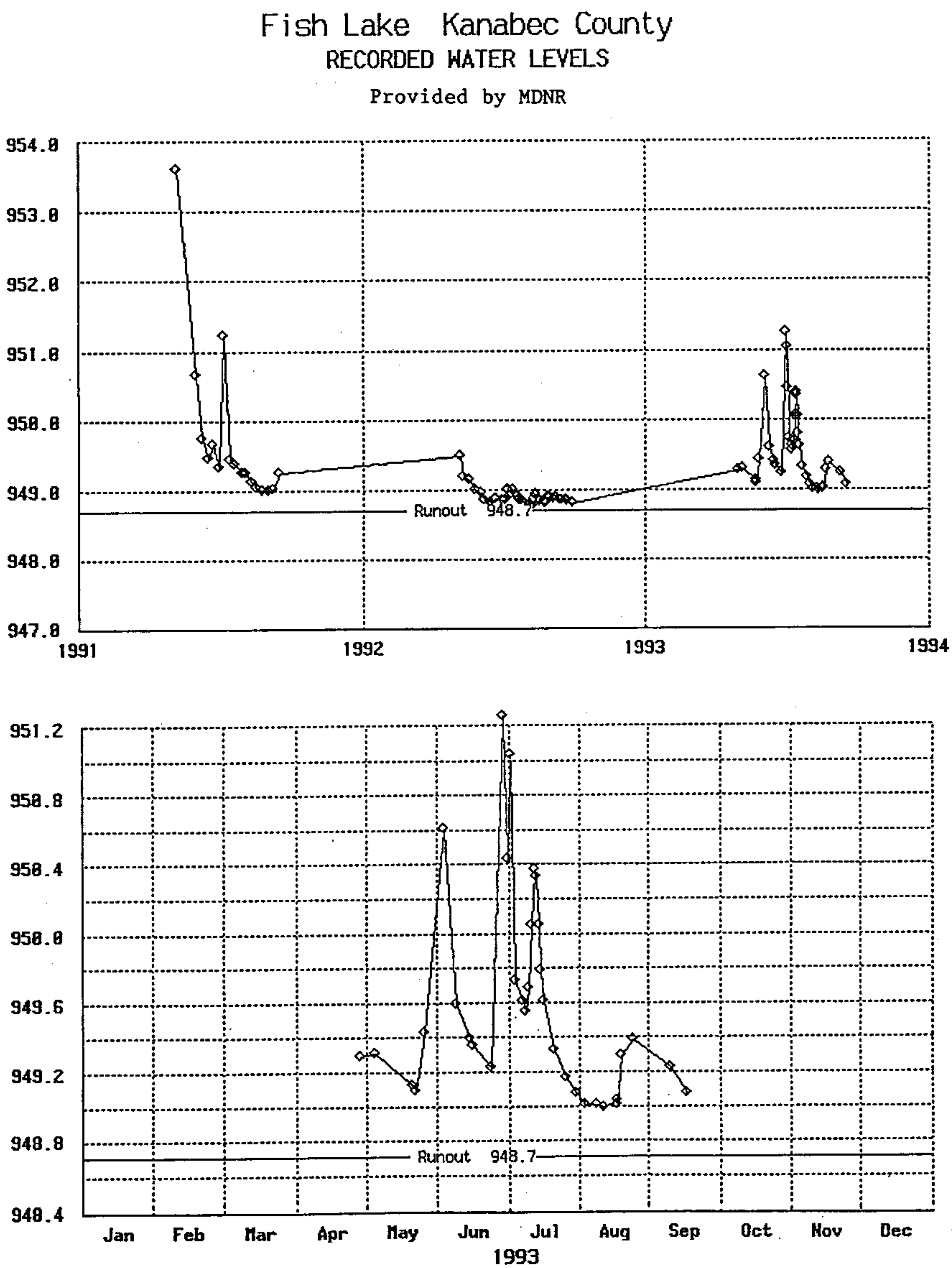


FIGURE 2. FISH LAKE - LAKE LEVELS



due to the Snake River being at high stages which then restricts outflow from Fish Lake. This often compounds already high levels from an increase of inflow from it's watershed.

Fishery Management

Fish Lake, Kanabec County, is ecologically classified as a centrarchid-largemouth bass lake and corresponds to Schupp's Lake Class 42. Since 1978, the Minnesota Department of Natural Resources (MDNR), Section of Fisheries has directed its attention toward walleye management for Fish Lake. Before that time, northern pike were stocked several times in order to boost their abundance in Fish Lake. These stockings did not significantly increase the northern pike population so the effort was discontinued. Currently, walleye fry stocking occurs on an alternate year basis (1,000 per littoral acre; 407,000 fry) and northern pike will be stocked if gillnet catches drop below one pike per net set.

Commercial roughfish removal has occurred almost annually since 1984. Carp and freshwater drum are the primary roughfish species removed. Recent winter seine hauls by commercial fishermen has allowed the DNR to monitor and collect valuable information from the lake sturgeon and channel catfish population in Fish Lake. This collection method seems to work best for sturgeon and catfish on river-type lakes such as Fish Lake. The potential for improving fish lake through wise watershed and in-lake management is within reason. Fisheries management programs will continue to administer surveys, some stocking, and monitor commercial fishing and winter dissolved oxygen levels.

Fish Lake is a shallow, turbid, sometimes bog stained reservoir lake that experiences significant water level fluctuations. Low winter dissolved oxygen concentrations have been observed, but a severe winterkill has not been recorded. Ann River and three smaller inlets flow into Fish Lake. The Snake River is located 1/4 mile downstream from the Fish Lake outlet dam (2 foot head dam).

A lake of this type lends itself towards a diverse gamefish population. Watershed problems can impact the lakes water quality and create poor habitat and environmental conditions that favor roughfish species like carp and freshwater drum. As a result, the more desirable gamefish populations (e.g. walleye, northern pike, panfish) have been altered to fit the quality of Fish lake. This process is very typical for lakes like this and cannot be rectified by removing roughfish and stocking more gamefish. In fact, roughfish removal has proven ineffective in reducing their overall abundance. Removing some of the roughfish, carp for instance, just creates a void in the total fish population to be filled by younger, more aggressive carp, subsequently making more of a nuisance. Removal efforts have no lasting effect to the roughfish community nor does it appear to make positive changes to the water quality.

The walleye abundance in Fish Lake has historically been in the normal range for this lake type. Their population is currently composed of both natural reproduced and stocked fish. The impact of the walleye stocking program on Fish Lake's walleye population is not certain. Generally, their abundance did not increase significantly during the past decade to warrant stocking as a major contributor. Stocking may, however, fill in the gap left by poor years of natural reproduction.

The northern pike population ranges from normal to below normal. Their abundance can greatly be affected by habitat loss and water fluctuations during the spawning season. Limiting factors like sparse emergent vegetation growth could be improved by reintroduction of plant beds (e.g. bulrush stands). This type of habitat improvement would benefit many gamefish species and may also reduce nutrient loading to the water by tying up nutrients.

Panfish are the most abundant gamefish present. It is not surprising since they are usually best suited for reservoir lakes like Fish Lake, especially when larger predator fish are found at low to moderate levels. These panfish (bluegills, white and black crappies) are adaptable to turbid waters but both need adequate submerged vegetation to maintain normal populations.

Water clarity limits the amount of rooted plant growth in Fish Lake. Further declines in water clarity and quality may further reduce plant growth and make the lake less suitable for gamefish species.

Lake and Watershed History

A history of the lake and watershed was assembled by Palmer Rodine of the Fish Lake Association and is summarized as follows:

1940's - Very few houses and cabins around the lake. There was a light growth of large trees around the lake. In fact, on the west side of the lake in the highland beach property it had mostly Sumac, some large oaks, and not many poplar. The north side of the lake had some woods, but you could see through them. Only three cabins then. On the west side, there were six cabins. The water was clean enough to drink and a person could cast out from shore and have a walleye almost every cast.

Mostly all the boats were wood and powered by oars or low H.P. motors.

Ann River to the east had a lot of weed beds in it. You could fish around them and get a lot of real large blue gills. Also, good sized northern, walleyes and bass.

It was small farms around the lake, mostly run by horse equipment or small tractors. Fertilizer was usually barn yard manure. Crops were cultivate instead of spraying with pesticides to kill weeds.

1950's - After the war the people started towards the lakes and cabin and home population started increasing. More land around the lake was platted with more homes and cottages (approximtely 30 according to MDNR records) being built. Also, with more boat traffic, larger boats and larger motors.

[September 27, 1950, MDNR lake survey cites heavy algae blooms and a transparency of 1.8 feet]

1970's - More of the farms along Ann River and lake platted making most all of the shoreline buildable.

The Pavilion on the south side of the lake was very popular during the early years. They also started renting camper sites, which has increased over the years.

[1973 DNR lake survey indicates two resorts with 45 trailers and five cabins, 77 homes/cottages]

Also Rockenhard Resort was sold and made into a resort and camping park with campers parked side by side over most of it.

Most of the land along Ann River to the north was small farms. Now there are large farms some with very high feeder cattle production. Also raising a lot of corn and hay. Using heavy amounts of fertilizer which is washing into the lake, giving the lake a heavy phosphorus and nitrogen content.

1980's - They have seined carp from the lake several times; they have removed from 35,000 pounds to 60,000 pounds each time, which has helped the lake some.

1990's - As of 1990, the tax rolls show 140 property owners around the lake and more lots are being sold all the time.

During 1992, Fish Lake Improvement Association conducted a lake and river survey using A & W Research Lab of Brainerd to conduct tests and to work out improvement solutions to clean up the water for us.

Flooding History

1930 - 70 During the earlier years from the 30's or before until the 80's, we had floods three times each year, first around Easter, then again during the middle of June, and again in September. The water would rise from 6 to 8 feet, and would flood the road and also some of the low cabins. This was caused by the St. Croix not being able to handle the water coming from the Snake and other rivers so it backed up into all the lakes. Generally when we had heavy rains around Aitkin, Minnesota we could look for high water.

In the 1960's the road on the west side of the lake was rebuilt and a new bridge over Tosier Creek was built. Also, built a new bridge over Ann River on north end of the lake and raised the height of them so they were mostly always passable.

In 1972 we had lots of heavy rain. They diked the Knife Lake dam that year, but the dike gave way causing the dam to go out and the lake drained. In turn, it flooded parts of the river property in Mora and along Snake River. The water in Fish lake raised 14 feet. When it was rising, the water flowing into Tosier Creek sounded like a freight train going through the bridge. That evening it washed out 10 feet of road on both sides of the bridge and flooded many homes, even on higher ground.

That winter there was a spot in the middle of the south part of the lake that remained open most of the winter.

TABLE 1a. FISH LAKE: MORPHOMETRIC, WATERSHED AND FISHERY CHARACTERISTICS.

STORET I.D. #33 - 0036

Area (Lake)[1]: 399 acres (161 ha)

Mean Depth: 4.7 feet (1.4 m)

Maximum Depth: 9.5 feet (2.89 m)

Volume: 1,874 acre-feet (2.3 hm^3)

Watershed Area[3]: 53,888 acres (84 mi^2)(21,817 ha)

Watershed Area: Lake Surface Ratio ~ 135:1

Estimated Average Water Residence Time: .08 - years (30 days)

Fisheries - Ecological type: Centrarchid - largemouth bass lake

Public Access: 1
Inlets: Major-Ann River, Tosher Creek, Devils Lake Creek, unnamed creek, Ditches (4).
Outlets: 1 Ann River

LAND USE (Percentage)	Forest	Water & Marsh	Pasture & Open	Cultivated	Urban
Fish Lake Watershed[3]	50	22	15	13	1
North Central Hardwood Forests[2]	6-25%	14-30%	11-25%	22-50%	2-9%
Northern Lakes and Forests[2]	54-81%	14-31%	0-6%	<1%	0-7%

Shoreland Zoning: Recreational Development

Development	Seasonal	Permanent	Total	Resort
1967[4]	47	38	85	
1982[5]	188	50	238	2 - (140 seasonal)
1993[5]	125*	61	186	2 - (108 seasonal)

[1]Planimetered by MPCA from 1958 MDNR bathymetric map.
[2]25-75 Percentile for representative lakes in the ecoregion (Fandrei 1988)
[3]From Kanabec County SWCD
[4]Swim data base, State Planning Agency, Information Center, St. Paul, MN
[5]From Fish Lake Improvement Association and/or MDNR records
* Includes resorts and trailers

TABLE 1b. ANN LAKE: MORPHOMETRIC, WATERSHED AND FISHERY CHARACTERISTICS.

STORET I.D. #33 - 0040

Area (Lake)[1]: 638 acres (258 ha)

Mean Depth: 6.4 feet (1.9 m)

Maximum Depth: 17 feet (5.2 m)

Volume: 4079.025 acre-feet (5.0 hm^3)

Watershed Area[3]: 24,699 acres (38.6 mi^2)(10,000 ha)

Watershed Area: Lake Surface Ratio ~ 39:1

Estimated Average Water Residence Time: .22 years (80 days)

Fisheries - Ecological type: Centrarchid - Walleye
Management class: Walleye - Centrachid

Public Access: 2
Inlets: Ann River, Camp Creek, Spring Brook
Outlets: 1 Ann River

LAND USE (Percentage)	Forest	Water & Marsh	Pasture & Open	Cultivated	Urban
Ann Lake Watershed[3]	71	20	8	2	0
North Central Hardwood Forest[2]	6-25%	14-30%	11-25%	22-50%	2-9%
Northern Lakes & Forest[2]	54-81%	14-31%	0-6%	<1%	0-7%

Shoreland Zoning: Recreational Development

Development	Seasonal	Permanent	Total
1967[4]	74	22	96
1982[4]	122	84	206
1990[5]	-	94	-

[1] Planimetered by MPCA from 1975 MDNR baythemetric map
[2] 25-75 Percentile for representative lakes in the ecoregion (Fandrei 1988)
[3] Supplied by Kanabec County SWCD
[4] Swim data base, State Planning Agency, Information Center, St. Paul, MN
[5] From MDNR records

Septic System Survey

A septic system survey form was sent out to about 78 property owners around Fish Lake by the Association. A copy of the form and summary of the results is included in the Appendix. The purpose of this survey is to provide the Association with some basic information regarding the type of systems on the lake, age of the systems, type of dwelling and the frequency of pumping. This information should assist the Association in determining whether more education is needed with respect to design and maintenance of on-site systems and whether assistance from Kanabec County is needed, e.g., education, inspections, etc.

Of the 78 surveys distributed, 55 (70 percent) were returned. This is a rather high percentage. In addition, two resorts on the lake have a total of 108 units. Based on the returned surveys, the following types of systems are noted: septic tank & drainfield - 53 percent; septic tank - drywell - 33 percent; shared septic & drainfield - 0 percent; cesspool, holding tank, privy, mound system - each at 4 percent. The majority of the systems (75 percent) are less than 20 years old, while 25 percent are greater than 25 years of age. About 11 percent of the respondents pump their systems at least once per year. Another 24 percent pump every two to three years. About 40 percent, do not pump, or only pump their systems every ten years. Minnesota Extension Service recommends pumping every one to three years for a 1,000 gallon tank serving a three-bedroom house and four occupants (assumes year-round use). Based on the results of the survey, it appears that more work on septic tank maintenance (education and inspection) may be appropriate.

RESULTS AND DISCUSSION

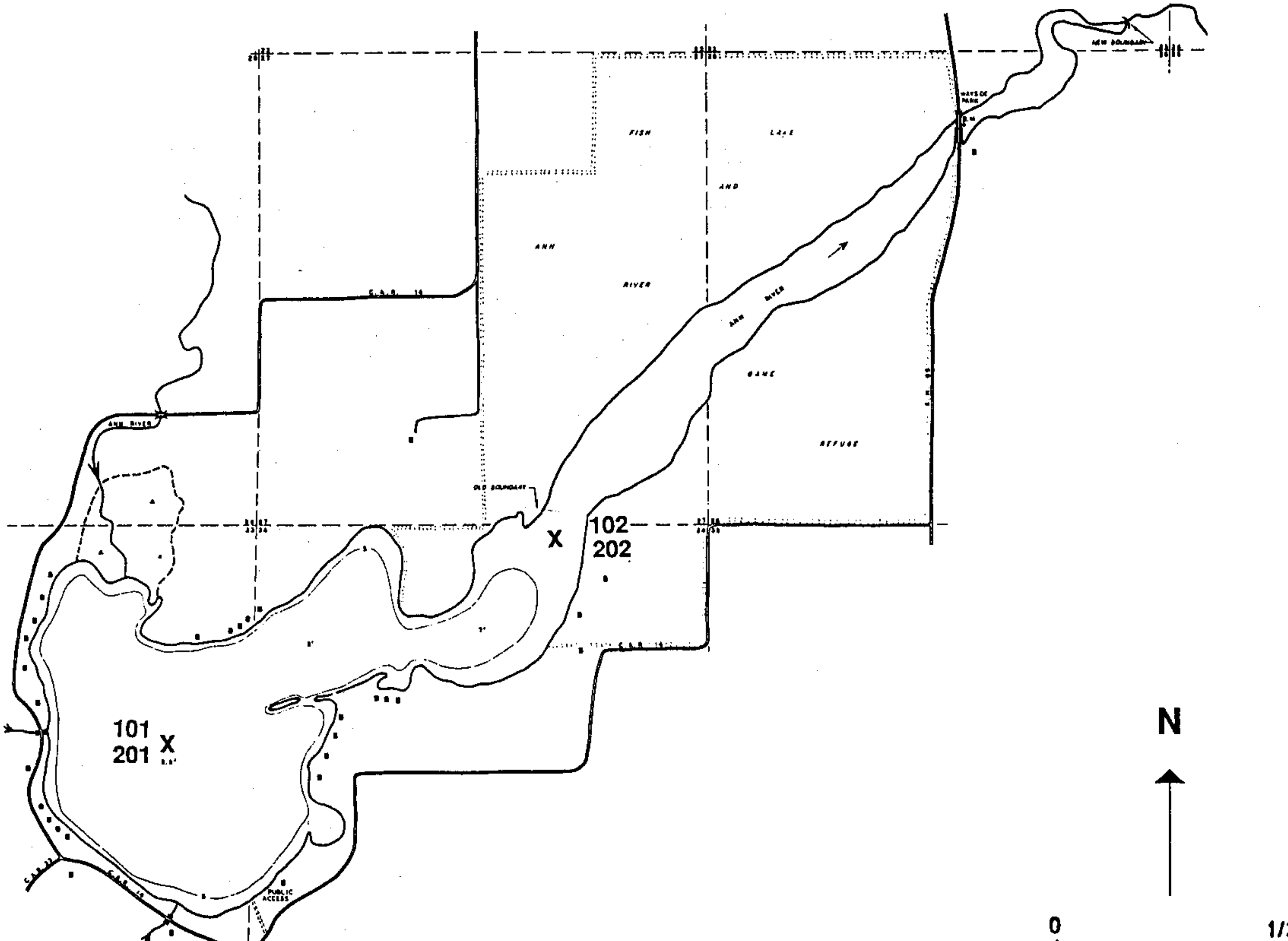
Water quality data was collected on May 4, June 7, July 8, August 2 and September 15, 1993. Two sites were used primarily: Site 101 over the point of maximum depth and site 102 (Figure 3). Lake surface samples were collected with an integrated sampler, which is a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). In addition, phytoplankton (algae) samples were taken at site 101 with the integrated sampler. Two sites had Secchi disk monitoring through the CLMP (sites 201, 204, Figure 3).

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. CLMP Secchi disk measurements from previous years were 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: Fish and Ann Lakes

Dissolved oxygen and temperatures profiles were taken at the point of maximum depth at sites 101 and 102 in Fish Lake. Profile data for site 101 are found in Appendix A.

Figure 3 FISH LAKE BATHYMETRIC MAP

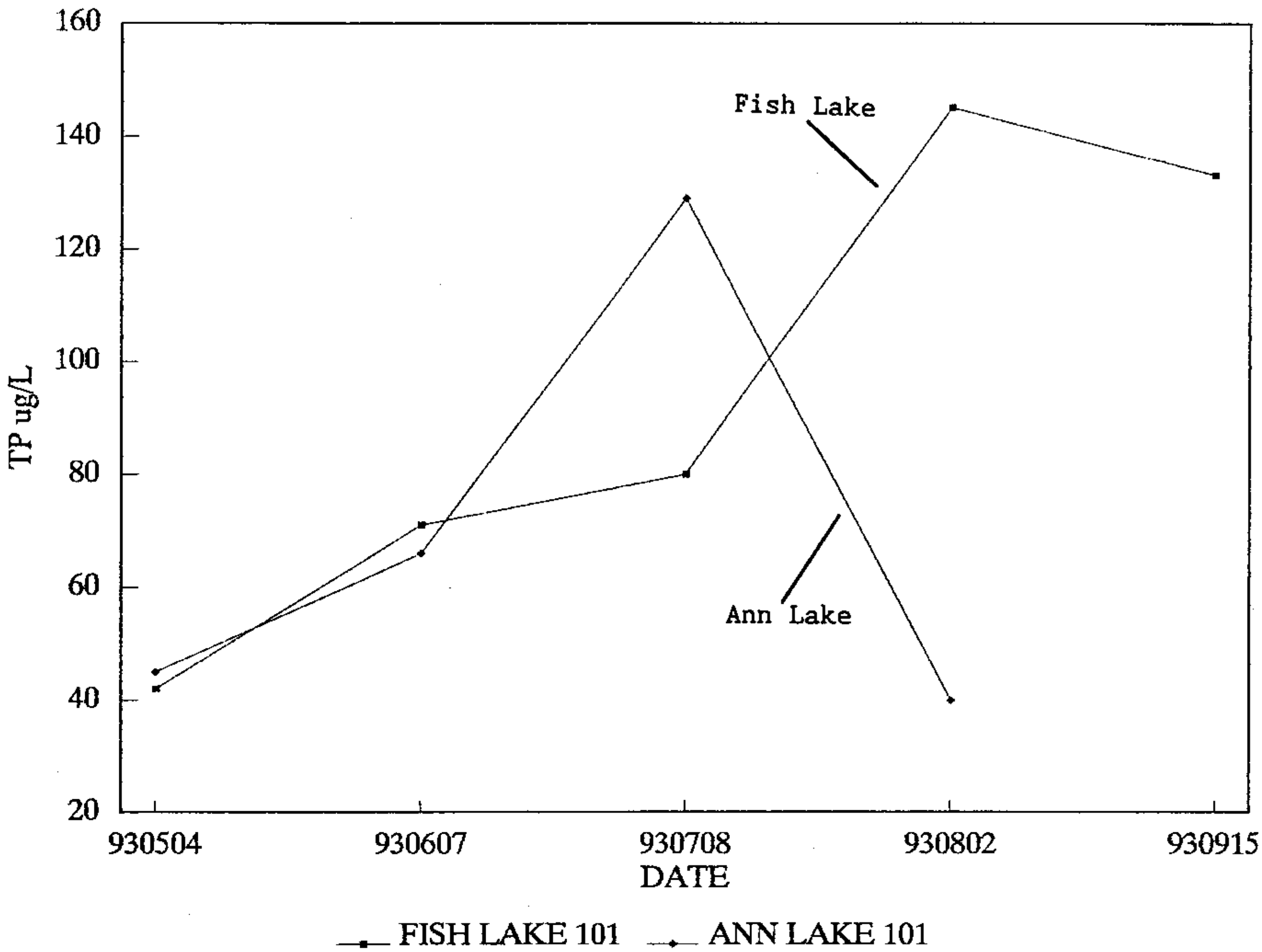


Key
200 Series----CLMP Lake Stations 100 Series----MPCA Lake Stations

Map - MDNR

MINNESOTA POLLUTION CONTROL AGENCY
DIVISION OF WATER QUALITY
JANUARY 1994

Figure 4 FISH/ANN LAKE EPILIMNETIC PHOSPHORUS CONCENTRATION



Fish Lake was well mixed on all sampling dates, with little or no change in dissolved oxygen or temperature from (Appendix) top to bottom due to the shallow depth of the lake (9.5 ft.). The lowest oxygen concentration measured was 4 mg/L. Game fish, typically require a dissolved oxygen concentration of 5 mg/L or greater for long-term survival. Based on the dissolved oxygen and temperature profiles, Fish Lake would be considered polymictic (well mixed on all sampling dates). This would apply to Ann Lake also.

Total phosphorus (TP) concentrations (an important nutrient for plant growth) averaged approximately 100 µg/L (micrograms per liter or parts per billion) in the epilimnion for the entire lake during the summer of 1993. This value is much higher than the range of concentrations typically found in reference lakes in the North Central Hardwood Forest ecoregion (Table 2). Ann Lake averaged 70 µg/L which is very high for a lake in the Northern Lakes and Forests ecoregion.

The summer mean phosphorus concentrations are fairly comparable between site 101 (107 µg/L) compared to site 102 in the east arm (92 µg/L) of fish lake. Epilimnetic concentrations in the main basin (site 101) ranged between 71-133 µg/L and 59-146 in the east arm (site 102) during the summer of 1993 (Figure 4).

Total nitrogen (TN) concentrations, which consists of total Kjeldahl nitrogen plus nitrite and nitrate-N, averaged 1.8 mg/L over the summer. This concentration is higher than typically observed for this region. Nitrite and nitrate-N concentrations are 0.018 mg/L, which is also higher than lakes in this region. Ann Lake averaged 1.3 mg/L, which is high for a lake in the Northern Lakes and Forests ecoregion.

The ratio of TN:TP can provide an indication as to which nutrient is limiting the production of algae in the lake. For Fish and Ann Lakes, the TN:TP ratio is about 18:1. This suggests that phosphorus is the limiting nutrient in both lakes. Generally, phosphorus is the least abundant nutrient and, therefore, is the limiting nutrient for biological productivity in a lake. The TN:TP ratio is lower than reference lakes in either ecoregion. The ratio is low because of the high phosphorus concentration in each lake.

Chlorophyll a concentrations provide an estimate of the amount of algal production in a lake. During the summer of 1993, chlorophyll a concentrations range from about 13 µg/L to 175 µg/L with an average of 77 µg/L in Fish Lake (Figure 5). Chlorophyll a averaged 40 µg/L in Ann Lake. Concentrations from 10-20 µg/L are frequently perceived as a mild algal bloom, while concentrations greater than 30 µg/L may be perceived as a severe nuisance (Heiskary and Walker, 1988). Both the average and maximum chlorophyll a concentrations for Fish and Ann Lakes are much higher than the reference lakes for either ecoregion. No significant difference was noted in the chlorophyll a concentrations between sites 101 and 102 in Fish Lake.

The composition of the phytoplankton (algae) population of Fish Lake is presented in Figure 5. Data are presented in terms of algal type based on samples collected at site 101. The May sample was dominated by the diatoms Melosira and Asterionella sp. By June, diatoms were less prominent, while

TABLE 2: FISH AND ANN LAKE: AVERAGE SUMMER WATER QUALITY AND TROPHIC STATUS INDICATORS. Based on 1993 epilimnetic data.

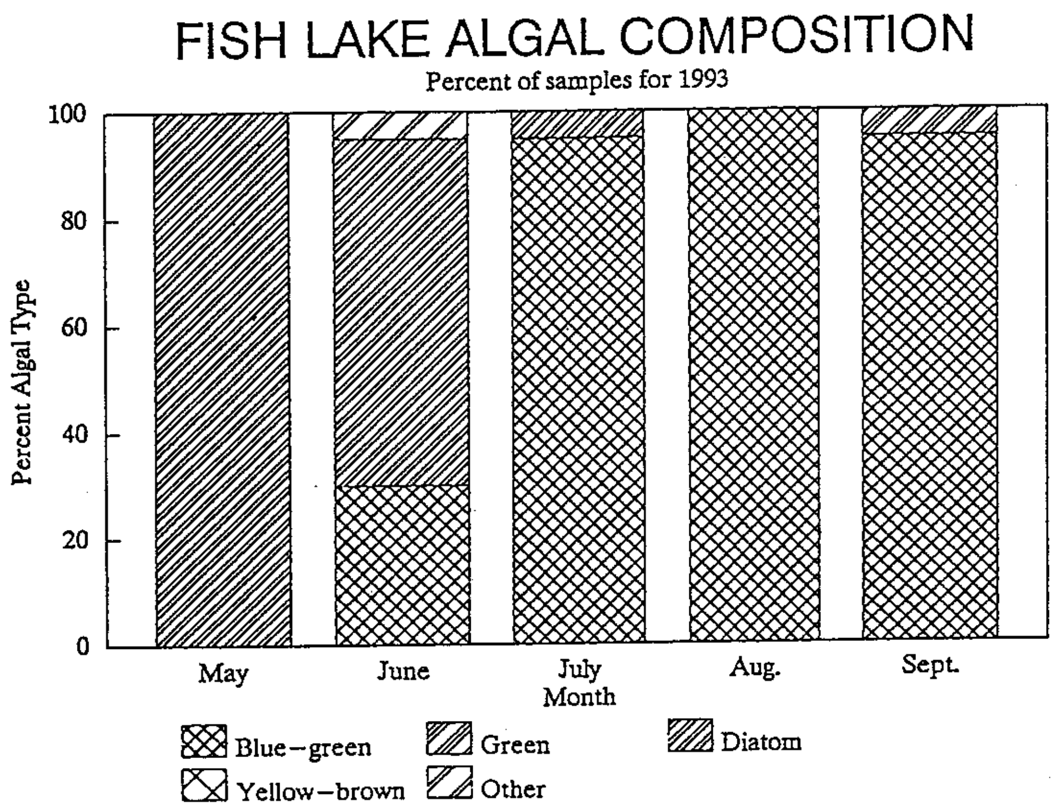
Parameter	Fish Lake	Ann Lake	Typical Range for NCHF Ecoregion[1]	Typical Range For NLF Ecoregion
Total Phosphorus (µg/L)	100	70	23-50	14-17
Chlorophyll a (µg/L)				
Mean	77	40	5-22	<10
Maximum	175	65	7-37	<15
Secchi disk (feet)	2.1	3.5	4.9-10.5	8-15
Total Kjeldahl Nitrogen (mg/l)	1.8	1.3	<0.60-1.2	<0.75
Nitrite + Nitrate-N (mg/l)	.018	.020	<0.01	<0.01
Alkalinity (mg/l)	80	67	75-150	40-140
Color (Pt-Co Units)	60	78	10-20	10-35
pH (SU)	8.2	8.3	8.6-8.8	7.2-8.3
Chloride (mg/l)	1.9	.9	4-10	<2
Total Suspended Solids (mg/l)	13.5	9.1	2-6	<1-2
Total Suspended Inorganic Solids	4.7	3.0	1-2	<1-2
Turbidity (NTU)	8.9	5.0	1-2	<2
Conductivity (umhos/cm)	149	120	300-400	50-250
TN:TP Ratio	18:1	19:1	25:1-35:1	25:1-35:1

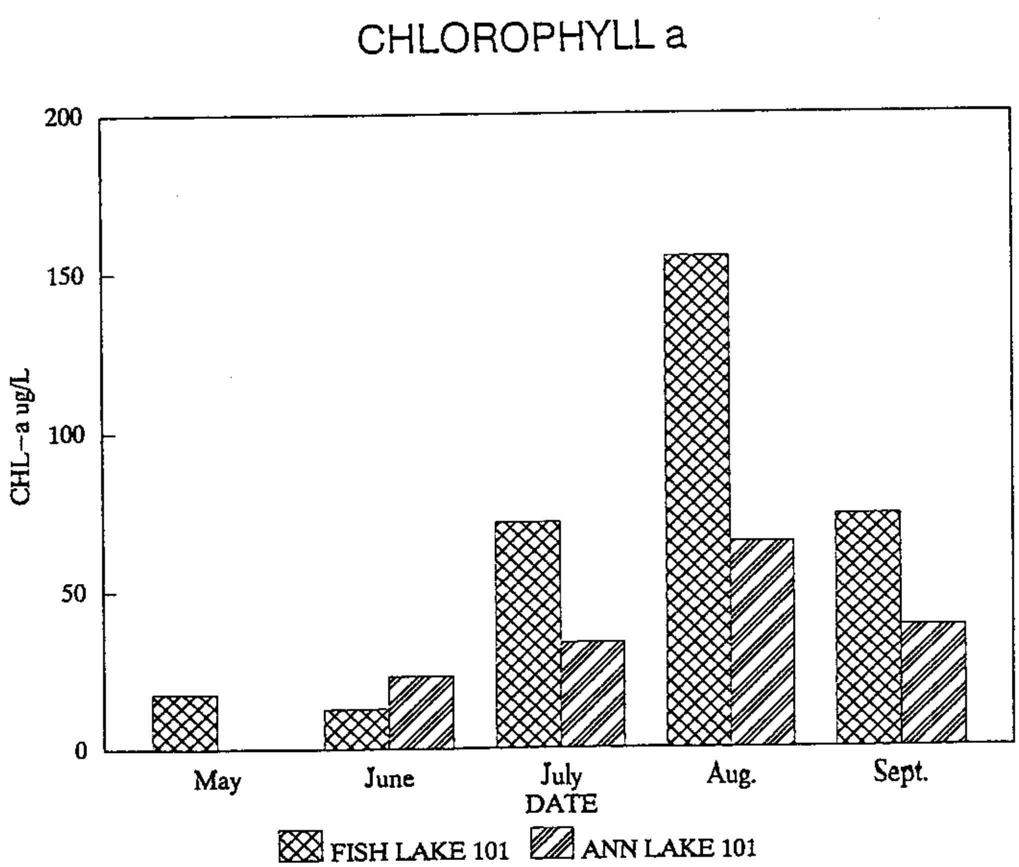
Trophic Status Indicators: 1993

Carlson Trophic State Index Values		Fish Lake	Ann Lk	Percentile[2] NCHF Ecoregion Fish	Percentile[2] NCHF Ecoregion Ann	Percentile[3] NLF Ecoregion Fish	Percentile[3] NLF Ecoregion Ann
TP	TSIP =	70	64				
Chl a	TSIC =	70	66				
Secchi	TSIS =	68	60				
Mean (All)	TSI =	68	63	22	35	1	2

[1]Derived from Heiskary and Wilson (1990).
[2]Relative to approximately 700 assessed lakes in NCHF 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]Relative to approximately 970 assessed lakes in the NLF Ecoregion.

FIGURE 5 FISH LAKE PHYTOPLANKTON AND CHLOROPHYLL COMPOSITION





blue-greens increased in dominance. During July through September, the bluegreens were dominant with the genera Aphanizomenon, Anabaena and Oscillatoria/Lyngbya being the most prominent. Chlorophyll a concentrations in July through September would be equated to severe bloom conditions. The seasonal transition in the algae from diatoms to greens to blue-green is rather typical for mesotrophic and eutrophic lakes in Minnesota.

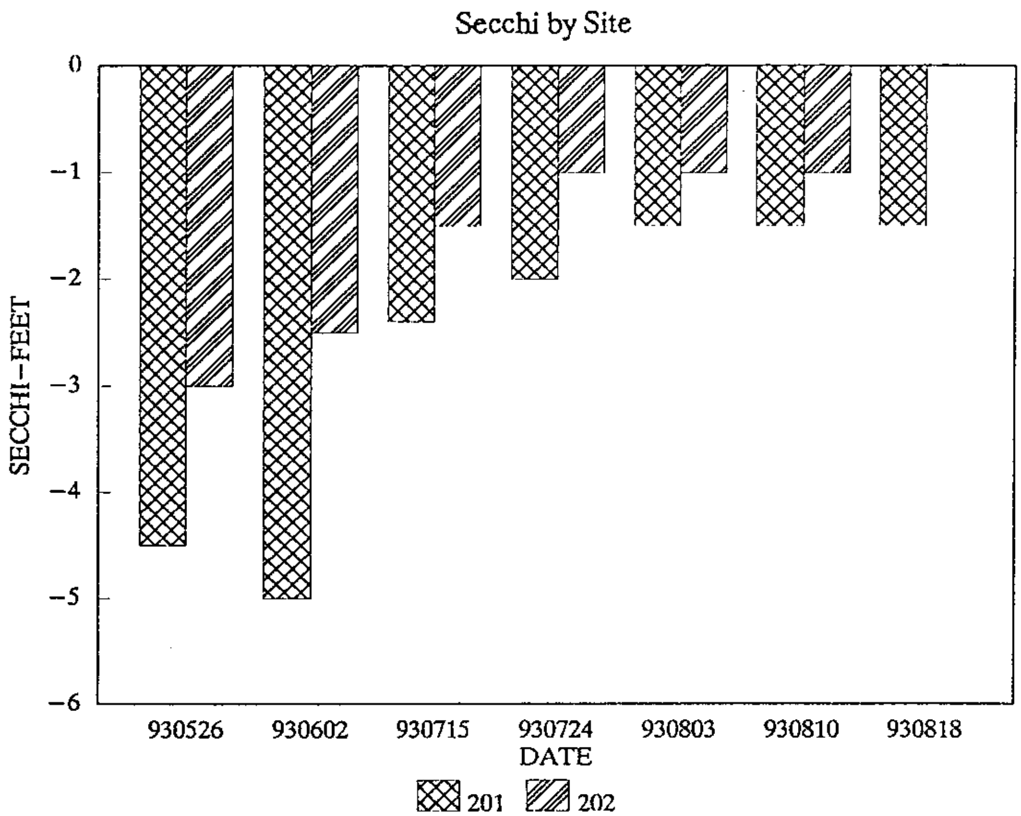
Secchi disk transparency is generally a function of the amount of algae in the water. Suspended sediments or color due to dissolved organics may also reduce water transparency. Color averaged about 60 and 78 Pt-Co Units for Fish and Ann Lakes indicating moderate coloration. Total suspended solids averaged 13.5 and 9.1 mg/L respectively over the summer. The total suspended solids values are high when compared to reference lakes in either region. A large proportion (approximately 75 percent) of the total suspended solids are caused by suspended algae and other organic matter. These levels of color and total suspended solids may limit water transparency in Fish Lake. Secchi disk transparency ranged from 1 to 5 feet (.3 to 1.5 m) and averaged 2.1 feet (.6 m) during the summer of 1993 based on measures taken at two sites by CLMP volunteers (Figure 6). Summer Secchi transparency was about one-half foot deeper at site 202 (east arm) on most sampling dates. Transparency averaged 3.5 feet (1.1 m) in Ann Lake. These transparency measures are much lower than the typical range for reference lakes in either ecoregion (Table 2).

Along with CLMP transparency measurements, subjective measures of Fish Lakes "physical appearance" and "recreational suitability" were made by the CLMP observers (Appendix 1). Physical appearance ratings range from "crystal clear" (Class 1) ... to "dense algal blooms, odor, etc." (Class 5) and recreational suitability ratings range from "beautiful, could not be any nicer" (Class 1) ... to "no recreation possible" (Class 5) in this rating system (Heiskary and Wilson, 1988). Transparency, physical appearance, and recreational suitability ratings for CLMP site 201 are presented in Figure 6.

The "physical appearance" and "recreational suitability" ratings were fairly similar between the two sites. Lake conditions were typically characterized as "definite algal green" (Class 3) throughout June and July (Figure 6). Secchi transparency was between 3-5 feet during June and 1.5 - 2.5 feet during July and chlorophyll a (algae) concentrations were in the 10-20 µg/L range in June, increasing to 60-70 µg/L in July. Conditions in August are characterized as "high and severe algal levels" (Class 4 and 5). The algal population is dominated by blue-green forms during this period of time. Secchi transparency is generally less than 1-1.5 feet (Figure 6) and chlorophyll a concentrations are in excess of 150 µg/L during this period of time (Figure 5).

The change in the transparency of Fish Lake over the course of the summer, is fairly typical for mesotrophic and eutrophic lakes in Minnesota. 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, the algae make use of available nutrients and as algae become more abundant, transparency declines. The decrease in the abundance of zooplankton may allow for further increases in the amount of algae. Later in the summer, surface blooms of algae may appear. On a day-to-day basis, transparency may differ between the sites measured, but the overall pattern is consistent among the two CLMP sites.

FIGURE 6. 1993 CLMP SECCHI AND USER PERCEPTION



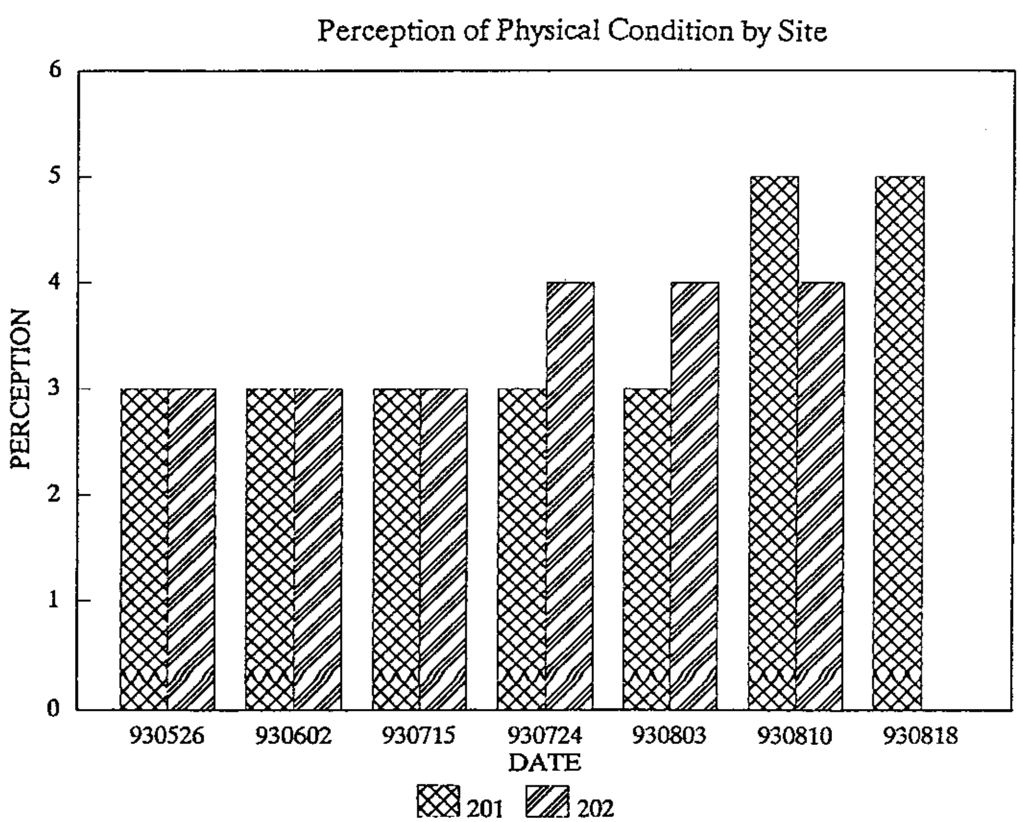


FIGURE 7. CARLSON'S TROPHIC STATE INDEX VALUES FOR FISH AND ANN LAKES
TSI Relationships Based on Mean Summer Data For 1993

Changes in the Biological Condition of Lakes With Changes in Trophic State

R.E. Carlson

TSI < 30 Classical oligotrophy: Clear water, oxygen throughout the year in 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.

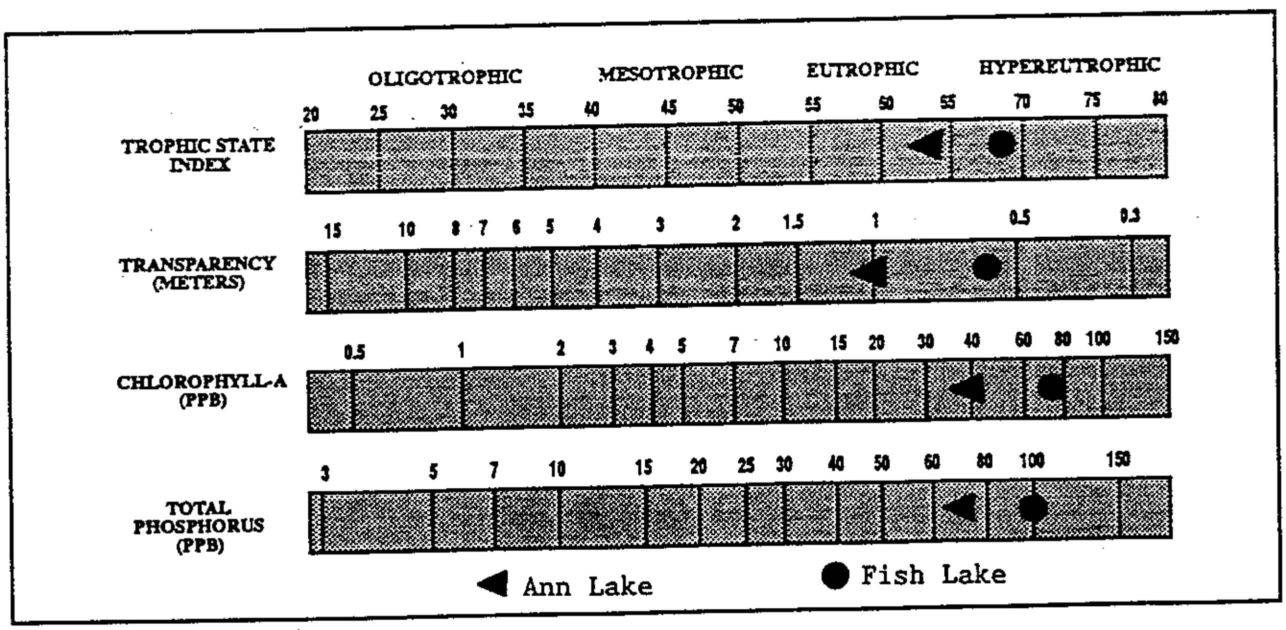
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer..

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 hypertrophic..

TSI > 80 Algal scums, summerfish 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..

Trophic Status

One means 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) = 9.91 ln (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 10 units represents a doubling of algal biomass.

Average values for the trophic variables in Fish and Ann Lake's respective TSIs are presented in Figure 7. Based on these values, Fish Lake would be considered hypereutrophic in condition. The mean TSI of 68 ranks Fish Lake at the 22 percentile relative to 700 other lakes in the North Central Hardwood Forest ecoregion. In other words, its TSI value is lower (less eutrophic) than 22 percent of the lakes assessed in this region. The individual TSI values agree fairly well with one another. Ann Lake's TSI averages 63. Relative to lakes in the Northern Lakes and Forests ecoregion, a TSI of 63 ranks at the ~~2nd~~ 35th percentile percentile.

Another means for comparing these three variables is graphically on scatterplots. Values for Fish Lake and Ann Lakes are noted on Figure 8. In general, we note that total phosphorus-chlorophyll *a*-Secchi transparency relationships in Fish and Ann Lakes are quite comparable to those observed in other Minnesota lakes.

Water Quality Trends

Very little data is available for determining long-term trends in the quality of Fish Lake. The best source of data, CLMP data, date back to 1976 (five years of observations).

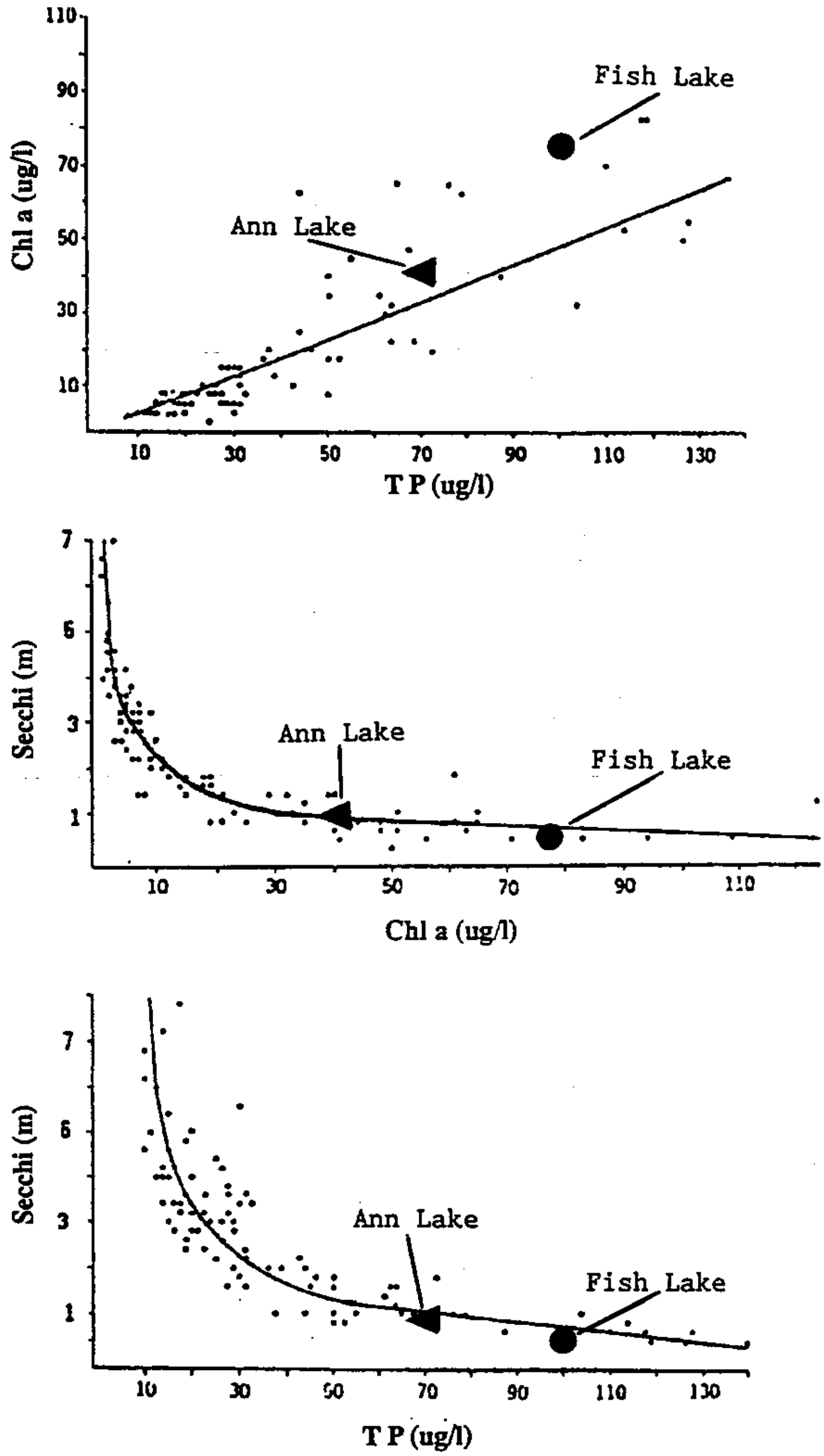
The values for the period of record are as follows:

CLMP HISTORICAL DATA - Summer means

YEARS	1976	1977	1991	1992	1993	5-year Mean
Secchi (feet)	2.4	1.6	2.0	1.5	2.0	1.9
#Observations	17	17	17	17	12	

These data do not reveal any long-term trends, but do indicate that transparency has been similar over the years. For example, summer-mean transparency during 1976-1977 ranged between 1.6 and 2.4 feet, while during 1991-1993 summer-mean transparency ranged between 1.5 and 2 feet.

FIGURE 8 SCATTERPLOTS OF CHLOROPHYLL, TOTAL PHOSPHORUS AND SECCHI TRANSPARENCY Based on summer data from a set of representative lakes.



Modeling Summary

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 or amount or water that enters the lake. To analyze the 1993 quality of Fish and Ann Lakes, the models of Reckhow and Simpson (1980) and MINLEAP (Wilson and Walker 1989) were used. Reckhow and Simpson's model is used extensively for assessing lake water quality. A more recently developed model, the "Minnesota Lake Eutrophication Analysis Procedures" (MINLEAP), was also used. This model 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 (1988).

No actual measure of water flow into or out of the lake or measures of nutrient concentrations into or out of the lake were made. Rather, published runoff coefficients, precipitation and evaporation data, and nutrient export coefficients were used in this modeling. Precipitation and evaporation data were derived from Gunnard (1985) and precipitation data from the State Climatology Office 1993.

For the MINLEAP modeling, Fish Lake is considered to be in the North Central Hardwood Forests ecoregion. Ann Lake is modeled for the North Central Hardwood Forests and Northern Lakes and Forests ecoregions.

The MINLEAP model predicts a phosphorus concentration of 106 µg/l for Fish Lake. This is equivalent to the 1993 mean of 100 µg/L. The predicted chlorophyll value was lower than measured and the predicted Secchi transparency was quite comparable.

Based on MINLEAP, the water residence time (average time it would take to replace the entire volume of the lake) for Fish Lake is on the order of 30 days. Fish Lake retains approximately 29 percent of the phosphorus that enters the lake.

Ann Lake's observed phosphorus in 1993 (70 µg/L) compares favorably to the MINLEAP prediction (78 µg/L) if the lake is considered to be in the North Central Hardwood Forests ecoregion. However, if the Northern Lakes and Forests model inputs are used, the observed value is significantly different than the predicted value (37 µg/L). Ann Lake retains approximately 50 percent of the phosphorus which enters the lake. Thus, about 950 kg P/yrs of the estimated 1,900 Kg P/yr which enters the lake, would be discharged to the Ann River and ultimately Fish Lake.

For the Reckhow and Simpson modeling estimates of precipitation, runoff and evaporation for the 1993 water year were used. Land use composition for the watershed was supplied by Kanabec SWCD based on a 1993 evaluation (input section, Table 4). The number of seasonal and permanent residences were provided by the Fish Lake Association and DNR records. Phosphorus export coefficients were taken from the literature and/or were calculated based on equations presented by Prairie and Kalff (1986). Their premise is that in large agricultural watersheds, much of the phosphorus exported by the various land uses is retained in the watershed.

This is probably realistic in watersheds where the drainage is not heavily channelized and there exists a number of lakes or wetlands which may act as sinks for phosphorus. This would seem to be the case for the Fish Lake watershed. These calculated coefficients are often lower than those in the literature. The soil retention coefficient is a means for estimating the soil's ability to trap phosphorus which may leach from septic tanks and potentially reach the lake. A high retention coefficient in the case of this model can reflect a high degree of trapping by the soils and/or well maintained septic systems.

For Fish Lake, the estimated P loading based on "high" P export values (Output Section 1 in Table 4) provides the best approximation of the in-lake P concentration (90 µg/L) compared to the observed in 1993 (100 µg/L). Based on these export values, watershed sources (including cultivated, pastured, forested lands, etc.) contribute about 96 percent of the P load to the lake (Output Section 2 in Table 4) with the remainder contributed from septic systems (approximately 4 percent) and precipitation on the lake. The estimated P loading from septic tank effluents to the lake may be a small component of the overall P loading to the lake (because the watershed is so large); however, these effluents can promote near-shore effects such as excess weed growth or attached algae growth.

For Ann Lake, the "high" P export coefficients also provide the best approximation of the P loading (approximately 1,900 kg/yr) and in-lake P (58 µg/L) relative to the observed in-lake P (70 µg/L) in 1993. As with Fish Lake, watershed sources contribute the majority of the P (86 percent) to the lake. However, septic systems <u>may</u> be a more significant portion of the P load (approximately 10 percent) to Ann Lake. This seems reasonable considering that Ann Lake's watershed is about one-half the size of Fish Lake's watershed and is predominately (71 percent) forested. This results in a lower P load to Ann Lake (approximately 1,700 Kg/yr) compared to the estimated P load (approximately 5,300 Kg/yr) which enters Fish Lake from its watershed.

Based on the previous modeling (MINLEAP and Reckhow-Simpson) and in-lake P concentrations for Fish Lake in 1993, it appears that Fish Lake is receiving a very high P loading from its watershed. Using the results from these two models and model results from Ann Lake, we can do some further estimation on potential sources of P to Fish Lake.

Based on MINLEAP and Reckhow-Simpson ("high P exports) P loading to Fish Lake ranges between 4,200 - 5,500 kg P/yr. Of this loading, approximately 950 Kg P/yr is estimated to arise from the Ann lake watershed (P load to Ann Lake is approximately 1,900 Kg/yr and the lake retains about 50 percent of the P load). If we subtract the loading from Ann Lake's watershed from the estimated loading to Fish Lake, we get a range of 3,250-4,550 Kg P/yr as the estimated P loading from Fish Lake's <u>immediate</u> (11,656 ha) watershed. Running MINLEAP for Fish Lake's immediate <u>watershed</u> area only yields an estimated P loading of 2300 Kg P/yr. If we compare this loading to that predicted by subtracting out Ann Lake

TABLE 3 MINLEAP MODEL SUMMARY

Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? Fish
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 2
WATERSHED AREA (HA) ? 21656
LAKE SURFACE AREA (HA) ? 161
LAKE MEAN DEPTH (M) ? 1.4
OBSERVED MEAN LAKE TP (UG/L) ? 100
OBSERVED MEAN CHL-A (UG/L) ? 77
OBSERVED MEAN SECCHI (M) ? .64

INPUT DATA:
LAKE NAME =Fish ECOREGION=CHF
LAKE AREA = 161 HA
WATERSHED AREA (EXCLUDING LAKE) = 21656 HA
MEAN DEPTH = 1.4 METERS
OBSERVED MEAN TP = 100 UG/L
OBSERVED MEAN CHL-A = 77 UG/L
OBSERVED MEAN SECCHI = .64 METERS

<press ENTER to view results>

LAKE = Fish ECOREGION = CHF
AVERAGE INFLOW TP = 149.374 UG/L TOTAL P LOAD = 4214.914 KG/YR
LAKE OUTFLOW = 28.2172 HM3/YR AREAL WATER LOAD = 17.52621 M/YR
RESIDENCE TIME = 7.988036E-02 YRS P RETENTION COEF = .2896757

VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	100.00	106.10	23.05	-0.03	-0.22
CHL-A	(UG/L)	77.00	59.95	28.53	0.11	0.46
SECCHI	(METERS)	0.64	0.69	0.24	-0.03	-0.22

NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)

CHL-A PPB	OBSERVED	PREDICTED CASE A	PREDICTED CASE B	PREDICTED CASE C	
10	100.00	99.98	99.94	99.13	"mild blooms"
20	99.49	97.97	97.06	91.84	"nuisance blooms"
30	95.77	88.55	86.67	79.38	
60	61.07	40.39	41.11	43.40	

CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED
Ok

Watersheds P loading, there is approximately 950 to 2250 Kg/yr unaccounted for using typical stream concentrations for the North Central Hardwood Forests ecoregion (MINLEAP).

One potential additional source of P to Fish lake not accounted for in the MINLEAP modeling or with the P export coefficients is the loading from feedlots or pasturing of animals. The Reckhow-Simpson model (Output Section 4) provides a framework for estimating the "P generation potential from animal units," estimating a range of "potential" P loads, and estimating the impact of the potential P loads on in-lake P concentrations.

It is estimated that approximately 800 head of cattle are pastured in the immediate watershed just above Fish Lake (personal communication - John Archambo, MPCA-Brainerd and Linda Peterson, Kanabec SWCD). The "potential" P loading from this number of cattle ranges from 2,400 - 9,500 kg P/yr. This does not imply that all the P from the cattle enters Fish Lake - rather, it is the "P generation potential." We can further estimate the impact of this loading to the lake by estimating a range of percentage loss rates from the land to the lake (ranging from 1 percent to 75 percent in Table 4, Output Section 4). A graphic representation of the potential impact of the animal P load on the in-lake P concentration is presented in Figure 9. Figure 9 begins with the average (most likely in-lake P concentrations of 68 ug/L (Table 4, Output Section 1) and incrementally "adds" the estimated animal ("most likely") P load to the lake (represented as a percent of total animal P load generated). In this instance, the model predicts that if 50 percent of the animal P loading reached the lake, the in-lake P concentration would rise from 68 ug/L to approximately 101 ug/L (equivalent to observed in-lake P in 1993). The P loading corresponding to the cattle is approximately 2,400 Kg P/yr (50% of 4,800 Kg P/yr). This 2,400 Kg P/yr compares favorably to our previously estimated range of "unaccounted for" P loading to the lake - 950 to 2,250 Kg P/yr.

The analysis of the impact of P generation from animals in the watershed is based on numerous estimates and should not be considered an exact representation of the P loading from the source. However, the analysis indicates that animals (pastured or feedlots) in the watershed of Fish Lake <u>may</u> be a significant source of P to the lake and, thus, should be considered in any strategy aimed at reducing the P loading to the lake.

Goal Setting

Total phosphorus concentrations and subsequently chlorophyll *a* concentrations are very high in Fish and Ann Lakes relative to lakes in the Northern Lakes and Forests or North Central Hardwood Forests ecoregion. The high phosphorus concentrations in the lakes are the result of the very large watersheds which drain to each lake (e.g. watershed: lake surface ration of 135:1 for Fish Lake), high P export from the watersheds and the shallowness of the lakes. Poor land use practices in the watershed, including runoff from feedlots and pastured lands, erosion of cultivated lands, excess fertilization of lawns, and leaching from poorly maintained septic systems all serve to increase the phosphorus loading to the lakes.

For lakes in this part of the state in-lake phosphorus concentration of 40 µg/L or less are desirable if the lake is to provide "swimmable" conditions throughout the majority of the summer. At a phosphorus concentration of 40 µg/L

TABLE 4 RECKHOW-SIMPSON MODELING FOR FISH LAKE

I N P U T   S E C T I O N

****

	Fish		
Watershed Area (ha)	21656	0.1	=Observed TP (mg/l)
Lake Area (ha)	161	0.0038	=Observed TP StDev
Water Runoff (m)	0.2	8	=N
Precipitation (m)	0.68	77	=Observed Chla (ug/l)
Mean Evaporation (m)	0.86	0.64	=Observed Secchi (m)
Mean Depth (m)	1.4	2.254	=Calc. Volume (Hm3)
County capitas/cabin	2.8		
No. Seasonal Cabins	125		
No. Permanent Res.	61		

****Fill in Est. Number Animal Units at a102****

	Before	After	Delta	%Total
Forest Area (ha)	10590	0.4	0	49%
Agric Area (ha)	2772	284.7	2487.3	13%
Urban Area (ha)	173	8.3	0	1%
Wetland Area (ha)	4699	53	0	22%
Pasture/Open (ha)	3422	68	0	16%
	21656			

Export Values	Low	Average	High
Forest P Export	0.1	0.1	0.15
Agric P Export	0.2	0.4	0.6
Urban P Export	0.5	1	1.25
Wetland P Export	0.1	0.1	0.1
Pasture/open Export	0.2	0.3	0.4
Atmospheric Export	0.3	0.3	0.3
Soil Retention Coef	0.75	0.5	0.25
Point Source Before kg/yr	0	0	0
Point Source After kg/yr	0	0	0
Delta Point Source kg/yr	0	0	0
Capita Years	259.7	259.7	259.7

TABLE 4 RECKHOW-SIMPSON MODELING FOR FISH LAKE (Continued)

OUTPUT SECTION #1
Reckhow-Simpson Modeling Summary

KG P/YEAR Low	Average	High	kg P/year
1059	1059	1589	Forested Flux
554	1109	1663	Ag flux
87	173	216	Urban flux
470	470	470	Wetland flux
684	1027	1369	Pasture/Open flux
48	48	48	Ppt flux
65	130	195	Septic flux
0	0	0	Point Souce
2967	4016	5550	Total P Flux
1843	2494	3447	P LOAD (kg)
69	93	128	Inflow P ug/l
			Predicted inlake P
52	68	90	CANFIELD/BACHMANN ug/L

OUTPUT SECTION 2 WATERSHED CONTRIBUTIONS

P load contribution

	Low flux	%	Avg flux	%	High flux	%
Wshed	2854	96%	3838	96%	5307	96%
Septic	65	2%	130	3%	195	4%
Ppt	48	2%	48	1%	48	1%
Point	0	0%	0	0%	0	0%
Sum kg/yr	2967		4016		5550	

OUTPUT SECTION 3. Reckhow-Simpson and MINLEAP Modeling Summary
Predicted changes in Secchi, Chlorophyll and Trophic Status

	Observed	Low Predicted	Average Predicted	High Predicted	MINLEAP Predicted
		Predicted inlake P conc. or insert other values.			4214 kg/yr
LAKE TP mg/l	0.100	0.052	0.068	0.090	0.106
LAKE CHLA ug/l	77	21.2	31.3	47.1	60
LAKE SECCHI m	0.64	1.3	1	0.8	0.69
TSI TP	71	61	65	69	71
TSI CHLA	73	61	64	68	71
TSI SD	66	56	60	63	65

Hydrologic Summary Information

Est Flow= 43311971 43.31 =HM3
Est Qs = 26.9
NOTE: 1HM3 = 1,000,000 M3; HM3=A-F/811; Ha=Ac/2.47; Km2=2.59*Mi2
0.10 =Water Residence (year)

TABLE 4 RECKHOW-SIMPSON MODELING FOR FISH LAKE (Continued)

OUTPUT SECTION 4.
Estimated P Generation Potential from Animal Units

		P kg/Year Low	ML	High
	Cows	3	6	12
	Pigs	0.9	1.6	3.8
	Sheep	0.5	0.75	1.1
Fillin estimated number	Poultry	0.1	0.1	0.2
of animal units here	Horses	3	5	7.8
800 =Estimated Number	Cows	2400	4800	9600
0 =Estimated Number	Pigs	0	0	0
0 =Estimated Number	Sheep	0	0	0
0 =Estimated Number	Poultry	0	0	0
0 =Estimated Number	Horses	0	0	0
-------- Total Estimated Kg P/Year				
Generation Potential		2400	4800	9600 kg
Ws Estimated Total Load		2967	4016	5550 kg
(*Without Animal P Loads)				
Animal P Load Addition Potential		81%	120%	173%
(Magnitude of Animal Unit P Generation Potential)				

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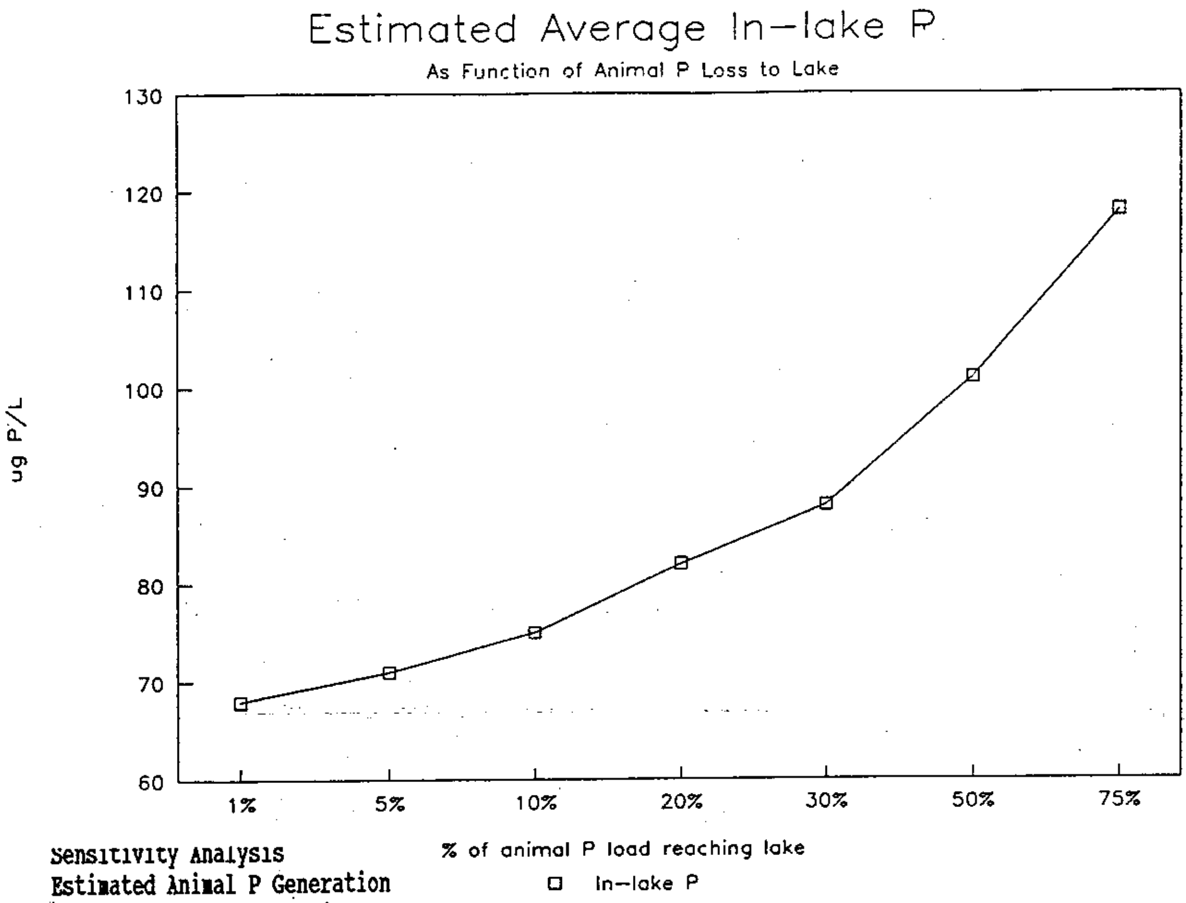
FIGURE 9 IN-LAKE P RELATED TO ANIMAL P LOADING



Sensitivity Analysis
Estimated Animal P Generation

	Low	ML	High
	2400	4800	9600
1%	24	48	96
5%	120	240	480
10%	240	480	960
20%	480	960	1920
30%	720	1440	2880
50%	1200	2400	4800
75%	1800	3600	7200

Use Most Likely Value to Estimate Net Predicted Inlake P due to Increase From Animal Units

	ML	Adj. Net	PredictedInflowP		Predicted P
Loss Rate	4800				
1%	48	4064	2524	94	68
5%	240	4256	2643	98	71
10%	480	4496	2793	104	75
20%	960	4976	3091	115	82
30%	1440	5456	3389	126	88
50%	2400	6416	3985	148	101
75%	3600	7616	4730	176	118

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Loss rate as a percent of the total P produced by animal units identified above. This is for illustrative purposes and should be tempered by the identification of likely scenarios by watershed analysis.

"severe nuisance" blooms of algae (chlorophyll a >30 ug/L) would occur less than ten percent of the summer and Secchi transparency would remain above one meter for the majority (90 percent) of the summer. This would be a substantial improvement over 1993 conditions in Fish lake which experienced severe nuisance blooms and Secchi transparency less than one meter throughout most of the summer.

Substantial reductions in the P loading to these lakes would be required in order to achieve an in-lake P concentration of 40 µg/L. For Ann Lake, the reduction in P loading is on the order of 30-40 percent. For Fish Lake, the reduction in P loading may be on the order of 50-60 percent.

Further study, such as a Clean Water Partnership study, is required to determine whether a goal of 40 µg/L or lower is reasonable for these lakes (i.e. could necessary reductions in P loading be achieved). This study would also determine where efforts to reduce P loading should be targeted. However, obvious sources near the lake (in the case of Fish Lake - downstream from Ann Lake) should be addressed first. This should include feedlots and heavily pastured lands, cultivated lands, residential areas (including septic tanks) near the lake, and any other sources which may be identified in a more comprehensive assessment of the watershed.

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APPENDIX

LAKE WATER QUALITY DATA. All MPCA data in STORET.

LAKEID=33-0036 Fish Lake

DATE	SITE	D	TP	RTP	TKN	N2N3	RN2N3	TSS	TSIN	ALK	PHF	CL	CONF	TURB	COLOR	CHLA	PHEO	SDF	PHYS	REC
920710	101	0	.100	Q	1.48	0.01	K	15.0	5.0	94	8.8	1.9	185	8.0	50	65.40	8.33	2.5	2	2
920813	101	0	.166	Q	2.29	0.01		28.0	14.0	110	7.7	1.6	.	12	30	130.00	9.61	1.6	3	3
920910	101	0	.198		2.50	0.01		41.0	17.0	110	8.3	3.5	.	15	40	152.00	5.34	1.3	3	3
930504	101	0	.042		0.25	0.01	K	8.8	4.4	86	7.3	2.9	160	3.5	30	17.60	4.81	4.3	3	3
930504	102	0	.046		0.32	.		.	.	.	.	.	.	.	.	.	.	3.6	3	3
930607	101	0	.071		0.76	0.01	K	6.4	4.0	74	7.7	2.0	150	3.8	50	12.80	1.28	3.6	2	2
930607	102	0	.059		0.78	0.01	K	.	.	.	.	.	.	.	.	21.10	2.56	.		
930708	101	0	.080		1.49	0.01	K	8.8	2.8	66	8.3	1.7	130	7.3	70	71.30	0.80	2.5	4	4
930708	102	0	.075		1.87	.		.	.	.	8.2	.	130	.	.	65.70	4.00	2.0	4	4
930802	101	0	.145		3.12	0.01	K	24.0	7.0	.	8.4	1.4	150	17	70	155.00	3.12	1.3	4	4
930802	102	0	.146		2.97	.		.	.	.	8.7	.	140	.	.	175.00	1.60	1.0	5	4
930915	101	0	.133		1.72	0.05	K	15.0	5.0	100	7.8	2.4	170	7.9	50	73.70	3.20	2.0	4	3
930915	102	0	.088		.	.		.	.	.	.	.	.	.	.	43.20	4.81	.		

LAKEID=33-0040 Ann Lake

DATE	SITE	D	TP	RTP	TKN	N2N3	RN2N3	TSS	TSIN	ALK	PHF	CL	CONF	TURB	COLOR	CHLA	PHEO	SDF	PHYS	REC
810813	101	0	.107		1.81	0.01	K	.	.	68	.	.	.	.	90	60.00	.	2.6		
930617	101	0	.045		1.05	0.01	K	4.4	1.8	54	7.9	1.1	110	3.5	90	23.10	1.28	4.3	2	2
930720	101	0	.066		1.45	0.01	K	7.0	1.4	78	8.3	0.9	110	3.5	100	33.30	0.64	3.9	3	3
930818	101	0	.129		1.60	0.01	K	10.0	1.2	62	8.7	0.5	.	8.0	70	64.90	0.80	2.3	3	2
930929	101	0	.040		1.18	0.05	K	15.0	7.6	74	8.2	1.2	140	5.0	50	38.40	7.05	3.3	2	2

Abbreviations and Units

SITE= sampling site ID
DM= sample depth in meters(0=0-2 m integrated)
D= sample depth in feet
TP= total phosphorus in mg/l
TKN= total Kjeldahl nitrogen in mg/l
N2N3= nitrite+nitrate N in mg/l
PH= pH in SU (field)
PHL= pH in SU (lab)
ALK= alkalinity in mg/l (lab)
TSS= total suspended solids in mg/l
TSV= total suspended volatile solids in mg/l
TSIN= total suspended inorganic solids in mg/l
TURB= turbidity in NTU
COND= conductivity in umhos/cm (l=lab)
CONF= conductivity (field)
CL= chloride in mg/l
DO= dissolved oxygen in mg/l
TEMP= temperature in degrees centigrade
SD= Secchi disk in meters
SDF= Secchi disk in feet
CHLA= chlorophyll-a in ug/l
PHEO= pheophytin in ug/l
PHYS= physical appearance rating
REC= recreational suitability rating
RTP, RN2N3...= remark code; k=less than,
Q = Sample held beyond normal holding time

Minnesota Pollution Control Agency
Citizen Lake-Monitoring Program

LAKEID: 33-0036

LAT.LON.: 454947 931856
LAKE: FISH
LOCATION: 1 MI S OF MORA
COUNTY: KANABEC
AREA: 311 acres
MAXDEPTH: 10 feet

DATE	TIME	D	00029 SITE	*00078 SECCHI FEET	84141 PHYSCON 1-5	84142 RECSUIT 1-5
760606	0001	0	201	5.00	-	-
760614	0001	0	"	5.00	-	-
760619	0001	0	"	5.00	-	-
760626	0001	0	"	4.00	-	-
760703	0001	0	"	2.00	-	-
760708	0001	0	"	1.50	-	-
760717	0001	0	"	1.40	-	-
760724	0001	0	"	1.00	-	-
760731	0001	0	"	1.00	-	-
760807	0001	0	"	1.00	-	-
760814	0001	0	"	1.00	-	-
760821	0001	0	"	1.00	-	-
760828	0001	0	"	1.00	-	-
760904	0001	0	"	2.00	-	-
760911	0001	0	"	3.00	-	-
760918	0001	0	"	3.50	-	-
760925	0001	0	"	2.50	-	-

DATE	TIME	D	00029 SITE	*00078 SECCHI FEET	84141 PHYSCON 1-5	84142 RECSUIT 1-5
770605	0001	0	201	1.50	-	-
770612	0001	0	"	1.50	-	-
770619	0001	0	"	1.50	-	-
770626	0001	0	"	1.50	-	-
770703	0001	0	"	1.50	-	-
770710	0001	0	"	1.50	-	-
770717	0001	0	"	1.50	-	-
770724	0001	0	"	1.50	-	-
770731	0001	0	"	1.50	-	-
770807	0001	0	"	1.50	-	-
770814	0001	0	"	1.50	-	-
770821	0001	0	"	1.50	-	-
770828	0001	0	"	1.50	-	-
770904	0001	0	"	1.50	-	-
770911	0001	0	"	2.00	-	-
770918	0001	0	"	2.00	-	-
770925	0001	0	"	2.00	-	-

DATE	TIME	D	00029 SITE	*00078 SECCHI FEET	84141 PHYSCON 1-5	84142 RECSUIT 1-5
910512	1100	0	201	4.00	1	1
910519	1030	0	"	2.50	2	2
910525	1100	0	"	3.00	2	2
910601	1400	0	"	3.00	3	2
910608	1000	0	"	3.00	3	2
910615	1000	0	"	2.00	3	2
910622	1030	0	"	2.00	4	3
910629	1100	0	"	2.00	4	3
910706	0900	0	"	3.50	3	2
910713	1000	0	"	2.50	3	2
910728	1130	0	"	1.50	4	3
910803	1330	0	"	1.50	4	3
910810	1400	0	"	1.50	5	4
910817	1800	0	"	1.50	4	3
910824	1045	0	"	1.50	4	4
910830	1100	0	"	1.50	4	4
910907	1130	0	"	1.50	4	4
910914	1130	0	"	1.50	5	4
910920	1600	0	"	1.50	5	4
910928	1130	0	"	2.00	5	4

DATE	TIME	D	00029 SITE	*00078 SECCHI FEET	84141 PHYSCON 1-5	84142 RECSUIT 1-5
920507		0	201	2.50	3	3
920516		0	"	4.50	2	3
920523		0	"	3.50	3	4
920530		0	"	2.50	5	5
920605	1000	0	"	2.50	4	4
920613	0935	0	"	2.50	4	4
920621	1045	0	"	1.50	5	5
920628	1030	0	"	1.25	4	5
920705	1030	0	"	1.50	4	5
920711	1000	0	"	2.00	4	4
920718	1100	0	"	1.75	3	4
920726	1500	0	"	1.50	4	4
920731		0	"	-	4	4
920801	1130	0	"	1.50	4	4
920809	1630	0	"	1.50	5	4
920815	1015	0	"	1.25	5	5
920823	1530	0	"	1.00	5	4
920828	1200	0	"	1.00	5	4
920905	1100	0	"	1.25	4	3
920912	0900	0	"	1.50	4	3
920920	1200	0	"	1.25	4	3
920926	1200	0	"	1.50	4	3

DATE	TIME	D	00029 SITE	*00078 SECCHI FEET	84141 PHYSCON 1-5	84142 RECSUIT 1-5
930526	1330	0	201	4.50	3	2
930602	1400	0	"	5.00	3	2
930715	1400	0	"	2.42	3	3
930724	1400	0	"	2.00	3	3
930803	1100	0	"	1.50	3	3
930810	1400	0	"	1.50	5	5
930818	1400	0	"	1.50	5	5
930615	1400	0	202	3.00	3	2
930720	1400	0	"	2.50	3	2
930725	1400	0	"	1.50	3	4
930803	1101	0	"	1.00	4	4
930810	1401	0	"	1.00	4	4
930818	1401	0	"	1.00	4	4

Physical Condition

Please use the ONE number, each day that you sample, that best describes the physical condition of the lake water AT YOUR SAMPLING SITE.

1 = Crystal clear water
2 = Not quite crystal clear - a little algae present/visible
3 = Definite algal.green, yellow, or brown color apparent
4 = High algal levels with limited clarity and/or mild odor apparent
5 = Severely high algae levels with one or more of the following:
- massive floating scums on the lake or washed up on shore
- strong, foul odor
- fish kill (please note the number and types of fish)

Suitability for Recreation

Please use the ONE number, each day that you sample, that best describes your opinion of how suitable the lake is for recreation and aesthetic enjoyment.

1 = Beautiful, could NOT be better.
2 = Very minor aesthetic problems; excellent for swimming, boating
3 = Swimming and aesthetic enjoyment slightly impaired because of algae levels
4 = Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels (i.e., would not swim, but boating is okay)
5 = Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels

LAKE WATER QUALITY DATA. All MPCA data in STORET

LAKEID=33-0036 Fish Lake

SITE	DATE	DM	DO	TEMP	TPUG
101	930504	0	11	12	42.000
101	930504	1	11	12	.
101	930504	2	11	12	.
101	930607	0	8.0	17	71.000
101	930607	1	7.9	17	.
101	930607	2	7.9	17	.
101	930708	0	10	20	80.000
101	930708	1	9.2	20	.
101	930708	2	4.2	20	.
101	930802	0	8.0	22	145.000
101	930802	1	7.9	22	.
101	930802	2	7.9	22	.
101	930915	0	8.3	14	133.000
101	930915	1	8.3	14	.
101	930915	2	8.1	14	.
102	930607	0	7.8	17	.
102	930607	1	7.7	17	.
102	930802	0	7.8	22	146.000
102	930802	1	7.4	22	.
102	930915	0	7.1	13	.
102	930915	1	6.4	13	.

LAKEID=33-0040 Ann Lake

SITE	DATE	DM	DO	TEMP	TPUG
101	930720	0	9.0	23	66.000
101	930720	1	9.0	23	.
101	930720	2	9.1	23	.
101	930720	3	3.0	21	.
101	930720	4	0.1	20	.
101	930818	0	7.9	24	129.000
101	930818	1	7.9	24	.
101	930818	2	7.3	23	.
101	930818	3	6.4	23	.
101	930929	0	10	12	40.000
101	930929	1	10	12	.
101	930929	2	10	12	.
101	930929	3	10	12	.
101	930929	4	10	12	.

Legend
DM = Depth in meters
DO = Dissolved Oxygen
TEMP = Temperature in degrees centigrade
TPUG = Total Phosphorus in µg/L

NA-01570-01

LAKE MANAGEMENT PLAN

DEPARTMENT OF MINNESOTA NATURAL RESOURCES

(Use reverse side and add additional sheets as needed)

Region	Area	D.O.W. Number	County	D.O.W. Lake Name	Acreage
III	Hinckley (330)	33 - 36	Kanabec	Fish Lake	407

Long Range Goal:

Maintain a walleye population of between 2.0 to 6.0 per gillnet lift (realistic goal). Maintain a northern pike population of between 1.0 and 3.0 per gillnet lift.

Operational Plan:

1) Conduct population assessments and lake surveys on a 5-year rotation with next assessment in 1997 and next full survey in 2002. Take spine and/or otolith samples on walleye to facilitate accurate age determinations and year class strengths.
2) Include night electrofishing during sampled years to effectively sample LMB population.
3) Stock walleye fingerlings on an alternate year basis at a rate of 1 pound per littoral acre (407 lbs.). Next stocking in 1994. Stock with known age fish of a single year class so an accurate determination of the stocked verses naturally reproduced walleye can be made.
4) Monitor commercial winter seine hauls for obtaining length frequencies and age and growth data on catfish and lake sturgeon populations. Determine potential for obtaining additional information on walleye population.
5) Cooperate with PCA's lake assessment study and discuss watershed management possibilities with homeowners' association, SWCD, and PCA.
6) Monitor dissolved oxygen levels during severe winters.
7) Stock NOP fingerlings if gillnet catchrates drop below 1.0 per net set.
8) Document northern pike spawning areas so they can be protected or enhanced.

Mid Range Objective:

Evaluate walleye natural reproduction and stocking success with alternate year stocking plan in place. To have collected information on LMB population through night electrofishing.

Potential Plan:

1. Creel survey to evaluate fishing pressure and catchrates.	$5000.00
2. Promulgate a watershed initiative.	$5000.00
TOTAL	$ 10,000.00

Primary Species Management	Secondary Species Management
WAE, NOP	LMB, BLG, BLC

Signature	Date
Area Supervisor's Signature: Roger A. Hugill	07/25/93
Regional Supervisor's Signature: Edward L. Feiler	09/05/93 (Month / Day / Year)

FOR CENTRAL OFFICE USE ONLY

Entry Date: __/__/__	Year Resurvey: __
Stock Species - Size - Number per Acre	
Fr./Sec.	
Schedule	Year Beginning __
Population Manipulation: ☐ YES ☐ NO	Year __
Development: ☐ YES ☐ NO	Year __
Creel or Use Survey: ☐ YES ☐ NO	Year __
Other	

NARRATIVE:

(Historical perspectives - various surveys; past management; social considerations; present limiting factors; survey needs; land acquisition; habitat development and protection; commercial fishery; stocking plans; other management tools; and evaluation plans)

NARRATIVE:

Past Surveys: Lake surveys or assessment nettings were conducted in 1992, 1987, 1982, 1979, 1973, 1963, and 1950. Winter dissolved oxygen has also been tested a number of times, most recently in 1989 and 1990. Historically, gillnet catches of NOP, WAE, and YEP have been below the first quartile or just within the second quartile for lake class 42 lakes. This is within the natural character of Fish Lake because it is a shallow reservoir lake with turbid and sometimes bog stained water, moderately low winter dissolved oxygen concentrations and very high water fluctuations. Bluegill trapnet catches have been within the 2nd and 3rd quartiles for all sampled years. The 1992 bluegill trapnet catchrate was the lowest observed. There was a significant columnaris kill of bluegill and black crappie during the spring of 1992. The crappie population has been highly variable with variations also occurring between white and black crappie. Black crappie catchrates have been within or above the 2nd and 3rd quartile ranges indicating their abundance. Growth rates for most species are close to average. Black crappie growth is above average for first few years.

Past Management: Past management has consisted primarily of stocking walleye, northern pike and rough fish removal. Walleye have been stocked an average of 2 out of 3 years since 1978; and northern pike were stocked in 1963, 1971, 1974, 1975, 1977, 1978, 1979, and 1980. Rough fish commonly removed in abundance include: carp, drum, and white sucker.

Social Considerations: Fish Lake is located within 1 mile of the city of Mora, and there are 75 homes or cabins around the lake.

Present Limiting Factors: Fish Lake is a shallow, turbid, sometimes bog stained reservoir lake that experiences significant water level fluctuations. Low winter dissolved oxygen concentrations have also been observed, but severe winterkill has not been observed. Bullhead populations are low, possibly due to the abundant channel catfish population present. The abundance of catfish also indicates only limited winter dissolved oxygen problems. Carp and drum populations appear to be stable and not expanding. Watershed problems are obviously impacting the lake's water quality.

Land Acquisition Needs: None at present.

Habitat Development and Protection: As stated above, great potential exists for improving this lake through wise watershed management. The PCA is doing a LAP survey of Fish Lake in 1993, and information gained by this survey should be helpful in determining what can be done to improve the lake's water quality. The lake has limited bulrush beds present so those should be protected. Also, all D.O.W. permits for Fish Lake as well as its watershed should be reviewed judiciously. Fish spawning in Ann River is important so barriers to their movement should not be permitted.

Commercial Fishery: Continue to permit the commercial fish operation now in place for Fish Lake.

Stocking Plans: Stock walleye fingerling at 1 lb. per littoral acre (407 lbs.) on an alternate year basis beginning in 1994. Stocking success and natural reproduction should be reviewed through the next 2 surveys.

Survey Needs and Evaluation Plans: Resurvey and test net on a 5-year rotation with next assessment in 1997 and next full survey in 2002. Spines and/or otolithes should be collected from all walleye sampled for accurate age determination to assist in determining the stocking verses natural reproductions contribution to the walleye population. Also, single aged walleye should be stocked so as not to complicate assessing stocking success. If that is not possible, then accurate counts should be made of stocking composition and the next stocking should be single age fish. Night electrofishing should be done during all sampled years to develop a sampling index for largemouth bass.

Dissolved Oxygen Testing: Winter dissolved oxygen testing should be done during severe winters.

Commercial rough fish seining operations should be used to gain information on catfish and sturgeon populations and for collection of age-growth data. Sturgeon could also be tagged to gain valuable information on their population and movement within the Snake River system.

MINLEAP MODEL SUMMARY

Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? Fish
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 2
WATERSHED AREA (HA) ? 11656 ——— (Fish Lake Immediate Watershed)
LAKE SURFACE AREA (HA) ? 161
LAKE MEAN DEPTH (M) ? 1.4
OBSERVED MEAN LAKE TP (UG/L) ? 100
OBSERVED MEAN CHL-A (UG/L) ? 77
OBSERVED MEAN SECCHI (M) ? .64

INPUT DATA:
LAKE NAME =Fish ECOREGION=CHF
LAKE AREA = 161 HA
WATERSHED AREA (EXCLUDING LAKE) = 11656 HA
MEAN DEPTH = 1.4 METERS
OBSERVED MEAN TP = 100 UG/L
OBSERVED MEAN CHL-A = 77 UG/L
OBSERVED MEAN SECCHI = .64 METERS

<press ENTER to view results>

LAKE = Fish ECOREGION = CHF
AVERAGE INFLOW TP = 150.5477 UG/L TOTAL P LOAD = 2290.914 KG/YR
LAKE OUTFLOW = 15.2172 HM3/YR AREAL WATER LOAD = 9.451676 M/YR
RESIDENCE TIME = .1481219 YRS P RETENTION COEF = .3638513

VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	100.00	95.77	22.41	0.02	0.15
CHL-A	(UG/L)	77.00	51.62	25.43	0.17	0.71
SECCHI	(METERS)	0.64	0.76	0.27	-0.07	-0.45

NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)

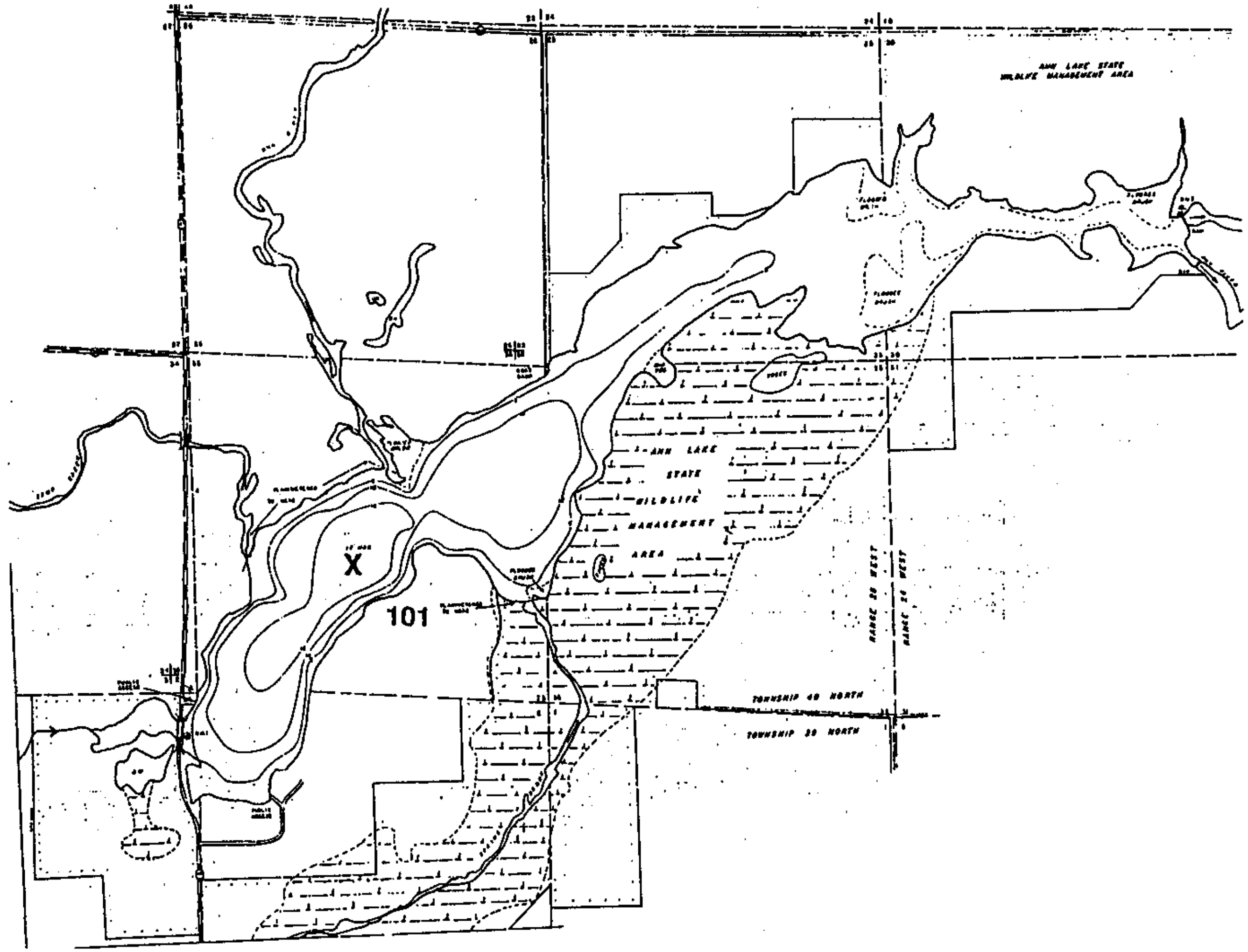
CHL-A		PREDICTED	PREDICTED	PREDICTED
PPB	OBSERVED	CASE A	CASE B	CASE C
10	100.00	99.93	99.83	98.34
20	99.49	95.87	94.55	87.77
30	95.77	81.37	79.48	72.51
60	61.07	28.96	30.43	35.49

CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED

MINLEAP MODEL SUMMARY

```
Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? Fish
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 1 ——(Northern Lakes and Forest ecoregion)
WATERSHED AREA (HA)          ? 21656
LAKE SURFACE AREA (HA)       ? 161
LAKE MEAN DEPTH (M)          ? 1.4
OBSERVED MEAN LAKE TP (UG/L) ? 100
OBSERVED MEAN CHL-A (UG/L)   ? 77
OBSERVED MEAN SECCHI (M)     ? .64

INPUT DATA:
LAKE NAME =Fish                ECOREGION=NLF
LAKE AREA = 161  HA
WATERSHED AREA (EXCLUDING LAKE) = 21656  HA
MEAN DEPTH = 1.4  METERS
OBSERVED MEAN TP = 100  UG/L
OBSERVED MEAN CHL-A = 77  UG/L
OBSERVED MEAN SECCHI = .64  METERS

<press ENTER to view results>


LAKE = Fish                             ECOREGION = NLF
AVERAGE INFLOW TP = 52.26523  UG/L      TOTAL P LOAD      = 2614.208  KG/YR
LAKE OUTFLOW      = 50.0181  HM3/YR     AREAL WATER LOAD  = 31.06715 M/YR
RESIDENCE TIME    = 4.506368E-02  YRS   P RETENTION COEF  = .1560147

VARIABLE  UNITS      OBSERVED PREDICTED STD ERROR  RESIDUAL   T-TEST
TOTAL P   (UG/L)      100.00     44.11      8.76      0.36     3.18
CHL-A     (UG/L)       77.00     16.64      7.63      0.67     2.89
SECCHI    (METERS)      0.64      1.48      0.49     -0.36    -2.32
NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
      T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)
CHL-A            PREDICTED PREDICTED PREDICTED
  PPB  OBSERVED    CASE A    CASE B    CASE C
   10    100.00     79.46     77.61     71.56
   20     99.49     26.64     28.23     33.27
   30     95.77      7.10      8.76     15.45
   60     61.07      0.18      0.36      2.19
CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED
Ok
```

ANN LAKE BATHYMETRIC MAP



Key
200 Series----CLMP Lake Stations 100 Series----MPCA Lake Stations

Map - MDNR

MINNESOTA POLLUTION CONTROL AGENCY
DIVISION OF WATER QUALITY
JANUARY 199

Minnesota Lake Eutrophication Analysis Procedure

ENTER INPUT VARIABLES

LAKE NAME ? Ann

ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 2 — (North Central Hardwood Forest ecoregion)

WATERSHED AREA (HA) ? 9742

LAKE SURFACE AREA (HA) ? 258

LAKE MEAN DEPTH (M) ? 1.9

OBSERVED MEAN LAKE TP (UG/L) ? 70

OBSERVED MEAN CHL-A (UG/L) ? 39.9

OBSERVED MEAN SECCHI (M) ? 1.05

INPUT DATA:

LAKE NAME =Ann ECOREGION=CHF

LAKE AREA = 258 HA

WATERSHED AREA (EXCLUDING LAKE) = 9742 HA

MEAN DEPTH = 1.9 METERS

OBSERVED MEAN TP = 70 UG/L

OBSERVED MEAN CHL-A = 39.9 UG/L

OBSERVED MEAN SECCHI = 1.05 METERS

<press ENTER to view results>

LAKE = Ann

AVERAGE INFLOW TP = 152.8659 UG/L

LAKE OUTFLOW = 12.7678 HM3/YR

RESIDENCE TIME = .3839346 YRS

ECOREGION = CHF

TOTAL P LOAD = 1951.761 KG/YR

AREAL WATER LOAD = 4.94876 M/YR

P RETENTION COEF = .4911341

VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	70.00	77.79	21.05	-0.05	-0.33
CHL-A	(UG/L)	39.90	38.10	20.23	0.02	0.08
SECCHI	(METERS)	1.05	0.91	0.33	0.06	0.37

NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)

CHL-A PPB	OBSERVED	PREDICTED CASE A	PREDICTED CASE B	PREDICTED CASE C
10	99.59	99.46	99.06	95.01
20	88.49	86.51	84.59	76.21
30	63.89	60.24	59.47	56.68
60	13.77	11.76	13.66	22.15

CASE A = WITHIN-YEAR VARIATION CONSIDERED

CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED

CASE C = CASE B + MODEL ERROR CONSIDERED

Ok

```
Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? Ann
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 1 —(Northern Lakes and Forest ecoregion)
WATERSHED AREA (HA)            ? 9742
LAKE SURFACE AREA (HA)         ? 258
LAKE MEAN DEPTH (M)            ? 1.9
OBSERVED MEAN LAKE TP (UG/L)   ? 70
OBSERVED MEAN CHL-A (UG/L)     ? 39.9
OBSERVED MEAN SECCHI (M)       ? 1.05

INPUT DATA:
LAKE NAME =Ann                  ECOREGION=NLF
LAKE AREA = 258  HA
WATERSHED AREA (EXCLUDING LAKE) = 9742  HA
MEAN DEPTH = 1.9  METERS
OBSERVED MEAN TP = 70  UG/L
OBSERVED MEAN CHL-A = 39.9  UG/L
OBSERVED MEAN SECCHI = 1.05  METERS

<press ENTER to view results>


LAKE = Ann                                   ECOREGION = NLF
AVERAGE INFLOW TP = 52.9348  UG/L            TOTAL P LOAD       = 1203.843  KG/YR
LAKE OUTFLOW      = 22.742  HM3/YR           AREAL WATER LOAD   = 8.814729 M/YR
RESIDENCE TIME    = .2155483  YRS            P RETENTION COEF   = .302786

VARIABLE  UNITS        OBSERVED PREDICTED STD ERROR  RESIDUAL    T-TEST
TOTAL P   (UG/L)          70.00     36.91      8.12      0.28      2.33
CHL-A     (UG/L)          39.90     12.83      6.14      0.49      2.07
SECCHI    (METERS)         1.05      1.72      0.59     -0.21     -1.34
NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
      T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)
CHL-A           PREDICTED PREDICTED PREDICTED
  PPB  OBSERVED    CASE A    CASE B    CASE C
   10     99.59     61.04     60.22     57.57
   20     88.49     12.18     14.09     21.41
   30     63.89      2.22      3.17      8.60
   60     13.77      0.03      0.07      0.95
CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED
Ok
```

RECKHOW-SIMPSON MODELING FOR ANN LAKE

Name	Ann			
Watershed Area (ha)	10000	19999778	=EST Q	20
Lake Area (ha)	258	7.75	=EST qs	
Water Runoff (m)	0.2	NOTE: 1HM3 = 1,000,000 M3; HM3=A-F/8		
Precipitation(m)	o.68	0.7	=Observed TP (mg/l	
Evaporation(m)	0.86	0.041	=Observed TP StDev	
Volume (HM3)	5	4	=N	
County capitas/cabin	2.8	39.9	=Observed Chla (ug	
Number Seasonal Cabi	0	1.05	=Observed Secchi (	
Number Perm. Cabins	94			

	Before	After	Delta	%Total
Forest Area (ha)	7068	7068	0	71%
Agric Area (ha)	235	235	0	2%
Urban Area (ha)	0	0	0	0%
Wetland Area (ha)	1928	1928	0	19%
Pasture/Open (ha)	768	768	0	8%
	9999			

Export Values		Low	Average	High
Forest P Export		0.1	0.1	0.15
Agric P Export		0.2	0.4	0.6
Urban P Export		0.5	1	1.25
Wetland P Export		0.1	0.1	0.1
Pasture/open Export		0.2	0.3	0.4
Atmospheric Export		0.3	0.3	0.3
Soil Retention Coef		0.75	0.5	0.25
Point Source Before	kg/yr	0	0	0
Point Source After	kg/yr	0	0	0
Delta Point Source	kg/yr	0	0	0
Capita Years		252.4	252.4	252.4

**** P EXPORT R E F E R E N C E ****

****

Prairie & Kalff (1986) \Wilson & Walker (1989)

"Effect of Catchment Size... \Development of Lake Assessment...

Use	Ha	P export	\Ecoreg.	Dominant Landuse	Net** P Export
Forest	7068	0.08	\NCHF	Cul+Mixed	0.19
Ag-mix	235	0.72	\NLF	For (75%)	0.12
Ag-row++	235	0.53	\NGP	Cul (83%)	0.76
Ag-nonrow++	235	0.7	\WCBP	Cul (84%)	0.74
Pasture	768	0.16	** Of all landuse values.		

Wat.Res.Bull 22:465-470 \ Lake Res.Man.5:11-22.

++Fill in this estimated landuse data

****

Low	KG P/YEAR Average	High (a)	
707	707	1060	=Forested Flux =
47	94	141	=Ag flux =
0	0	0	=Urban flux =
193	193	193	=Wetland flux =
154	230	307	=Pasture/Open flux =
77	77	77	=Ppt flux =
63	126	189	=Septic flux =
0	0	0	=Point Souce =
1241	1427	1967	=Total P Flux =
481	553	762	= P LOAD (kg) =
62	71	98	= Inflow P ug/l=
40	45	58	CANFIELD/BACHMANN ug/L

P load contribution

	Low flux	%	Avg flux	%	High flux	%
Wshed	1101	89%	1224	86%	1701	86%
Septic	63	5%	126	9%	189	10%
Ppt	77	6%	77	5%	77	4%
Point	0	0%	0	0%	0	0%
Sum kg/yr	1241		1427		1967	

MINLEAP Predictions

1952 =kgP/yr flux

0.078 =mg/L P
38 =ug/L Chl a
0.91 =m Secchi

67 MINLEAP TSIP
66 MINLEAP TSIC
61 MINLEAP TSIS

Predicted changes in Secchi, Chlorophyll and Trophic S

	Observed	(low) Predicted	(average)	(high) Predicted
		Predicted inlake P conc. or insert other values.		
LAKE TP mg/l	0.7	0.04	0.045	0.058
LAKE CHLA ug/l	39.9	14.4	17.1	24.8
LAKE SECCHIm	1.05	1.6	1.5	1.2
TSI TP	99	57	59	63
TSI CHLA	67	57	59	62
TSI SD	59	53	54	57

Septic System Survey Results
Lake: FISH LAKE
Date: 1993

PARTICIPATION
About 78 surveys were sent to property owners around Fish Lake.
About 55 surveys were returned. (70%)

TYPE OF DWELLING	# of Response	%
Seasonal	17*	22
Year Round	61*	78
Year round, but not a primary residence		

SYSTEM AGES (years)		
0-5	9	16
6-10	5	9
11-15	12	22
16-20	15	27
21-25	8	15
26-30	6	11
31+	-	-
unknown	-	-

DISTANCE FROM LAKE TO CLOSEST POINT OF SYSTEM (feet)		
0-50	4	7
51-100	27	49
101-150	17	31
151-200	4	7
201-250	-	-
251+	3	5
no response	-	-

System Types	# of Response
Septic tank - drainfield	29
Septic tank - drywell	18
Shared septic tank - drainfield	-
Cesspool	2
Holding tank	2
Privy	2
Mound system	2
Don't know	-
Other	-

System Pumping	
More than once per year	4
Every year	2
Every 2 years	8
Every 3 years	5
Every 4 years	1
Every 5 years	13
Every 10 years	6
When problems	-
Never	16
No response	-

Problems	
Freeze ups	
Back ups	NO
Inadequate drainage	
Some - not bad	RESPONSE
None in the last two years	

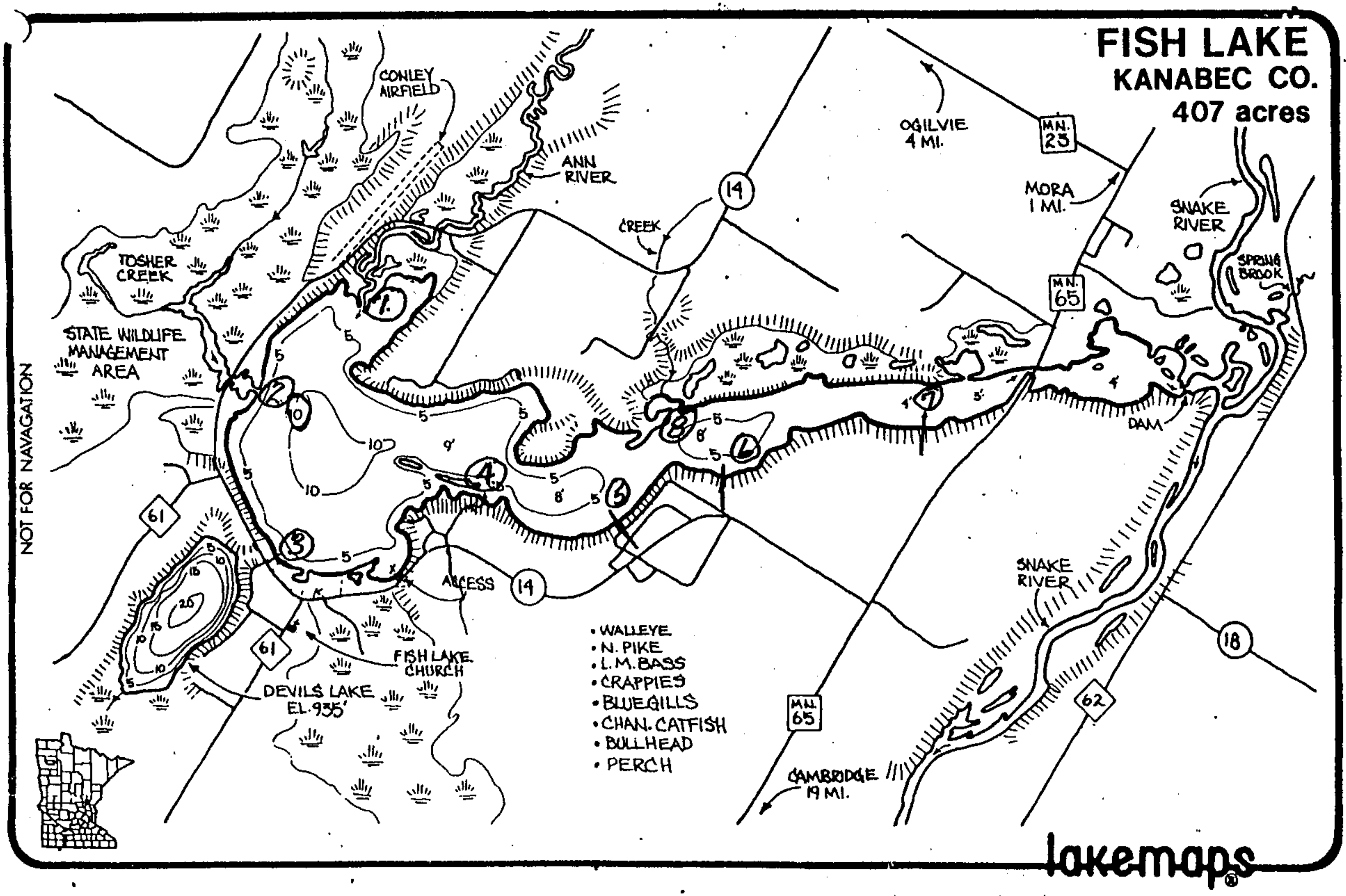
Summary

Fifty-three percent of the systems around the lake are the conventional septic tank drainfield type. Most systems are less than 20 years old (74%). An issue the results raise is frequency of pumping.

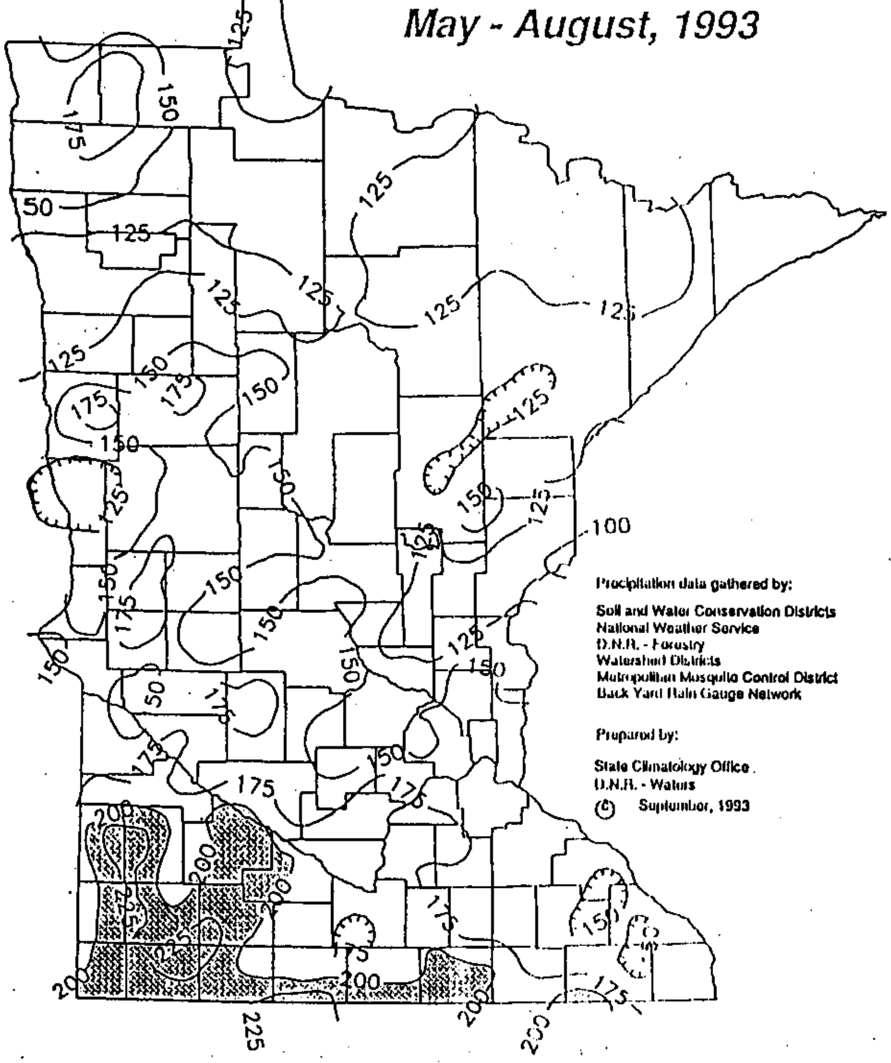
* Total number of dwellings around lake (does not include resorts)

TRIBUTARIES, STORM SEWERS, ETC.

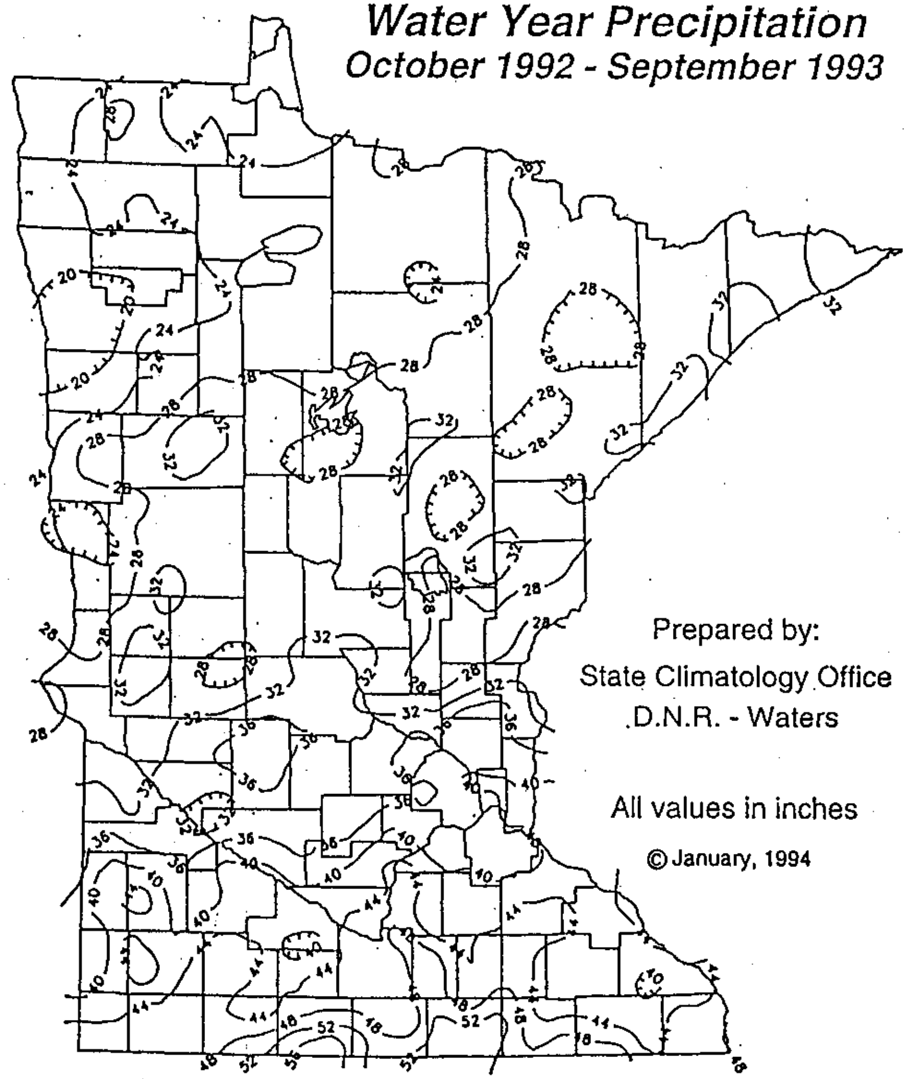
1. ANN RIVER
2. TOSHER CREEK
3. DEVILS LAKE INLET
4. TROUPES DRAINAGE DITCH
5. DRAIN PIPE HIGHWAY UNDERGROUND
6. " " " "
7. " " " "
8. CREEK DRAINING FARM FIELDS & ROAD DITCH - NORTH



Percent of Normal Precipitation
May - August, 1993



Water Year Precipitation
October 1992 - September 1993



Data source: National Weather Service, Soil & Water Conservation Districts, DNR Forestry, Metro Mosquito Control, Back Yard Rain Gauge Network, Future Farmers of America, Deep Portage Conservation Reserve, Minnesota Association of Watershed Districts